Species at Risk Act

Recovery Strategy Series

Recovery Strategy for the Wavyrayed Lampmussel (*Lampsilis fasciola*) in Canada

Wavyrayed Lampmussel

October 2006

Fisheries and Oceans Canada
Pêches et Océans Canada
Canada

About the Species at Risk Act Recovery Strategy Series

What is the *Species at Risk Act* (SARA)?

SARA is the Act developed by the federal government as a key contribution to the common national effort to protect and conserve species at risk in Canada. SARA came into force in 2003 and one of its purposes is *"to provide for the recovery of wildlife species that are extirpated, endangered or threatened as a result of human activity."*

What is recovery?

In the context of species at risk conservation, **recovery** is the process by which the decline of an endangered, threatened or extirpated species is arrested or reversed, and threats are removed or reduced to improve the likelihood of the species' persistence in the wild. A species will be considered **recovered** when its long-term persistence in the wild has been secured.

What is a recovery strategy?

A recovery strategy is a planning document that identifies what needs to be done to arrest or reverse the decline of a species. It sets goals and objectives and identifies the main areas of activities to be undertaken. Detailed planning is done at the action plan stage.

Recovery strategy development is a commitment of all provinces and territories and of three federal agencies — Environment Canada, Parks Canada Agency and Fisheries and Oceans Canada — under the Accord for the Protection of Species at Risk. Sections 37–46 of SARA (http://www.sararegistry.gc.ca/the_act/default_e.cfm) spell out both the required content and the process for developing recovery strategies published in this series.

Depending on the status of the species and when it was assessed, a recovery strategy has to be developed within one to two years after the species is added to the List of Wildlife Species at Risk. Three to four years is allowed for those species that were automatically listed when SARA came into force.

What's next?

In most cases, one or more action plans will be developed to define and guide implementation of the recovery strategy. Nevertheless, directions set in the recovery strategy are sufficient to begin involving communities, land users, and conservationists in recovery implementation. Cost-effective measures to prevent the reduction or loss of the species should not be postponed for lack of full scientific certainty.

The series

This series presents the recovery strategies prepared or adopted by the federal government under SARA. New documents will be added regularly as species get listed and as strategies are updated.

To learn more

To learn more about the Species at Risk Act and recovery initiatives, please consult the SARA Public Registry (http://www.sararegistry.gc.ca/) and the web site of the Recovery Secretariat (http://www.speciesatrisk.gc.ca/recovery/default_e.cfm).

Recovery Strategy for the Wavyrayed Lampmussel (*Lampsilis fasciola*) in Canada

October 2006

Recommended citation:

Morris, T. J. 2006. Recovery Strategy for the Wavyrayed Lampmussel (*Lampsilis fasciola*) in Canada. Species at Risk Act Recovery Strategy Series, Fisheries and Oceans, Ottawa, viii + 43pp.

Additional copies:

You can download additional copies from the SARA Public Registry (http://www.sararegistry.gc.ca/)

Cover illustration: courtesy Environment Canada (male on left, female on right)

Également disponible en français sous le titre
« Programme de rétablissement de la lampsile fasciolée (*Lampsilis fasciola*) au Canada »

ISBN 0-662-43968-6
Cat. no. En3-4/15-2006E-PDF

DECLARATION

The recovery strategy for the Wavyrayed Lampmussel has been prepared in cooperation with the jurisdictions listed under the heading Responsible Jurisdictions. Fisheries and Oceans Canada has reviewed and accepts this document as its recovery strategy for the Wavyrayed Lampmussel as required under the *Species at Risk Act* (SARA). This recovery strategy also constitutes advice to other jurisdictions and organizations on the recovery goals, approaches and objectives that are recommended to protect and recover the species.

Success in the recovery of this species depends on the commitment and cooperation of many different constituencies that will be involved in implementing the directions set out in this strategy and will not be achieved by Fisheries and Oceans Canada or any other jurisdiction alone. In the spirit of the National Accord for the Protection of Species at Risk, the Minister of Fisheries and Oceans invites all Canadians to join Fisheries and Oceans Canada in supporting and implementing this strategy for the benefit of the Wavyrayed Lampmussel and Canadian society as a whole. Fisheries and Oceans Canada will support implementation of this strategy to the extent possible, given available resources and its overall responsibility for species at risk conservation. Implementation of the strategy by other participating jurisdictions and organizations is subject to their respective policies, appropriations, priorities, and budgetary constraints.

The goals, objectives and recovery approaches identified in the strategy are based on the best existing knowledge and are subject to modifications resulting from new findings and revised objectives. The Minister of Fisheries and Oceans will report on progress within five years.

This strategy will be complemented by one or more action plans that will provide details on specific recovery measures to be taken to support conservation of the species. The Minister of Fisheries and Oceans will take steps to ensure that, to the extent possible, Canadians interested in or affected by these measures will be consulted.

RESPONSIBLE JURISDICTIONS

The responsible jurisdiction for the Wavyrayed Lampmussel under SARA is Fisheries and Oceans Canada. The Wavyrayed Lampmussel occurs only in Ontario, and the Ontario Ministry of Natural Resources (OMNR) and other agencies cooperated in the production of this recovery strategy.

AUTHORS

This document was prepared by Todd J. Morris on behalf of the Ontario Freshwater Mussel Recovery Team.

ACKNOWLEDGMENTS

The Ontario Freshwater Mussel Recovery Team would like to thank the following organizations for their support in the development of the Wavyrayed Lampmussel recovery strategy: Fisheries and Oceans Canada, Environment Canada, Ontario Ministry of Natural Resources, University of Guelph, University of Toronto/Royal Ontario Museum, McMaster University, Ausable-Bayfield Conservation Authority, Grand River Conservation Authority, Maitland Valley Conservation Authority, St. Clair Region Conservation Authority, Upper Thames River Conservation Authority, Lower Thames valley Conservation Authority and the Walpole Island Heritage Information Centre.

STRATEGIC ENVIRONMENTAL ASSESSMENT

A strategic environmental assessment (SEA) is conducted on all SARA recovery planning documents, in accordance with the *Cabinet Directive on the Environmental Assessment of Policy, Plan and Program Proposals*. The purpose of a SEA is to incorporate environmental considerations into the development of public policies, plans, and program proposals to support environmentally-sound decision making.

Recovery planning is intended to benefit species at risk and biodiversity in general. However, it is recognized that strategies may also inadvertently lead to environmental effects beyond the intended benefits. The recovery planning process based on national guidelines directly incorporates consideration of all environmental effects, with a particular focus on possible impacts on non-target species or habitats. The results of the SEA are incorporated directly in the strategy itself, but are also summarized below.

This recovery strategy will clearly benefit the environment by promoting the recovery of the Wavyrayed Lampmussel. The potential for the strategy to inadvertently lead to adverse effects on other species was considered. The SEA concluded that this strategy will clearly benefit the environment and will not entail any significant adverse effects.

RESIDENCE

SARA defines residence as: "*a 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*" **[SARA S2(1)]**.

Residence descriptions, or the rationale for why the residence concept does not apply to a given species, are posted on the SARA public registry:
http://www.sararegistry.gc.ca/plans/residence_e.cfm

PREFACE

The Wavyrayed Lampmussel is a freshwater mussel and is under the jurisdiction of the federal government. The *Species at Risk Act* (SARA, Section 37) requires the competent minister to prepare recovery strategies for listed extirpated, endangered or threatened species. The Wavyrayed Lampmussel was listed as Endangered under SARA in June 2003. Fisheries and Oceans Canada – Central and Artic Region led the development of this recovery strategy. The proposed strategy meets SARA requirements in terms of content and process (Sections 39-41). It was developed in cooperation or consultation with:

- Jurisdictions – Environment Canada, Province of Ontario
- Aboriginal groups – Chippewa of Kettle and Stoney Point, Aamjiwnaang First Nation, Caldwell First Nation, Moravia of the Thames First Nation, Chippewa of the Thames, Oneida, Munsee-Delaware First Nation, Southern First Nation Secretariat, Mississauga of New Credit First Nation, Six Nations of the Grand, Walpole Island First Nation, Metis Nation of Ontario.
- Environmental non-government groups – Ausable Bayfield Conservation Authority, Grand River Conservation Authority, Lower Thames Valley Conservation Authority, Maitland Valley Conservation Authority, St. Clair Region Conservation Authority, Upper Thames River Conservation Authority, McMaster University, University of Guelph, University of Toronto/Royal Ontario Museum.

EXECUTIVE SUMMARY

The Wavyrayed Lampmussel (*Lampsilis fasciola*, Rafinesque 1820) is a small sexually dimorphic mussel recognized by its yellow or yellowish-green rounded shell. The shell is characterized by numerous thin wavy green rays that may be narrow and individual or coalesced into wider rays in some specimens. Regardless of size, the rays are always wavy with multiple interruptions giving rise to the common name of this mussel. The species is typically found in small to medium, clear, hydrologically stable rivers where it inhabits clean sand/gravel substrates in and around shallow riffle areas. The Wavyrayed Lampmussel is considered globally secure (G4). It is nationally secure within the United States (N4) although it is declining throughout its range, particularly in the north where it is considered endangered in Illinois, threatened in Michigan and New York and of special concern in Indiana. This species is considered imperiled (N1) in Canada where it is listed as Endangered by COSEWIC. The Canadian distribution is restricted to Ontario where it was likely always a rare species. The historical Canadian range included western Lake Erie, Lake St. Clair, and the Maitland, Ausable, St. Clair, Sydenham, Thames, Detroit and Grand Rivers, however current distributions are limited to a small portion of the Lake St. Clair delta and the Ausable, Grand, Thames and Maitland rivers with only the Grand, Thames, and Maitland populations believed to be healthy.

Threats to the Wavyrayed Lampmussel are many and varied. The main reason for the declines in lake populations, and the major current threat to the Lake St. Clair population, is the presence of the exotic zebra mussel (*Dreissena polymorpha*). Zebra mussels attach to the shells of native mussels and act to inhibit feeding, respiration, excretion and locomotion. Riverine populations of Wavyrayed Lampmussel are subject to different threats than lake populations with the primary threats being declining water quality and the loss of habitat. Most of the watersheds where Wavyrayed Lampmussels are still found are predominantly agricultural with high nutrient and sediment inputs to the watercourse from the adjacent terrestrial lands. The obligate parasitic nature of the reproductive cycle of the Wavyrayed Lampmussel necessitates a consideration of threats to the host fish species as well as the direct threats to the mussel.

The long-term goal of this recovery strategy is to prevent the extirpation of the Wavyrayed Lampmussel in Canada and to promote the recovery of this species by:

i. protecting existing populations to prevent further declines,
ii. restoring degraded populations to healthy self-sustaining levels by improving the extent and quality of habitat and
iii. re-introducing the Wavyrayed Lampmussel into areas where it formerly existed where feasible.

The following specific short term objectives have been identified to assist with meeting the long term goal:

i. Determine extent, abundance and population demographics of existing populations.
ii. Determine/confirm fish hosts, their distributions and abundances.
iii. Define key habitat requirements to identify Critical Habitat.
iv. Establish a long-term monitoring program for Wavyrayed Lampmussels, their habitat and that of their hosts.
v. Identify threats, evaluate their relative impacts and implement remedial actions to reduce their effects.
vi. Examine the feasibility of relocations, reintroductions and artificial propagation.
vii. Increase awareness of the significance of the Wavyrayed Lampmussel and its status as a Canadian Species at Risk.

The Recovery Team has identified a variety of approaches that are necessary to ensure that the objectives are met. These approaches have been organized into four categories: Research and Monitoring, Management, Stewardship and Awareness.

This Recovery Strategy represents one piece of a multi-faceted approach to ensure the preservation of this endangered mussel. The needs of the Wavyrayed Lampmussel have been directly considered in the development of aquatic ecosystem recovery strategies for the Sydenham River, the Ausable River and the Thames River and the goals, objectives and approaches outlined in these ecosystem strategies will therefore benefit the Wavyrayed Lampmussel. Although not directly considered in the Grand River Fish Recovery Strategy or the Walpole Island Ecosystem Recovery Strategy, the Recovery Team feels that the actions proposed by these ecosystem oriented teams will likely benefit the Wavyrayed Lampmussel through overall improvement of aquatic habitat. In addition to these recovery planning efforts a number of ongoing research programs will assist with achieving the goals outlined in this strategy. A team at the University of Guelph has established a research facility to investigate potential host species for the Wavyrayed Lampmussel and other mussel species at risk while a laboratory at the University of Toronto/Royal Ontario Museum has recently begun to examine the conservation genetics of mussel species at risk with a focus on the Wavyrayed Lampmussel. Researchers from the Fisheries and Oceans Canada and the National Water Research Institute of Environment Canada are conducting ongoing surveys for mussel species at risk in southwestern Ontario and examining the feasibility of establishing managed refuge sites in the St. Clair delta region.

The specification of Critical Habitat is a crucial component to the recovery of endangered species under the Species at Risk Act and requires a thorough knowledge of the species needs during all life stages as well as an understanding of the distribution, quantity, and quality of habitat across the range of the species. At present, this information is not available for the Wavyrayed Lampmussel; therefore, the Ontario Freshwater Mussel Recovery Team has identified a series of tasks that will assist with collecting the information required to characterize Critical Habitat for the species. Until Critical Habitat can be identified the Recovery Team has identified habitats in need of protection that include:

- 60km of the upper Grand River between Inverhaugh and Cambridge,

- a 30 km section of the North Thames River above London including Medway and Fish creeks. A 25 km section of the Middle Thames River from London to Dorchester as well as the lower reaches of the Middle Thames from Thamesford to its confluence with the South Thames
- a 45 km stretch of the Maitland River from the confluence with the South Maitland River upstream to Wingham, the lower reaches of the South Maitland, Middle Maitland and Little Maitland Rivers,
- the lower section of the Little Ausable River, a 12km stretch of the main channel of the Ausable River upstream of Nairn and
- a 12 km^2 region of the St. Clair delta.

