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Canadian Science Advisory Secretariat — **Secrétariat canadien de consultation scientifique**

Research Document 2010/117 — **Document de recherche 2010/117**

Information in Support of a Recovery Potential Assessment of Atlantic Mud-piddock (*Barnea truncata*) in Canada

L'information a l'appui de l'évaluation du potentiel de rétablissement de la pholade tronquée (*Barnea truncata*) au Canada

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ISSN 1499-3848 (Printed / Imprimé)
ISSN 1919-5044 (Online / En ligne)

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Correct citation for this publication:

Hebda, A. 2011. Information in Support of a Recovery Potential Assessment of Atlantic Mud-piddock (*Barnea truncata*) in Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/117: vi + 30 p.

ABSTRACT

The Atlantic Mud-piddock (*Barnea truncata*) was listed as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in November, 2009. The designation was due to its' small, disjunct Canadian distribution, entirely dependent on a single geological formation, the red-mudstone facies within the Minas Basin, Nova Scotia. This document provides the information and scientific advice required to meet the various requirements of the *Species at Risk Act* (SARA), such as deciding whether or not to add the Atlantic Mud-piddock to Schedule 1 under *SARA*, developing a Recovery Strategy if it is listed, and informing decisions on authorization to carry out activities that would otherwise violate the *SARA* provisions. This Research Document describes the current state of knowledge of the biology, distribution, ecology, habitat requirement and threats to the Atlantic Mud-piddock. It outlines the protection under current legislation, and what additional protection would be afforded if listed under *SARA*.

RÉSUMÉ

La pholade tronquée (*Barnea truncata*) a été évaluée en novembre 2009 par le Comité sur la situation des espèces en péril au Canada (COSEPAC) comme étant une espèce menacée. Cette décision était fondée sur le fait qu'il n'existe au Canada qu'une petite population isolée de cette espèce vivant exclusivement sur un seul type de formation géologique, soit les mudstones rouges du bassin Minas, en Nouvelle-Écosse. Le présent document contient l'information et l'avis scientifique nécessaires pour satisfaire aux diverses exigences de la *Loi sur les espèces en péril* (LEP), par exemple pour déterminer s'il convient d'ajouter la pholade tronquée aux espèces figurant à l'annexe 1 de la LEP et, le cas échéant, concevoir un programme de rétablissement, et également pour éclairer les décisions visant à autoriser certaines activités qui enfreindraient normalement les dispositions de la LEP. Le présent document de recherche décrit l'état actuel des connaissances sur la biologie, la répartition, l'écologie et les besoins en matière d'habitat de la pholade tronquée ainsi que les menaces qui pèsent sur elle. Il décrit aussi les mesures de protection découlant des lois qui régissent actuellement l'espèce et la protection supplémentaire dont elle bénéficierait si elle était inscrite à l'annexe de la LEP.

SPECIES SUMMARY

Common Name: Atlantic Mud-piddock, pholade tronquée

Scientific Name: *Barnea truncata* (Say, 1822)

Assessment Summary

Status: Threatened

Reason for designation: Climate change, Industrial development*

Occurrence: Minas Basin of the Bay of Fundy

Status History: designated Threatened (COSEWIC) in November 2009

***Reasons for Designation** (full text COSEWIC 2010): This intertidal marine bivalve species is restricted to a single population in the Minas Basin, Nova Scotia. Although this species is adapted to boring into hard clay and soft rock, in Canada it is entirely dependent on a single geological formation, the red-mudstone faces within the basin. The total available habitat for this species is < 0.6 km^2. This species settles on and bores into the mudstone, and once settled, is immobile. Any changes in deposition of sediments can smother individuals or cover entire areas of habitat. Disturbances that change the sediment depositional regime are considered the main threat. Most serious is the increased frequency and severity of storms, due to climate change, which have the potential to rapidly bury habitat and smother individuals. It is expected that erosion from rising sea levels (storm surges) and increased rainfall (floods), would also contribute to habitat loss by sediment deposition. Proposed development in the basin could also alter or add to sediment deposition. The Canadian population is clearly disjunct from the nearest population, 350 km south, in Maine, and rescue is very unlikely.

BACKGROUND

The Atlantic Mud-piddock is a lithophagous bivalve mollusc found in a variety of intertidal habitats associated with the Atlantic Ocean. It is found embedded in a variety of substrates throughout its range varying from firm peats in its southern distribution to a single, restricted, mud-stone substrate in its Canadian range. The only Canadian population is restricted to the Minas Basin of the Bay of Fundy and is noted to be a relic population from an earlier (hyspsithermal) period. (For place names, refer to Figure 6).

With the exception of a handful of publications, the range, habitat use and biology of the Atlantic Mud-piddock are poorly-defined in the scientific literature, with the majority of insight into distribution restricted to lay documents and field guides. Since, with the exception of one report, it is not harvested for consumption, is not spectacular in appearance and is cryptic in habitat use throughout its range, it tends to receive little attention even in the lay literature. This species was reviewed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in November 2009 and designated as Threatened. This paper provides the background information for a species Recovery Potential Assessment (RPA) process developed by Fisheries and Oceans Canada (DFO) Science in order to provide the information and scientific advice required to meet the various requirements of the *Species at Risk Act* (*SARA*), such as deciding weather or not to add the Atlantic Mud-piddock to Schedule 1 under *SARA*, developing a Recovery Strategy if it is listed, and informing decisions on authorization to carry out certain activities.

TAXONOMY

The recognized authority for the nomenclature of aquatic molluscs in the United States and Canada is Turgeon et al. (1998). The current accepted classification of the species is, with clarification by Monari (2009):

Phylum:	Mollusca
Class:	Bivalvia
Subclass:	Heterodonta
Order:	Myoida
Suborder:	Pholadina
Super family:	Pholadoidea
Family:	Pholadidae
Subfamily:	Pholadinae
Genus:	*Barnea*
Subgenus:	*Anchomasa*
Species:	*Barnea truncata* (Say, 1822)

The sub generic (or sometimes generic) designation Anchomasa (Leach, 1852) is still used in invertebrate palaeontology and related literature (Cox et al. 1969), so should be kept in mind.

Although this scientific taxonomy and nomenclature has been generally accepted, there is considerable variation in the vernacular names of the species. In the light of the significance of the lay literature in outlining the distribution, and to some degree the biology of the species, it is important to be aware of the variation in names, irrespective of the currently accepted name. Turgeon et al. (1998) present the species as the Atlantic Mud-piddock. Additional names in the literature include: Fallen Angelwing, Fallen Angel Wing, (Bousfield 1960; Abbott 1974), Truncated Borer (Miner 1950; Morris 1957), Truncate Borer (Anonymous 2006), Truncated Piddock (Rogers 1936) and Truncated Angel's Wings (Vilas and Vilas 1952).

