NOVA SCOTIA

RECOVERY PLAN FOR THE BROOK FLOATER (*ALASMIDONTA VARICOSA*) 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: Brook Floater shell from East St. Marys River, Nova Scotia. Photograph by Desiree Roberts 2021.

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 Brook Floater 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 Brook Floater biology, consult the COSEWIC Assessment and Status Report (COSEWIC 2009).

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 Brook Floater 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:

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- Shanna Fredericks
- Andrew Lowles
- Kim Robichaud-Leblanc
- Dr. Shannon Sterling
- Kellie White

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EXECUTIVE SUMMARY

The Brook Floater (*Alasmidonta varicosa*) is a freshwater mussel native to northeastern North America with the Canadian population restricted to New Brunswick and Nova Scotia. The species has never been abundant in Nova Scotia, normally representing only 1-5% of the mussels in the watercourse where they are found. Brook Floater is reported from several disjunct sites in southwestern and central Nova Scotia, in seven separate watersheds where there is little chance of population mixing. These include: the Annapolis River (Annapolis River watershed), LaHave River (LaHave River watershed), Stewiacke, Gays and Nine Mile Rivers (Stewicake/Shubenacadie River watersheds), Wallace River and Mattatall Lake (Wallace and French River watersheds), St. Marys River including East and North branches, Eden Lake and Lochaber Lake (St. Marys River watershed) and Salmon River and Bordens Lake (Salmon River watershed). In most locations where the species has been observed there have been less than five individuals recorded at any one time. The exception is in the East St. Marys River which has the highest recorded abundance with several thousand individuals; anecdotal evidence also suggests that Brook Floater may be abundant in the Annapolis River.

The habitat needs of Brook Floater are not well understood. The species is found in both rivers and lakes. It is often found in rivers with moderate flow and waters that are low in calcium and nutrient poor. In Nova Scotia it is found in waterbodies with a pH above 5.4. In general, it requires clean, well-oxygenated water, with sand or gravel substrate and low siltation. Brook Floater requires a fish host to complete its life cycle; however, the host fish species for Brook Floater is unknown.

The greatest threats to Brook Floater are water pollution and degradation of aquatic habitat from sedimentation (siltation), runoff, nutrient loading and eutrophication resulting from shoreline activities. The main sources of these are agriculture, forestry, and land development. Effects are exacerbated by the removal of riparian vegetation, which leads to an increase in erosion, sedimentation and runoff in adjacent streams and rivers. Additional threats include pollution from industrial activity such as mining, dam operation and maintenance, invasive species, and direct mortality of mussels caused by OHV stream crossings, trampling by livestock, and in-stream construction associated with development (e.g., docks, boat launches). Finally, climate change is expected to cause increased river temperatures and increased frequency and severity of droughts, storms, and extreme flooding events, but local effects on freshwater mussels are highly uncertain.

The long-term recovery goal (> 20 years) for Brook Floater 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 improve baseline population data and to maintain functioning sub-populations at

known sites (i.e., no net loss of area of occupancy) over five years. Efforts should be made to identify fish hosts for Brook Floater. Population monitoring should also assess mussel numbers over time to establish baseline trend data at known sites, as well as surveys of additional waterbodies for potentially undiscovered populations.

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. 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 Brook Floater 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. Information about the Brook Floater population[1] in Nova Scotia is limited (e.g., population size, dynamics, trends, etc.). However, recruitment has been previously reported in the Annapolis and St. Marys Rivers (Fisheries and Oceans Canada 2018) and more recent surveys suggest that sub-populations[2] in both the eastern and northern branches of the St. Marys River, as well as in the Salmon River are large enough to be maintained through recruitment. Further surveys are needed to update information for the Annapolis River, and determine whether sub-populations in the LaHave, Stewiacke, Gays, Nine Mile and Wallace Rivers are large enough to support recruitment.

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

Yes. Information about Brook Floater habitat requirements is limited; however, the species is currently found in a wide range of unconnected watersheds, including both lakes and rivers distributed throughout the southwestern and central parts of the province. This suggests that there is suitable habitat available in many areas of the province.

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

Yes. The major threats to Brook Floater are pollution and degradation of aquatic habitat (e.g., sedimentation, nutrient loading, eutrophication, toxins) resulting from shoreline activities such as agriculture, forestry, and land development. All these impacts can be avoided or mitigated, and many are regulated by the Nova Scotia government.

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

Yes. Further information is needed to establish quantitative population and distribution objectives for Brook Floater. However, available information suggests that if threats are mitigated, it should be possible to achieve the current recovery objectives for the species (i.e., to maintain and promote a self-sustaining and ecologically functioning

[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).

population within the province). Note that specific techniques for population augmentation and reintroduction with propagated mussels have been developed in the U.S. (Roy et al. 2022) should they become needed.

The Recovery Team concludes that the recovery of Brook Floater 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: March 2013 (NSSARWG)

Common Name: Brook floater

Scientific Name: *Alasmidonta varicosa*

Status: Threatened (NSESA)

Reason for Designation: Designated as Threatened in Nova Scotia (2013) due to its rarity in the province and threats to aquatic habitat. Known from only seven watersheds in Nova Scotia, this mussel has never been abundant, usually representing only 1-5% of the total freshwater mussel fauna present. Its habitat is subject to threats from agricultural and forestry practices, shoreline development, sedimentation, and changes in quality and quantity of water. Because this mussel has disappeared from approximately half of its U.S. locations, the Canadian population (Nova Scotia and New Brunswick) now represents an important global stronghold for the species.

Occurrence: Nova Scotia occurrence: Annapolis County, Antigonish County, Colchester County, Cumberland County, Guysborough County, Halifax County, Hants County, Lunenburg County, Pictou County. Native to Eastern North America with the Canadian population restricted to New Brunswick and Nova Scotia.

Status history: Provincially assessed as Threatened by the NSSARWG in March 2013. Federally assessed as Special Concern by COSEWIC in April 2009.

2. SPECIES STATUS INFORMATION

Brook Floater has a global conservation status rank of Vulnerable (G3), and national ranks of Vulnerable in both the United States (N3) and Canada (N3) (Table 1). Across its distribution in Canada, it is considered Vulnerable in both New Brunswick (S3) and Nova Scotia (S3) (NatureServe 2019).

Brook Floater was listed as Threatened under the *Nova Scotia Endangered Species Act* in 2013.

In Canada, Brook Floater was assessed as Special Concern by COSEWIC in 2009 and listed under as Special Concern under Schedule 1 of the federal *Species at Risk Act* (S.C. 2002, c. 29) in in 2013.

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 2018) and is published on the Species at Risk Registry: https://wildlife-species.canada.ca/species-risk-registry/virtual_sara/files/plans/Mp-BrookFloater-v00-2018Mar-Eng.pdf.

Table 1. NatureServe conservation status ranks for Brook Floater in Canada* (NatureServe, 2019).

Global (G) Rank[a]	National (N) Rank[b]	Subnational (S) Rank[c]
G3	N3	S3 – New Brunswick S3 – 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

Brook Floater is a small to medium-sized freshwater mussel with a thin, oblong shell, which reaches a shell length of approximately 70 mm. The curvature of the ventral margin gives the shells a kidney shape. The colour of the periostracum (outer shell layer) ranges from yellowish to brownish-black, and young adult shells usually display greenish or tan-coloured rays. The nacre (inner shell layer) is usually white or bluish white. Brook Floater does not have lateral hinge teeth, and its pseudocardinal hinge teeth (two in the left valve, one in the right valve) are rudimentary and weak. The anterior adductor muscle scar is shallow and well defined, while the posterior adductor muscle scar is ambiguous. The exterior of the shell is smooth except for weak ridges on the posterior slope. While the species is not sexually dimorphic, female shells may be slightly more swollen in the posterior ridge area.

More detailed descriptions can be found in Clarke (1981), Nedeau et al. (2000), Bogan and Alderman (2004), and COSEWIC (2009), with field identification features illustrated in McAlpine et al. (2018).

3.2 Population and Distribution

Globally, Brook Floater is endemic to northeastern North America, found in streams and rivers of the Atlantic coastal region (Nedeau et al. 2000; Davis 2007). Its range spans from northeastern Georgia through the eastern United States to the southern half of New Brunswick and central Nova Scotia (Nedeau 2008).

In Nova Scotia, the distribution of Brook Floater is scattered across the southern and central parts of the province with sub-populations reported from several disjunct waterbodies, including: the Annapolis River (Annapolis County); LaHave River (Lunenburg County); Gays River (Halifax and Colchester Counties); Wallace River (Cumberland County); Mattatall Lake (Cumberland County); St Mary's River including East and North branches, Eden Lake and Lochaber Lake (Pictou, Antigonish and Guysborough Counties), and; Salmon River and Bordens Lake (Guysborough County) (Davis 2007; COSEWIC 2009; Marshall and Pulsifer 2010; Fisheries and Oceans Canada 2018) (Figure 1). A report from the Stewiacke River (Colchester County) was considered historical (COSEWIC 2009; Fisheries and Oceans Canada 2018) but has since been reconfirmed with live specimens found in 2017-2019 (Reader and Lachance 2017; D'Souza and Ransome 2018; Ransome and MacDonald 2019), and a new location was reported from Nine Mile River in the Stewiacke/Shubenacadie watershed in 2020-2021 (MacDonald 2020; Lachance and Roberts 2021). Occurrences of Brook Floater in Nova Scotia are disjunct, located in separate watersheds with little chance of population mixing (COSEWIC 2009; Fisheries and Oceans Canada 2018). There are no known occurrences of Brook Floater in Cape Breton; however, there are many rivers and lakes in Cape Breton with similar habitat and fish assemblages to those where Brook Floater is currently found on the mainland. Additional search effort should include suitable watercourses in Cape Breton as well as other parts of Nova Scotia.

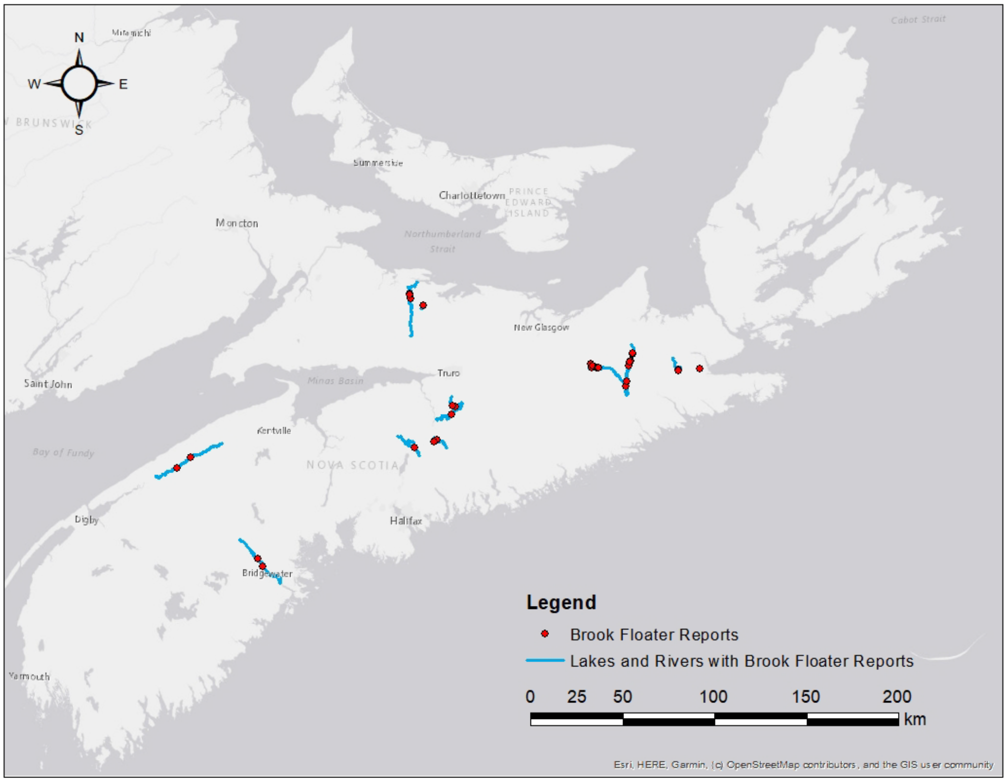

Figure 1. Distribution of Brook Floater in Nova Scotia. Data compiled from: Marshall and Pulsifer 2010; Reader and Lachance 2017; D'Souza and Ransome 2018; Ransome and MacDonald 2019; MacDonald 2020; Lachance and Roberts 2021; AC CDC 2022; Nova Scotia Museum 2022.

3.2.1 Population Size and Trends

Trend data are not available for the Canadian Brook Floater population (Fisheries and Oceans Canada 2018). Population estimates based on survey data were calculated using catch per unit effort (CPUE) for the following watersheds in Nova Scotia, as summarized in COSEWIC (2009): Annapolis, LaHave, Stewiacke/Shubenacadie, Wallace, French, St Marys and Salmon watersheds (Table 2). The total Nova Scotia population of Brook Floater at that time was estimated between 8,000-12,000 individuals, with the largest sub-populations presumed in the Annapolis and St. Marys Rivers (the latter including East and North branches, as well as Eden Lake and Lochaber Lake). However, it was noted that these estimates were based on semi-quantitative survey data compiled from available sources from 1951-2007 and carry a number of limitations, assumptions and potential sources of error (COSEWIC 2009). A subsequent qualitative assessment found that Brook Floater presence in the two areas with the largest concentrations (Annapolis and St. Marys) was 'maintained' with recruitment observed, while in the LaHave, Gays and Wallace Rivers presence was 'maintained' but with no recruitment observed (Jacques Whitford Stantec Limited 2012). The report reiterated that there was insufficient data for quantitative estimates of population trends, and trend detection was based on qualitative assessment using presence-absence data.

Surveys conducted in Nova Scotia in 2009 re-confirmed the presence of Brook Floater in the Annapolis River, Gays River, Wallace River, Salmon River, East and North branches of St. Marys River, Eden Lake and Lochaber Lake (dead specimen only). No living or dead specimens were located in the LaHave River, Mattatall Lake or Bordens Lake (Marshall and Pulsifer 2010). The authors suggest previous reports from Mattatall Lake may have been based on misidentification, but this has not been confirmed. Data limitations made population estimates possible only for the Wallace (96), East St. Marys (3600), North St. Marys (168) and Salmon (2044) rivers (Table 2), but in all cases estimates are presented per 100 m sampling reach (as compared to COSEWIC estimates for the whole system), suggesting considerably more Brook Floater in these systems than previously reported. The authors note that these data should be interpreted cautiously because of variability in habitat, patchiness of mussel occurrences, and limitations of sampling protocols (Marshall and Pulsifer 2010).

Additional ongoing surveys by the Confederacy of Mainland Mi’kmaq – Mi’kmaw Conservation Group since 2017 have confirmed presence of Brook Floater in the LaHave, Gays, Wallace and St. Marys Rivers with the greatest concentration of mussels in East Branch St. Marys. They have also re-confirmed what was previously considered a historical occurrence in the Stewiacke River (Reader and Lachance 2017; D’Souza and Ransome 2018; Ransome and MacDonald 2019) and reported a new location from Nine Mile River in the Stewiacke/Shubenacadie watershed (Table 2) (MacDonald 2020; Lachance and Roberts 2021). They surveyed the Annapolis River and Mattatall Lake in 2021 and did not find Brook Floater (4 hours of search effort in each system) (Lachance and Roberts 2021). They do not provide population estimates at this time. Ongoing work includes timed searches in known and potential waterbodies, development of a habitat suitability index, eDNA sampling, and tag-recapture studies to assess survival and recruitment (Lachance 2022; Lachance and Roberts 2022).

