Species at Risk Act
Recovery Strategy Report Series

Report on the Progress of Recovery Strategy Implementation for the Round Hickorynut (*Obovaria subrotunda*) and the Kidneyshell (*Ptychobranchus fasciolaris*) in Canada for the Period 2006–2011

Round Hickorynut and Kidneyshell

2012

Canada

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PREFACE

Section 46 of the *Species at Risk Act* (SARA) requires the competent Minister to report on the implementation of the recovery strategy for a species at risk, and on the progress towards meeting its objectives within five years of the date when the recovery strategy was placed on the Species at Risk Public Registry.

Reporting on the progress of recovery strategy implementation requires reporting on the collective efforts of the competent Minister, provincial organizations and all other parties involved in conducting activities that contribute towards the species' recovery.

EXECUTIVE SUMMARY

As a result of the overlap in the historic and current ranges of the Round Hickorynut and Kidneyshell, there is substantial commonality in threats to their continued survival. A key component in the progress towards fulfilling recovery objectives has been the systematic collaboration with existing ecosystem recovery teams. This collaboration has taken the form of multiple research projects as well as stewardship teams that actively monitor and coordinate habitat improvement projects on the Ausable, Sydenham, and Thames rivers systems. These collaborative efforts resulted in concrete progress in the form of habitat improvement and protection, and important biological insights of these two species.

The following is a list of the most important accomplishments in meeting the recovery objectives as stated in the recovery strategy:

- Much of the current and historic ranges of the two species have been surveyed; this has resulted in the discovery of the Kidneyshell in the upper Thames River, a location where it was thought to be extirpated. An improvement in the understanding of population demographics of the two species has occurred.
- New host fishes have been confirmed for both species in the laboratory, while fish surveys have advanced range and abundance knowledge for all known host fish species.
- Habitat requirements are adequately described in the recovery strategy for these species, which has allowed for the partial identification of critical habitat in the species' riverine habitat. The identification of critical habitat in lacustrine environments has yet to be defined but is in progress.
- Long-term monitoring programs have been developed that not only include provisions for the mussel species but also for their host fishes and habitat. Monitoring stations have been added and now cover important locations currently and formerly occupied by the Round Hickorynut and Kidneyshell.
- Some threat mitigation has occurred, often in coordination with the applicable conservation authority, and has focused on reducing the impact of agricultural practices on lands adjacent to mussel habitat. The restriction of livestock from watercourses and the protection and restoration of riparian habitat are expected to improve water quality and general habitat conditions.
- Advancement of genetic techniques and knowledge specific to Unionid mussels has reached a point where mapping of the genetic structure of the Round Hickorynut and Kidneyshell is possible and will be key to further efforts that may involve relocation and reintroduction programs.
- Outreach programs have successfully reached the general public within the applicable watersheds, with conservation authorities playing a leading role. Landowners have been targeted and numerous successful habitat stewardship programs have been completed as a result of direct contact with agricultural operators with land adjacent to mussel habitat.

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1. BACKGROUND

1.1. COSEWIC assessment summary

COSEWIC assessment summary – May 2003

Common name: Round Hickorynut
Scientific name: *Obovaria subrotunda*
COSEWIC status: Endangered
COSEWIC reason for designation: This species has been lost from 90% of its former range in Canada. Populations in the Grand and Thames rivers are extirpated and populations in the Sydenham River are declining, all due to the combined effects of pollution and agricultural impacts. Most of the Great Lakes populations have been lost due to impacts of the Zebra Mussel, and the remaining population in the St. Clair delta near Walpole Island may be at risk. If the Eastern Sand Darter were the host of this species, then the decline of this threatened fish would affect the mussel's survival.
Occurrence: Ontario
COSEWIC status history: Designated Endangered in 2003.

COSEWIC assessment summary – May 2003

Common name: Kidneyshell
Scientific name: *Ptychobranchus fasciolaris*
COSEWIC status: Endangered
COSEWIC reason for designation: This species has been lost from about 70% of its historical range in Canada due to impacts of the Zebra Mussel and land use practices. It is now restricted to the East Sydenham and Ausable rivers. Although both populations appear to be reproducing, there is evidence that abundance has declined in the East Sydenham River. Agricultural impacts, including siltation, have eliminated populations in the Grand and Thames rivers, and threaten the continued existence of this species in Canada.
Occurrence: Ontario
COSEWIC status history: Designated Endangered in 2003.

1.2. Threats

1.2.1. Threats to the species

Table 1 is an assessment of the threats to extant populations of the Round Hickorynut (*Obovaria subrotunda*) and Kidneyshell (*Ptychobranchus fasciolaris*) in the St. Clair River delta, Sydenham River, and Ausable River as found in the previously published recovery strategy (Morris 2006).

Table 1. Assessment of threats to extant populations of the Round Hickorynut and Kidneyshell in Canada. St. Clair River delta and Sydenham River threats apply to Round Hickorynut and Kidneyshell populations. Ausable River threats apply to Kidneyshell populations. (n/a = not applicable). Table adapted from Morris (2006).