DESCRIPTION

[Adapted from Davis and van Ingen (1992); based on Gould (1870) and Turner (1954).]

In the Canadian population, the adult mollusc has a greyish-white shell of moderate size, typically 3-5 cm in length (Figure 1). The shell is thin, delicate, elongated and gapes widely at both the anterior and posterior ends. Sculpturing is strong at the more pointed anterior end but diminishes in strength on the truncate posterior end. The dorsal margins of the valves near the umbones are curled back, the margins of the reflections being free at the anterior end. The shell valves are not articulated, or hinged, but are held to the animal's body by the apophyses, which are prominent internal structures that project from underneath the umbones of each valve. The anterior dorsal area of the shell is protected by a thin plate known as the protoplax, an important diagnostic feature.

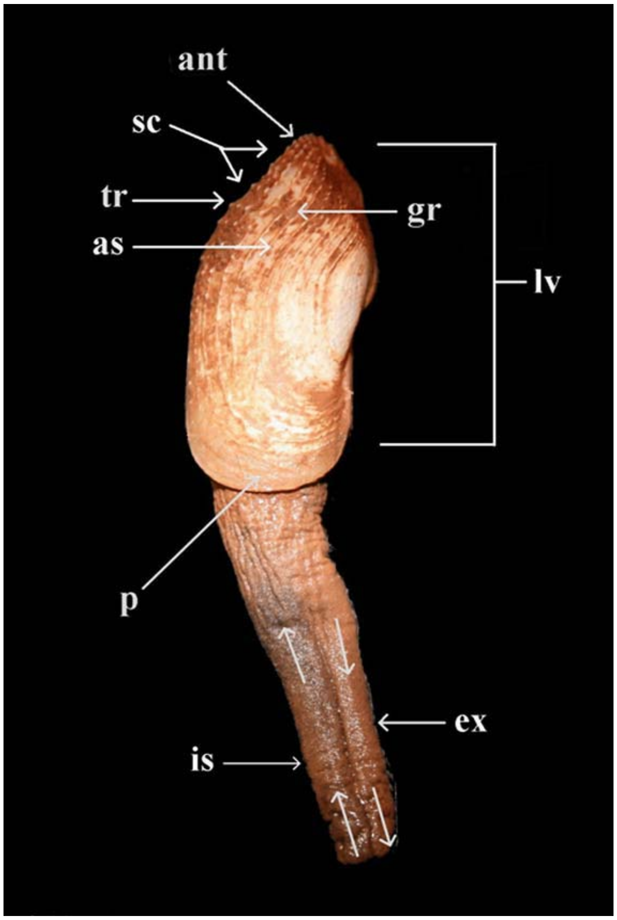

Figure 1. Lateral view (left side) of Barnea truncata. Adult specimen collected alive, Noel Bay, Hants County, Nova Scotia. Left valve (lv), inhalant siphon (is), exhalant siphon (ex), shell sculpture (sc), growth rings (gr), anterior slope (as), tooth ridges (tr), beaked anterior end (ant) and truncate posterior end (p) (Photo by Christina McCorry.) (Source COSEWIC 2009)

The protoplax lies on top of the anterior adductor muscle but is not attached to it and consequently is not found in association with dead shell valves.

The body cannot be totally withdrawn into the shell, leaving substantive portions of the siphon visible when extracted from substrate. Protection is therefore provided principally by the burrow. The siphons are united in a single sheath (differentiating it from other lithophagous species such as *Petricolaria pholadiformis* – formerly *Petricola pholadiformis*). The muscular foot is visible through the anterior gape in the shell (Figure 2B).

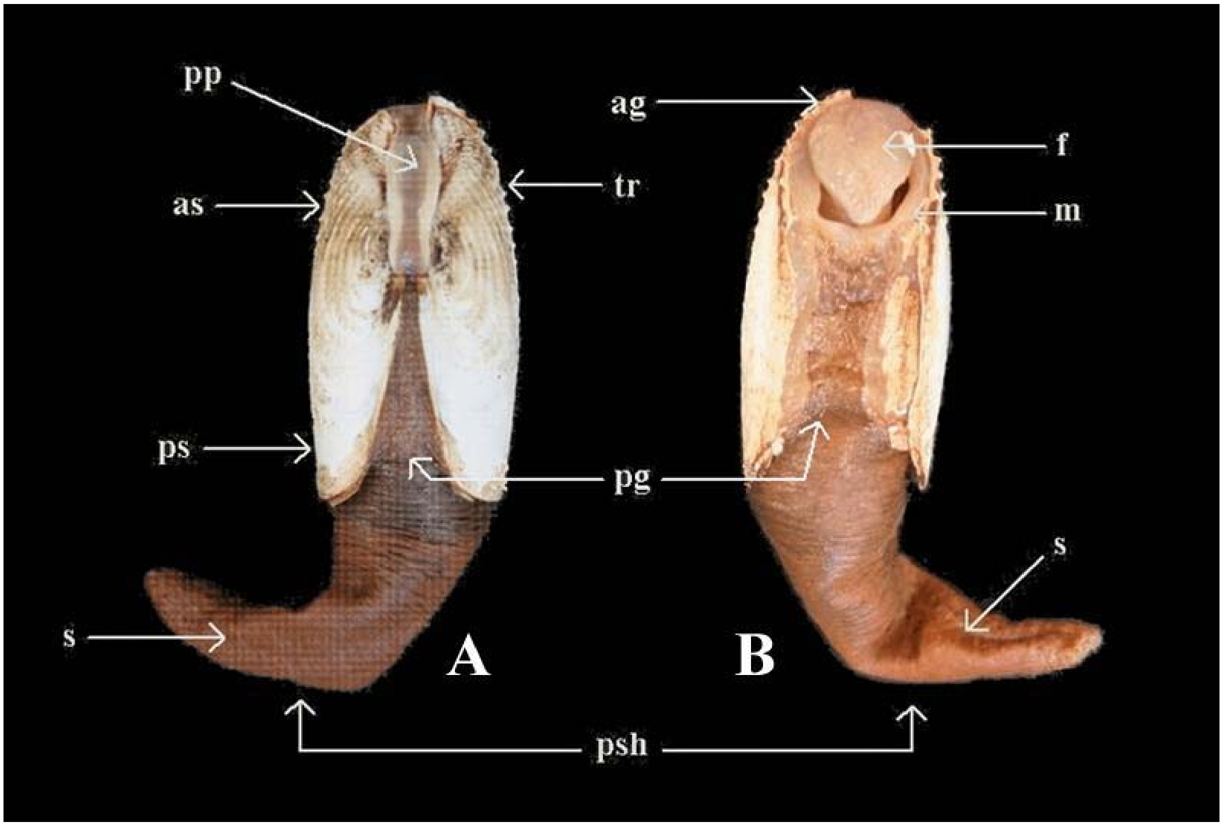

Figure 2. Dorsal (A) and ventral (B) views of Barnea truncata. Adult specimen collected alive, Noel Bay, Hants County, Nova Scotia. Anterior gape (ag), posterior gape (pg), protoplax (pp), anterior slope ridges (as), smooth posterior slope (ps), tooth ridges (tr), siphons paired in periostracal sheath (psh) showing paired valves with foot (f) protruding through anterior gape (ag) in mantle (m) and siphons (s) in posterior gape. (Photo by Christina McCorry) (Source COSEWIC 2009)

External sculptural features called tooth ridges are found on the anterior slope of the shell (Cox et al. 1969); the posterior end is smooth. Anterior riblets also create sharp edges where they cross the concentric ridges (Gould 1870). Unlike *Zirfaea crispata*, which also occurs in the Minas Basin (Bleakney et al. 1980), *B. truncata* does not have a clearly defined umbonal–ventral sulcus. This is a very useful field identification feature where the two species co-occur (Bromley and Bleakney 1984).

