# RECOVERY PLAN FOR THE YELLOW LAMPMUSSEL (*LAMPSILIS CARIOSA*) IN NOVA SCOTIA

**A report prepared for the Nova Scotia Department of Natural Resources and Renewables**

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**[FINAL]**

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**Cover illustration**: Yellow Lampmussel shell. Photograph by Vonica Flear.

# PREFACE

This Recovery Plan has been prepared by the responsible jurisdiction, the Nova Scotia Department of Natural Resources and Renewables, in cooperation with the Nova Scotia Aquatic Species at Risk Recovery Team. The Recovery Plan outlines the recovery goals, objectives, and actions that are deemed necessary to protect, conserve, and recover Yellow Lampmussel in Nova Scotia.

Recovery plans are not designed to provide a comprehensive summary of the biology and status of Species at Risk in Nova Scotia. For more information regarding Yellow Lampmussel biology, consult the COSEWIC Assessment and Status Report (COSEWIC 2004) and Status Appraisal Summary (COSEWIC 2013).

Under the *Nova Scotia Endangered Species Act (2007)*, a Recovery Plan must be developed for species listed as Endangered or Threatened under the Act and include the following:

- Identification of the needs and threats of the species;
- The viable status needed for recovery;
- The options for recovery as well as the costs and benefits of these options;
- The recommended course of action or combination of actions to achieve recovery of the species;
- A schedule for implementation of the recovery plan including a prioritized listing of recommended actions;
- Identification of habitat; and
- Identification of areas to be considered for designation as core habitat.

The goals, objectives, and actions identified in this Recovery Plan are based upon the best available information on the species and are subject to modifications and/or revisions as new information becomes available. Recovery of Species at Risk is a shared responsibility and the collaborative approach emphasized in this document is reflective of that. Implementation of the actions and approaches identified in this plan are subject to budget constraints, appropriations, and changing priorities.

## ACKNOWLEDGEMENTS

The province contracted Lauren Douglas to draft this Recovery Plan under the guidance of Kellie White, and in consultation with members of the Nova Scotia Aquatic Species at Risk Recovery Team and the Nova Scotia Department of Natural Resources and Renewables.

The Department would like to thank those individuals and/or organizations who have contributed to the recovery of Yellow Lampmussel in Nova Scotia. In particular, the following members of the Nova Scotia Aquatic Species at Risk Recovery Team are recognized for their significant contributions to the development of this Recovery Plan:

- Dr. Paul Bentzen
- Kim Robichaud-Leblanc
- Dr. Linda Campbell
- Shanna Fredericks
- Andrew Lowles
- Dr. Shannon Sterling
- Kellie White

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## EXECUTIVE SUMMARY

The Yellow Lampmussel (*Lampsilis cariosa*) is a freshwater bivalve found along the north Atlantic seaboard from Georgia to Nova Scotia. In Nova Scotia, the species is considered threatened due to its restricted distribution. The species has only been observed in a limited area (four lakes and a connected river) within three distinct watersheds (Pottle Lake, Forresters Lake and Sydney River) draining into Sydney Harbour, Cape Breton. All these locations connect to the ocean and are <10 km from an estuary. Surveys completed in 2018-19 estimated the adult Yellow Lampmussel population in Nova Scotia to be 3,757,000 (± 747,800 SE). This population estimate is roughly three times higher than the previous 2002 estimate, but this is due to the species being found in two new locations (Pottle Lake and Forresters Lake) between the survey periods, rather than a population increase in the Sydney River watershed.

Yellow Lampmussel is a benthic suspension feeder. It prefers sand and fine gravel substrate and typically is not found in areas with high silt. In Nova Scotia, the species is only found in waterbodies with pH above 7.0 and salinity levels below 0.5 ppt. Yellow Lampmussel populations in Nova Scotia also require the presence of White Perch (*Morone americana*) to complete their life cycle. White Perch are a semi-anadromous fish that live in fresh and brackish water. They are the only available larval host for Yellow Lampmussel in Cape Breton.

The largest threat to Yellow Lampmussel is invasive species. Chain Pickerel (*Esox niger*) negatively impacts White Perch in waterbodies they share. Chain Pickerel are well established in Blacketts Lake and the connected waterbodies of Gillis Lake and the upper Sydney River. Surveys in 2018-2019 found no evidence of Yellow Lampmussel recruitment in Blacketts Lake likely due to the presence of Chain Pickerel reducing the numbers of White Perch. Other threats to Yellow Lampmussel include habitat loss and degradation due to shoreline development and riparian zone removal, residential and industrial runoff leading to reduced water quality, and dams and other anthropogenic barriers that could alter water levels or impede White Perch passage, reducing their presence in Yellow Lampmussel habitat. Finally, climate change may lead to more extreme weather events, including storm surges, increased water temperatures and increased risk of summer droughts.

The long-term recovery goal (>20 years) for Yellow Lampmussel is to maintain and promote a self-sustaining and ecologically functioning population within the province. A numerical population goal is not established at this time, due to uncertainty about natural distribution and population trends. The short-term population and distribution objective is to continue to monitor the current population and maintain functioning sub-populations in the three watersheds in its current range in Cape Breton. Research should focus on monitoring population size over time to establish baseline trend data at known sites, as well as surveys of additional waterbodies for potentially undiscovered populations. Research should also consider the potential for experimental relocation of

individuals, either to increase distribution and population size in future or maintain current numbers in the face of severe threats (e.g., Chain Pickerel). The lack of recruitment observed currently in Blacketts Lake suggests interventions for population rescue may become necessary.

Broad recovery measures and actions are identified to address threats, protect and enhance habitat (including core habitat), improve communication and outreach, advance policy and guidance to support recovery, and provide a basis for surveys and assessment. In particular, development of a plan to address the threat of Chain Pickerel in Blacketts Lake, protection of undeveloped property around Forresters Lake, and working with Cape Breton Regional Municipality to ensure continued protection of Pottle Lake are highlighted as priorities. Other recommendations include defining and protecting core habitat, raising awareness among private landowners, partnership and cooperation between government and non-governmental organizations and continued monitoring and research to address knowledge gaps.

# RECOVERY FEASIBILITY SUMMARY

The recovery of Yellow Lampmussel in Nova Scotia is considered technically and biologically feasible if the following four criteria can be met:

*1. Individuals of the wildlife species that are capable of reproduction are available now or in the foreseeable future to sustain the population or improve its abundance.*

Yes. Currently the Nova Scotia population[1] of Yellow Lampmussel consists of just three large sub-populations[2], all in Cape Breton. There is evidence of reproduction and recent recruitment in two of the sub-populations (Forresters Lake and Pottle Lake). However, there is no evidence of recent recruitment in the third (Blacketts Lake/upper Sydney River) and it appears that it may be "non reproductive" due to the introduction of Chain Pickerel eliminating the obligate fish host (White Perch) for Yellow Lampmussel.

*2. Sufficient suitable habitat is available to support the species or could be made available through habitat management or restoration.*

Yes. Lakes or medium to large rivers with sandy substrates, water pH greater than 7 and salinity less than 0.5 ppt provide suitable habitat for Yellow Lampmussel. These types of habitats are abundant in Nova Scotia.

*3. The primary threats to the species or its habitat (including threats outside Nova Scotia) can be avoided or mitigated.*

Yes. The primary threat to Yellow Lampmussel involves the invasive species Chain Pickerel and Zebra Mussels. Chain Pickerel are present in one of the lakes where the species occurs but not in the other two. Introduction of this species into these two lakes can be avoided. Zebra Mussels have not been observed in the wild in Nova Scotia and their invasion can be avoided with continuing education and monitoring. Additional threats include the loss or degradation of aquatic habitat and water pollution resulting from shoreline development, as well as dams and water management, which can be mitigated through promotion of best practices and enforcement of existing regulations.

*4. Recovery techniques exist to achieve the population and distribution objectives or can be expected to be developed within a reasonable timeframe.*

Yes. Propagation and population augmentation or reintroduction techniques have been used to restore freshwater mussel populations since the early 1900s (Lima et al. 2012) and have been used for Yellow Lampmussel in the United States (e.g., Kurth 2007;

[1] Population is defined as the total number of individuals of the taxon (COSEWIC 2019), in this case in Nova Scotia.
[2] Subpopulation is defined as geographically or otherwise distinct groups in the population between which there is little demographic or genetic exchange (typically one successful migrant individual or gamete per year or less) (COSEWIC 2019).

Martell 2020) and this work can be used to develop recovery techniques appropriate for Yellow Lampmussel in Nova Scotia.

The Recovery Team concludes that the recovery of Yellow Lampmussel in Nova Scotia is technically and biologically feasible based on the criteria discussed above.

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# 1. NSSARWG and/or COSEWIC ASSESSMENT SUMMARY*

* The following definitions are applicable in this section and elsewhere: NSSARWG (Nova Scotia Species at Risk Working Group); NSESA (Nova Scotia Endangered Species Act); COSEWIC (Committee on the Status of Endangered Wildlife in Canada); SARA (Species at Risk Act).

**Date of Assessment:** November 2005 (NSSARWG)

**Common Name**: Yellow Lampmussel

**Scientific Name**: *Lampsilis cariosa*

**Status:** Threatened (NSESA)

**Reason for Designation**: Designated as Threatened in Nova Scotia (2005) due to its restricted distribution in the Sydney River area and potential threats posed by invasive species and water pollution. Cumulative threat impacts from non-native species of fish and from industrial pollution are high, although there is uncertainty about the timing and possibility of invasion by Zebra Mussels and the impact of non-native species of fish on host fish [note that since assessment, Yellow Lampmussel has been reported from two additional lakes near Sydney, Nova Scotia, and that the invasive Chain Pickerel is now present in the Sydney River system].

**Occurrence:** Nova Scotia occurrence: Cape Breton County. Native to Eastern North America with the Canadian population restricted to New Brunswick and Nova Scotia.

**Status history:** Provincially assessed as Vulnerable by the NSSARWG in November 2005. Federally assessed as Special Concern by COSEWIC in May 2004 and re-assessed in November 2013.

# 2. SPECIES STATUS INFORMATION

Yellow Lampmussel has a global conservation status rank of Vulnerable (G3G4), and national ranks of Vulnerable in the US (N3N4) and Imperiled in Canada (N2) (Table 1). Across its distribution in Canada, it is considered Vulnerable in New Brunswick (S3) and Critically Imperiled in Nova Scotia (S1) (NatureServe 2019).

Yellow Lampmussel was listed as Threatened under the *Nova Scotia Endangered Species Act* in 2006.

In Canada, Yellow Lampmussel was assessed as Special Concern by COSEWIC (2004; 2013) and listed as Special Concern under Schedule 1 of the federal *Species at Risk Act* (S.C. 2002, c. 29) in 2005.

A federal Management Plan for the species was developed by Fisheries and Oceans Canada in cooperation and consultation with the provinces of New Brunswick and Nova Scotia and others (Fisheries and Oceans Canada 2010) and is published on the Species at Risk Registry: https://wildlife-species.canada.ca/species-risk-registry/virtual_sara/files/plans/mp_yellow_lampmussel_0410_e.pdf.

**Table 1.** NatureServe conservation status ranks for Yellow Lampmussel in Canada* (NatureServe, 2019).

| Global (G) Rank[a] | National (N) Rank[b] | Subnational (S) Rank[c] |
|---|---|---|
| G3G4 | N2 | S2 – New Brunswick<br>S1 – Nova Scotia |

[a] G-Rank – Global Conservation Status Rank, G1 = Critically Imperiled; G2 = Imperiled; G3 = Vulnerable; G4 = Apparently Secure; G5 = Secure
[b] N-Rank – Provide ranking for each province the species is found in. National Conservation Status Rank, N1 = Critically Imperiled; N2 = Imperiled; N3 = Vulnerable; N4 = Apparently Secure; N5 = Secure
[c] S-Rank – Sub-national (provincial or territorial) ranks, S1 = Critically Imperiled; S2 = Imperiled; S3 = Vulnerable; S4 = Apparently Secure; and S5 = Secure. B = breeding; and U = Unrankable.
*A full list of definitions can be found in Definitions of NatureServe Conservation Status Rankings at http://help.natureserve.org/biotics/Content/Record_Management/Element_Files/Element_Tracking/ETRACK_Definitions_of_Heritage_Conservation_Status_Ranks.htm

# 3. SPECIES INFORMATION

## 3.1 Species Description

Yellow Lampmussel is a freshwater bivalve which usually reaches between 75 mm to 115 mm in length. It is a sexually dimorphic species, with adult males appearing more elongated than adult females. Both sexes are oval in a lateral view and have a moderately thick shell with a yellow-orange glossy periostracum (outer shell layer). Rays are not usually present on the periostracum but are well defined when present. The nacre (inner shell layer) of the shell is white, or bluish white, with some pink in the beak area. Hinge teeth are well defined, and pseudocardinal teeth are usually strong and conical and almost directly under the umbo. There are also two lateral teeth in the left valve and one in the right valve. In juvenile Yellow Lampmussel, the beak is comprised of five to six bars. Female mussels have modified mantle tissue that is visible along the shell margin that resembles a “minnow” (Figure 1). This minnow-like mantle extension flaps rhythmically when females are gravid and is thought to serve as lure for fish hosts.

More detailed descriptions can be found in COSEWIC (2004) and Fisheries and Oceans Canada (2010), with field identification features illustrated in McAlpine et al. (2018).


**Figure 1.** Minnow-shaped mantle lure with eyespots protruding from shell of Yellow Lampmussel (photo by K. White).

### 3.2 Population and Distribution

Globally, Yellow Lampmussel is found along the Northeast Atlantic slope, east of the Appalachian Mountains in North America (Williams et al. 1993; COSEWIC 2004). Its range spans from Georgia to Maine in the United States and is restricted to New Brunswick and Nova Scotia in Canada.

In Nova Scotia, Yellow Lampmussel is rare, known only within three watersheds in Cape Breton County. Originally, it was only known from the Sydney River system, including Blacketts Lake, the small, connected waterways of Gillis Lake, and the upper Sydney River (Clarke and Meachem 1963; COSEWIC 2004). More recent surveys have confirmed additional sub-populations in Pottle Lake in 2011 and Forresters Lake in 2015 (White 2015; 2017)**.** The three sub-populations occur in three distinct watersheds (Pottle Lake, Forresters Lake and Sydney River watersheds) that drain into the Sydney Harbour (Figure 2).

#### 3.2.1 Population Size and Trends

There is a high degree of uncertainty associated with population estimates for Yellow Lampmussel, due to challenging field sampling conditions and its high degree of spatial aggregation (clumping) (Fisheries and Oceans Canada 2010). The current estimate of mature individuals of Yellow Lampmussel in Nova Scotia is 3,757,000 (± 747,800 SE[3]) based on surveys done by K. White in 2018-2019 (White et al. 2022). This represents an overall increase from the 2002 count of 1,266,637 (± 189905 SE) individuals reported in the 2004 COSEWIC status report (COSEWIC 2004) for the Sydney River population; the increase is due to the discovery of two new sites (Pottle Lake and

[3] SE refers to the standard error of the mean.

Forresters Lake) rather than increases at previously known sites. Of the current estimate of mature individuals, approximately 38% (988,000 ± 187000 SE) are in Blacketts Lake, 36% (1,359,000 ± 271,800 SE) in Pottle Lake and 26% (988,000 ± 187,000 SE) in Forresters Lake.