Threat	**Relative Impact** predominant/ contributing			**Spatial/Temporal** widespread/local chronic/ephemeral			**Certainty** probable/speculative/unknown		
	St. Clair River delta	Sydenham River	Ausable River	St. Clair River delta	Sydenham River	Ausable River	St. Clair River delta	Sydenham River	Ausable River
Dreissenid* mussels	predominant	n/a	n/a	widespread chronic	n/a	n/a	probable	n/a	-
Siltation	n/a	predominant	predominant	n/a	widespread chronic	widespread chronic	n/a	probable	probable
Water quality – nutrients and contaminants	contributing	contributing	contributing	widespread chronic	widespread chronic	widespread chronic	speculative	probable	probable
Water quantity	n/a	contributing	contributing	n/a	widespread ephemeral	widespread ephemeral	n/a	speculative	speculative
Decline of host fish	contributing	contributing	n/a	widespread chronic	widespread chronic	n/a	speculative	speculative	-
Urbanization	n/a	contributing	contributing	n/a	local chronic	local chronic	n/a	speculative	speculative
Impoundments	n/a	contributing	n/a	n/a	local chronic	n/a	n/a	unknown	-
Predation	n/a	contributing	contributing	n/a	local ephemeral	local ephemeral	n/a	unknown	unknown

*Zebra Mussel (*Dreissena polymorpha*) and Quagga Mussel (*D. bugensis*)

1.2.2. Threats to critical habitat

Note that critical habitat was not identified in the original recovery strategy for these species but will be identified to the extent possible in an updated proposed recovery strategy to be published in 2012 (DFO 2012). As critical habitat had not been identified by Morris (2006), the original recovery strategy references threats to currently occupied habitat, which are summarized below.

Critical habitat of these two species could be negatively affected by a wide variety of activities; some of the more probable and potentially deleterious threats to their habitat are identified in the original recovery strategy and include the following:

- Direct habitat destruction could result from in-stream activities such as dredging, bridge and pipeline crossings or the construction of dams.

- Water quality or quantity can be negatively affected by land-based activities such as 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.

- Any activity that disrupts the connectivity between mussel populations and their host species (i.e., various darter species), which can be considered habitat for mussels during the glochidial stage, may result in the destruction of habitat. Such activities can include damming, dewatering, and sport or commercial harvest activities that harm host species.

2. RECOVERY

2.1. Recovery goals and objectives

Recovery goal
The long-term recovery goals as stated in the original recovery strategy for Round Hickorynut and Kidneyshell (Morris 2006) are:

i. To prevent the extirpation of the Round Hickorynut and Kidneyshell in Canada;
ii. To return healthy self-sustaining populations of Round Hickorynut to the Sydenham River and St. Clair River delta;
iii. To maintain healthy self-sustaining Kidneyshell populations in the Ausable and Sydenham rivers while returning the St. Clair River delta population to a self-sustaining level; and,
iv. To re-establish populations in historically occupied habitats.

These populations can only be considered recovered when they have returned to historically estimated ranges and/or population densities and are showing signs of reproduction and recruitment.

Recovery objectives (Short-term: 5-years)

i. Determine extent, abundance and population demographics of existing populations;
ii. Determine fish hosts and their distributions and abundances;
iii. Define key habitat requirements to identify critical habitat;
iv. Establish a long-term monitoring program for Round Hickorynut and Kidneyshell populations, their hosts and the habitat of both;
v. Identify threats, evaluate their relative importance and implement remedial actions to minimize their impacts;
vi. Examine the feasibility of relocations, reintroductions and the establishment of managed refuge sites; and,
vii. Increase awareness about the distribution, threats and recovery of these species.

2.2. Performance measures

Performance measures were not identified in the original recovery strategy; therefore, progress will be measured against the stated short-term recovery objectives as listed above (Section 2.1. Recovery objectives).

3. PROGRESS TOWARDS RECOVERY

The original recovery strategy for Round Hickorynut and Kidneyshell divided the recovery approaches into four categories: Research and Monitoring, Management, Stewardship, and Awareness. Progress in each of these four categories is addressed separately (Sections 3.1-3.4), providing a summary of the implementation of the documented recovery approaches (Tables 2-5). The emphasis of the current progress review is on approaches that were deemed Urgent and, where applicable, Necessary, and Beneficial in the original recovery strategy. The assessment of Stewardship Activities (Section 3.3) has been subdivided by watershed as these activities have been performed by distinct groups operating within watersheds. The listing of results is meant to briefly touch on some of the more significant accomplishments and is not meant to be exhaustive.

3.1. Research and monitoring activities

Table 2. Research and monitoring activities conducted/ongoing since the completion of the recovery strategy. RHN = Round Hickorynut; KS = Kidneyshell.

Activities	Recovery objectives addressed[1]	Results[2]	Agencies involved[2]	Funding sources[2]	References
(1-1) Confirm the host fish species for the Round Hickorynut (further studies on the host fish of Kidneyshell have also been deemed important)					
Development of experimental protocol to test fish host (2006-2011)	i, ii, iv, v	• Experimental protocol developed for screening fish hosts • Over 100 fish and freshwater mussels combinations (19 fishes; 8 unionids) have been examined with a success rate (i.e., host fishes determined) of 20-45%	U of G	CWF, DFO, EC, OMNR[3], WWF	In progress, McNichols (2007), McNichols et al. (2011)
Fish host identification	ii	• Fish hosts for the RHN and KS determined in the laboratory • Determined presence and gravidity periods of SAR mussels in the Sydenham, Grand, Ausable, and Thames rivers (gravidity observed in KS) • Determined the settling velocity of glochidia and juvenile mussel SAR • Fecundity estimates generated (RHN/KS) • Observation of length of glochidial attachment to host species (KS)	U of G	CWF, DFO, EC, OMNR, WWF	In progress, McNichols (2007), McNichols et al. (2011), Schwalb and Ackerman (2011)
(1-2) Determine the distribution and abundance of the host species					
Collection of fish data in Sydenham, Thames, and Ausable rivers (2007)	ii	• Host fish population data gathered and levels of encystment recorded • Host fish predictive models developed for KS • Functional connectivity calculated for KS in Sydenham and Ausable rivers	Trent U., U of G	DFO, EC, NSERC, OMNR, WWF	Woolnough et al. 2007
Host fishes surveyed in the Ausable River (2009)	ii	• Host fish distributions assessed	ABCA, DFO	ABCA, DFO, OMNR, SARRFO	Upsdell et al. (2011)
Miscellaneous fish surveys (2006-2011)	ii	• Host species distribution and abundance data have been compiled as a result of non-specific fish sampling within the range of these two mussel species	e.g., DFO, OMNR, Trent U, U of G, U of T	e.g., DFO, NSERC, OMNR, WWF	e.g., Poos et al. 2010

Table 2 (Con't). Research and monitoring activities conducted/ongoing since the completion of the recovery strategy.