Other bivalves generally have a single anterior and a single posterior adductor muscle. *Barnea truncata* and *Z. crispata* have a pair of anterior adductor muscles, one dorsal (the anterior adductor muscle) and one ventral (the ventral adductor muscle) in addition to the posterior adductor. This appears to be an adaptation to the specific mechanical drilling process used by these species (Cox et al. 1969).

Larval *B. truncata* are characterized by a swimming structure called a velum (Figure 3), and therefore are classified as veliger larvae (Chanley 1965). The larval stage of *B. truncata* has been described only once (Chanley 1965) and larvae from high turbidity waters in Canada have not been described.

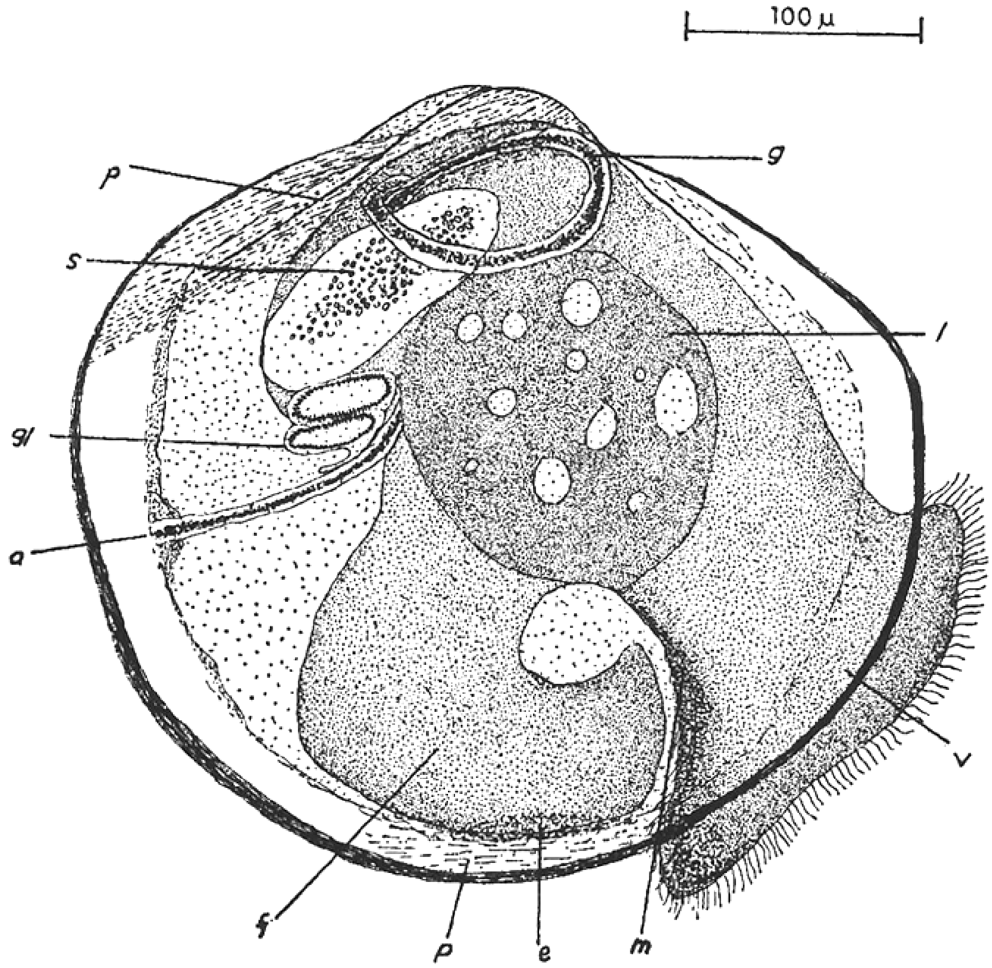

Figure 3. Prominent features in the internal anatomy of the Barnea truncata larva. Anus (a), granular swelling in mantle (e), foot (f), gut (g), Gills (gl), liver or digestive gland (l), mouth (m), pink or purple shell colour (p), stomach (s), velum (v). (Reproduced from Chanley (1965) with permission of Springer Science and Business Media.)

BASIC BIOLOGY

[Adapted from COSEWIC 2009]

Although the sexes are separate and male and female internal organs are distinct, there is no (external) sexual dimorphism. As with many aquatic molluscs, fertilization is external. Ova and sperm are shed into the water where fertilization takes place. This process appears to be temperature mediated in pholadids (Chanley 1965). Duval (1963b) noted that a congener, *Barnea candida*, was unusual in that it starts to spawn as temperatures drop in the fall. This infers that the other Barnea spp. start to spawn as temperatures increase. In his larval studies, Chanley (1965) spawned adult *B. truncata* from Virginia in mid-May as well as through August and September. Maurer et al. (1974) suggested a spawning period of April through November for *B. truncata* in the Delaware region. Chanley (1965) noted that individual *B. truncata* could release as many as 11 million eggs in one spawning and that eggs were 40-45 µm in diameter.

After fertilization, the eggs develop through a trochophore larval stage to shelled veliger larvae which feed on phytoplankton in well-aerated and productive shallow waters. Larval development progresses and in culture metamorphosis takes place in about 35 days (Chanley 1965). The larvae measure approximately 55 µm in length initially, but larvae with a functional velum are found at 315 µm (Figure 3). The rate of growth is dependent on the availability of food (Chanley 1965) suggesting a limiting factor in deeper oceanic habitats (e.g. Bay of Fundy vs. Minas Basin) where particulate food may be less abundant and temperatures are lower. In this single feeding study, Chanley (1965) was not able to sustain growth through to settlement and start of boring, so knowledge of dietary needs of this stage is incomplete.

The metamorphosed larvae settle on substrates, probably at high slack tide. Many substrates are too hard or too soft and thus not suited for settlement and boring. The presence of a functional foot and a still-functional velum suggests a degree of mobility allowing for some substrate selection at time of settlement. This is significant in the Minas Basin populations, where protected horizontal habitats are limited (even where appropriate substrate is present).