The discovery of new sites in Cape Breton County since the last status report in 2004 (COSEWIC 2004) suggests Yellow Lampmussel may be more common in the province than it appears to be. However, 37 lakes in Cape Breton were surveyed for presence of Yellow Lampmussel in 2015 and 2016 without locating additional sites (White 2015; 2017). While surveying is also ongoing on mainland Nova Scotia, no mainland populations have been observed.

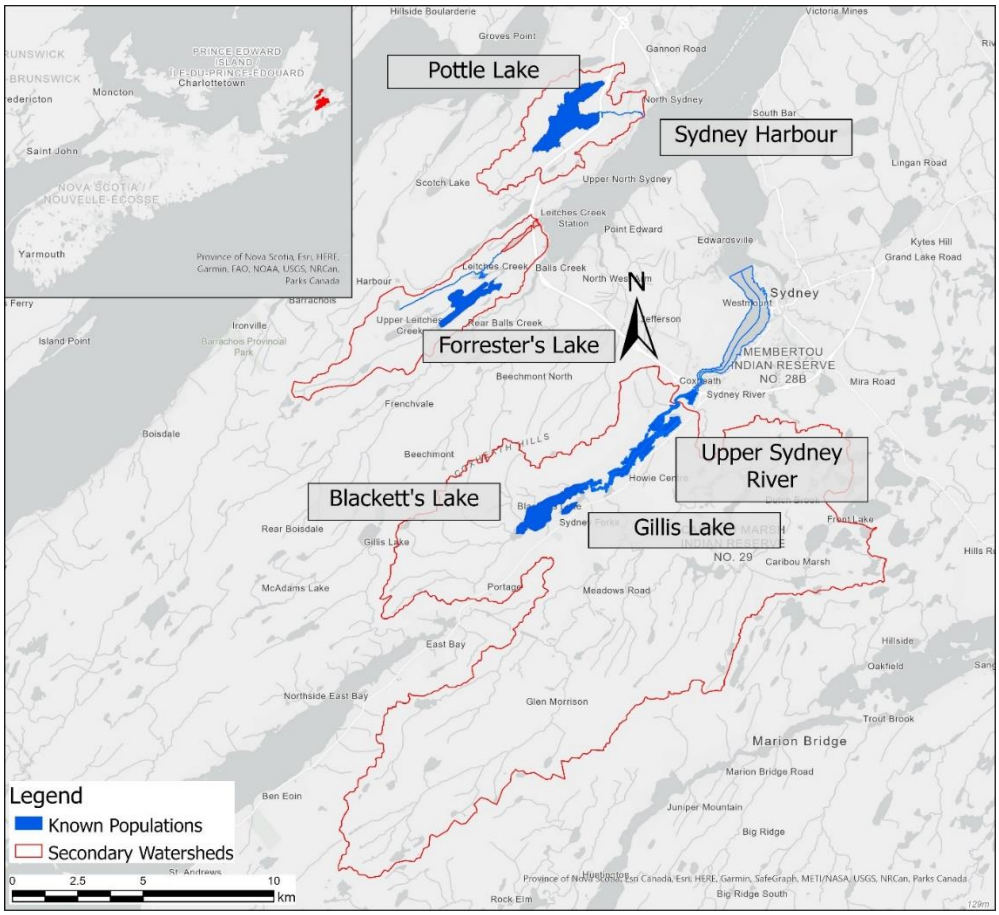


**Figure 2.** Known distribution of Yellow Lampmussel in Nova Scotia.

## 3.3 Species Needs

### 3.3.1 Habitat Needs

Throughout its range in North America, Yellow Lampmussel is found predominantly in medium to large rivers and lakes that have a connection to the ocean (Nedeau et al. 2000). Yellow Lampmussel is a heavy-shelled species and prefers sand and fine gravel

substrate to burrow into; it is not typically found in areas with high silt concentrations as silt can bury and smother individuals and interfere with feeding (Fisheries and Oceans Canada 2010; White 2015; 2017). It also tends to occur in higher numbers in areas that are low in macrophyte cover (COSEWIC 2004). The species is found at varying water depths ranging from 0.75-6.0 m within Nova Scotia and other areas of North America (COSEWIC 2004; White 2015; 2017). In Nova Scotia, Yellow Lampmussel is not found in waterbodies with a pH lower than 7.0 and salinity levels above 0.5 ppt (White 2015; 2017). The species requires clean water to survive and with very limited mobility is particularly vulnerable to sudden changes in water quality and water level drops associated with summer droughts.

### 3.3.2 Biological Needs and Ecological Role

Yellow Lampmussel is a benthic suspension feeder that filters organic debris and phytoplankton from the water and expels waste material as pseudofaeces (COSEWIC 2004). Freshwater mussels like Yellow Lampmussel play an important ecological role in aquatic ecosystems. This role includes nutrient recycling and storage, substrate and food web modification, and “cleaning” water through filter feeding (Vaughn 2018). They are an important component of aquatic food webs and may be preyed upon by birds, fish and mammals such as otters, muskrats and raccoons (Fisheries and Oceans Canada 2010).

Yellow Lampmussel is dependent on a fish host for completion of its life cycle (COSEWIC 2004; Haag 2012; White et al. 2022). The species is dioecious and has internal fertilization. Males release sperm into the water column and females carry their eggs in their gills, where they are fertilized with sperm filtered in from the water column. After fertilization mussel larva, referred to as glochidia, are brooded in the gills and released through the adult female’s siphons. Female Yellow Lampmussel have modified mantle tissue that resembles a small fish lure protruding from their shell. This fish-like lure flaps rhythmically when the mussel is gravid and serves to attract host fish to the mussel (Haag 2012). When the lure is struck by a fish, the females release glochidia and they attach to the gills of the fish. After between 40-80 days attached to the fish host, the larvae drop from the fish as a juvenile mussel.

The fish host is thought to contribute to the nutrition and dispersal of mussel glochidia (Haag 2012; COSEWIC 2004); it may also facilitate the movement of glochidia between freshwater systems linked by brackish coastal waters (White 2015). Currently, White Perch (*Morone americana*) appear to be the only fish species that serve as hosts for Yellow Lampmussel glochidia in Nova Scotia (White et al. 2022). Other fish species including Yellow Perch (*Perca flavescens*), Banded Killifish (*Fundulus diaphanous*), Chain Pickerel (*Esox niger*), White Sucker (*Catostomus commersoni*), Smallmouth Bass (*Micropterus dolomieu*) and Largemouth Bass (*Micropterus salmoides*) have been identified as potential Yellow Lampmussel fish hosts in lab experiments carried out in Maine. However, White Perch and Yellow Perch had the highest infection rates in both

lab and subsequent field studies (Wick and Huyrn 2002; Kneeland and Rhymer 2008). Yellow Perch does not occur in the areas of Nova Scotia where Yellow Lampmussel are currently found. White Perch is the only species that has been observed with Yellow Lampmussel glochidia attached to their gills in Nova Scotia (COSEWIC 2004, White 2017; White et al. 2022).

### 3.3.3 Limiting Factors

Presence and free movement of appropriate fish hosts is a limiting factor for Yellow Lampmussel. Direct threats to their fish host species or habitat will have indirect impacts on Yellow Lampmussel; the removal of suitable host species or habitat could result in the disappearance of annual cohorts of Yellow Lampmussel as they cannot complete their life cycle (Fisheries and Oceans Canada 2010).

Adult Yellow Lampmussel have limited dispersal abilities. They have a muscular foot which allows limited movement for feeding or in response to environmental cues such as seasonal changes in water levels. However, their main means of dispersal as a species is through glochidia transport on fish hosts (Fisheries and Oceans Canada 2010).

# 4. THREATS

## 4.1 Threat Assessment

The Yellow Lampmussel threat assessment (Table 2) is based on the IUCN-CMP (World Conservation Union–Conservation Measures Partnership) unified threats classification system (IUCN 2012). Threats are defined as the proximate activities or processes that have caused, are causing, or may cause in the future the destruction, degradation, and/or impairment of the entity being assessed (population, species, community, or ecosystem) in the area of interest (in this case, the province of Nova Scotia). Limiting factors are not considered during this assessment process. For purposes of the threat assessment, only present and future threats are considered. Historical threats, indirect or cumulative effects of the threats, or any other relevant information that would help understand the nature of the threats are presented in Section 4.2 *Description of Threats*.

**Table 2.** Threat calculator assessment.

| Threat # | Threat description | Impact[a] | Scope[b] | Severity[c] | Timing[d] | Comments |
|---|---|---|---|---|---|---|
| 1 | Residential & commercial development | Medium | Large | Moderate | High | |
| 1.1 | Housing & urban areas | Medium | Large | Moderate | High | Blacketts Lake and the upper Sydney River system have significant commercial and residential development along their shorelines and Forresters Lake may be subject to development in the future. Disturbance from docks/wharves, potential impacts from maintenance activities and new shoreline construction associated with residential and commercial / industrial development could pose a direct threat to Yellow Lampmussel survival in these lakes (e.g., crushing or removal of mussels, habitat destruction). Removal of riparian vegetation and |

| Threat # | Threat description | Impact[a] | Scope[b] | Severity[c] | Timing[d] | Comments |
|---|---|---|---|---|---|---|
| | | | | | | shoreline hardening by landowners also poses a threat to freshwater mussels, by altering aquatic habitat through increased bank erosion, sedimentation, increased water temperatures, pollution, etc. This is discussed further in 7.3 [effects on water temperature, shading, fish habitat] and 9.1 [runoff, erosion, siltation / sedimentation, pollution]. |
| 1.2 | Commercial & industrial areas | | | | | Direct impacts of commercial shoreline development are included with the ratings under 1.1; runoff from commercial and industrial areas is covered in 9.2. |
| 1.3 | Tourism & recreation areas | | | | | Not applicable. |
| 2 | Agriculture & aquaculture | | | | | |
| 2.1 | Annual & perennial non-timber crops | | | | | The presence of farms in the vicinity of Blacketts Lake and Forresters Lake is a potential contributor to pollutants in these systems. Runoff from agricultural activities is covered in 9.3.<br><br>Threats to aquatic habitat associated with removal of riparian vegetation for agricultural activity are covered in 7.3 [effects on water temperature, shading, fish habitat] and 9.3 [runoff, erosion, siltation / sedimentation, pollution]. |
| 2.2 | Wood & pulp plantations | | | | | Not applicable. |

| Threat # | Threat description | Impact[a] | Scope[b] | Severity[c] | Timing[d] | Comments |
|---|---|---|---|---|---|---|
| 2.3 | Livestock farming & ranching | | | | | Horse farms near Blacketts Lake and Forresters Lake could be contributing to nutrient overload in the lakes (e.g., runoff from manure piles). Runoff from agricultural activities is covered in 9.3. |
| 2.4 | Marine & freshwater aquaculture | | | | | Not applicable. |
| 3 | Energy production & mining | | | | | |
| 3.1 | Oil & gas drilling | | | | | Not applicable. [Note there is currently a moratorium on fracking in Nova Scotia: https://energy.novascotia.ca/oil-and-gas/onshore/hydraulic-fracturing-review]. |
| 3.2 | Mining & quarrying | | | | | There are several non-operational mines in the Sydney River watershed that could be contributing polluted effluent to the system. Runoff from mining and quarrying is covered in 9.2. |
| 3.3 | Renewable energy | | | | | Not applicable. |
| 4 | Transportation & service corridors | | | | | |
| 4.1 | Roads & railroads | | | | | All known waterbodies with Yellow Lampmussel are less than 1 km from a paved road. Runoff from roads and road maintenance activities is covered in 9.1. |
| 4.2 | Utility & service lines | | | | | There are a number of power line right-of-ways in proximity to Yellow |

| Threat # | Threat description | Impact[a] | Scope[b] | Severity[c] | Timing[d] | Comments |
|---|---|---|---|---|---|---|
| | | | | | | Lampmussel habitat. Runoff from pesticide use to maintain power line right-of-ways is covered in 9.1 |
| 4.3 | Shipping lanes | | | | | Not applicable. |
| 4.4 | Flight paths | | | | | Not applicable. |
| 5 | Biological resource use | Not a threat | Large | Neutral or Potential Benefit | High | |
| 5.1 | Hunting & collecting terrestrial animals | Not a threat | Large | Neutral or Potential Benefit | High | Muskrats are a predator of Yellow Lampmussel in Cape Breton (COSEWIC 2004). Decreased numbers of muskrat due to hunting and trapping could positively impact freshwater mussel populations. Muskrats have been trapped previously around Pottle Lake. |
| 5.2 | Gathering terrestrial plants | | | | | Not applicable. |
| 5.3 | Logging & wood harvesting | | | | | Logging and wood harvesting in the vicinity of Blacketts and Forresters Lakes are potential contributors to pollutants in these systems. Threats to aquatic habitat associated with removal of riparian vegetation for forestry are covered in 7.3 [effects on water temperature, shading, fish habitat] and 9.3 [runoff, erosion, siltation / sedimentation, pollution]. Note that current regulations in Nova Scotia require a 20 m 'special management zone' for forest clearing |

| Threat # | Threat description | Impact[a] | Scope[b] | Severity[c] | Timing[d] | Comments |
|---|---|---|---|---|---|---|
| | | | | | | near watercourses: https://novascotia.ca/just/regulations/regs/fowhwp.htm |
| 5.4 | Fishing & harvesting aquatic resources | Not a threat | Large | Neutral or Potential Benefit | High | Recreational fishing could potentially cause removal of Yellow Lampmussel glochidia / juveniles but there are no data on population level impacts. Fishing is prohibited in Pottle Lake (see 6.1) and limited in Forresters Lake (limited access). Recreational fishing of Chain Pickerel in Blacketts Lake could help reduce their populations and thus benefit Yellow Lampmussel. |
| 6 | Human intrusions & disturbance | Low | Small | Moderate | High | |
| 6.1 | Recreational activities | Low | Small | Moderate | High | Recreational boating in Blacketts Lake and Forresters Lake could pose a risk to Yellow Lampmussel, with mussels being crushed at boat launch areas. Gas and oil pollution associated with boating may also affect water quality. Note that boating, fishing and swimming are prohibited in Pottle Lake due to its Protected Water Area Designation (CBRM Water Utility 2013). |
| 6.2 | War, civil unrest, & military exercises | | | | | Not applicable. |
| 6.3 | Work & other activities | Negligible | Negligible | Negligible | High | Research may involve removal of mussels from their habitat (e.g., voucher specimens) or activities such |

| Threat # | Threat description | Impact[a] | Scope[b] | Severity[c] | Timing[d] | Comments |
|---|---|---|---|---|---|---|
| | | | | | | as timed and quadrat searches, in which researchers enter mussel habitat and excavate sediment and may occasionally cause accidental harm (e.g., crushing, burying). Note that most research is non-destructive (e.g., eDNA, tissue swabs, tag-recapture) and permits are required by province of Nova Scotia to conduct research on at-risk mussels.<br><br>Work related to dam maintenance is covered in 7.2. |
| 7 | Natural system modifications | Medium | Pervasive | Moderate | Moderate - Low | |
| 7.1 | Fire & fire suppression | | | | | Not applicable. |
| 7.2 | Dams & water management/use | Medium | Pervasive | Moderate | Moderate - Low | Blacketts Lake and Pottle Lake are both dammed and managed as former (Blacketts) or current (Pottle) domestic water supplies. While this affords a level of protection (e.g., water quality monitoring, controlled access) conflicting interests in future could pose a potential threat (e.g., drawdown of water could leave mussels stranded along the shoreline).<br><br>Improper maintenance of dam infrastructure could also pose a future threat as dams can create a barrier between mussels and their fish hosts. By blocking host fish from swimming to mussel beds upstream, dams can |