Activities	Recovery objectives addressed[1]	Results[2]	Agencies involved[2]	Funding sources[2]	References
(1-3) Determine the habitat requirements for all life-stages (critical habitat identification)					
Channel stability assessed and mussels and host fishes surveyed in the Ausable River (2009)	i, ii	• Increased understanding of the influence of geomorphology on mussel and host fish distributions • Comparison of mussel surveys to past efforts accomplished	ABCA, DFO	ABCA, DFO, OMNR, SARRFO	Upsdell et al. (2011)
Refinement and inquiry into environmental conditions for all life-stages	iii	• Chloride and copper limits refined • Increased knowledge of dissolved oxygen, flow and substrate requirements	EC, McMaster U, U of G	CDA, DFO, EC WWF	Gillis et al. (2008), Gillis et al. (2010), Gillis (2011)
Measurement of chemical/physical characteristics of rivers and hyporheic zones	iii	• Characterization of surface and groundwater to aid identification of critical habitat	U of G	CWF, DFO, OMNR	In progress
Investigating reproductive attributes	iii, v	• Timing and water temperatures of gravid females observed (KS)	U of G	CWF, DFO, EC, OMNR, WWF	McNichols (2007)
(1-4) Prepare a distribution map of areas of suitable habitat (critical habitat identification)					
Mapping exercises for the Ausable River watershed (2008)	i, iii	• Development of suitable habitat criteria and mapping for KS	ABCA, DFO	ABCA (in kind), ABCF, DFO, OMNR, TTLT, WWF	Upsdell et al. (2010)
(1-6) Establish a network of permanent monitoring stations throughout the distribution of Round Hickorynut (and Kidneyshell) **(1-7) Establish permanent monitoring sites for tracking changes in habitat**					
Ausable River watershed monitoring program establishment (2006-2008)	i, iv	• Seven permanent monitoring stations established • Baseline density estimates and population demographics established for KS • A monitoring program was developed for the Ausable River • Physical site characteristics (e.g., substrate type, water depth and velocity) were related to mussel presence	ABCA, DFO	ABCA (in kind), DFO, IRF	Baitz et al. (2008)

Table 2 (Con't). Research and monitoring activities conducted/ongoing since the completion of the recovery strategy.

Activities	Recovery objectives addressed[1]	Results[2]	Agencies involved[2]	Funding sources[2]	References
(1-6) Establish a network of permanent monitoring stations throughout the distribution of Round Hickorynut (and Kidneyshell) (1-7) Establish permanent monitoring sites for tracking changes in habitat					
Survey monitoring stations in the Ausable River watershed (2011)	i, iv	• Seven permanent monitoring stations surveyed five years after they were established • Preliminary data show a possible decline in mussel densities	ABCA, DFO	ABCA, ABCF, DFO, HSP, OMNR	In progress
Sydenham River monitoring program establishment and implementation (1999 – 2007)	iv	• A monitoring program was developed for the Sydenham River • 15 stations established • Physical site characteristics (e.g., substrate type, water depth and velocity) were related to mussel presence • In the Sydenham River, the KS was also found in close proximity to the Plain Pocketbook (*Lampsilis cardium*), suggesting a similarity in habitat and/or environmental preferences	EC, ROM	DFO, IRF	Metcalfe-Smith et al. (2007b)
St. Clair River delta (Walpole Island) monitoring program establishment and implementation (2003 - 2011)	iv	• A monitoring program was developed for the St. Clair River delta • Nine sites were established in the Canadian waters of the delta in 2003-2004 • Eight of these sites were revisited in 2011 • Established to assess population changes and monitor threat of dreissenid mussels • Studies reveal that, despite declining dreissenid levels, freshwater mussels continue to decline, with RH and KS essentially extirpated from this system.	DFO, EC, WIFN	DFO, WWF	MS in preparation, Metcalfe-Smith et al. (2007a)
Grand River monitoring program establishment and implementation (2007 – present)	i, iv	• Four index stations were established in the upper Grand River • Mussel communities and reproduction were assessed at each site • No KS or RHN encountered	DFO	DFO	MS in preparation - Morris and McNichols-O'Rourke

Table 2 (Con't). Research and monitoring activities conducted/ongoing since the completion of the recovery strategy.

Activities	Recovery objectives addressed[1]	Results[2]	Agencies involved[2]	Funding sources[2]	References
1-6) Establish a network of permanent monitoring stations throughout the distribution of Round Hickorynut (and Kidneyshell) (1-7) Establish permanent monitoring sites for tracking changes in habitat					
Thames River monitoring program establishment and implementation and expansion of Grand River monitoring program (2010)	i, iv	• Surveys were completed in the lower Grand and Thames river systems • No live KS or RHN encountered; fresh KS shells were found in the lower Thames River, suggesting that the species is still present in this section of river • Six permanent monitoring stations were established on the lower Thames River and three on the lower Grand River	DFO	DFO	MS in preparation - Morris and McNichols-O'Rourke
Surveys in the lower Thames and Grand river systems (2010)	i	• Exploration of new methods (dredging and trawling) for sampling lower river mussel populations • Due to low unionid densities and unfavourable habitat conditions, these methods are not being further investigated	DFO	DFO	N/A
Mussel surveys – Welland River (2008)	i	• Surveys were completed in the Welland River drainage • No KS or RHN encountered	DFO	DFO	Morris et al. 2012b
Mussel surveys – Bayfield River, Nottawasaga River (2007-2009)		• Surveys were completed in the Bayfield River and Nottawasaga River drainages • No KS or RHN encountered	DFO	DFO	Minke-Martin et al. 2012, Morris et al. 2012a.
Abundance and population demographic determination	i	• Marked and measured the size of all species at risk mussels found in the field, which provided mark-recapture and growth data • New location for KS detected in Ausable River tributary (Nairn Creek) and fresh shells observed in the lower Thames River	U of G	CWF, DFO, EC, OMNR WWF	In progress, McNichols (2007), McNichols et al. (2011)

Table 2 (Con't). Research and monitoring activities conducted/ongoing since the completion of the recovery strategy.

