Preliminary Assessment of the Recovery Potential of the Brook Floater (*Alasmidonta varicosa*), Canadian Population

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PRELIMINARY ASSESSMENT OF THE RECOVERY POTENTIAL OF THE BROOK FLOATER (*ALASMIDONTA VARICOSA*), CANADIAN POPULATION

by

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The Brook Floater (*Alasmidonta varicosa*) is a freshwater mussel endemic to North America; within Canada, its distribution is currently restricted to 15 watersheds in New Brunswick and Nova Scotia. COSEWIC has assessed this species as Special concern. Populations of this native burrowing bivalve, like other unionids, continue to decline, mainly because of anthropogenic activities that affect habitat and water quality. Given the very limited species-specific data available, the current report does not attempt to quantitatively predict Brook Floater distribution or abundance; it outlines qualitative objectives to develop recovery or maintenance targets for the Brook Floater. The recommended primary target is the recovery or maintenance of long-term viable populations within all of the rivers identified as currently supporting Brook Floater; the secondary target is the rediscovery of viable populations within rivers identified as historically supporting this freshwater mussel. Measures are suggested to reduce threats to the population and to better assess population dynamics, including mortality rate, fecundity, productivity, and population trajectory. From a qualitative perspective, the recovery or maintenance potential of Brook Floater populations in Canada is anticipated to be high.

RÉSUMÉ

L’alasmidonte renflée (*Alasmidonta varicosa*) est une moule d’eau douce endémique à l’Amérique du Nord; au Canada, sa distribution est couramment limitée à 15 bassins versants du Nouveau-Brunswick et de la Nouvelle-Écosse. Cette espèce est listée comme préoccupante par COSEPAC. Tout comme pour d’autres unionidés, les populations de ces bivalves fouisseurs indigènes continuent de diminuer, principalement en raison des activités anthropiques qui affectent leur habitat et la qualité de l'eau. Étant donné le manque de données disponibles spécifiques à l'espèce, le rapport ne tente pas de prédire quantitativement la répartition ou l'abondance de l’alasmidonte renflée; il décrit des objectifs qualitatifs pour élaborer des cibles de rétablissement ou de maintien pour l’espèce. L'objectif principal recommandé est le rétablissement ou le maintien à long terme des populations viables au sein de toutes les rivières identifiées comme soutenant actuellement l’alasmidonte renflée, la cible secondaire étant la redécouverte de populations viables dans les rivières identifiées comme ayant historiquement soutenu cette moule d’eau douce. Des mesures sont proposées pour réduire les menaces à la population et afin de mieux évaluer la dynamique des populations, y compris les taux de mortalité, la fécondité, la productivité, et la trajectoire de la population. D’un point de vue purement qualitatif, on anticipe que le potentiel de rétablissement ou de maintien des populations d’alasmidonte renflée au Canada soit élevé.

PREFACE

In April 2009, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed the status of Brook Floater (*Alasmidonta varicosa*) as a species of "Special Concern". In anticipation of that decision, Fisheries and Oceans Canada (DFO) had given a contract to Jacques Whitford Stantec Ltd. to prepare an assessment of the Brook Floater's situation and of its potential for recovery. This assessment considers the scientific data available with which to assess the maintenance or recovery potential of the Canadian populations of Brook Floater.

During the preparation of a Recovery Strategy, further consideration must be given to the impacts of human activities on the species and its ability to recover, as well as the alternatives and mitigation measures that can be pursued to reduce human impacts to the species. The goal is to reduce impacts such that they will not jeopardize the survival and recovery of the species. To that effect, DFO science has to prepare a species Recovery Potential Assessment (RPA) to provide the information and scientific advice needed to meet the various requirements of the *Species at Risk Act* (SARA).

This scientific information serves as advice to the Minister of Fisheries and Oceans Canada regarding the listing of the species under the SARA. The RPA scientific information is also used when analyzing the socio-economic impacts of adding the species to the list as well as during subsequent consultations, where applicable. This information is normally required to make a final listing decision following the designation by COSEWIC of "Threatened" or "Endangered".

In this case, since the COSEWIC assessment for the Brook Floater was "Special Concern" listing under the *Species at Risk Act* (SARA) would not invoke any prohibitions or measures to protect the species' critical habitat, thus, a recovery potential assessment was not required. The following report had nonetheless been commissioned and is published in the DFO Manuscript Report Series in order to provide recovery teams with the information needed to prepare a management plan for the species. This will allow groups or members of the public who want to be or are currently involved in conservation or recovery efforts of this freshwater species to quickly access the information required.

Information that is provided in this manuscript is taken directly from the 2009 Jacques Whitford Stantec Limited report; as a result, certain comments are not up to date with respect to the current status of Brook Floater in Canada.

1. INTRODUCTION

Brook Floater (*Alasmidonta varicosa*) is a freshwater mussel in the Unionoidea superfamily (i.e. unionid or pearly mussel) and remains extant within eastern North America, from northeastern Georgia through the eastern United States of America (USA) and into central Nova Scotia and southern New Brunswick. The following is a summary of the information available about its current status and distribution.

- Brook Floater coverage was formerly extensive throughout its range in the USA but it has diminished, currently occupying approximately half of the previously identified locations.
- Within Canada, the Brook Floater occurs in a relatively small number of watersheds (Figure 1).

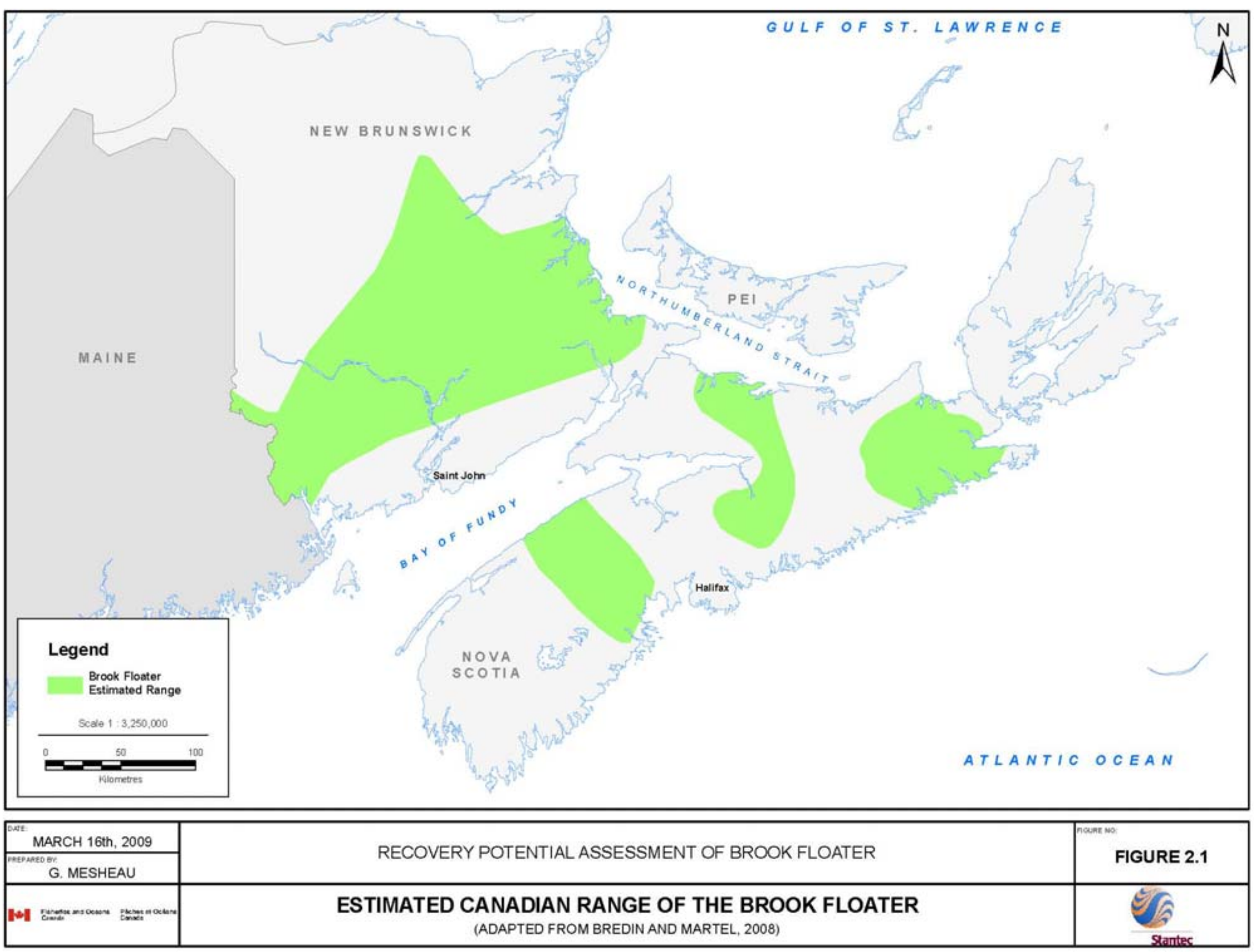

Figure 1 - Estimated Canadian range of the Brook Floater (adapted from COSEWIC 2009).