| Threat # | Threat description | Impact[a] | Scope[b] | Severity[c] | Timing[d] | Comments |
|---|---|---|---|---|---|---|
| | | | | | | prevent freshwater mussels from completing their life cycle (Liu et al. 1996). In addition, a breach of the Sydney River dam could reduce water levels in the river and allow for the intrusion of saltwater upstream of the dam, with negative effects on Yellow Lampmussel habitat. However, both dams appear to be in good working order. The Pottle Lake dam was inspected in 2017 and the Sydney River dam recently installed a new fish ladder (White 2018b), therefore timing is rated “Moderate-low”. |
| 7.3 | Other ecosystem modifications | Unknown | Large | Unknown | High | A number of land-based activities noted above (e.g., residential and commercial development, agriculture, forestry, road construction, etc.) may involve removal of riparian vegetation with resulting impacts on Yellow Lampmussel habitat; these include increased water temperature, decreased shade and changes to vegetation and fish habitat [rated here] as well as increased bank erosion, sedimentation / siltation, runoff and pollution [covered in 9.3]. Lack of data on these habitat changes and their impacts for Yellow Lampmussel make severity “Unknown”.<br><br>Other ecosystem modifications could result from control methods for invasive fish, including mechanical |

| Threat # | Threat description | Impact[a] | Scope[b] | Severity[c] | Timing[d] | Comments |
|---|---|---|---|---|---|---|
| | | | | | | methods (e.g., fishing, electrofishing) or water treatment with chemicals such as rotenone. Molluscicides have also been used elsewhere to control host snail populations of Swimmer's Itch which has been reported in Blacketts Lake. There are no current plans to use rotenone or molluscicides in that system. |
| 8 | Invasive & other problematic species & genes | Very High | Pervasive | Extreme | High | |
| 8.1 | Invasive non-native/alien species | Very High | Pervasive | Extreme | High | Chain pickerel (*Esox niger*) is an invasive predatory fish that was illegally introduced to Blacketts Lake in 2010. Chain Pickerel is a known predator of White perch (*Morone americana*), the host fish for Yellow Lampmussel. White (2018a; 2018b) found that Chain pickerel was well established in Blacketts Lake, and that the White perch population may be severely depleted or extirpated, potentially rendering Yellow Lampmussel unable to complete its life cycle (e.g., through predation of glochidia; absence of a suitable host; elimination of a life stage). It is unclear whether Yellow Lampmussel will adapt to use other fish host species. Data show a lack of recruitment in the Blacketts Lake Yellow Lampmussel sub-population in recent surveys. |

| Threat # | Threat description | Impact[a] | Scope[b] | Severity[c] | Timing[d] | Comments |
|---|---|---|---|---|---|---|
| | | | | | | The introduced Zebra mussel (*Dreissena polymorpha*) poses a severe threat to freshwater mussel populations elsewhere in North America, as it has the potential to extirpate native species (Ricciardi et al. 1998). It is not yet present in Nova Scotia but preventing introduction should be a priority.<br><br>The Chinese Mystery Snail (*Cipangopaludina chinensis*) is an invasive species that is established in several lakes in Nova Scotia where it causes ecosystem changes that could be detrimental to mussels (Kingsbury et al. 2021).<br><br>Neither Zebra Mussels nor Chinese mystery snails are currently found in Yellow Lampmussel habitat in Nova Scotia but pose a potential future threat. |
| 8.2 | Problematic native species | Low | Pervasive | Slight | High | Muskrat (*Ondatra zibethicus*) predation is a threat to endangered mussel populations (Zahner-Meike and Hanson 2001) and Muskrats are the main predator of Yellow Lampmussel in Cape Breton. Based on complete excavation of three midden sites on Blacketts Lake, the predation rate was 10.5 (± 8.7 SD) individuals/week. Muskrat predation primarily takes place during winter |

| Threat # | Threat description | Impact[a] | Scope[b] | Severity[c] | Timing[d] | Comments |
|---|---|---|---|---|---|---|
| | | | | | | months when vegetation (preferred food source) is not available.<br><br>Since the Yellow Lampmussel sub-population in Blacketts Lake has been observed to have little to no recruitment due to the extirpation of their fish host, muskrat predation could pose a more severe threat to the Blacketts Lake population. |
| 8.3 | Introduced genetic material | | | | | Not applicable. |
| 8.4 | Problematic species/diseases of unknown origin | Not Calculated (outside assessment timeframe) | Pervasive | Moderate | Low - Insignificant/ negligible | The protozoans *Conchophthirus* spp. have been described infecting Yellow Lampmussel (Carella et al. 2016), as well as Eastern Elliptio (*Elliptio complanata*) and Eastern floater (*Pyganodon cataracta*), which occupy similar habitats in Nova Scotia. There is limited information on the effects of *Conchophthirus* spp. on Yellow Lampmussel.<br><br>Trematode infections have been found in other *Lampsilis* species (Tsakiris et al. 2016). Trematode infections lead to sterilization and could reduce the number of reproducing individuals, thereby lowering the effective population size. This can be especially problematic if mussel densities are low (Haag and Leann Staton 2003) as they are for Yellow Lampmussel. |

| Threat # | Threat description | Impact[a] | Scope[b] | Severity[c] | Timing[d] | Comments |
|---|---|---|---|---|---|---|
| 8.5 | Viral/prion-induced diseases | | | | | Unknown. |
| 8.6 | Diseases of unknown cause | | | | | Unknown. |
| 9 | Pollution | Medium | Large | Moderate | High | |
| 9.1 | Household sewage & urban wastewater | Medium | Large | Moderate | High | Pollution from urban shoreline development can degrade or destroy aquatic habitat and reduce water quality; these were identified as primary threats to Yellow Lampmussel in the federal management plan, particularly in the Sydney River System (Fisheries and Oceans Canada 2010).<br><br>Increased sedimentation (siltation) from shoreline construction and property maintenance can smother and bury freshwater mussels and affect their biological functioning (Fuller 1974; COSEWIC 2004; Goldsmith et al. 2021). Excess nutrient loading from lawn chemicals and sewage / septic tank runoff can cause eutrophication, promote algal and aquatic plant growth and reduce oxygen levels, thus reducing water quality. Excess nutrients are negatively associated with both juvenile and adult mussel survival (Fuller 1974).<br><br>Removal of riparian vegetation compounds the impacts described above. Intact riparian zones act as |

| Threat # | Threat description | Impact[a] | Scope[b] | Severity[c] | Timing[d] | Comments |
|---|---|---|---|---|---|---|
| | | | | | | bank stabilizers and sediment and nutrient filters, reducing contaminant and nutrient inputs to aquatic systems (Dosskey et al. 2010; Mondal and Patel 2018). Removal of riparian vegetation increases runoff, erosion, sedimentation / siltation and pollution that can negatively impact freshwater mussels, as above.<br><br>In addition to nutrients and bacteria from septic tanks, pharmaceuticals and personal care products found in municipal wastewater have the potential to cause adverse effects on the immune system of freshwater mussels (Gagné et al. 2006; Blair et al. 2013; Srain et al. 2020).<br><br>Roads and road maintenance can cause contamination of nearby aquatic systems with runoff from road salts in winter months (Paschka et al. 1999) and herbicides in summer months (Huang et al. 2004). Maintenance of power line right-of-ways though vegetation clearing and herbicide use can also result in runoff to adjacent waterbodies. All Yellow Lampmussel habitat in Cape Breton is less than 1 km from a paved road, and less than 1 km from a power line right-of-way. It is not yet known how these contaminants may affect Yellow Lampmussel. |

| Threat # | Threat description | Impact[a] | Scope[b] | Severity[c] | Timing[d] | Comments |
|---|---|---|---|---|---|---|
| 9.2 | Industrial & military effluents | Low | Large | Slight | High - Moderate | Abandoned mines and quarries can have a negative impact on freshwater ecosystems, mainly through uncontrolled effluent discharge and leaching (Vendrell-Puigmitja et al. 2020). Metal and coal mines can also be a source of acid mine drainage (AMD), releasing acidic runoff and dissolved heavy metals into watercourses downstream (Akcil and Koldas 2006; Trudell and White 2013). There are several non- operational mines in the Sydney River watershed (3 coal and 1 iron (Hennick & Poole 2020)).<br><br>There is an auto-salvage yard approximately 150 m from the shoreline of Forresters Lake. Effluent from auto-salvage yards has been shown to contain contaminants that are harmful to fish, such as heavy metals (Shostell & Harson 2006). |
| 9.3 | Agricultural & forestry effluents | Low | Large | Slight | High | Agricultural runoff can result in excess sediment, nutrients, and chemicals in receiving waterbodies (Schoonover et al. 2005), which can cause habitat and water quality degradation. Runoff from farms, including manure piles at horse farms, near Blacketts Lake and Forresters Lake could be contributing to nutrient overload in the lakes. |

| Threat # | Threat description | Impact[a] | Scope[b] | Severity[c] | Timing[d] | Comments |
|---|---|---|---|---|---|---|
| | | | | | | Removal of riparian vegetation for agriculture and forestry can also cause increased runoff, erosion, siltation / sedimentation and pollution as discussed in 9.1. |
| 9.4 | Garbage & solid waste | | | | | Not applicable. |
| 9.5 | Air-borne pollutants | | | | | Not applicable. |
| 9.6 | Excess energy | | | | | Not applicable. |
| 10 | Geological events | | | | | |
| 10.1 | Volcanoes | | | | | Not applicable. |
| 10.2 | Earthquakes/tsunamis | | | | | Not applicable. |
| 10.3 | Avalanches/landslides | | | | | Not applicable. |
| 11 | Climate change & severe weather | Not Calculated (outside assessment timeframe) | Pervasive | Serious | Low | |
| 11.1 | Habitat shifting & alteration | Not Calculated (outside assessment timeframe) | Large | Moderate | Low | Global sea levels are rising approximately one eighth of an inch per year, and local effects can be higher than the global average (NOAA 2021). Sea levels rising above the Sydney River dam could allow saltwater into the Sydney River, which would degrade water quality in Yellow Lampmussel habitat. |
| 11.2 | Droughts | Not Calculated (outside | Restricted | Serious | Low | Warmer temperatures and more frequent droughts are predicted for |

| Threat # | Threat description | Impact[a] | Scope[b] | Severity[c] | Timing[d] | Comments |
|---|---|---|---|---|---|---|
| | | assessment timeframe) | | | | many areas (UCS 2021). Mussels close to the shoreline are at risk of being stranded out of the water during drought conditions (Sousa et al. 2018). This can make them more vulnerable to predation, and eventually causes mussel death. |
| 11.3 | Temperature extremes | Not Calculated (outside assessment timeframe) | Pervasive | Serious | Low | Temperature anomalies such as heat waves are happening with increased frequency and severity due to climate change. A sudden onset of exceptionally high temperatures could impact Yellow Lampmussels in shallow water if not given enough time to move to deeper, cooler waters.<br><br>River and lake temperatures are also expected to increase in the long term due to climate change (Caissie et al. 2017). No temperature tolerance data is available for Yellow Lampmussel but a study on Fatmucket clams (*Lampsilis siliquoidea*) found that the LT50 for glochidia was 32.8$^{o}$C and 34.4$^{o}$C – 35.6$^{o}$C for juveniles (Pandolfo et al. 2012). The upper incipient lethal temperature for White Perch was 36$^{o}$C (Hasnain et al. 2010). |
| 11.4 | Storms & flooding | Not Calculated (outside assessment timeframe) | Large | Moderate | Low | Storms are increasing in frequency and intensity with climate change,, and storm surges could cause a breach of the Sydney dam as discussed in 11.1. Storm intensity can also cause flash |

| Threat # | Threat description | Impact[a] | Scope[b] | Severity[c] | Timing[d] | Comments |
|---|---|---|---|---|---|---|
| | | | | | | events of increased runoff and flooding, which could exacerbate the pollution effects described above. |

[a] **Impact** – The degree to which a species is observed, inferred, or suspected to be directly or indirectly threatened in the area of interest. The impact of each threat is based on Severity and Scope rating and considers only present and future threats. Threat impact reflects a reduction of a species population or decline/degradation of the area of an ecosystem. The median rate of population reduction or area decline for each combination of scope and severity corresponds to the following classes of threat impact: Very High (75% declines), High (40%), Medium (15%), and Low (3%). Unknown: used when impact cannot be determined (e.g., if values for either scope or severity are unknown); Not Calculated: impact not calculated as threat is outside the assessment timeframe (e.g., timing is insignificant/negligible or low as threat is only considered to be in the past); Negligible: when scope or severity is negligible; Not a Threat: when severity is scored as neutral or potential benefit.

[b] **Scope** – Proportion of the species that can reasonably be expected to be affected by the threat within 10 years. Usually measured as a proportion of the species' population in the area of interest. (Pervasive = 71–100%; Large = 31–70%; Restricted = 11–30%; Small = 1–10%; Negligible < 1%).

[c] **Severity** – Within the scope, the level of damage to the species from the threat that can reasonably be expected to be affected by the threat within a 10-year or three-generation timeframe. Usually measured as the degree of reduction of the species' population. (Extreme = 71–100%; Serious = 31–70%; Moderate = 11–30%; Slight = 1–10%; Negligible < 1%; Neutral or Potential Benefit ≥ 0%).

[d] **Timing** – High = continuing; Moderate = only in the future (could happen in the short term [< 10 years or 3 generations]) or now suspended (could come back in the short term); Low = only in the future (could happen in the long term) or now suspended (could come back in the long term); Insignificant/Negligible = only in the past and unlikely to return, or no direct effect but limiting.

## 4.2 Description of Threats

Yellow Lampmussel has a very limited distribution in Nova Scotia, currently known from just three watersheds near Sydney, Cape Breton. Therefore, threats that impact any one of these systems could have a significant impact on the Yellow Lampmussel population. All three primary lakes (Blacketts, Forresters and Pottle) are freshwater with sandy or gravelly bottoms, in close proximity to each other, and with connections to the ocean (Sydney Harbour). Blacketts Lake (with approximately 38% of the Yellow Lampmussel population) is heavily used with significant residential and commercial shoreline development and both public and private access; Pottle Lake (36% of the population) is close to roads and urban areas but protected as the primary potable water supply for Cape Breton Regional Municipality (CBRM) with no shoreline development or access; and Forresters Lake (26% of the population) is quite isolated and undisturbed with very little public or private access. Two of the lakes are dammed; Blacketts Lake at the lower end where it meets the Sydney River and Pottle Lake on the southeast arm where it draws water into a water treatment facility.