The Ontario Freshwater Mussel Recovery Team feels that the approaches outlined in this strategy to achieve recovery of the Wavyrayed Lampmussel are best accomplished through cooperation with existing ecosystem recovery teams. In watersheds with these teams, implementation of recovery actions should be coordinated to ensure that activities are beneficial to all species at risk and to eliminate the possible duplication of efforts. Where ecosystem teams are absent, Recovery Implementation Groups (RIGs) may be struck to facilitate the carrying out of recovery actions. Evaluation of the success of recovery actions will be achieved primarily through the routine monitoring programs established to track changes in population demographics and habitat, however, RIGs will also incorporate specific milestones into Recovery Action Plans. The entire Recovery Strategy will be reassessed after 5 years to evaluate the progress towards achieving the goals and objectives and to incorporate new information.

TABLE OF CONTENTS

INTRODUCTION

The Wavyrayed Lampmussel (*Lampsilis fasciola*, Rafinesque 1820) is a small sexually dimorphic mussel recognized by its yellow or yellowish-green rounded shell. The shell is characterized by numerous thin wavy green rays that may be narrow and individual or coalesced into wider rays in some specimens (Figure 1). Regardless of size, the rays are always wavy with multiple interruptions giving rise to the common name of this mussel. The species is usually found in small to medium, clear, hydrologically stable rivers where it inhabits clean sand/gravel substrates in and around shallow riffle areas.

Figure 1: The Wavyrayed Lampmussel (*Lampsilis fasciola*). Photo courtesy of S. Staton, Fisheries and Oceans Canada.

The Wavyrayed Lampmussel is considered globally secure (G4). It is considered nationally secure within the United States (N4) although it is declining throughout its range, particularly in the north where it is considered endangered in Illinois, threatened in Michigan and New York, and of special concern in Indiana. This species is considered imperiled (N1) in Canada where it was listed as Endangered in 1999 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The Wavyrayed Lampmussel is listed under the 'Species at Risk in Ontario List' as Endangered (not regulated). The Canadian distribution is restricted to Ontario where it has likely always been a rare species (Metcalfe-Smith and McGoldrick 2003) with a historical range that included western Lake Erie, Lake St. Clair, and the Maitland, Ausable, St. Clair, Sydenham, Thames, Detroit and Grand Rivers. Current populations are known only from a small portion of the Lake St. Clair delta and the Ausable, Grand, Thames and Maitland Rivers.

The Ontario Freshwater Mussel Recovery Team (OFMRT) was formed in the spring of 2003 to address concerns about the status of Ontario's freshwater mussel populations and to begin to address the recovery planning obligations under Canada's new Species at Risk Act (SARA). The National Recovery Strategy for the Wavyrayed Lampmussel was developed by the OFMRT using the best available information in an effort to reduce the threats, prevent extirpation and, if possible, to restore the species to healthy, self-sustaining levels. It is anticipated that many of the actions proposed in this strategy to benefit the Wavyrayed Lampmussel will also act to reduce threats and improve habitat for other freshwater mussels and aquatic species in general.

I. BACKGROUND

Species Information

Scientific Name: *Lampsilis fasciola*
Common Name: Wavyrayed Lampmussel
Current COSEWIC Status & Year of Designation: Endangered (1999)
Range in Canada (provinces and territories where found): Ontario
Rationale for Status: The Wavyrayed Lampmussel has declined significantly in recent years across its historical range. Its numbers have been reduced in Great Lakes waters by the zebra mussel while populations in the Thames, Sydenham and Ausable Rivers are disappearing or have been lost primarily as a result of agricultural impacts.

Distribution

Figure 2: North American distribution of the Wavyrayed Lampmussel (modified from Parmalee and Bogan 1998)

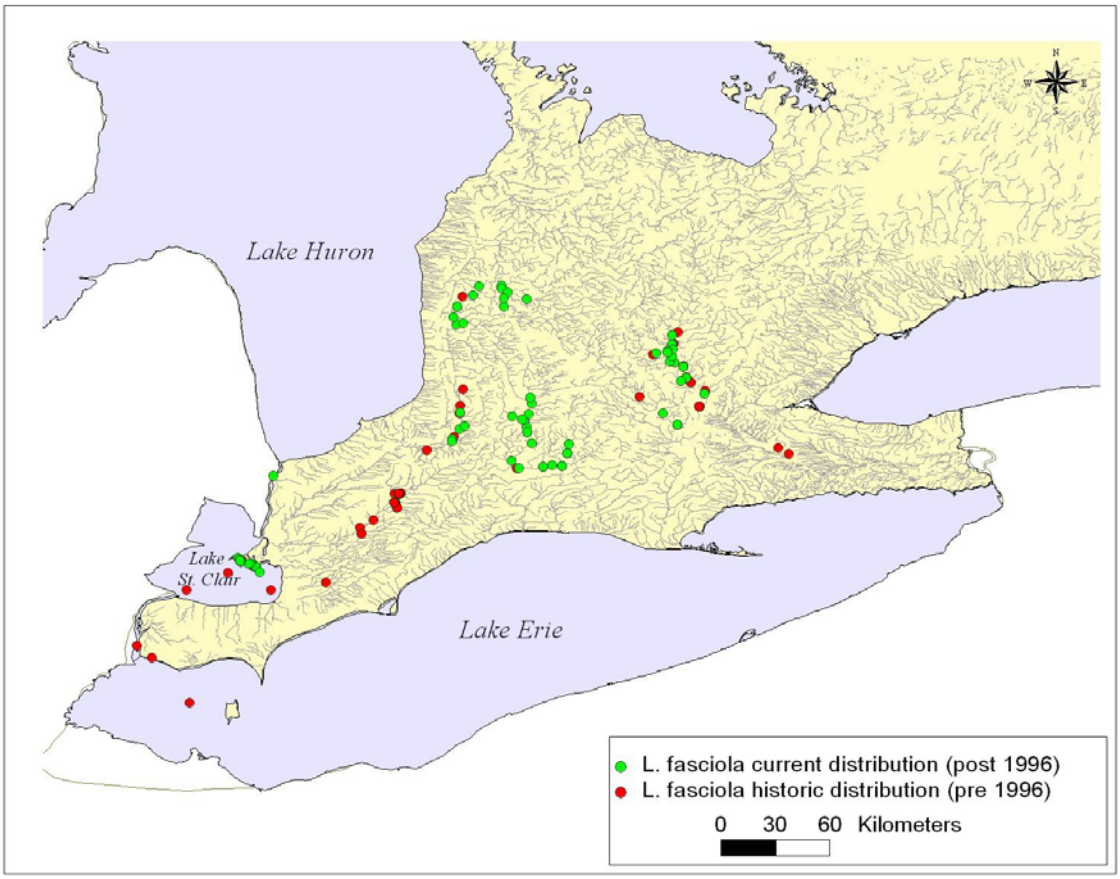

Figure 3: Current and historic distribution of the Wavyrayed Lampmussel in Canada.

Global Range: In the United States, the Wavyrayed Lampmussel is considered nationally secure and currently occurs in Alabama, Indiana, Illinois, Kentucky, Michigan, New York, North Carolina, Pennsylvania, Tennessee, West Virginia and Virginia (Figure 2), however recent declines have been observed across its distribution (Parmalee and Bogan 1998). It historically occurred in Georgia and Ohio, but the status of the species in these states is currently unknown. In Canada the Wavyrayed Lampmussel is considered critically imperiled and occurs only in southwestern Ontario (Figure 3; Table 1) (Metcalfe-Smith *et al.* 2000).

Canadian Range: The current Canadian distribution of the Wavyrayed Lampmussel is restricted to the upper Grand River and its tributaries (Metcalfe-Smith and McGoldrick 2003), the upper Thames River (T. Morris, Fisheries and Oceans, Burlington, unpublished data), all four branches of the Maitland River (Janice Metcalfe-Smith, NWRI, Burlington, pers. comm. October 2003), a small section of the Ausable River (Metcalfe-Smith and McGoldrick 2003) and the Canadian waters of the Lake St. Clair delta (Zanatta *et al.* 2002) (Figure 3).

Percent of Global Range in Canada: Less than 5% of the species' global distribution is found in Canada.

Distribution Trend: The range of the Wavyrayed Lampmussel has been significantly reduced as it has been extirpated from its historical range in the western basin of Lake Erie, the majority of Lake St. Clair, the Detroit River, and the Sydenham River. Distributions in the Ausable and Grand rivers have been reduced while the full extent of the historic range appears to still be occupied in the Thames River. The trend in the Maitland River can not be assessed since no historical surveys exist. The largest populations of this species occupy a 60 km stretch of the upper Grand River, a 45 km stretch of the Maitland River, 65 km in the upper Thames watershed divided between the North, Middle and South Thames Rivers and an area of approximately 12 km^2 in the Lake St. Clair Delta (Metcalfe-Smith and McGoldrick 2003).

Table 1: Canadian and U.S. national and provincial/state heritage status ranks (NatureServe 2004).

Canada (N1)	ON (S1)
United States (N4)	AL (S1S2), GA (S2?), IL (S2), IN (S2), KY (S4S5), MI (S2), NY (S1), NC (S1), OH (S?), PA (S4), TN (S4), VA (S4), WV (S2)

Population Abundance

Global Range: The Wavyrayed Lampmussel is globally secure (G4) but is an uncommon species throughout its range usually comprising less than 2% of the mussel community where it is found (Metcalfe-Smith and McGoldrick 2003).

Canadian Range: The Maitland River, upper reaches of the Grand River and the upper Thames River support the largest populations of this species in Canada while a smaller population exists in the Lake St. Clair delta. The Wavyrayed Lampmussel also occurs in the Ausable River but is represented only by large individuals with no evidence of successful reproduction. A single live specimen was found in a recent benthic survey at one location on the St. Clair River.

Percent of Global Abundance in Canada: Less than 1%

Population Trend: The rate of population change for the Wavyrayed Lampmussel is unknown. The only stable population of this species in Canada occurs in the Upper Grand River while the status of the second largest population (Maitland R.) is unknown due to a lack of historical information. The Grand R. population appears to have recovered from the poor water quality conditions present in the 1970's and early 1980's. Overall densities of all mussel species in the St. Clair delta appear to be declining over time although the small numbers of Wavyrayed Lampmussels make it difficult to interpret results for this species specifically (Metcalfe-Smith *et al.* 2004). All other Canadian populations have declined sharply to only a few individuals or have been extirpated.

Biologically Limiting Factors

Reproductive Attributes: The Wavyrayed Lampmussel, like all unionids, has a complicated reproductive cycle characterized by a period of obligate parasitism. This parasitic phase makes the Wavyrayed Lampmussel particularly sensitive to external factors that may indirectly affect them via their hosts (Bogan 1993).
The Wavyrayed Lampmussel is a medium sized, moderately long-lived, sexually dimorphic species. During spawning season, males release sperm into the water column and females located downstream take in the sperm via their incurrent siphons. Females brood the young from egg to larval stage in the posterior portions of the outer gills. Distended shells which swell along the posterior-ventral margins to allow room for expanded gill pouches (Metcalfe-Smith et al. 2000) characterize mature female Wavyrayed Lampmussels. Wavyrayed Lampmussels are long-term brooders (bradytictic) with spawning occurring in August and glochidial release occurring the following year (May through August in Virginia (Zale and Neves 1982), June through August in Canada (Woolnough 2002)).