- In New Brunswick, populations are found in the following watersheds: Bouctouche, Kouchibouguacis, Magaguadavic, Petitcodiac, Scoudouc, Shediac, Southwest Miramichi and St. Croix (Figure 2).

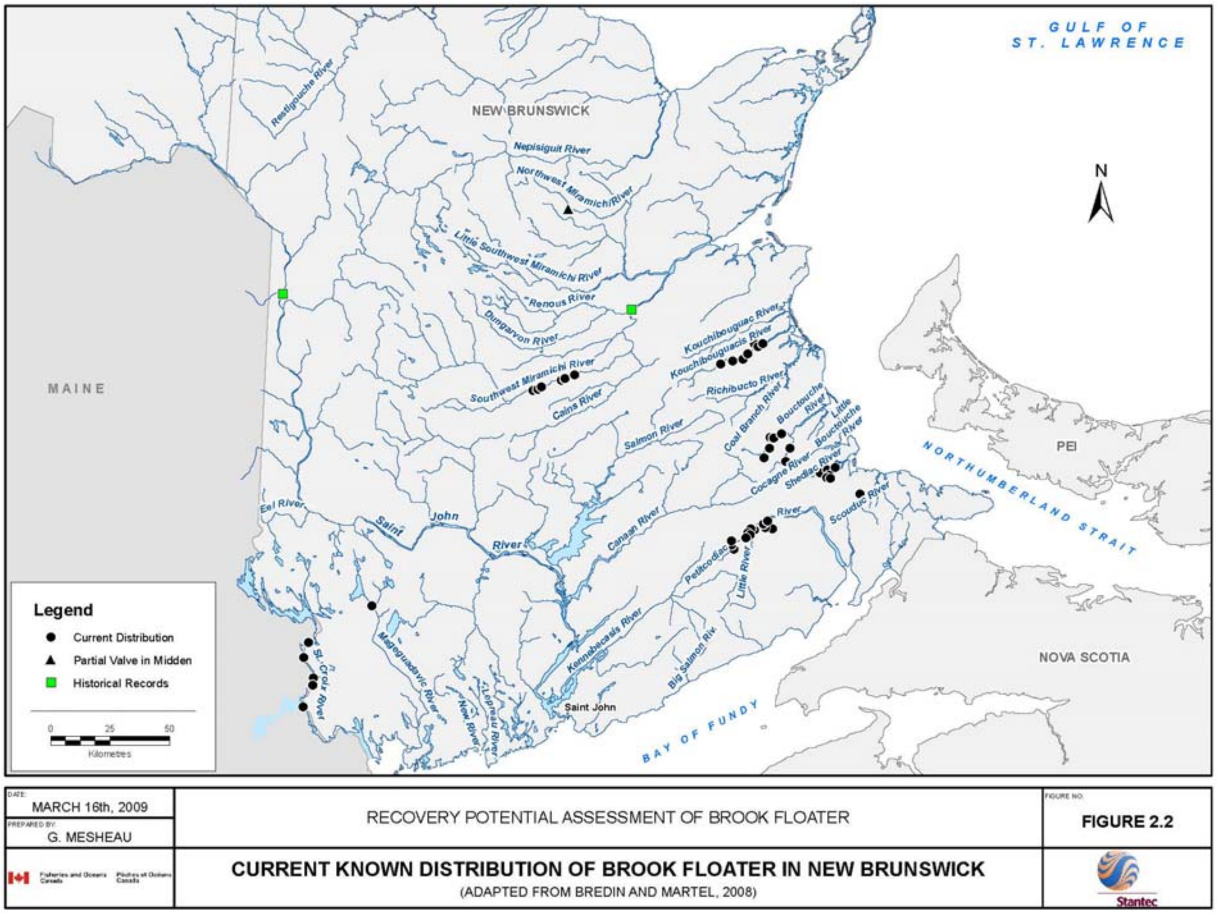

Figure 2 - Current known distribution of the Brook Floater in New Brunswick (adapted from COSEWIC 2009).

- In Nova Scotia, Brook Floater populations are spread amongst the Annapolis, Saint Mary's, Gays, LaHave, Salmon, Mattatall and Wallace Rivers (Figure 3) (COSEWIC 2009).

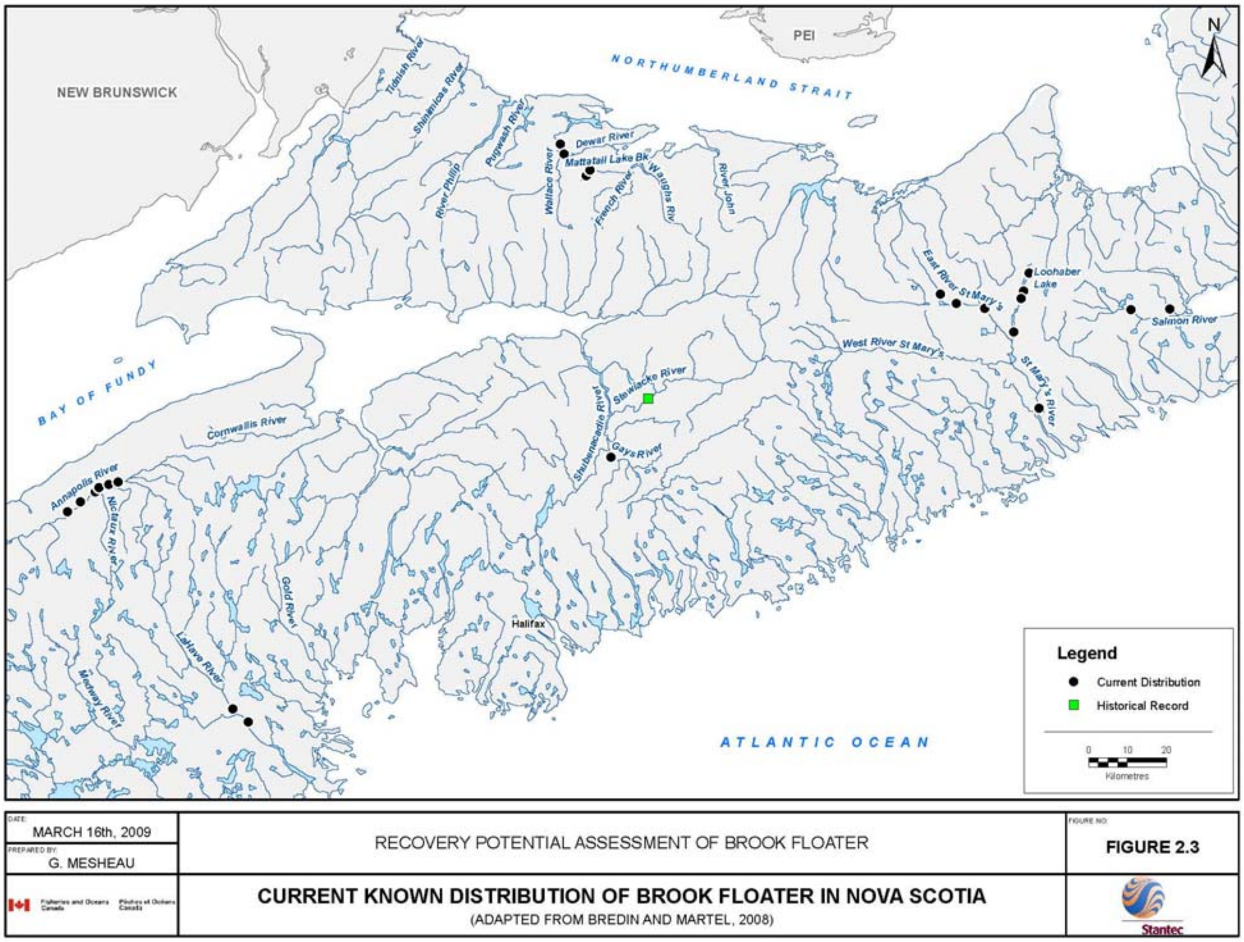

Figure 3 - Current known distribution of Brook Floater in Nova Scotia (adapted from COSEWIC 2009).

- Historical population data are not readily available as the Brook Floater was of limited historical interest; with increased sampling effort, new populations within Canada are presenting themselves (COSEWIC 2009).
- The global status of Brook Floater is G3 (vulnerable) and, within Canada, it has the national status of N2 (nationally imperilled).
- The COSEWIC has assessed the Brook Floater as a species of "Special Concern" in April 2009 (COSEWIC.2009)

- The Nova Scotia Department of Natural Resources (NSDNR) ranks the status of the Brook Floater as yellow (sensitive to human activities or natural events) (NSDNR 2009).
- The Atlantic Canada Conservation Data Centre (ACCDC) lists the Brook Floater as an S1S2 species in both Nova Scotia and New Brunswick (ACCDC 2010).
- The New Brunswick Department of Natural Resources' (NBDNR) ranking is "may be at risk" (NBDNR 2002).