The primary threat to Yellow Lampmussel is the invasive Chain Pickerel, a predatory fish introduced into Blacketts Lake in 2010 and causing documented declines in their host fish (White Perch) with potentially devastating impacts on the Yellow Lampmussel's life cycle and recruitment. Other threats include residential and commercial shoreline development, particularly around Blacketts Lake and the Sydney River system, and other land-based activities such as agriculture, forestry and mining that may affect aquatic habitat and water quality though shoreline alteration (e.g., removal of riparian vegetation) and associated pollution (e.g., runoff, nutrient loading and sedimentation). Water management and dam maintenance are potential future threats as changes to water levels could harm freshwater mussels (e.g., drawdown could leave them stranded on the shoreline) and poor maintenance of infrastructure could impede host fish movement. Current management of Pottle Lake in particular affords a level of protection (e.g., limited development, limited access, regular water quality monitoring, etc.) but could be subject to changes in future. Lower impact threats include recreational activities such as boating which could damage mussels and increase pollution in some waterbodies, and predation by native muskrats (noted around Blacketts Lake) although hunting and fishing that remove muskrats or Chain Pickerel from Yellow Lampmussel habitat could have a net benefit. Climate change effects are highly uncertain but could include rising sea levels (e.g., breach of dams, intrusion of salt water into freshwater systems), droughts, temperature increases and storm surges.

The overall threat impact to Yellow Lampmussel is Very High. The overall threat impact considers the cumulative impacts of multiple threats. A description of each threat is provided below, in order of decreasing level of concern.

***Invasive & other problematic species & genes – Invasive non-native/alien species (Very High)***

Chain pickerel (*Esox niger*) is an invasive species that was illegally introduced to Blacketts Lake in 2010 for sport fishing purposes (White 2018a). Chain pickerel is a known predator of White perch (*Morone americana*), the host fish for Yellow Lampmussel. Mitchell et al. (2010) found that Chain Pickerel have a dramatic impact on native fish communities within lakes where they are introduced. These impacts include reducing abundance and diversity within fish communities, the total loss of small-bodied fish species, and the truncating of fish body size distribution, leaving only larger fish like large White Suckers (*Catostomus commersoni*). The introduction of Chain Pickerel also likely alters the trophic food web complexity.

Chain Pickerel is now well established in Blacketts Lake, the connected waterbodies of Gillis Lake, and the upper Sydney River (White 2018a; 2018b). The invasive fish species has had a severe negative impact on the White Perch population in these waterbodies, severely depleting or extirpating their numbers and potentially rendering Yellow Lampmussel unable to reproduce. There were no Yellow Lampmussel under six years of age found in Blacketts lake during a 2018 study, suggesting that the Blacketts Lake population is no longer a breeding population (White 2018a; 2018b). It does not appear likely that Chain Pickerel will naturally migrate from Blacketts Lake to one of the other lakes that contain Yellow Lampmussel due to the fact that the high salinity Sydney Harbour presents a barrier to their movement (A. Lowles, personal communication, February 15, 2022). However, it is possible that Chain pickerel will be illegally transferred and introduced to the other Nova Scotia lakes where Yellow Lampmussel occurs. This would have a catastrophic impact on Yellow Lampmussel in Nova Scotia.

In addition to Chain Pickerel, several other invasive species pose a potential future threat to Yellow Lampmussel. The Zebra Mussel (*Dreissena polymorpha*) is not yet present in Nova Scotia but poses a severe threat to freshwater mussel populations elsewhere in North America, as it has the potential to extirpate native species (Ricciardi et al. 1998). Although previous reports have suggested there was a low risk of Zebra mussel becoming established in the Sydney River (COSEWIC 2004), moss balls infected with Zebra mussels were confirmed in Nova Scotia pet stores in 2021 (Fisheries and Oceans Canada 2021). Moss ball sales for use in home aquariums were halted in Nova Scotia in response to the risk of Zebra mussel infestation, however this demonstrates one possible pathway through which Zebra Mussels could be introduced to Nova Scotia lakes in future.

The Chinese Mystery Snail (*Cipangopaludina chinensis*) is an invasive species that is established in several lakes in Nova Scotia (Kingsbury et al. 2021). Chinese Mystery Snails can be more resistant to predation than native snail populations due to their size and strong operculum. Chinese Mystery Snails can alter nitrogen: phosphorus ratios, which can contribute to eutrophication, impacting the health and survival of other aquatic species. Modelling by Kingsbury et al. (2021) indicates that suitable habitat for

Chinese mystery snail overlaps with Yellow Lampmussel habitat, and that there is potential for Chinese mystery snail to become widespread in Nova Scotia.

Neither Zebra mussels nor Chinese mystery snails are currently found in Yellow Lampmussel habitat in Nova Scotia but pose a potential future threat. There may also be additional invasive species introduced in the future.

***Residential & Commercial Development – Housing & Urban Areas (Medium)***

Blacketts Lake and the upper Sydney River system have significant and increasing commercial and residential development along their shorelines (Fisheries and Oceans Canada 2010) and Forresters Lake may be subject to development in the future. Direct impacts to Yellow Lampmussel (e.g., crushing, removal, habitat destruction) could occur from the construction or maintenance of docks and wharves, and other shoreline development activities that result in aquatic habitat destruction and degradation.

Removal of riparian vegetation during shoreline development also causes a suite of impacts on aquatic habitat including increased bank erosion, sedimentation, increased water temperatures, pollution, etc. Effects of shoreline development on water quality (e.g., pollution, runoff, nutrient loading) and habitat (e.g., water temperatures, sedimentation) are discussed further below.

***Natural system modifications – Dams & water management/use (Medium)***

Blacketts Lake and Pottle Lake are both dammed and subject to management for potable water supply. Blacketts Lake was once a primary domestic water supply and remains a backup water supply for CBRM and an industrial water supply for SYSCO (Sydney Steel Corporation) (Fisheries and Oceans Canada 2010). It is dammed at the lower end where it meets the Sydney River and allows fish passage through a fish ladder. Water quality is still regulated under the Nova Scotia *Environment Act (1994-5)* but this could change in future if the area ceases to be a backup. Pottle Lake is the current drinking water supply for CBRM's Northside (CBRM Water Utility 2013). As such, it is subject to extensive management including research, monitoring and controlled access. It is dammed on its southeast arm where water is drawn into the water treatment plant. Water levels are managed at the outflow using a stop log structure, water quality is monitored on a regular basis, and activities such as boating, fishing and swimming are prohibited in the lake in accordance with its Protected Water Area Designation (CBRM Water Utility 2013). While the level of management and oversight by CBRM afford current protections and offer opportunities to collaborate on conservation activities, there is potential for conflicting interests in future, such as artificial drawdown to meet water demands in drought conditions which could expose mussels in shallow areas.

Improper maintenance of dam infrastructure could also pose a future threat to Yellow Lampmussel as dams can create a barrier between the mussels and their fish hosts. By

blocking host fish from swimming to mussel beds upstream, dams can prevent freshwater mussels from completing their life cycle (Liu et al. 1996). The Sydney River dam, which separates Blacketts Lake from the Sydney River, could impede fish movement into the lake if the fish ladder associated with the dam was not well maintained. In Pottle Lake, the dam at the water treatment plant could have a similar effect. However, the dam and fish ladder at Pottle Lake was inspected in 2017 and found to be in good working condition (White 2018b) and a new fish ladder was recently installed at the Sydney River dam (White 2018b).

A breach of the Sydney River dam could reduce water levels in the river and could allow for the intrusion of saltwater upstream of the dam (Fisheries and Oceans Canada 2010). This would destroy Yellow Lampmussel habitat and kill mussels in the upper Sydney River. The dam is currently owned and maintained by Nova Scotia Lands Corporation (NSLC) and is subject to Canadian Dam Association Safety and Maintenance Regulations. Proper maintenance of dam infrastructure should be monitored in future.

***Pollution – Household sewage & urban waste water (Medium)***

Pollution associated with urban shoreline development could lead to the degradation or destruction of aquatic habitat and deteriorating water quality, particularly in the Sydney River system. This was identified as one of the primary threats to Yellow Lampmussel in the federal management plan (Fisheries and Oceans Canada 2010). In particular, sedimentation (siltation) from shoreline activities such as construction and property maintenance can affect benthic habitat and harm freshwater mussels. Yellow Lampmussel prefer sandy substrate, as it can be difficult for the species to maintain reproductive and filtering positioning in soft, silty substrate (COSEWIC 2004). Fine sediments may clog mussels' filtration apparatus, interfere with filter feeding and respiration, and lead to mussel death (Fuller 1974). Increased sediment concentrations have been correlated with declines in mussel fertilization success and glochidial development and ultimately reproductive failure (Goldsmith et al. 2021). Increased sedimentation / siltation can also smother and bury burrowing species like Yellow Lampmussel (Fisheries and Oceans Canada 2010).

Effects of pollution on water quality are also a concern for Yellow Lampmussel as healthy mussel and host fish populations are dependent upon good water quality (Fisheries and Oceans Canada 2010). Runoff from pesticides and fertilizers used in property maintenance, and localized inputs from sewage and septic tanks can cause eutrophication in nearby waterbodies. Approximately 45% of homes in Nova Scotia have an on-site sewage disposal system, including septic tanks. Nutrient loading from septic tank overflow can promote algal and aquatic plant growth, which can reduce oxygen levels and degrade water quality. Rain events can also cause overflow in treatment plants (Fisheries and Oceans Canada 2010; US-EPA 2021). Juvenile survival and establishment of freshwater mussels has been found to be negatively associated with phosphate loadings, whereas adult survival was negatively correlated with nitrate

loading (Fuller 1974). Low levels of oxygen are related to increased stress and mortality in freshwater mussels (Sparks & Strayer 1998).

Shoreline development often involves removal of riparian vegetation which exacerbates these impacts on aquatic habitats. Intact, vegetated riparian zones play a key role in regulating the physical, chemical and biological health of aquatic ecosystems (Collison and Gromack 2022). Riparian zones act as sediment stabilizers and water quality filters and their removal can impact mussels by leading to higher rates of runoff, erosion and sedimentation / siltation. Removal of riparian vegetation can also result in increased nutrient flow into waters (Dosskey et al. 2010; Mondal and Patel 2018).

In addition to nutrients (e.g., nitrogen, phosphorous, other organic matters) and bacteria found in municipal wastewater effluents, pharmaceuticals and personal care products are becoming a concern to the health of aquatic species and ecosystems (Blair et al. 2013; Srain et al. 2020). Gagné et al. (2006) demonstrated that pharmaceuticals and personal care products found in municipal wastewater discharge have the potential to cause adverse effects on the immune system of freshwater mussels.

Finally, roads and road maintenance can cause contamination of nearby waterbodies, with runoff from road salt in winter months (Paschka et al. 1999) and herbicides used for management of roadside vegetation in spring and summer months (Huang et al. 2004). Similarly, vegetation clearing and herbicide use along power line right-of-ways can result in runoff to adjacent waterbodies (Nova Scotia Environment and Labour, n.d.). All known areas of Yellow Lampmussel habitat are less than 1 km from a paved road and less than 1 km from a power line right-of-way. Pesticides can affect aquatic ecosystems both directly, by contaminating water, and indirectly through the loss of riparian vegetation and reduction in food supply for fish and other aquatic organisms (Nova Scotia Environment and Labour, n.d.; Huang et al. 2004; Schäfer et al. 2011). It is not yet known how these contaminants may affect Yellow Lampmussel.

### *Human intrusions & disturbance – Recreational activities (Low)*

Recreational boating in Blacketts Lake and Forresters Lake might pose risk to Yellow Lampmussel, with mussels being crushed at boat launch areas. There is also potential for gas and oil pollution associated with boating as well as fuel leaks to contaminate the surrounding water. Note that boating, fishing and swimming are prohibited in Pottle Lake due to its Protected Water Area Designation (CBRM Water Utility 2013).

### *Invasive & other problematic species & genes – Problematic native species (Low)*

Zahner-Meike and Hanson (2001) have identified Muskrat (*Ondatra zibethicus*) predation as a threat to endangered mussel populations. Yellow Lampmusel shells have been observed in muskrat middens in Nova Scotia, and muskrats appear to be the main predator of Yellow Lampmussel in the Sydney River watershed as well as Forresters

and Pottle Lake (COSEWIC 2004, Douglas 2016). Based on complete excavation of three midden sites on Blacketts Lake, the predation rate was 10.5 (± 8.7 SD) Yellow Lampmussel per week. Similar predation rates are observed in all Yellow Lampmussel lakes (Douglas 2016). Muskrat predation occurs mainly during winter months when other preferred food sources are not available. Muskrats are mainly herbivores and are known to prey heavily on mussels when vegetation is scarce (Edelman et al. 2015). Muskrats and mussels have evolved together and the impact of muskrat predation on healthy populations of Yellow Lampmussel is likely low. However, muskrat predation could pose a more severe threat to the Blacketts Lake population because Yellow Lampmussel in that lake have been observed to have low or no recruitment due to the unavailability of their fish host,

***Pollution – Industrial & military effluents (Low)***

Abandoned mines and quarries can have a negative impact on freshwater ecosystems, mainly through uncontrolled effluent discharge and leaching (Vendrell-Puigmitja et al. 2020). Metal and coal mines can also be a source of acid mine drainage (AMD), releasing acidic runoff and dissolved heavy metals into watercourses downstream (Akcil and Koldas 2006; Trudell and White 2013). There are several non-operational mines in the Sydney River watershed (3 coal and 1 iron (Hennick & Poole 2020)) that could be contributing polluted effluent to the system (Hennick et al. 2014), with the closest mine being <500 m from Yellow Lampmussel habitat. The are also many open drillholes from exploration activity in the Blacketts Lake and Forresters Lake watersheds (O'Neill & Poole 2016). It should be clarified whether these abandoned mines and drillholes are contributing runoff or acid mine drainage to nearby waterbodies.

There is an auto-salvage yard approximately 150 m from the shoreline of Forresters Lake (White 2018a). Effluent from auto-salvage yards has been shown to contain contaminants that are harmful to fish, such as heavy metals (Shostell and Harson 2006). Vehicle salvage yards are required to update their spill contingency plan annually and make it available to Nova Scotia Environment (Province of Nova Scotia 2020). However, metals and other contaminants could be introduced to the lake if employees do not follow management best practices regarding environmental stewardship.

***Pollution – Agricultural & forestry effluents (Low)***

The presence of farms in the vicinity of Forresters Lake and Blacketts Lake is a potential contributor to pollutants in these systems. Agricultural runoff can result in excess sediment, nutrients, and chemicals in receiving waterbodies (Schoonover et al. 2005), which can cause habitat and water quality degradation, as discussed above. Runoff from manure piles at horse farms near Blacketts Lake and Forresters Lake could be contributing to nutrient overload in the lake.

Removal of riparian vegetation for agriculture and forestry also causes excess runoff, erosion, sedimentation / siltation and pollution with detrimental effects on mussels and aquatic habitat, as discussed above.

***Human intrusions & disturbance – Work & other activities (Negligible)***

Research activities may include removing mussels from their habitat (e.g., voucher specimens) or field surveys such as timed and quadrat searches, in which researchers enter mussel habitat and excavate sediment and may occasionally cause accidental harm (e.g., crushing, burying). Note that most research is non-destructive (e.g., eDNA, tissue swabs, tag-recapture) and permits are required by province of Nova Scotia to conduct research on at-risk mussels.

***Natural system modifications – Other ecosystem modifications (Unknown)***

A number of land-based activities such as agriculture, forestry, road construction, etc. may involve removal of riparian vegetation with resulting impacts on Yellow Lampmussel habitat; these include increased bank erosion, sedimentation / siltation, runoff and pollution (discussed above) as well as other ecosystem modifications including increased water temperature through removal of canopy shading and changes to vegetation and fish habitat. The specific effects of these changes on Yellow Lampmussel are not known.