Table 2. Brook Floater surveys and population estimates in Nova Scotia.

Site / location		**COSEWIC (2009)[a]**		**Marshall and Pulsifer (2010)[b]**		**CMM-MCG Surveys (2017-2021)[c]**	
Waterbody	Watershed	Present	Estimate (total)	Present	Estimate (/100m)	Present	Estimate
Annapolis River	Annapolis	Yes	6020	Yes	Not available	No	Not available
LaHave River	LaHave	Yes	350	No	Not available	Yes	Not available
Stewiacke River	Stewiacke / Shubenacadie	No	0	No	Not available	Yes	Not available

Gays River	Stewiacke / Shubenacadie	Yes	110	Yes	Not available	Yes	Not available
Nine Mile River	Stewiacke / Shubenacadie	N/A	N/A	N/A	N/A	Yes	Not available
Wallace River	Wallace	Yes	233	Yes	96	Yes	Not available
Mattatall Lake	French	Yes	50 – 200	No	Not available	No	Not available
St. Marys River	St. Marys	Yes	1000 – 5000	N/A	N/A	N/A	N/A
East St. Marys	St. Marys	Yes		Yes	3600	Yes	Not available
North St. Marys	St. Marys	Yes		Yes	168	N/A	N/A
Eden Lake	St. Marys	Yes		Yes	Not available	N/A	N/A
Lochaber Lake	St. Marys	Yes		Shell	Not available	N/A	N/A
Salmon River	Salmon	Yes	100 – 500	Yes	2044	N/A	N/A
Bordens Lake	Salmon	Yes		No	Not available	N/A	N/A

[a] Population estimates are based on catch per unit effort (CPUE) using survey data compiled from 1950-2007 as described in COSEWIC (2009); N/A indicates that sites were not surveyed or data unavailable.
[b] Presence/absence and population estimates are based on surveys conduced in 2009 and summarized in Marshall and Pulsifer (2010); note that estimates are given per 100 m reach.
[c] Presence/absence is based on surveys conducted in 2017-2021 by CMM-MCG, compiled from: Reader and Lachance (2017); D'Souza and Ransome (2018); Ransome and MacDonald (2019); MacDonald (2020); Lachance and Roberts (2021). Note that not every site was visited every year; absence from Annapolis River and Mattatall Lake should be treated with caution as they are based on a single survey (4 hours search effort) in 2021.

In summary, the current size of the Nova Scotia Brook Floater population is not clearly known (Fisheries and Oceans Canada 2018). Further work is needed to calculate population estimates for known sites based on consistent monitoring. In addition, the discovery of new records in recent surveys suggests that increased search effort could result in new locations being identified.

3.3 Species Needs

3.3.1 Habitat Needs

The habitat needs of Brook Floater are not well understood (Fisheries and Oceans Canada 2018). The species is frequently found in flowing-water habitats (rivers and streams) that have low calcium levels and are nutrient poor (Nedeau et al. 2000). However, it is also known to occur in some lakes with no evident water flow (COSEWIC

2009). In Nova Scotia, Brook Floater is found in waterbodies with a pH above 5.4 (Davis 2007). It requires clean, well-oxygenated water and thrives best in waters that have low siltation (Sabine 2006). It is usually associated with sand or gravel substrate, or where sand and gravel occur between cobble and boulders (Marshall and Pulsifer 2010). It is often found near rooted aquatic vegetation (Davis 2007). Marshall and Pulsifer (2010) found that Brook Floater in Nova Scotia occurs most frequently adjacent to lands with a mixedwood riparian zone forest cover. As a species primarily found in running water, the Brook Floater may be more sensitive to eutrophication than mussel species found in slow-water habitats (Nedeau et al. 2000).

3.3.2 Biological Needs and Ecological Role

Freshwater mussel species such as Brook Floater are important components of aquatic ecosystems. They are considered indicators of water quality and play a role in filtering water and sediment, altering nutrient composition and stabilizing and modifying the substrate (Fisheries and Oceans Canada 2018). At higher densities they act like ecosystem engineers and modify aquatic habitats, making them more suitable for other aquatic organisms and increasing production across trophic levels (Spooner and Vaughn 2006). They are filter-feeders, removing zooplankton, algae, bacteria and detritus from the water column, transferring nutrients and energy, and in turn being eaten by birds, fish and mammals comprising aquatic food webs (Vaughn 2018).

Brook Floater is dependent on a fish host for completion of its life cycle (COSEWIC 2009; Fisheries and Oceans Canada 2018). The species is thought to be dioecious with male and female reproductive organs in separate individuals (Haag and Leann Staton 2003). Female mussels carry their eggs in their gills, where the eggs are fertilized with sperm filtered from the water column. Glochidia are brooded in the gills and released through the adult female’s siphons. Brook Floater is a long-term brooder, with brooding lasting from August to the following May (Davis 2007). The release of Brook Floater glochidia is temperature-dependent, typically occurring at a water temperature of 14°C (U.S. Fish and Wildlife Service 2018). Once released, glochidia can only survive a few days in the water column before they must attach to a fish host for nutrition (Hagg and Leann Staton 2003). Scanning electron micrographs of Brook Floater glochidia show that they have sensory hairs and hooks for detecting and attaching to the gills or fins of their host fish (U.S. Fish and Wildlife Service 2018). While attached to the fish host, the glochidia form a cyst while they mature. After a few weeks to months attached to the fish host, the larvae drop from the fish as a juvenile mussel. Age of sexual maturity among freshwater mussel species is variable (Haag and Leann Staton 2003), however observations from the United States and New Brunswick suggest that the majority of reproducing Brook Floater individuals are between 7 and 14 years old, with an average generation time of 10 years (COSEWIC 2009).

The host fish for Brook Floater in Nova Scotia is currently unknown. Several fish species have been reported as potential hosts for Brook Floater in the eastern United

States, including: Ninespine Stickleback (*Pungitius pungitius*), Longnose Dace (*Rhinichthys cataractae*), Blacknose Dace (*Rhinichthys atratulus*), Golden Shiner (*Notemigonus crysoleucas*), Common Shiner (*Luxilius cornutus*) Pumpkinseed Sunfish (*Lepomis gibbosus*), Slimy Sculpin (*Cottus cognatus*), White Sucker (*Catostomus commersonii*), Atlantic Salmon (*Salmo salar*), Spotted Killifish (*Fundulus luciae*), Yellow Perch (*Perca flavescens*), Brown Bullhead (*Ameiurus nebulosus*), Brook Trout (*Salvelinus fontinalis*), Fallfish (*Semotilus corporalis*) and Margined Madtom (*Noturus insignis*) (COSEWIC 2009, U.S. Fish and Wildlife Service 2018). In Nova Scotia Beaudet (2006) found a single Brook Floater glochidia on a Ninespine Stickleback in the Kouchibouguac River, NB, indicating that this species may be a potential Brook Floater host in the Maritimes. However, more research is needed to better understand the Brook Floater – host fish relationship.

3.3.3 Limiting Factors

Limiting factors for Brook Floater include its lack of dispersal ability, reliance on host fish to complete its life cycle, genetic isolation of disjunct sub-populations and low reproductive potential. Adult Brook Floater are mostly sessile and cannot move to escape from disturbance or habitat degradation. They rely on their muscular foot for minor adjustments for feeding or in response to seasonal changes in the water level; however, the species' primary means of dispersal is at the larval stage, through movement of glochidia on fish hosts (Fisheries and Oceans Canada 2018). This is a limiting factor in its ability to respond to environmental change.

As outlined above, Brook Floater depends on fish hosts for completion of its life cycle and dispersal of glochidia. This dependence on a fish host makes it important to consider factors affecting host fish species in recovery planning, as any activity or impact that affects host fish populations could have severe repercussions for Brook Floater. Currently, the host fish species for Brook Floater in Nova Scotia is unknown (COSEWIC 2009). Therefore, it is difficult assess potential threats to host fish. Aquatic Invasive Species (AIS) such as Chain Pickerel (*Esox niger*) and Smallmouth Bass (*Micropterus dolomieu*) are responsible for depleting host fish populations for other freshwater mussel species in Nova Scotia (Fisheries and Oceans Canada 2010).

Genetic descriptions of unionid species along the North Atlantic Slope drainage basins suggest that these populations are distinct biogeographic "islands" of diversity with each population being on its own evolutionary trajectory (COSEWIC 2009). According to Fisheries and Oceans Canada (2018), "until molecular data show otherwise, it is prudent to assume that the Canadian Brook Floater population is similarly fragmented". This makes it unlikely that fragmented sub-populations of Brook Floater would recolonize watersheds if resident individuals were lost (COSEWIC 2009).

Finally, the rarity and limited density of Brook Floater in Nova Scotia may impact its reproductive success since their method of reproduction relies on close proximity of individuals. The abundance of Brook Floater is typically estimated at less than 5% of the total freshwater mussels present in a waterbody (COSEWIC 2009).

4. THREATS

4.1 Threat Assessment

The Brook Floater threat assessment (Table 3) 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 3. Threat calculator assessment.

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
1	Residential & commercial development	Negligible	Negligible	Serious	High	
1.1	Housing & urban areas	Negligible	Negligible	Serious	High	Increased residential development is identified as a potential threat along the St. Marys, Wallace and LaHave Rivers, and particularly around associated lakes where Brook Floater occurs in Nova Scotia (Lochaber, Eden and Mattatall Lakes) (COSEWIC 2009; Fisheries and Oceans Canada 2018). Threats associated with removal of riparian vegetation for housing development are covered in 7.3 [effects on water temperature,

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
						shading, fish habitat] and 9.1 [runoff, erosion, siltation / sedimentation, pollution]. Ratings here reflect direct impacts of in-stream construction only (e.g., infilling, docks, boat launches and other structures).
1.2	Commercial & industrial areas					Not applicable.
1.3	Tourism & recreation areas					Threats associated with tourism and recreation area runoff are covered in 9.1.
2	Agriculture & aquaculture	Negligible	Negligible	Serious	High	
2.1	Annual & perennial non-timber crops					There is extensive annual crop agriculture within the watersheds where Brook Floater is found in Nova Scotia. Threats associated with removal of riparian vegetation for agriculture 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. There are no known wood or pulp plantations within watersheds of Brook Floater. The impacts of forestry practices are addressed in 5.3.
2.3	Livestock farming & ranching	Negligible	Negligible	Serious	High	There is livestock farming within the watersheds where Brook Floater is found in Nova Scotia. Threats

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
						associated with contaminant runoff associated with livestock farming (e.g., nutrient and sediment) are addressed in 9.3. Ratings here reflect direct mortality of mussels from cattle stream crossings.
2.4	Marine & freshwater aquaculture					Not applicable. However, note that there are open pen net Atlantic Salmon and Rainbow Trout farms near the mouths of several Brook Floater rivers (e.g., Annapolis, LaHave, Salmon). High concentrations of fish could attract predators, such as seals, which could increase predation of fish hosts (species yet to be identified). Impacts on host fish are captured under 7.3.
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 is a lead-zinc mine located on the Gays River, upstream of a known Brook Floater site. Mining activities were paused in 2009 but are proposed for restart in 2023 (Alper 2022; EDM 2022). Threats

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
						associated with effluent and leaching from active and abandoned mines and tailings ponds are covered in 9.2.
3.3	Renewable energy					FORCE operates in Parrsboro (https://fundyforce.ca/about-us) as a tidal energy research centre, and there is a test site for tech / turbines in Minas Basin. Turbines increase the risk of injury and mortality in fish (Algera et al. 2020). Tidal energy could potentially have a negative impact on host fish but data are lacking.
4	Transportation & service corridors	Unknown	Unknown	Unknown	High	
4.1	Roads & railroads	Unknown	Unknown	Unknown	High	Road construction that is poorly managed can lead to blockages in fish passageways (through improperly maintained culverts) and negatively impact fish hosts and therefore reproduction and dispersal of Brook Floater (Fisheries and Oceans Canada 2018). Impacts on fish hosts are covered in 7.3. Runoff from roads and railroads can also be a threat to mussels and is covered in 9.2. Ratings here reflect direct mortality of mussels from culvert replacement, construction and maintenance. Note that data are lacking on location / numbers and

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
						condition of culverts near Brook floater occurrences.
4.2	Utility & service lines					Not applicable.
4.3	Shipping lanes					Not applicable.
4.4	Flight paths					Not applicable.
5	Biological resource use					
5.1	Hunting & collecting terrestrial animals					Muskrat (*Ondatra zibethicus*) and River otter (*Lontra canadensis*) are major predators of freshwater mussels (Tyrrell and Hornbach 1998; COSEWIC 2009). Decreased numbers of muskrat or otter due to hunting or trapping could positively impact freshwater mussel populations, however data are lacking to quantify this.
5.2	Gathering terrestrial plants					Not applicable.
5.3	Logging & wood harvesting					Most Brook floater sites in Canada occur in forested and/or agricultural landscapes. Threats 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 NS require a 20 m 'special management zone' for forest clearing near

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
						watercourses: https://novascotia.ca/just/regulations/regs/fowhwp.htm
5.4	Fishing & harvesting aquatic resources					Recreational fishing could cause removal of glochidia / juveniles but there are no data on population level impacts. Declines in fish host populations due to fishing would be covered under 7.3.
6	Human intrusions & disturbance	Low	Small	Moderate	High	
6.1	Recreational activities	Low	Small	Moderate	High	Off-highway vehicles (OHVs) crossing streams can damage sections of mussel habitat and crush mussel beds (Fisheries and Oceans Canada 2018). Associated increases in erosion and siltation as well as gas and oil pollution from OHV use and recreational boating are covered in 9.1.
6.2	War, civil unrest, & military exercises					Canadian Forces Base (CFB) Greenwood is upstream of Brook Floater records in the Annapolis River. Threats associated with potential spills of fuel or coolant from military activities are covered in 9.2.
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 as timed and quadrat searches, in which researchers

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
						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. Work related to dam maintenance is covered in 7.2.
7	Natural system modifications	Unknown	Large-Pervasive	Unknown	High	
7.1	Fire & fire suppression					Not applicable. Bucketing for fire fighting may result in removal of water from some systems. There is a fire station along the banks of east St Mary's River for example, but it is not known whether water from the river is used or what impact that might have on Brook Floater.
7.2	Dams & water management/use	Negligible	Restricted	Negligible	High	There is some concern that water level drawdown could cause stranding of mussels along some rivers (COSEWIC 2009). Annapolis and LaHave Rivers have dams; however, these have been in place for many years and are not located in proximity to known Brook Floater occurrences (Fisheries and Oceans Canada 2018). Maintenance or

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
						decommissioning of dams could have implications for Brook Floater by changing water levels (e.g., Annapolis River generating station). Gibson et al. (2019) found fish mortality related to the Annapolis Tidal Hydroelectric Generating Station. Effects of fish mortality are covered under 7.3.
7.3	Other ecosystem modifications	Unknown	Large-Pervasive	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 Brook Floater 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 Brook Floater make severity “Unknown”. Impacts of invasive fish on host fish (predation / changes in fish species diversity) are also rated here, along with other activities that affect host fish populations (road construction, culvert maintenance, fishing, etc.).