When the larvae are mature they are released by the female and must undergo a period of encystment on the gills of a suitable host. Two host species have been identified for the Wavyrayed Lampmussel in the U.S.. Zale and Neves (1982) reported successful laboratory infestations of smallmouth bass (*Micropterus dolomieu*) with Wavyrayed Lampmussel glochidia while G.T. Watters (Ohio State University, cited in Metcalfe-Smith *et al*. 2000) reported success with largemouth bass (*M. salmoides*). The largemouth bass and smallmouth bass have recently

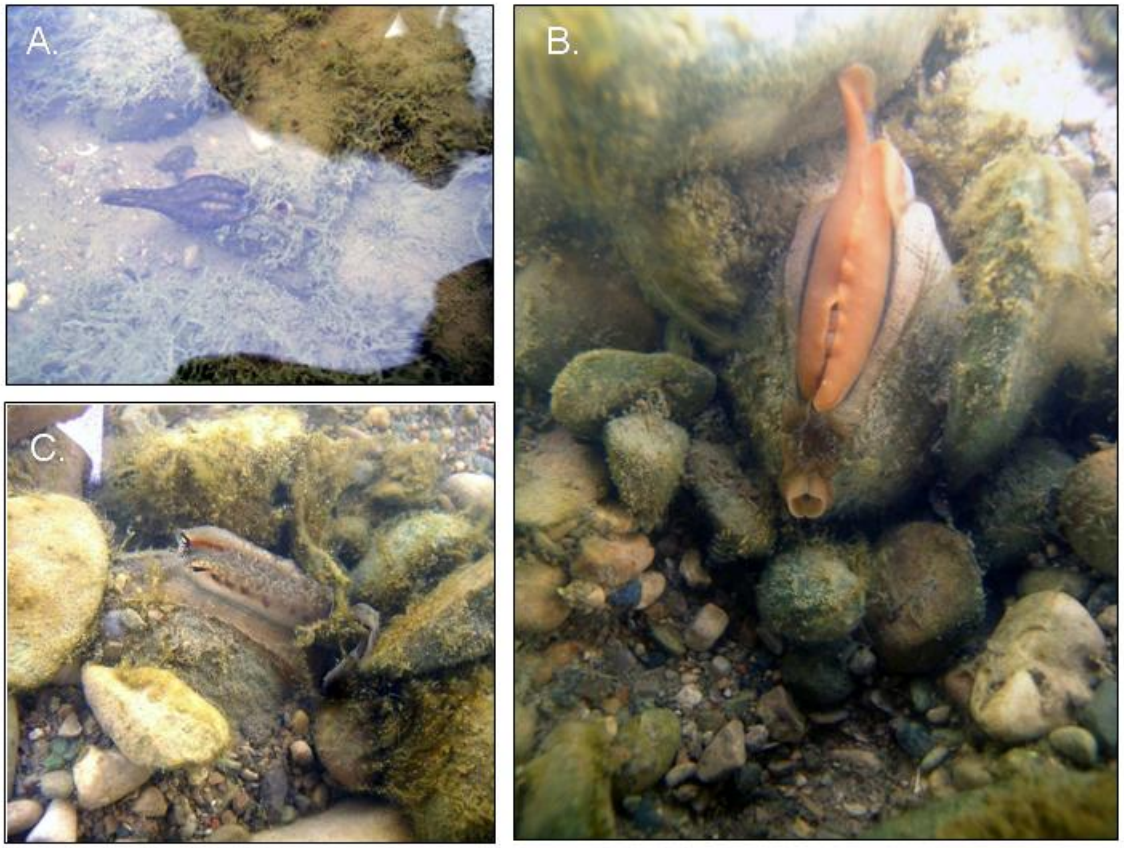

Figure 4: Three lure morphologies of the Wavyrayed Lampmussel: black (a), red (b) and fish-like (c). All three animals were observed in the North Thames River during 2004. Photos courtesy of T. Morris, Fisheries and Oceans Canada.

been confirmed as hosts for the Wavyrayed Lampmussel in Canada (McNichols *et al.* 2005). Researchers at the University of Guelph have also successfully infected mottled sculpin (C*ottus bairdii*) and brook stickleback (*Culaea inconstans*) with Wavyrayed Lampmussel glochidia although it is unclear whether these species functions as hosts under natural conditions (K. McNichols, University of Guelph, pers. comm., September 2003).

To increase the likelihood of encountering an appropriate host and facilitate successful encystment, female Wavyrayed Lampmussels have developed specialized mantle tissue to function as a lure (Strayer and Jirka 1997). Three co-occurring mantle lure morphologies have been observed on displaying female Wavyrayed Lampmussels during field surveys of the Grand, Thames, Ausable and Maitland Rivers. The three morphologies consist of a black lure, a bright red lure, and a fish-like lure (Figure 4). It is unknown if the three lure morphologies constitute sibling species or if they are ecomorphs. Molecular phylogenetic analysis is required to resolve this knowledge gap.

When a suitable host fish touches the mantle lure the mantle flaps are retracted into the shell, placing pressure on the marsupia and causing the release of the mature larvae (glochidia). The structure of the lure (e.g., eyespots and pigmentation consistent with a small minnow-shaped fish in the fish-like lure morph) and the method of glochidial release are consistent with a host species which is a visual predator. This indicates that water clarity likely plays a critical role in the successful completion of the reproductive cycle of the Wavyrayed Lampmussel.

Dispersal: Adult Wavyrayed Lampmussels have very limited dispersal abilities. Although adult movement can be directed upstream or downstream, studies have found a net downstream movement through time (Balfour and Smock 1995; Villella *et al.* 2004). The primary means for large scale dispersal, upstream movement, and the invasion of new habitat or evasion of deteriorating habitat, is limited to the encysted glochidial stage on the host fish.

Threats

The Wavyrayed Lampmussel is subject to a broad array of threats across its range. The eight categories identified in Table 2 represent the most likely threats to Canadian populations of the Wavyrayed Lampmussel.

Table 2: Threats to the Wavyrayed Lampmussel.

Threat	**Relative Impact** predominant/ contributing	**Spatial/Temporal** widespread/local chronic/ephemeral	**Certainty** probable/speculative/ unknown
Siltation/Suspended solids	predominant	widespread / chronic	probable
Exotics	predominant	local / chronic	probable
Impoundments	contributing	local / chronic	probable
Water Quality – contaminants & nutrients	contributing	widespread / chronic	probable
Disruption of host fish relationship	contributing	local / chronic	speculative

Threat	Relative Impact predominant/ contributing	Spatial/Temporal widespread/local chronic/ephemeral	Certainty probable/speculative/ unknown
Predation	contributing	local / ephemeral	speculative
Urbanization	contributing	local / chronic	speculative
Recreational activity	contributing	local / ephemeral	unknown

Siltation/Suspended Solids: High silt inputs can act to suffocate mussels by clogging gill structures and may also disrupt reproductive functions by decreasing the likelihood of encountering a suitable host fish (a visual predator). Susceptibility to siltation varies from species to species and the Wavyrayed Lampmussel has been shown to be mildly tolerant of high silt conditions during periods of low flow (Dennis 1984). However, recent studies in southern Ontario show that the Wavyrayed Lampmussel is associated with areas of low silt loads. Mean water clarity is higher in areas where Wavyrayed Lampmussels are found than in areas where they are not found and catch-per-unit-effort is positively correlated with water clarity (Metcalfe-Smith and McGoldrick 2003).

Exotics: Zebra mussels (*Dreissena polymorpha*) have decimated populations of freshwater mussels in the Lower Great Lakes by virtually eliminating historical habitats in Lake St. Clair (Nalepa et al. 1996) and western Lake Erie (Schloesser and Nalepa 1994). Although the Wavyrayed Lampmussel is primarily a riverine species, and therefore at lower risk to zebra mussel infestation, the presence of impoundments may increase the risk (see section on impoundments below). Zebra mussels pose a much greater risk for the St. Clair delta population: the last known lake population in Canada.

Other exotic species may indirectly affect the Wavyrayed Lampmussel by disrupting host fish relationships. For example, the mottled sculpin has shown recruitment failure and steep declines in abundance in the Great Lakes basin since the introduction of the exotic round goby (*Neogobius melanostomus*) (Dubs and Corkum 1996, Jannsen and Jude 2001).

Impoundments: Damming of the stream channel has been shown to detrimentally affect mussels in many ways. Reservoirs alter downstream flow patterns and disrupt the natural thermal profiles of the watercourse while impoundments act as physical barriers potentially separating mussels from their host fish. Impoundments also act to increase water retention times thereby making river systems more susceptible to invasion by exotics such as the zebra mussel. Reservoirs with retention times greater than 20-30 days allow enough time for veligers to settle and act as seed populations for downstream sites (Metcalfe-Smith *et al*. 2000). Zebra mussels were reported from the Fanshawe Reservoir (UTRCA 2003) and Springbank Reservoir (pers. comm., S. Hohn, UTRCA, June 2003) on the Thames River during 2003 (UTRCA 2003). At present, both of these zebra mussel infestations are downstream of most sections where Wavyrayed Lampmussels are found. Similar infestations, should they occur in Wildwood or Pittock reservoirs, higher up in the system could prove very harmful to the Wavyrayed Lampmussel populations in the North and South Thames. The Grand River is heavily impounded with 34 dams or weirs (GRCA 1998) and establishment of zebra mussels in the Luther, Belwood, Guelph, or Conestogo reservoirs could seriously impact the reach where the Wavyrayed Lampmussel is found.

Water Quality

Contaminants: Evidence suggests that mussels are sensitive to PCBs, DDT, Malathion and Rotenone that can inhibit respiration and accumulate in mussel tissue (USFWS 1994). PCBs have been detected in mussel tissue in the Middle Maitland River (pers. comm. D. Kenny, MVCA, July 2003). The glochidial stage appears to be particularly sensitive to heavy metals (Kellar and Zam 1990), ammonia (Goudreau *et al.* 1993; Mummert *et al.* 2003)), acidity (Huebner and Pynnonen 1992) and salinity (Liquori and Insler, as cited in USFWS 1994). While freshwater mussels, as a group, appear to be sensitive to poor water quality, two contaminants stand out as being particularly problematic. Recent research has shown that *Lampsilis fasciola,* and most freshwater mussel species tested, are among the most sensitive organisms to ammonia and copper (Mummert *et al*. 2003; Jacobsen *et al*. 1997; Ingersoll unpublished data). A comparison of the reported toxicity data for these two contaminants with Canadian water quality guidelines for the protection of aquatic life shows that current objectives for unionized ammonia are probably sufficient to protect *L. fasciola* (Table 3). On the other hand, the EC50 for copper reported by Ingersoll (unpublished data) falls within the range of the current objectives for the protection of aquatic life in Canadian waters. Considering that 50% of *L. fasciola* tested showed effects (reduced growth or death) at copper concentrations of ranging from less than 5 to 7 µg/L, the current objectives of 2-5 µg/L are unlikely to protect this species from harm. Copper levels exceed federal guidelines in several sub-basins of the Thames River in which the Wavyrayed Lampmussel is still found. Only the upper reaches of the Grand River have copper levels that fail to exceed the federal guidelines and these correspond to the only portions of the watershed where the Wavyrayed Lampmussel is found (Metcalfe-Smith et al. 2000). Copper levels exceed federal guidelines in the Middle Maitland River as well (pers. comm. D. Kenny, MVCA July 2003).

Table 3. Toxicity of ammonia and copper to the glochidia and juveniles of *Lampsilis fasciola*.

Contaminant	Life stage tested	Result	Source	Water Quality Guidelines
Unionized Ammonia (NH_3-N)	Juvenile	LC50 (mg/L): 24h : 0.28-0.36 48h : 0.21-0.24 72h : 0.21-0.24 96h : 0.21-0.25	Mummert *at al*. (2003)	CCME[a]: 0.019 mg/L PWQO[b]: 0.020 mg/L
Ammonia (Total)	Glochidia Juvenile	48h EC50: 6 mg/L 10d EC50: 1.7 mg/L	Ingersoll (unpublished data)	N/A
Copper	Glochidia	24h LC50: 26-48 µg/L[1] 48h EC50: 7 µg/L[2] 72h EC50:	[1]Jacobsen *et al*. (1997) [2]Ingersoll (unpublished data)	CCME: 2-4 µg/L PWQO: 5 µg/L

Contaminant	Life stage tested	Result	Source	Water Quality Guidelines
	Juvenile	4.7 µg/L[2] 10d EC50: 4.8 µg/L[2]		

[a] Canadian Council of Ministers of the Environment (CCME 2005)
[b] Ontario Provincial Water Quality Objectives – (PWQO 2005)

Nutrients: The primary land use in the Ausable and Sydenham River basins is agriculture. Row crops (corn, beans) predominate in the Ausable River watershed while cash crops dominate the Sydenham River watershed (Nelson 2000). Water quality in the Ausable River is generally considered poor resulting from agricultural runoff and manure seepage (ABCA 1995, ARRT 2003). In the Grand River, clearing of riparian vegetation and allowing livestock to access the river has resulted in poor water quality with increased sediment loads (WQB 1989a). Agricultural activity is expected to increase in the Grand River basin over the next 25 years leading to a predicted increase in sediment, pesticide, fertilizer, and manure runoff. Water quality in the Thames River basin has historically suffered greatly from agricultural activities. Tile drainage, wastewater drains, manure storage and spreading, and insufficient soil conservation have all contributed to poor water quality within the Thames basin (Metcalfe-Smith *et al.* 2000). Phosphorus and nitrogen loadings have increased steadily and some of the highest livestock loadings for the entire Great Lakes basin have been reported for the Thames River watershed (WQB 1989b). Mean ammonia concentrations in all sub-basins of the Thames River exceed the federal freshwater aquatic life guidelines (Metcalfe-Smith *et al.* 2000). It has recently been reported that juvenile freshwater mussels are among the most sensitive aquatic organisms to unionized ammonia toxicity, typically showing adverse responses at levels well below those used as guidelines for aquatic safety in U.S. waterways (Newton 2003; Newton *et al.* 2003). The recently discovered Maitland River population faces threats from agricultural run-off with 75% of nitrate samples on the Middle Maitland exceeding the federal guidelines for negatively impacting aquatic health while 56% of total phosphorus levels exceed those indicating a high likelihood of algal blooms (pers. comm. D. Kenny, MVCA, July 2003).

Disruption of Host Fish Relationship: Any factors that directly or indirectly affect host fish distributions will impact Wavyrayed Lampmussel distributions. Smallmouth bass, the likely host species, are very rare in the Sydenham River system (M. Poos, University of Guelph, cited in Metcalfe-Smith and McGoldrick 2003) which may explain the disappearance of Wavyrayed Lampmussels from this watershed. Smallmouth bass populations have also been reduced in the Grand River between Cambridge and West Montrose, likely as a result of angling pressure (Cooke *et al.* 1998).

Urbanization: The Grand River watershed has a population of approximately 780,000 and is expected to increase by nearly 40% over the next 20 years (GRCA 1998; Krause et al. 2001). More than 80% of the population occupies less than 7% of its area. Wastewater discharge is a major input in these urban areas and will only increase with increasing population. Within the Thames River basin all industrial

outfalls and 70% of municipal outfalls are located within the heavily populated upper reaches where the Wavyrayed Lampmussel is found.