Other ecosystem changes may result from control methods for invasive fish, including mechanical removal (e.g., fishing, electrofishing) or water treatment with chemicals such as rotenone which has been used elsewhere in Nova Scotia (e.g., https://novascotia.ca/news/release/?id=20220908002). There are no current plans to use rotenone in Blacketts Lake.

Molluscicides have been used elsewhere to control host snail populations of Swimmer's Itch or cercarial dermatitis, an allergic reaction in humans to various trematode parasites that has been reported in Blacketts Lake (Fisheries and Oceans Canada 2010). While the use of molluscicides is a direct threat to Yellow Lampmussel 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 (Fisheries and Oceans Canada 2010; 2017).

## 5. POPULATION AND DISTRIBUTION OBJECTIVES

***Viable status for recovery***

The limited distribution of Yellow Lampussel in just three watersheds in Nova Scotia and the fragmented nature of its habitat make it vulnerable to a number of threats that could impact or exterminate entire sub-populations. Due to a lack of information about

historical distribution and population trends, it is unclear whether it was previously more widespread or abundant in the province. The recent discovery of two new sites psuggests that increased search effort could reveal new occurrences. More research is needed to determine the viable status for recovery for Yellow Lampmussel, intended as a long-term goal of removing the species from the NSESA. It is possible that Yellow Lampmussel is naturally rare in Nova Scotia and will always be limited to a small number of watersheds; as such, the measures outlined in this document to reduce or eliminate threats may not result in de-listing of the species.

The long-term recovery goal (>20 years) for Yellow Lampmussel is to **maintain and promote a self-sustaining and ecologically functioning population within the province**. In keeping with the federal management plan (Fisheries and Oceans Canada 2010), this includes the following objectives:

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

A long-term numerical population goal is not established at this time, due to uncertainty about natural distribution and population trends. Research should focus on monitoring population size over time to establish baseline trend data at known sites, as well as surveys of additional waterbodies for potentially undiscovered populations. Research should also consider the potential for experimental relocation of individuals, either to increase distribution and population size in future or maintain current numbers in the face of severe threats (e.g., Chain Pickerel). The lack of recruitment observed currently in Blacketts Lake suggests interventions for population rescue may become necessary.

### *Population and distribution objective*

The short-term population and distribution objective for the recovery of Yellow Lampmussel is to continue to monitor the current provincial population of 3,757,000 (± 747,800 SE) and to maintain functioning sub-populations in the three watersheds in its current range in Cape Breton (i.e., no net loss of numbers of individuals or area of occupancy) over five years. This should include monitoring of mussel bed density and recruitment. Note that current population numbers should be used as a benchmark rather than a specific numerical population goal due to uncertainty resulting from challenging survey conditions; the standard error allows for 20% fluctuation around the mean.

### *Rationale*

Population and distribution objectives assist with the identification of activities needed for recovery, and for Yellow Lampmussel are based on the best available information (White 2015; 2017; 2018a; 2018b; White et al. 2022). Surveys performed in 2018-2019 offer the most accurate population estimate to date of 3,757,000 (± 747,800 SE) individuals, which represents an increase over 2002 numbers (1,298,400 individuals) (COSEWIC 2004). This increase is primarily due to the discovery of two additional sites (i.e., Pottle Lake and Forresters Lake) between 2002 – 2015. Prior to 2002, there are no detailed historical data on which to base population trends.

The short-term population and distribution objective of continuing to monitor the current provincial population of 3,757,000 (± 747,800 SE) individuals and maintaining functioning sub-populations in all three watersheds in its known range over five years aims to enhance current knowledge of population size and trends and prevent further population decline, while allowing for some landscape-wide natural fluctuation. Current population numbers provide a foundation and additional survey data will continue to build and refine estimates of population size over time. Monitoring data, together with surveys of additional waterbodies for potentially undiscovered populations will help support the long-term goals above.

Additional research is required to consider the potential for experimental relocation of individuals, and the role this could play in recovery planning. The current lack of recruitment in Blacketts Lake due to predation of White Perch by Chain Pickerel suggests that mussel population numbers will continue to decline in that system if the situation remains unchanged. Although relocation of mussels carries ecological risks, intervention may be required to rescue what currently represents almost 40% of the known Yellow Lampmussel population. Careful evaluation of the pros and cons of all available options for Blacketts Lake including management of Chain Pickerel and relocation of Yellow Lampmussel should be considered in that context. The longer-term possibility of establishing Yellow Lampmussel outside of its current extent to expand its overall distribution and population size also requires careful risk assessment to determine the feasibility and advisability of such actions.

# 6. BROAD STRATEGIES AND GENERAL APPROACHES TO RECOVERY

## 6.1 Actions Completed or Underway

Extensive reporting on conservation activities undertaken in support of the federal Management Plan for Yellow Lampmussel is available from Fisheries and Oceans Canada, for the period 2010-2015 (Fisheries and Oceans Canada 2017). This covers activities in both New Brunswick and Nova Scotia and can be found here: https://wildlife-species.canada.ca/species-risk-registry/virtual_sara/files/MpPr-YellowLampmussel-v00-2017Jan25-Eng.pdf.

Additional activities undertaken in support of Yellow Lampmussel recovery in Nova Scotia since 2015 include:

- Continuation of a multi-faceted, multi-year research project on Yellow Lampmussel at Cape Breton University including components addressing the species' life history, reproduction, population dynamics and threats, as well as field detection and identification and regular surveys and monitoring (White 2015; 2017; 2018a; 2018b; White et al. 2022).
- Population monitoring conducted as part of the research project above, and to meet objectives of the federal management plan (Fisheries and Oceans 2010), including development of monitoring protocols (White 2015; 2017; 2018a; 2018b; 2022), eDNA primers (Button-Sibley 2022) and collection of data to estimate the density, age/size structure, and sex ratio of Yellow Lampmussel within the three lakes (White 2015; 2017; 2018a; 2022).
- Development of the *Aquatic Invasive Species Regulations* under the federal *Fisheries Act*, which came into effect in May 2015, aimed at preventing the spread and introduction of invasive species in Canadian waters, and managing them once introduced (Fisheries and Oceans Canada 2019).
- Continuation of monitoring programs for invasive fish and Yellow Lampmussel host fish by the Nova Scotia Department of Fisheries and Aquaculture (NSDFA):
    - Pottle Lake was thoroughly sampled by boat electrofishing and no invasive fish were found (2021).
    - White Perch populations were monitored in Blacketts Lake (2021).
- A national response to the sale of aquarium moss balls in 2021 which were accidentally contaminated with Zebra Mussels was coordinated by Fisheries and Oceans Canada; sales were halted and the public was encouraged to check moss balls and dispose of them properly (Fisheries and Oceans Canada 2021).
- Inclusion of an annual insert about invasive species in the NSDFA's Nova Scotia Anglers' Handbook describing how recreational anglers and fishers can take actions to prevent the spread of aquatic invasive species (2015; ongoing).
- Formation of the Nova Scotia Invasive Species Council (NSISC) in 2018 from the former Invasive Species Alliance of Nova Scotia which resulted in increased stakeholder engagement and public outreach efforts on invasive species awareness through a new website, social media accounts, public presentations and publications, and a number of behaviour change campaigns such as "Clean Drain Dry", encouraging people to clean, drain and dry their boats when moving between watersheds to prevent the spread of aquatic invasive species (see https://nsinvasives.ca/). Other activities include:
    - Coordination with NSDFA to update the invasive species insert in the Nova Scotia Anglers' Handbook to align with Clean Drain Dry and Don't Let it Loose campaigns (2020-21)
    - Creation and promotion of an invasive species project on iNaturalist to encourage public reporting of invasive species occurrences (2021)

- Development of various communication and outreach materials tied to the Clean Drain Dry and Don't Let It Loose campaigns (e.g., stickers, handout materials) (2021; ongoing)
- Installation of 17 Clean Drain Dry signs at boat launches throughout the province (2021) and purchase of 15 additional Clean Drain Dry signs and 15 Don't Let it Loose signs to be installed at additional boat launches and popular fishing locations (2022; ongoing)
- Publication of a second edition of the "*Invasive Species in Nova Scotia Identification and Information Guide*" in partnership with the Mersey Tobeatic Research Institute, to encourage the public to prevent the further introduction of Chain Pickerel, Smallmouth Bass and Zebra Mussels and providing information on stewardship actions and reporting (2022).
- Development of a reporting network and coordinated, centralized data management and mapping platform for tracking invasive species distributions (iMap Invasives + EDDMapS) (2022; ongoing)
- Purchase of 7 boat cleaning stations to install at and support compliance with Clean Drain Dry recommendations (2022; ongoing)

## 6.2 Options for Recovery

The following table (Table 3) summarizes recovery actions and specific steps recommended to address threats and achieve successful recovery of Yellow Lampmussel in Nova Scotia, along with their priority and approximate costs.

**Table 3.** Recovery options planning table.

| **Recovery Measures** | **Threats Addressed*** | Actions | **Priority**** | **Cost***** | **Benefit** |
|---|---|---|---|---|---|
| Habitat Protection, Management and Stewardship | | | | | |
| Protect Yellow Lampmussel habitat through stewardship, land purchase and conservation easements | 1.1, 6.1, 6.3, 7.3, 9.1, 9.2, 9.3 | ● Develop stewardship agreements with private landowners to promote healthy shoreline activities within Yellow Lampmussel habitat.<br>● Provide opportunities for landowners to make ecological land donations or, if they wish to retain the land, enter into conservation agreements. | M | $$$$ | Habitat protection and enhancement; threat reduction; stakeholder investment in SAR recovery |
| Evaluate options for rescue of the Blacketts Lake sub-population in light of declining recruitment | 8.1 | ● Identify options to reverse current population trends in Blacketts Lake (e.g., Chain Pickerel management, alternate fish hosts, relocation of Yellow Lampmussel)<br>● Conduct a risk assessment to evaluate the pros and cons of available options<br>● Develop an action plan with timelines and criteria for measuring progress | H | $$ | Population protection; threat reduction |

| | | | | | |
|---|---|---|---|---|---|
| Evaluate a long-term conservation strategy to augment Yellow Lampmussel population and establish the species outside of its current extent | All threats | ● Explore the possibility/feasibility and pros and cons of translocation of individuals to new areas that have been identified to provide suitable habitat and have healthy host fish populations (i.e., with no Chain Pickerel present) to reduce threats, augment the population and/or increase its distribution.<br>● Identify lakes and rivers that have habitat suitable for Yellow Lampmussel in Nova Scotia. | L | $$ | Habitat protection and expansion; increase in population size |
| Surveys and Monitoring | | | | | |
| Conduct ongoing monitoring of Yellow Lampmussel population | All threats | ● Coordinate with Fisheries and Oceans Canada to support a monitoring plan with standardized survey approaches and timelines.<br>● Monitoring should include tracking of changes in Yellow Lampmussel population density and recruitment over time.<br>● More frequent monitoring is needed to track the impact of Chain Pickerel on Yellow Lampmussel reproduction in Blacketts Lake (look for evidence of recruitment success).<br>● Establish baseline measurements of for White Perch abundance (possibly using eDNA) and monitor to record changes over time. | H | $ | Population and distribution knowledge to support recovery actions. |
| Conduct surveys to identify and track threats | All threats | ● Conduct regular monitoring for the presence of Chain Pickerel or other potential invasive species within Forresters and Pottle Lake. | H | $ | Increased knowledge of threats and their impacts; early warning of serious |

| | | | | | |
|---|---|---|---|---|---|
| | | ● Conduct regular monitoring of dams and fish ladders to ensure passage of fish hosts into Yellow Lampmussel sites.<br>● Conduct monitoring of Yellow Lampmussel habitat to identify any other threats or disruptive activities that may have a negative effect (e.g., changes in predation, recreational activity, new shoreline development, etc.) | | | impacts. |
| Conduct surveys of potential sites to identify possible new occurrences of Yellow Lampmussel | All threats | ● Conduct surveys of sites with habitat suitable for Yellow Lampmussel where Yellow Lampmussel may occur but has not been previously/adequately searched/documented. | H | $ | Population and distribution knowledge to inform recovery planning process. |
| Communication, Outreach and Education | | | | | |
| Increase landowner awareness about the presence and status of Yellow Lampmussel in waterbodies adjacent to private land | 1.1, 6.1, 7.3, 8.1, 9.1, 9.2, 9.3 | ● Develop digital resources (e.g., factsheets, videos, best management practices) summarizing information about the ecology of Yellow Lampmussel and what activities are beneficial or harmful (like Chain Pickerel).<br>● Targeted outreach and education needed within local communities, schools, Indigenous groups, ENGOs, Industry, etc.<br>● Provide information to landowners in relevant areas (i.e., core habitat and surrounding watershed) to inform them about species present on their lands and their responsibilities as landowners with species at risk.<br>● Attach informative statement and relevant contact information to transactional | H | $ | Habitat protection and enhancement; increased awareness and public engagement; stakeholder investment in SAR recovery. |

| | | | | | |
|---|---|---|---|---|---|
| | | processes (e.g., land purchase) and permit applications. | | | |
| Define / clarify responsibilities of various agencies municipal, provincial, and federal departments to aid in the protection of Yellow Lampmussel | 1.1, 6.1, 7.3, 8.1, 9.1, 9.2, 9.3 | ● Define responsibilities and communication pathways between provincial, municipal and non-government organizations responsible for the management of land on which core habitat occurs.<br>● Provide detailed information to relevant agencies about Yellow Lampmussel distribution, ecology and conservation.<br>● Work with CBRM to ensure continued consideration of Yellow Lampmussel conservation in the management of Pottle Lake. | M | $ | Habitat protection and enhancement; increased cooperation and efficiencies. |
| Law, Policy and Enforcement | | | | | |
| Core habitat requirements and considerations | 1.1, 6.1, 7.1, 7.3, 8.1, 8.2, 9.1, 9.2, 9.3 | ● Define and designate core habitat under the *Nova Scotia Endangered Species Act*.<br>● Work to eliminate threats on crown lands adjacent to known occurrences and develop Special Management Practices for Yellow Lampmussel. | H | $ | Habitat protection; threat reduction. |
| Enforce legislation and policies related to resource extraction and other development activities in core habitat | 1.1, 7.3, 9.1, 9.2, 9.3 | ● Enforce existing regulations pertaining to shoreline development and setbacks for riparian zones<br>● Ensure restrictions of mining activities that may impact the Sydney River and Forresters Lake watersheds. | M | $ | Habitat protection; threat reduction. |
| Research to Address Knowledge Gaps | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Conduct research on Yellow Lampmussel biology and ecology | All threats | ● Form partnership(s) with local indigenous groups, local governments, universities, and non-governmental organizations.<br>● Gather traditional indigenous knowledge on the biology, habitat or ecological requirements of Yellow Lampmussel and their fish hosts and integrate it into recovery planning.<br>● Conduct research on Yellow Lampmussel population and reproductive biology focusing on fish host interactions.<br>● Determine genetic relationships within and between Yellow Lampmussel populations in Nova Scotia and elsewhere.<br>● Evaluate experimental relocation trials to refine techniques to support artificial migration. | H | $$ | Increased population and distribution knowledge to support recovery planning. |
| Conduct research on Yellow Lampmussel habitat requirements | All threats | ● Conduct research on Yellow Lampmussel habitat including water quality and sediment properties.<br>● Conduct habitat manipulation studies such as creating areas of differing sediment types and vegetation cover. | M | $$ | Increased population and distribution knowledge to support recovery planning. |
| Conduct habitat modelling for Yellow Lampmussel and assess habitat suitability in currently unoccupied waterbodies. | All threats | ● Conduct habitat modelling based on hydrology, geology, tree cover, bathymetry (using aerial imagery and/or LiDAR) and indicator species from the AC CDC database.<br>● Assess habitat availability of potentially suitable new areas (e.g., hydrology, | M | $$ | Potential increase in suitable habitat. |

| | | | | | |
|---|---|---|---|---|---|
| | | calcium, connection to the ocean, salinity, pH).<br>● Conduct surveys to identify sites outside the current population extent where transplanting could be used to expand the distribution of Yellow Lampmussel into new suitable habitats. | | | |
| Assess effects of threats such as dams, riparian zone disturbance, human activity, etc. | | ● Conduct multi-year surveys to assess the effects of threats on Yellow Lampmussel.<br>● Study impacts of dams on Yellow Lampmussel and fish host and monitor for maintenance or flooding.<br>● Consider mitigation measures if necessary, e.g., stocking of fish host to allow for ecological succession and the persistence of Yellow Lampmussel. | M | $$ | Increased understanding of threats; threat reduction. |
| Increase research and educational outreach on the impacts of climate change on species at risk such as Yellow Lampmussel. | | ● Conduct research on drought, temperature, and water quality sensitivity of glochidia and adults.<br>● Incorporate results into outreach materials for local landowners, conservation groups, etc. | L | $$ | Increased understanding of threats. |

*Threat or Limitation should refer to the IUCN Threat Classification Table Rankings. Either the first level or second level threat ranking can be used depending on how the Broad Strategy affects the threat. Multiple threats can be addressed under a single Recovery Measure.
**Priority should be classified as High(H), Medium(M), or Low(L). "Priority" is a qualitative measure of the relative degree to which an approach will have a positive impact on the recovery objective. High priority conservation approaches are considered those most likely to have an immediate and/or direct influence on reaching the management objective for the species. Medium priority conservation approaches may have a less immediate or less direct influence on reaching the management objective but are still considered important measures to implement. Low priority conservation approaches will likely have an indirect or gradual influence on reaching the management objective and are more tied to increasing knowledge or public perception/education.