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
						Lack of data about host species for Brook Floater and uncertainty about future introductions of predatory fish make severity 'Unknown'. Fish habitat restoration projects (e.g., installing digger logs) can also crush mussel beds and increase downstream siltation.
8	Invasive & other problematic species & genes	Low	Large-Pervasive	Slight	High	
8.1	Invasive non-native/alien species	Low	Large-Pervasive	Slight	High	Several invasive species occur or could occur in Brook Floater habitat, such as Chain Pickerel, Smallmouth Bass, Zebra Mussel and Chinese Mystery Snail. Impacts on host fish and aquatic ecosystems could be severe but lack of data about host fish species make this threat difficult to quantify [see ratings in 7.3]. Ratings here are for direct impacts on Brook floater only (predation, destruction, competition). Predation of host fish / glochidia by Chain Pickerel and Smallmouth Bass is a potential threat for Brook Floater although these invasive fish species prefer lake habitat and are not expected to occur at high densities in smaller river systems.

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
						The introduced Zebra Mussel poses a severe threat to freshwater mussel populations elsewhere in North America and has the potential to extirpate native species (Ricciardi et al. 1998). It is not yet present in Nova Scotia and preventing introduction should be a priority. Introduction into Brook Floater habitat may be somewhat limited by habitat preference, as Zebra Mussels tend to prefer lake habitats and large rivers over smaller river systems. The Chinese Mystery Snail 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). Neither Zebra Mussels nor Chinese mystery snails are currently found in Brook Floater habitat in Nova Scotia but pose a potential future threat.
8.2	Problematic native species	Negligible	Small	Negligible	High	Muskrat (*Ondatra zibethicus*) predation has been identified as a threat to endangered mussel populations (Zahner-Meike and Hanson 2001). River otters (*Lontra canadensis*) and Raccoons (*Procyon lotor*) also prey upon

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
						freshwater mussels (Tyrrell and Hornbach 1998).
8.3	Introduced genetic material					Not applicable.
8.4	Problematic species/diseases of unknown origin	Not calculated (outside assessment timeframe)	Large	Unknown	Low	The protozoans *Conchophthirus* spp. have been described infecting Triangle Floater (*Alasmidonta undulata*) (Carella et al. 2016) which co-occurs with Brook Floater in Nova Scotia. Trematode infections have been found in *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 Brook Floater. It is unclear to what extent these pathogens pose a threat to Brook Floater.
8.5	Viral/prion-induced diseases					Unknown.
8.6	Diseases of unknown cause					Unknown.
9	Pollution	High	Pervasive	Serious	High	
9.1	Household sewage & urban wastewater	Low-Medium	Large	Slight-Moderate	High	An increase in residential and recreational areas alongside Brook Floater habitat will contribute to

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
						increased pollution that can degrade or destroy aquatic habitats if best management practices are not followed. Increased sedimentation (siltation) from shoreline construction and property maintenance can smother and bury freshwater mussels and affect their biological functioning (Fuller 1974; Fisheries and Oceans Canada 2018; 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). Removal of riparian vegetation compounds the impacts described above [see further discussion under 9.3]. The degradation and clearing of riverside vegetation associated with suburban development has been shown to reduce the size of freshwater mussel populations and inhibit recruitment (Brainwood et al. 2006).

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
						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). 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 (e.g., glyphosate) in summer months (Huang et al. 2004). All known Brook Floater locations in Nova Scotia are within a few 100 m of roads.
9.2	Industrial & military effluents	Low	Small	Serious	Moderate	Proposed mining activities on the Gays River could pose a risk to Brook Floater if a spill resulted in toxic contamination of downstream habitat. Juvenile mussels are particularly susceptible to toxic effluents (Fisheries and Oceans Canada 2018). Potential spills of fuel or coolant from military activities at CFB Greenwood could negatively impact mussel habitat and water quality

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
						downstream but no data are available to quantify this threat.
9.3	Agricultural & forestry effluents	High	Pervasive	Serious	High	All Brook Floater sites in Nova Scotia occur in forested and/or agricultural landscapes. Poor agricultural and forestry practices were the primary threat to Brook Floater identified in the federal management plan (Fisheries and Oceans Canada 2018). Agricultural runoff can result in excess sediment, nutrients, and chemicals in receiving waterbodies, which can cause habitat and water quality degradation (Schoonover et al. 2005). Increased sedimentation (siltation) can smother and bury freshwater mussels and affect their biological functioning and excess nutrients are negatively associated with both juvenile and adult mussel survival [see 7.1]. Converting natural landscapes to agricultural lands has been shown to cause habitat degradation, loss of biodiversity, and local extinctions of some freshwater mussels (Poole and Downing 2004). Removal of riparian vegetation for agriculture and forestry can exacerbate these impacts. Intact riparian zones act as bank

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
						stabilizers and sediment and nutrient filters, reducing contaminant and nutrient inputs to aquatic systems (Dosskey et al. 2010; Mondal and Patel 2018; Caskenette et al. 2020). Removal of riparian vegetation increases runoff, erosion, sedimentation / siltation and pollution that can negatively impact freshwater mussels, as above. In addition to land-based agricultural activities, there is active aquaculture (i.e., open pen net Atlantic Salmon and Rainbow Trout farms) at the mouths of several Brook Floater rivers (e.g., Annapolis, LaHave, Salmon). Nutrient overload from feed and high concentrations of fish waste could contribute to the degradation of fish host habitat, and poorly maintained vessels could be a source of minor oil and coolant spills.
9.4	Garbage & solid waste					Not documented, although localized illegal dumping could pollute Brook Floater habitat.
9.5	Air-borne pollutants	Not calculated (outside	Large	Unknown	Low	Many Nova Scotia lakes and rivers have been severely impacted by acidification from airborne pollutants (acid rain), particularly in

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
		assessment timeframe)				the Western ecoregion where thin soils have limited neutralizing capabilities (Watt et al. 2000; Neily et al. 2017). Acidification is known to reduce fish populations (Baker and Schofield 1985) which may affect fish hosts of Brook Floater. Data are lacking for effects on mussels.
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	Unknown	Pervasive	Unknown	High	
11.1	Habitat shifting & alteration					No applicable.
11.2	Droughts	Unknown	Pervasive	Unknown	Moderate	Droughts are expected to increase in frequency and severity in the future due to climate change (UCS 2021). Reduced water levels could leave mussels stranded out of the water, which could lead to increased predation or mortality. Rapid decrease in river water levels have been attributed to die-offs of other freshwater mussel species (Sousa et al. 2018). There is also an increased risk of predation by terrestrial predators, such as

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
						raccoons (Wolff et al. 2016). In shallow water, mussels are also more vulnerable to high temperatures in summer and low temperatures and freezing in winter (see below).
11.3	Temperature extremes	Unknown	Pervasive	Unknown	Moderate	River temperatures are expected to increase in the long term due to climate change (Caissie et al. 2016). The lethal temperature (LT50) for Brook Floater glochidia was 36.1°C – 38.0°C and 35.0°C – 35.1°C for juveniles (Pandolfo et al. 2012). Increased temperatures have been shown to cause changes in filtration rate and immune response in freshwater mussels (New York Natural Heritage Program 2021). Temperature anomalies such as heat waves are happening with increased frequency and severity due to climate change. A sudden onset of exceptionally high temperatures may impact mussel populations in shallow water if not given enough time to move to deeper, cooler waters.
11.4	Storms & flooding	Unknown	Pervasive	Unknown	High	Storms are increasing in frequency and intensity with climate change and increased magnitude of flood events is expected to increase

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
						erosion and sedimentation of rivers (EPA 2022). In the Annapolis River, storm events and periods of high rainfall have caused sudden increases in sediment and *E. coli* counts, and nutrient loads have been recorded at levels sufficient to cause significant eutrophication (Sharpe 2007).

[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

Brook Floater is currently known to occur in seven separate watersheds in Nova Scotia, including eight rivers and four lakes spread across the western and central parts of the province. Most sites are limited reaches in small to medium-sized rivers with moderate flow, cool waters, low to moderate gradient and low alkalinity (Millar et al. 2019); others are lakes with no apparent water flow (COSEWIC 2009). All known sites occur in forested and/or agricultural landscapes; several are experiencing increases in residential development including rural housing and vacation properties (e.g., LaHave, Wallace, and St. Marys Rivers and associated lakes); two have dams upriver from Brook Floater locations (Annapolis and LaHave Rivers) and one has a former lead-zinc mine upstream from a Brook Floater site, proposed for re-opening in 2023 (Gays River).

The primary threat to Brook Floater in Nova Scotia is pollution and degradation of aquatic habitat due to agriculture and forestry practices on adjacent land, as well as shoreline development. This includes increased sedimentation (siltation), pesticide and fertilizer runoff, nutrient loading and eutrophication resulting from these activities, with associated impacts on Brook Floater habitat. Removal of riparian vegetation often associated with shoreline activities exacerbates these impacts by increasing erosion, sedimentation and rates of runoff. Additional threats include potential pollution from industrial activity such as mining on the Gays River, invasive species, and direct mortality of mussels caused by OHV stream crossings, trampling by livestock, and in-stream construction associated with development (e.g., docks, boat launches). Dam operations and maintenance are considered a threat at the national level (Fisheries and Oceans Canada 2018) but dams only occur in two watersheds with Brook Floater in Nova Scotia (Annapolis and LaHave systems) where they have been in place for many years. Dams should be managed to avoid water level draw-down which could affect Brook Floater downstream; potentially stranding mussels and leaving them vulnerable to desiccation and predation. Climate change effects are highly uncertain but are predicted to include increased temperatures and increasing frequency and severity of droughts, storms and extreme flood events, with potentially negative impacts on mussels and aquatic habitats.

The overall threat impact to Brook Floater is 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.

Pollution – Agriculture & forestry effluents (High)

All Brook Floater sites in Nova Scotia occur in watersheds with forested and/or agricultural landscapes and, consequently, activities within these areas can influence the adjacent watercourses. The Annapolis and LaHave Rivers in particular, and parts of the Stewiacke watershed, have extensively agricultural landscapes, while the St Mary’s River sees some pesticide runoff from corn and blueberry crops (Fisheries and Oceans

Canada 2018). Poor agricultural and forestry practices were the primary threat to Brook Floater identified in the federal management plan (Fisheries and Oceans Canada 2018), and sedimentation and nutrient overload are potential issues in most waterbodies where Brook Floater occurs.

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. Converting natural landscapes to agricultural lands has been shown to cause habitat degradation, loss of biodiversity, and local extinctions of some freshwater mussels (Poole and Downing 2004). Poor forestry practices can lead to increased pesticide inputs and increased erosion and runoff through compaction and vegetation removal near watercourses (Fisheries and Oceans Canada 2018).

In particular, sedimentation (siltation) resulting from agricultural and forestry activities can affect benthic habitat and harm freshwater mussels. Fine sediments may clog mussels' filtration apparatus, interfere with filter feeding and respiration, and lead to mussel death (Fuller 1974; Henley et al. 2000). Increased sediment concentrations have been correlated with declines in mussel fertilization success and glochidial development and ultimately reproductive failure (Goldsmith et al. 2021).

In addition to sedimentation, excess nutrient loading from pesticides and fertilizers can cause eutrophication in nearby waterbodies. Nutrient loading can promote algal and aquatic plant growth, which can reduce oxygen levels and degrade water quality. 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). Increased nutrient loads have been shown to negatively impact mussel species richness (Metcalfe-Smith et al. 2003). Low levels of oxygen are related to increased stress and mortality in freshwater mussels (Sparks and Strayer 1998). In addition to nutrient loading, agricultural waste spills can cause direct mussel mortality, as juvenile mussels and glochidia are sensitive to heavy metals, chlorine and ammonia (New Hampshire Fish and Game Department 2005).

Habitat degradation associated with agriculture and forestry is exacerbated by removal of riparian vegetation. 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. Removal of riparian vegetation can also result in increased nutrient flow into waters (Dosskey et al. 2010; Mondal and Patel 2018; Caskenette et al. 2020).

In addition to land-based agriculture and forestry activities, Brook Floater in the LaHave River may be affected by aquaculture. The mouth of the LaHave River is situated between two Atlantic salmon open pen net farms (Saddle Island / Liverpool). Nutrient overload from feed and high concentrations of fish waste could contribute to the degradation of fish host habitat. Vessels at both farms are in various states of disrepair and could be a source of minor oil and coolant spills.

Pollution – Household sewage & urban wastewater (Medium / Low)

Increased residential development is identified as a potential threat along the LaHave, Wallace and St. Marys Rivers, and particularly around associated lakes where Brook Floater occurs in Nova Scotia (e.g., Mattatall, Eden and Lochaber Lakes) (COSEWIC 2009; Fisheries and Oceans Canada 2018). An increase in residential and recreational areas alongside Brook Floater habitat will contribute to increased pollution that can degrade or destroy aquatic habitats if best management practices are not followed.

Increased sedimentation from shoreline construction and property maintenance can smother and bury freshwater mussels and affect their biological functioning (Fuller 1974; Fisheries and Oceans Canada 2018; 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. Shoreline development often involves removal of riparian vegetation which exacerbates these impacts on aquatic habitats (see discussion under *Pollution – Agriculture and forestry effluents*, above). The degradation and clearing of riverside vegetation associated with suburban development has been shown to reduce the size of freshwater mussel populations and inhibit recruitment (Brainwood et al. 2006).

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.

Roads and trails associated with urban development and associated recreational activities can also have an impact on freshwater mussels. OHV use near waterbodies can cause increased erosion and degradation of riparian areas, and OHVs and recreational boating can also cause gas and oil pollution (see discussion under *Human intrusions & disturbance – Recreational activities*, below). 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). All known areas of Brook Floater habitat are within a few hundred metres of roads. 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 Brook Floater.

Human intrusions & disturbance – Recreational activities (Low)

Stream crossing by OHVs can damage sections of mussel habitat and crush mussel beds, causing direct mortality (Fisheries and Oceans Canada 2018). Associated increases in erosion, siltation and degradation of riparian habitat can also negatively impact mussels (see discussion under *Pollution – Household sewage & urban wastewater*, above). While impacts of OHVs are reported as more significant in New Brunswick (Fisheries and Oceans Canada 2018), they could also impact Nova Scotia populations. Note that it is prohibited for OHV drivers to cross watercourses in Nova Scotia when they are not frozen, except on crossings approved under the Environment Act (https://novascotia.ca/natr/ohv/).

Invasive & other problematic species & genes – Invasive non-native/alien species (Low)

Several invasive species occur or could occur in Brook Floater habitat, such as as Chain Pickerel (*Esox niger*), Smallmouth Bass (*Micropterus dolomieu*), Zebra Mussel (*Dreissena polymorpha*) and Chinese Mystery Snail (*Cipangopaludina chinensis*). Impacts on host fish and aquatic ecosystems could be severe but lack of data about host fish species make this threat difficult to quantify. Predation of host fish (and thus Brook Floater glochidia) by Chain Pickerel and Smallmouth Bass is a potential threat although these invasive fish species prefer lake habitat and are not expected to occur at high densities in faster-flowing river systems. Chain Pickerel and Smallmouth Bass are currently reported from the LaHave and Stewiacke/Shubenacadie watersheds, with Smallmouth Bass also present in the Annapolis watershed and Mattatall Lake (A. Lowles, personal communication, October 31, 2022).