Once they have settled they begin the process of boring into the substrate. Within the Pholadidae, this process varies from species to species but has not been documented for *B. truncata*. In general, once the larva has initiated the hole, it goes through metamorphosis, and then starts the boring cycle. In *Barnea spp.* this process is by longitudinal movements of the shell facilitated by the foot (Purchon 1968; Yonge and Thompson 1976).

Based on field observations (Hebda et al. 2008) they appear to be thigmotactic (boring at right angles to the surface upon which they settle). As the animal grows, it continues to bore along this initial axis. Because the size of the hole increases in diameter with growth of the adult, the result is a conical bore-hole Figure 4. Consequently the adult animal is trapped for life inside its burrow. This differentiates it from the circular boring of species such as *Petricolaria pholadiformis* described by Duval (1963a) which produces a cylindrical bore-hole (a good diagnostic feature for differentiating these species in substrate). Although *P. pholadiformis* is absent under the capstones, it is present in horizontal (unprotected) habitats, so may compete with *B. truncata* for settlement surfaces.

Figure 4. Barnea truncata in conical bore-hole illustrating entrapment of adults within substrate (Photo by G. Jones).

There are no published data on either generation time or longevity of *B. truncata*. Chanley (1965) spawned individuals from barrier islands off Virginia. Based on reported sizes and image provided, these individuals were probably four to five years old. Examination of valves from field studies by Hebda et al. (2008) suggests a life span of up to nine years, with sexual maturity possibly as early as two years.

FOOD AND FEEDING

There are no specific published data on the feeding of *B. truncata*. However, as with all sessile marine bivalves, they are probably generalist feeders, filtering fine particulates such as phytoplankton and other organic particulate matter from the incurrent siphon. Because the feeding is indiscriminate, they segregate inorganic particulates from potential food items which had been transported by ciliary action from the gills. Inorganic particulates are segregated from food particulates by the labial palps and are expelled as pseudofaeces (Yonge and Thompson 1976). Digestible matter is then directed by ciliary action to the mouth. Digestion is carried out within the hepatopancreas and waste matter is expelled through the anus. The waste is then carried away though water movement via the excurrent siphon.

SALINITY TOLERANCE

In general, all Pholadidae live under strictly marine or slightly brackish water conditions. They are euryhaline and can possibly withstand dilution down to 50% (16 ppt.) for short periods of time as might be expected for an intertidal species (Turner 1954). At sites occupied by *B. truncata* in the Minas Basin, mid-summer salinites of between 27 to 30 ppt. have been recorded for surface waters at low water (Bousfield and Leim 1959; Parker et al. 2007) although it is noted that during spring and fall salinities may decrease to as low as 14-15 ppt. or substantially lower immediately following significant freshet events. Salinity tolerance has been reported to be as low as 5-10 ppt. (Turner 1954, Matthews and Fairweather 2004). Von Cosel (personal communication) noted *B. truncata* in turbid brackish estuarine waters in Guyana and Columbia.

DISPERSAL

The distribution of *B. truncata*, on both a local and global scale, suggest two possible dispersal mechanisms at play. The first relates to dispersal associated with reproductive activity, which is a local-scale event. The second relates to the mechanism(s) by which the species is found on three of the four continents bordering the Atlantic Ocean.

The dispersal of planktonic larvae by tidal currents can readily explain the distribution of *B. truncata* within the Minas Basin and its absence from coastal waters in Maine. Greenberg (1983) illustrated modeling of residual tidal currents in the basin (Figure 5). While it is probable that these planktonic larvae disperse relatively-freely with tidal movement throughout the basin, the presence of adult *B. truncata* is constrained by the availability of appropriate substrate for successful larval settlement and boring.

With the production of large numbers of larvae and high tidal flushing out of the basin (3 billion cubic meters per tide (Parker et al. 2007)) there is probably a significant export of larvae into the Bay of Fundy. The absence of records of *B. truncata* from the Bay of Fundy, Chignecto Bay or northern portions of the Gulf of Maine suggests there are factors restricting its establishment in these habitats outside of the Minas Basin. These may relate to the absence of appropriate substrate for settlement and establishment in those waters.

The counter-clockwise circulation within this Gulf of Maine system results in the importation of predominantly oceanic waters into the Bay of Fundy and may suggest that the planktonic larvae flushed out of the Minas Basin could be the source of recruitment for those noted in the disjunct population off central Maine. Genetic evaluation of the Gulf of Maine and Minas Basin populations of *B. truncata* could determine any links among these populations.

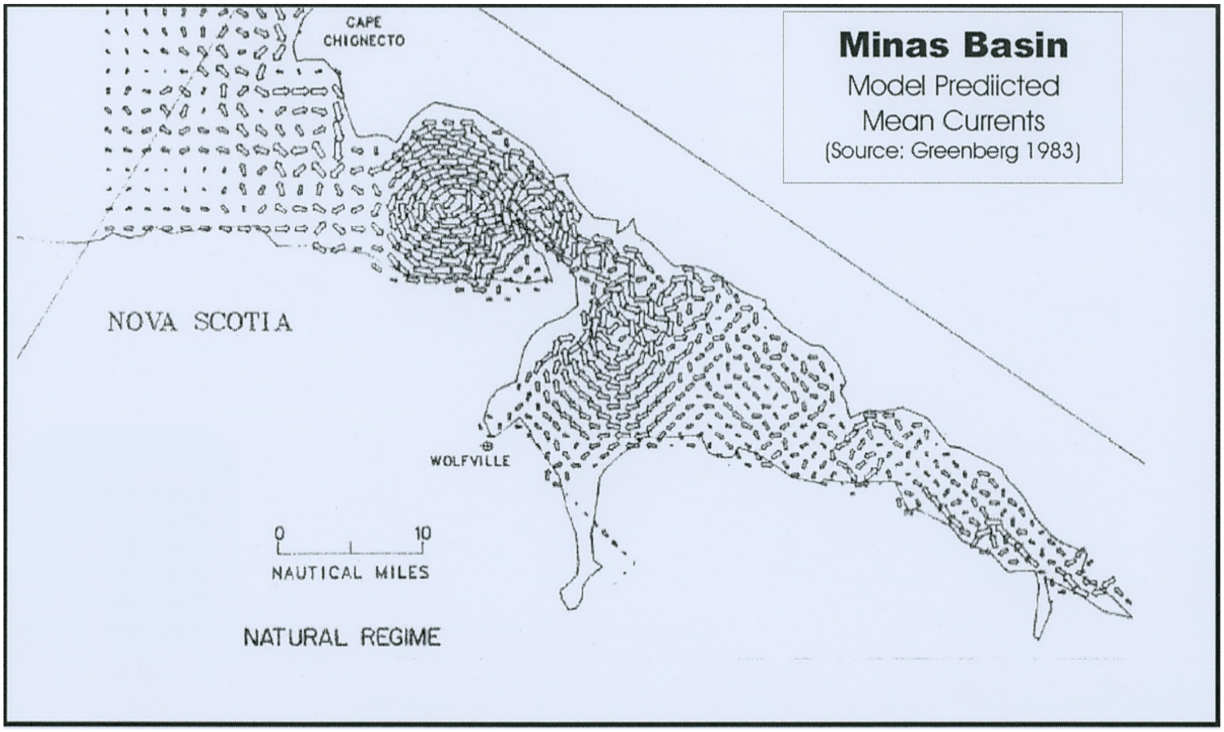

Figure 5. Mean currents (adapted from Greenberg, 1983).