***Use the following to assign a cost estimate to proposed activities: $ = < 10 000; $$ = 10 000-50 000; $$$ = 50 000-100 000; $$$$=>100 000-1,000,000, $$$$$ >1,000,000.

## 6.3 Narrative to Support the Recovery Options Planning Table

The recovery of Yellow Lampmussel will require a number of coordinated activities to address threats, protect existing sub-populations and evaluate strategies for long-term conservation of the species. Recommendations include the development of an action plan to address the impacts of invasive species in Blacketts Lake, and careful evaluation of the feasibility and advisability of long-term conservation strategies such as artificial relocation of mussels to augment the existing population or increase its distribution. These will rely on continued research to better understand the species' biology, ecology and resistance to threats, including the possibility of adaptation to new fish hosts. Additional recommendations include ongoing population monitoring, the identification and protection of core habitat, outreach to landowners to raise awareness and encourage best practices around shoreline activities, and coordination between federal, provincial and municipal governments to ensure continued cooperation and enforcement of current regulations.

### *Habitat Protection, Management and Stewardship*

Habitat protection is a key component of Yellow Lampmussel recovery and one of the most effective ways to prevent loss or degradation of aquatic habitat and declining water quality due to shoreline development and other land-based activities such as agriculture and forestry; it may also help prevent the introduction of invasive fish species such as Chain Pickerel into Pottle Lake and Forresters Lake. Pottle Lake and its entire watershed are currently protected as a municipal water supply for the town of North Sydney and surrounding communities (Cape Breton Water Utility, 2013). These protections fall under the *Water Act*, now under the *Environment Act*, and include a prohibition on fishing, bathing, boating, the disposal of wastes, and the use of biocides. There is also no public or private access to the lake. These protections make this lake low risk for illegal introductions of Chain Pickerel and anthropogenic activities that would result in habitat loss.

Forresters lake, however, is surrounded by private land, much of which is currently undeveloped. Future shoreline development could negatively impact habitat quality and increased public and private access to the lake would also increase the chance of the illegal introduction of Chain Pickerel into the lake (which would have a devastating impact on the Yellow Lampmussel fish host). Purchase of land along the Forresters Lake shoreline and a surrounding buffer should be pursued to protect populations of Yellow Lampmussel. These areas could be purchased directly by government or conservation groups or protected by promoting opportunities for private landowners to make ecological land donations or enter into conservation agreements. Land purchase and protection should be supported and incentivized wherever possible to help achieve recovery objectives. Protection of land ensures the protection of Yellow Lampmusel habitat through decreased sedimentation and water quality parameter changes.

Management and stewardship activities will also be important in the recovery of Yellow Lampmussel. In light of the severe impacts of Chain Pickerel on the Yellow Lampmussel fish host populations in Blacketts Lake there is a need to evaluate options and develop an action plan for the rescue of that sub-population (representing approximately 38% of the known population in Nova Scotia). Options may include management of Chain Pickerel or translocation strategies where mussels from Blacketts Lake could be moved to another Lake with suitable habitat and fish host populations. Options would be informed by ongoing monitoring of Yellow Lampmussel recruitment and research on adaptability to alternate fish hosts. Currently, without their only known fish hosts (White Perch) in Blacketts Lake, Yellow Lampmussel appear to be unable to complete their life cycle. Sampling in 2018 and 2019 found no evidence of Yellow Lampmussel recruitment in this lake. Translocation of Yellow Lampmussel into a lake with a healthy White Perch population would allow these mussels to complete their life cycle. However, such interventions also carry ecological risks and the pros and cons need to be carefully considered. Given that Yellow Lampmussel live to up to 25 years and in 2019 there were mussels between 5 and 25 years found in Blacketts Lake, the evaluation of the need and feasibility of translocating mussels from this lake needs to be made in the next five years (by 2027).

In addition to the immediate situation in Blacketts Lake, the role of translocation in the long-term conservation of Yellow Lampmussel should also be considered. The restricted nature of its distribution leaves the species extremely vulnerable to multiple threats which can impact large proportions of the population including invasive species and unforeseen events resulting from climate change. Ongoing surveys of additional lakes may reveal new populations however, it is possible that Yellow Lampmussel is naturally rare in the province and will always be restricted to small number of watersheds. The potential role of *ex situ* conservation in species recovery should be rigorously examined and incorporated into long-term recovery planning.

### *Surveys and Monitoring*

Monitoring of Yellow Lampmussel populations is essential to collect baseline information required to understand species demographics and trends and to inform decision-making processes in the lakes where Yellow Lampmussel is known to occur. Monitoring has been initiated by Fisheries and Oceans Canada in collaboration with K. White and a standardized monitoring plan has been developed (White 2015; 2017; 2018a; 2018b). This monitoring plan includes standardized methodologies and timelines for tracking changes in population density, recruitment, and monitoring habitat parameters and threats (e.g., water quality, dams and fish ladders, etc.). The province should coordinate monitoring with Fisheries and Oceans Canada in Forresters and Pottle Lake at 5 to 10-year intervals. More focused and frequent monitoring (2-year intervals) of the Yellow Lampmussel population in Blacketts Lake is needed to assess the impact Chain Pickerel is having on the reproduction and recruitment. Baseline

measurements for White Perch abundance (possibly using eDNA) should be established in all three lakes (Blacketts, Forresters, and Pottle) to monitor and record changes in availability of Yellow Lampmussel fish hosts.

Given the drastic impact that introduction of Chain Pickerel could have on Forresters and Pottle Lakes there is a need for regular monitoring for the presence of Chain Pickerel in these waterbodies. It would likely be too late to do anything to eliminate Chain Pickerel by the time it is observed in one of these lakes (A. Lowles, personal communication, February 15, 2022). However, knowledge of Chain Pickerel introductions in either of these waterbodies would allow for decisions to be made about management.

Habitat monitoring within the three watersheds where Yellow Lampmussel occurs is also needed. Operators of the Sydney River Dam (which is managed by Nova Scotia Lands – a Provincial Crown corporation) were sent a list of the Yellow Lampmussel federal management goals, objectives and strategies in January 2015. Operators are aware of species needs and inspect the dam and fish ladders yearly and make repairs as required. Similar annual inspections are done by CBRM for the dam and fish ladder at the outflow of Pottle Lake.

In addition to monitoring known sites, it is important to survey for Yellow Lampmussel in other waterbodies within Nova Scotia. The recent discovery of two new sub-populations of Yellow Lampmussel (Pottle Lake in 2011 and Forresters Lake in 2015) indicates that there may be further undiscovered occurrences in Nova Scotia. There has been a fairly extensive survey of Cape Breton lakes with habitat suitable for Yellow Lampmussel (37 lakes) without additional new discoveries. However, there are still many lakes on the mainland with habitat suitable for Yellow Lampmussel that should be searched for the presence of the species. These surveys could be done by searching for live individuals and/or shell remains as well as through eDNA sampling.

### *Communication, Outreach and Education*

Communication, outreach and education are important elements in the recovery of Yellow Lampmussel in Nova Scotia and complementary to other recovery actions. Private landowners should be informed of any Yellow Lampmussel occurrences adjacent to their property and provided with information on the valuable ecosystem services provided by the species and what activities are beneficial or harmful to the species and its habitat. There is an opportunity to raise awareness among landowners, users and managers to advance best management practices such as reducing shoreline disturbance, maintaining riparian zones and mitigating pollution. For example, landowners could be informed through digital media and townhall meetings about the threatened status of the species and ways to mitigate threats. Another approach to ensure that landowners are aware of this is to pass this information on during property

sales transactional processes. This would ensure that all new property owners would be aware that they have a species at risk adjacent to their property.

There is a need for communication, support and cooperation between federal, provincial and municipal government agencies responsible for land and water use and associated activities. Roles and responsibilities should be clarified and training activities and support for enforcement personnel need to be undertaken on a regular basis. There is a need to provide more detailed information to the relevant municipalities as well as to other appropriate provincial (and federal) agencies about Yellow Lampmussel sites and conservation. Development officers and municipal planners review development projects and home construction. Knowing that there is an endangered species on a site can flag that site so that appropriate departments can be contacted, and any necessary restrictions can be incorporated into the development plans.

### *Law, Policy and Enforcement*

Law, policy, and enforcement augments or reinforces many of the actions identified in other sections and can be achieved through the creation of new policy, improvements to pre-existing policies, and guidance to support Species at Risk recovery. The federal management plan for Yellow Lampmussel (Fisheries and Oceans Canada 2010) highlights current protection for the species, and the progress report for the management plan (Fisheries and Oceans Canada 2017) summarizes the recovery actions completed or underway during the timeframe of the report. Both of these documents can be used to inform future policies and procedures surrounding Yellow Lampmussel and its habitat.

Identifying and designating provincial core habitat for Yellow Lampmussel would provide a legal underpinning for many of the habitat protection, stewardship and public outreach measures discussed above. Developing and enforcing legislation and policies related to urban development, resource extraction and other activities in core habitat would also help to protect Yellow Lampmussel from threats that impact aquatic habitat and water quality. Development of municipal land use by-laws, policies, stewardship agreements and guidance governing activities in watersheds where Yellow Lampmussel occur should be encouraged. Special management practices should be developed to inform activities on crown land.

Pottle Lake is currently protected by the Pottle Lake Source Water Protection Plan and the Protected Water Area designation provisions under the Environment Act. Development of a stewardship agreement with CBRM would ensure continued consideration of Yellow Lampmussel conservation in the management of Pottle Lake.

### *Research to Address Knowledge Gaps*

Additional research is needed to inform recovery planning for Yellow Lampmussel, particularly in regard to population dynamics, habitat needs, viable fish host species and the impacts of threats, including the impact that Chain Pickerel is having on the Blacketts Lake population. Research partnerships have already been formed between Fisheries and Oceans Canada and Cape Breton University; additional partnerships should be encouraged with local indigenous groups, local governments, universities and non-government organizations to promote cooperation, leverage research opportunities and ensure the integration of Mi'kmaq ecological knowledge in recovery planning.

Habitat modelling will play an important role in identifying lakes with suitable habitat, to support surveys for new, undiscovered sub-populations and/or to support ex situ conservation in the event that approach is taken. Research on climate change will also be important to help predict and mitigate impacts on the Yellow Lampmussel population.

# 7. RECOMMENDED COURSE OF ACTION(S) FOR RECOVERY

Table 4 provides the recommended course of actions for recovery of the species and the timeframe for completing these actions.

**Table 4.** Recovery actions and implementation schedule.

| **Habitat Protection, Management and Stewardship** | | **Implementation Schedule** |
|---|---|---|
| Approach 1.1 Protect Yellow Lampmussel habitat through stewardship, land purchase and conservation easements. | | |
| Action 1.1.1 | Develop stewardship agreements with private landowners to promote healthy shoreline activities within Yellow Lampmussel habitat. | 2023-2027 |
| Action 1.1.2 | Provide opportunities for landowners to make ecological land donations or, if they wish to retain the land, enter into conservation agreements. | 2023-2027 |
| Approach 1.2 Evaluate options for rescue of the Blacketts Lake sub-population in light of declining recruitment | | |
| Action 1.2.1 | Identify options to reverse current population trends in Blacketts Lake (e.g., Chain Pickerel management, alternate fish hosts, relocation of Yellow Lampmussel) | 2022-2023 |
| Action 1.2.2 | Conduct a risk assessment to evaluate the pros and cons of available options | 2023-2025 |
| Action 1.2.3 | Develop an action plan with timelines and criteria for measuring progress | 2024-2026 |
| Approach 1.3 Evaluate a long-term conservation strategy to augment Yellow Lampmussel population and establish the species outside of its current extent | | |
| Action 1.3.1 | Explore the possibility/feasibility and pros and cons of translocation of individuals to new areas that have been identified to provide suitable habitat and have healthy host fish populations (i.e., with no Chain Pickerel present) to reduce threats, augment the population and/or increase its distribution. | 2023-2026 |
| Action 1.3.2 | Identify lakes and rivers that have habitat suitable for Yellow Lampmussel in Nova Scotia. | Ongoing |