Recreational Activities: Reaches of the Grand River where Wavyrayed Lampmussels occur are popular areas for canoeists. Metcalfe-Smith *et al.* (2000) observed that paddlers in shallow water often disturbed the riverbed creating the potential for dislodging mussels and promoting downstream transport. Increasing popularity of recreational activities like canoeing may further increase stresses on unstable populations.

Predation: Predation by terrestrial predators such as muskrats (*Ondatra zibethicus*) and raccoons (*Procyon lotor*) has been shown to be an important limiting factor for some populations (Neves and Odom 1989). Neves and Odom (1989) reported that muskrats are both size and species specific predators and that they actively choose Wavyrayed Lampmussels when available. Metcalfe-Smith and McGoldrick (2003) reported observing raccoon predation on mussels in Ontario waters. Human-related activities, such as the adoption of conservation tillage practices, have resulted in surges in predator populations which may increase the importance of predation related threats in the future (Metcalfe-Smith and McGoldrick 2003). Southwestern Ontario farmers have reported a surge in raccoon numbers in recent years that may correspond with the adoption of conservation tillage practices (Metcalfe-Smith and McGoldrick 2003). This anecdotal observation needs verification in order to quantify the effects of human-related activities on predator populations.

Table 4: Predominant threats to the Wavyrayed Lampmussel in each currently or historically occupied locality.

Locality	Predominant Threat
Ausable R.	Siltation, Water Quality
Grand R.	Host Fish, Urbanization
Lake St. Clair delta	Exotics (dreissenid mussels)
Maitland R.	Unknown
Thames R.	Water Quality; Siltation, Exotics
Great Lakes (extirpated)	Exotics (dreissenid mussels)
Sydenham R. (extirpated)	Siltation (disruption of reproductive cycle); Loss of Host

Habitat Description

The Wavyrayed Lampmussel is typically found in clear, hydrologically stable rivers and streams. Clarke (1981) and Cummings and Mayer (1992) reported the species from gravel or sandy bottoms of riffle-areas in medium sized streams. Strayer (1983) reported the Wavyrayed Lampmussel in Michigan from medium-sized and large streams characterized by low gradients, clear waters, steady flows and substrates of sand and gravel. Dennis (1984) examined the habitat preferences of 72 species in the Tennessee River basin and reported *L. fasciola* from small (2^{nd} to 4^{th} order creeks) and medium (5^{th} to 7^{th} order) sized streams. Dennis (1984) reported that the most productive habitat consisted of stable substrates with a mixture of fine particles, gravel and rocks. Within Ontario waters it is usually found in clean sand or gravel substrates in shallow (< 1m)

riffle areas. In the Great Lakes it has been found along shallow wave-washed shoals (Metcalfe-Smith and McGoldrick 2003).

Currently Occupied Habitat:

Geospatial Description:

Habitat in need of conservation for the Wavyrayed Lampmussel has been geospatially located using the methods developed by McGoldrick *et al.* (in press) (Figure 5 - 8) who recommend using the Ontario Ministry of Natural Resource's Aquatic Landscape Inventory Software (ALIS version 1) (Stanfield and Kuyvenhoven 2005) as the base unit for definition of important habitat within riverine systems. The ALIS system employs a valley classification approach to define river segments with similar habitat and continuity on the basis of hydrography, surficial geology, slope, position, upstream drainage area, climate, landcover and the presence of instream barriers. For Great Lakes populations where ALIS segments can not be employed, McGoldrick *et al.* (in press) recommend using a 5km buffer around known species occurrences. The 5km buffer was selected in light of the spatial extent of historic sampling within Lake St. Clair. Within all identified river segments the width of the habitat zone in need of protection is defined as the area from the mid-channel point to bankfull width on both the left and right banks.

Currently occupied habitat for the Wavyrayed Lampmussel can be summarized as:

- A 60 km stretch of the Grand River between Inverhaugh and Cambridge (Metcalfe-Smith and McGoldrick 2003).
- A 30 km section of the North Thames River above London including Medway and Fish creeks. A 25 km section of the Middle Thames River from London to Dorchester as well as the lower reaches of the Middle Thames from Thamesford to its confluence with the Middle Thames (T. Morris, Fisheries and Oceans Canada, Burlington, unpublished data).
- The lower reaches of the Middle, Little and South Maitland Rivers and the 45 km section of the main branch of the Maitland River from Wingham to the confluence with the South Maitland.
- The lower section of the Little Ausable River and a 12 km stretch of the main channel of the Ausable River upstream of Nairn (Metcalfe-Smith *et al*. 1999).
- A 12km^2 region of the St Clair delta (Zanatta *et al*. 2002).

Functional Description:

Within the area defined under Geospatial Description only areas meeting the characteristics described below are deemed to represent habitat in need of conservation:

- permanently wetted and
- of a stream order greater than 2 (riverine populations only) and
- having clean sand/gravel substrates sometimes stabilized by larger material (rubble, boulder or bedrock) and
- riffle/run habitat (riverine populations only) or
- shallow sand flats (Great Lakes populations) and

- providing access to suitable host specimens during the period of female gravidity (June 1 – October 15).

Activities Likely to Impact Currently Occupied Habitat

The currently occupied habitat of the Wavyrayed Lampmussel could be negatively affected by a variety of activities. Direct destruction of habitat could result from in-stream activities such as dredging, road crossings and pipeline crossings or the construction of dams. Currently occupied habitat could also be negatively affected by any land-based activities that affect water quality or quantity. Such activities would include (but are not limited to) the input of nutrients, sediment and toxic substances through improperly treated storm water, cultivation of riparian lands, unfettered access of livestock to the river, channelization and drainage works, water taking, aggregate extraction, and the release of improperly treated sewage.

McGoldrick *et al*. (in press) have earlier identified a number of threshold values which can be used to gage the likelihood that an activity will negatively impact or destroy currently occupied habitat. Any activity that results in an exceedance of the threshold values in Table 5 should be considered likely to destroy currently occupied habitat.

Table 5: Threshold values for determining the likelihood that an activity will negatively impact currently occupied habitat.

Variable	Threshold
unionized ammonia	0.21 mg/L
total ammonia	1.7 mg/L
copper	4.7 µg/L
total phosphorus	0.05 mg/L
nitrate-nitrite ratio	2.0 mg/L
turbidity	8 JTU
potassium	6 mg/L

When dealing with freshwater mussels it is necessary to consider not only the physical and chemical components of habitat but also the biological. Any activity which disrupts the connectivity between Wavyrayed Lampmussel populations and their host species (see section on Life Cycle and Reproduction) may result in the destruction of currently occupied habitat. Activities which may disrupt the mussel-host relationship include, but are not limited to, damming, dewatering and harvest. Note that activities occurring outside the currently occupied habitat zone may affect the host population within the zone (e.g., downstream damming activities may prevent the movement of fish into the currently occupied habitat zone during the period of mussel reproduction (June 1 – October 15)). Any activity that impacts a host population within an area of currently occupied habitat should be evaluated to ensure that the reproductive cycle is not disrupted.

Figure 5: Currently occupied habitat for the Wavyrayed Lampmussel (*Lampsilis fasciola*) in the Great Lakes and connecting channels.

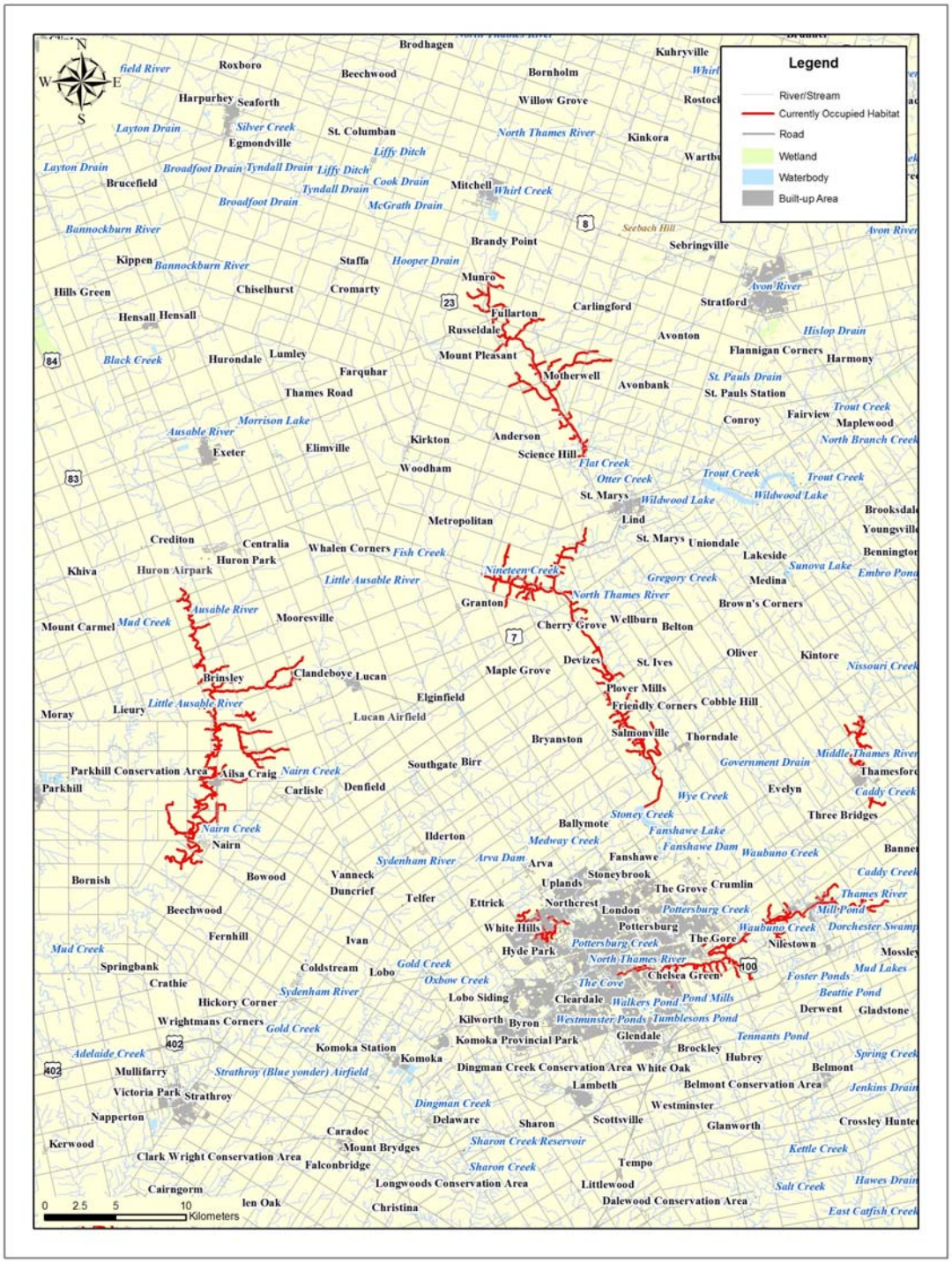

Figure 6: Currently occupied habitat for the Wavyrayed Lampmussel (*Lampsilis fasciola*) in the Upper Thames and Ausable rivers.

Figure 7: Currently occupied habitat for the Wavyrayed Lampmussel (*Lampsilis fasciola*) in the Maitland River.

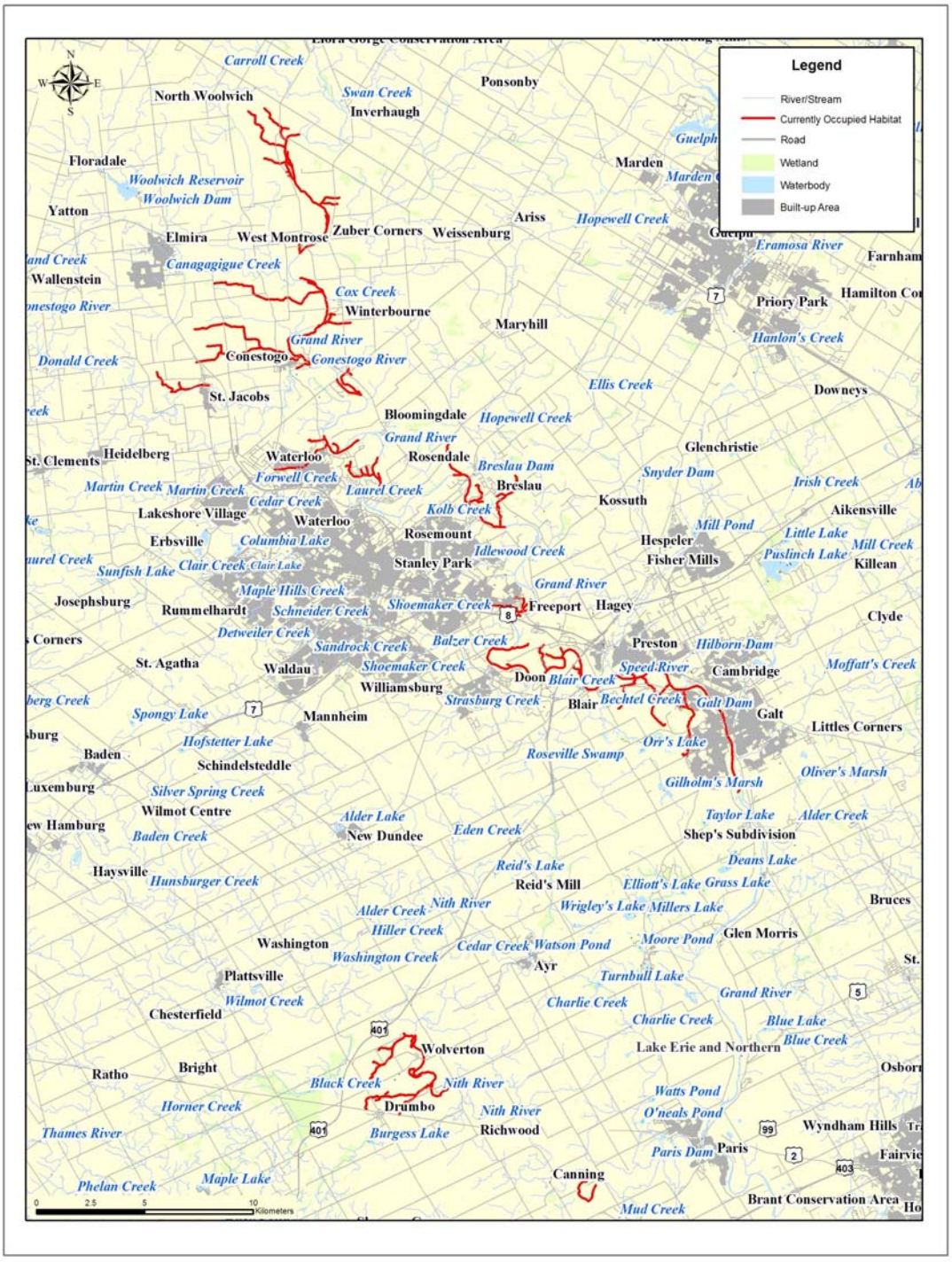

Figure 8: Currently occupied habitat for the Wavyrayed Lampmussel (*Lampsilis fasciola*) in the Upper Grand River.