The second mechanisms to consider are those responsible for the presence of the species in northern and southern latitudes and both east and western Atlantic margins. It is unlikely that larval dispersal can be used to explain the amphi-Atlantic distribution of this species without evidence of settlement in any of the oceanic islands in either the North and South Atlantic. Review of records from the Azores, Bermuda, and islands in the South Atlantic Ocean and Caribbean Sea did not reveal presence of *B. truncata* on oceanic islands. The only exception is a single site in Puerto Rico. There are similar examples of amphi-Atlantic planktonic dispersal of Gastropod larvae, such as *Cymatium parthenopaeum* (Gofas et al. 1989) for which oceanic stages may persist for months. There is only a single published account on persistence of the larval forms of *B. truncata* (Chanley 1965). Chanley observed that cultured larvae of *B. truncata* metamorphosed in approximately 35 days, which is an insufficient time frame for trans-Atlantic larval dispersal but adequate for coastal dispersal. It is noted that his studies were in culture, so the time frame he determined may not reflect that of wild populations.

It is not entirely clear if movement of larvae via ballast water could be a factor. It is also not clear if possible movement of adults with firm or high-density ballast could be an alternate dispersal mechanism although documentation of use of peats or firm muds for ballast in ocean-going vessels is lacking (COSEWIC 2009). Two references to the presence of *B. truncata* collected in waterlogged wood (Turner, 1954; Jacobson and Emerson 1961) may offer some insight into long-distance dispersal. Long-distance dispersal of the species requires further investigation.

The occurrence of the species within an ancient oyster bed (3,800 ybp), in the Minas Basin (The Guzzle, Figure 6) appears to predate the arrival of vessels carrying ballast (Bleakney pers. comm. 2008).

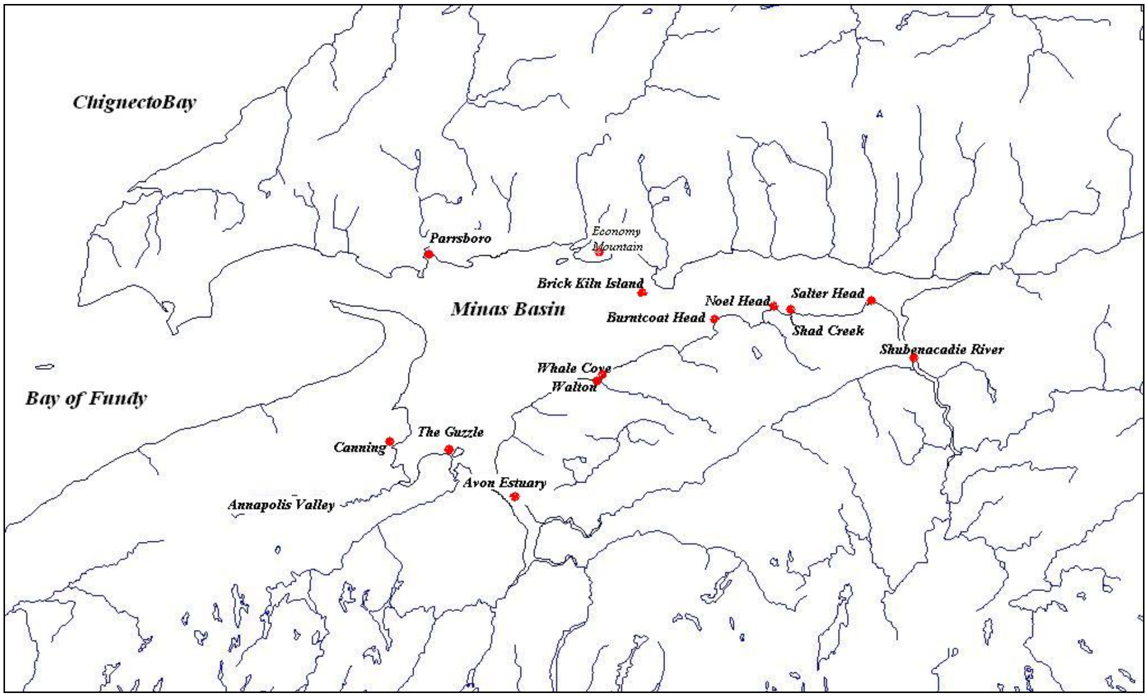

Figure 6 Minas Basin with locations noted in text marked.

HABITAT REQUIREMENTS [adapted from COSEWIC 2009]

As a filter feeder that is immobile within its substrate, it can only persist in areas where there is no rapid or significant accumulation of sediments.

It was noted in COSEWIC (2009) that habitat requirements for *B. truncata* were not clearly defined in the literature. Field observations suggest that it occurs in intertidal areas with a salinity range of 19-25 ppt although it has a low salinity threshold of 5-10 ppt, considerably lower than many other estuarine molluscs (Turner 1954; Matthews and Fairweather 2004). Turner (1954) and Jacobson and Emerson (1961) suggested that it may occur subtidally under some circumstances, but the only published record of *B. truncata* living subtidally is from southwest Florida where it was reportedly dredged from a depth of 6-12 m in soft sediments (Frank 2009). Turner (1954) also suggested that toward the periphery of its range, *B. truncata* may occur in deeper waters, but this has not been confirmed and has not been shown for the peripheral Canadian population.

As a filter feeder, it requires a dependable source of particulate organic matter but is tolerant of some exposure during low tidal periods. Unlike bivalves that are not attached to or encased by their substrate, it is not able to tolerate any degree of rapid sediment accumulation and so is subject to smothering in acute sedimentation events or with natural migration of deposition plumes common in many estuaries.

The principal habitat constraint appears to be the requirement of a firm to semi-consolidated substrate for settlement of post-larval juveniles (spat). Throughout the balance of its range, it is recorded as inhabiting firm peat-muds and rarely, submerged wood (Turner 1954; Jacobson and Emerson 1961). Throughout its distribution in the north-eastern coastal states it is noted to be a resident of eel grass peats. No Canadian records are associated with these or salt marsh habitats.

