FINAL

Species at Risk Act
Management Plan Series

Management Plan for the Yellow Lampmussel (*Lampsilis cariosa*) in Canada

Yellow lampmussel

April 2010

Fisheries and Oceans Canada
Pêches et Océans Canada
Canada

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 manage species of special concern to prevent them from becoming endangered or threatened."*

What is a species of special concern?

Under SARA, a species of special concern is a wildlife species that could become threatened or endangered because of a combination of biological characteristics and identified threats. Species of special concern are included in the SARA List of Wildlife Species at Risk.

What is a management plan?

Under SARA, a management plan is an action-oriented planning document that identifies the conservation activities and land use measures needed to ensure, at a minimum, that a species of special concern does not become threatened or endangered. For many species, the ultimate aim of the management plan will be to alleviate human threats and remove the species from the List of Wildlife Species at Risk. The plan sets goals and objectives, identifies threats, and indicates the main areas of activities to be undertaken to address those threats.

Management plan development is mandated under Sections 65-72 of SARA http://www.sararegistry.gc.ca/approach/act/default_e.cfm.
A management plan has to be developed within three years after the species is added to the List of Wildlife Species at Risk. Five years is allowed for those species that were initially listed when SARA came into force.

What's next?

Directions set in management plans will enable jurisdictions, communities, land users, and conservationists to implement conservation activities that will have preventative or restorative benefits. Cost-effective measures to prevent species from becoming further at risk should not be postponed for lack of full scientific certainty and may, in fact, result in significant cost savings in the future.

The series

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

To learn more

To learn more about the *Species at Risk Act* and conservation initiatives, please consult the SARA Public Registry (http://www.sararegistry.gc.ca/).

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April 2010

Recommended citation:

Fisheries and Oceans Canada. 2010. Management Plan for the Yellow Lampmussel (*Lampsilis cariosa*) in Canada [Final]. *Species at Risk Act* Management Plan Series. Fisheries and Oceans Canada. Ottawa. iv + 44 pp.

Additional copies:

Additional copies can be downloaded from the SARA Public Registry (http://www.sararegistry.gc.ca/).

Cover illustration: Fisheries and Oceans Canada

Également disponible en français sous le titre
« Plan de gestion de la lampsile jaune (*Lampsilis cariosa*) au Canada »

ISBN 978-1-100-14035-3
Catalogue no. En3-5/6-2009E-PDF

PREFACE

The yellow lampmussel (*Lampsilis cariosa*) is a freshwater mollusc and is under the responsibility of the federal government. The *Species at Risk Act* (SARA, Section 65) requires the competent minister to prepare management plans for species listed as Special Concern. The yellow lampmussel was listed as a species of special concern under SARA in 2005. The development of this management plan was led by Fisheries and Oceans Canada – Maritimes Region, in cooperation and consultation with many individuals, organizations and government agencies, as indicated below. In particular, this management plan has been prepared in cooperation with the Governments of Nova Scotia and New Brunswick. The plan meets SARA requirements in terms of content and process (SARA sections 65-68).

Success in the conservation 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 plan and will not be achieved by Fisheries and Oceans Canada or any other party alone. This plan provides advice to jurisdictions and organizations that may be involved or wish to become involved in activities to conserve this species. In the spirit of the Accord for the Protection of Species at Risk, the Minister of Fisheries and Oceans Canada invites all responsible jurisdictions and Canadians to join Fisheries and Oceans Canada in supporting and implementing this plan for the benefit of the yellow lampmussel and Canadian society as a whole. The Minister will report on progress within five years.

COMPETENT MINISTER

Under the *Species at Risk Act*, the Minister of Fisheries and Oceans Canada is the competent Minister for the yellow lampmussel.

AUTHORS

This document was prepared by Fisheries and Oceans Canada, Maritimes Region in collaboration with the Governments of Nova Scotia and New Brunswick.

ACKNOWLEDGMENTS

Fisheries and Oceans Canada (DFO) is grateful to those who have participated in the development of the Yellow Lampmussel Management Plan: Mark Elderkin, Nova Scotia Department of Natural Resources (NSDNR), Wildlife Division; Jason LeBlanc, Nova Scotia Department of Fisheries and Aquaculture (NSDFA), Inland Fisheries Division; and Mark McGarrigle, New Brunswick Department of Natural Resources (NBDNR), Fish and Wildlife Branch. Reviews of drafts were provided by Kellie White, Cape Breton University (CBU); Donald McAlpine, New Brunswick Museum (NBM), Mike James (DFO), and Mark Hanson (DFO). Marian Munro, Nova Scotia Museum (NSM); Karen Madden, Nova Scotia Department

of the Environment (NSDoE); Joel McLean, Nova Scotia Lands Corporation (NSLC); Craig Power, Atlantic Coastal Action Program Cape Breton (ACAP-CB), and David Maguire, New Brunswick Department of the Environment, (NBDoE) provided useful background and technical information. The photographs and illustrations found in Figures 1 – 4 were adapted from the COSEWIC status report with the permission of Derek Davis. Kellie White provided the photograph found in Figure 5.

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 plans may also inadvertently lead to environmental effects beyond the intended benefits. The 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 into the plan itself, but are also summarized below.

This management plan will clearly benefit the environment by promoting the recovery of the yellow lampmussel. The potential for the plan to inadvertently lead to adverse effects on other species was considered. The SEA concluded that this plan will clearly benefit the environment and will not entail any significant adverse effects. The reader should refer to the sections of the document referring to the species' biology; and management actions for specific details on potential environmental benefits of this management plan.

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The yellow lampmussel (*Lampsilis cariosa*) is a freshwater bivalve mollusc that is typically up to 75 mm in length and is almost oval in outline, with a glossy, bright yellow or reddish brown outer shell. It is a suspension feeder which filters organic debris and phytoplankton from the water. The sexes are separate and early larval (glochidial) development takes place within females. Development proceeds through a period of parasitism where the larvae attach to the gills of a host fish species, usually white perch (*Morone americana*) or yellow perch (*Perca flavescens*), although there may be other suitable species. Young mussels drop to bottom sediments to grow to adult size. Usually found on level, sand and gravel bottoms in medium-large rivers, they can also be found in lakes and reservoirs on sandy bottoms with sparse vegetation.

The yellow lampmussel (YLM) occur along the Northeast Atlantic Slope of North America from Georgia to Nova Scotia. They are considered to be threatened and declining throughout much of their range in the United States. They are listed as a species of Special Concern under the Canadian *Species at Risk Act*. In Canada, the YLM is only known to exist in two locations: the Sydney River, Cape Breton, Nova Scotia and the lower Saint John River near Fredericton, New Brunswick. Blackett's Lake, which formed when the Sydney River was dammed in 1902, is the main centre of the YLM population in Nova Scotia. However, the majority of the Canadian population of YLM are found below the head-of-tide in the Saint John River, below the Mactaquac Dam including five of its large tributaries and several large lakes.

Both populations appear to be large and stable at present, and are not under imminent threat. There are concerns related to the potential introduction of non-native zebra mussels into the Saint John River and maintaining habitat quality of the Sydney River population, located within a suburban and industrial environment where development is increasing. Since YLM populations are biologically limited by their dependence on host fishes, direct threats to these fish species will have indirect impacts on mussel populations.

The goal of this management plan is to:

maintain the existing yellow lampmussel populations in Canada.

The five objectives of the plan are to:

- Maintain current quality and quantity of known YLM habitat;
- Reduce direct threats to YLM populations
- Improve our understanding of YLM populations in New Brunswick and Nova Scotia;
- Maintain existing host fish populations; and
- Increase public awareness and involvement in YLM conservation efforts.

These objectives will be accomplished through conservation and management strategies that:

- Reduce threats to water and habitat quality, and to YLM and their host fish;
- Contribute to a better understanding of YLM population size, dynamics and distribution;
- Maintain existing populations of YLM and their host fish;

- Encourage, develop and support education, communication and stewardship programs that promote habitat conservation and species preservation, and
- Adopt and/or develop tools and approaches to reduce the risk of non-native and invasive species introductions.

There are a number of gaps in our knowledge about the YLM in Canadian waters including in the areas of biology and ecology, habitat requirements, and additional potential threats. While there has been significant progress in narrowing knowledge gaps, it is widely accepted that research and management efforts must continue. In Section 2.3 of this document, specific actions are identified as necessary to facilitate the objectives and goals of this management plan. In summary, the specific actions fall into the following categories: protection, management, research, monitoring and assessment and outreach and communication. A number of actions are already ongoing to protect and manage the YLM. For example, protection of the species and its host fish already exists pursuant to federal and provincial legislation and regulations. Furthermore, there are a number of threat mitigation and research efforts currently underway that will contribute to meeting the objectives outlined in this management plan. Specific details regarding actions proposed or underway for the yellow lampmussel can be found in Section 4 of this document in Tables 4 and 5 for both the Sydney and Saint John rivers respectively.

1. SPECIES INFORMATION

1.1. Species Assessment Information from COSEWIC

Date of Assessment: May 2004

Common Name (population): yellow lampmussel

Scientific Name: *Lampsilis cariosa*

COSEWIC Status: Special Concern

Reason for Designation: Populations are quite large and apparently stable in Canada but are found only in the Sydney River, Nova Scotia and the Saint John River watershed, New Brunswick. Threats are currently very limited but there are long-term concerns related to the potential for introduction of zebra mussels into the Saint John River, and maintaining habitat quality for the sole population in the Sydney River.

Canadian Occurrence: Nova Scotia, New Brunswick

COSEWIC Status History: Designated Special Concern in May 2004. Assessment based on a 2004 status report.

1.2. Description

The yellow lampmussel (YLM) is one of 12 species or subspecies of freshwater mussels recorded in Atlantic Canada[1]. Like all freshwater mussels, the YLM is a benthic suspension feeder that filters organic detritus and phytoplankton from the water, and expels unwanted material as pseudofaeces.

The YLM's bivalve shells are typically about 75 mm in length, but may be up to 110 mm in length. The shells are almost oval in outline, and adult males appear (Figure 1, bottom) more elongated than adult females (Figure 1, top and middle). The shell is moderately thick, up to 4.0 mm in the largest specimens, and its surface is smooth except for concentric growth-rest lines. The outer shell (periostracum) of Atlantic specimens is normally glossy, straw-yellow or in some cases reddish brown (D. McAlpine, NBM, pers. comm. 2007). Specimens do not usually have linear shell markings (rays) but, when present, they are well defined and found on the posterior slope of the shell. Specimens collected from Sydney River often have a mineral deposit on the posterior end, which may obscure the rays (D. McAlpine, NBM, pers. comm. 2007).