Historically Occupied Habitat: Historically occupied habitat includes a 40km stretch of the East Sydenham River and a small stretch of the lower Grand River near York. Although the St Clair and Detroit rivers, Lake St Clair (excluding the delta) and the western basin of Lake Erie represent historically occupied habitat they are low priority sites for recovery/re-establishment due to the presence of high abundances of dreissenid mussels.

Critical Habitat: The identification of Critical Habitat requires a thorough knowledge of the species needs during all life stages as well as an understanding of the distribution, quantity, and quality of habitat across the range of the species. At present, this information is not available for the Wavyrayed Lampmussel although Table 6 outlines activities that would assist with obtaining the required information. The activities listed in Table 6 are not exhaustive but outline the range and scope of actions identified by the OFMRT as necessary to identify Critical Habitat for the Wavyrayed Lampmussel. It is likely that the process of investigating the actions in Table 5 will lead to the discovery of further knowledge gaps that will have to be addressed. Until Critical Habitat can be defined the recovery team has identified the areas listed in the Currently Occupied Habitat section as areas in need of conservation.

Table 6: Schedule of activities to identify Critical Habitat

Activity	Approximate Time Frame[1]
Conduct mussel population surveys	2006-2008
Assess habitat conditions in occupied areas (e.g., flow, substrate, water clarity and quality)	2006-2008
Determine any life stage differences in habitat use	2007-2009
Survey and map areas of suitable but unused habitat within historical range	2008-2010
Assess genetic structure of populations	2006-2008
Determine host fish species	2006
Conduct host fish population surveys	2006-2008
Assess habitat use by host species	2006-2008
Determine areas of overlap between mussel and host habitat	2009-2010

[1] timeframes are subject to change as new priorities arise or as a result of changing demands on resources or personnel

Habitat Trends: The majority of Lake St. Clair (excluding the delta) the Detroit River and the western basin of Lake Erie are no longer suitable habitat for the Wavyrayed Lampmussel because of the infestation of dreissenid mussels. There is strong evidence that poor water clarity limits the distribution of the Wavyrayed

Lampmussel (Metcalfe-Smith & McGoldrick, 2003). High turbidity and suspended solids in the Sydenham and Ausable rivers have rendered large portions of habitat unsuitable. Water clarity in the occupied reaches of the Grand, Thames and Maitland Rivers does not seem to be a problem.

Habitat Protection: The federal Species at Risk Act (SARA) was proclaimed in June of 2003. Under SARA there are general prohibitions against killing, harming, taking, possessing, capturing, and collecting the Wavyrayed Lampmussel and against damaging or destroying its residences, as well as prohibitions on the destruction of Critical Habitat. The *Fisheries Act* represents an important tool for habitat protection and along with other federal environmental legislation is complimentary to the *Species at Risk Act*. Under the federal Fisheries Act mussels are considered shellfish, falling under the definition of 'fish', and their habitat is therefore protected from harmful alteration, disruption or destruction unless authorized by the Minister of Fisheries and Oceans, or his/her delegate. Planning authorities must be consistent with the provincial Policy Statement under Section 3 of Ontario's Planning Act, which prohibits development and site alteration in the significant habitat of endangered species. The Ontario Lakes and Rivers Improvement Act prohibits the impoundment or diversion of a watercourse if siltation will result while the voluntary Land Stewardship II program of the Ontario Ministry of Agriculture, Food and Rural Affairs is designed to reduce erosion on agricultural lands. Stream-side development in Ontario is managed through floodplain regulations enforced by local conservation authorities.

A majority of the land adjacent to the rivers where Wavyrayed Lampmussels are found is privately owned, however, the river bottom is generally owned by the Crown. The Municipality of Southwestern Middlesex (formerly Mosa Township) owns a 20 ha section of forest along the reach of the Sydenham River where Wavyrayed Lampmussel shells were found in 1997 (Muriel Andreae, St. Clair Region Conservation Authority, cited in Metcalfe-Smith *et al.* 2000) and the SCRCA owns approximately 1816 ha of property in the watershed. The Ausable Bayfield Conservation Authority (ABCA) owns approximately 1830 ha of property split between a number of locations in the Ausable River basin (K. Vader, ABCA, cited in Metcalfe-Smith *et al.* 2000) and the Maitland Valley Conservation Authority owns 28 properties covering 1800 ha within the Maitland River watershed including one site where the Wavyrayed Lampmussel was found (Wawanosh Conservation Area). Much of the land adjacent to the refuge site identified in the Lake St. Clair delta is within the boundaries of the Walpole Island First Nation (Zanatta *et al.* 2002).

Ecological Role

Freshwater mussels play an integral role in the functioning of aquatic ecosystems. Vaughn and Hakenkamp (2001) have summarized much of the literature relating to the role of unionids and identified numerous water column (size-selective filter-feeding; species-specific phytoplankton selection; nutrient cycling; control of phosphorus abundance) and sediment processes (deposit feeding decreasing sediment organic matter; bio-deposition of feces and pseudo-feces; epizoic invertebrates and epiphytic algae colonize shells; benthic invertebrate densities positively correlated with mussel density) mediated by the presence of mussel beds. Welker and Walz (1998) have demonstrated that freshwater mussels are capable of limiting plankton in European rivers while Neves and Odom (1989) reported that mussels also play a role in the

transfer of energy to the terrestrial environment through predation by muskrats and raccoons.

Importance to People

Although this species has no immediate economic significance, freshwater mussels are sensitive to environmental pollution and a diverse mussel community indicates a healthy aquatic ecosystem. Besides decreased biodiversity in Canada, the decline of the Wavyrayed Lampmussel may indicate further environmental degradation of southern Ontario watercourses which would adversely affect those people who use surface water for drinking, recreation or watering livestock. Recovery of the species may require the participation of recreational anglers as the likely host species, smallmouth bass, are popular sportfish.

Anticipated Conflicts or Challenges

A general shortage of malacological experts in southern Ontario and the specific retirements of two prominent experts are going to pose a problem of continuity over the 5 year implementation period of this recovery strategy. There will be a need to fill the voids created by these retirements and to train new experts to carry on the research programs of these scientists to ensure that the approaches outlined in this strategy are effectively addressed.

The re-establishment of viable populations in the Ausable and Sydenham Rivers will require watershed scale recovery prior to any re-introduction of the Wavyrayed Lampmussel. Critical improvements to riparian zones can be accomplished over the short term however these can be ephemeral solutions as they are subject to reversal with changes in land ownership.

Knowledge Gaps

Survey Needs:

Watershed	Location	Reason
Ausable	Hay Swamp, Little Ausable, main channel downstream of Nairn	To determine the extent, abundance, and population demographics of the Wavyrayed Lampmussel.
Grand	Tributaries including Conestogo R.	
Maitland River	Upper reaches of all 4 branches.	
Thames	Lower reaches and tributaries	
Lake St. Clair	Delta	

These locations represent areas identified by the Recovery Team as ones for which data are currently insufficient. Further areas in need of survey may be identified in the future as needs arise. No additional surveys are foreseen for the Sydenham River as the OFMRT feels that the river has been adequately surveyed.

Biological/Ecological Research requirements:

Research Requirement	Details
Host fish identification	Investigate other potential hosts.
Juvenile propagation	Develop a protocol for rearing juvenile mussels under laboratory conditions.
Genetics – variability	Examine degree of variation across Canadian range and compare with variability across global distribution to assist in determining appropriateness of augmentation efforts and selecting source populations if action is warranted.
Genetics – propagation guidelines	Develop genetically sound propagation guidelines for freshwater mussels estimating the number of individuals needed to maintain or reintroduce 95% of the known genetic variation in propagated populations.
Genetics - molecular phylogenetics	Determine if the three lure morphologies found in Canadian populations are actually monophyletic or are sister taxa.

Threat Clarification Requirements:

Threat	Details
Exotics	Examine the zebra mussel threat to Wavyrayed Lampmussels within the St. Clair delta refuge site. Examine host fish dynamics in relation to exotic species (e.g., mottled sculpins and gobies)
Recreational Activity	Determine if recreational activity poses a serious threat to the Wavyrayed Lampmussel.
Predation	Quantify predation levels. Track changes in predator abundance in response to human-induced changes in the environment (e.g., urbanization, agricultural practices).
Toxicity	Determine the vulnerability of all life stages to known and suspected pollutants. Initial focus on glochidial and juvenile stages

Threat	Details
	which are known to be most sensitive.
Water clarity	Test hypothesis that water clarity limits the reproductive success of the Wavyrayed Lampmussel.

Biological and Technical Feasibility of Recovery
Recovery of the Wavyrayed Lampmussel is believed to be both biologically and technically feasible as reproducing populations still exist as potential sources to support recovery, suitable habitat can be made available through recovery actions, threats can be mitigated and proposed recovery techniques are anticipated to be effective.

i. Mussels are slow growing and sedentary animals dependant on their host fishes for the survival and dispersal of their young. The slow rate of population growth makes the natural recovery of decimated populations a lengthy process.

ii. The habitat that supports this species in the Upper Grand River and Thames rivers appears to be of high quality due to high water clarity and ample evidence of successful reproduction. Current habitat in the Ausable River is of low quality because of high turbidity or poor water quality. The habitat formerly occupied in the Sydenham River is also of low quality due to poor water clarity and the absence of its host fish. The waters of Lake St. Clair delta are clear and clean but the habitat is of marginal quality due to the presence of dreissenid mussels. Habitat in the Maitland River appears to be of high quality but there is still a need for further assessment.

iii. The habitat in the Sydenham and Ausable Rivers could be improved significantly with proper stewardship of both agricultural and urban lands in each watershed.

iv. Reductions in soil erosion and turbidity in all the watersheds are achievable goals but would be challenging due to the number and intensity of the impacts.

v. Eliminating the impacts of dreissenid mussels on the Great Lakes populations is not possible although the establishment of managed refuge sites in the Lake St. Clair delta may be possible.

vi. Artificial propagation of the Wavyrayed Lampmussel has been successful in the U.S. (Hanlon and Neves 2000).

The Wavyrayed Lampmussel is naturally a rare component of the mussel community where it is found. The level of effort required for recovery of this species would be low (e.g. habitat preservation) for the Grand, Thames and Maitland Rivers, moderate for the St. Clair delta (managed refuge sites, zebra mussel cleaning), high for the Ausable (e.g. translocation, long-term population augmentation), and high for the Sydenham River which likely requires the re-introduction of both the mussel and smallmouth bass.

Recommended Scale of Recovery
Although the Wavyrayed Lampmussel has a geographically restricted range at a national scale it is relatively broadly distributed across southern Ontario where it is still found

alive in 4 major rivers (Ausable, Grand, Maitland, Thames) and in Lake St. Clair. Aquatic Ecosystem Recovery Strategies are in development for the Ausable and Thames Rivers. Although these ecosystem strategies give consideration to the Wavyrayed Lampmussel they can not be relied upon to provide the sole means of protecting this species as each focuses on only a small portion of the total range. Boersma *et al.* (2001) reported that species covered by ecosystem plans are 4 times less likely to show improvement relative to species covered by single species plans in part because less time and money are typically spent per species in ecosystem plans. A single species approach is necessary to ensure that no critical elements are omitted from the ecosystem plans and to represent the only means of protection in watersheds where ecosystem strategies are lacking (Grand R., Maitland R., Lake St. Clair). If ecosystem plans are developed in the future for these watersheds the single species strategy will provide a strong foundation to build upon.

II. RECOVERY

Recovery Goal

The long-term goal of this recovery strategy is to prevent the extirpation of the Wavyrayed Lampmussel in Canada and to promote the recovery of this species by:

i. protecting existing populations to prevent further declines,
ii. restoring degraded populations to healthy self-sustaining levels by improving the extent and quality of habitat and
iii. re-introducing the Wavyrayed Lampmussel into areas where it formerly existed where feasible.