Activities	Recovery objectives addressed[1]	Results[2]	Agencies involved[2]	Funding sources[2]	References
(1-8) Identify and evaluate threats to all life stages (1-8).					
Determine the sensitivity of glochidia to copper and examine the role of dissolved organic carbon in protecting mussels from acute copper exposure. (2006-2010)	iii, v	• Increased understanding of toxicity of copper to glochidia (including KS/RHN), including the influence of water hardness and dissolved organic carbon on copper sensitivity • Compiled data on copper levels (and other water chemistry parameters) in key mussel habitats in Ontario and compared to concentrations shown to be toxic to larval mussels • Determined that the levels of water hardness and dissolved organic carbon in many mussel habitats in southern Ontario will provide protection from copper exposure, but episodic pulses or spills may exceed protective capacity	EC, U of G	CDA, DFO, WWF	Gillis et al. (2008, 2010)
Assess the effect of environmentally relevant chronic copper exposure on juvenile freshwater mussels (2010-2011)	iii, v	• Assessed effects of copper on survival and growth, as well as biomarkers of metal exposure, respiration and oxidative stress • Determined the toxic mode of action of copper in juvenile mussels	EC, Federal U of Rio Grande (Brazil), McMaster U.	CRC Program, IDRC	MS in preparation Jorge et al. (2012)
Studying the sensitivity of glochidia to road salt run-off and assessing the potential for chloride induced toxicity in mussel habitats (2008-2011)	iii, v	• Assessed the toxicity of NaCl to various mussel glochidia (including KS) • Compiled data on chloride levels for key mussel habitats in Ontario and compared to concentrations shown to be acutely toxic to larval mussels • Determined that chloride levels in some mussel habitats in southern Ontario reach levels acutely toxic to glochidia • Provided results to the CCME for the development of the Chloride Canadian Water Quality Guidelines for the Protection of Aquatic Life	EC	EC	Gillis (2011)

Table 2 (Con't). Research and monitoring activities conducted/ongoing since the completion of the recovery strategy.

Activities	Recovery objectives addressed[1]	Results[2]	Agencies involved[2]	Funding sources[2]	References
(1-8) Identify and evaluate threats to all life stages (1-8).					
Examine the impact of urban inputs (municipal wastewater effluents and road runoff) on wild mussel health (2008-2011)	iii, v	• Demonstrated significantly reduced condition factor and mussel age and some impacts on immune status in mussels living downstream of multiple municipal wastewater effluents and urban runoff, when compared to mussels from upstream locations	EC	EC	MS in review - Gillis (2012)
Examine the effect of municipal wastewater effluents on caged freshwater mussels (2010-2011)	iii, v	• Deployed (i.e., caged) mussels both up and directly downstream of the outfall of municipal wastewater effluent outfalls in multiple rivers (results of an assessment of biomarkers of stress and immune status in field-deployed mussels are pending)	EC, Trent U., U of A, UNB, U of O, U of W	CWN, EC	MS in preparation – Gillis et al. (2012)
Identify those exotic species that may be deleterious to SAR mussels	ii, v	• The Round Goby (*Neogobius melanostomus*) was deemed a potential fish host for KS, while transformation rates were significantly reduced compared to darter species (only one juvenile) • The Round Goby has been identified as a threat to mussel populations due to the potential disruption of their reproductive cycle	DFO, OMNR, U of G, U of T	DFO, NSERC, OGS, OMNR, Trent U, WWF	McNichols et al. (2010), Poos et al. (2010)
Quantify sediment and nutrient inputs from agricultural drainage systems and point sources	v	• Research on sediment and nutrient input has informed recommendations for more effective strategies for reduction of loading to rivers	AAFC, DFO	AAFC, IRF	Ball Coelho et al. 2010
(1-9) Compare the within and among population genetic variability of Canadian populations and determine if populations show genetic structure by comparing variability between populations in Canadian and U.S. waterways.					
Review of literature of genetic and environmental implications of reintroductions (2008)	v, vi	• Recommendations made to preserve genetic variability, maintain population fitness and reproductive success for future reintroductions	DFO, U of G	DFO	Hoftyzer et al. (2008)
Optimization of genetic techniques	vi	• Assessed methods for obtaining genetic material • Genetic marker development and optimization successful for KS • DNA extraction and amplification procedures for glochidia investigated	CMU, Trent U, U of G	DFO, NSERC, OMNR, WWF	In progress, McNichols et al. (2010)

Table 2 (Con't). Research and monitoring activities conducted/ongoing since the completion of the recovery strategy.