The Zebra Mussel 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). 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. Introduction into Brook Floater habitat may be somewhat limited by habitat preference, as Zebra Mussels tend to prefer lake habitats and large rivers over smaller river systems. However, preventing Zebra Mussel introduction should be a priority.

The Chinese Mystery Snail 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 Brook Floater 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 Brook Floater habitat in Nova Scotia but pose a potential future threat.

Pollution – Industrial & military effluents (Low)

There is a lead-zinc mine located on the Gays River, upstream of a known Brook Floater site. Mining activities were paused in 2009 but are proposed for restart in 2023, with a focus on lead, zinc and gypsum (Alper 2022; EDM 2022). Proposed mining activities could pose a risk to Brook Floater if a spill resulted in toxic contamination of downstream habitat. Legislation governing mining operations requires that effluents comply to water quality standards and activities are monitored; however, standards are not developed specifically for mussels and juvenile mussels are particularly susceptible to toxic effluents in cases where spills do occur (Fisheries and Oceans Canada 2018).

CFB Greenwood is located alongside Annapolis River, upstream of known Brook Floater locations. Potential spills of fuel or coolant from military activities could negatively impact mussel habitat and water quality downstream but no data are available to quantify this threat.

Residential & commercial development – Housing & urban areas (Negligible)

In addition to pollution associated with housing and urban developments (discussed above, under *Pollution – Household sewage & urban wastewater*), shoreline development could cause direct harm to mussels through in-stream construction activities (e.g., infilling, docks, boat launches and other structures).

Agriculture & aquaculture – Livestock farming & ranching (Negligible)

In addition to pollution associated with agricultural activities (discussed above, under *Pollution – Agriculture & forestry effluents*), open access to stream crossings by livestock can cause direct mortality to mussels through trampling of mussel beds (Fisheries and Oceans Canada 2018). It can also lead to habitat degradation and loss through trampling surrounding vegetation thus increasing siltation, and from nutrient enrichment from livestock manure (Fisheries and Oceans Canada 2018).

Human intrusions & disturbance – Work and 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 – Dams & water management/use (Negligible)

COSEWIC (2009) identified dam operations and associated impoundments as threats to Brook Floater, specifically the concern that water level drawdown could cause stranding of mussels along rivers, leaving them exposed above the water line and susceptible to dessication and increased predation. This only applies to two of the known Brook Floater waterbodies in Nova Scotia; the Annapolis and LaHave Rivers. Both rivers have dams, however these have been in place for many years and are not located in proximity to known Brook Floater occurrences, with limited effects on water levels (COSEWIC 2009; Fisheries and Oceans Canada 2018). Maintenance or decommissioning of dams could have implications for Brook Floater by changing water levels and should be monitored accordingly (e.g., Annapolis River generating station).

In addition to mussels, freshwater fish can be negatively affected by fluctuations in hydrological regimes. Effects related to the operation of dams include habitat fragmentation, increased turbidity, colder water temperatures, sedimentation, changes in flow patterns, physical structure and chemical composition of the watercourse, and alteration of the food web (Fisheries and Oceans Canada 2018). These could all affect host fish populations. Gibson et al. (2019) found fish mortality related to the Annapolis Tidal Hydroelectric Generating Station. More information is needed to understand host fish relationships and determine potential effects of dams on host fish for Brook Floater.

Invasive & other problematic species & genes – Problematic native species (Negligible)

Zahner-Meike and Hanson (2001) identified muskrat (*Ondatra zibethicus*) predation as a threat to endangered mussel populations. River otters (*Lontra canadensis*) have also been documented preying upon freshwater mussels (Tyrrell and Hornbach 1998). These natural predators have evolved together with freshwater mussels and the impact of predation on healthy mussel populations is likely low; however more information is needed to better understand the impacts on at-risk mussel populations.

Transportation & service corridors – Roads & railroads (Unknown)

Road construction that is poorly managed can lead to blockages in fish passageways (through improperly maintained culverts) and negatively impact fish hosts and therefore reproduction and dispersal of Brook Floater (Fisheries and Oceans Canada 2018). Activities such as culvert replacement, construction and maintenance can also result in direct mortality of mussels (e.g., by crushing). Numerous culverts and road crossings are present near Brook Floater sites in Nova Scotia, however detailed information on location / numbers and condition of crossings and culverts is lacking. Runoff from roads can also be a threat to mussels (see discussion under *Pollution – Household sewage & urban wastewater*).

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 Brook Floater 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 Brook Floater are not known.

Other ecosystem changes may result from changes to host fish populations or fish species diversity, for example impacts of invasive fish on host fish (e.g., predation, competition), or activities that affect host fish populations (e.g., road construction, culvert maintenance, fishing, etc.). Control methods for invasive fish could also cause ecosystem changes, including mechanical removal (e.g., fishing, electrofishing) or water treatment with chemicals such as rotenone. Rotenone has been used previously to eradicate introduced Smallmouth Bass in Piper Lake in the St. Marys River watershed (e.g., https://novascotia.ca/news/release/?id=20220908002). Note that rotenone can inhibit freshwater mussel respiration (Watters 1994) and cause irreversible behavioural deficits in snails (Vehovszky et al. 2007); such impacts should be carefully considered when proposing treatments such as rotenone in aquatic systems. Lack of data about host species for Brook Floater make threats related to host fish populations difficult to quantify.

Fish habitat restoration projects (e.g., installing digger logs) can crush mussel beds and increase downstream siltation.

Climate change & severe weather – Droughts (Unknown)

Droughts are expected to increase in frequency and severity in the future due to climate change (UCS 2021). Reduced water levels associated with summer droughts could leave mussels that are close to the shore out of the water, which could lead to predation or mortality. Rapid decrease in river water levels have been attributed to die-offs of other freshwater mussel species (Sousa et al. 2018).

There is also an increased risk of predation by terrestrial predators, such as raccoons. The foraging efficiency of wading predators increases with decreased depth, and aquatic prey species are more vulnerable to predation from terrestrial predators during drought conditions (Wolff et al. 2016). In shallow water mussels are also more vulnerable to high temperatures in summer and low temperatures and freezing in winter (see below).

Climate change & severe weather – Temperature extremes (Unknown)

River temperatures are expected to increase in the long term due to climate change (Caissie et al. 2016). The lethal temperature (LT50) for Brook Floater glochidia is reported as 36.1^{o}C – 38.0^{o}C and 35.0^{o}C – 35.1^{o}C for juveniles (Pandolfo et al. 2012). Increased temperatures have been shown to cause changes in filtration rate and immune response in freshwater mussels (New York Natural Heritage Program 2021).

Temperature anomalies such as heat waves are happening with increased frequency and severity due to climate change. A sudden onset of exceptionally high temperatures may impact mussel populations in shallow water if not given enough time to move to deeper, cooler waters.

Climate change & severe weather – Storms & flooding (Unknown)

Storms are increasing in frequency and intensity with climate change, and increased frequency and magnitude of extreme flood events is expected to increase erosion and therefore sedimentation of rivers (EPA 2022). This may increase pollution in aquatic habitats and cause changes to the morphology of river reaches where Brook Floater is found. For example, In the Annapolis River, storm events and periods of high rainfall have caused sudden increases in sediment and *E. coli* counts, and nutrient loads have been recorded at levels sufficient to cause significant eutrophication (Sharpe 2007).

5. POPULATION AND DISTRIBUTION OBJECTIVES

Viable status for recovery

Brook Floater is known from seven separate watersheds in Nova Scotia and considered threatened due to its rarity and threats to aquatic habitat. Available records suggest that it has never been abundant, typically representing 1-5% of the total freshwater fauna present; however, there is limited data quantifying abundance, range and number of individuals (Fisheries and Oceans Canada 2018). Population trend data is limited to qualitative assessment using presence-absence data. Population estimates place the total number of individuals at 8,000-12,000 for the province but are based on limited data and carry a number of caveats and limitations (COSEWIC 2009). These knowledge gaps are typical for freshwater mussel communities, due to low search effort, lack of experts in the field and difficulties in species identification and detection (Fisheries and Oceans Canada 2018). More information is needed to determine population size, density and recruitment with greater certainty and evaluate demographic trends. In addition, the recent discovery of a new site and re-confirmation of a historical site suggests that increased search effort could reveal new occurrences. Further research is needed to determine the viable status for recovery for Brook Floater, intended as a long-term goal of removing the species from the NSESA. It is possible that Brook Floater 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 Brook Floater is to **maintain and promote a self-sustaining and ecologically functioning population within the province**. In keeping with the federal management plan, this includes current and new locations, including historical sites should they become naturally re-established (Fisheries and Oceans Canada 2018), with the following objectives:

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

A long-term numerical population goal is not established at this time, due to lack of data about natural distribution and population trends. Research should focus on establishing baseline population data at known sites, developing monitoring protocols to track trends, and surveys of additional waterbodies for potentially undiscovered populations.

Population and distribution objective

The short-term population and distribution objective for the recovery of Brook Floater is to improve baseline population data and to maintain functioning sub-populations at known sites (i.e., no net loss of area of occupancy) over five years. This should include monitoring of mussel bed density and recruitment.

Rationale

Population and distribution objectives assist with the identification of activities needed for recovery and for Brook Floater are based on the best available information (e.g., COSEWIC 2009; Marshall and Pulsifer 2010; Reader and Lachance 2017; D'Souza and Ransome 2018; Fisheries and Oceans Canada 2018; Ransome and MacDonald 2019; MacDonald 2020; Lachance and Roberts 2021; 2022). The lack of trend data and limitations with available population estimates highlight the need for quantitative surveys and monitoring protocols to better understand population dynamics.

The short-term population and distribution objective of improving baseline population data and maintaining functioning sub-populations at known sites (i.e., no net loss of area of occupancy) over five years aims to prevent further population decline while allowing for further research to clarify and quantify recovery objectives. The aim is to conserve habitat where the species currently exists and where new occurrences are discovered, including areas where it may re-establish in historical locations. The focus at this time is to encourage measures that help Brook Floater to be self-sustaining in Nova Scotia.

6. BROAD STRATEGIES AND GENERAL APPROACHES TO RECOVERY

6.1 Actions Completed or Underway

Conservation activities supporting Brook Floater recovery that were undertaken prior to 2018 are summarized in the federal Management Plan. 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/plans/Mp-BrookFloater-v00-2018Mar-Eng.pdf

Additional activities undertaken in support of Brook Floater recovery in Nova Scotia since 2018 include:

Population monitoring and research

- Surveys by the Confederacy of Mainland Mi'kmaq – Mi'kmaq Conservation Group (CMM-MCG):
    - From 2017 to 2022 (ongoing) CMM-MCG has partnered with Fisheries and Oceans Canada (DFO), Cape Breton University and others to conduct stream surveys to determine the range and abundance of Brook Floaters in Nova Scotia. A significant contribution of this work was to extensively survey the historic Brook Floater range in the Shubenacadie and Stewiacke River watersheds, establishing that Brook Floater was still present in the Stewiacke and Gays Rivers, reporting a new location in Nine Mile River (Reader and Lachance 2017; D'Souza and Ransome 2018; Ransome and MacDonald 2019; MacDonald 2020; Lachance and Roberts 2021; Lachance 2022; Lachance and Roberts 2022).
- Development of a habitat suitability index:
    - Survey work by CMM-MCG has included data collection on habitat characteristics at Brook Floater sites to aid in the development of a habitat suitability index (see references above).
- eDNA sampling, development of primer:
    - The development and testing of an eDNA primer and eDNA surveys of potential Brook Floater sites in an ongoing collaboration between CMM-MCG and the Kellie White Lab at Cape Breton University.
- Mark-recapture studies:
    - Initiated by CMM-MCG in 2022 to measure survival and recruitment of Brook Floater in East St. Marys River (Lachance 2022).

Invasive species threat management

- Inclusion of an annual insert about invasive species in the Nova Scotia Department of Fisheries and Aquaculture (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).
- Monitoring programs for invasive fish by NSDFA, including:
  - Tracking reports from recreational fishers and boaters
  - Maintaining a database of infested waterways
  - Eradication of Smallmouth Bass from Piper Lake in the St. Marys River watershed with rotenone in 2020 (https://novascotia.ca/news/release/?id=20220908002)
- A national response coordinated by Fisheries and Oceans Canada to the sale of aquarium moss balls in 2021 which were accidentally contaminated with Zebra Mussels; sales were halted and the public was encouraged to check moss balls and dispose of them properly (Fisheries and Oceans Canada 2021)
- Formation of the Nova Scotia Invasive Species Council (NSISC) in 2018 from the former Invasive Species Alliance of Nova Scotia which has 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 4) summarizes recovery actions and specific steps recommended to address threats and achieve successful recovery of Brook Floater in Nova Scotia, along with their priority and approximate costs.

Table 4. Recovery options planning table.

Recovery Measures	Threats Addressed*	Actions	Priority**	Cost***	Benefit
Habitat Protection, Management and Stewardship					
Protect Brook Floater habitat through stewardship, land purchase and conservation easements		• Develop stewardship agreements with private landowners to promote healthy shoreline activities within Brook Floater habitat. • Promote targeted delivery of Agricultural Biodiversity Conservation (ABC) Plans in Brook Floater locations with significant agricultural land use. • Provide opportunities for landowners to make ecological land donations or, if they wish to retain the land, enter into conservation agreements. • Support federal and/or provincial land conservation processes in Brook Floater habitat, such as Parks and Heritage designations, Wilderness Protected Areas or Ecologically Significant Areas.	M	$$$$	Habitat protection and enhancement; threat reduction; stakeholder investment in SAR recovery
Surveys and Monitoring					
Establish baseline population information for Brook Floater at known sites	All threats	• Build on existing work to survey Brook Floater sub-populations at known sites to gather baseline data to assess population dynamics, including presence/absence, density, recruitment and population estimates.	H	$$	Population and distribution knowledge to support recovery actions.