2. ASSESSMENT

2.1 PHASE I: ASSESS CURRENT SPECIES STATUS

2.1.1 Present Status and Trajectory

Trend data are unavailable for Canadian populations of Brook Floater mussels, but an increase in survey number and frequency over the past 15 years has led to population estimates for all the known populations within New Brunswick and Nova Scotia (see Table 1).

It is anticipated that five rivers in Nova Scotia and New Brunswick (i.e., Petitcodiac, Southwest Miramichi, Shediac, Annapolis and St. Mary's) make up the majority of the population and area of occupancy (habitat). These five large populations are located in major waterways in their respective watersheds and are heavily influenced by anthropogenic factors including forestry, agriculture, sewage discharges, recreational use, residential development, and industrial discharges (COSEWIC 2009). Summaries of the five largest known populations are presented below. Background information concerning the remaining, smaller populations is available in the COSEWIC assessment and status report (COSEWIC 2009).

2.1.1.1 Petitcodiac River, New Brunswick: Population estimates range from 730-7300 individuals in a 23.0 km stretch of reach. The large variance in the estimated population size is due to the approach taken in sampling methods. This survey was prompted by concern for the Dwarf Wedgemussel (*Alasmidonta heterodon*), which resulted in the surveying of 66 sites from 1997 to 2000. Brook Floater mussels were found in sandy deposits along the main river and in the tributaries Little River and North River. Of note, individuals of less than 15 mm were observed, suggesting recruitment in the area. The majority of the stretch of river supporting the Brook Floater population is privately owned and zoned for either residential or agricultural land use (COSEWIC 2009). It is anticipated that the main anthropogenic pressure is agricultural runoff related to poor land use practices, which increases productivity and suspended sediments, as well as loss of riparian habitat. The loss of riparian habitat also increases suspended sediment loads through increased potential for runoff and loss of bank stabilization.

A quantitative population trajectory for the Petitcodiac River can not be determined as previous data available from the 1951 and 1966 surveys do not include abundance results. It can be confirmed that a population was first recorded for this river in 1949, with follow-up monitoring confirming continued presence of a population in 1951, 1966 and from 1997 to 2000. Further, the most recent of these surveys confirmed ongoing recruitment in the area through identification of juvenile Brook Floater mussels. As such, a qualitative presence-absence population status for the Petitcodiac River can be suggested. This status is suggested as: presence maintained, recruitment observed, based on the most recent survey results; however, the Petitcodiac River has not been surveyed in more than eight years.

Table 1 - Summary of known Brook Floater population estimates in Canada (adapted from COSEWIC 2009)

WATER BODY	SURVEY DATES	AREA OF OCCUPANCY (KM^2)	POPULATION ESTIMATES (NUMBER OF INDIVIDUALS)
New Brunswick			
St. Croix R.	1994, 2001, 2006	0.165	950
Magaguadavic R.	2001, 2006	0.002	40
Petitcodiac R.	1997, 1998, 1999, 2000	0.840	730-7300
Southwest Miramichi R.	2002, 2006, 2007	0.560	5600
Kouchibouguacis R.	2001	0.224	980
Bouctouche R.	2002, 2004	0.091	630
Shediac R.	2002, 2005	0.119	6100
Scoudouc R.	2005	0.012	190
Nova Scotia			
Annapolis R.	2005	0.216	6020
Gays R.	2002	0.027	110
Wallace R.	1991 to 2001, 2006	0.006	25
Mattatall R.	2001	0.015	50-200
LaHave R.	2006	0.072	350
St. Mary’s R.	1999, 2000, 2001	0.582	1000-5000
Salmon R.	2006	0.014	100-500

2.1.1.2 Southwest Miramichi, Miramichi River system, New Brunswick: A newly discovered population, estimated at 5600 individuals, was found in a 28.0 km section of the Miramichi River system near Doaktown. The survey was completed by a contributor to the COSEWIC assessment and status report (2009) between 2006 and 2007 and confirmed Brook Floater mussels at six sites along the reach, including juveniles (K. Bredin, Bird Studies Canada, personal communication, 2009). A survey in 2002 failed to find any individuals on the Cains River, a tributary to the Miramichi River system, or 20-50 km downstream from Doaktown where the velocity increases, and the river is deeper and wider (COSEWIC 2009). Two valves were found on the Little Southwest Miramichi River (3 km upstream from the Redbank Bridge) in October 2008, but thus far a population of live animals has not been located or confirmed.

A quantitative population trajectory for the Southwest Miramichi River can not be determined as previous abundance data are unavailable to correlate with the most recent surveys. A qualitative presence-absence population trajectory status for the Southwest Miramichi River can be suggested, taking into consideration that this population is newly discovered and, therefore, no historical records exist. The suggested status is: presence found, recruitment observed.

2.1.1.3 Shediac, Bouctouche and Scoudouc Rivers, New Brunswick: The latest population estimate of 6100 individuals for the Shediac River is produced from a series of surveys completed by Bredin (2002) *in* COSEWIC (2009), Caissie (2005) *in* COSEWIC (2009) and Caissie and Audet (2006). Bredin confirmed populations at 2 sites along the Shediac River; juveniles were also identified (K. Bredin, Bird Studies Canada, personal communication, 2009). The 2005 and 2006 surveys identified juvenile individuals at 6 sites as well, inferring continued recruitment. Smaller populations were also identified on the nearby Bouctouche and Scoudouc Rivers, estimated at 630 and 190 respectively, along a 7.0 km section of reach.

Population trajectories for the Shediac, Bouctouche and Scoudouc Rivers can not be determined as previous abundance data are unavailable to correlate with the most recent surveys. A qualitative presence-absence population trajectory status for all three rivers can be suggested. The suggested status is: presence found, recruitment observed.

2.1.1.4 Annapolis River, Nova Scotia: The latest population estimate of 6020 in a 18.0 km section of the Annapolis River is from a 2006 survey done by Bredin, which comes following identification of species at all 7 sites surveyed, including some juveniles (K. Bredin, Bird Studies Canada, personal communication, 2009). Brook Floater mussels were deemed most abundant near Middleton, which corresponded to a substrate of mostly sand, with occasional boulders and a water depth of approximately 1 m.

A quantitative population trajectory for the Annapolis River can not be determined, as there are only 2 points of data available for direct comparison. More specifically, Athearn and Clarke (1962 *in* COSEWIC 2009) recorded finding "occasional" specimens at the Lawrencetown location within the river, and surveys conducted in 2006 found only two specimens in three quarters of an hour in the same area. Looking at the river qualitatively as a whole, the species was confirmed present in 1953, 1962, and 2006 (when juveniles were also reported). As such, a qualitative presence-absence population trajectory can be assigned in lieu of quantitative information. The status suggested for this population is: presence maintained, recruitment observed.

2.1.1.5 St Mary's River, Nova Scotia: The latest population estimate of 1000-5000 individuals in a 30.0 km section of the St. Mary's River shows a wide range due to differences in the sampling approaches taken. The semi-quantitative survey in 2007 was conducted by Davis, and followed the 1999-2001 surveys conducted by Nova Scotia Department of Natural Resources (NSDNR), where records were produced throughout the watershed including Lochaber Lake and Eden Lake, the headwaters for the East River St. Mary's (a tributary of the St. Mary's River). Juveniles are anticipated to be present in the St. Mary's River system (K. Bredin, Bird Studies Canada, personal communication, 2009).

A quantitative population trajectory for the St. Mary's River can not be determined as previous abundance data are unavailable to correlate with the current round of surveys. From a qualitative, presence-absence perspective, the Brook Floater has been confirmed in the St. Mary's River system in 1946, between 1999 and 2001, and in 2007. Therefore, a qualitative presence-absence population trajectory can be assigned and is suggested to be: presence maintained, recruitment observed.

2.1.1.6 Supporting Populations: Multiple, smaller populations were identified within New Brunswick in addition to the three major populations discussed above. All of the smaller populations are known to support juvenile Brook Floater mussels, with the exception of the Magaguadavic River (K. Bredin, Bird Studies Canada, pers. comm., 2009). The presence of juveniles within the various watersheds provides insight into recruitment potential. A qualitative presence-absence status for the remaining, smaller New Brunswick populations is suggested as: presence found, recruitment observed. The exception is the Magaguadavic River, which is suggested as: presence found, no recruitment observed.

Several small populations have been identified within Nova Scotia in addition to the two dominant populations discussed above (i.e., Annapolis River and St. Mary's River). Of the smaller populations, juveniles were not found in the Wallace, LaHave and Gays Rivers (K. Bredin, Bird Studies Canada, pers. comm., 2009). The remaining smaller populations were identified during NSDNR surveys of 1999-2001. Juveniles were not recorded during these surveys (K. Bredin, Bird Studies Canada, pers. comm., 2009); as such, the recruitment potential of the water bodies can not be determined. A qualitative presence-absence status based solely on the adult populations is suggested to be: presence maintained, no recruitment observed for all Nova Scotia populations.