[1] At present only 11 species are found in Atlantic Canada as the dwarf wedgemussel, *Alasmidonta heterodonta*, is considered extirpated (DFO 2007).

Figure 1. The yellow lampmussel, *Lampsilis cariosa* from Blacketts Lake, Nova Scotia. Top and middle panels show exterior and interior of female specimen, respectively, length 60 mm. Bottom panel shows live male specimen, length 75 mm (from COSEWIC, 2004, courtesy of D. Davis).

The inside of the shell (nacre) is white. The soft living parts (mantle) are visible along the shell margins. The mantle edge is smooth with grey streaks or dots and has a well developed, brightly pigmented flap-like extension and a dark eyespot. These characteristics are best developed in the female. A more technical description of the YLM can be found in COSEWIC (2004).

The maximum age of YLMs found in the Sydney River is 17 years, and the average is 7.8 (±2.7) (White 2003). Yellow lampmussels exist as separate sexes. The age of sexual maturity is not known, but based on estimates in related species, it may occur at age 5 years, with the range of rate of survival to maturity estimated at 9-18% (Jansen and Hanson 1991).

The exact timing of fertilization and release of glochidia are unknown, however the release of glochidia happens at the same time as the display of the mantle lure and the presence of swollen, darkened marsupium in females. In the Sydney River, females are thought to be gravid from at least June until mid November (White 2003). Research is required to determine the lifespan, age at sexual maturity and the period of gravidity for the New Brunswick population.

1.3. Populations and Distribution

The YLM occurs along the Northeast Atlantic slope of North America, east of the Appalachian Mountains and from Ogeechee River, Georgia, United States (US) in the south to Sydney River, Nova Scotia in the north (Figure 2). In the US, where their range and numbers are declining, there are species records from Georgia, South Carolina, North Carolina, Virginia, Maryland, Delaware, Pennsylvania, New Jersey, New York, Connecticut, Massachusetts, and Maine. They are not listed under the US *Endangered Species Act* at present.

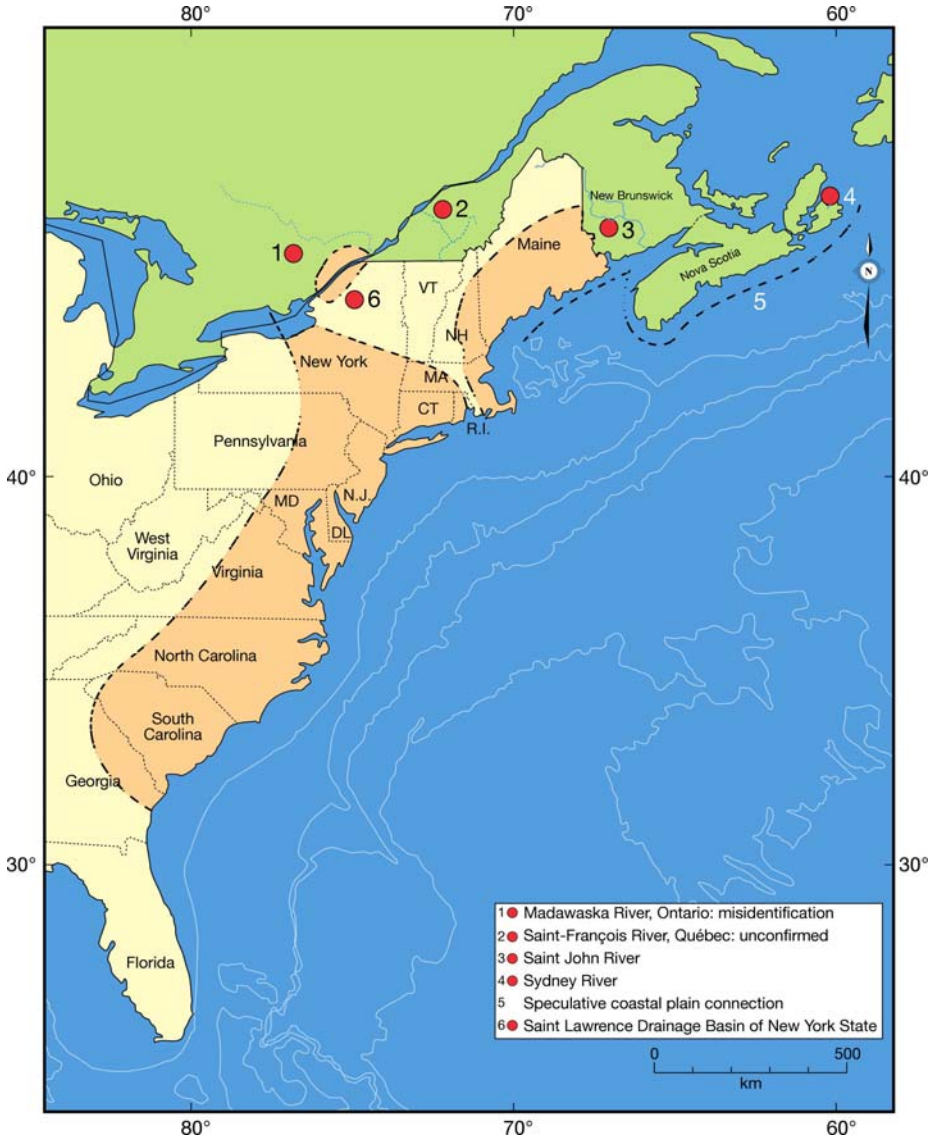

Figure 2. The general range of the yellow lampmussel, *Lampsilis cariosa*, on the Atlantic slope of eastern North America (adapted from COSEWIC, 2004, courtesy of D. Davis).

In Canada, *L. cariosa* is known to occur in only two locations: the Sydney River, Cape Breton Island, NS and the Saint John River and tributaries near Fredericton, NB (Figure 2). Some early

reports from Madawaska River, Ontario and lower St. Lawrence River have been discounted as misidentifications. The identification of a specimen taken in the St. François River, Quebec, in 1952 cannot be confirmed as the specimen is missing. The current status of the species in Quebec therefore remains uncertain and in need of investigation given its presence in the Upper Susquehanna River watershed (east of Lake Erie and south of Lake Ontario in New York State) (Strayer and Fetterman 1999) and in the St. Lawrence River basin in northern New York State (Strayer and Jirka 1997).

The Sydney River, NS, is a small 140 km^2 system that drains north into the Atlantic Ocean at Sydney Harbour (Figure 3). The main stream, r oughly 15 km long, was dammed in 1902. Above the Sydney River dam, the river is essentially a long lake and there are two additional lakes at the top of the river: Blacketts Lake (187 hectares) and Gillis Lake (11.6 hectares). The Sydney River population is found above the Sydney River dam, mainly in Blacketts Lake. The

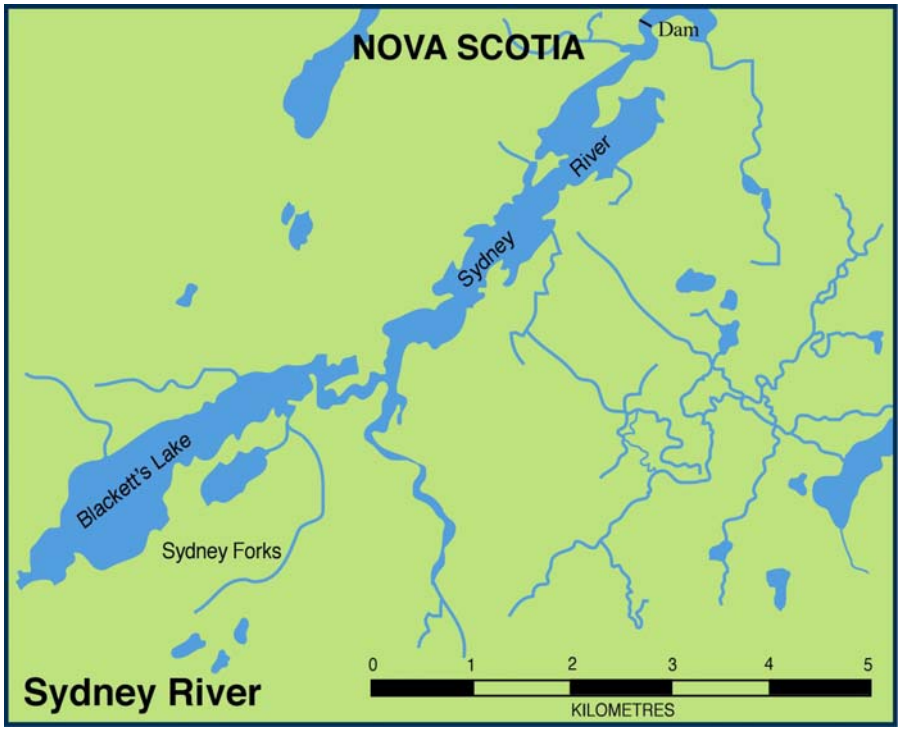

Figure 3. Sydney River, NS showing location of the Sydney River Dam, and Blacketts Lake, where most of the yellow lampmussel population is located (adapted from COSEWIC, 2004, courtesy of D. Davis).

species reached Nova Scotia approximately 7000 years ago during a post-glacial warming period (Davis and Browne 1996). As a result of the rising sea level and climatic cooling that have occurred since, as well as geological factors such as bedrock type, the Sydney River YLM population has become isolated (disjunct) from other populations. This population is located at the northern-most extent of the species range (confirmed populations) in North America.

The Saint John River, NB has a main stream length of 700 km, and a drainage area greater than 55 000 km^2. The lower Saint John River watershed (below head of tide) is thought to harbour

most of the Canadian YLM population (Sabine et al. 2004) (Figure 4). This portion of the system includes the lower 140 km of the main river as well as 5 large tributary rivers, and covers 15 000 km^2 (27%) of the entire drainage. The lower Saint John River contains several large lakes, including Grand Lake (17 100 hectares) which contains YLMs. Yellow lampmussel populations are known in nearby drainages in Maine (the Mattawamkeag and the Penobscot) and the Saint John River is within the general range of the species.

Some reduction in range may have occurred in NB. Above the Mactaquac dam, the YLM host fish species is present, as is the mussel species used to indicate possible or likely YLM presence (see discussion below). There is also suitable and available YLM habitat. Nonetheless, there is no direct evidence that the yellow lampmussel was present historically in this section of the Saint John River (Sabine et al. 2004).