Activities	Recovery objectives addressed[1]	Results[2]	Agencies involved[2]	Funding sources[2]	References
Other Activities					
Developing methods of artificial propagation in the laboratory (2008-11)	ii, vi	• Successfully transformed and attempted to rear juvenile KS • Developed new re-circulating system for rearing juvenile mussels, including determination of the role of substrate in the rearing process • Determined water source and optimal diet for rearing juvenile mussels	U of G	CWF, DFO, OMNR	In progress
Developing methods of artificial propagation in the field (2008-11)	ii, iv, vi	• Confirmed success of field enclosures • Determined methods for rearing infested fishes overwinter and successfully obtaining juvenile mussels	U of G	CWF, DFO, OMNR	In progress
Examined the dispersal ability of mussels and their conservation status	i, ii and v	• Found that, in southwestern Ontario, the mussels with the most precarious conservation status relied on host fishes that had short movement distances • Results suggest dispersal limitations should be included in conservation and management decisions	U of G	DFO, NSERC	In Progress, Schwalb (2009), Schwalb et al. (2011), Schwalb et al. (2012)

[1] Refers to all relevant recovery objectives from the recovery strategy as stated within Section 2.1 [2] A list of acronyms has been provided at the end of this report. [3] OMNR funding may have come from various OMNR sources, such as: Species at Risk Stewardship Fund, Species at Risk Research Fund, Aquatic Research and Development Section, Biodiversity Branch, Southern Region etc.

3.2. Management activities

Table 3. Management activities conducted/ongoing since the completion of the recovery strategy.

Activities	Recovery objectives addressed[1]	Results[2]	Agencies involved[2]	Funding sources[2]	References
(2-1) Promote and enhance expertise in freshwater mussel identification/biology and provide for the transfer of knowledge.					
Ontario Freshwater Mussel Identification Workshop	vii	• DFO freshwater mussel identification course has been developed and trained over 200 people	DFO, EC, U of T	DFO	N/A
Development of a Canadian Freshwater Mussel Guide	vii	• A national freshwater mussel identification application for Smartphone devices is under development	DFO, LU	DFO	N/A
Development of Ontario Field Guide	vii	• A freshwater mussel field-guide has been produced and is being promoted	EC, DFO, NHIC, SCRCA, SCRCF, STFN	EC, HSP, OMNR[3], SCRCF, STFN	Metcalfe-Smith et al. (2005)
Mussel sampling standardization and relocation techniques	i, iv, vi	• Publication of protocols and methods for addressing the presence and relocation of mussel species	DFO, U of G	DFO	Mackie et al. (2008)
(2-2) Work with existing ecosystem recovery teams to implement recovery actions.					
Collaborative efforts; further details are contained in Section 3.3 (ongoing)	All	• Ongoing collaboration with applicable recovery teams (e.g., Sydenham and Ausable rivers) on stewardship and research activities has maximized knowledge and resource transfer and minimized redundancy	ABCA, DFO, ERCA, GRCA, SCRCA, UTRCA	HSP	N/A
Other Activities:					
Proclamation of Ontario's *Clean Water Act*	v	• The Act, which came into effect in 2006, protects Ontario's source water via local committees that list existing and potential threats and implement actions that will reduce or eliminate these threats • Based on sound science, this approach allows for communities to take a "hands on" approach to conserve and protect their own watersheds	OMOE	N/A	OMOE (2012)

[1] Refers to all relevant recovery objectives from the recovery strategy as stated within Section 2.1 [2] A list of acronyms has been provided at the end of this report [3] OMNR funding may have come various OMNR sources, such as: Species at Risk Stewardship Fund, Species at Risk Research Fund, Aquatic Research and Development Section, Biodiversity Branch, Southern Region etc.

3.3. Stewardship activities

Table 4. Stewardship activities conducted/ongoing since the completion of the recovery strategy.

Activities	Recovery objectives addressed[1]	Results[2]	Agencies involved[2]	Funding sources[2]	References
Ausable River watershed					
Habitat enhancement and protection programs in the Ausable River watershed (2005-2009; ongoing)	v	• These projects resulted in the protection or improvement of nearly 60 km^2 of habitat or riparian zone and approximately 36 km of shoreline • Project examples include, agricultural equipment modification, livestock restriction from watercourses, and tree planting • Impacts of stewardship programs are being evaluated by the collection and monitoring of water quality and mussels	ABCA, DFO	HSP + matching funds (e.g., OMNR[3])	N/A
Sydenham River watershed					
Best management practices on watershed lands in Sydenham River watershed (2001-2010; ongoing)	v	• Best management practices on rural properties, including livestock restrictions, riparian buffers, streambank stabilization, wetland creation or enhancement, well decommissioning, septic upgrades, sediment control/trapping • The implementation of these best management practices have translated to over 2.9 km^2 of habitat or riparian zone protected or improved, 55 km of shoreline restored, 14 wells decommissioned, 23 septic systems upgraded, nine manure storage facilities improved and 20 km of watercourse restricted from livestock access	DFO, RLSN, SCRCA	DUC, HSP, SCRCA (in kind), private landowners	N/A
Thames River watershed					
Habitat Stewardship Programs in the upper Thames River watershed (2003-2009; ongoing)	v	• Water quality improvement through agricultural best management projects including milkhouse washwater system installation, livestock fencing and clean water diversion • Fish and benthos sampling has been undertaken to provide insight into the effectiveness of habitat improvement efforts • Water quality improvements have been noted in several portions of the watershed	UTRCA	HSP + matching funds (e.g., OMNR)	UTRCA (2010)

Table 4 (Con't). Stewardship activities conducted/ongoing since the completion of the recovery strategy.

Activities	Recovery objectives addressed[1]	Results[2]	Agencies involved[2]	Funding sources[2]	References
Grand River watershed					
Habitat enhancement and protection programs in the Grand River watershed (2005-2010)	v	• Tree planting and the promotion of nutrient management plans • Improvement of water quality and increased riparian habitat	GRCA	HSP + matching funds (e.g., OMNR)	N/A

[1] Refers to all relevant recovery objectives from the recovery strategy as stated within Section 2.1 [2] A list of acronyms has been provided at the end of this report [3] OMNR funding may have come various OMNR sources, such as: Species at Risk Stewardship Fund, Species at Risk Research Fund, Aquatic Research and Development Section, Biodiversity Branch, Southern Region etc.