2.1.1.7 Historical Populations Not Re-Discovered: In addition to multiple recently documented populations of the Brook Floater, there were also several populations confirmed historically, but lacking any individuals in recent surveys. These include the Stewiacke River (Nova Scotia) and Aroostook and Renous Rivers (New Brunswick) (COSEWIC 2009). Live individuals were not found in the Stewiacke River in Nova Scotia during recent studies, but fresh valves were discovered in the 2006 surveys (COSEWIC 2009).

2.1.1.8 Summary: The known Canadian population of the Brook Floater likely ranges between 23 000 and 34 000 individuals, based on population estimates calculated for the COSEWIC report (COSEWIC 2009). With the very limited amount of data quantifying abundance, range and number of populations, trend detection was limited to qualitative population assessment using presence-absence data (see Table 2). Insufficient data for quantitative assessment of population trends is not unique to the Brook Floater within freshwater mussel communities (Strayer 2008). The current qualitative assessment has found that in the five largest populations, population trajectory status is either “maintained” or “new presence”, with observed recruitment. Similarly, the smaller populations in New Brunswick are assessed as presence maintained, with recruitment observed (with the exception of one river). By comparison, the smaller Nova Scotian populations generally exhibited the status of presence maintained, with no recruitment observed.

Increased survey efforts have resulted in new populations being found and more are anticipated to exist in currently unexplored areas (e.g., New Brunswick Rivers with appropriate habitat, as described in the section 2.1.3 on habitat requirements and use patterns, flowing into the Bay of Fundy). These areas would benefit from systematic surveys for the Brook Floater.

Table 2 – Summary of Presence-Absence status suggested for rivers located in New Brunswick and Nova Scotia

RIVER SYSTEM	PRESENCE-ABSENCE STATUS SUGGESTED
Petitcodiac R., NB	presence maintained, recruitment observed
Southwest Miramichi R., Miramichi River system, NB	presence found, recruitment observed
Shediac R., Bouctouche R. and Scoudouc R., NB	presence found, recruitment observed
Annapolis R., NS	presence maintained, recruitment observed
St Mary's R., NS	presence maintained, recruitment observed
Wallace R., LaHave R., Gays R., NS	presence maintained, no recruitment observed
Stewiacke R., NS	Confirmed historically but lacking individuals in recent surveys (fresh valves discovered in 2006)
Aroostook R., Renous R., NB	Confirmed historically but lacking individuals in recent surveys

2.1.2 Life History Characteristics

Insufficient data are available to quantify total mortality, natural mortality, fecundity or recruitment for Brook Floater populations in Canada. However, a general overview of life history characteristics can be provided. These characteristics will be taken into consideration during the assessment of habitat requirements, habitat use, management options and mitigation suggestions.

The Brook Floater life cycle is similar to that of other freshwater bivalve mussels. Individual Brook Floater mussels are of separate sexes but not sexually dimorphic, and are of relatively small size (50-65 mm in length) (COSEWIC 2009). The motility of adults is limited to meters per day, with the glochidia (larva) being the most motile life stage. The larva attaches to a fish host, thereby allowing them to move kilometres upstream or downstream of their origin and into adjacent rivers or watersheds. The fish species to which the glochidia attaches are a limiting factor in the efficacy of movement from one watershed to another. For example, attachment to strictly freshwater species results in the lack of potential to move through estuarine environments and into adjacent watersheds. The salinity tolerance of glochidia is unknown; as such, movement between watersheds through estuarine environments is hypothesized but not confirmed.

Fertilization success diminishes where mussel densities are extremely low; given Brook Floater use of microhabitats (refer to the section 2.1.3.1 - Habitat for adults and spawning); extremely low densities may be rare within a population. Mature adult females have a long-term brooding period (fall-spring) during which glochidia reside in the marsupial pouches of the female Brook Floater. This life history characteristic can be detrimental to the potential for population expansion of a species at risk because any death of a brooding female results in the death of the substantial number of glochidia she is carrying as well (Dillon 2000). High fecundity is necessary to ensure that an adequate number of glochidia survive and attach to the host. Once mature, juvenile Brook Floater mussels drop from the gills of the host fish and settle into the substrate, if the substrate is appropriate. If satisfactory substrate presents itself, the juvenile Brook Floater will bury into the substrate and remain there for multiple years (Dillon 2000).

Within Canada, ages of Brook Floater individuals have been estimated for populations from the upper reaches of the Petitcodiac River. These populations produce mean ages between 7-14 years based on shell growth ring counts (assuming one growth ring represents one year of age). Freshwater mussels, in general, may live for one to several decades (Strayer 2008); the Brook Floater comes out on the lower end of this age range. Strayer (2008) states that some mussel experts believe most estimates of unionid life spans underestimate actual life spans by a factor of three to five. This could extend potential Brook Floater age spans to more than fifty years.

Mortality in the adult Brook Floater is a result of typical biological processes such as age and predation, as well as anthropogenic factors that affect habitat quality and quantity as well as food availability.

2.1.3 Brook Floater Habitat Requirements and Use Patterns

As outlined in the previous sections, quantitative data are limited for Brook Floater habitat requirements and habitat use. However, habitat requirements and use can be interpreted qualitatively and applied to various life stages. Habitat is commonly thought of as a limiting factor for freshwater mussel populations. Traditional habitat descriptors (e.g., high level substrate type and flow dynamics) have been used in many of the Brook Floater surveys referenced in this report.

2.1.3.1 Habitat for Adults and Spawning: The majority of Brook Floater mussels are found in moving waters where the currents bring nutrients and oxygen past the organisms; flow conditions range from large rivers to small creeks. The substrate tends to be stable and composed of sand or gravel, with the mussels having a preference for microhabitats of sandy bars or shoals. The microhabitats that support the Brook Floater can also include sandy pockets deposited in the lee of logs, boulders or other debris which creates a slack current. Areas with high scour are generally absent of the Brook Floater habitats (COSEWIC 2009).

Freshwater mussels require calcium in their environment to support shell growth. It has also been suggested that environmental calcium can have indirect effects on freshwater mussels. For example, it has been observed that host fishes for unionids seem more abundant in hard water (Dillon 2000). Strayer (2008) reiterates that there is likely a great deal of variance in tolerance for calcium levels amongst the various freshwater mussel species and life stages. Some species of adult unionids can survive at low concentrations of dissolved calcium (e.g., <5 mg/L), while juveniles of some species may have higher calcium requirements (Strayer 2008). The calcium requirement of Brook Floater mussels specifically is currently unknown.

It should also be noted that high calcium concentrations can be a result of high nutrient loading in water bodies. An increase in nutrients can propagate a decrease in oxygen levels (Strayer 2008), which is detrimental to Brook Floater populations. This is an example of the complex relationships that exist between the multiple controlling factors of freshwater mussels in general. It is assumed that Brook Floater mussel populations are also influenced by these types of interactions. For example, habitat in the headwaters of the Bouctouche River is preferred by the Brook Floater compared to the more agriculture intensive lower reaches (COSEWIC 2009) where presumably increased siltation and nutrient loadings occur. Brook Floater mussels are poor at coping with anoxic conditions (Harman and Underwood 2007) and a pH of greater than 5.4 is preferred. Acidic conditions in Nova Scotia waters may limit availability of habitat for the Brook Floater, as pH values are commonly observed below 5.4 in streams and rivers. Strayer (2008) confirms that adult freshwater mussels also require habitat that does not contain materials toxic to unionids, such as ammonia and heavy metals; these toxins can be the result of natural processes but often have anthropogenic sources and/or confounding triggers (e.g., domestic, agricultural and industrial activities).

As sessile organisms, Brook Floater mussels spawn within their respective population nucleus; that is, dispersal of the Brook Floater occurs primarily through fish host dispersal and not as part of the spawning life stage. The male releases sperm through the excurrent siphon; the ovocytes are held in specialized marsupial pouches in the gill lamellae and females receive the sperm through the inhalant siphon while filter feeding. The eggs mature within the marsupial pouches from fall to early spring, and glochidia are released when stimulated by nearby host fish (Dillon 2000). Therefore, no spawning-specific habitat is required other than the need for overlap with host fish species to stimulate glochidia release.

2.1.3.2 Habitats for Juveniles: When released from the marsupial pouch, the glochidia of unionid mussels attach to and encapsulate themselves on the gills of the host fish and metamorphose into juvenile mussels (Strayer 2008). Once the abductor muscles, foot and gill structures are formed, the juvenile mussels drop off the host and begin a sedentary lifestyle. Thus, habitat for juvenile unionids, including the Brook Floater, is dependent on fish species abundance, as well as water and habitat quality. Species reported as hosts for the Brook Floater glochidia include: Ninespine stickleback (*Pungitius pungitius*); Longnose dace (*Rhinichthys cataractae*); Blacknose dace (*Rhinichthys atratus*); Golden shiner (*Notemigonus crysoleucas*); Pumpkinseed sunfish (*Lepomis gibbosus*); Slimy sculpin (*Cottus cognatus*); and Yellow perch (*Perca flavescens*) (COSEWIC 2009).