It is difficult to make accurate density estimates and to track population trends of the YLM due to its high degree of spatial aggregation (clumping) and challenging field sampling conditions. A high degree of uncertainty associated with population estimates obtained for the Sydney River population in 2001 and 2002 (White 2003) make these almost meaningless. A recent estimate of the overall Sydney River population is about 2.5 million (Sabine et al. 2004), and field studies are underway to determine the size of this population. The most extensive study on YLM distribution in NB is provided by Sabine et al. (2004), and most specimens were collected at an almost 4km long site of optimal pure sand habitat. Although their methodology did not allow for density estimates, the number of specimens observed here was thought to indicate a significant population in the Saint John River and its tributaries. Using YLM density estimates from the Sydney River (White 2003) or Maine (Wick and Huryn 2002), the population for this small area of the river alone could be estimated at over two million individuals. Even assuming densities an order of magnitude lower would indicate a total NB population well into the millions.

Figure 4. Saint John River system, NB (adapted from COSEWIC 2004, courtesy of D. Davis).

1.4. Needs of the Yellow Lampmussel

1.4.1. Habitat and biological needs

The YLM is typically found in medium to large rivers. Detailed US macrohabitat research (Strayer 1993) suggests that the species prefers lowland rivers and streams with drainage basins >1200 km^2, hard water and stable, nearly level bottoms. Like other mussel species, they are not adapted to soft, silty bottoms (Bogan 1993), where silt can bury and smother individuals and interfere with feeding and reproduction (Morris and Burridge 2006).

The habitat used by YLMs in the Sydney River is best characterised as a lake reservoir habitat with imperceptible flow rates except at three locations: the constriction caused by the road causeway, the bridge at Blacketts Lake, and at the Sydney River dam. The lake water is alkaline and YLMs are not found below the dam, where waters may be too brackish to support the species. The damming of the tidal Sydney River has increased the area of habitat available to the YLM in the last century. In Blacketts Lake, YLMs are most commonly found in areas of sandy substrate with low macrophyte cover, and highest densities are recorded between 0.75 – 6.0 m in depth (White 2003). None are recorded below the thermocline which is estimated at 6.0 m. During winter, much of Sydney River is typically ice covered except in areas of higher flow at the tributary stream outlets.

The nearly level bottom and tidal nature of the lower Saint John River have resulted in the formation of extensive sand bars which appear to offer excellent conditions for YLMs. During surveys, the YLM has occasionally been found on cobble substrates, but was at highest numbers in unvegetated bars of fine to coarse sand, and at depths up to 5.15 m. Damming of the Saint John River at Mactaquac may have reduced the area of habitat available to the species as none have been encountered in surveys of the Mactaquac headpond. Further survey work is required to determine if populations exist above the headpond.

Suitable habitat for the YLM may exist elsewhere in both NS and NB, however until comprehensive surveys are made of additional river systems, this cannot be confirmed. Given the level of river inventory conducted in NS, however, the presence of YLM outside the Sydney River population is unlikely (M. Elderkin, NSDNR, pers. comm. 2007). In NB, YLMs have not been found during recent surveys of the Petitcodiac River and its tributaries (Hanson and Locke 2001) or in the rivers of Kouchibouguac National Park (M. Hanson, DFO, pers. comm. 2007). Additional suitable habitats may exist in large rivers such as the Miramichi and the Magaguadavic.

Yellow lampmussels are dependent upon a fish host for completion of their life cycle. Males release sperm into the water column which find their way to the females to fertilize eggs, and the larvae, called glochidia, initially develop inside the brood pouch (marsupium) of the females. Gravid (pregnant) females have modified mantles (mantle lure) that resemble fish (Figure 5.) which are thought to attract the fish hosts required for the development and dispersal of their parasitic larvae. When the lure is struck by a predatory fish, the glochidia are released and attach to the host fish. After a period of time, the glochidia mature into juvenile mussels, and drop from the fish to the bottom substrate where they grow into adult mussels.

White perch (*Morone americana*) is known to be a host fish for the YLM in the Sydney River (White 2003). Banded killifish (*Fundulus diaphanous*) may also be a host species in this system (K. White, CBU, per. comm. 2007). Fish host species in the Saint John River have not been confirmed, but based on research in the US (Wick and Huryn 2002, 2003), and known fish species in the Saint John River, they are thought to be white perch and/or yellow perch (*Perca flavescens*) (Sabine et al. 2004). The YLM is not likely dependant on a single species of host fish to reproduce successfully; further research should test whether a limited diversity of fish species serve as their hosts in Canada.

Figure 5: Minnow-like mantle lure of female *Lampsilis cariosa* from Blacketts Lake, NS (photo courtesy of K. White).

The Sydney River YLM population exhibits significant spatial aggregation (clumping) (White 2003). Living in dense clumps may facilitate reproduction; it may also occur due to habitat preferences. Whether or not these same distributions of mussels remain stable over time is unknown. In both the Sydney and Saint John rivers, the YLM is found in association with other mussel species (Table 1). In the Saint John and its tributaries, the presence of the tidewater mucket (*Leptodea ochracea*) is a useful indicator for the possible presence of the YLM (Sabine et al. 2004).

Table 1: Mussel species found in association with the yellow lampmussel (in order of frequency)

Sydney River (COSEWIC 2004)	Saint John River (Sabine et al. 2004)
Eastern elliptio (*Elliptio complanata*)	Eastern elliptio (*Elliptio complanata*)
Eastern floater (*Pyganodon cataracta*)	Eastern floater (*Pyganodon cataracta*)
Tidewater mucket (*Leptodea ochracea*)	Tidewater mucket (*Leptodea ochracea*)
Alewife floater (*Anodonta implicata*)	Alewife floater (*Anodonta implicata*)
	Eastern lampmussel (*Lampsilis radiate*)
	Triangle floater (*Alasmidonta undulata*)
	Eastern pearlshell (*Margaritifera margaritifera*)

1.4.2. Ecological role

Yellow lampmussels, like other species of freshwater mussels, are an important component of aquatic food webs. Larval and young mussels may be consumed by ducks, herons, fish and other invertebrates, while older, larger mussels are preyed upon by muskrats, otters and raccoons.

As suspension feeders, YLMs help improve water quality by filtering phytoplankton, diatoms, micro-organisms, bacteria and detritus from the water column. As they filter-feed, they remove toxins from water and sediment. For this reason, they are used as biological monitors in aquatic ecosystems.

Due to their large standing stock (often greater than the combined biomass of all other fauna in a waterbody), freshwater mussels represent a major nutrient sink in healthy waterbodies and an important link between the pelagic and detrital energy cycles.

1.4.3. Limiting factors

Yellow lampmussels are limited by their dependence upon a fish host for completion of their life cycle. Direct threats to their host fish species or their habitat will have indirect impacts on YLMs; the removal of suitable host species or their habitat will likely result in the subsequent disappearance of annual cohorts of yellow lampmussels.

Yellow lampmussels have limited dispersal abilities. Although they have a muscular foot enabling them to move to adjust their position for feeding or to accommodate seasonal changes in water level, their main means of dispersal is at the glochidial stage through the movement of the fish host.

1.5. Threats

North American freshwater mussels are among the most imperiled taxa, with over 70% of the approximately 300 species showing evidence of decline (Morris and Burridge 2006; Williams et al. 1993). Degradation and destruction of habitat, barriers to fish passage, declining water quality and the introduction and establishment of zebra mussels have been implicated as the causes of the dramatic declines in mussel populations in the past 30 years (Nalepa and Schloesser 1993; Metcalfe-Smith et al. 2000, 2003, DFO 2007). While the two YLM populations in Canada are not under imminent threat, and appear quite large and stable at present, it is important to preserve, monitor and manage them to ensure their future health and survival.

Threats to the two populations of YLM differ somewhat in nature and degree of potential impact. Its location within a suburban and industrial environment presents several water quality and habitat threats to the Sydney River population; whereas the Saint John River population is more threatened by the potential introduction of zebra mussels (COSEWIC, 2004). The known and potential threats to YLM that were identified by COSEWIC (2004) (unless otherwise indicated) are discussed separately for each population.

1.5.1. Threat classification

Threats, and the risk or level of concern posed by them, are summarized in Appendix 3 for the Sydney River YLM population and in Appendix 4 for the Saint John River population. Threats are listed in descending order of risk in the Tables. Terms used in the classification and description of threats were obtained from Environment Canada (2006). For the purposes of this discussion, the extent of a threat refers to the entire known range of each of the separate populations. A localized threat is one that is restricted to one or more locations, or point sources within the species' range.

In assigning an overall level of concern for each threat, the overall balance of the factors describing the threat was considered. For example, a current threat carried more risk than a potential one, but if a potential threat represented continuous or severe consequences to YLMs, it was assigned an overall moderate level of concern.

Degradation and destruction of habitat and degradation of water quality are the most serious threats facing the YLM population in the Sydney River. The overall level of concern of these threats is moderate: all are current and continuous threats, but all can be managed through existing Acts and Regulations (see Section 1.6.1 below) and public awareness and stewardship initiatives. Non-native and invasive species are moderate to low risk threats in the Sydney River (Table 2). A moderate threat is posed by the potential introduction of zebra mussels, based on their demonstrated severe and direct impacts on mussel populations elsewhere. Other invasive species pose a low overall risk, as they would affect YLMs indirectly through habitat or community effects that would probably not occur to a great extent in this habitat. The threat of a dam breach is judged to be low, as is muskrat predation. Seasonal low water levels may also occur, but the nature of this threat is unknown at the present.

The potential introduction of zebra mussels poses a serious threat to YLM populations in the Saint John River. Habitat loss and degradation and water quality issues are judged to be low-moderate risk for YLM in the Saint John River. These threats are current and continuous however, they are manageable using existing regulations. The presence of muskellunge is an unknown-moderate risk at this time, as more information is required to accurately assess this potential threat. Seasonal low water levels have potential to reduce YLM habitat, and while this is not thought to be limiting at this time, the overall risk of this threat is unknown.

1.5.2. Description of threats

Threats to the Sydney River population

Changes to habitat and water quality

Habitat destruction and degradation, and the deterioration of water quality, are the greatest threats to YLMs in the Sydney River where shoreline residential and industrial development are increasing.

Sedimentation (siltation) resulting from shoreline activities, such as construction activities and property maintenance, can alter the quality and extent of suitable benthic habitat for YLMs. Most mussel species are not adapted to soft, silty substrates (Bogan 1993), which can bury and smother burrowing species and interfere with feeding and reproduction (Morris and Burridge 2006).