Although firm mud habitats are sporadically present subtidally within the Bay of Fundy and lower Gulf of Maine, there is no published evidence from fieldwork to suggest the presence of *B. truncata* in these habitats in Canadian waters.

The entire Canadian population is associated with one specific geological structure in the Minas Basin, the red-mudstone facies found inter-bedded in Jurassic age sandstone formations (Hebda et al. 2008) (Figures 7, 11) in association with hard conglomerates. This substrate is limited subtidally by the presence of stable masses of sands and fine gravels (Figure 8). This geological formation and associated facies are absent from the balance of the Bay of Fundy and from Chignecto Bay, although they may be present, subtidally in the Minas Channel (west of Parrsboro, Cumberland County).

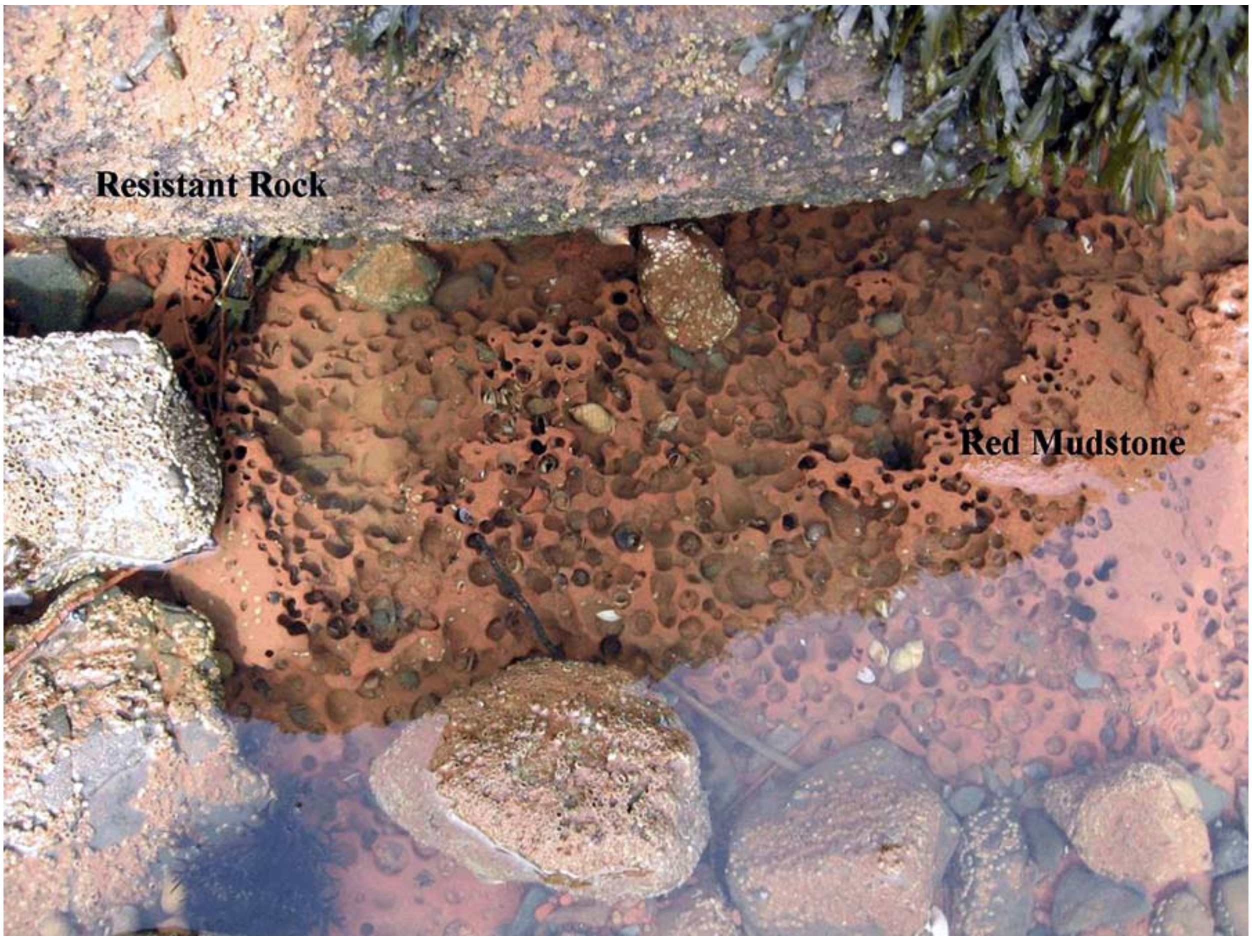

Figure 7. Soft red mudstone substrate under resistant capstone at Burntcoat Head, Hants County, Nova Scotia. Note heavy riddling of mudstone facies by B. truncata burrows, and evidence of recent recruitment on freshly-exposed surfaces. Less than 10% of visible burrows are occupied. (Photo by A. Hebda)

Figure 8. Sand and silt body limiting habitat use by Barnea truncata (Noel Head, Hants County, N.S.) (Photo by A. Hebda)

STATUS AND TRENDS

DISTRIBUTION - RANGE

The Atlantic Mud-piddock has an enigmatic global distribution. It has been recorded, intermittently along the west Coast of Africa from Senegal in West Africa to South Africa – ranging from 15° N latitude to 34°S latitude. In western parts of the Atlantic, it is also found sporadically. It is reported from several locations in Brazil through the Gulf of Mexico. It is then found, discontinuously, from Florida to the southern part of Maine, with a major disjunction to the only Canadian population in the Minas Basin of the Bay of Fundy – ranging from 45.4°N latitude to 24°S latitude.

It is not reported from any oceanic island with the exception of a single report from Puerto Rico. Its distribution can best be described as amphi-Atlantic (Figure 9).