Once dropped from the host, unionid juveniles inhabit the interstitial spaces between gravel and sand substrate and are less mobile than their adult counterparts. Because of their inhabitancy of interstitial spaces, juvenile unionid mussels are limited by inadequate oxygen more often than adults and are more sensitive to pollutants that can concentrate in sediments (e.g. metals, polyaromatic hydrocarbons, polychlorinated biphenyls, etc.) (Strayer 2008). As a member of the unionid family, the Brook Floater would also be oxygen limited and sensitive to sediment-based pollutants.

2.1.4 Population and Distribution Recovery Targets

The current review of existing population estimates, trajectories, historical presence, life history parameters and habitat use patterns allows suggestions to be offered for population and distribution targets. Strayer (2008) recently completed a thorough assessment of multi-factor theory and potential modeling options related to the distribution and abundance of unionid mussel populations. He assessed the application of the three popular approaches to integration (i.e., Liebig's Law of Minimum; comprehensive, mechanistic modeling; and empirical modeling) as currently practiced by ecologists. His conclusion was that none of the current options is likely to lead to a satisfactory predictive understanding of unionid distribution and abundance (although his suggestion for future efforts is to pursue empirical modeling, as discussed in more detail in the section 2.3.3 - Population Models). As such, and given the very limited species-specific data available, the current report will not attempt to quantitatively predict Brook Floater distribution or abundance. Instead, suggestions are offered for consideration and to stimulate further critical thought during the recovery or maintenance process.

The COSEWIC assessment and status report (COSEWIC 2009) identified one potential cause of overestimating the population size and three potential causes of underestimating the population size in their assessment. Therefore, the current report suggests that the maximum estimated population sizes presented in COSEWIC (2009) be considered as the target population recovery size based on the current known range of distribution. This target could be considered short-term (i.e., one to two generations, or 10-20 years) in the hopes that more quantitative data are available for recalculation of targets in the future. If this approach is considered for target setting, it is further suggested that the upper ranges of all population estimates be used, resulting in an overall Canadian population short-term target of 34 000 individuals. River-based population size estimates (and therefore targets) are included in Table 1.

In order to support maintenance and potential recovery (i.e., increased population size and distribution) of Brook Floater mussel populations, a target for geographic distribution should be considered. The recommended primary target for qualitative geographic distribution is the recovery or maintenance of long-term viable populations within all of the rivers identified as currently supporting Brook Floater populations in New Brunswick and Nova Scotia. Some of the currently identified populations are estimated to have very low numbers of mussels (see Table 1).

Setting a target of maintaining or establishing populations with long-term viability at all of these sites can be a strong starting point for maintenance or recovery potential since the presence of appropriate habitat (quality and quantity) is confirmed by the presence of even a few individuals at the sites. A secondary target for qualitative geographic distribution is the rediscovery of viable populations within rivers identified as historically supporting Brook Floater populations (e.g. Stewiacke River and Aroostook River).

2.1.5 Expected Population Trajectories, Time to Recovery Target, and Residence Requirements

Insufficient quantitative data (e.g., mortality rates, productivity) currently exist to use analytic practices such as demographic modeling for forward projections of populations within specific timeframes (Strayer 2008). Strayer's (2008) critical evaluation of multiple-factor theories related to unionid distribution and abundance led to several valuable observations related to unionid population response timeframes; his observations are outlined below and are applicable to Brook Floater.

The processes that led to losses of unionid populations and species in the past are not necessarily those that are causing mussel populations to decline today, or that present the greatest threats in the future. The identity, severity, taxonomic selectivity, and geography of anthropogenic threats to unionids change continuously, and care must be taken in extrapolating future trends from patterns of past losses.

Freshwater mussels are long-lived and typically exhibit slow response times to key parts of the ecosystem, such as sediment routing through a drainage network and nutrient saturation in a watershed. Given the longevity and slow response to potential stressors of unionids, the effects of human actions may take many years or decades to be fully expressed as changes in mussel populations. Such time lags substantially complicate analyses of human effects on unionids, and probably generally lead one to vastly underestimate the effects of human actions on unionids.

These observations by Strayer (2008) reflect the challenges and obstacles currently associated with assessment of recovery potential for the Brook Floater mussel. These challenges are compounded by a lack of long-term and robust population, fecundity, mortality, habitat quality and habitat quantity data for Canadian populations.

2.2 PHASE II: SCOPE FOR MANAGEMENT TO FACILITATE RECOVERY OR MAINTENANCE

Brook Floater populations have been lost from certain historical locations but new populations have recently been discovered (COSEWIC 2009). The global Brook Floater population has declined in North America but Canadian populations are doing better and may be the last global stronghold for the species. Brook Floater mussels in Canada may be more likely to currently face diminishment of local populations as opposed to a threat of species extinction. This situation can also be referred to as range thinning. Strayer (2008) identifies four main results of range thinning that, in turn, can affect recovery potential of unionid mussel species and eventually jeopardize survival. This current report advocates that Strayer’s list of the potential results of range thinning can be applied to the Brook Floater mussel as well:

- A diminished role of the species in local communities and ecosystems;
- Loss of genetic diversity within species;
- Increased distance and presumably greatly reduced dispersal among remaining populations, which may lead to further losses of populations through metapopulation dynamics and,
- Increased risk of extinction for the species.

2.2.1 <u>Identification of Key Recovery and Maintenance Parameters</u>

Population dynamics, including mortality, productivity, recruitment, dispersal and fecundity, have not been quantified for the Brook Floater mussel. A minimum viable population size is unable to be quantitatively confirmed at this point. Given these factors, the current assessment can not quantify the probability of achieving the qualitative recovery targets set in the previous sections. Detailed analyses of population viability and dynamics require more empirical data on the species.

2.2.2 <u>Identification and Assessment of Mortality Risks</u>

While it was not possible to quantify the magnitude of major potential sources of Brook Floater mortality, the current report did identify and rank threats to the Brook Floater based on information presented in the COSEWIC report (2009). This activity provides a relative measure of importance of mortality risks. Richter et al. (1997) concluded that the three most significant threats to freshwater ecosystems include (in no specific order):

1) Sedimentation and suspended sediment loading with nutrient loading from agricultural operations;
2) Interactions with exotic species and
3) Impoundment operations that alter hydrology and result in habitat alteration and fragmentation.

In regards to the latter threat, the rivers in Atlantic Canada are not impacted by major impoundments at the majority of locations where Brook Floater mussels are or were historically found; however, hydrology alterations can occur based on other anthropogenic factors.

The current report reviewed existing conditions (as reported in COSEWIC 2009) and used the information to identify the dominant mortality risks for Canadian populations of the Brook Floater. Specifically, there are two main threats to Brook Floater populations: sedimentation and habitat loss. Both can be correlated, as sedimentation can lead to the loss of interstitial spaces required by juveniles.

Sedimentation arises from numerous anthropogenic factors, as well as some natural events.

The main factors resulting in an increase in sedimentation within Brook Floater habitat in Canada are poor agricultural and forestry practices. In their assessment of 11 rivers, contributors to the COSEWIC report (2009) described forestry as the primary land use on 6 rivers and agriculture as the primary land use on 5 rivers. Forestry was a secondary land use on four of the rivers primarily influenced by agriculture. Poor agricultural and forestry practices can lead to the erosion of stream banks through riparian losses and poorly designed or maintained crossing structures (or lack thereof). Loss of riparian zones can also increase water temperatures as shading of the water body decreases. Increased temperature can result in loss of viability in unionid glochidia and increases in mortality from other stressors (Strayer 2008).

Sediment can also have direct effects on Brook Floater mussels themselves since sediments can degrade mussel shells through erosion, and heavy sedimentation can reduce gill efficacy (Watters 2000). Sedimentation can directly impact juvenile freshwater mussel species as they live completely buried for several years; with increased sediment deposition over top of a buried juvenile, dissolved oxygen cannot be freely exchanged from the water column to the juvenile (Watters 2000).

Furthermore, excessive nutrient inputs, from agriculture or residential use of fertilizers, combined with low flows and high water temperature can cause the formation of macroalgae beds on sediments. This combination can lead to anoxic conditions under the alga mat and therefore is a source of mortality for all unionids (Hanson and Locke 2001).

Direct habitat loss at the Brook Floater juvenile stage can occur as a result of sedimentation and at the glochidia stage, through the absence of appropriate fish host species. The lack of fish host availability can result from fish passage issues associated with dams, as well as predation of fish hosts through the introduction of non-native species (discussed in more detail below). Direct habitat loss at all life stages can come from impoundments, which decrease stream velocities, increasing the area of the water body. In addition, impoundments create head ponds which are not suitable habitat for the Brook Floater and which are barriers to fish passage, including potential fish host species.

Of the rivers assessed in the COSEWIC report, three currently have dams (COSEWIC 2009). The St. Croix River in New Brunswick has 9 dams; 3 of which are in areas occupied by Brook Floater populations, including one dam which has a head pond that empties completely for periods of time. While habitat quality has been designated as stable (i.e. no recent decline in quality) within the past decade, habitat fragmentation occurred in the past with the construction of the dams and likely contributed to the Brook Floater population decline observed 60-100 years ago (COSEWIC 2009). Further threats to Brook Floater habitat supply and quality are discussed in the section 2.2.3 - Quantification of habitat need and supply, below.