		• Establish consistent survey protocols to ensure data can be used to evaluate trends over time.			
Conduct ongoing monitoring of Brook Floater population at known sites	All threats	• Develop and implement a long-term monitoring plan with standardized survey protocols and timelines. • Coordinate with partners in New Brunswick and the U.S. to ensure communication, knowledge sharing and consistent approaches to surveys and monitoring. • Conduct workshops to develop capacity in freshwater mussel ID and survey techniques among government and non-government partners. • Train watershed restoration groups in Brook Floater and mussel bed identification, and include training modules in existing programs (e.g., NSSA Adopt-a-Stream, Watercourse Alteration Certification courses, etc.).	H	$	Population and distribution knowledge to support recovery actions.
Conduct monitoring of Brook Floater habitat characteristics and trends		• Establish baseline measurements of Brook Floater site and habitat parameters and monitor to record changes over time. • Work with partners to encourage long-term monitoring of water quality parameters associated with Brook Floater habitat in key river systems (e.g., temperature, pH, calcium, etc.). • Compile habitat information to inform surveys for potential new sites.	H	$	Population, distribution and habitat knowledge to support recovery actions.
Conduct surveys to identify and track threats to Brook Floater	All threats	• Conduct regular monitoring of Brook Floater habitat to identify any threats including new activities that may have a negative effect (e.g., new shoreline development, removal of riparian	H	$	Increased knowledge of threats and their impacts; early

		vegetation, recreational activity, OHV and cattle crossings, changes in predation, etc.). ● Track the distribution/spread of Chain Pickerel and Smallmouth Bass or any other potential aquatic invasive species (e.g., Zebra Mussels, Chinese Mystery Snail) into Brook Floater habitat to support early detection and rapid response to new infestations. ● Work with partners to ensure regular monitoring and maintenance of dams and fish ladders to minimize negative effects on Brook Floater habitat or potential fish hosts.			warning of serious impacts.
Conduct surveys of potential sites to identify possible new occurrences of Brook Floater	All threats	● Conduct surveys of sites with habitat suitable for Brook Floater where Brook Floater may occur but has not yet been documented. ● Conduct surveys of historical sites where Brook Floater has been reported in the past to reconfirm presence/absence. ● Encourage the use of citizen science / volunteer monitoring groups to help identify new Brook Floater locations.	H	$	Increased knowledge of threats and their impacts; early warning of serious impacts.
Communication, Outreach and Education					
Increase landowner awareness about the presence and status of Brook Floater in waterbodies adjacent to private land		● Develop a landowner / land use database for Brook Floater core habitat to support outreach activities. ● Develop digital resources (e.g., social media, factsheets, videos, best management practices) summarizing information about the ecology of Brook Floater and what activities are beneficial or harmful (e.g., shoreline best practices, retention	M	$	Habitat protection and enhancement; increased awareness and public engagement; stakeholder investment in SAR

		of riparian areas, preventing introductions of invasive species, etc. • 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. • Work with industry groups representing agriculture, forestry and mining to raise awareness and encourage voluntary adoption of best practices. • Work with OHV associations to encourage responsible use of OHVs and raise awareness about impacts of illegal stream crossings on Brook Floater. • Conduct outreach and education with local communities, schools, Indigenous groups, ENGOs, etc. • Attach informative statement and relevant contact information to transactional processes (e.g., land purchase) and permit applications.			recovery.
Define / clarify responsibilities of various agencies including municipal, provincial, and federal departments to aid in the protection of Brook Floater.		• Define responsibilities and communication pathways between provincial, municipal and non-government organizations responsible for the management of land/water on which core habitat occurs. • Provide detailed information to relevant agencies about Brook Floater distribution, ecology and conservation to enhance consideration of the species and its habitat during project reviews.	M	$	Habitat protection and enhancement; increased cooperation and efficiencies.

		• Work with municipalities to promote awareness and protection of Brook Floater adjacent to private lands. • Encourage incorporation of species at risk considerations and protections into municipal development plans.			
Law, Policy and Enforcement					
Core habitat requirements and considerations		• Designate core habitat under the *Nova Scotia Endangered Species Act*. • Work to mitigate or eliminate threats on crown lands adjacent to known occurrences (e.g., forestry) and develop Special Management Practices for Brook Floater.	H	$	Habitat protection; threat reduction.
Enforce legislation and policies related to resource extraction and other development activities in core habitat		• Enforce existing regulations pertaining to water quality, aquatic habitat, shoreline development and setbacks for riparian zones. • Propose changing the *Nova Scotia Wildlife Habitat and Watercourses Protection Regulations* to increase the existing 20 m buffer requirement to 30 m, and apply it to all activities including agriculture (not just forestry). • Ensure monitoring and compliance with regulations for mining activities (e.g., effluent discharge, water quality standards) that may impact core habitat in the Gays River watershed.	M	$	Habitat protection; threat reduction.
Research to Address Knowledge Gaps					
Conduct research on Brook Floater biology and ecology	All threats	• Form partnership(s) with Indigenous groups, local governments, universities and NGOs. • Work with Indigenous groups to integrate traditional Indigenous knowledge on the biology	H	$$	Increased population and distribution knowledge to support recovery

		and ecology of Brook Floater into recovery planning. • Conduct research on Brook Floater biology and ecological requirements, with a particular focus on reproductive biology and host fish interactions. • Determine genetic relationships within and between Brook Floater populations in Nova Scotia and elsewhere.			planning.
Conduct research on Brook Floater habitat requirements	All threats	• Conduct research on Brook Floater habitat including water quality, flow rate and sediment properties. • Conduct habitat manipulation studies such as creating areas of differing sediment types and vegetation cover.	M	$$	Increased understanding of habitat to support recovery planning.
Conduct habitat modelling for Brook Floater and assess habitat suitability in currently unknown/unoccupied waterbodies.	All threats	• Conduct habitat modelling based on hydrology, geology, tree cover, bathymetry (using aerial imagery and/or LiDAR) and indicator species from the AC CDC database. • Assess habitat suitability in new areas (e.g., hydrology, calcium, connection to the ocean, salinity, pH) to support expanded surveys to detect new occurrences.	M	$$	Increased understanding of habitat to support recovery planning.
Assess effects of threats on Brook Floater habitat and population		• Conduct research to assess the effects of threats on Brook Floater, including shoreline activities, riparian zone disturbance, water quality, invasive species, dams, recreational activity, etc.	M	$$	Increased understanding of threats; threat reduction.
Increase research and educational outreach on the impacts of climate change on SAR such as Brook Floater		• Conduct research on drought, temperature, and water quality sensitivity of glochidia and adults. • Incorporate results into outreach materials for local landowners, conservation groups, etc.	L	$$	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 Brook Floater will require a number of coordinated activities to increase our knowledge of population dynamics and habitat, protect existing sub-populations, address threats, and evaluate long-term strategies for conservation of the species. Recommended priority activities include continued surveys to determine baseline population information at known sites and the development of standardized monitoring protocols to assess population and habitat trends over time. Another priority involves research to address knowledge gaps about Brook Floater reproductive ecology and host fish relationships. Increased knowledge of Brook Floater biology, ecology and habitat requirements is needed to help refine and quantify recovery objectives for the species. Additional recommendations include: habitat protection through stewardship agreements and other conservation initiatives; outreach to landowners and industry associations (e.g., agriculture, forestry) to raise awareness and promote best practices around shoreline activities; identification and protection of core habitat, and; coordination between federal, provincial and municipal governments to ensure continued cooperation and enforcement of current regulations.

Habitat Protection, Management and Stewardship

Habitat protection, management and stewardship will be key components of Brook Floater recovery and are effective ways to mitigate the impacts of multiple threats. The small population size and distribution of Brook Floater along rivers that are heavily influenced by agriculture, forestry and shoreline development make this particularly important. In particular, development of stewardship agreements with private landowners would help promote healthy shoreline activities in Brook Floater habitat, including protection of riparian areas to prevent loss or degradation of aquatic habitat. Stewardship agreements could be informed by educational materials (see discussion below, under *Communication, Outreach and Education*) and supported by outreach to industry associations (e.g., agriculture, forestry) to encourage voluntary adoption of best practices. In particular, targeted delivery of Agricultural Biodiversity Conservation (ABC) Plans should be promoted in Brook Floater locations with significant agricultural land use.

In addition to stewardship agreements, purchase of land along rivers and lake shorelines in Brook Floater core habitat should be pursued where possible. 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 Brook Floater habitat through decreased sedimentation and water quality parameter changes.

Supporting federal and provincial conservation processes (e.g., parks and heritage designations, wilderness areas, ecologically significant areas, etc.) may be another way to protect Brook Floater habitat and should be encouraged. Increased government protection for rivers is another potential approach to be explored. Stringent monitoring and management of water quality in Brook Floater habitat would help to ensure sufficient habitat quality to support the species.

Surveys and Monitoring

Accurate baseline information is required in order to better understand Brook Floater population dynamics and to inform decision-making processes. This is particularly important in light of the lack of historical data on which to base population estimates and trends. Surveys of known sites for presence/absence, population size and recruitment have been initiated by CMM-MCG in partnership with Fisheries and Oceans Canada, Cape Breton University, and others. The province should coordinate with partners to support ongoing survey efforts and develop a standardized monitoring plan that includes methodologies and timelines for consistent population monitoring over time at all known sites. This should include regular monitoring of habitat parameters and threats (e.g., water quality, shoreline activities, road maintenance, recreational activities, invasive species, etc.). Data should be used to model population trends and habitat suitability and continue to refine core habitat over time. Coordination with partners in New Brunswick and the U.S. would ensure communication, knowledge sharing and consistent approaches to surveys and monitoring so that data can be shared. Workshops to train government staff and partners in freshwater mussel ID and survey techniques would increase capacity for these activities. Training should be provided to watershed restoration groups in Brook Floater and mussel bed identification, and training modules included in existing programs such as Nova Scotia Salmon Association (NSSA)'s Adopt-a-Stream program or Watercourse Alteration Certification courses.

In addition to monitoring known sites, it is important to survey for Brook Floater in additional locations with suitable habitat, including areas of historical occurrence. Work to develop a habitat suitability index and techniques for eDNA sampling is ongoing and will help with these efforts. In addition to current conservation partners, citizen science could potentially be leveraged to help identify new Brook Floater sites. While Brook Floater may be difficult to identify *in situ*, citizen scientists can be trained to identify shells along the shoreline. Muskrat middens can provide valuable information about the species diversity of a lake, as they can contain hundreds of shells which represent multiple species. A monitoring group could be created, where citizens attend a Brook Floater identification session provided by experts, and then search their local shorelines for muskrat middens or individual shells. Voucher specimens could be collected and submitted to local experts for identification confirmation, and locations of found shells could be searched for live individuals.

Communication, Outreach and Education

Communication, outreach and education are important elements in the recovery of Brook Floater in Nova Scotia, and complementary to other recovery actions. Private landowners should be informed of any Brook Floater 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. Many landowners may be unaware that they have Brook Floater adjacent to their property, as the species is underwater and often buried in the sediment; likewise, they may not know that activities on their property such as cutting shoreline vegetation can have a detrimental effect on adjacent Brook Floater 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. A database of landowners and land use in Brook Floater core habitat would help with implementation of these efforts.

Given the importance of shoreline activities and healthy riparian zones for Brook Floater, targeted outreach should also include industry associations (e.g., agriculture, forestry) and recreation organizations (e.g., OHV groups) to encourage dialogue and raise awareness among their membership. Partnership with industry and OHV associations could help identify the best way to reach out to their members, streamline communications, and encourage compliance with regulations and voluntary best practices.

There is a need for more 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 Brook Floater 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 Brook Floater (Fisheries and Oceans Canada 2018) highlights current protection for the species and summarizes the recovery actions completed or underway during the timeframe of the report. This document can be used to inform future policies and procedures surrounding Brook Floater and its habitat.

Designating core habitat for Brook Floater 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 Brook Floater from threats that impact aquatic habitat and water quality. In particular, it is noted that the current Nova Scotia *Wildlife Habitat and Watercourses Protection Regulations* under the *Forests Act* requires a 20 m buffer to protect water quality and the riparian zone; however current research suggests 20 m may not be enough (e.g., see Collison and Gromack 2022) and the regulations only apply to forestry (https://novascotia.ca/just/regulations/regs/fowhwp.htm). Revision of these regulations should be encouraged to consider new information, and application of the regulations to other shoreline activities (e.g., agriculture, development).

Development of municipal land use by-laws, policies, stewardship agreements and guidance governing activities in watersheds where Brook Floater occur should be encouraged. Special Management Practices for Brook Floater should also be developed, to inform activities on crown land.

Research to Address Knowledge Gaps

Additional research is needed to inform recovery planning for Brook Floater and will dovetail with the surveys and monitoring activities outlined above with regard to population dynamics, habitat needs, and the impacts of threats. A particular priority for Brook Floater is research on reproductive biology and fish host species, which are currently unknown in Nova Scotia. Research partnerships have already been formed between CMM-MCG, Fisheries and Oceans Canada and Cape Breton University; additional partnerships should be encouraged with 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. Research on climate change will also be important to help predict and mitigate impacts on the Brook Floater population.

7. RECOMMENDED COURSE OF ACTION(S) FOR RECOVERY

Table 5 provides the recommended course of actions for recovery of the species and the timeframe for completing these actions.

Table 5. Recovery actions and implementation schedule.

Habitat Protection, Management and Stewardship		**Implementation Schedule**
Approach 1.1 Protect Brook Floater habitat through stewardship, land purchase and conservation easements		
Action 1.1.1	Develop stewardship agreements with private landowners to promote healthy shoreline activities within Brook Floater habitat.	2024-2027
Action 1.1.2	Promote targeted delivery of Agricultural Biodiversity Conservation (ABC) Plans in Brook Floater locations with significant agricultural land use.	2024-2027
Action 1.1.3	Provide opportunities for landowners to make ecological land donations or, if they wish to retain the land, enter into conservation agreements.	2023-2027
Action 1.1.4	Support federal and/or provincial land conservation processes in Brook Floater habitat, such as Parks and Heritage designations, Wilderness Protected Areas or Ecologically Significant Areas.	Where possible
Surveys and Monitoring		**Implementation Schedule**
Approach 2.1 Establish baseline population information for Brook Floater at known sites		
Action 2.1.1	Build on existing work to survey Brook Floater sub-populations at known sites to gather baseline data to assess population dynamics, including presence/absence, density, recruitment and population estimates.	Ongoing
Action 2.1.2	Establish consistent survey protocols to ensure data can be used to evaluate trends over time.	2023-2024
Approach 2.2 Conduct ongoing monitoring of Brook Floater population at known sites		
Action 2.2.1	Develop and implement a long-term monitoring plan with standardized survey protocols and timelines.	2023-2024
Action 2.2.2	Coordinate with partners in New Brunswick and the U.S. to ensure communication, knowledge sharing and consistent approaches to surveys and monitoring.	2023-2024
Action 2.2.3	Conduct workshops to develop capacity in freshwater mussel ID and survey techniques among government and non-government partners.	2023-2025
Action 2.2.4	Train watershed restoration groups in Brook Floater and mussel bed identification and include training modules in existing programs (e.g., NSSA Adopt-a-Stream, Watercourse Alteration Certification courses, etc.).	2024-2026
Approach 2.3 Conduct monitoring of Brook Floater habitat characteristics and trends		
Action 2.3.1	Establish baseline measurements of Brook Floater site and habitat parameters and monitor to record changes over time.	Ongoing
Action 2.3.2	Work with partners to encourage long-term monitoring of water quality parameters associated with Brook Floater habitat in key river systems (e.g., temperature, pH, calcium, etc.).	2024-2027
Action 2.3.3	Compile habitat information to inform surveys for potential new sites.	2025-2027
Approach 2.4 Conduct surveys to identify and track threats to Brook Floater		
Action 2.4.1	Conduct regular monitoring of Brook Floater habitat to identify any threats including new activities that may have a negative effect (e.g., new shoreline development, removal of riparian vegetation,	2023-2027