The potential for deteriorating water quality in the Sydney River is of concern for YLMs. Healthy mussel and host fish populations are dependent upon, and indicative of, good water quality (Williams et al. 1993). The area of the river above the Sydney River dam was once a primary domestic water supply. The area remains a backup domestic water supply, and an industrial water supply for SYSCO (Sydney Steel corporation). While water quality is still regulated under the NS *Environment Act* (1994-5), this might change in the future if the area ceases to be used as a backup.

Water quality might also decline if local residents adopt less stringent best management practices for shoreline works and activities than those currently encouraged through an ongoing public outreach and awareness campaign detailed below (Section 1.6.3). Human use of garden or agricultural chemicals can lead to eutrophication. Localised sewage and septic tank inputs may also promote the growth of algae and aquatic plants and reduce oxygen levels, further degrading habitat and water quality. The increasing industrial and residential development around the Sydney River could also result in transportation accidents and accidental discharge of pollutants into the river. Although recreational activities in Blacketts Lake are not extensive at present, an increase in boating activities might pose potential risk for YLMs if sediments and water are contaminated from spills or leakage of motor boat oil.

A breach of the Sydney River dam could also alter habitat and water quality to the detriment of YLM. A breach could reduce water levels and result in an increase in saltwater intrusion upstream of the dam, further reducing YLM habitat. The dam is currently owned and maintained by Nova Scotia Lands Corporation (NSLC), and is subject to Canadian Dam Association Safety and Maintenance Regulations. The last major inspection of the dam (to evaluate potential changes in sweep and elevation) occurred in 2004; another is scheduled for 2009; and no obvious deterioration was noted in 2007 (J. MacLean, NSLC, pers. comm. 2009). The associated fish ladder is also inspected and repaired annually and no repairs were necessary in 2008 (J. MacLean, NSLC, pers. comm. 2009). Given the current management and maintenance of the dam, the threat of a dam breach is considered unlikely.

Use of molluscicides

"Swimmer's itch", caused by a trematode parasite, has been reported in Blacketts Lake and molluscicides have been used elsewhere to control the host snail populations. Molluscicides are not species-specific, and non-target organisms may be affected by their application (Waller et al. 1993). While their potential episodic use is a direct threat to YLM and macroinvertebrate populations, there is no indication that they have ever been used in Blacketts Lake, nor are they likely to be approved provincially for future use (K. Madden, NSDoE, pers. comm. 2007).

Non-native and invasive species

The introduction of non-native and invasive species poses serious threats to biodiversity, ecological function and habitat integrity in many aquatic habitats. While not explicitly identified by COSEWIC as a threat to the Sydney River population, non-native and invasive species do have the potential to negatively impact YLMs, their habitat, and their host fish if introduced.

Several species recently identified as established, or with potential for establishment, in Nova Scotia may threaten native communities, and YLMs, in the Sydney River if introduced. Information about these species is summarised in Table 2. The likelihood of establishment of these species in the Sydney River watershed is not known at this time.

Table 2: Non-native and invasive species with potential to threaten yellow lampmussels in the Sydney River watershed[1]

Species	Type	Record in N.S.	Vector	Nature of threat to YLM
Yellow floating heart (*Nymphoides peltata)*	Aquatic plant	Yes - one lake in mainland Nova Scotia * Also present in Maine.**	Residential gardens	Change water quality: may grow in dense stands which alter habitat character and create stagnant conditions
Eurasian milfoil (*Myriophyllum spicatum*)	Aquatic plant	No – present in Maine.**	Residential gardens	Change water quality: may grow in dense stands which alter habitat character and create stagnant conditions
Crayfish *(Orconectes virilis)*	Freshwater crustacean	Yes – recently documented***	Aquarium, recreational fishing bait.	Can displace native species and impact macroinvertebrate communities which are prey for host fish populations. Sandy Blacketts Lake habitat likely marginal crayfish habitat.
Chain pickerel (*Esox niger*)	Predatory freshwater fish	Yes ****	Intentional introduction as sport fish	May prey upon host fish, although they prefer soft-rayed fish
Northern pike (*Esox lucius*)	Predatory freshwater fish	Yes ****	Intentional introduction as sport fish	May prey upon host fish, although they prefer soft-rayed fish
Muskellunge (*Esox masquinongy*)	Predatory freshwater fish	No ****	Intentional introduction as sport fish	May prey upon host fish, although they prefer soft-rayed fish
Common/European carp (*Cyprinus carpio*),	Freshwater fish	No ****	Artificial ponds and water gardens; recreational fishing bait; release from aquarium trade	May disrupt the food chain and alter habitat and biotic communities
Zebra mussels (*Dreissena polymorpha*)	Freshwater mussel	No ****	Recreational boating	Will smother native mussel communities

[1] The list of species is not intended to be exhaustive; it may change with enhanced understanding of the ecology of YLM. For example, the introduction of any predatory fish could impact host species abundance through predation or competition.

* M. MacDonald, NS Museum, pers. comm. 2007).

** (www.maine.gov/dep/blwq/topic/invasives, accessed July 25, 2007)

*** Lambert et al. 2007

**** Nova Scotia Department of Fisheries and Aquaculture

Muskrat predation

Muskrats (*Ondatra zibethicus*) are the main predators of adult YLMs in the Sydney River. On Blacketts Lake, it is estimated that roughly 546 adults are eaten by muskrats annually, a relatively small number, given the estimated size of the mussel population (2.5 million). Given that muskrat and freshwater mussel populations co-exist in many areas and that muskrats prefer to eat thin-shelled mussel species (Zahner-Meike and Hanson 2001), predation is likely a minor threat to the population.

Threats to the Saint John River population

Changes to habitat and water quality

Riparian development and sedimentation in some areas of the Saint John River watershed may pose a threat to YLMs and their habitat. Erosion following deforestation or resulting from poor agricultural practices may result in increased siltation which impairs filter-feeding and respiration by bivalves, and creates unstable bottoms (Bogan 1993; Williams et al. 1993) which are unsuitable YLM habitat. Indirect protection for YLM habitat is afforded by the New Brunswick Watercourse and Wetland Alteration Regulation of the *Clean Water Act*, which requires a permit and approval by the Department of the Environment, and the Department of Natural Resources, for any alteration, including removal of trees, within 30 m of most streams.

Changes in water quality may also threaten YLM in the Saint John River. Eutrophication due to run off of agricultural chemicals and localized sewage is another ongoing threat to YLMs along the Saint John River. Increased nutrient levels can lead to blooms of algae and aquatic plants, altering overall water quality and reducing oxygen levels above the substrate which may affect mussels and their host fish. Agricultural pesticide and chemical run off may also result in kills of invertebrates and fish, and in decreased vigour or death of resident bivalve populations as they accumulate toxic substances in their tissues. The Saint John River is a multi-use water supply used as a drinking water supply, and to replenish the wellfields and aquifers supplying several communities. The River also receives point-source treated and untreated effluents along its length. Under the provisions of the New Brunswick *Clean Water Act*, water must remain potable, providing indirect protection to YLMs, their host fish and macroinvertebrate communities.

Low water levels, which may occur during the late summer, have also been identified as a problem for YLMs on the Saint John River. Yellow lampmussels have limited locomotory abilities, and probably could not relocate quickly when faced with air-exposure and increasing water temperature as the depth of overlying water decreases. Mortality was observed during

2001, a particularly dry year, possibly due to elevated water temperatures over sand bars (Sabine et al. 2004). Since this is a naturally occurring threat related to climatic events, its management may not be possible. There is little information at present on the extent of this threat.

Non-native and invasive species

The potential introduction of non-native zebra mussels has been identified as a serious threat to YLMs in the Saint John River. The introduction of zebra mussels in the Great Lakes and St. Lawrence River from the ballast water of ocean-going ships has resulted in the decline and regional extirpation of freshwater mussel populations in many lake and river systems in North America (Martel et al. 2001; Nalepa and Schloesser 1993; Ricciardi et al. 1998). Zebra mussels colonize other mussel species, preventing valve closure which exposes them to environmental extremes, and affects normal metabolic function (Mackie 1993). If accidentally introduced as fouling organisms on recreational fishing boats, anchors and gear from the St. Lawrence River or elsewhere, zebra mussels could establish and displace populations of YLMs.

While not explicitly identified by COSEWIC as a threat to the Saint John River population, muskellunge (*Esox masquinongy*), a predatory, non-native fish, may adversely affect YLM through impacts to fish abundance that can affect the entire native fish assemblage within the river including the host fish population (He and Kitchell 1990; Wynne 1995; Curry et al. 2007). Muskellunge is currently found in the Saint John River and was first recorded at the Mactaquac dam in 1988 (Stocek et al. 1999). Although there is a breeding population of muskellunge in the Woodstock/Florenceville area above the dam, the breeding status of muskellunge in the Saint John River below the Mactaquac dam, where YLM is found, is unclear (Curry et al. 2007). If new occurrences of YLM were found in the area above the dam, the larval host fish could be at risk. Muskellunge caught by DFO at the Mactaquac Dam are destroyed, and the province of NB has maintained high catch and bag limits for the species (daily bag and possession limit of 10 fish). However, there is pressure from local angling groups to stop this practice, and to promote catch and release for trophy-sized fish.

Both smallmouth bass (*Micropterus dolomieu*) and chain pickerel (*Esox niger*), two non-native and invasive species, have been present in the Saint John River system since the 1800's and are well established in some areas for well over 100 years, primarily southwestern New Brunswick / lower Saint John watershed (DFO 2009; NBDNR, pers. comm.). Although YLMs may have adapted to the presence of these species in the watershed, anything that might enhance the populations of these non-native species, to the point of them actively selecting larval host fish as prey because their regular prey base is inadequate, would potentially be of concern.

Table 3: Non-native and invasive species with potential to threaten yellow lampmussels in the Saint John River watershed[1]

Species	Type	Record in N.B.	Vector	Nature of threat to YLM
Muskellunge (*Esox masquinongy*)	Predatory freshwater fish	Yes, currently in the Saint-John River both above and below the Mactaquac dam	Intentional introduction as sport fish	May prey upon host fish, although they prefer soft-rayed fish
Zebra mussels (*Dreissena polymorpha*)	Freshwater mussel	No	Recreational boating	Will smother native mussel communities
Chain pickerel (*Esox niger*)	Predatory freshwater fish	Yes *	Intentional introduction as sport fish	May prey upon host fish, although they prefer soft-rayed fish
Smallmouth bass (*Micropterus dolomieu*)	Predatory freshwater fish	Yes *	Intentional introduction as sport fish	May prey upon host fish if their regular prey base becomes inadequate

* New Brunswick Department of Natural Resources

1.6. Actions Already Completed or Underway

1.6.1. Protection and management

The federal *Fisheries Act* (1985) and its Regulations, administered by DFO, provides protection for freshwater mussels (shellfish) and their host fish. The *Act* prohibits the killing of fish (which includes shellfish) by means other than fishing (Section 32), and also prohibits activities that result in the harmful alteration, disruption or destruction of fish habitat (Section 35). Section 36(3) of the *Act*, administered by Environment Canada, prohibits the deposition of deleterious substances into waters frequented by fish.