3.4. Awareness activities

Table 5. Awareness activities conducted/ongoing since the completion of the recovery strategy.

Activities	Recovery objectives addressed[1]	Results[2]	Agencies involved[2]	Funding sources[2]	References
(4-1) Increase public knowledge of stewardship options and financial assistance available to participate in activities. (4-3) Encourage public support and participation by developing awareness materials and programs.					
Increase awareness through public outreach in Ausable River watershed (2006-2011)	vii	• Multipronged promotion of HSP (e.g., article on HSP included in ABCA's "Your Watershed" publication, display boards at community events, flyer distribution, public service announcements and press releases) • Annual meeting of Stewardship and Outreach Recovery Implementation Group to coordinate efforts and foster partnerships • Increase student awareness and engagement by delivering information regarding natural heritage, distribution, threats and recovery of mussel SAR	ABCA	A Channel (in kind), ABCA (in kind) ABCF, HSC, HSP, OMNR[3]	N/A
Increase awareness through public outreach in Sydenham River watershed (2006-2011)	vii	• Annually, 65 000 landowners and community members are provided with the SAR newsletter • Community outreach through activities, such as media releases, public service announcement and the maintenance of the Sydenham River Watershed website	DFO, RLSN, SCRCA	HSP, SCRCA (in kind)	N/A

Table 5 (Con't). Awareness activities conducted/ongoing since the completion of the recovery strategy.

Activities	Recovery objectives addressed[1]	Results[2]	Agencies involved[2]	Funding sources[2]	References
(4-1) Increase public knowledge of stewardship options and financial assistance available to participate in activities. (4-3) Encourage public support and participation by developing awareness materials and programs.					
Increase awareness through public outreach in Thames River watershed (2006-2011)	vii	• Outreach on SAR using public service announcements on CFPL-TV was estimated to reach at least 855 000 viewers per week • Species-specific community education and awareness through multimedia presentations to schools, community groups, special interest groups, and at public events is estimated to have reached over 5000 individuals • The yearly Thames River Clean Up (approximately 2000 yearly participants) has harnessed public interest and support to remove garbage from up to 200 km of river shoreline each year	UTRCA	HSP + matching funds (e.g., OMNR)	N/A
Walpole Island Heritage Centre (WIHC) stewardship and outreach	i, vii	• Provided presentations on threats and protection measures to Walpole Island First Nation schools and gatherings on SAR (including KS, RHN) found in their area • Mussel identification workshop and local surveys were performed to help raise awareness	WIFN	OMNR	WIHC (2009 & 2010)
(4-2) Increase public awareness of the potential impacts of transporting/releasing exotic species.					
Implementation of the Invasive Alien Species Strategy (ongoing)	vii	• Dissemination of aquatic invasive species information through the Watercraft Inspection Program • Distribution of aquatic invasive species educational information through public postings and direct engagement	DFO	DFO	N/A
Implementation of Hazard Analysis and Critical Control Point (HACCP) training	vii	• Licensed commercial baitfish harvesters in Ontario have completed HACCP training, which focuses on impacts and prevention of the spread of aquatic invasive species • As of 2006, baitfish licence holders must prepare a Hazard Analysis and Critical Control Point (HACCP) plan to address the threat of invasive species associated with their operations	BAO, OFAH, OMNR	OMNR	N/A

Table 5 (Con't). Awareness activities conducted/ongoing since the completion of the recovery strategy.

Activities	Recovery objectives addressed[1]	Results[2]	Agencies involved[2]	Funding sources[2]	References
Other Activities:					
Conference presentations (2007-2011)	vii	• Presentations delivered at multiple conferences (e.g., ASLO, NABS, FMCS, SETAC, ATW), which forged connections with the academic community, including graduate students	N/A	DFO, EC, NSERC, OMNR, WWF	See list of Conference Presentations at the end of this document
Presentations to naturalist groups, schools, etc.	vii	• Presentations delivered to multiple groups (e.g., Niagara restoration council, Halton Peel Naturalists, Nature London, Our Lady of Fatima Elementary School)	DFO	DFO	See list of Conference Presentations at the end of this document

[1] Refers to all relevant recovery objectives from the recovery strategy as stated within Section 2.1 [2] A list of acronyms has been provided at the end of this report [3] OMNR funding may have come various OMNR sources, such as: Species at Risk Stewardship Fund, Species at Risk Research Fund, Aquatic Research and Development Section, Biodiversity Branch, Southern Region etc.

3.5. Summary of progress towards recovery

To summarize progress towards recovery, implementation of the short-term recovery objectives have been assessed as follows:

i. Determine extent, abundance and population demographics of existing populations.

Recent surveys have updated the known distribution of the Kidneyshell, adding the upper Thames River (Medway Creek) to the previously stated distribution of the Sydenham and Ausable rivers, with a few specimens scattered in the St. Clair River delta. The population estimate for Kidneyshell in the Ausable River has also been updated (Baitz et al. 2008) and, as of 2006, comprised approximately 4% of the overall mussel community at seven sites throughout the watershed. Further surveys have been performed in significant species at risk mussel habitat where these two species are thought to be extirpated, namely the Grand, Welland, and lower Thames rivers. Fresh Kidneyshell shells were discovered in the lower Thames River near Tate Corners in June 2011 (S. Staton, DFO, pers. comm. 2012), indicating that the species is likely still present at this location. With the exception of this record, Round Hickorynut and Kidneyshell were not encountered during these efforts.

ii. Determine fish hosts and their distributions and abundances.