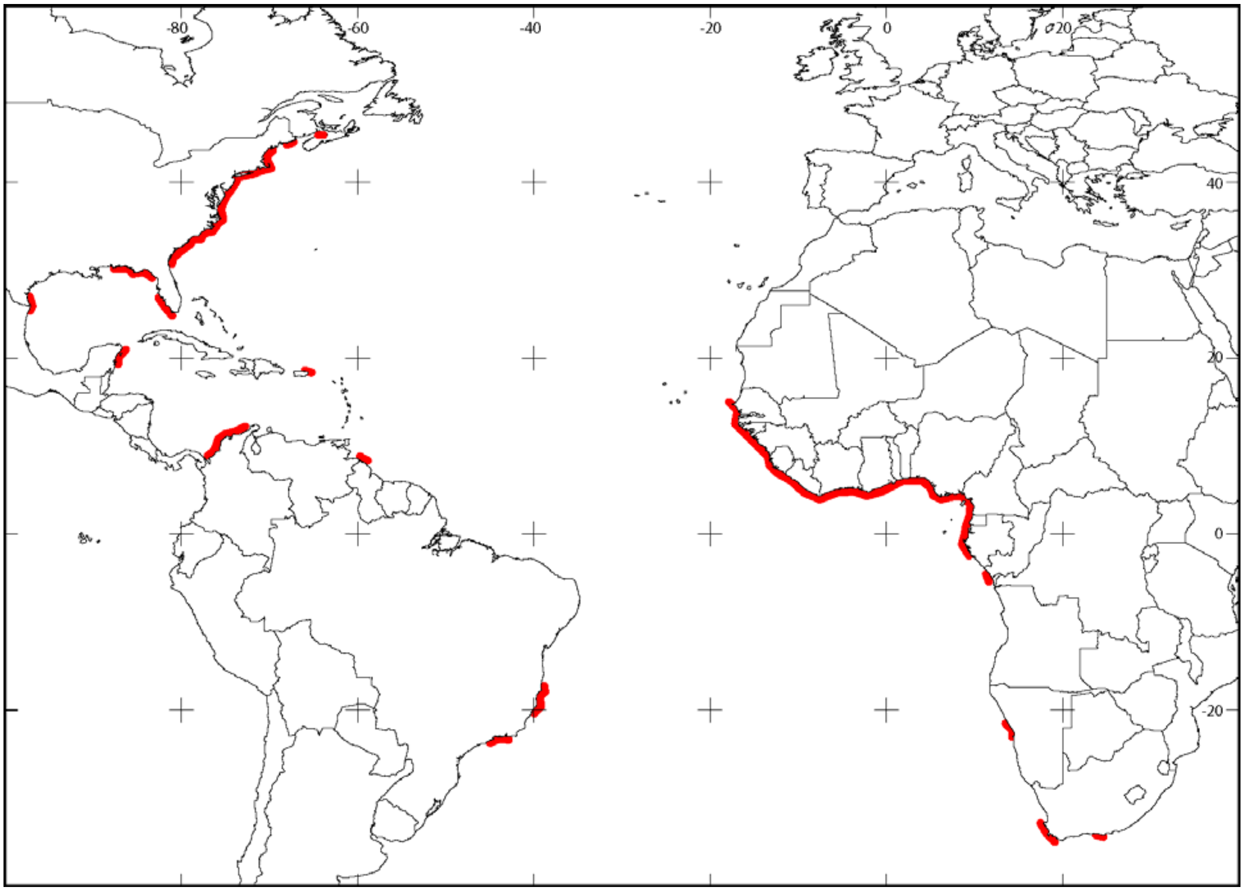

Figure 9. Global Distribution of Barnea truncata (Adapted from COSEWIC 2009 and Monari, 2009).

There are two apparently erroneous reports of its distribution outside these areas, one in the eastern Pacific, is an unattributed citation reported in the ITIS database (ITIS 2010), a probable reference to *B. subtruncata* (refer to Turner, 1954, Olsson, 1961, Abbott 1974 and Monari, 2009) and one from a commercial shell supplier, indicating a specimen from the Spanish (Western) Sahara.

With the exception of COSEWIC (2009), there are no published data on densities or other elements of habitat use throughout its global range with the exception of anecdotal general surveys

North-Eastern United States

The Atlantic mud-piddock is reported as occurring from Florida to Nova Scotia in most field guides (Morris, 1957, Abbott, 1974, Emmerson and Jacobson, 1976) in substrates such as "eel-grass peats". Its occurrence has been reported as "exceedingly rare" in southern Maine by Turner (1954) although no archived specimens were documented. There has been a recent introduction of the species to Bath, in mid-Maine at 43° 52' 38"N, 69° 49'16" W (Anonymous 2006) although there are no published records between this site and either the northern (Minas Basin) or southern (Massachusetts) populations.

Canadian Distribution

This relic Canadian population is restricted to the Minas Basin of the Bay of Fundy. Within this basin, it is found at 13 discrete sites (Figure 10). An extensive field program in 2007 to 2008 and further reconnaissance in 2009 - 2010 confirmed the occurrence in only one substrate type in intertidal portions of the Minas Basin but not in other parts of the Bay of Fundy (Table 1). Once it had been confirmed that *B. truncata* required a firm substrate and was not able to settle and persist in soft sediments or in hard rock, a map reconnaissance was undertaken of the basin and adjacent areas. This included examination of surficial and bedrock mapping, examination of high resolution aerial photographs and satellite photography (Google Earth). Geological mapping indicated areas where possible exposures of appropriate substrate could occur. All intertidal mapped sites with settlement potential were examined as well as adjacent areas for presence of suitable substrate. Based on historic surveys, it is not found in the Northumberland Strait or Atlantic coast of Nova Scotia. The presence of large bodies of sands and muds in most sub-tidal portions of the basin preclude its persistence in those parts of the basin. It may be present where appropriate substrate exists sub-tidally where there are no sediment accumulation occurs.