Provincial legislation and regulations provide additional protection for YLMs and their habitat.

In Nova Scotia:
In Nova Scotia, the YLM is listed as threatened under the Department of Natural Resources *Endangered Species Act*, 1998. Other Acts and associated Regulations provide water quality and habitat protection for the species as follows:

- The *Environment Act* 1994-5, (Department of the Environment) which prohibits the release of substances into water that may cause adverse effects:
  - Pesticide Regulations, require approval and permitting for any pesticide treatments to a water body, or in watersheds where pesticides may enter waterbodies through run-off;
  - On-site Sewage Disposal System Regulations govern the construction, maintenance and operation of sewage systems; and
  - Quality of potable water is ensured under the Water and Wastewater Facilities and Drinking Water Supplies.

- The Wildlife Habitat and Watercourses Protection Regulation of the *Forest Act*, 1989, administered by the Department of Natural Resources, requires the creation of special management zones (SMZs) within 20 m of all bodies of water exceeding 50 cm in diameter, and prohibits or restricts tree-cutting and clearing, and activities resulting in deposition of silt or soil in a waterbody.

In New Brunswick:

- Several Regulations of the *Clean Water Act*, administered by the Department of the Environment provide indirect protection for YLMs:
    - The Potable Water Regulations and Watercourse Setback Designation Order provide protection of water used as drinking water supplies; and
    - The Watercourse Alteration Regulation protects the banks and beds of watercourses by requiring permits for activities that would unduly affect the function of a watercourse (such as the disturbance of soil or trees within 30 m of a watercourse). All applications for permits are reviewed by the NB Departments of the Environment and Natural Resources, and DFO.
- The *Pesticides Control Act* requires that a Pesticide Use Permit must be obtained before anyone can apply a pesticide (including aerial application).

1.6.2 Research, monitoring and assessment

The Atlantic Coastal Action Program Cape Breton (ACAP-CB) 2001 Science Linkage project addressed vital information gaps identified in the 2001 COSEWIC Status Report. In 2002, a long-term community based monitoring program aimed at detecting fluctuations in the population and identifying habitat threats was initiated. An education campaign and the development of training materials were part of this project. The project also provided information on YLM life history traits, population distribution and density estimates in the Sydney River watershed (White 2003).

Surveys to determine the presence of YLMs in the Saint John River and its tributaries were conducted in 2001 and 2002 at 180 sites (Sabine et al. 2004).

1.6.3 Stewardship, outreach and communication

Since 2000, the ACAP-CB has been actively involved in raising awareness of, and providing information about threats to, the YLM population in the Sydney River. With funding support from the Habitat Stewardship Program, this group has continued its YLM education activities by conducting workshops and school presentations, producing and delivering over 2,000 resident handbooks, and organizing riparian tree planting by community volunteers since the summer of 2005. The resident handbooks give information on best practises for maintaining water and habitat quality in the Sydney River watershed through the use of natural pesticides, proper well and septic system maintenance and the creation of riparian buffer zones. The group will include information on non-native and invasive species, such as zebra mussels, in its 2008 resident handbook and community presentations. This group has an established relationship with local residents, with potential to pro-actively educate these stakeholders on the threats posed by other non-native species, which are at low risk of introduction at present. ACAP-CB is also well

placed to inform the general public of the threat posed by molluscicide application in Blacketts Lake.

The Department of National Defence, Canadian Forces Base, Gagetown, New Brunswick hosted a YLM identification course for all personnel including DFO and NBDoE regional staff in November of 2008.

The Nova Scotia Department of Fisheries and Aquaculture focuses on the aquatic invasive species issue through public distribution of the following materials:

- A brochure entitled *Information for Boaters*, which highlights seven invasive marine and freshwater species in Nova Scotia. It includes a Boater's Checklist, and information on an invasive species hotline operated by the Ontario Federation of Anglers and Hunters and the Ontario Ministry of Natural Resources; and
- *Nova Scotia Angler's Handbook*, which contains a section on Introduced Species, and information on cleaning boats and equipment to limit their spread.

The zebra mussel is a potentially serious threat to the native mussel population in New Brunswick. Numerous publications concerning invasive species in NB are available to the public, including:

- *Fish 2008*, the New Brunswick Fishing Guide, is given to everyone applying for an angling license in the province; inside the guide there is a one page section on the zebra mussel, the threat it poses to river systems, and what can be done to minimize its' intrusion;
- "An invasive species program for New Brunswick", coordinated by the Fisheries Program of the New Brunswick Department of Natural Resources (NBDNR), is a public education campaign to inform recreational boaters and anglers of potential invasive species and how to prevent their spread. The zebra mussel is one of the species included in the campaign. The campaign was launched in the spring of 2009.
- A brochure on the New Brunswick government website providing information on invasive species (http://www.gnb.ca/0254/pdf/2986nativefishbrochure-e.pdf); and
- An invasive species guide published by ACAP-Saint John and available online (http://www.acapsj.com/Current_Projects.html), developed as part of a project using community participation to digitize and map the distribution and abundance of invasive species.

1.7 Knowledge Gaps

Knowledge gaps identified by COSEWIC (2004) and during the development of this Management Plan are given below in order of priority.

1.7.1 Population estimates and trends

Due to their spatial aggregation and challenging field conditions, it is difficult to accurately estimate the population size and trends of YLM populations. There is currently no accurate population estimate for either the Sydney River or the Saint John River population.

1.7.2 Distribution outside current known range

The current status of the YLM in Quebec remains uncertain and is in need of investigation. A historic record from the Saint Francois River, near Drummondville, in 1952, cannot be confirmed as the specimen is missing. Given the presence of YLM populations in Maine (Williams et al. 1993) and upstate New York (Strayer and Fetterman 1999; Strayer and Jirka 1997), it is possible that additional populations exist.

The species may also occur in other rivers in Nova Scotia, although this is unlikely (M. Elderkin, per. comm. 2007), and in New Brunswick. In New Brunswick, limited surveys have occurred in the upper Saint John River above the Mactaquac dam without success. Potential suitable habitat does exist in the river, however, and the larval host fish species are present both above and below the dam (Sabine et al. 2004). Additional work on the section of river above the Mactaquac dam, and other rivers in New Brunswick is required to more accurately describe the distribution of the species in the province.

1.7.3 Extent of risk posed by threats

The extent of risk posed by the following threats to YLMs and their habitats is unknown at this time:

- muskrat predation in Blacketts Lake;
- muskellunge and other fish predation on host fish in the Saint John River;
- potential predator-prey and host-parasite relationships with Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) and shortnose sturgeon (*Acipenser brevirostrum)* in the Saint John River; and
- seasonal low-water levels in the Saint John River.

1.7.4 Knowledge of basic biology

Several aspects of YLM biology remain largely unstudied:

- identification of host fish in the Saint John River (not known with certainty);
- age of sexual maturity (both populations);
- exact timing of fertilization and glochidial release (both populations); and
- period of gravidity of the New Brunswick population.

2. MANAGEMENT

2.1. Goal

The goal of this management plan is to:

maintain the existing yellow lampmussel populations in Canada.

The geographic scale for managing the species is within the Sydney River, NS and Saint John River, NB systems. Maintaining the distribution of YLM is a key component for management, therefore, should naturally occurring populations be found elsewhere, the goal will be to maintain those populations as well. There is no current need to provide for the expansion of YLM's range in Canada.

A numerical population goal cannot be established at this time because there are no accurate abundance estimates for either the NS or the NB population. Population goals may be defined once the population size for the two provinces is determined. There is currently no evidence to suggest historic changes in abundance of the YLM in Canada.

2.2. Objectives

The following objectives and strategies will help to maintain the existing YLM population in Canada. An objective is an accomplishment in support of the overall Management Plan goal, while a strategy is a plan which, if accomplished, will contribute to meeting the objective. Actions, or specific tasks or steps taken to implement a strategy, are outlined and discussed in Section 2.3.

Objective 1 (O1): *Maintain current quality and quantity of known YLM habitat*

Strategies:

S1. Reduce threats to YLM habitat
   a. Maintain current levels of water quality at all known sites
   b. Monitor water quality conditions at known sites
   c. Meet with, and disseminate information to water quality and aquatic habitat regulators to ensure that they are informed about YLM presence and its water quality needs and sensitivities
   d. Inform and encourage stakeholders to implement water quality best practices
   e. Prevent or reduce activities which result in shoreline degradation, habitat alteration, and sedimentation
   f. Determine risk posed by low-water levels in the Saint John River and Sydney River
   g. Enforce existing riparian zone protection regulations

Objective 2 (O2): R*educe direct threats to YLM populations*

Strategies:

S1. Determine level of risk and reduce direct threats to YLM populations
   a. Discourage the use of molluscicides in Blacketts Lake
   b. Determine level of risk posed by muskrat predators on Sydney River population
   c. Prevent the introduction of zebra mussels

Objective 3 (O3): *Improve our understanding of YLM populations in New Brunswick and Nova Scotia*

Strategies:

S1. Gain a better understanding of YLM population size, population dynamics, and distribution
   a. Develop and implement a long-term monitoring protocol for all existing populations to gather abundance and trend information
   b. Develop and implement a survey protocol to look for new occurrences of YLM in suitable habitat
   c. Gather information on habitat and biology which is necessary to assist activities in (a) and (b)

S2. Gain a better understanding of the interactions between YLM populations and other native fish species in the watershed
   a. Determine potential interactions with Atlantic sturgeon and shortnose sturgeon in the Saint John River.