Morris *et al.* (2005) recommend that recovery of the Wavyrayed Lampmussel be assessed using a hierarchical approach where recovery at the species level is dependent upon achieving desired goals at the population and individual levels. They have identified 6 extant and 4 extirpated population units and suggest that these units should form the basis for any evaluation of species recovery.

Recovery Objectives (5 year)

i. Determine extent, abundance and population demographics of existing populations.
ii. Determine/confirm fish hosts, their distributions and abundances.
iii. Define key habitat requirements to identify Critical Habitat.
iv. Establish a long-term monitoring program for Wavyrayed Lampmussels, their habitat and that of their hosts.
v. Identify threats, evaluate their relative impacts and implement remedial actions to reduce their effects.
vi. Examine the feasibility of relocations, reintroductions and artificial propagation.
vii. Increase awareness of the significance of the Wavyrayed Lampmussel and its status as a Canadian Species at Risk.

Approaches to Meeting Recovery Objectives

The approaches to recovery have been organized into four distinct groups – research and monitoring, management, stewardship and awareness. Successful recovery across the range of the Wavyrayed Lampmussel will require consideration of all approaches from all categories. Approaches have been prioritized in a relative sense only as the OFMRT feels that all approaches would assist in meeting the recovery objectives. Recovery actions that consider multiple approaches will likely have a greater chance of achieving the recovery goals. A narrative has been included after each table where appropriate.

1) Research and Monitoring Approaches

Priority	Number	Objective Addressed	Broad Approach/ Strategy	Specific Steps	Anticipated Effect	Threat Addressed
Urgent	1-1	i, iii	Surveys – Ausable R., Grand R., Thames R.	Conduct further surveys to determine the extent and abundance of the Ausable R., Grand R. and Thames R. populations.	Will identify distribution, density and assist with identification of Critical Habitat.	
Urgent	1-2	i, iii	Surveys – Maitland R.	Intensive surveys to quantify distribution and abundance of this newly discovered population.	Will characterize these populations and determine their status. Will assist with identification of Critical Habitat.	
Urgent	1-3	iii	Research – Critical Habitat	Determine the habitat requirements of all life stages of the Wavyrayed Lampmussel.	Will define Critical Habitat for the Wavyrayed Lampmussel.	All threats.
Urgent	1-4	iii	Surveys - Habitat	Map areas of suitable habitat.	Will assist with identification of Critical Habitat.	

Priority	Number	Objective Addressed	Broad Approach/ Strategy	Specific Steps	Anticipated Effect	Threat Addressed
Urgent	1-5	iii	Research – Cross-basin habitat comparison	Determine critical conditions for Wavyrayed Lampmussel survival by cross-basin comparisons of populations which are stable (e.g., Grand R.) with those that are declining (e.g., Thames R., Ausable R.).	Will assist with determination of critical conditions necessary for recovery in all habitats.	All threats.
Urgent	1-6	ii	Research – host fish	Investigate other host fish species for the Wavyrayed Lampmussel.	Identify other host species.	Disruption of Host Fish Relationship.
Urgent	1-7	ii, iv	Surveys – host fish	Determine the distribution and abundance of the identified host species.	Determine if Wavyrayed Lampmussels are limited by host availability. Assist in identifying Critical Habitat.	Disruption of Host Fish Relationship.
Urgent	1-8	iv	Monitoring - populations	Establish routine surveys to monitor changes in the distribution and abundance of all populations	Will provide trend through time data for tracking recovery progress.	
Urgent	1-9	iv	Monitoring - habitat	Establish monitoring stations to track changes in Wavyrayed Lampmussel habitat	Will identify habitat trends.	

Priority	Number	Objective Addressed	Broad Approach/ Strategy	Specific Steps	Anticipated Effect	Threat Addressed
Urgent	1-10	v	Monitoring - exotics	Monitor reservoirs for establishment of zebra mussels.	Will provide early warning of threat to populations and habitat.	Exotics.
Urgent	1-11	v	Barrier analysis	Assess the distribution of in-stream barriers in all basins. Determine their impact and the feasibility of barrier removal or mitigation where appropriate.	Will determine if dams impact population distributions.	Impoundments.
Urgent	1-12	v	Toxicity testing	Determine glochidial sensitivity to environmental contaminants	Will identify threats and potential limiting factors.	Water quality – contaminants and nutrients.
Urgent	1-13	vi	Population augmentation	Examine the feasibility of translocations and re-introductions.	Will determine if small populations can be augmented or if the species can be reintroduced in historical range.	
Urgent	1-14	vi	Research – conservation genetics	Compare genetic variation in Canadian range with variation across entire North American range.	Will assist in determining appropriateness of population augmentation and selecting source population if action is warranted.	

Priority	Number	Objective Addressed	Broad Approach/ Strategy	Specific Steps	Anticipated Effect	Threat Addressed
Necessary	1-15	vi	Research – propagation guidelines	Develop genetically sound propagation guidelines for freshwater mussels.	Will give an estimation of the number of individuals required to maintain or reintroduce 95% of the known genetic variability in propagated populations.	
Necessary	1-16	vi	Research - phylogenetics	Determine if different observed lure morphologies are monophyletic.	Will resolve taxonomic uncertainty and ensure correct management of unique taxonomic units.	

1-1 & 1-2: Additional surveys are required to confirm the complete extent of Wavyrayed Lampmussel distributions in the Ausable, Grand and Thames Rivers. Particular areas in need of additional survey work have been identified under Knowledge Gaps in the Background section. A thorough understanding of all current and historic distributions is a necessity for determination of Critical Habitat as indicated by the schedule of activities in Table 4. In the case of the newly discovered Maitland River population, additional surveys will need to be more exhaustive than in the other drainages.

1-3 – 1-5: Critical Habitat is a cornerstone concept of SARA and represents one of the best tools for preserving the Wavyrayed Lampmussel. Given the present knowledge of the species it is not possible to identify Critical Habitat at this time however the activities identified in items 1-3 to 1-5, and those in Table 4, will begin to fill the gaps and allow for a description of Critical Habitat. Additional data collected in conjunction with the populations surveys will assist with determining habitat requirements while surveys to map areas which possess the identified habitat requirements will assist with identifying areas of Critical Habitat.

1-6 & 1-7: The obligate parasitic larval stage of the Wavyrayed Lampmussel represents a potential bottleneck in its lifecycle. Research and recovery actions focusing on the pre or post encystment period may prove unproductive if the presence of a host fish is the limiting step. In order to determine if these species are host limited it is necessary to first confirm the host species and then to confirm that the distributions of the mussel and its host overlap in time and space in a manner that will permit successful encystment. The identification of high host specificity in some mussel species requires that hosts be

identified for local populations whenever possible. Efforts should be directed towards confirming that species identified as hosts for American populations also function as hosts in Canada.

Once the Canadian hosts have been confirmed it is necessary to ensure that host species distributions overlap with Wavyrayed Lampmussel distributions. Since the adult mussels are sedentary this can be accomplished by confirming that members of the hosts species occur in reaches with mature female mussels at times when the female mussels possess mature glochidia.

1-8 – 1-10: A network of detailed, permanent monitoring stations should be established throughout the present and historic ranges of the Wavyrayed Lampmussel. Monitoring sites should be established in a manner so as to permit:

- Quantitative tracking of changes in mussel abundance or demographics (size distribution, age structure etc.) or that of their hosts.
- Detailed analyses of habitat use and the ability to track changes in use or availability.
- The ability to detect the presence of exotic species (i.e. zebra mussels). Reservoirs represent the likely seed locations for zebra mussels in the inland rivers. Monitoring sites should be established within or close to these reservoirs to permit the early detection of zebra mussels in the event that they invade these systems. Monitoring of exotics in the Lake St. Clair delta will likely be conducted in close association with the managed refuge sites.

Monitoring stations established to benefit Wavyrayed Lampmussels will provide the opportunity to collect data on the distribution, demographics, habitat and hosts of all mussel species and will be incorporated into the recovery plans for other mussel SAR.

1-11: An assessment of instream barriers should be conducted for all watersheds where the Wavyrayed Lampmussel is known to exist. Barriers should be mapped and their effects on local habitat conditions (e.g., flow, temperature, substrate stability and composition) should be assessed to determine if they are impacting Wavyrayed Lampmussel habitat. While instream barriers have been largely cited as having a detrimental effect on mussels through temperature and hydraulic changes as well as restricting host distributions, anecdotal evidence indicates that small barriers on the Sydenham River may be providing habitat for hosts of the Wavyrayed Lampmussel (pers. comm., M. Andreae, SCRCA, October 2003).

1-13 – 1-16: Additional surveys and monitoring may reveal that some populations are not likely to persist without active intervention. In some cases these populations may benefit from supplementation with individuals from nearby stable locations or through stocking with artificially reared juveniles. Research into the feasibility of population augmentation should begin immediately to prepare for this possibility and should be directed towards:

- Identifying genetically suitable stocks for source populations.
- Establishing laboratory rearing procedures. U.S. groups have had great success in producing juvenile Wavyrayed Lampmussels in captivity and successfully rearing them to reproductive maturity (Hanlon 2000). Consultation with these groups will likely contribute to the development of successful protocols in Canada.

- Evaluating methods to maximize survival of transplanted individuals.

2) Management Approaches

Priority	Number	Objective Addressed	Broad Approach/ Strategy	Specific Steps	Anticipated Effect	Threat Addressed
URGENT	2-1	i, ii	Capacity Building	Promote and enhance expertise in freshwater mussel identification/biology and provide for the transfer of knowledge.	Will ensure correct identification of mussel species at risk, sound experimental design and maximize efficiency.	All threats.
URGENT	2-2	v, vii	Cooperation – ecosystem recovery strategies	Work with existing ecosystem recovery teams to implement recovery action plans.	Ensure a seamless implementation of all recovery actions.	All threats.
URGENT	2-3	v	Fish Management Plan	Encourage the development of management plans for host fish species.	Will assist with ensuring that host fish abundance and distributions do not limit recovery of the Wavyrayed Lampmussel.	Disruption of Host Fish Relationship.
URGENT	2-4	v	Exotic Species Management Plan	Develop an implementation plan to respond to the identification of exotic species invasion of Wavyrayed Lampmussel habitat	Will ensure a timely and coordinated response to the invasion of exotic species (e.g., zebra mussels)	Exotics.

Priority	Number	Objective Addressed	Broad Approach/ Strategy	Specific Steps	Anticipated Effect	Threat Addressed
URGENT	2-5	v	Drainage	Work with drainage supervisors, engineers and contractors to limit the effects of drainage activities on Wavyrayed Lampmussel habitat.	Will mitigate harmful effects of drainage activities.	Siltation/Suspended solids.
URGENT	2-6	v	Wastewater Treatment Plants and Stormwater Management Facilities	Identify potential problem areas and encourage upgrading where appropriate.	Will improve water quality by reducing nutrient and suspended solid inputs from urban centres.	Siltation/Suspended solids; Water quality – contaminants and nutrients.
URGENT	2-7	v	Water Supply Management	Ensure that flow requirements of the Wavyrayed Lampmussel are considered in management of flow regimes.	Will help ensure that minimum baseflow conditions are maintained for the Wavyrayed Lampmussel.	Urbanization
NECESSARY	2-8	v	Municipal Planning	Encourage municipal planning authorities to consider Recovery Goals in official plans.	Will provide further protection for the Wavyrayed Lampmussel and ensure that future development does not degrade important habitat.	Urbanization; Water quality.

Priority	Number	Objective Addressed	Broad Approach/ Strategy	Specific Steps	Anticipated Effect	Threat Addressed
BENNEFICIAL	2-9	v	Policy and Legislation	Encourage and support the development and implementation of legislation and policies at all levels of government that will protect existing populations and enhance recovery.	Will ensure a coordinated approach to species protection.	All threats.

2-1: The current capacity within southern Ontario to perform the necessary survey and monitoring work is insufficient. Knowledge of freshwater mussel identification, distribution, life history and genetics is limited to a small number of individuals from a limited number of government and academic institutions with the retirement of several key researchers expected prior to the 5-year re-evaluation period for this strategy. A concerted effort must be made to increase this capacity by:

- Training personnel in the identification of all mussel species with emphasis on the rare species.
- Producing a field guide to the mussels of Ontario.
- Encouraging graduate and post-graduate research aimed at fulfilling the needs identified under Research and Monitoring.

2-2: Many of the threats to the Wavyrayed Lampmussel can be classified as widespread and chronic (See Threats section) and represent general ecosystem threats affecting numerous other aquatic species. Efforts to remediate these threats will benefit many species in addition to the Wavyrayed Lampmussel and should be implemented in close connection with the aquatic ecosystem recovery teams for the Thames, Grand and Sydenham rivers (see section entitled Activities already completed or underway) to eliminate duplication of efforts and ensure that undertaken activities are not detrimental to other species.

2-3: The host fish for the Wavyrayed Lampmussel may have to be afforded some degree of protection beyond those of the Ontario Fishery Regulations if the species is to recover. The likely host species, smallmouth bass, is a popular sport-fish species and subject to intense angling pressure throughout the distribution of the Wavyrayed Lampmussel. Since the smallmouth bass is not listed by COSEWIC this species receives no direct protection under SARA although the potential role of hosts as residences for larval mussels may trigger future protection under the act. It will be necessary to develop a formal management plan for the smallmouth bass and any species identified as a host for the Wavyrayed Lampmussel to ensure that host populations remain healthy and do not hinder recovery of the mussels.

2-4: In the event that the routine monitoring programs (1-10) detect the presence of zebra mussels or other exotic species within the range of the Wavyrayed Lampmussel, a coordinated plan should be developed to ensure a quick response. The plan should include an assessment of potential risks and proposed actions (e.g., eradication of exotics, relocation of native mussels or shell cleaning).