| **Surveys and Monitoring** | | **Implementation Schedule** |
|---|---|---|
| Approach 2.1 Conduct ongoing monitoring of Yellow Lampmussel population | | |
| Action 2.1.1 | Coordinate with Fisheries and Oceans Canada to support a monitoring plan with standardized survey approaches and timelines. | 2022-2027 |
| Action 2.1.2 | Include tracking of changes in Yellow Lampmussel population density and recruitment over time. | Ongoing |
| Action 2.1.3 | More frequent monitoring to track the impact of Chain Pickerel on Yellow Lampmussel reproduction in Blacketts Lake (look for evidence of recruitment success). | 2022-2027 |
| Action 2.1.4 | Establish baseline measurements of for White Perch abundance (possibly using eDNA) and monitor to record changes over time. | 2023-2025 |
| Approach 2.2 Conduct surveys to identify and track threats | | |
| Action 2.2.1 | Conduct regular monitoring for the presence of Chain Pickerel or other potential invasive species within Forresters and Pottle Lake. | 2023-2027 |
| Action 2.2.2 | Conduct regular monitoring of dams and fish ladders to ensure passage of fish hosts into Yellow Lampmussel sites. | Ongoing |
| Action 2.2.3 | Conduct monitoring of Yellow Lampmussel habitat to identify any other threats or disruptive activities that may have a negative effect (e.g., changes in predation, recreational activity, new shoreline development, etc.) | 2023-2027 |
| Approach 2.2 Conduct surveys of potential sites to identify possible new occurrences of Yellow Lampmussel | | |
| | Conduct surveys of sites with habitat suitable for Yellow Lampmussel where Yellow Lampmussel may occur but has not been previously/adequately searched/documented. | Ongoing |
| **Communication, Outreach and Education** | | **Implementation Schedule** |
| Approach 3.1 Increase landowner awareness about the presence and status of Yellow Lampmussel in waterbodies adjacent to private land. | | |
| Action 3.1.1 | Develop digital resources (e.g., factsheets, videos, best management practices) summarizing information about the ecology of Yellow Lampmussel and what activities are beneficial or harmful (like Chain Pickerel). | 2023-2025 |
| Action 3.1.2 | Deliver targeted outreach and education within local communities, schools, Indigenous groups, ENGOs, Industry, etc. | 2024-2027 |
| Action 3.1.3 | Provide information to landowners in relevant areas (i.e., core habitat and surrounding watershed) to inform them about species present on their lands and their responsibilities as landowners with species at risk. | 2024-2027 |
| Action 3.1.4 | Attach informative statement and relevant contact information to transactional processes (e.g., land purchase) and permit applications. | 2024-2027 |
| Approach 3.2 Define/clarify responsibilities of various agencies to aid in the protection of Yellow Lampmussel. | | |
| Action 3.2.1 | Define responsibilities and communication pathways between provincial, municipal and non-governmental organizations responsible for the management of land on which core habitat occurs. | 2023-2027 |
| Action 3.2.2 | Provide detailed information to relevant agencies about Yellow | 2023-2027 |

| | | |
|---|---|---|
| | Lampmussel distribution, ecology and conservation. | |
| Action 3.3.4 | Work with CBRM to ensure continued consideration of Yellow Lampmussel conservation in the management of Pottle Lake. | 2023-2027 |
| **Law, Policy and Enforcement** | | **Implementation Schedule** |
| Approach 4.1 Core habitat requirements and considerations | | |
| Action 4.1.1 | Define and designate areas of core habitat for Yellow Lampmussel under the *Nova Scotia Endangered Species Act*. | 2022-2027 |
| Action 4.1.2 | Work to eliminate threats on crown lands adjacent to known occurrences and develop Special Management Practices for Yellow Lampmussel. | 2023-2025 |
| Approach 4.2 Enforce legislation and policies related to resource extraction and other development activities in core habitat. | | |
| Action 4.2.1 | Enforce existing regulations pertaining to shoreline development and setbacks for riparian zones | Ongoing |
| Action 4.2.2 | Ensure restrictions of mining activities that may impact the Sydney River and Forresters Lake watersheds. | 2023-2027 |
| **Research to Address Knowledge Gaps** | | **Implementation Schedule** |
| Approach 5.1 Conduct research on Yellow Lampmussel biology and ecology | | |
| Action 5.1.1 | Form partnership(s) with local indigenous groups, local governments, universities, and non-governmental organizations. | 2022-2027 |
| Action 5.1.2 | Consider traditional indigenous knowledge on the biology, habitat or ecological requirements of Yellow Lampmussel and their fish hosts and integrate it into recovery planning. | 2022-2027 |
| Action 5.1.3 | Conduct research on Yellow Lampmussel population and reproductive biology focusing on fish host interactions. | Ongoing |
| Action 5.1.4 | Determine genetic relationships within and between Yellow Lampmussel populations in Nova Scotia and elsewhere. | Ongoing |
| Action 5.1.5 | Evaluate experimental relocation trials to refine techniques to support artificial migration. | 2024-2027 |
| Approach 5.2 Conduct research on Yellow Lampmussel habitat requirements. | | |
| Action 5.2.1 | Conduct research on Yellow Lampmussel habitat including water quality and sediment properties | 2023-2027 |
| Action 5.2.2 | Conduct habitat manipulation studies such as creating areas of differing sediment types and vegetation cover. | 2023-2027 |
| Approach 5.3 Conduct habitat modelling for Yellow Lampmussel and assess habitat suitability in currently unoccupied waterbodies. | | |
| Action 5.3.1 | Conduct habitat modelling based on hydrology, geology, tree cover, bathymetry (using aerial imagery and/or LiDAR) and indicator species from the AC CDC database. | 2023-2027 |
| Action 5.3.2 | Assess habitat availability of potentially suitable new areas (e.g., hydrology, calcium, connection to the ocean, salinity, pH). | Ongoing |
| Action 5.3.4 | Conduct surveys to identify sites outside the current population extent where transplanting could be used to expand the distribution of Yellow Lampmussel into new suitable habitats. | Ongoing |
| Approach 5.5 Assess effects of threats such as dams, riparian zone disturbance, human activity, etc. | | |
| Action 5.5.1 | Conduct multi-year surveys to assess the effects of threats on Yellow Lampmussel | Ongoing |
| Action 5.5.2 | Study impacts of dams on Yellow Lampmussel and fish host and monitor for maintenance or flooding | 2023-2027 |

| | | |
|---|---|---|
| Action 5.5.3 | Consider mitigation measures if necessary, e.g., stocking of fish host to allow for ecological succession and the persistence of Yellow Lampmussel. | 2024-2027 |
| Approach 5.6 Increase research and educational outreach on the impacts of climate change on species at risk such as Yellow Lampmussel. | | |
| Action 5.6.1 | Conduct research on drought, temperature, and water quality sensitivity of glochidia and adults. | 2023-2027 |
| Action 5.6.2 | Incorporate results into outreach materials for local landowners, conservation groups, etc. | 2025-2027 |

# 8. IDENTIFICATION OF CORE HABITAT

Under the Nova Scotia Endangered Species Act, core habitat is defined as “specific areas of habitat essential for the long-term survival and recovery of endangered or threatened species and that are designated as core habitat pursuant to Section 16 or identified in an order made pursuant to Section 18”. A definition for Yellow Lampmussel core habitat is included here using the best available information at the time of writing; however, given the knowledge gaps and anticipated increases in our collective knowledge of this species’ needs in Nova Scotia, this definition should be updated as soon as new information is available.

## 8.1 Core Habitat Definition and Attributes

The highly restricted distribution of Yellow Lampmussel in just three watersheds in Cape Breton County, Nova Scotia and the severity of threats posed by invasive species (e.g., Chain Pickerel) support the inclusion of all known habitat in the definition of core habitat for the species. In addition to known locations of adult Yellow Lampmussel, core habitat must consider areas frequented by the fish hosts which carry their larval stage (glochidia), which are required for completion of their life cycle. Yellow Lampmussel, like many freshwater mussel species, requires a fish host for nutrition and dispersal of glochidia (COSEWIC 2004). Their fish host, White Perch, is a semi-anadromous fish species that is known to move between fresh and brackish waters in its adult life stages to breed, tolerating salinities from 0-13 and occasionally up to 17 (Mansueti 1961; Hanks 2009; Feiner et al. 2012). All known lakes and rivers with Yellow Lampmussel have a direct connection to the ocean and are within 1.7 to 7.3 km of an estuary, which may be due to seasonal movements of semi-anadromous fish hosts. Therefore, to account for areas that may be inhabited by fish hosts carrying glochidia, core habitat must include connected tributaries upstream of Yellow Lampmussel habitat (lakes and streams within the watershed), as well as waterways connecting Yellow Lampmussel habitat downstream to estuaries. Upstream waterbodies are also considered core habitat because water quality within these areas could directly impact Yellow Lampmussel downstream.

Core habitat for Yellow Lampmussel is defined as all known waterbodies with records of Yellow Lampmussel (Blackett’s Lake, the small, connected waterways of Gillis Lake and

the upper Sydney River, Pottle Lake, and Forrester's Lake) as well as the connected waterbodies both upstream and downstream in those watersheds, including connections to the estuaries of the Sydney Harbour. In addition, a 30 m riparian buffer is added to all these waterbodies because research suggests that protection of these areas is essential for conserving populations of freshwater mussels (Pandolfi et al., 2022). A 30 m buffer is the minimum size recommended in a recent assessment of the importance of riparian zone management for fish and fish habitat protection (Collison and Gromack 2022).

In summary, Yellow Lampmussel core habitat can be identified based on the following criteria (map included in Appendix 1):

- All waterbodies with known occurrences of Yellow Lampmussel;
- All connected waterbodies (lakes and rivers/streams) either upstream or downstream within the watersheds of areas with known occurrences, including connections to the Sydney Harbour;
- A thirty-meter riparian buffer around all waterbodies with known occurrences and connected waterbodies.

The delineation of core habitat will be updated periodically as factors such as population dynamics and location of known occurrences may change over time.

### 8.2 Activities Likely to Result in the Destruction of Core Habitat

Destruction of Yellow Lampmussel core habitat would result if part of the habitat was degraded, either permanently or temporarily, such that it would not serve its function when needed by the species. Destruction may result from single or multiple activities at one point in time or from the cumulative effects of one or more activities over time and must be determined on a case-by-case basis.

Activities likely to result in destruction might occur within the core habitat boundary but might also occur outside of the core habitat. Activities that are likely to result in the destruction of Yellow Lampmussel core habitat include but are not limited to:

- Deliberate or accidental introduction of invasive species (e.g., Chain Pickerel, Zebra Mussel) to waterbodies where they are not yet present
- Shoreline development and other land-based activities that result in the loss or degradation of riparian zones and/or Yellow Lampmussel habitat, including
    - Urban/commercial development
    - Maintenance of shoreline infrastructure
    - Agricultural activities
    - Logging and wood harvesting

  - Mining, quarrying and related exploration
  - Road construction and maintenance
  - Recreational activities (e.g., boating)

- Water pollution from improper disposal of sewage or municipal wastewater, use of pesticides and fertilizers and poor management of runoff from industrial or other activities (e.g., agriculture, forestry)

- Management and maintenance of dams and fish ladders that may result in:

  - Alteration of water levels
  - Obstruction of host fish passage
  - Intrusion of salt water into freshwater systems

### 8.3 Habitat Protection / Ownership

Two of the lakes where Yellow Lampmussel occurs are currently protected to some degree. Pottle Lake is a potable water source for the Cape Breton Regional Municipality (CBRM) and is a designated Protected Water Area under the *Environment Act* (CBRM Water Utility 2013). Blacketts Lake was once a primary domestic water supply and remains a backup water supply for CBRM and an industrial water supply for SYSCO (Sydney Steel Corporation) (Fisheries and Oceans Canada 2010). It is still regulated under the Nova Scotia *Environment Act (1994-5)* but this could change in future if the area ceases to be a backup.

The area identified as core habitat for Yellow Lampmussel in this document consists of 4,172 ha, of which approximately 64% is land and 36% is water. Of the land portion, approximately 72.4% is privately owned, 21.0% is provincial land (20.8% unprotected and 0.2% protected), 4.9% is municipal, and 1.5% is unprotected federal land. It is also likely that additional waters adjacent to core habitat that are outside of Nova Scotia jurisdiction are required for the continued survival of this species. Therefore, Nova Scotia will continue to work with the federal government to manage this species.

## 9. MEASURING PROGRESS

### 9.1 Performance Indicators

The performance indicators identified below (Table 5) are a means by which progress towards population and distribution objectives can be measured. Progress will be monitored and reported on during the 5-year review process of the Recovery Plan. Performance will be assessed through the completion of actions identified under Table 5 of Section 7, *Recommended Course of Action(s) for Recovery*.

**Table 5**. Performance measures used to determine whether Yellow Lampmussel recovery objectives are being met.

| Performance Measure | Check-In |
|---|---|
| **Planning:** | |
| Number of Recovery Team meetings to discuss recovery activities and assess performance to date (minimum one per year) | Annually |
| Number of initiatives and groups involved in recovery-related projects such as monitoring and surveys, habitat mapping, research, production of educational materials, land protection efforts etc. | Annually |
| **Conservation**: | |
| Policies and guidance identified within the recovery actions have been developed and implemented | Every five years |
| Increased percentage of core habitat protected (e.g., through land acquisition, conservation agreements, Special Management Practices, etc.) | Every five years |
| Total amount of private land or number of landowners involved in stewardship | Every five years |
| Number and type of communication products that target general public, property owners, industry, government and others identified in the recovery actions table | Annually |
| Number of surveys conducted to monitor Yellow Lampmussel and host fish populations | Annually |
| Number of new Yellow Lampmussel records or documented effort to survey for new occurrences | Every five years |
| Increased cooperation between federal, provincial and municipal governments to coordinate activities and enforce existing regulations | Every five years |
| Significant knowledge gaps addressed by research | Within five to ten years |
| Threats reduced, mitigated or removed | Every five years |
| Known occurrences and population maintained | Every five years |

## 9.2 Monitoring

A Yellow Lampmussel monitoring plan is aimed at providing consistent data over time to assess population dynamics, habitat parameters and threats in Nova Scotia on an ongoing basis. Coordination with activities already underway by Fisheries and Oceans Canada will ensure a unified approach and support data sharing and cooperation.

The overall strategy involves two parts including population monitoring and threat/habitat monitoring, as follows:

**Population monitoring**

- Yellow Lampmussel population monitoring in Forresters and Pottle Lake at 5 to 10-year intervals
- More focused and frequent monitoring (2-year intervals) of Yellow Lampmussel in Blacketts Lake to assess the impact Chain Pickerel is having on reproduction and recruitment
- Baseline measurements for White Perch abundance (possibly using eDNA) in all three lakes (Blacketts, Forresters, and Pottle)

Threat/habitat monitoring

- Regular monitoring (1-2 year intervals) for the presence of Chain Pickerel in Forresters and Pottle Lakes, to enable rapid response to any new introductions
- Regular monitoring of water quality, dams and fish ladders in cooperation with partners (e.g., Fisheries and Oceans Canada, CBRM)
- Regular monitoring of shorelines to identify new threats or changes to threats (e.g., increased development, recreational activity, predation, etc.)

A standardized method for population monitoring has been developed and implemented by Fisheries and Oceans Canada in collaboration with K. White using a quadrat sampling approach. Three 30-meter areas were established for monitoring on Blacketts Lake, Forresters Lake and Pottle Lake between 2015 and 2016 (White 2015; 2016). Within each 30-meter monitoring site sampling (via viewing scopes in wade-able depths and scuba in depths deeper than 1.5 m) was carried out using 30 randomly placed 0.25 $m^2$ quadrats (90 quadrats total per lake). All live mussels at the surface and within excavated sediment were collected and identified to species and counted. All Yellow Lampmussel found were aged (via external annuli count), sexed (based on shell morphology) and measured for shell length (to the nearest mm using the posterior/anterior axis). This data was used to estimate the density, age/size structure, and sex ratio of Yellow Lampmussels within the three lakes. This data serves as baseline data and with repeated sampling over time within these established monitoring sites (5-10 year intervals) will allow for the estimation of short-term fluctuations in size of the Yellow Lampmussel population in Nova Scotia.

More detailed methodologies for threat/habitat monitoring will be developed along with field checklists. Success of this monitoring plan will be reviewed and adjusted as needed as management and recovery actions change.