Objective 4 (O4): *Maintain existing host fish populations*

Strategies:

S1. Identify and gather information on host fish species in NB and NS
S2. Assess and reduce potential threats to host fish populations, including potential negative impacts from non-native and invasive species

Objective 5 (O5): *Increase public awareness and involvement in YLM conservation efforts*

Strategies:

S1. Encourage education and communication programs with stakeholders and the general public that:
   a. Raise awareness of the presence of YLMs in the Saint John and Sydney rivers and conservation efforts under the *Species at Risk Act*
   b. Raise awareness of the effects of non-native and invasive species on

YLM and other species at risk

c. Raise the importance of maintaining biodiversity and the functional components of existing habitats for YLMs and other native species
d. Raise awareness of existing federal and provincial regulations which protect YLM habitat
e. Raise awareness on issues pertaining to riparian zone degradation and the potential for sediment deposition in the lower Saint John River watershed

S2. Adopt and/or develop tools and approaches which reduce the risk of non-native and invasive species introductions

2.3 Actions

The following non-prioritized list identifies specific actions that are recommended to implement the strategies identified to achieve the five objectives outlined in this Management Plan. Some of these actions are ongoing initiatives, as outlined in Section 1.6 above. Actions are outlined in five categories: Protection, Management, Research, Monitoring and Assessment and Outreach and Communication. The corresponding Objective and Strategy is indicated, in abbreviated form, for each action (eg. O5, S2 refers to Objective 5, Strategy 2).

2.3.1 Protection

Protection will be achieved through compliance with Acts and Regulations (see Section 1.6.1) that afford protection for YLM populations, their habitat and associated water quality, and their host fish. Communication, cooperation and coordination among all jurisdictions involved in the permitting review and approvals processes for impacting activities will be necessary to achieve success. Information on known population locations and sizes should be disseminated to DFO Oceans, Habitat and Species at Risk Regional and Area staff, and Provincial Environment, Natural Resources and Fisheries Departments in both NS and NB, and specifically directed to professionals involved in project and permit application reviews. This is particularly important in the Sydney River Watershed, should its use as a backup drinking water supply be discontinued in the future. With the potential identification of new populations in NB, this information must be made available to relevant Departments.

Meet with, and disseminate information to:

1. Water quality regulators to ensure that they are informed about YLM presence and its water quality needs and sensitivities (O1, S1)
2. Aquatic habitat regulators to ensure that they are informed about YLM presence and its habitat needs (O1, S1)
3. Operators of the Sydney River Dam (NSLC) to ensure that they are informed about YLM presence and its habitat and water quality needs (O1, S1)
4. Stakeholders and the general public to raise awareness on issues pertaining to riparian zone degradation in the lower Saint John River (O1, S1)

2.3.2 Management

Actions to manage threats to existing YLM populations, and preserve those populations, include:

5. Encourage stakeholders to implement water quality best practises (O1, S1)
6. Encourage stakeholders to implement best practises to reduce impacts to aquatic habitat (O1, S1)
7. Discourage use of molluscicides in Blacketts Lake (O2, S1)
8. Meet with and/or disseminate information to jurisdictions involved in fish management to ensure that they are informed about YLM and the needs of its host fish (O4, S2)
9. Support existing programs that reduce the risk of non-native and invasive species introductions (O2, S1; O4, S2)

2.3.3 Research

The following research actions are needed to fill knowledge gaps in YLM biology, and determine the extent and nature of direct threats to YLM populations:

10. Initiate studies to evaluate potential risk posed to YLM habitat in the Sydney River and Saint John River by recurrent seasonal low-water levels (O1, S1)
11. Initiate research to provide more information about reproductive issues and longevity (O3, S1), such as:
    - Age at sexual maturity and longevity
    - Timing of fertilization and glochidial release
    - Period of gravidity in NS (confirm) and NB (determine)
12. Initiate research to determine host fish species in NB and determine additional host fish species in NS (including banded killifish) (O4, S1)
13. Determine the effect of muskellunge and other non-native invasive species on fish assemblage in the Saint John River (O4, S2)
14. Determine potential predator-prey and host-parasite interactions with Atlantic and shortnose sturgeon in the Saint John River (O3, S2)

2.3.4 Monitoring and assessment

Habitat and population surveys should be undertaken, using reliable methods and established protocols, by experienced biologists. The use of trained volunteers in this work represents an important stewardship opportunity. Monitoring of changes in the YLM population, and existing and potential threats, should be conducted every 5-10 years by either trained volunteers or experienced biologists. Habitat and occurrence data might also be gathered opportunistically as part of existing management programs or stewardship initiatives.

Surveys should be conducted to determine:

15. Locations of suitable habitat quality (including substrate conditions, water quality and salt water intrusion) and quantity (area within a watershed or body of water) in NB (above the Mactaquac Dam) and NS (O3, S1)
16. New occurrences in potential YLM habitat in NB and NS (O3, S1)
17. More precise YLM population estimates for NB and NS populations (O3, S1)
18. Short-term fluctuations in size and distribution of YLM populations (O3, S1)
19. Abundance and health of host fish populations (O4, S1)
20. Threats to host fish populations (O4, S2)

Monitoring programs should be initiated, established and supported to assess:

21. YLM population dynamics at 5-10 yr. intervals (O3, S1)
22. Level of risk posed by muskrat predation on Sydney River YLM population (monitoring shell middens) (O2, S1)
23. Threats to YLM habitat (O1, S1) at 5-10 yr. intervals

2.3.5 Outreach and communication

Community education and awareness programs that provide members of the public, local residents and stakeholders with the information, skills and tools to reduce and mitigate threats to YLM populations and their habitats are crucial to the conservation and management of the two known populations. Public awareness campaigns for the zebra mussel, and for non-native and invasive species in general should at a minimum be maintained at current levels. Expansion of these efforts by local conservation, environmental and angling groups will ensure a pro-active and precautionary approach that may lower the potential risk of introduction.

Outreach and communications actions in support of the Goal of this Management Plan are:

24. Support education programs and stewardship initiatives in the Sydney River watershed (O5, S1)
25. Encourage and support the development and implementation of education, outreach and stewardship initiatives in areas of YLM occurrence in the Saint John River watershed (O5, S1)
26. Provide information on zebra mussels and other invasive species to stakeholders in the Sydney River and Saint John River watershed (O5, S1)

3. PROPOSED IMPLEMENTATION SCHEDULE

Fisheries & Oceans Canada encourages other agencies and organizations to participate in the conservation of the Yellow lamp mussel through the implementation of this management plan. Fisheries and Oceans Canada is committed to implementing actions identified in this Management Plan in partnership with organizations and sectors listed in Table 4. Tables 5 and 6

summarize those actions that are recommended to support the management goals and objectives. The activities implemented by Fisheries & Oceans Canada will be subject to the availability of funding and other required resources. Where appropriate, partnerships with specific organizations and sectors will provide the necessary expertise and capacity to carry out the listed action. However, this identification is intended to be advice to other agencies, and carrying out these actions will be subject to each agency's priorities and budgetary constraints.

Table 4. Organizations with whom the Fisheries and Oceans Canada will work in partnership, where and when appropriate, to accomplish the actions outlined in this Management Plan:

Organization	Acronym
Atlantic Coastal Action Program – Cape Breton	ACAP-CB
Atlantic Coastal Action Program – Saint John	ACAP-SJ
Cape Breton Regional Municipality	CBRM
Cape Breton University	CBU
Environment Canada	EC
Environmental non-government organizations	ENGOs
New Brunswick Department of Natural Resources	NBDNR
New Brunswick Department of the Environment	NBDoE
New Brunswick Museum	NBM
Nova Scotia Department of the Environment	NSDoE
Nova Scotia Department of Fisheries and Aquaculture	NSDFA
Nova Scotia Department of Natural Resources	NSDNR
Nova Scotia Lands Corporation	NSLC
Nova Scotia Museum	NSM
Post-secondary institutions	Academia
University of New Brunswick – Canadian Rivers Institute	UNB-CRI

Table 5. Implementation Schedule, Sydney River, NS

Action	Priority	Threats or concerns addressed	Participating Agencies	Timeline
Objective 1: Maintain current quality and quantity of known YLM habitat				
Action 1: Inform water quality regulators (NSDoE, CBRM, EC) about YLM presence, needs and sensitivities	High	Industrial pollution Degradation of water quality through nutrient enrichment	DFO ACAP-CB	Ongoing
Action 2. Inform aquatic habitat regulators (NSDoE, NSDNR, DFO, NSDFA, CBRM) about YLM presence and its habitat needs	High	Habitat degradation through development and construction activities Sedimentation Removal of riparian vegetation	DFO ACAP-CB	Ongoing
Action 3. Inform operators of Sydney River Dam about YLM presence and habitat needs	High	Breach of Sydney River Dam Reduction in habitat above dam Salt water intrusion above dam	DFO ACAP-CB	Ongoing
Action 5. Encourage stakeholders to implement water quality best practices	High	Deterioration of water quality through household chemical and sewage inputs Reduced oxygen content	ACAP-CB DFO NSDoE	Ongoing
Action 6. Encourage stakeholders to implement best practices to reduce impacts to aquatic habitat	High	Habitat degradation via construction and maintenance activities: Sedimentation and Removal of riparian vegetation	ACAP-CB DFO NSDoE	Ongoing
Action 10: Initiate studies to evaluate risk from seasonal low-water levels in YLM habitat	Low	Reduction in extent of habitat due to air exposure and increase in water temperature	ACAP-CB Academia	2010-2012
Action 23: Initiate monitoring programs to assess threats to YLM habitat at 5-10 yr. intervals	Low	Monitoring of current or emergent habitat threats	ACAP-CB NSDNR	2012
Objective 2: Reduce direct threats to YLM populations				
Action 7: Contact NSDoE to discourage use of molluscicides in Blacketts Lake	High	Accidental mortality from direct exposure to non-species specific pesticide	DFO ACAP-CB	

Table 5. Implementation Schedule, Sydney River, NS

Action	Priority	Threats or concerns addressed	Participating Agencies	Timeline
Action 9: Support existing programs that reduce the risk of non-native and invasive species introductions	High	Potential threat of introduction of zebra mussels Potential loss of habitat, biodiversity and community structure through establishment of non-native and invasive species	DFO ACAP-CB CBU NSDNR NSDoE NSDAF	Ongoing 2008-2012
Action 21: Determine level of risk posed by muskrat predation by monitoring shell middens	Low	Knowledge of importance of threat posed by muskrat predation	ACAP-CB Academia	2011-2012
Objective 3: Improve our understanding of YLM populations in New Brunswick and Nova Scotia				
Action 11: Initiate research to determine longevity, age at sexual maturity, timing of fertilization and glochidial release and confirm period of gravidity	Moderate -Low	Lack of knowledge about biology and reproduction of YLM	Academia NSDNR	2009-2013
Action 15: Conduct surveys to determine location of suitable habitat in NS	Moderate -Low	Sites of potential new occurrences known	NSDNR NSM	2010-2012
Action 16: Conduct surveys to determine new occurrence in potential YLM habitat in NS	Moderate -Low	Knowledge of distribution in NS	NSDNR NSM	2010-2012
Action 17: Conduct surveys to determine more precise YLM population estimates for NS	Moderate -Low	More accurate estimate of size of NS YLM population	NSDNR NSM	2010-2012
Action 18: Conduct surveys to determine short-term fluctuations in size and distribution of population	Moderate -Low	Lack of knowledge about spatial and temporal fluctuations in Sydney River population	ACAP-CB NSDAF NSDNR	Ongoing 2008-2010
Action 21: Monitor YLM population dynamics at 5-10 yr. intervals	Moderate -Low	Lack of knowledge about population fluctuations	ACAP-CB NSDNR	2012