2-5: Drainage development and maintenance activities that mitigate existing threats and prevent the continued degradation of aquatic habitat within the range of the Wavyrayed Lampmussel should be supported and promoted.

2-7: The Wavyrayed Lampmussel is a species adapted to hydrologically stable flow regimes and does not possess any of the shell modifications typical of species adapted to high shear environments (Watters 1994). The species has also been identified by Tetzloff (2001) as one of the most susceptible species to low dissolved oxygen conditions which may be associated with toxic events or reductions in flow conditions (Johnson *et al*. 2001). Careful consideration must be paid to the management of flow regimes in rivers with Wavyrayed Lampmussels to ensure that flow conditions remain within preferred levels for this species.

3) Stewardship Approaches

Priority	Number	Objective Addressed	Broad Approach/ Strategy	Specific Steps	Anticipated Effect	Threat Addressed
URGENT	3-1	v	Riparian buffers	Establish riparian buffer zones in areas of high erosion potential by encouraging naturalization or planting of native species.	Will improve water quality by reducing bank erosion, sedimentation and overland run-off.	Siltation/suspended solids; water quality-contaminants and nutrients.
URGENT	3-2	v	Tile drainage	Work with landowners to mitigate the effects of tile drainage.	Will reduce nutrient and sediment inputs.	Siltation/suspended solids; water quality-contaminants and nutrients.
NECESSARY	3-3	v	Soil Testing	Encourage soil testing to determine fertilizer application rates.	Will reduce nutrient inputs to the river.	Water quality-contaminants and nutrients.

Priority	Number	Objective Addressed	Broad Approach/ Strategy	Specific Steps	Anticipated Effect	Threat Addressed
NECESSARY	3-4	v	Livestock access	Limit livestock access to rivers.	Will improve habitat quality by reducing nutrient inputs, bank erosion, and physical disturbance.	Siltation/suspended solids; water quality-contaminants and nutrients.

The activities characterized in this section, and represented by the sample of activities above, embody sound agricultural practices that when implemented will benefit both the terrestrial and aquatic ecosystems. These activities can generally be referred to as “best management practices”. In the three watersheds with aquatic ecosystem recovery strategies (Sydenham, Thames, Ausable) as well as the two watersheds with other recovery plans (Grand, Lake St. Clair) it will be important for members of the OFMRT to interact closely with members of these teams when carrying out recovery actions for the Wavyrayed Lampmussel. Many of the ecosystem teams will have established stewardship liaisons and have activities already underway which will mesh nicely with the actions required to benefit the Wavyrayed Lampmussel.

4) Awareness Approaches

Priority	Number	Objective Addressed	Broad Approach/ Strategy	Specific Steps	Anticipated Effect	Threat Addressed
URGENT	4-1	v, vii	Recreational Angler Outreach	Increase awareness within the angling community about the role of the smallmouth bass as a host for the Wavyrayed Lampmussel.	Will reduce the impact of angling on host fish species.	Host fish disruption; recreational activity.

Priority	Number	Objective Addressed	Broad Approach/ Strategy	Specific Steps	Anticipated Effect	Threat Addressed
URGENT	4-2	v	Exotic species	Increase public awareness of the potential impacts of transporting/releasing exotic species.	Will reduce the risk of zebra mussels becoming established in the reservoirs.	Exotics.
NECESSARY	4-3	i, vii	Field guide	Develop a field guide to the freshwater mussels of Southern Ontario.	Will assist with identification of species at risk and the transfer of knowledge.	All threats.
NECESSARY	4-4	i, vii	Mussel identification workshop	Coordinate a 2 day workshop covering topics of mussel biology, ecology and the identification of all freshwater mussel species found in southern Ontario.	Will assist with identification of species at risk and the transfer of knowledge.	All threats.
NECESSARY	4-5	vii	Public Outreach	Encourage public support and participation by developing awareness materials and programs.	Will increase public awareness of the importance of species at risk.	All threats.

4-1: The likely host of the Wavyrayed Lampmussel, the smallmouth bass, is a popular sport-fish in southern Ontario and necessitates a thorough outreach program with the sport-fish industry. Outreach activities should be directed at ensuring a non-destructive sport-fishery directed at locations and times when smallmouth bass are unlikely to be harbouring Wavyrayed Lampmussel glochidia.

4-3 & 4-4: Increasing basic mussel knowledge and identification skills was identified as a key Management objective (2-1) and can be assisted through the development of the Awareness materials identified here including the development of a mussel field guide for Ontario and a hands-on workshop for interested government, agency, NGO, Aboriginal peoples and individuals.

4-5: Increased public knowledge and understanding of the Wavyrayed Lampmussel will play a key role in the recovery of this, and other, endangered mussels. The role that freshwater mussels play within the aquatic ecosystem and their role as indicators of habitat degradation and human health hazards must be conveyed to all stakeholder groups. Outreach programs should be developed for landowners, interest groups, schools and any interested parties.

Potential Impacts of Recovery Strategy on Other Species/Ecological Processes: The Wavyrayed Lampmussel is a sensitive species, particularly to issues of water clarity and quality. For this reason, we expect that efforts made to improve conditions for the Wavyrayed Lampmussel will benefit most other aquatic species. A few opportunistic species that can readily adapt to degraded conditions (e.g., *Pyganodon grandis* or *Pimephales promelas*) may see a decline in numbers/range as a result of rehabilitative efforts. These changes should not be viewed in a negative light but rather as a resetting of the aquatic community to pre-disturbance conditions.

Actions Already Completed or Underway

Sydenham Recovery Ecosystem Strategy: The Sydenham River Recovery Team was formed in 1999 and charged with developing an ecosystem based recovery strategy for the Sydenham River basin. The recovery strategy focuses on the 14 aquatic species (5 mussels including the Wavyrayed Lampmussel, 8 fishes, 1 turtle) within the basin that have been listed as endangered, threatened or of special concern by the COSEWIC. The primary objective of the recovery strategy "is to sustain and enhance the native aquatic communities of the Sydenham River through an ecosystem approach that focuses on species at risk" (Dextrase *et al.* 2003). The Sydenham River Recovery Team has formed four Recovery Implementation Groups (RIG): management, stewardship, research and monitoring, and community outreach.

Thames River Recovery Ecosystem Strategy: The Thames River Recovery Team has set out to develop an ecosystem based recovery strategy for the Thames River watershed. The stated goal is to develop "a recovery plan that improves the status of all aquatic species at risk in the Thames River through an ecosystem approach that sustains and enhances all native aquatic communities" (Thames River Recovery Team 2003). This recovery strategy addresses 25 COSEWIC listed species including 7 mussels, 12 fishes and 6 reptiles.

Ausable River Ecosystem Recovery Strategy: The Ausable River Recovery Team is developing an ecosystem Recovery Strategy for the 14 COSEWIC listed aquatic species in the Ausable River basin. This plan covers 4 endangered mussel species including the Wavyrayed Lampmussel. The goal of the strategy is to "prepare a recovery plan (recovery strategy + action plan) that sustains and enhances the native aquatic communities of the Ausable River through an ecosystem approach that focuses on species at risk " (Ausable River Recovery Team 2003).

Grand River Fish Species at Risk Recovery Strategy: The Grand River Recovery Team has developed a draft recovery strategy for fish species at risk in

the Grand River. The goal of this strategy is “to conserve and enhance the native fish community using sound science, community involvement and habitat improvement measures” (Portt *et al.* 2003). Although the strategy does not directly address the Wavyrayed Lampmussel, “(its) habitat preferences and requirements will be taken into account when assessing management actions targeting fish species at risk. In most cases, it is anticipated that recovery actions benefiting fishes at risk will also benefit these other rare species” (Portt *et al.* 2003).

Walpole Island Ecosystem Recovery Strategy: The Walpole Island Ecosystem Recovery Strategy Team was established in 2001 to develop an ecosystem based recovery strategy for the area containing the St. Clair delta with the goal of outlining steps to be taken to maintain or rehabilitate the ecosystem and species at risk (Walpole Island Heritage Centre 2002). Although the strategy is initially focusing on terrestrial ecosystems, aquatic species are included in the draft strategy.

Fish Host Identification: A research group led by Dr. G. L. Mackie and Dr. J Ackerman has been established at the University of Guelph to investigate aspects of the reproductive cycle of freshwater mussels (host fish determination, glochidial development, juvenile growth and survival). The group conducts its research at the Hagen Aqua Lab on the grounds of the university in Guelph, Ontario, Canada. This facility has already been used to investigate potential hosts for five species of endangered mussels including the Wavyrayed Lampmussel (McNichols *et al.* 2005).

Source Protection Planning: A White Paper on Watershed-based Source Protection Planning was released in February 2004 (Ontario Ministry of the Environment 2004). Source Protection Planning will identify potential sources of contamination to the surface water and groundwater, determine how much water is readily available, evaluate where that water is vulnerable to contamination and implement programs to minimize risk of contamination to water quality as well as minimizing threats to water quantity.

Allowable Harm Analysis: Fisheries and Oceans Canada, in partnership with other interested parties, has initiated an analysis of the potential for Wavyrayed Lampmussel populations to withstand any additional level of human-induced mortality without impeding recovery of the species. This Allowable Harm Analysis (AHA) is being conducted on the population units recommended by Morris *et al*. (2005) and will assist managers when making decisions regarding development activities within the watersheds occupied by the Wavyrayed Lampmussel.

Recovery Action Plans

One or more action plans relating to this recovery strategy will be produced within 5 years of the strategy being published.

Evaluation

The routine monitoring programs will provide the primary means of evaluating the success of the listed recovery approaches. The monitoring programs will provide trend through time data allowing the tracking of Wavyrayed Lampmussel populations and habitat and will form the basis of an adaptive management program. Recovery Implementation Groups will develop specific goals in the Recovery Action Plans to provide a further basis for evaluating success. The entire Recovery Strategy will be

reviewed in 5 years at which time all goals, objectives and approaches will be re-evaluated.

References Cited

ABCA (Ausable-Bayfield Conservation Authority). 1995. Watershed management strategy. Prepared by Snell and Cecile Environmental Research. Guelph, Ontario, with the Ausable-Bayfield Conservation Authority, Exeter, Ontario.

Ausable River recovery Team. 2003. Ausable River Recovery Team – draft terms of Reference. April 2003.

Balfour, D. L. and L. A. Smock. 1995. Distribution, age structure, and movements of the freshwater mussel *Elliptio complanata* (Mollusca: Unionidae) in a headwater stream. Journal of Freshwater Ecology 10: 255-268.

Boersma, P.D., P. Kareiva, W. F. Fagan, J. A. Clark and J. M. Hoekstra. 2001. How good are endangered species recovery plans? BioScience 51: 643-649.

Bogan, A. E. 1993. Freshwater bivalve extinctions (Mollusca: Unionidae): a search for causes. American Zoologist 33: 599-609.

Clarke, A. H. 1981. The freshwater molluscs of Canada. National Museums of Canada, Ottawa, Canada. 446 pages.

Cooke, S. J., C. M. Bunt, and S. McKinley. 1998. Derby-determined vital statistics and trends of the smallmouth bass, *Micropterus dolomieu*, recreational fishery in the middle reaches of the Grand River, Ontario. Canadian Field-Naturalist 112: 451-458.

Cummings, K.S., and C. A. Mayer. 1992. Field guide to the freshwater mussels of the midwest. Illinois Natural History Survey Manual 5. 194 pages.

Dennis, S. D. 1984. Distributional analysis of the freshwater mussel fauna of the Tennessee River system, with special reference to possible limiting effects of siltation. Ph.D. thesis, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 245 pages.

Dextrase, A. J., S. K. Staton, and J. L. Metcalfe-Smith. 2003. National Recovery Strategy for Species at Risk in the Sydenham River: An ecosystem approach. National Recovery Plan No. 25. Recovery of Nationally Endangered Wildlife (RENEW). Ottawa, Ontario. XXpp.

Downing, J.A., Y. Rochon and M. Perusse. 1993. Spatial aggregation, body size, and reproductive success in the freshwater mussel *Elliptio complanata*. Journal of the North American Benthological Society 12: 148-156.

Dubs, D.O.L., and Corkum, L.D. 1996. Behavioural interactions between round gobies (Neogobius melanostomus) and mottled sculpins (Cottus bairdi).

Journal of Great Lakes Research. 22:838-844.

Goudreau, S. E., R. J. Neves, and R. J. Sheehan. 1993. Effects of wastewater treatment plant effluents on freshwater molluscs in the upper Clinch River, Virginia, USA. Hydrobiologia 252: 211-230.

GRCA (Grand River Conservation Authority). 1998. State of the Watershed Report: Background Report on the Health of the Grand River Watershed 1996-1997. Prepared for the Grand Strategy Co-ordinating committee. Grand River Conservation Authority, Cambridge, Ontario.

Hanlon, Shane D., and Richard J. Neves. 2000. A comparison of reintroduction techniques for recovery of freshwater mussels. Report to the Virginia Department of Game and Inland Fisheries, Richmond, Virginia. April, 2000. 118pp.

Henley, W.F., J.W. Jones, J.L. Bpyes, J.M. McLeod and R.J. Neves. 2002. An evaluation of the suitability of the Cedar Bluff spill site for recovery of freshwater mussels, Clinch River, Tazewell County, Virginia. Final Report to the U.S. Fish and Wildlife Service, Gloucester, Virginia. 25pp.