The work of the research group dedicated to Unionids at the University of Guelph (led by Drs. Ackerman and Mackie) has resulted in additional information pertaining to the host fishes of these two species in the laboratory. In addition to the Blackside Darter (*Percina maculata*), Fantail Darter (*Etheostoma flabellare*), and Johnny Darter (*E. nigrum*), the Iowa Darter (*E. exile*) and Brook Stickleback (*Culaea inconstans*) have been identified as host fishes for the Kidneyshell in Canada (McNichols 2007). Furthermore, the Round Goby, an exotic species, may serve as a fish host, albeit at a reduced level of effectiveness (McNichols et al. 2010).

Host fishes for the Round Hickorynut in Canada have been identified as the Blackside Darter, Fantail Darter, and Iowa Darter (McNichols 2007). It now appears that the Greenside Darter (*E. blennioides*) is not a host fish as glochidia did not metamorphose during host identification experiments (McNichols 2007). Additional research is needed to identify primary hosts (i.e., high infestation and metamorphosis rates for glochidia and juvenile Round Hickorynut and Kidneyshell) and marginal hosts (i.e., low rates), as well as to confirm functional hosts (e.g., distributional overlap between species, availability and density). In addition, there may be other species that act as hosts for these two species at risk that have yet to be examined in Canada. For example, the Eastern Sand Darter (*Ammocrypta pellucida*), a threatened species in Canada, has been suggested as a possible host for Round Hickorynut (COSEWIC 2003); however, this has not been tested in the laboratory.

Numerous fish surveys, both targeted and otherwise, have been performed in the Ausable, Thames, and Sydenham rivers. This information is being compiled and assessed to allow for a clearer understanding of population characteristics and ranges for known host fishes for the Round Hickorynut and Kidneyshell.

iii. Define key habitat requirements to identify critical habitat.

The recovery strategy for the Round Hickorynut and the Kidneyshell in Canada is currently being updated to include a partial identification of critical habitat for both species (DFO 2012). The approach and the methods used to identify reaches of critical habitat will be consistent with the approaches recommended by DFO (2011) for freshwater mussels.

Using the best available information, critical habitat will be identified for Round Hickorynut and Kidneyshell populations in the following areas:

1. East Sydenham River (Round Hickorynut and Kidneyshell)
2. Ausable River (Kidneyshell)
3. Medway Creek (Kidneyshell)

The areas to be identified may be insufficient to achieve the recovery objectives for the species. As such, the schedule of studies in the revised recovery strategy will be updated to further refine the description of critical habitat (in terms of its biophysical functions/features/attributes as well as its spatial extent) to support its protection.

iv. Establish a long-term monitoring program for Round Hickorynut and Kidneyshell populations, their hosts and the habitat of both.

To meet this objective, monitoring stations have been established and baseline data collected in the Ausable River (seven stations), Sydenham River (15), Thames River (six), and Grand River (seven) (Metcalfe-Smith et al. 2007b, Baitz et al. 2008, T. Morris, DFO, unpubl. data). Additionally, nine stations have been established in the St. Clair River delta (Metcalfe-Smith et al. 2007a). These monitoring programs include provisions for mussel and host fish(es) habitat monitoring.

v. Identify threats, evaluate their relative importance and implement remedial actions to minimize their impacts.

Various aspects of chemical contamination have been investigated. It is now thought that the glochidial stage is the most vulnerable and specialized life-stage, because it is during this stage that the species must successfully attach to an appropriate host to complete their metamorphosis to the juvenile stage and that they are most sensitive to contaminant exposure (Gillis et al. 2008, 2010, Gillis 2011).

Threats from exotic species, such as the Round Goby, have also been identified (Poos et al. 2010); a graduate student is currently studying the potential impacts of Round Goby on mussel species at risk. In the Thames River, dreissenid mussels can now be found from Fanshawe Reservoir downstream to Thamesville (UTRCA 2012). In the lower Thames River near Big Bend, Zebra Mussel have been found attached to adult unionids (Morris and Edwards 2007).

Additional research conducted on quantifying sediment and nutrient inputs from agricultural drainage systems and point sources has informed recommendations for more effective strategies for reduction of loading to rivers (e.g., Ball Coelho et al. 2010).

vi. Examine the feasibility of relocations, reintroductions and the establishment of managed refuge sites.

Methods have been developed for artificial propagation of mussel species in the laboratory and the field, and continued efforts are expected to refine and improve current approaches. The feasibility of relocations and reintroductions of mussel species has been partially addressed by investigations into the genetic and environmental implications of these approaches (Hoftyzer et al. 2008). Additionally, a mussel relocation protocol has been developed by Mackie et al. (2008) and is currently being implemented when development projects require that mussels be moved to prevent harm from habitat alterations.

Efforts to expand our understanding of the genetic structure of mussel populations has been advanced with studies on genetic parentage analyses of glochidia, and genetic diversity within and among mussel populations, driven by genetic marker development and optimization (McNichols et al. 2010). An investigation into the feasibility of establishing actively managed refuge sites in the St. Clair River delta still needs to be addressed; collaborative efforts with the Walpole Island First Nation are planned to determine the effectiveness of managed refuge sites.

vii. Increase awareness about the distribution, threats and recovery of these species.

Outreach programs have been successful in reaching the public at large (e.g., naturalist clubs, farming communities, schoolchildren). The Stewardship and Outreach Recovery Implementation Group (Sydenham River Recovery Team) has held annual meetings to engage landowners on stewardship programs. A further emphasis on presenting research findings at conferences has increased awareness of the plight of mussel species at risk, highlighted key knowledge gaps and fostered valuable collaborative efforts.

Action plans: DFO, in partnership with the Sydenham River Recovery Team, has developed a proposed multi-species, ecosystem-based action plan for the Sydenham River to be completed in 2012. This action plan will include several species at risk mussels, including the Round Hickorynut and Kidneyshell.