	recreational activity, OHV and cattle crossings, changes in predation, etc.).	
Action 2.4.2	Track the distribution/spread of Chain Pickerel and Smallmouth Bass or any other potential aquatic invasive species (e.g., Zebra Mussels, Chinese Mystery Snail) into Brook Floater habitat to support early detection and rapid response to new infestations.	2023-2027
Action 2.4.3	Work with partners to ensure regular monitoring and maintenance of dams and fish ladders to minimize negative effects on Brook Floater habitat or potential fish hosts.	2024-2027
Approach 2.5 Conduct surveys of potential sites to identify possible new occurrences of Brook Floater		
Action 2.5.1	Conduct surveys of sites with habitat suitable for Brook Floater where Brook Floater may occur but has not yet been documented.	2025-2027
Action 2.5.2	Conduct surveys of historical sites where Brook Floater has been reported in the past to reconfirm presence/absence.	Ongoing
Action 2.5.3	Encourage the use of citizen science / volunteer monitoring groups to help identify new Brook Floater locations.	2024-2027
Communication, Outreach and Education		**Implementation Schedule**
Approach 3.1 Increase landowner awareness about the presence and status of Brook Floater in waterbodies adjacent to private land		
Action 3.1.1	Develop a landowner / land use database for Brook Floater core habitat to support outreach activities.	2024-2027
Action 3.1.2	Develop digital resources (e.g., social media, factsheets, videos, best management practices) summarizing information about the ecology of Brook Floater and what activities are beneficial or harmful (e.g., shoreline best practices, retention of riparian areas, preventing introductions of invasive species, etc.	2023-2025
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	Work with industry groups representing agriculture, forestry and mining to raise awareness and encourage voluntary adoption of best practices.	2024-2027
Action 3.1.5	Work with OHV associations to encourage responsible use of OHVs and raise awareness about impacts of illegal stream crossings on Brook Floater.	2024-2027
Action 3.1.6	Conduct outreach and education with local communities, schools, Indigenous groups, ENGOs, etc.	2025-2027
Action 3.1.7	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 including municipal, provincial, and federal departments to aid in the protection of Brook Floater.		
Action 3.2.1	Define responsibilities and communication pathways between provincial, municipal and non-government organizations responsible for the management of land/water on which core habitat occurs.	2023-2027
Action 3.2.2	Provide detailed information to relevant agencies about Brook Floater distribution, ecology and conservation to enhance consideration of the species and its habitat during project reviews.	2023-2027
Action 3.2.3	Work with municipalities to promote awareness and protection of Brook Floater adjacent to private lands.	2023-2027
Action 3.2.4	Encourage incorporation of species at risk considerations and protections into municipal development plans.	2023-2027

Law, Policy and Enforcement		**Implementation Schedule**
Approach 4.1 Core habitat requirements and considerations		
Action 4.1.1	Designate core habitat under the *Nova Scotia Endangered Species Act*.	2023-2027
Action 4.1.2	Work to mitigate or eliminate threats on crown lands adjacent to known occurrences (e.g., forestry) and develop Special Management Practices for Brook Floater.	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 water quality, aquatic habitat, shoreline development and setbacks for riparian zones.	Ongoing
Action 4.2.2	Propose changing the *Nova Scotia Wildlife Habitat and Watercourses Protection Regulations* to increase the existing 20 m buffer requirement to 30 m and apply it to all activities including agriculture (not just forestry).	2023-2025
Action 4.2.3	Ensure monitoring and compliance with regulations for mining activities (e.g., effluent discharge, water quality standards) that may impact core habitat in the Gays River watershed.	2023-2027
Research to Address Knowledge Gaps		**Implementation Schedule**
Approach 5.1 Conduct research on Brook Floater biology and ecology		
Action 5.1.1	Form partnership(s) with Indigenous groups, local governments, universities and NGOs.	2022-2027
Action 5.1.2	Work with Indigenous groups to integrate traditional Indigenous knowledge on the biology and ecology of Brook Floater into recovery planning.	2022-2027
Action 5.1.3	Conduct research on Brook Floater biology and ecological requirements, with a particular focus on reproductive biology and host fish interactions.	Ongoing
Action 5.1.4	Determine genetic relationships within and between Brook Floater populations in Nova Scotia and elsewhere.	2023-2027
Approach 5.2 Conduct research on Brook Floater habitat requirements		
Action 5.2.1	Conduct research on Brook Floater habitat including water quality, flow rate and sediment properties.	2023-2027
Action 5.2.2	Conduct habitat manipulation studies such as creating areas of differing sediment types and vegetation cover.	2024-2027
Approach 5.3 Conduct habitat modelling for Brook Floater and assess habitat suitability in currently unknown/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.	2025-2027
Action 5.3.2	Assess habitat suitability in new areas (e.g., hydrology, calcium, connection to the ocean, salinity, pH) to support expanded surveys to detect new occurrences.	2024-2027
Approach 5.4 Assess effects of threats on Brook Floater habitat and population		
Action 5.4.1	Conduct research to assess the effects of threats on Brook Floater, including shoreline activities, riparian zone disturbance, water quality, invasive species, dams, recreational activity, etc.	2023-2027
Approach 5.6 Increase research and educational outreach on the impacts of climate change on SAR such as Brook Floater		

Action 5.5.1	Conduct research on drought, temperature, and water quality sensitivity of glochidia and adults.	2023-2027
Action 5.5.2	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 Brook Floater 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 high level of uncertainty about Brook Floater distribution and population dynamics, along with knowledge gaps about habitat requirements, support the inclusion of all known sites in the definition of core habitat for the species. This is a precautionary approach until further information is available. The interconnected nature of stream habitat (essential for Brook Floater survival) and the surrounding riparian zone must also be considered when defining core habitat, as protection of riparian zones is of primary importance in protecting aquatic habitat and water quality. Upstream waterbodies are also considered as part of core habitat because water quality within these areas could directly impact Brook Floater habitat downstream. Consideration of areas frequented by host fish which carry their larval stage (glochidia) are not included for Brook Floater at this time due to uncertainty about host fish species and the specificity of the host fish relationship.

Core habitat for Brook Floater is defined as all known sites with records of Brook Floater, including stream reaches in the Annapolis River, LaHave River, Stewiacke River, Gays River, Nine Mile River, Wallace River, St. Marys River (East and North branches) and Salmon River, and associated lakes (Eden Lake, Lochaber Lake, Bordens Lake). The exception is Mattatall Lake which is excluded from core habitat until the question of possible misidentification can be resolved. Sites are defined using survey data compiled from available sources since 1985 (Marshall and Pulsifer 2010; Reader and Lachance 2017; D'Souza and Ransome 2018; Ransome and MacDonald 2019; MacDonald 2020; Lachance and Roberts 2021; AC CDC 2022; Nova Scotia Museum 2022). This represents the timeframe when concerted efforts to sample freshwater mussels with standardized methods began (Fisheries and Oceans Canada 2011). Stream reaches are defined using an area of occupancy approach and fixed distance buffer (Fisheries and Oceans Canada 2011) and include contiguous wetted areas within 500 m of all known records, along with river segments between records when more than one record occurs on the same river. Lakes with Brook Floater records are included in their entirety. Core habitat also includes the connected waterbodies upstream in these watersheds to protect water quality. In addition, a 30 m riparian buffer is added to all these waterbodies because research suggests that protection of riparian 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, Brook Floater core habitat is identified based on the following criteria objectives:

- All sites with known Brook Floater occurrences including 1) lakes and 2) river segments extending 500 m upstream and downstream from known records and including the distance between them when they occur on the same river;
- All connected waterbodies (lakes and rivers/streams) upstream of these waterbodies within the tertiary watersheds associated with them, and;
- 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 known locations could change over time.

8.2 Activities Likely to Result in the Destruction of Core Habitat

Destruction of Brook Floater 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 Brook Floater core habitat include but are not limited to:

- Land-based activities that result in the loss or degradation of riparian zones and/or Brook Floater habitat, including:
    - Agricultural activities
    - Logging and wood harvesting
    - Urban/commercial development, including infilling of shorelines and river channels for construction
    - Mining, quarrying and related exploration

    - Road construction and maintenance
    - Recreational activities (e.g., OHV use)

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

- Deliberate or accidental introduction of invasive species (e.g., Chain Pickerel, Smallmouth Bass, Zebra Mussel) to waterbodies where they are not yet present

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

    - Alteration of water levels
    - Obstruction of host fish passage

8.3 Habitat Protection / Ownership

Most of the land immediately adjacent to rivers and lakeshores occupied by Brook Floater in Nova Scotia is privately owned, with much of it used for various forms of agriculture. There are small amounts of provincial crown land in the upper portions of the Annapolis, LaHave, Stewiacke and Wallace River watersheds, while about 50% of the upper St. Marys and 50% of the upper Salmon River watersheds are crown land. About 6 km of the south bank of the Annapolis River immediately upstream from Brook Floater is federally owned as Canadian Forces Base (CFB) Greenwood. One provincial park and two wilderness areas lie in the upper reaches of the Wallace, LaHave and Salmon River watersheds (Wentworth Provincial Park, Cloud Lake Wilderness Area, and Ogden Round Lake Wilderness Area, respectively) (COSEWIC 2009).

The area identified as core habitat for Brook Floater in this document consists of 21,179 ha, of which approximately 76% is land and 24% is water. Of the land portion, approximately 79.6% is privately owned, 17.8% is provincial land (15.7% unprotected and 2.2% protected), 0.7% is municipal and 0.02% is unprotected federal land.

9. MEASURING PROGRESS

9.1 Performance Indicators

The performance indicators identified below (Table 6) 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 6. Performance measures used to determine whether Brook Floater 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 Brook Floater and host fish populations	Annually
Number of new Brook Floater 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 Brook Floater 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. The first step will be determining distribution and population estimates at existing sites using standard protocols. A monitoring plan for Nova Scotia should be coordinated with activities already underway by CMM-MCG, Fisheries and Oceans Canada and other partners to ensure a unified approach and support data sharing and cooperation; it should also be coordinated with monitoring plans for Brook Floater populations in New Brunswick and the United States. See Sterrett et al. (2018) for a description of a Brook Floater Rapid Assessment protocol used in the U.S.

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

Population monitoring

- Brook Floater population monitoring at known sites at 5 to 10-year intervals using the Rapid Assessment Protocol cited above
- More focused and frequent monitoring (2-year intervals) of Brook Floater in the largest known population in East St. Marys River to help refine methodologies and establish baselines for population density and recruitment

Threat/habitat monitoring

- Regular monitoring (1-2 year intervals) of shorelines to identify new threats or changes to threats (e.g., increased agriculture, forestry, development, removal of riparian vegetation, recreational activity, predation, etc.)
- Regular monitoring for the presence of invasive species such as Chain Pickerel and Smallmouth Bass in the northern half of Brook Floaters' range, to enable rapid response to any new introductions
- Regular monitoring of dam operation and maintenance in cooperation with partners (e.g., Nova Scotia Power)

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 Brook Floater in Nova Scotia