Other less large-scale threats to mortality include predation and physical destruction. Predation is a typical biological mortality risk. Small mammals (e.g. muskrat and otters) have an affinity for freshwater mussels and a preference for those with light musculature and a smaller size (COSEWIC 2009). This predation could cause a threat to population numbers if the habitat for the predatory mammal coincides with the habitat of a rare freshwater mussel species, like the Brook Floater.

Direct mortality and direct habitat loss results from the physical destruction of Brook Floater mussel beds as well. For example, this is observed in environments in which livestock or all-terrain vehicles (ATVs) are given open access to rivers and subsequently trample mussel beds and surrounding habitat when crossing rivers.

One potential future threat to Brook Floater populations is a decrease in water quality. Water quality of the river systems assessed in the COSEWIC Status Report was deemed fair to excellent, with fairly consistent status between the current designation and the designation for 10 years previous (COSEWIC 2009). Increased sedimentation is reported to occur in 2 of the river systems (Kouchibouguacis / Bouctouche and Shediac / Scoudouc, both in New Brunswick) and effluent from a lead-zinc mine is released into a tributary of Gays River, Nova Scotia (COSEWIC 2009). Under the currently understood conditions, water quality does not appear to affect mortality of Brook Floater populations in Canada. More detailed discussion of potential effects of water quality on habitat supply is presented in the following section.

2.2.3 Quantification of Habitat Need and Supply

The currently available data do not allow a quantitative estimate of the total population of Brook Floater mussels that can be supported by existing habitat. However, sufficient information does exist to provide a qualitative interpretation of general, species-level and site-specific habitat need, supply, and quality.

The primary habitat requirements or needs of Brook Floater mussels have been discussed previously in this document and include the following:

- Stable substrate for burrowing with interstitial spaces for oxygen exchange and juvenile deposition;
- Sufficient flow to deliver nutrients and oxygen but not so much as to affect the ability of the organisms to attach to the substrate and,
- Sufficient calcium to support shell production.

The general threats to habitat supply include:

- Sedimentation and suspended solids,
- Water quality,
- Introduced species and,
- Impoundments.

As discussed above (section 2.2.2 - Identification and Assessment of Mortality Risks), sedimentation effects can result in mortality of Brook Floater populations. However, sedimentation and suspended sediments can cause general habitat degradation as well, prior to species mortality. Habitat is particularly vulnerable to degradation from sedimentation when the source is recurrent.

Similar to long-term effects of recurring sedimentation events, poor water quality can result in reduced habitat supply over time. Cumulative effects of changes in water temperature and chemistry can render previously suitable habitat areas unsuitable in relation to mussel needs.

The water quality parameters of primary concern are oxygen and ammonia. Adult freshwater mussels have the ability to survive with oxygen levels as low as 1 mg/L, although this may reduce growth and cause females to abort glochidia (Strayer 2008). Juveniles require higher oxygen levels and their survival may be affected at levels where adults would persist (Strayer 2008). The addition of sediment to the interstitial spaces in the substrate decreases the potential for oxygen availability. Dissolved oxygen can also decrease as a result of anthropogenic influences. An example of the latter is an increase in biological oxygen demand (BOD) resulting from the release of sewage, either untreated or of primary treatment, reducing the levels of dissolved oxygen if sewage discharges are large enough or if there is insufficient dilution from the point source.

Ammonia concentrations are generally elevated in environments of low oxygen (hypoxic). Therefore, it is not anticipated that elevated ammonia is currently a threat to adult Brook Floater mussel populations in areas presently identified to support populations in Canada since the water quality in those water bodies reportedly ranges from fair to excellent as summarized in the COSEWIC report (assuming dissolved oxygen was measured) (COSEWIC 2009). The majority of the water bodies assessed were generally of higher water quality. However, there is the potential for hypoxic conditions to be present in the substrate of these water bodies. This low oxygen concentration would cause nitrate in the system to reduce to ammonia and, depending on pH and temperature, would allow for differing ratios of ionized ammonia to unionized ammonia. The unionized form of ammonia is more toxic than the ionized form (Canadian Council of Ministers of the Environment 2010). As pH and temperature increase, the ratio favours the unionized form of ammonia, which increases toxicity. Increased organic loadings, either anthropogenic or natural, will increase nitrogen concentrations and, thus, ammonia, as will decrease dissolved oxygen (Strayer 2008).

Reduction in cover from loss of riparian zone vegetation can lead to increased stream temperature and increased sedimentation through run-off and erosion. As discussed previously, poor agriculture, forestry and development practices contribute to each of these inputs.

Two additional general, species-level threats to Brook Floater habitat supply are

1) Introduced species and,
2) Impoundment.

A key habitat for the Brook Floater glochidia life stage is the availability of appropriate fish host species. The introduction of Chain pickerel (*Esox niger*) and Smallmouth bass (*Micropterus dolomieui*) increases pressure on small bodied fish, including multiple potential host species for Brook Floater mussels.

As a popular recreational fish, Smallmouth bass are being introduced within Nova Scotia and New Brunswick even though introductions have been prohibited (NSFA 2009).

Numerous studies have been completed on the deleterious effects of dams on freshwater mussel species (e.g. Locke et al. 2003; COSEWIC 2009; Strayer 2008) as the impoundments tend to homogenize upstream habitats and alter historical habitats, thus changing habitat supply. A compounding effect is improperly constructed fish passage, which leads to barriers to fish migration. This restricts movement of potential fish hosts, which in turn results in diminished dispersal capacity of Brook Floater juveniles through the glochidia life stage. Water level fluctuations can leave juvenile Brook Floater mussels stranded above the water line, and cold water fed downstream from hypolimnetic-release dams suppresses unionid mussel reproduction (Strayer 2008).

Many of these general species-level threats to habitat supply for Brook Floater mussels are exemplified by site-specific conditions observed in the Canadian rivers known to currently support this species. In the Petitcodiac River system, poor agricultural practices are anticipated to be the main threat (see section 2.2.2 - Identification and Assessment of Mortality Risks for a discussion of the effects of poor agricultural practices). Also, since the opening of the Riverview-Moncton causeway gates in April 2010, salt waters as well as marine silt enter some of the lower Petitcodiac River sites where Brook Floater were detected during a 1997-2000 survey (Hanson and Locke 2001). Deposits of marine silt might threaten the survival of Brook Floater aggregations. Eventual instalment of a bridge across part of the causeway will provide an opportunity to monitor the new dynamics of the river and potential changes in the upstream distribution of Brook Floater mussels.

One of the poor agricultural practices carried out upstream in the area of the Brook Floater populations is the open access to watercourses that is given to cattle. More specifically, cattle are permitted within the river which has direct effects on sedimentation and disturbance of habitat at the crossing and downstream. An aforementioned mortality effect is the physical destruction of mussel beds as a result of trampling by cattle.

In Nova Scotia, the Annapolis River is affected during storm events where runoff brings *Escherichia coli* and nutrients into the river from nearby agricultural lands. Levels have been recorded which indicate significant eutrophication (COSEWIC 2009). Water quality is threatened along the St. Mary's River due to pesticide, fertilizer and sediment runoff, which is compounded by the decreased riparian zone due to nearby agricultural activities (COSEWIC 2009). Residential activities increase ammonia and nitrogen levels in the water while also decreasing riparian habitat, which in turn lowers the buffering capacity for absorbing nutrients of manicured urban plots (Watters 2000).

2.2.4 <u>Assessment of Habitat Threats</u>

While it was not possible to quantitatively assess the magnitudes of threats to the habitat of the Brook Floater, it is possible to infer that habitat quality concerns take precedence over habitat quantity concerns. Area of occupancy (AO) for the brook floater was calculated in the COSEWIC report (COSEWIC 2009) by determining the river length between the furthest upstream and furthest downstream Brook Floater record for the river. The calculated AO is substantially smaller than the Index of Area of Occupancy (IAO) (COSEWIC 2009). The IAO calculated by the IUCN method is the sum of the 2 km by 2 km grids overlaid on all the extent of occurrences (EO). The majority of the identified threats to habitat relate to effects on the quality of the microhabitat in which the Brook Floater lives. It is anticipated from available information that the Brook Floater as a species has room to increase its population in the streams, rivers and lakes it now inhabits. Increasing habitat quality in the areas of New Brunswick and Nova Scotia in which it is found would require the decrease of riparian destruction and removal along watercourses, thereby decreasing the sediment loadings in the watercourses. Habitat quality could be further increased by decreasing substrate damage from in-stream development, cattle crossings, recreational use (including ATV crossings), inappropriate agricultural and forestry practices and cosmetically applied lawn fertilizers as well as sewage discharge from increased residential development. All of these threats are not necessarily relevant to every Brook Floater population; instead, these represent a range of conditions that the Brook Floater must overcome to succeed.