Table 5. Implementation Schedule, Sydney River, NS

Action	Priority	Threats or concerns addressed	Participating Agencies	Timeline
Objective 4: Maintain existing host fish populations				
Action 8: Inform jurisdictions involved in fish management about YLM and needs of host fish	Moderate	Direct threats to host fish species Health of host fish populations	DFO ACAP-CB NSDAF	2009-2012
Action 9: Support existing programs that reduce the risk of non-native and invasive species introductions	High	Potential loss of habitat, biodiversity and community structure through establishment of non-native and invasive species	DFO ACAP-CB, CBU, NSDNR, NSDoE, NSDAF	Ongoing 2008-2012
Action 12: Initiate research to determine existence of additional host fish species	Low	Knowledge of potential host fish species	ACAP-CB CBU Academia	2009-2010
Action 19: Initiate surveys to determine abundance and health of host fish populations	Moderate	Size of host fish populations Health of host fish populations	NSDAF Academia	2010-2012
Action 20: Initiate surveys to determine threats to host fish populations	High	Threats to host fish	NSDAF Academia	Ongoing 2009-2011
Objective 5: Increase public awaremess amd involvement in YLM conservation efforts				
Action 24: Support existing education programs and stewardship initiatives led by ACAP-CB	High	Stewardship of YLM, its host fish and its habitat Water and habitat quality	DFO NSDAF, NSDNR, NSDoE	Ongoing 2008-2012
Action 26: Provide information on zebra mussels and other invasive species to stakeholders and residents	High	Introduction of zebra mussels and other invasive and non-native species	DFO CBU, ACAP-CB, NSDAF, NSDNR	Ongoing

Table 6. Implementation Schedule, Saint John River, NB

Action	Priority	Threats or concerns addressed	Participating Agencies	Timeline
Objective 1: Maintain current quality and quantity of known YLM habitat				
Action 1: Inform water quality	High	Industrial pollution	DFO	Ongoing

Table 6. Implementation Schedule, Saint John River, NB

Action	Priority	Threats or concerns addressed	Participating Agencies	Timeline
regulators (NBDoE, Local Municipalities) about YLM presence, needs and sensitivities		Agricultural Pollution Degradation of water quality through nutrient enrichment	ACAP-SJ ENGO's	
Action 2: Inform aquatic habitat regulators (NBDoE, NBDNR) about YLM presence and habitat needs	High	Habitat degradation through development and construction activities Sedimentation Removal of riparian vegetation	DFO ACAP-SJ ENGO's NBDNR	Ongoing
Action 4: Inform stakeholders and the general public to raise awareness on issues pertaining to riparian zone degradation	Moderate	Potential for sediment deposition in the watershed which could result in direct habitat loss and indirect loss through establishment of aquatic plants	DFO ACAP-SJ ENGO's	Ongoing 2008-2012
Action 5: Encourage stakeholders to implement water quality best practices	High	Deterioration of water quality through household chemical and sewage inputs Reduced oxygen content	ACAP-SJ ENGO's DFO NBDoE	Ongoing 2008-2012
Action 6: Encourage stakeholders to implement best practices to reduce impacts to aquatic habitat	High	Habitat degradation through construction,property maintenance and agricultural activities Sedimentation Removal of riparian vegetation	ACAP-SJ ENGO's DFO NBDoE	Ongoing 2008-2012
Action 10: Initiate studies to evaluate risk from seasonal low-water levels in YLM habitat	Low	Reduction in extent of habitat due to air exposure and increase in water temperature	Academia	2010-2012
Action 23: Initiate monitoring programs to assess threats to YLM habitat at 5-10 yr. intervals	Low	Monitoring of current or emergent habitat threats	ACAP-SJ NBDNR	2012

Table 6. Implementation Schedule, Saint John River, NB

Action	Priority	Threats or concerns addressed	Participating Agencies	Timeline
Objective 2: Reduce direct threats to YLM populations				
Action 9: Support existing programs that reduce the risk of non-native and invasive species introductions	High	Potential threat of introduction of zebra mussels Potential loss of habitat, biodiversity and community structure through establishment of non-native and invasive species	DFO ACAP-SJ NBDNR NBDoE	Ongoing 2008-2012
Objective 3: Improve our understanding of YLM populations in New Brunswick and Nova Scotia				
Action 11: Initiate research to determine longevity, age at sexual maturity, timing of fertilization and glochidial release and period of gravidity	Moderate -Low	Lack of knowledge about biology and reproduction of YLM	UNB-CRI NBDNR NBM	2009-2013
Action 14: Determine potential interactions with Atlantic and shortnose sturgeon	Moderate -Low	Lack of knowledge on potential interactions between YLMs and sturgeons	UNB-CRI NBDNR	2010-2012
Action 15: Identify suitable habitat for surveys of potential new occurrences in NB	Moderate -Low	Sites of new potential occurrences known	NBDNR NBM	2010-2012
Action 16: Conduct surveys for potential new occurrences in previously-identified suitable habitat in NB	Moderate - Low	Knowledge of distribution in NB	NBDNR NBM	2010-2012
Action 17: Conduct surveys to determine more precise YLM population estimates for NB	Moderate - Low	More accurate estimate of size of NB YLM population	NBDNR NBM	2010-2012
Action 21: Develop and implement a monitoring protocol to determine YLM population dynamics at 5-10 yr. intervals	Moderate -Low	Lack of knowledge about population fluctuations	ACAP-SJ ENGO's NBDNR	2012

Table 6. Implementation Schedule, Saint John River, NB

Action	Priority	Threats or concerns addressed	Participating Agencies	Timeline
Objective 4: Maintain existing host fish populations				
Action 8: Inform jurisdiction (NBDNR) involved in fish management about YLM and needs of host fish	Moderate	Direct threats to host fish Health of host fish populations	DFO ENGO's	Ongoing
Action 9: Support existing programs that reduce the risk of non-native and invasive species introductions	High	Threats to host fish Potential loss of habitat, biodiversity and community structure through establishment of non-native and invasive species	DFO ACAP-SJ ENGO's NBDNR NBDoE	Ongoing 2008-2012
Action 12: Initiate research to determine additional host fish species and potential predators to these host fish species	Moderate	Knowledge of potential host and host predator fish species	NBDNR	2011-2012
Action 13: Determine the effect of non-native and invasive species (e.g., muskellunge, smallmouth bass, chain pickerel) on fish assemblage	Moderate	Knowledge of extent of potential threat posed by non-native and invasive species on YLM host fish	NBDNR DFO	2009-2011
Action 19: Initiate surveys to determine abundance and health of host fish populations	Moderate	Size of host fish populations Health of host fish populations	NBDNR UNB - CRI	2010-2012
Action 20: Initiate surveys to determine threats to host fish populations	Moderate	Threats to host fish	NBDNR UNB - CRI	2009-2011
Objective 5: Increase public awareness and involvement in YLM conservation efforts				
Action 25: Encourage and support development and implementation of education, outreach and stewardship initiatives in SJR watershed	High	Stewardship of YLM, its host fish and its habitat Water and habitat quality	DFO NBDNR NBDoE ENGO's	Ongoing 2008-2012
Action 26: Provide information on zebra mussels and other invasive species to stakeholders and residents in SJR watershed	High	Introduction of zebra mussels and other invasive and non-native species	DFO ACAP-SJ NBDNR ENGO's	Ongoing

4.0 ASSOCIATED PLANS

The following recovery plans for freshwater mussel populations in Canada identify similar threats and/or contain similar recovery actions and recommendations for mitigation of threats or potential research activities as identified in this Management Plan.

- Morris, T.J. 2006. Recovery strategy for the Wavyrayed Lampmussel (*Lampsilis fasciola*) in Canada. Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa, viii + 43 pp.
- Morris, T.J. and M. Burridge. 2006 Recovery strategy for Northern Riffleshell, Snuffbox, Round Pigtoe, Mudpuppy Mussel and Rayed Bean in Canada. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa, x + 76 pp.
- Lepitzki, D.A.W. and C. Pacas. 2007. Recovery strategy and action plan for the Banff Springs Snail (*Physella johnsoni*), in Canada. *Species at Risk Act* Recovery Strategy Series. Parks Canada Agency, Ottawa, 61 pp.
- Fisheries and Oceans (DFO). 2007. Recovery strategy for the Dwarf Wedgemussel (*Alasmidonta heterodonta*) in Canada. *Species at Risk Act* Recovery Strategy Series. Department of Fisheries and Oceans, Ottawa. vi + 9 pp.

A SARA Management Plan for the shortnose sturgeon, a species listed as Special Concern under the *Act*, will need to consider potential interactions with the yellow lampmussel once accomplished.

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APPENDIX 1. GLOSSARY[2]

Bivalve: a mollusk with a shell that consists of two symmetrical valves

Glochidia (um): bivalved larval stage of freshwater mussels, generally parasitic on a fish host; analogous to free living veliger stage in other bivalves

Mantle: a tissue lining the inside of a mussel shell that encloses the viscera and secretes new shell material from its edges for continued shell growth

Marsupium: vertically partitioned interlamellar gill space of female mussels that contains glocihidia (larvae); brood pouch or gill pouch

Nacre: the inner-most layer of shell that often has a pearl-like appearance

Periostracum: the outside layer or covering of the shell

Ray: a linear color marking, usually green, which appears on the outer surface (periostracum) of some mussel species

[2] All glossary terms of taken from the United States Fish and Wildlife Service: http://www.fws.gov/midwest/mussel/glossary.html accessed Feb 19, 2007; Illinois State Museum 2006. http://www.museum.state.il.us/ismdepts/zoology/mussels/mussel_glossary.html accessed Feb 19, 2007; and New York Metropolitan Region and New Jersey Freshwater Mussel Identification Handbook: http://cbc.amnh.org/mussel/glossarypageframeset.html accessed Feb 19, 2007.