Huebner, J. D., and K. S. Pynnonen. 1992. Viability of glochidia of two species of Anodonta exposed to low pH and selected metals. Canadian Journal of Zoology 70: 2348-2355.

Jacobson, P. J., R. J. Neves, D. S. Cherry, and J. L. Farris. 1997. Sensitivity of glochidial stages of freshwater mussels (Bivalvia: Unionidae) to copper. Environmental Toxicology and Chemistry 16: 2384-2392.

Janssen, J., and Jude, D.J. 2001. Recruitment failure of mottled sculpin (*Cottus bairdi*) in Calumet Harbor, southern Lake Michigan, induced by the newly introduced round goby *Neogobius melanostomus*. J. Great Lakes Res. 27:319-328.

Johnson, Paula M., Anna E. Liner, Stephen W. Golladay, and William K. Michener. 2001. Effects of drought on freshwater mussels and instream habitat in Coastal Plains tributaries of the Flint River, southwest Georgia (July-October, 2000). Final Report to the Nature Conservancy Apalachicola River and Bay Project, August 25, 2001. 30 pp. Available at: http://www.jonesctr.org/education/education.resources.html.

Keller, A. E., and S. G. Zam. 1990. Simplification of in vitro culture techniques for freshwater mussels. Environmental Toxicology and Chemistry 9: 291-1296.

Kjos, C., O. Byers, P. Miller, J. Borovansky and U. S. Seal (eds.) 1998. Population and habitat viability assessment workshop for the winged mapleleaf (*Quadrula fragosa*): Final Report. CBSG, Apple Valley MN.

Krause, P., A. Smith, B. Veale and M. Murray. 2001. Achievements of the Grand River Conservation Authority, Ontario, Canada. Water Science and Technology 43(9): 45-55.

McGoldrick, D.J., T.J. Morris, J.L. Metcalfe-Smith, V.S. Jackson. In press. Developing critical habitat descriptions for Threatened and Endangered freshwater mussels – A case study using the Wavyrayed Lampmussel (*Lampsilis fasciola*). DFO Can. Sci. Advis. Sec. Res. Doc.

McNichols, K., G. Mackie and J. Ackerman. 2005. Fish host determination of endangered freshwater mussels in the Sydenham River Ontario, Canada. ESRF 2004-05 Final Report. 20 pages.

Metcalfe-Smith, J. L., D. J. McGoldrick, M. Williams, D. W. Schloesser, J. Biberhoffer, G. L. Mackie, M. T. Arts, D. T. Zanatta, K. Johnson, P. Marangelo, and T. D. Spencer. 2004. Status of a refuge for native freshwater mussels (Unionidae) from the impacts of the exotic zebra mussel (*Dreissena polymorpha*) in the delta area of Lake St. Clair. Environment Canada, National Water Research Institute, Burlington, Ontario, Technical Note No. AEI-TN-01-001.

Metcalfe-Smith, J. L., and D. J. McGoldrick. 2003. Update on the status of the Wavyrayed Lampmussel (*Lampsilis fasciola*) in Ontario waters. Environment Canada, National Water Research Institute, Burlington, Ontario. NWRI Contribution No. 03-003.

Metcalfe-Smith, J. L., S. K. Staton, and E. L. West. 2000. Status of the Wavyrayed Lampmussel, *Lampsilis fasciola* (Bivalvia: Unionidae), in Ontario and Canada. The Canadian Field-Naturalist 114: 457-470.

Morris, Todd J., Daryl J. McGoldrick and Janice L. Metcalfe-Smith. 2005. Assessing characteristics of recovery: a case study using the Endangered Wavyrayed Lampmussel (Lampsilis fasciola, Rafinesque 1820). DFO Can. Sci. Advis. Sec. Res. Doc. 2005/062.

Mummert, A. K., R. J. Neves, T. J. Newcomb and D. S. Cherry. 2003. Sensitivity of juvenile freshwater mussels (*Lampsilis fasciola*, *Villosa iris*) to total and un-ionized ammonia. Environmental Toxicology and Chemistry. 22: 2545-2553.

Nalepa, T.F. 1994. Decline of native unionid bivalves in Lake St Clair after infestation by the zebra mussel, Dreissena polymorpha. Canadian Journal of Fisheries and Aquatic Sciences 51: 2227-2233.

Nalepa, T. F., D. J. Hartson, G. W. Gostenik, D. L. Fanslow, and G. A Lang. 1996. Changes in the freshwater mussel community of Lake St. Clair: from Unionidae to *Dreissena polymorpha* in eight years. Journal of Great Lakes Research 22: 354-369.

Nelson, Mike, Mari Veliz, Shawn Staton, and Erin Dolmage. 2003. Towards a recovery strategy for species at risk in the Ausable River: Synthesis of background information. Final Report prepared for the Ausable River Recovery Team. September 2003. 92 pp.

Newton, Teresa J. 2003. The effects of ammonia on freshwater unionid mussels. Environmental Toxicology and Chemistry 22: 2543-2544.

Newton, Teresa J., and John W. Allran, Jonathon A. O'Donnell, Michelle R. Bartsch, and William B. Richardson. 2003. Effects of ammonia on juvenile unionid mussels (*Lampsilis cardium*) in laboratory toxicity tests. Environmental Toxicology and Chemistry 22: 2554-2560.

Neves, R. J., and M. C. Odom. 1989. Muskrat predation on endangered freshwater mussels in Virginia. Journal of Wildlife Management 53: 934-941.

Ontario Ministry of the Environment. 2004. White Paper on Watershed-based Source Protection Planning. February 2004. Integrated Environmental Planning Division, Strategic Policy Branch, Ministry of the Environment. Queen's Printer for Ontario. 45pp.

Parmalee, Paul W., and Arthur E. Bogan. 1998. The freshwater mussels of Tennessee. The University of Tennessee Press, Knoxville. 328 pp.

Portt, C., G. Coker, and K. Barrett. 2003. recovery strategy for fish species at risk in the Grand River, Ontario. Draft report prepared for the Grand River Recovery Team, March 31, 2003.

Schloesser, D. W., and T. F. Nalepa. 1994. Dramatic decline of unionid bivalves in offshore waters of western Lake Erie after infestation by the zebra mussel, *Dreissena polymorpha*. Canadian Journal of Fisheries and Aquatic Sciences 51: 2234-2242.

Smaal, A.C., T.C. Prins, N. Dankers and B. Ball. 1998. Minimum requirements for modeling bivalve carrying capacity. Aquatic Ecology 31: 423-428.

Strayer, D. L. 1983. The effects of surface geology and stream size on freshwater mussel (Bivalvia: Unionidae) distribution in southwestern Michigan, USA. Freshwater Biology 13: 253-264.

Strayer, D. L., and K. J. Jirka. 1997. The pearly mussels of New York State. Memoirs of the New York State Museum 26: 113 pages + 27 plates.

Thames River Recovery Team. 2003. Thames River Recovery Plan – Terms of Reference. Upper Thames Region Conservation Authority web site - http://www.thamesriver.org/Species_at_Risk/terms_of_reference.htm. Accessed May 21, 2003.

Tetzloff, J. 2001. Survival rates of unionid species following a low oxygen event in Big Darby Creek, Ohio. Ellipsaria 3: 18-19.

USFWS (United States Fish and Wildlife Service). 1994. Clubshell (*Pleurobema clava*) and Northern Riffleshell (*Epioblasma torulosa rangiana*) Recovery Plan. Hadley Massachusetts. 68 pages.

UTRCA. 2003. Zebra mussels found in Fanshawe Reservoir. UTRCA press release, June 19, 2003.

Vaughn, C. C., K. B. Gido and D. E. Spooner. 2004. Ecosystem processes performed by unionid mussels in stream mesocosms: species roles and effects of abundance. Hydrobiologia 527: 35-47.

Villella, R. F., D. R. Smith and D. P. Lemarie. 2004. Estimating survival and recruitment in a freshwater mussel population using mark-recapture techniques. American Midland Naturalist 151: 114-133.

Watters, G. T. 1994. Form and function of unionoidean shell sculpture and shape (Biavalvia). American Malacological Bulletin 11: 1-20.

Welker, M. and N. Walz. 1998. Can mussels control the plankton in rivers? A Plantological approach applying Lagrangian sampling strategy. Limnology and Oceanogarphy 43: 753-762.

Woolnough, D.A. 2002. Life-history of Endangered freshwater mussels of the Sydenham River, southwestern Ontario. MSc. Thesis, University of Guelph, Guelph, Ontario, Canada. 128 pp.

WQB (Water Quality Branch). 1989a. The application of an interdisciplinary approach to the selection of potential water quality sampling sites in the Grand River basin. Environment Canada, Water Quality Branch, Ontario Region. 111 pages.

WQB (Water Quality Branch). 1989b. The application of an interdisciplinary approach to the selection of potential water quality sampling sites in the Thames River basin. Environment Canada, Water Quality Branch, Ontario Region. 122 pages.

Zale, A.V., and R. J. Neves. 1982. Reproductive biology of four freshwater mussel species (Mollusca: Unionidae) in Virginia. Freshwater Invertebrate Biology 1: 17-28.

Zanatta, D. T., G. L. Mackie, J. L. Metcalfe-Smith, and D. A. Woolnough. 2002. A refuge for native freshwater mussels (Bivalvia: Unionidae) from impacts of the exotic zebra mussel (*Dreissena polymorpha*) in Lake St. Clair. Journal of Great Lakes Research 28(3): 479-489.

APPENDIX 1: Record of Cooperation and Consultation

Fisheries and Oceans Canada has attempted to engage all potentially affected aboriginal communities in Southern Ontario during the development of the proposed recovery strategy for the Wavyrayed Lampmussel. An information package, which includes a copy of the Wavyrayed Lampmussel Recovery Strategy and a summary description of the strategy, was prepared to solicit comments from potentially affected aboriginal groups prior to the finalization of the proposed recovery strategy. This package was sent to the Chief and Council of the Chippewas of Kettle and Stoney Point, Aamjiwnaang First Nation, Caldwell First Nation, Delaware Nation Council (Moravian of the Thames First Nation), Chippewas of the Thames, Oneida Nation of the Thames, Munsee-Delaware First Nation, Mississaugas of New Credit First Nation, Six Nations of the Grand, Walpole Island First Nation and the Southern First Nations Secretariat. Information packages were also sent to Metis Nation of Ontario (MNO) Captains of the Hunt for Region 7, 8, and 9 and the MNO senior policy advisor. Members of these communities may have traveled or harvested fish or freshwater mussels from the waters of the Sydenham River, Thames River, Grand River, Lake St. Clair or Lake Erie where this mussel species was historically found. Follow-up telephone calls were made to each community office to ensure that packages were received and to ask if they would like to schedule a meeting to learn more about the proposed recovery strategy.

As a result of these calls, meetings were held with Oneida Nation of the Thames Councillor for environmental issues, Chief and council of Kettle and Stoney Point First Nation, the environment committee from Aamjiwnaang First Nation, Walpole Island First Nation – Heritage Centre Staff, and a Council meeting of the Metis of Nation of Ontario. To date no comments have been received.

In addition to the above activities, DFO has established an ongoing dialogue with the policy advisor to the Southern First Nations Secretariat and has engaged the London Chiefs Council (an association of the 8 area First Nation governments in Southwestern Ontario) on several occasions. Meetings have been held with the director of the Walpole Island Natural Heritage Centre and the Fish and Game Enforcement Officer from Walpole Island First Nation. During these meetings, general information on the Species at Risk Act and proposed recovery strategy development was presented and the Walpole Island Recovery Strategy, which includes the Wavyrayed Lampmussel, was discussed. Walpole Island First Nation has been represented in the membership of the Ontario Freshwater Mussel Recovery Team since the formation of the recovery team in 2003. DFO also discussed SARA issues with a representative of the Six Nations of the Grand who works for the Six Nations EcoCentre and who also represents First Nation interests on the Grand River Fishes at Risk Management Plan, the Thames River Fish Management Plan and the St. Clair River Management Strategy.

The Ontario Freshwater Mussel Recovery Team has representatives from all of the Conservation Authorities responsible for managing the rivers where Wavyrayed Lampmussels are presently or were historically found. In addition to this, DFO has prepared a list of non governmental organizations and municipalities which may be impacted by the proposed recovery strategy. Information packages have been prepared to inform these groups that proposed the recovery strategy is about to be approved and inviting each group to comment on the strategy. As well an announcement has been prepared and will be placed in newspapers with circulation in the area where these

mussels are found to inform landowners and the general public about the strategy and to request their comments. These packages will be sent and the announcements published at the time the proposed recovery strategy is posted on the SARA registry.

The province of Ontario is represented on the Recovery Team by the Ministry of Natural Resources (OMNR) and has actively participated in the development of this proposed recovery strategy. Further to their participation in the development of the recovery strategy, the OMNR has conducted a thorough review of the penultimate draft (December 2004) providing valuable additional insight. A letter has been drafted to request further Provincial comment on the proposed Recovery Strategy. This will be sent to the OMNR when the proposed Recovery Strategy is posted on the SARA Registry.

The National Water Research Institute of Environment Canada has been actively engaged in the development of this recovery strategy providing two members to the Ontario Freshwater Mussel Recovery Team. Environment Canada was invited to review and provide comment on the December 2004 draft of the Wavyrayed Lampmussel Recovery Strategy.

The Recovery Team has contacted representatives from Resource Management agencies at the state and federal levels in the USA where Wavyrayed Lampmussel occur. This mussel is only found in Canada and the United States of America. Information packages will be sent to each U.S. agency when the strategy is posted on the Sara Registry.