2.3 PHASE III: SCENARIOS FOR MITIGATION AND ALTERNATIVES TO ACTIVITIES

2.3.1 Inventory of Suggested Feasible Mitigation Measures and Alternative Activities

The current report is the first step in the development of a recovery or maintenance process and, as such, has not been formally vetted by the scientific community. An inventory of recommended mitigation measures and alternative activities associated with identified threats to the Brook Floater has been prepared to stimulate discussion (Table 3). This inventory illustrates the overlapping nature of many of the threats. Multiple threats can be addressed by the same or similar mitigation measure or alternative action. These interacting threats exemplify the need for an ecosystem science approach to the management of Brook Floater species maintenance.

Ecosystem science takes a broad approach to studying relationships and interactions in the ecosystem, and integrates science outputs to provide a sound scientific foundation for policies and programs (DFO 2007). The complexity of interacting threats and responses (i.e., multiple controlling variables) within freshwater mussel communities is one of the reasons that those such as Strayer (2008) suggest that comprehensive mechanistic modeling is not possible for freshwater mussels. Adopting an ecosystem approach to address threats to the Brook Floater mussel should help improve the recovery or maintenance potential of the species.

Table 3 - Proposed mitigation measures and alternative actions.

THREAT	MITIGATION / ALTERNATIVE	LIFE STAGE ENHANCED
Sedimentation	Buffer zones around all water bodies (e.g. BMPs)	All
	Land use management (e.g. slope and stability)	All
	Erosion control measures (e.g. BMPs)	All
	Run-off control measures (e.g. BMPs)	All
	Monitoring programs (possibly including rain event monitoring)	All
	Consider special needs during environmental permitting processes	All
Direct habitat loss	Sedimentation mitigation and alternative actions, as described above	Juveniles
	Control of invasive fish species (e.g. prevention of new introductions in systems identified to support Brook Floater populations)	Glochidia
	Hydrologic impact assessments prior to dam installation	All
	Restrict access of livestock to rivers	All
	Habitat assessments	All
	Habitat restoration	All
	Consider special needs during environmental permitting processes	All
Impoundment	Effective fish passage design and implementation	Glochidia
	Hydrologic impact assessments prior to dam installation	All
	Minimum (maintenance) flow requirements	All
	Minimum drawdown	All
	Minimize number of impoundments (reduce habitat fragmentation)	All
	Consider special needs during environmental permitting processes	All

Predation	Identification of overlapping occurrences of mammalian predators and mussel populations (prioritize reduction of other negative cumulative effects on these populations)	All
	Monitor for invasive species (i.e. predation on host fish species)	All
	Muskrat predation control (natural or anthropogenic)	juveniles, adults
Water quality degradation	Reduction in contaminant load of run-off (e.g. BMPs)	All
	Run-off and sedimentation control measures (e.g. BMPs)	All
	Monitoring programs	All
Insufficient quantitative population dynamics data	Focused scientific assessments	All
	Integration with other comprehensive water quality monitoring programs (e.g. Nova Scotia provincial Water Resources Management Strategy and the Halifax Regional Municipality Water Quality Functional Plan; see Appendix A).	All
Potential unknown population locations	Partnerships with volunteer and non-profit groups to identify potential Brook Floater habitat and populations in currently un-sampled areas of New Brunswick and Nova Scotia (see suggested organizations in Appendix A)	All
	Land stewardship practices (e.g. public education programs amongst resource users)	All
Residential development or urbanization	Adequate riparian and buffer zones	All
	Limiting in-stream construction and structures (i.e. permitting processes)	All
	Higher-level sewage treatment	All
	Limit pesticide/herbicide application (including enforcement measures)	All

2.3.2 <u>Mortality Rate, Productivity, Survivorship, Population Trajectory</u>

As discussed in previous sections, insufficient quantitative data exist to calculate mortality rate, productivity, survivorship, or population trajectory.

2.3.3 <u>Population Models</u>

While sufficient quantitative population dynamics data do not currently exist for the Canadian populations of the Brook Floater mussel, it is important to identify the type of data needed to facilitate model development and implementation in the future. There is a lack of quality baseline data for population size and population modeling. In consequence, it is clear that repeat monitoring at existing known population locations will only help to observe population size and detect population trend at a large scale (presence-absence in watershed).

It is further recommended that future survey efforts include functional habitat analysis. Traditional approaches to mussel habitat assessment provide high level, qualitative comments on general habitat characteristics (e.g. sandy substrate with low-moderate flow). It has been suggested that evaluating functional characteristics of mussel habitat can be valuable in assessing distribution and abundance trends (Strayer 2008). This approach would improve opportunities for modeling the population dynamics of the Brook Floater in the future. Proposed functional characteristics of suitable mussel habitat include the following (Strayer 2008):

- Allows juveniles to settle (shears are not excessive during juvenile settlement);
- Provides support (soft enough for burrowing, firm enough for support);
- Is stable (stays in place during floods, no sudden scour or fill);
- Delivers food (sediment organic matter for juveniles, current provides suspended food to adults);
- Delivers essential materials (oxygen, calcium, etc.);
- Provides favourable temperatures for growth and reproduction;

- Provides protection from predators (interstitial juveniles) and
- Contains no toxic materials.

In addition to the collection of quantitative population dynamics and functional habitat data for the Brook Floater mussel, scientific information gathering and assessment is required at the superfamily (i.e. Unionidea) or family (i.e. Unionidae) level. This would facilitate the development of quantitative, predictive models of mussel distribution and abundance. In Strayer's (2008) detailed consideration of available unionid data sets throughout North America, it was confirmed that there are five controlling factors that limit the distribution and abundance of unionids: 1) dispersal; 2) habitat; 3) fish hosts; 4) food; and 5) enemies (predators, parasites and disease). Strayer (2008) was able to further conclude that while a great deal is known about freshwater mussel ecology, there are many missing pieces concerning the critical information needed for these five controlling factors. To help define direction for future Brook Floater mussel scientific research, Strayer's (2008) list of critically needed data to quantify distribution and abundance of unionids via the five controlling factors is summarized for consideration:

- Estimates of past and present dispersal rates within and across drainage basins are needed to assess whether human-made barriers in stream systems are likely to lead to local and global loss of unionid species, to estimate the speed of such species losses, and to determine whether unionids will be able to adjust their ranges in response to climate change.
- More extensive tests of the importance of sediment stability in limiting unionid populations, and development of practical, robust methods to estimate sediment stability would be highly desirable.
- Field surveys of interstitial unionized ammonia are needed to determine if excessive ammonia has caused recent declines in unionid populations.
- More bioassays are needed to determine the extent to which residues from past episodes of pollution have resulted in sediments that are toxic to

juvenile unionids, and thereby prevented the re-colonization of unionids to sites that are otherwise suitable.

- It would be useful to apply demographic tools to estimate the effect of mortality from toxins or predators on the size and viability of mussel populations.
- It would be helpful to measure the strength of the fish immune responses and the extent of immunity in natural fish populations, to determine whether density-dependent depletion of hosts regulates the size of mussel populations or causes interspecific competition.
- Critical studies are needed to determine if, how often, and under what circumstances mussel populations are limited by the availability of hosts.
- More information on the effects of food quantity and quality on growth and fecundity of unionids would be desirable, ultimately to be linked to the demographic response of the mussel population. Information on the effects of widespread human-caused eutrophication would be especially important (eutrophication may also increase densities of fish hosts).
- More extensive information on the prevalence and effects of parasites is needed to assess whether control by parasites is likely to occur, and whether it is strongly density-dependent.

Strayer's (2008) evaluation of various modeling options for freshwater mussel populations resulted in the recommendation that empirical analyses are likely to be more successful than comprehensive, mechanistic modeling for assessing unionid abundance and distribution. He further suggests that the flexibility of empirical models, the wide availability of statistical software, and the availability of environmental data at multiple scales makes empirical modeling an attractive tool for managing the multiple controlling factors of unionid populations.

If empirical modeling is pursued as a quantitative assessment tool for Brook Floater mussel populations, the following situations should be avoided to minimize problems: 1) a large number of independent variables relative to the number of sites studied; 2) variables that are chosen without a reasonable expectation that they are related to mussel populations; and 3) models developed for one set of circumstances being inappropriately extrapolated to other sites or times (Strayer 2008).

3. CONCLUSION

The functional role of burrowing bivalves, such as Brook Floater mussels, is still being explored in scientific communities (Strayer 2008; Vaughn and Hakenkamp 2001). However, it is anticipated that if native burrowing bivalves continue to decline at the drastic rate observed in various areas of North America (e.g. Vaughn and Hakenkamp 2001; COSEWIC 2009; New York Natural Heritage Program (NYNHP) 2008; NatureServe 2009), an alteration of ecosystem processes and functions will be observed (Vaughn and Hakenkamp 2001). Human impacts on the aquatic environment have affected Brook Floater habitat in Canada both historically and currently. While increasing regulatory support for the maintenance of freshwater environments and protection of aquatic life will help to mitigate future human impacts, the slow response time of unionids to environmental pressures means that populations are still reacting to past impacts.