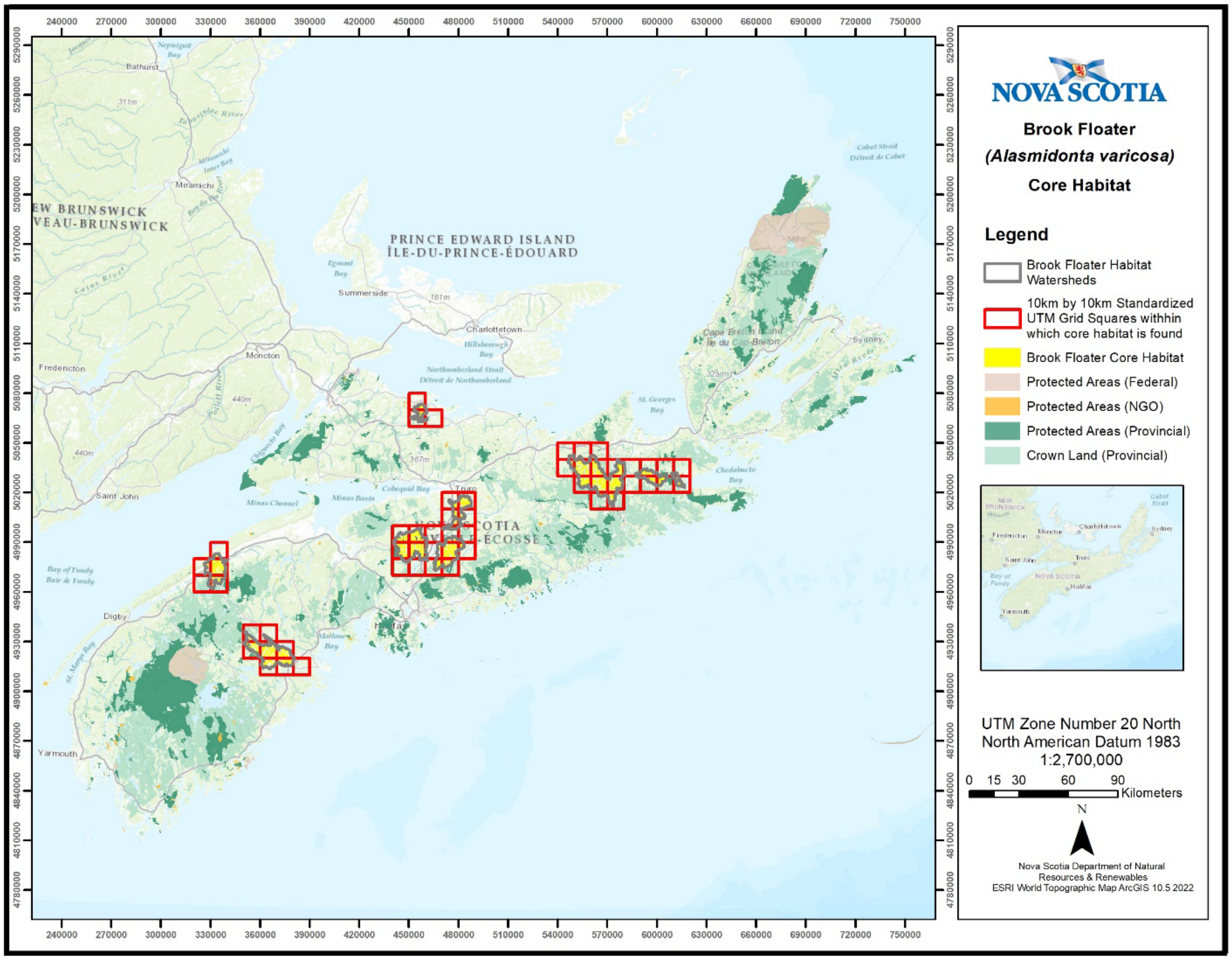

Figure 2. Identified core habitat for Brook Floater in Nova Scotia

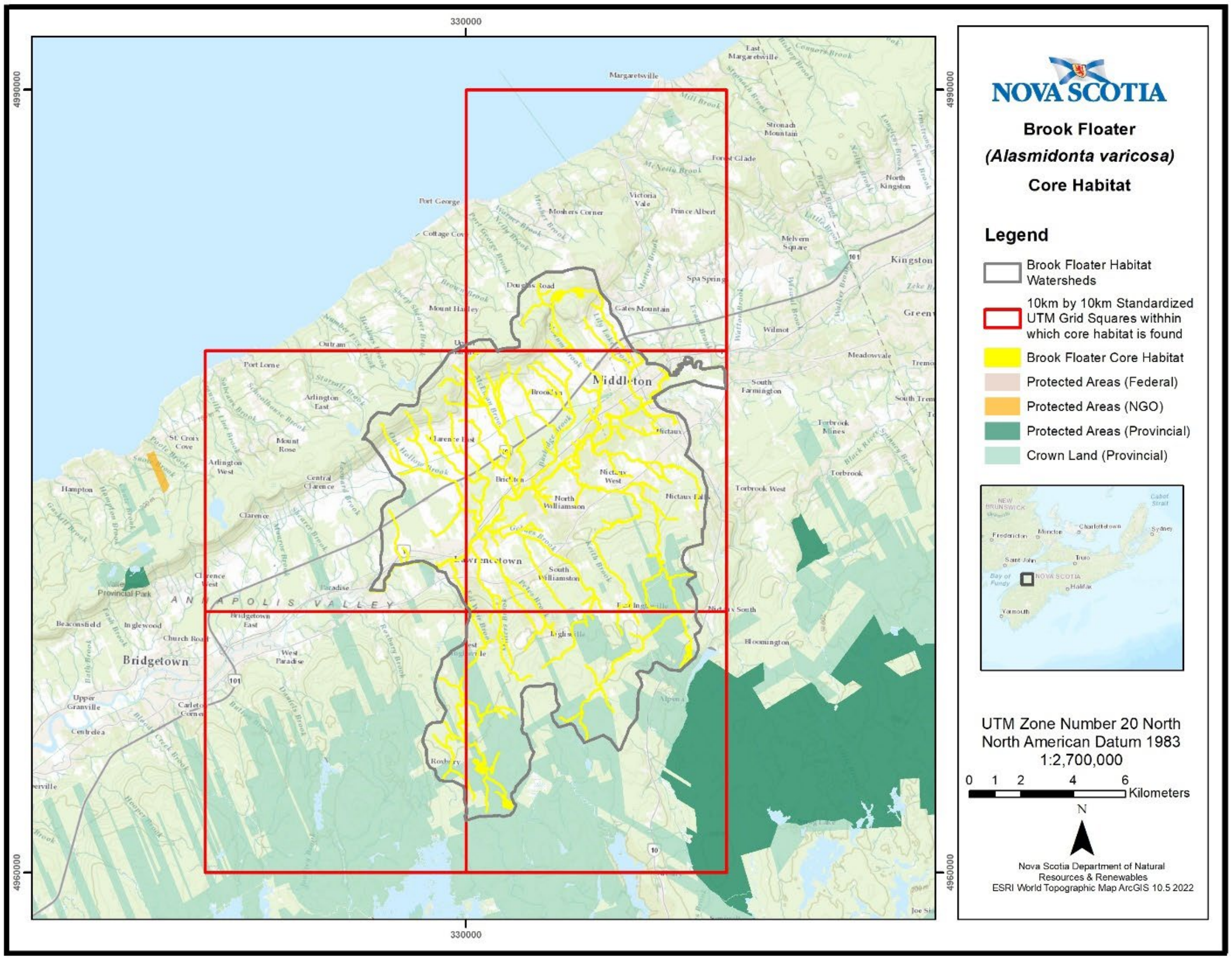

Figure 3. Identified core habitat for Brook Floater in the Annapolis River watershed, Nova Scotia

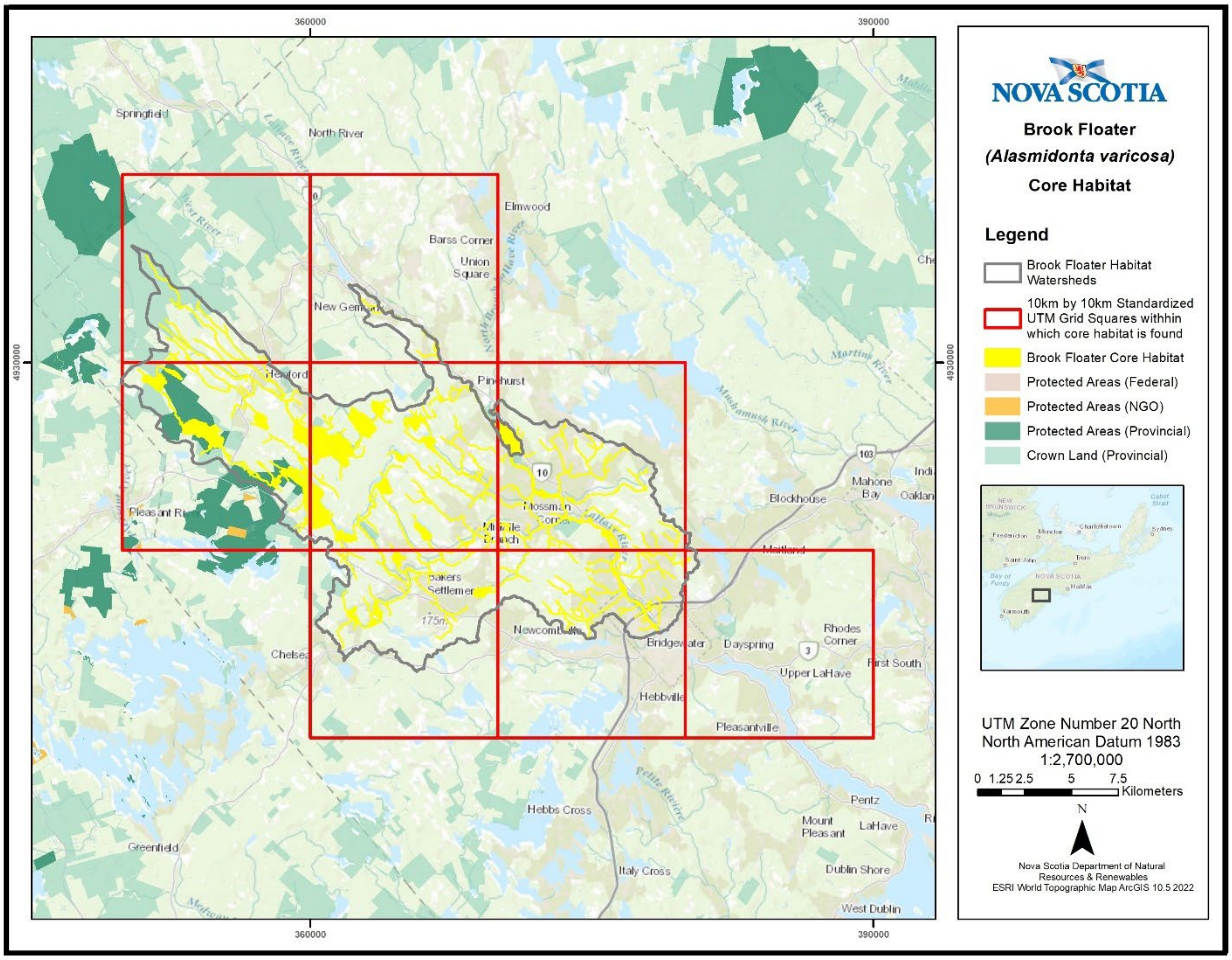

Figure 4. Identified core habitat for Brook Floater in the LaHave River watershed, Nova Scotia

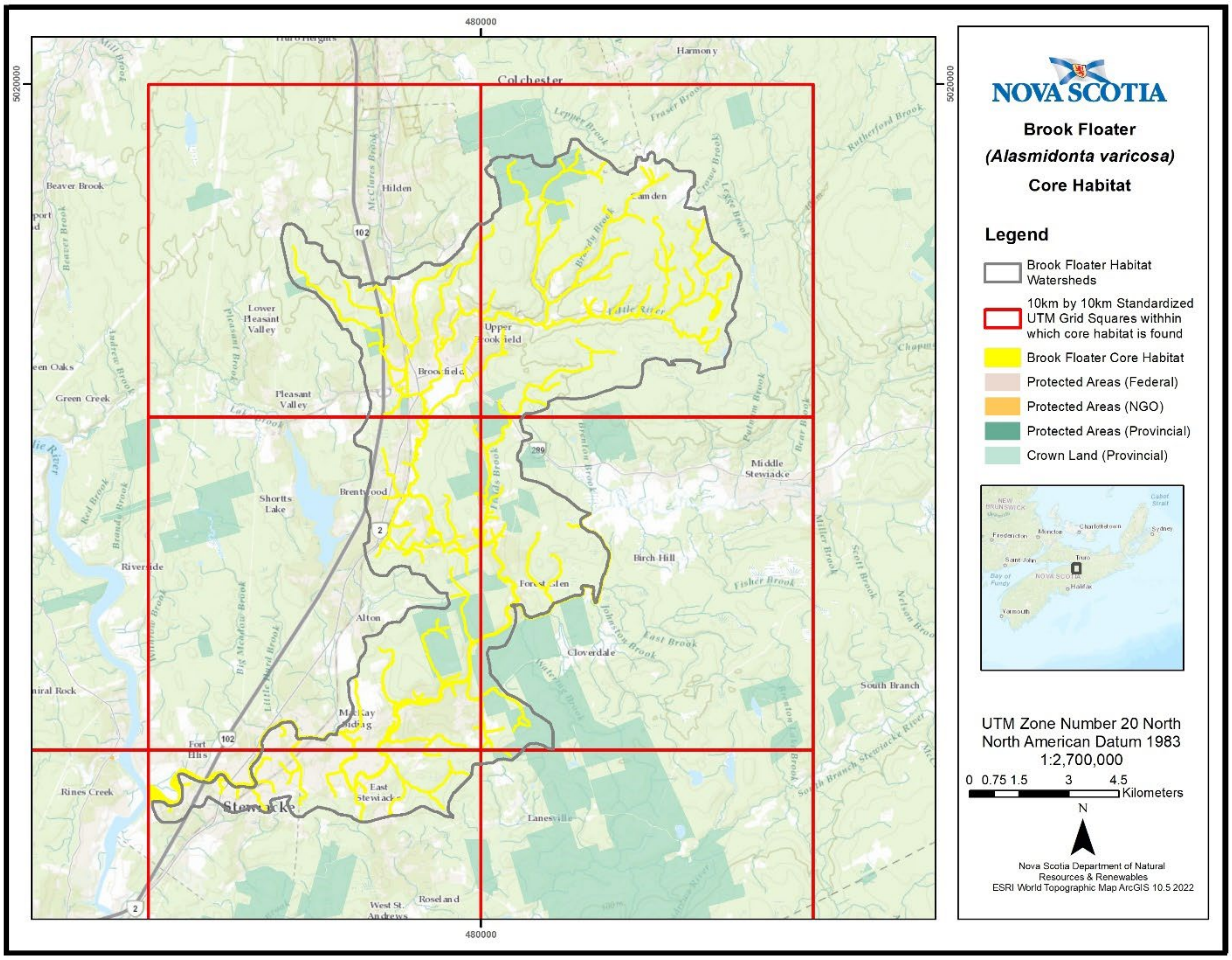

Figure 5. Identified core habitat for Brook Floater in the Stewiacke River watershed, Nova Scotia

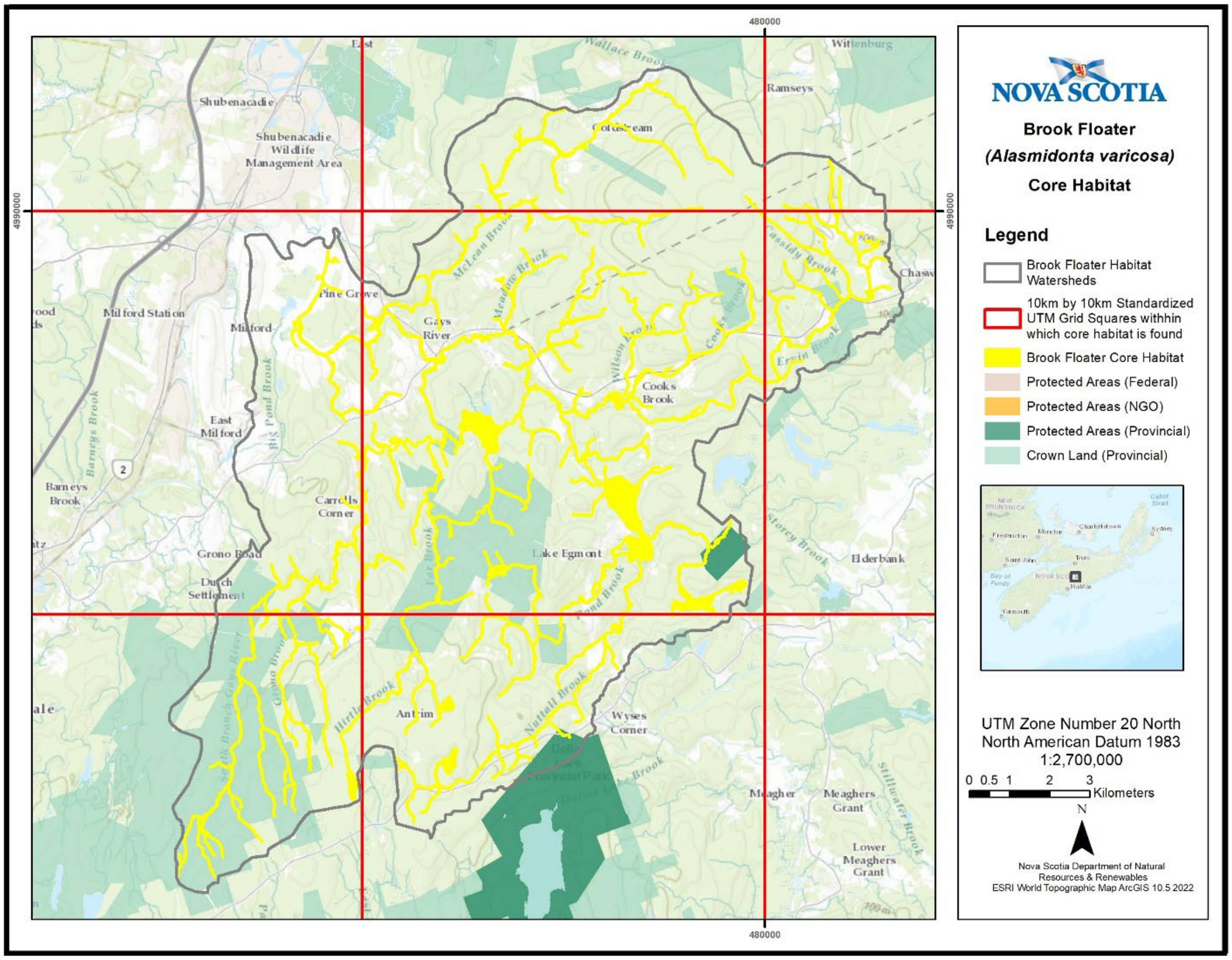

Figure 6. Identified core habitat for Brook Floater in the Gays River watershed, Nova Scotia