4. RECOMMENDATIONS

The long-term goals of preventing extirpation, maintaining or returning self-sustaining populations and re-establishing populations to historical sites are still valid. As a result of the five-year accumulation of knowledge regarding the Round Hickorynut and Kidneyshell, the recovery strategy will be updated to include a partial identification of critical habitat for both species, as well as slightly revised recovery goals (based on new distribution data).

The following discoveries or changes may be deemed important in redirecting recovery approaches:

- An upstream invasion of the Round Goby in the Ausable, Sydenham, and Thames rivers is in progress (Poos et al. 2010), furthering concern of impacts on host fish species. The impacts of Round Goby on mussel species at risk is currently being investigated by a graduate student at the University of Guelph. An expansion of dreissenid mussels into unionid mussel habitat has also been detected.
- The glochidium of a species at risk mussel has been demonstrated to be acutely sensitive to sodium chloride, which is used as a road de-icing agent in winter (Gillis 2011). This is a relevant finding as the Round Hickorynut and Kidneyshell reside in Canada's most road-dense region where chloride levels have been increasing over time.
- Additional host fishes for both mussel species have been identified in the laboratory and should be confirmed in the field (to verify which fish[es] are 'functional' hosts).
- A relict population of the Kidneyshell has been discovered in the Thames River basin (Medway Creek), an area heavily impacted by agricultural activities and residential development.
- Fresh Kidneyshell shells have been discovered in the lower Thames River near Tate Corners, suggesting that the species is extant in the lower Thames River.
- The St. Clair River delta populations of both species now appear functionally extirpated.
- A projected decrease in water quantity, resulting from climate change and changing water use patterns, may result in severe reductions in mussel and fish richness (Spooner et al. 2011).
- Further protection to Ontario's source water was enacted in 2006 via the *Clean Water Act* and is supported by local committees that list existing and potential threats and implement actions that will reduce or eliminate these threats (OMOE 2012).
- The Round Hickorynut and Kidneyshell are both listed as Endangered under the *Endangered Species Act*, *2007*, which came into force in 2007. Under the Act, individuals of both species are protected and their habitat will be protected under the general habitat protection provisions as of June 30, 2013, unless a species-specific habitat regulation is developed by the provincial government at an earlier date.

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Morris, T.J. 2009. Towards the recovery of Canada's freshwater mussels: population and life history characters of the Endangered Wavyrayed Lampmussel. Invited Speaker, University of Guelph, Loaves and Fishes Seminar Series. February 2009.

Morris. T.J. 2009. Protecting and preserving Ontario's freshwater mussels: more than just a shell game. Invited Speaker, Niagara College. March 2009.

Morris, T.J. 2009. An introduction to Ontario's freshwater mussels. COSEWIC Mollusc SSC annual meeting. September 2009.

Morris, T.J. 2009. Ontario's Freshwater Mussels: A vanishing treasure. Invited Speaker, Peninsula Naturalists Annual General Meeting. November 2009.

Morris, T.J. 2010. Ontario's freshwater mussels: a vanishing treasure. Invited Speaker, Halton Peel Naturalists Annual General Meeting. February 2010.

Morris, T.J. 2010. Introduction to pondlife. Building Blocks Nursery School. May 2010.

Morris T.J. 2011. Species at risk and aquatic invasive species. Our Lady of Fatima Elementary School. Invited presentation to primary grades. May 2011.

Morris T.J. 2011. Freshwater mussels of the Thames River: an historical perspective. Invited presentation to Nature London, London, ON. October 2011.

Morris T.J. 2011. Freshwater mussels of the SOSMART area. Invited presentation to SOSMART working group. Toronto, ON. December 2011.

ACRONYMS

AAFC	Agriculture and Agri-Food Canada
ABCA	Ausable Bayfield Conservation Authority
ABCF	Ausable Bayfield Conservation Foundation
ATW	Aquatic Toxicity Workshop
BAO	Bait Association of Ontario
CCME	Canadian Council of Ministers of the Environment
CDA	Copper Development Agency
CMU	Central Michigan University
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CRC	Canadian Research Chair
CWF	Canadian Wildlife Federation
CWN	Canadian Water Network
DFO	Fisheries and Oceans Canada
DUC	Ducks Unlimited Canada
EC	Environment Canada
ERCA	Essex Region Conservation Authority
GRCA	Grand River Conservation Authority
HSC	Huron Stewardship Council
HSP	Habitat Stewardship Program
IDRC	International Development Research Centre
IRF	Interdepartmental Recovery Fund
KS	Kidneyshell
LU	Lakehead University
NHIC	Natural Heritage Information Centre
NSERC	Natural Sciences and Engineering Research Council
OFAH	Ontario Federation of Anglers and Hunters
OGS	Ontario Graduate Scholarship
OMNR	Ontario Ministry of Natural Resources
OMOE	Ontario Ministry of the Environment
RHN	Round Hickorynut
RLSN	Rural Lambton Stewardship Network
ROM	Royal Ontario Museum
SAR	Species at Risk
SARRFO	Species at Risk Research Fund for Ontario
SCRCA	St. Clair Region Conservation Authority
SCRCF	St. Clair Region Conservation Foundation
SETAC	Society of Environmental Toxicology and Chemistry
STFN	St. Thomas Field Naturalists
TTLT	Thames Talbot Land Trust
U of A	University of Alberta
U of G	University of Guelph
U of O	University of Ottawa
U of T	University of Toronto
U of W	University of Waterloo
UNB	University of New Brunswick
UTRCA	Upper Thames River Conservation Authority
WIFN	Walpole Island First Nation
WIHC	Walpole Island Heritage Centre
WWF	World Wildlife Fund