Multiple ecosystem processes in freshwater systems are likely influenced by burrowing bivalves like the Brook Floater, including the removal of particles from the water column (e.g. filtration feeding), excreting nutrients, biodepositing feces and pseudofeces, and bioturbation of the sediment (e.g. burrowing can increase sediment water content, sediment homogenization and the depth of oxygen penetration) (Vaughn and Hakenkamp 2001). Given the ecosystem processes affected by freshwater burrowing bivalves, it is anticipated that reduced unionid biomass would, in turn, result in an alteration of ecological processes and functions (Vaughn and Hakenkamp 2001).

The increased survey effort within the past two decades in Canada and the limited historical data make population trend detection difficult. Quantitative assessment of Brook Floater population dynamics requires additional monitoring and collection of empirical data. By taking an ecosystem science approach to resource management, the proposed mitigation measures and alternative actions could benefit many aspects of aquatic ecosystems in Nova Scotia and New Brunswick, including Brook Floater populations. The proposed mitigation measures and alternative actions are feasible and already underway in some areas. As such, from a qualitative perspective, the recovery or maintenance potential of Brook Floater populations in Canada is anticipated to be high.

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APPENDIX 1. NEW BRUNSWICK AND NOVA SCOTIA BASED ORGANIZATIONS WHICH MAY SUPPORT RESEARCH AND CONSERVATION EFFORTS FOR THE BROOK FLOATER

NEW BRUNSWICK AQUATIC BASED ORGANIZATIONS

The following profiled organizations and programs may provide opportunities for partnerships to advance scientific survey and research efforts on the Brook Floater in New Brunswick. This includes qualitative habitat and population identification, and identification of potential habitat and/or populations. New Brunswick's Watershed Classification Program (as stated in NBENV 2002): "The Water Classification Regulation is a regulation administered under the New Brunswick Clean Water Act by the New Brunswick Department of Environment. The purpose of water classification is to set goals for surface water quality and promote management of water on a watershed basis. The Water Classification Regulation establishes water quality classes, and associated water quality standards, and outlines administrative processes and requirements related to the classification of water."

Petitcodiac Watershed Alliance: The Petitcodiac Watershed Alliance (PWA) was founded in 1997. They are a non-profit environmental science and education organization that works to enhance and maintain the Petitcodiac and

Memramcook Rivers and their tributaries. PWA promotes watershed awareness, encourages the community to take part in identifying environmental problems and follows through with actions to restore and protect the watershed. The PWA is highly involved with the New Brunswick Water Classification Regulation. http://petitcodiacwatershed.org/

Miramichi River Environmental Assessment Committee: The Miramichi River Environmental Assessment Committee (EAC) assesses the health and subsequently addresses problems within the Miramichi watershed. The group was established in first form in 1989. http://www.mreac.org/introduction.htm

Eastern Charlotte Waterways Inc.: Eastern Charlotte Waterways is a non-profit group that addresses facilitation, sustainable development, education, integrated watershed management, and coastal zone management. http://www.ecwinc.org/main.htm

Hammond River Angling Association: The Hammond River Angling Association (HRAA) is a non-profit, community-based, membership driven organization dedicated to the protection of the Hammond River Watershed. HRAA is also involved in salmon restoration programs, habitat restoration and public outreach. HRAA is an active conservation/community group. http://www.hraa.ca/

Tabusintac Watershed Association: The Tabusintac Watershed Association was established in 1998. The group completed a provisional water classification and is implementing an action path set by the water classification report. The group's work includes road stabilization, sediment reduction projects, implementation and development of best management practices (BMPs) for agriculture and forestry sectors, environmental education, and repair of septic systems impacting water quality. http://www.tabusintac.org/watershed/

Shediac Bay Watershed Association: The Shediac Bay Watershed Association was established in 1999. The group is focused on water quality and habitat integrity, with the purpose "to enable persons, associations and communities within the Shediac Bay watershed to participate in the development and implementation of a comprehensive environmental management plan for the bodies of water within the coastal area of Shediac Bay." http://www.sbwa□abvbs.net/en/who.htm

Kennebecasis Watershed Restoration Committee: The Kennebecasis Watershed Restoration Committee is a non-profit organization in operation since 1994. The group was formed after discouraging results from a stream habitat assessment project in 1994. The group works on restoration projects towards supporting long-term, naturally functioning systems. http://www.kennebecasisriver.ca/index.php

Friends of the Kouchibouguacis: The Friends of the Kouchibouguacis is a non-profit group founded in 1999. http://www.amiskouchibouguacis.ca/a_qui_nous_sommes.html

Petitcodiac Riverkeeper: Petitcodiac Riverkeeper is a non-profit group established in 1999. http://www.petitcodiac.org/riverkeeper/english/welcome.htm

Association des bassins versants de la Grande et Petite Rivière Tracadie: Work of the association des bassins versants de la Grande et Petite Rivière Tracadie focuses on the northeastern tip of New Brunswick. http://www.rivierestracadie.ca/

Comité de gestion intégrée du bassin versant de la baie de Caraquet: Work of the comité de gestion intégrée du bassin versant de la baie de Caraquet focuses on Northern New Brunswick. http://www.cipanb.ca/baiedecaraquet/index.php?option=com_content&task=view&id=2&Itemid=19&date=2009□04□01

Société d'aménagement de la rivière Madawaska et du lac Témiscouata Inc.: Société d'aménagement de la rivière Madawaska et du lac Témiscouata (SARMLT) was incorporated in 1991. The group is focused on long-term planning, tree-planting, stream clean-up, shoreline stabilization, and creation of a linear park between Cabano and Edmundston. http://www.umce.ca/sarmlt/history.html

Nashwaak Watershed Association, Inc.: Nashwaak Watershed Association is a non□profit group established in 1995. The group is involved in the Atlantic Salmon Federation's Fish Friends Programs, smolt rearing to sexual maturity in fresh water for a gene banking program, restoration of river banks by tree planting, water sampling, participation in Crown forest land lease advisory groups, trail improvement, salmon smolt assessment, and more. http://www.nashwaakwatershed.ca/

NOVA SCOTIA AQUATIC-BASED ORGANIZATIONS

The following profiled organizations and programs may provide opportunities for partnerships to advance scientific survey and research efforts on the Brook Floater in Nova Scotia. This includes qualitative habitat and population identification, and identification of potential habitat and/or populations.

In addition to the groups and associations listed below, three watershed advisory boards (Dartmouth Lakes Advisory Board, Halifax Watershed Advisory Board and

Bedford Watershed Advisory Board) in Halifax Regional Municipality (HRM) actively engaged in the municipal regulatory process that assesses implications for water quality associated with development activities. A Water Quality Functional Plan is currently being developed for HRM, within which key parameters and sampling periods have been identified. The Province of Nova Scotia is also in the process of developing a Water Resources Management Strategy which may be able to be integrated with key mitigation measures recommended for Brook Floater conservation (e.g. sedimentation and water quality threats).

Clean Annapolis River Project (CARP): CARP is a charitable, community-owned corporation created to work with the community and interested organizations to foster the conservation, restoration and sustainable use of the freshwater and marine ecosystems of Southwestern Nova Scotia's Annapolis River and its watershed. http://www.annapolisriver.ca/aboutcarp.php

Bay of Fundy Ecosystem Partnership: The Bay of Fundy Ecosystem Partnership promotes the integrity, vitality, biodiversity and productivity of the Bay of Fundy Ecosystem, and the social well-being and economic sustainability of its coastal communities. http://www.bofep.org/

Gays River Environmental Protection Association (EPA): The Gays River EPA is working to: preserve the quality of life we enjoy in the country; measure the safety of our environment - water, land and air; find answers to questions and concerns raised by residents; connect with other organizations and individuals across the province experiencing the same problems; and keep government aware of our concerns and demand changes that place the protection of people and land ahead of business concerns. http://www.gaysrivervalleyepa.ca/

Avon Peninsula Watershed Protection Society: The Avon Peninsula Watershed Preservation Society (APWPS) has been formed to be a voice for the commons watershed and for residents living in the Avondale, Belmont, Poplar Grove and Mantua communities which make up the Avon Peninsula. http://www.apwps.ca/

Cumberland County River Enhancement Association: The Cumberland County River Enhancement Association is working to enhance the watersheds of Cumberland County, maintain and improve the quality and environmental health of the watersheds, and enjoy the natural beauty of our lands. Since 2003 they have worked on restoration of fish habitat on the Wallace River. http://www.geocities.com/ccreaonline/

Bluenose Costal Action Foundation (LaHave River Monitoring Project): The Bluenose Costal Action Foundation is expanding on its LaHave River WATERS project which developed a community stewardship strategy for the LaHave River watershed. The group is now focusing on a monitoring project where the water quality of the LaHave River will be monitored and assessed to identify existing or potential problems. http://www.coastalaction.org/

St. Mary's River Association: The St. Mary's River Association is a charitable, non-profit organization providing leadership and engaging partners to enhance, protect, and promote the St. Mary's River as a healthy ecosystem for Atlantic salmon and other native animals and plant species, as well as providing a rich community resource. Stream restoration, incorporating bank stabilization and digger logs, and habitat water quality improvements through liming of the river to lower the acidity were conducted in 1998. http://www.geocities.com/StMarysRiverAssociation/projects.html