APPENDIX 2. RECORD OF COOPERATION AND CONSULTATION

The management plan for yellow lampmussel in Canada was developed through the cooperative efforts of Fisheries and Oceans Canada, the New Brunswick Department of Natural Resources, the Nova Scotia Department of Fisheries and Aquaculture and the Nova Scotia Department of Natural Resources. Earlier drafts were circulated for input by the various individuals identified in the Acknowledgments section.

The management plan was also reviewed by various DFO sectors in Maritimes Region, DFO Gulf Region as well as by DFO representatives in the National Capital Region. All comments received during this level of review were considered.

Engagement and confirmation of the various organizations and agencies ability and willingness to participate in the implementation of the actions to which they are identified as a potential partner in the Implementation Schedule was sought.

The proposed management plan was also circulated to relevant First Nations and Aboriginal communities to seek additional input. No comments were received during this review.

Comments received on the proposed management plan during the 60-day public registry comment period (November 3, 2009 to January 2, 2010) were incorporated in the final version of the document.

APPENDIX 3. THREAT CLASSIFICATION TABLE- SYDNEY RIVER (SR) POPULATION

1 Sedimentation resulting from shoreline alteration		Threat Information		
Threat Category	Habitat Loss or Degradation	**Extent**	Widespread (SR watershed)	
			Local	**Range-wide**
General Threat	Construction and property maintenance, clearing of riparian vegetation	**Occurrence**		Current
		Frequency		Continuous
Specific Threat	Increased siltation, loss of benthic habitat	**Causal Certainty**		High
		Severity		Moderate
Stress	Physiological changes, reduced population viability, increased mortality	**Level of Concern**	Moderate	

2 Industrial spills and inputs		Threat Information		
Threat Category	Pollution, Degradation of Water Quality, Habitat Degradation	**Extent**	Localized (below SR dam)	
			Local	**Range-wide**
General Threat	Industrial chemicals and compounds, gasoline and oil	**Occurrence**	Current	
		Frequency	Continuous	
Specific Threat	Direct exposure to toxic chemicals and compounds, accumulation of toxins in sediments	**Causal Certainty**	Moderate-High	
		Severity	Moderate	
Stress	Physiological changes, reduced population viability, increased mortality	**Level of Concern**	Moderate	

3 Household chemical inputs		Threat Information		
Threat Category	Pollution, Degradation of Water Quality, Habitat Degradation	**Extent**	Widespread (SR watershed)	
			Local	**Range-wide**
General Threat	Garden and household chemicals and compounds	**Occurrence**		Current
		Frequency		Continuous
Specific Threat	Nutrient enrichment, direct exposure to toxic chemicals and compounds	**Causal Certainty**		Moderate-High
		Severity		Moderate
Stress	Physiological changes, reduced population viability, increased mortality	**Level of Concern**	Moderate	

4	Sewage inputs	Threat Information		
Threat Category	Pollution , Degradation of Water Quality, Habitat Degradation	**Extent**	Widespread (SR watershed)	
			Local	**Range-wide**
General Threat	Organic and biological inputs	**Occurrence**		Current
		Frequency		Continuous
Specific Threat	Nutrient enrichment, reduced aquatic oxygen concentrations	**Causal Certainty**		Moderate-High
		Severity		Moderate
Stress	Physiological changes, reduced population viability, increased mortality	**Level of Concern**	Moderate	

5	Introduction of invasive zebra mussels	Threat Information		
Threat Category	Non-native and Invasive Species	**Extent**	Widespread (SR watershed)	
			Local	**Range-wide**
General Threat	Zebra mussels	**Occurrence**		Potential
		Frequency		Recurrent
Specific Threat	Resource competition, displacement of native populations	**Causal Certainty**		High
		Severity		High
Stress	Physiological change, increased mortality, local extinctions	**Level of Concern**	Moderate	

6	Introduction of non-native plants and animals	Threat Information		
Threat Category	Non-native and Invasive Species	**Extent**	Widespread (SR watershed)	
			Local	**Range-wide**
General Threat	Fish , crayfish, plants	**Occurrence**		Potential
		Frequency		Recurrent
Specific Threat	Resource competition, habitat alteration, displacement of native populations	**Causal Certainty**		Moderate
		Severity		Low
Stress	Physiological changes, local extinctions	**Level of Concern**	Low	

7 Breach of Sydney River Dam		Threat Information		
Threat Category	Habitat Loss or Degradation	**Extent**	Localized	
			Local	**Range-wide**
General Threat	Damage or deterioration of dam	**Occurrence**	Potential	
		Frequency	One-time	
Specific Threat	Drop in water levels above dam, intrusion of salt water above dam	**Causal Certainty**	Low	
		Severity	Moderate	
Stress	Physiological changes, increased mortality	**Level of Concern**	Low	

8 Low water levels		Threat Information		
Threat Category	Natural Processes	**Extent**	Unknown	
			Local	**Range-wide**
General Threat	Seasonal drop in water levels	**Occurrence**	Potential	Potential
		Frequency	Seasonal	Seasonal
Specific Threat	Elevated water temperatures, exposure	**Causal Certainty**	Unknown	Unknown
		Severity	Unknown	Unknown
Stress	Physiological changes	**Level of Concern**	Low	

9. Use of molluscicides		Threat Information		
Threat Category	Accidental Mortality	**Extent**	Localized (Blacketts Lake)	
			Local	**Range-wide**
General Threat	Pest control of freshwater snails	**Occurrence**	Potential	
		Frequency	One-time	
Specific Threat	Direct exposure, altered benthic community and food web	**Causal Certainty**	Moderate	
		Severity	Moderate	
Stress	Physiological changes, local extinctions, increased mortality	**Level of Concern**	Low	

10. Muskrat predation		Threat Information		
Threat Category	Natural processes	**Extent**	Localized (above dam)	
			Local	**Range-wide**
General Threat	Muskrats	**Occurrence**	Current	
		Frequency	Continuous	
Specific Threat	Predation on existing population	**Causal Certainty**	Low	
		Severity	Unknown	
Stress	Reduced population size	**Level of Concern**	Unknown	

APPENDIX 4. THREAT CLASSIFICATION TABLE- SAINT JOHN RIVER (SJR) POPULATION

1. Introduction of invasive zebra mussels		**Threat Information**		
Threat Category	Non-native and Invasive Species	**Extent**	Widespread (lower SJR watershed)	
			Local	**Range-wide**
General Threat	Zebra mussels	**Occurrence**		Potential
		Frequency		Recurrent
Specific Threat	Resource competition, displacement of native populations	**Causal Certainty**		High
		Severity		High
Stress	Physiological change, increased mortality, local extinctions	**Level of Concern**	Moderate	
2. Sedimentation resulting from shoreline alteration		**Threat Information**		
Threat Category	Habitat Loss or Degradation	**Extent**	Widespread (lower SJR watershed)	
			Local	**Range-wide**
General Threat	Agriculture, construction and property maintenance activities, clearing of riparian vegetation	**Occurrence**		Current
		Frequency		Continuous
Specific Threat	Increased siltation, loss of benthic habitat	**Causal Certainty**		High
		Severity		Moderate
Stress	Physiological changes, reduced population viability, increased mortality	**Level of Concern**	Moderate	
3. Agricultural inputs		**Threat Information**		
Threat Category	Pollution, Degradation of Water Quality, Habitat Degradation	**Extent**	Widespread	
			Local	**Range-wide**
General Threat	Agricultural fertilizers and chemicals, herbicides, pesticides	**Occurrence**		Current
		Frequency		Continuous
Specific Threat	Nutrient enrichment, direct exposure to toxic chemicals and compounds, accumulation of toxins in sediments	**Causal Certainty**		Moderate-High
		Severity		Moderate
Stress	Physiological changes, reduced population viability, increased mortality	**Level of Concern**	Moderate	
4. Household chemical inputs		**Threat Information**		

Threat Category	Pollution, Degradation of Water Quality, Habitat Degradation	**Extent**	Widespread (Sydney River Watershed)	
			Local	**Range-wide**
General Threat	Garden and household chemicals and compounds	**Occurrence**		Current
		Frequency		Continuous
Specific Threat	Nutrient enrichment, direct exposure to toxic chemicals and compounds	**Causal Certainty**		Moderate-High
		Severity		Low-Moderate
Stress	Physiological changes, reduced population viability, increased mortality	**Level of Concern**	Low-Moderate	
5.	**Sewage inputs**	**Threat Information**		
Threat Category	Pollution, Degradation of Water Quality, Habitat Degradation	**Extent**	Widespread (lower SJR watershed)	
			Local	**Range-wide**
General Threat	Organic and biological inputs	**Occurrence**		Current
		Frequency		Continuous
Specific Threat	Nutrient enrichment, reduced aquatic oxygen concentrations	**Causal Certainty**		Moderate-High
		Severity		Low-Moderate
Stress	Physiological changes, reduced population viability, increased mortality	**Level of Concern**	Low-Moderate	
6.	**Introduction of non-native fish**	**Threat Information**		
Threat Category	Non-native and Invasive Species	**Extent**	Widespread (lower SJR watershed)	
			Local	**Range-wide**
General Threat	Muskellunge, smallmouth bass, chain pickerel	**Occurrence**		Current
		Frequency		Recurrent
Specific Threat	Resource competition, habitat alteration, displacement of native populations	**Causal Certainty**		Moderate
		Severity		Unknown
Stress	Physiological changes, local extinctions	**Level of Concern**	Unknown	
7.	**Industrial spills and inputs**	**Threat Information**		
Threat Category	Pollution, Degradation of Water Quality, Habitat Degradation	**Extent**	Localized (point source along SJR)	
			Local	**Range-wide**
General Threat	Industrial chemicals and compounds, gasoline and oil	**Occurrence**	Current	
		Frequency	Continuous	
Specific Threat	Direct exposure to toxic chemicals and compounds, accumulation of toxins in sediments	**Causal Certainty**	Moderate	
		Severity	Low	

Stress	Physiological changes, reduced population viability, increased mortality	**Level of Concern**	Low	
8. Low water levels		**Threat Information**		
Threat Category	Natural Processes	**Extent**	Unknown	
			Local	**Range-wide**
General Threat	Seasonal drop in water levels	**Occurrence**	Current	
		Frequency	Seasonal	
Specific Threat	Elevated water temperatures, exposure	**Causal Certainty**	Unknown	
		Severity	Unknown	
Stress	Physiological changes	**Level of Concern**	Unknown	