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## Appendix 1: Maps of identified core habitat for Yellow Lampmussel in Nova Scotia

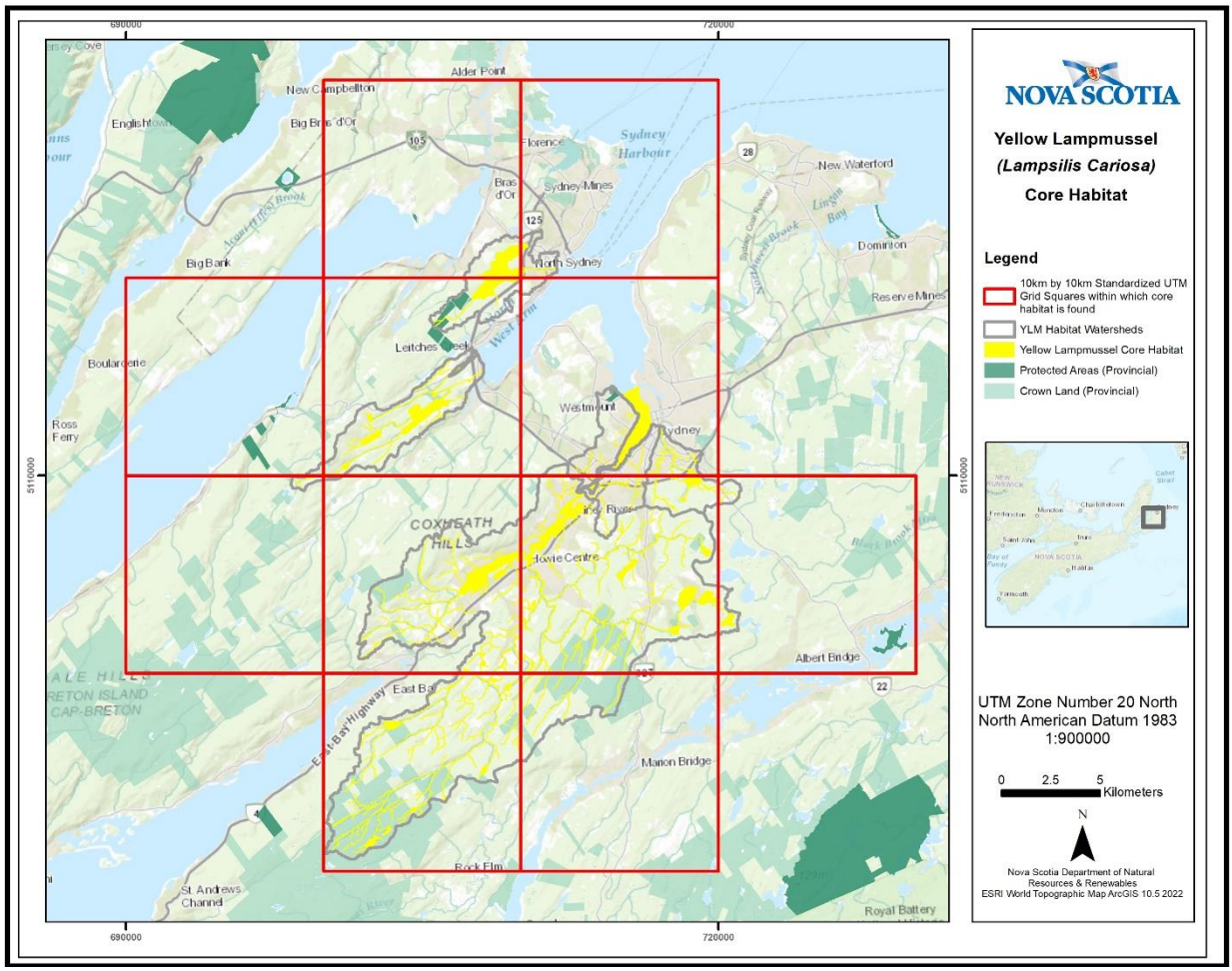


**Figure 3.** Identified core habitat for Yellow Lampmussel in Nova Scotia

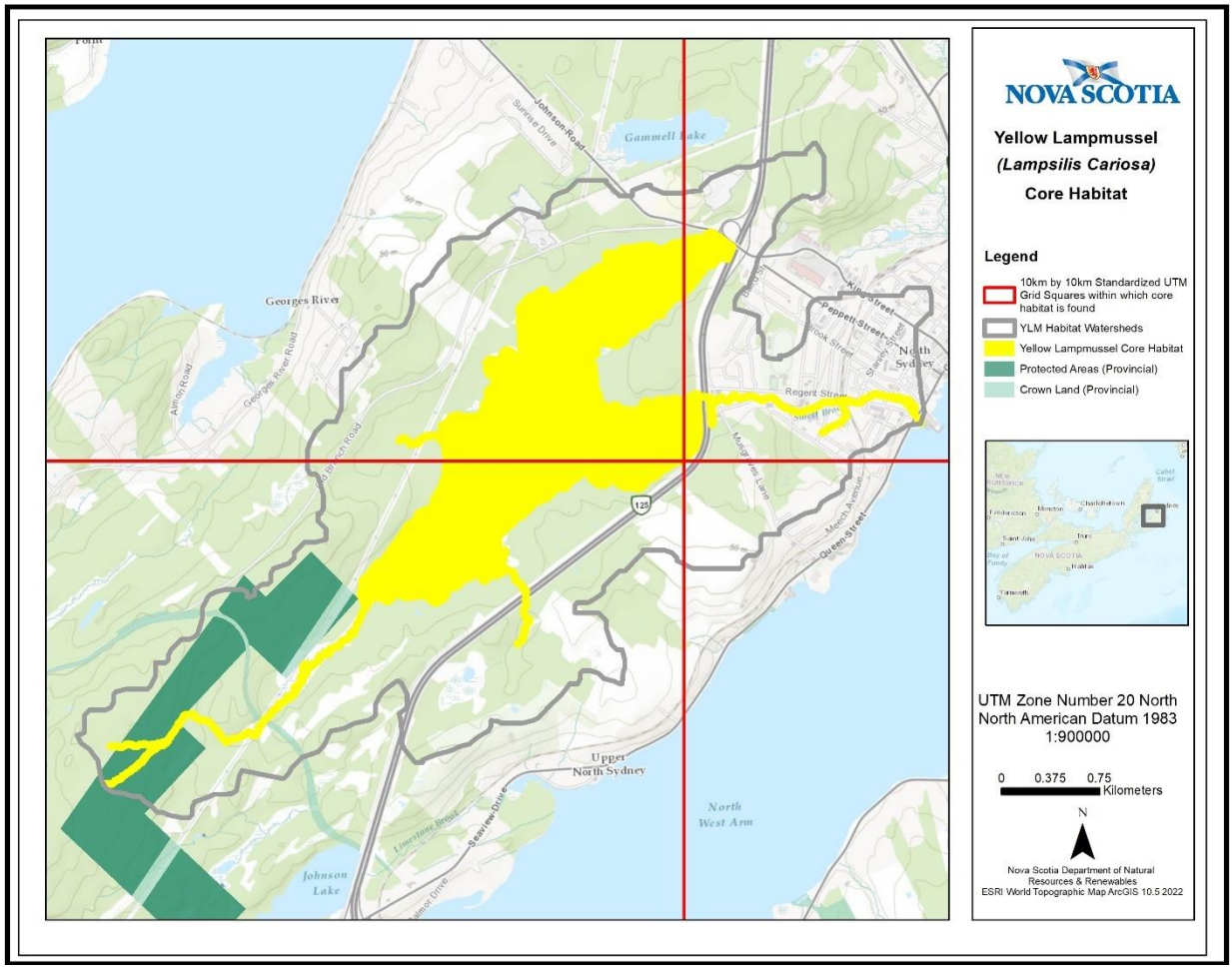


**Figure 4.** Identified core habitat for Yellow Lampmussel in the Pottle Lake watershed, Nova Scotia

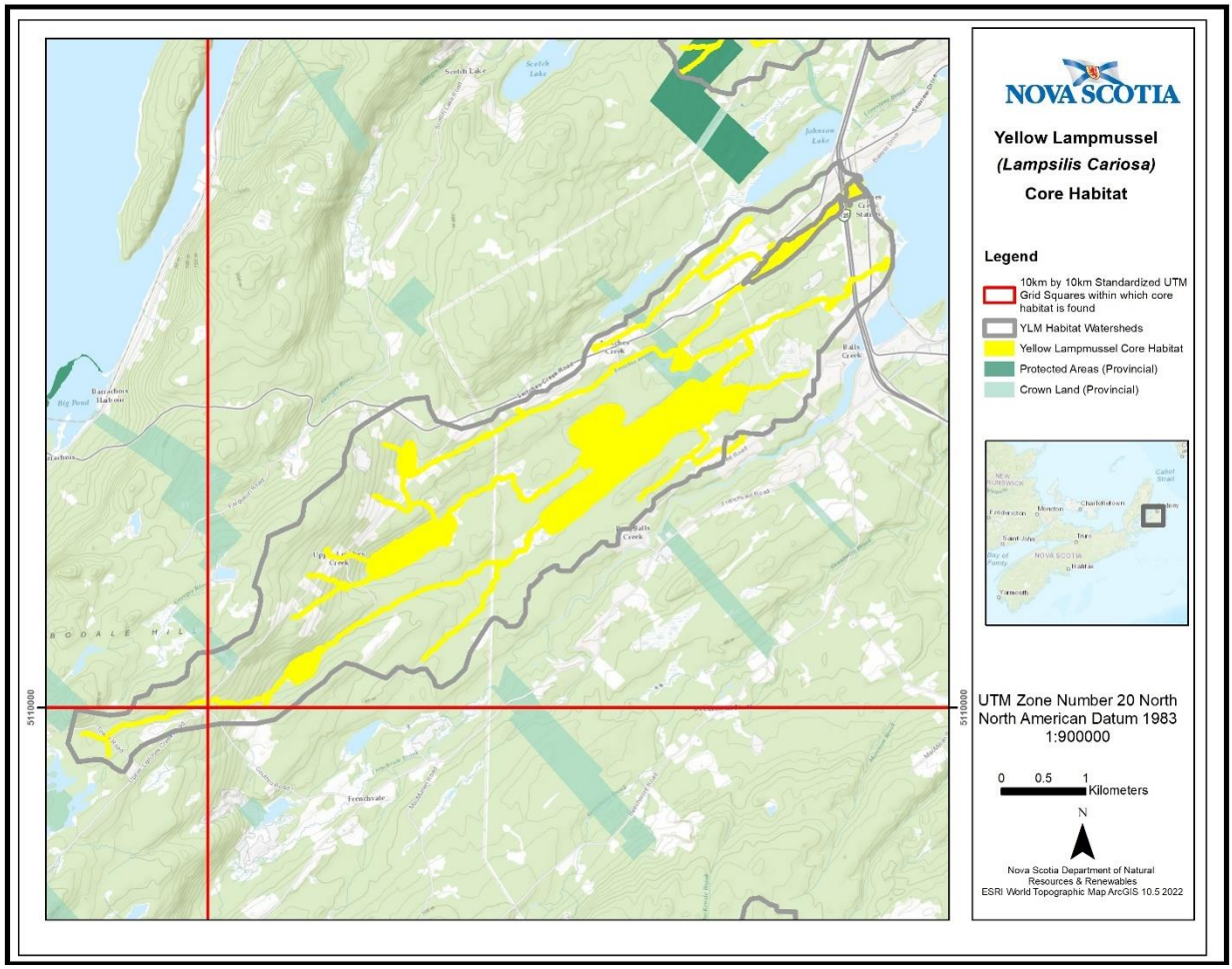


**Figure 5.** Identified core habitat for Yellow Lampmussel in the Forresters Lake watershed, Nova Scotia

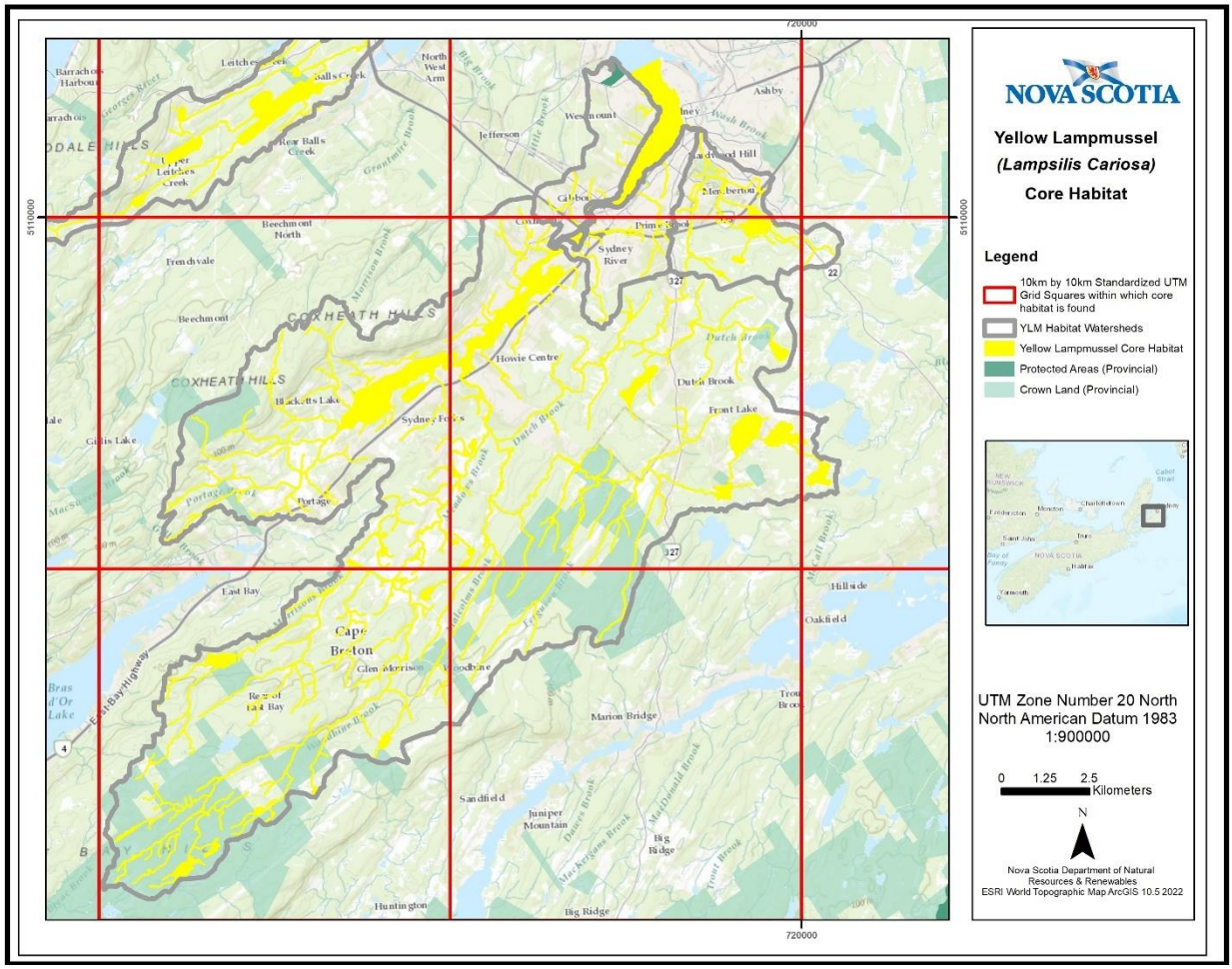


**Figure 6.** Identified core habitat for Yellow Lampmussel in the Sydney River / Blacketts Lake watershed, Nova Scotia