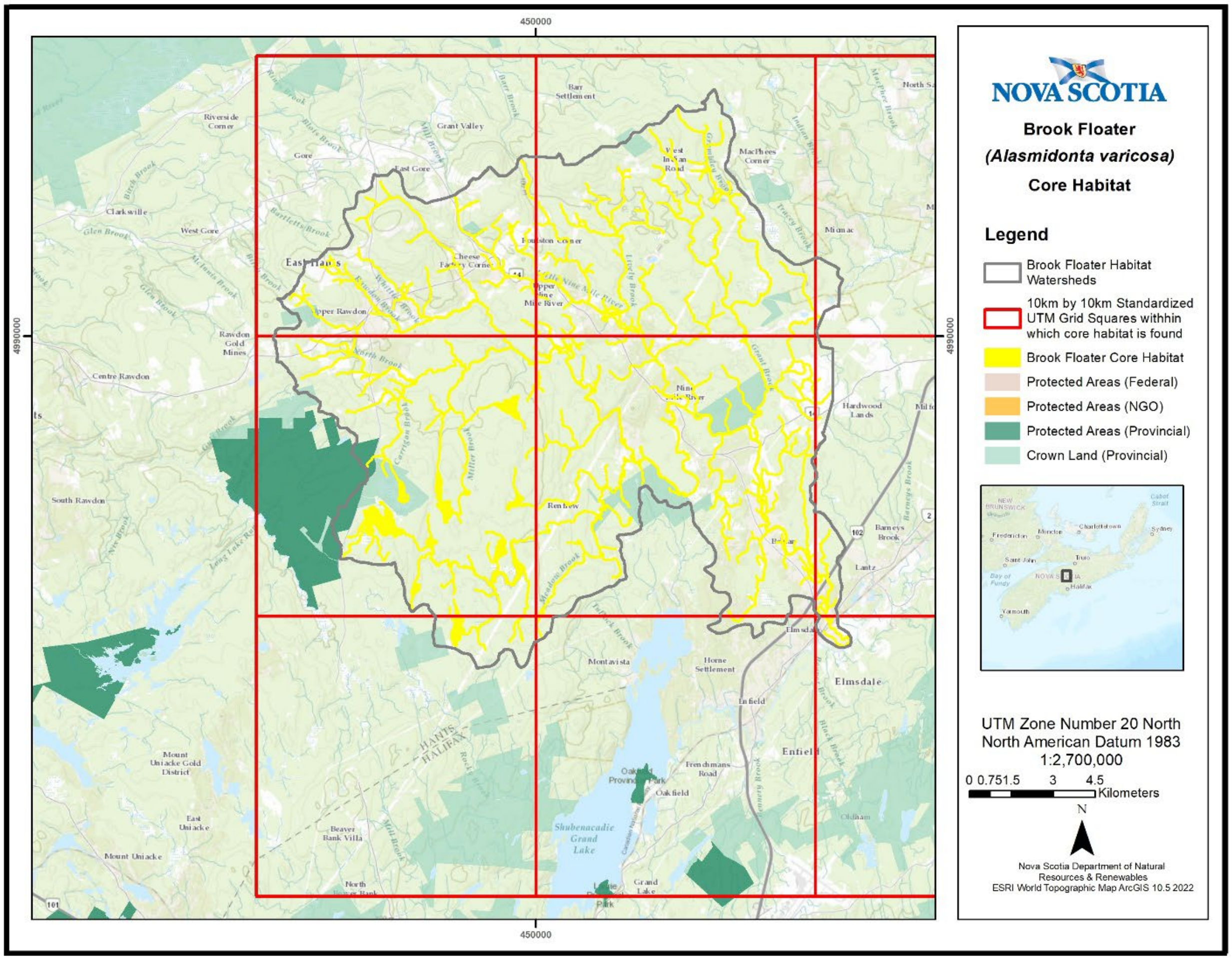

Figure 7. Identified core habitat for Brook Floater in the Nine Mile River watershed, Nova Scotia

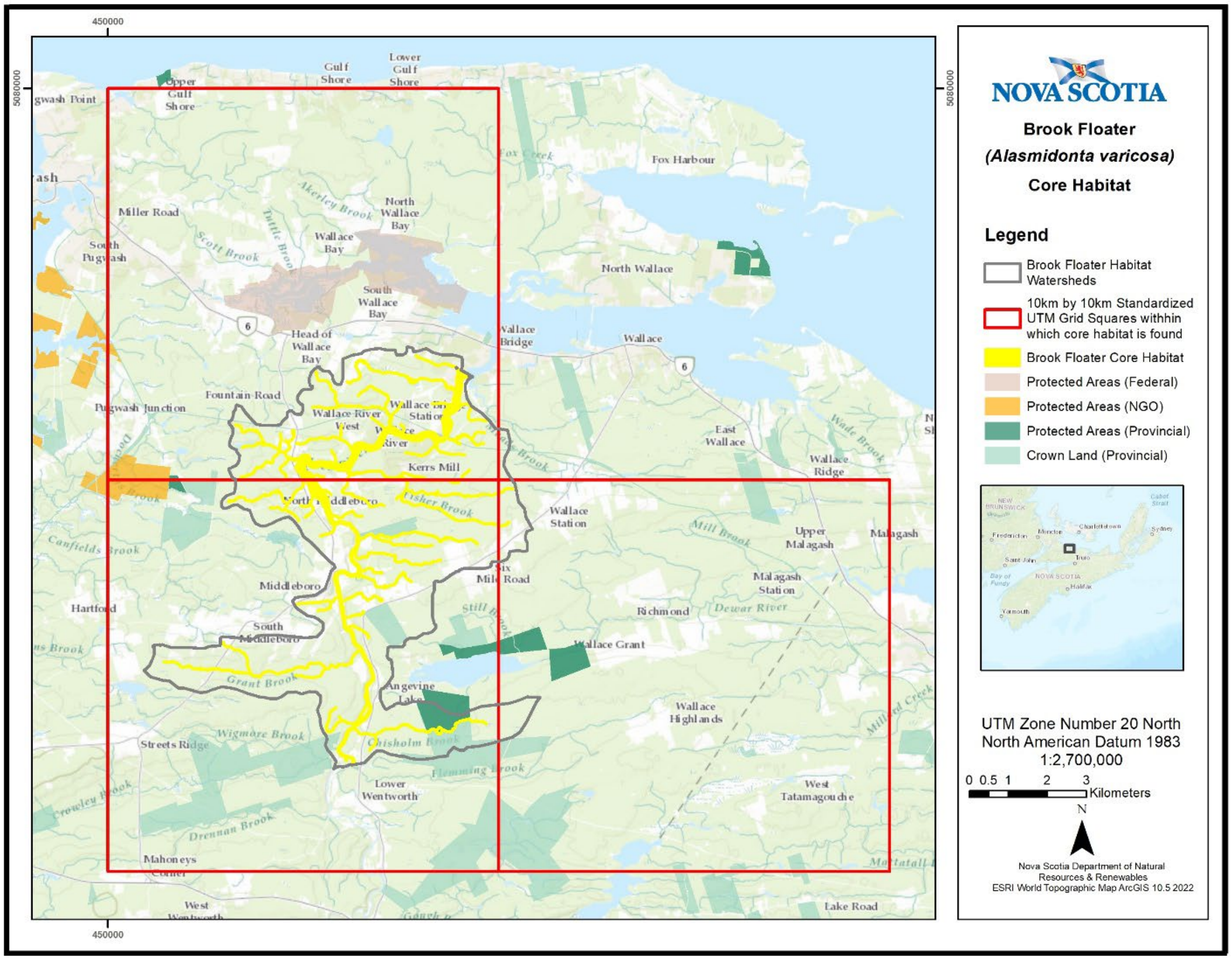

Figure 8. Identified core habitat for Brook Floater in the Wallace River watershed, Nova Scotia

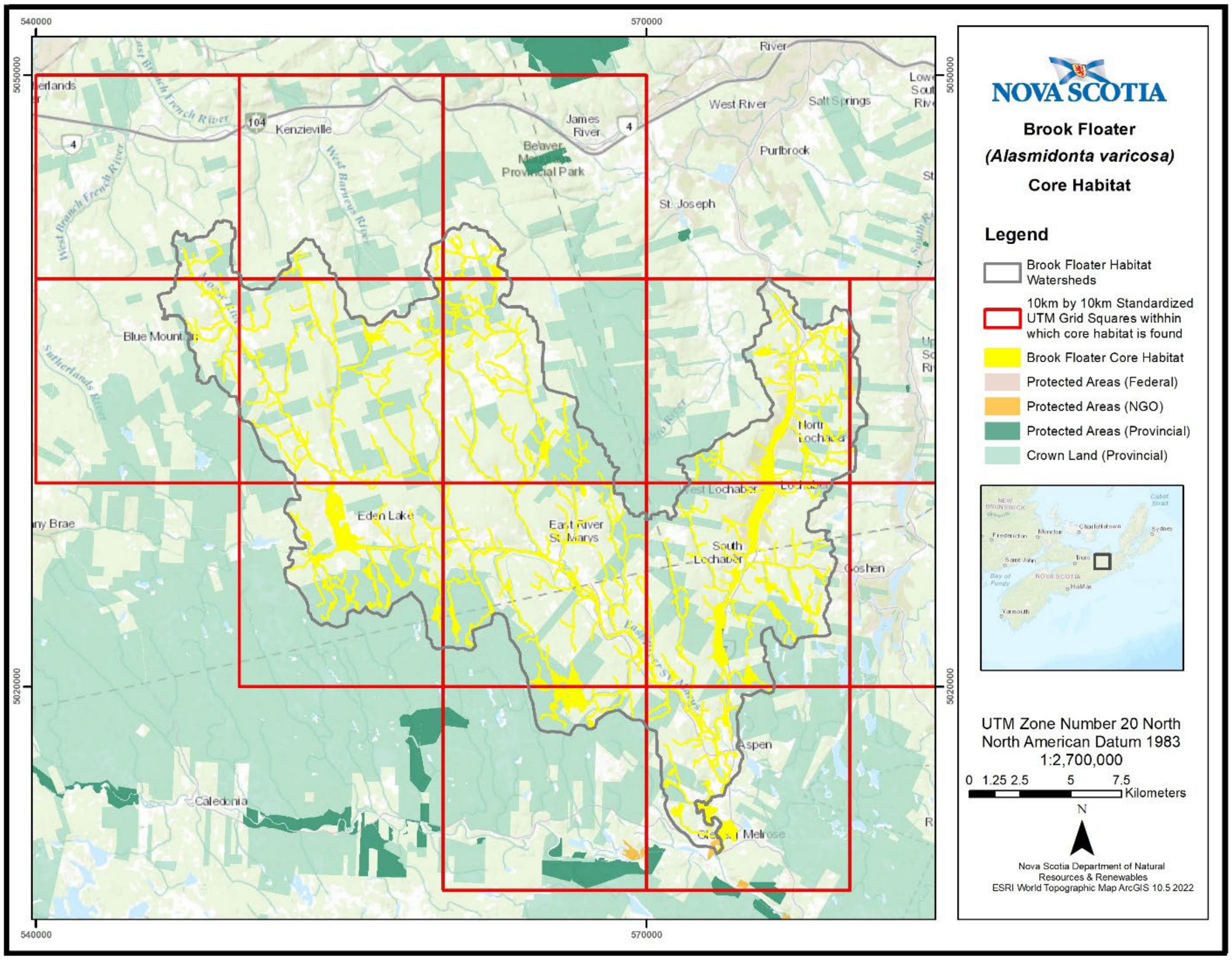

Figure 9. Identified core habitat for Brook Floater in the St. Marys River watershed, Nova Scotia

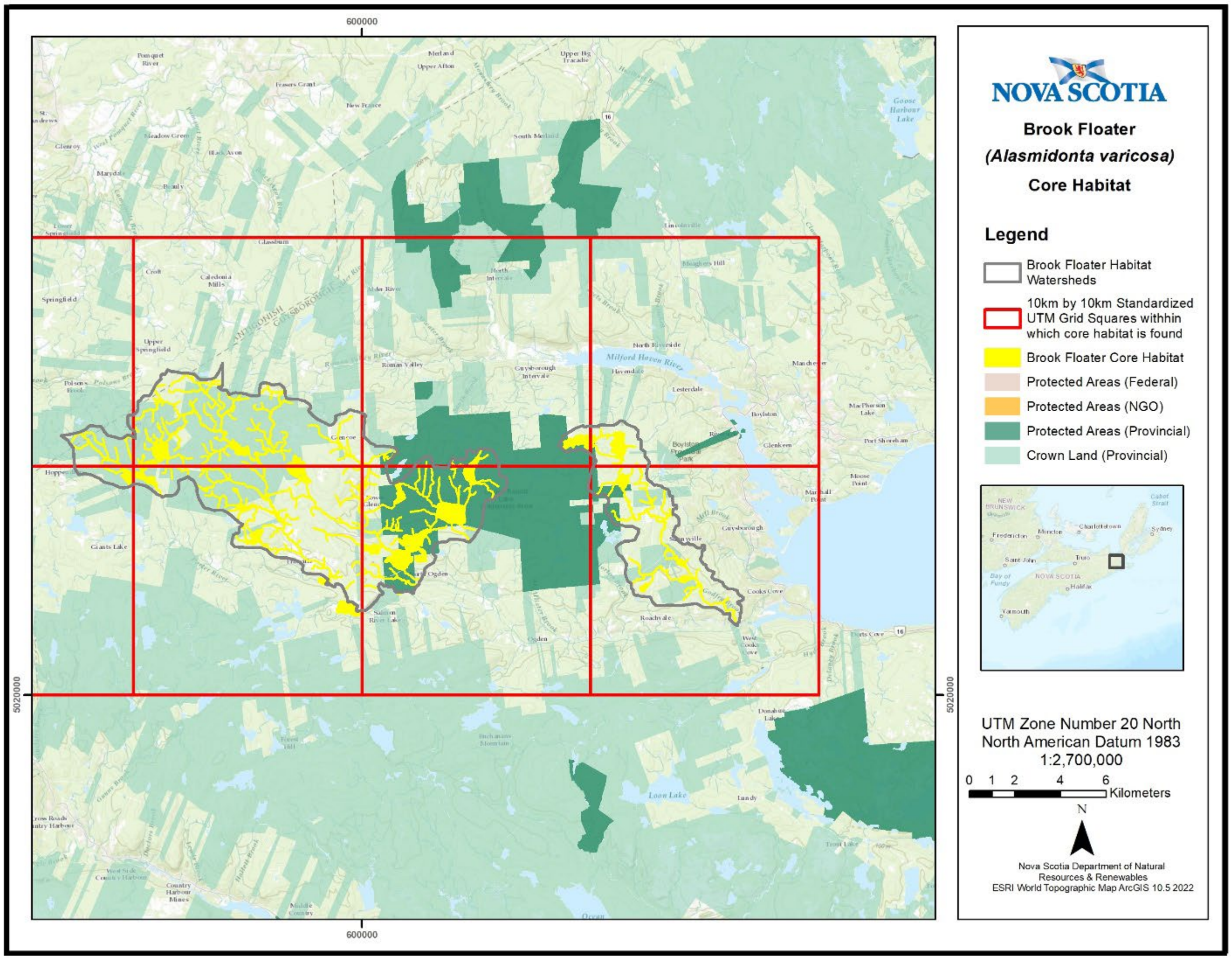

Figure 10. Identified core habitat for Brook Floater in the Salmon River watershed, Nova Scotia