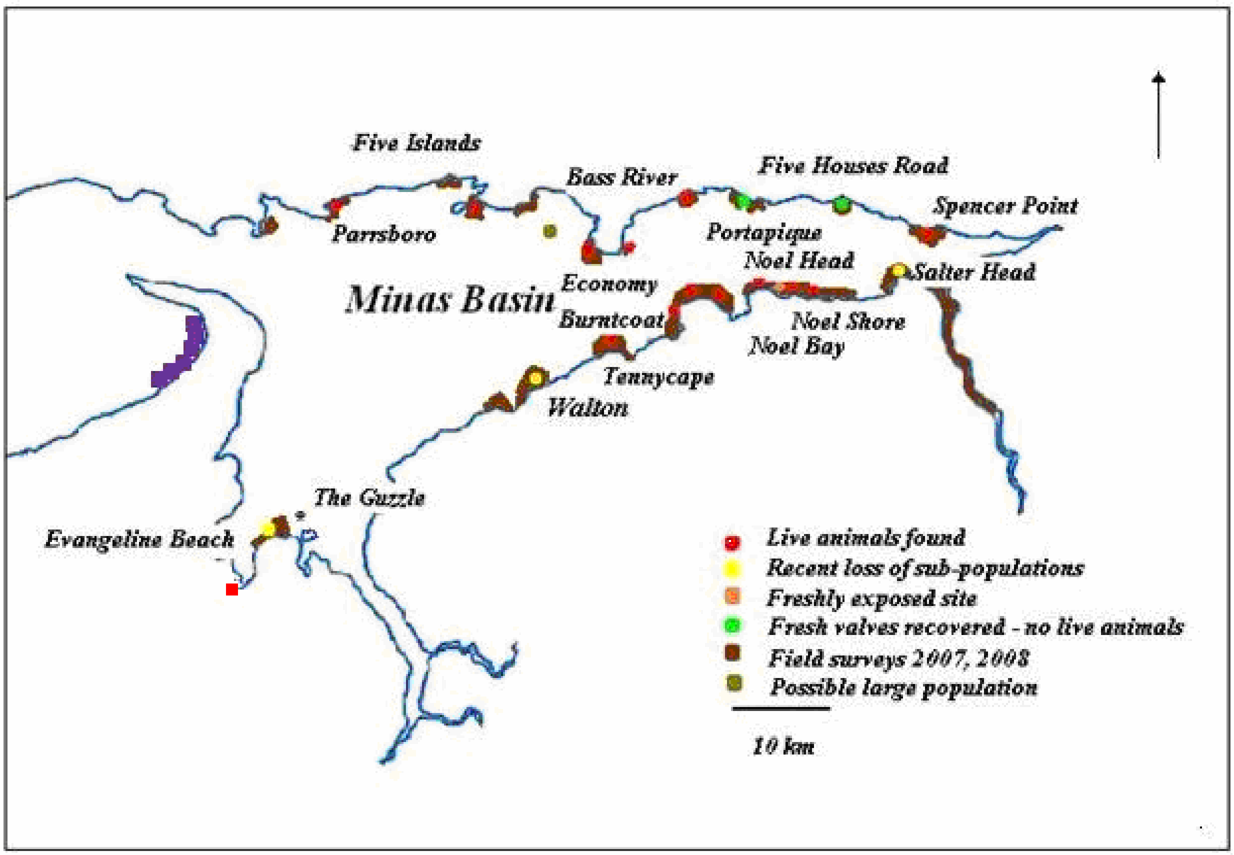

Figure 10. Summary of current and historic distribution of Barnea truncata, including search effort in 2007-2008 and 2009, 2010 (Adapted from COSEWIC 2009) Purple colour denotes Nova Scotia Museum 2010 field survey

ABUNDANCE

Although the Atlantic Mud-piddock is restricted to one substrate type, it was found in three types of habitat settings in field investigations between 2007 -2010:

1. embedded under a more-resistant "capstone" substrate (Figure 11);
2. associated with more-resistant bedrock features such as large Cobbles or other exposed rock material; and

3. in exposed surfaces including rock pools where resistant rock has been eroded (probably through ice scour or movement of lithic materials during tidal exchange) (Figure 12).

Figure 11. Hard conglomerate capstone with Barnea truncata bore-holes underneath. Note collapse of cap-stone (Photo by G Jones).

Figure 12. Tide Pools formed by Ice and Lithic erosion with exposure of red-mudstone substrate (Photo by G. Jones).

The exposed surfaces (type 3) offer the large surface areas of burrow (bore-hole) occurence. However, less that 1% of the exposed holes are occupied by lithophagous molluscs, and a majority of these are by the False Angelwing (*Petricolaria pholadiformis*). This is also very patchy within areas of apparently-appropriate substrate. As noted, earlier, there may be competition between these two species for horizontal surfaces at time of larval settlement, but not under capstone-type habitats.

The boreholes associated with rock and cobble protection are occupied at a slightly higher frequency (estimated to be less 5%). As in the rock pools noted above, occupancy of burrows is mixed, with the False Angelwing dominating. These habitats appear to comprise < 5% of total surveyed area occupied by *B. truncata*.

The most significant habitat setting from the point of view of abundance is the burrow association under protective capstones (category 1). In this setting, the mudstone substrates tend to be riddled with boreholes. (Figure 7). It is not possible to estimate degree of occupancy, in that the riddling can extend for substantial distance under the protective cap, possibly up to 50-100 cm. This is evidenced in ice-mediated collapse of capstones each spring, exposing some existing burrows. Interestingly, this periodic refreshing of new surface areas of mudstone may be critical from the point of view of maintaing a core population of *B. truncata* for larval production and long-term peristence of the species in these northern latitudes.

In order to get appropriate population estimates for the Minas Basin, it would be necessary to undertake disruptive and destructive sampling through removal of capstone protection at selected sites, then cutting cross-sections through bore-hole assemblages. In areas surveyed, capstone thickness varied up to 80 cm in depth.

During the survey work undertaken, and subsequent map reconnaisance, it was noted that *B. truncata* may possibly be associated with a reef structure to the south-east of Economy Mountain, west-south-west of Economy Point, as well as possibly at Brick Kiln Island (Figure 6). These sites would have to be evaluated. In addition, there is a possibility that *B. truncata* may exist sub-tidally where there is no sediment accretion (i.e. Minas Channel), even though there is little evidence in the literature that this occurs.

Consequently there is no current estimate of abundance or densities of *B. truncata* in Canadian waters.

RECENT TRAJECTORY FOR SPECIES ABUNDANCE AND RANGE

In the absence of any systematic sampling or monitoring activity since the recording of the species in Canadian waters by Bousfield and Leim, 1959, there are no data to use as a basis for trajectory evaluation. It was observed that there was evidence for periodic losses of occupied sites due to sedimentation episodes (The Guzzle, Shad-Creek – Noel Head, Salter Head), some long-term reduction in substrate availability (Bass River) and some species displacement through establishment of extensive barnacle beds (Walton – Whale Cove). These suggest that local populations of *B. truncata* in the Minas Basin have been subject to suppression or elimination through large- scale events or processes in the past.

There is no evidence for successful colonization outside the Minas Basin.

RECENT LIFE HISTORY PARAMETERS

As can be seen in the background information provided in the initial part of this report, there is very little known about this species anywhere throughout its range. Two other lithophagous species are found within Canadian waters (including the Minas Basin), *Zirfea crispata* and *Petricolaria pholadiformis*. Both are wide-spread in the western Atlantic Ocean from the Gulf of St. Lawrence southward, contiguously, to Cape Cod for the former and the Gulf of Mexico for the latter species. Both are associated with higher energy habitats. However, lack of species-specific information on their life history traits reduces their potential as surrogates. *Zirfea crispata* is restricted to higher energy habitat in the western Minas Basin, and it is associated with a more-common substrate type in that part of the basin (shale).

<u>Natural Mortality</u>

Natural mortality in these Canadian Populations probably occurs in four ways:

1. loss of larvae through consumption by filter-feeders or through export by tidal flushing;
2. loss of adults through substrate alteration (collapse of cap-stone cover or grinding off by movement of ice or lithic materials);
3. loss through old age;and

4. loss through sediment incursion onto bore-holes/burrows.

There is no evidence of predation on *B. truncata* adults, and they appear relatively immune to action of other species. The only exception may be Pyramidellid gastropods which are parasites of marine bivalves (Fretter and Graham 1962). While one species, *Boonea bisuturalis,* co-occurs with *B. truncata* in the Minas Basin (Bousfield and Leim 1959) it has not been recorded parasitizing *B. truncata.*

Loss of adults through physical alteration of their substrates is probably a limiting factor in the persistance of specific sites within the basin. Capstone loss through collapse, or scouring is probably the main factor affecting core populations. This occurs in areas of somewhat higher energy regimes, portions of the basin that are not subject to periodic sedimentation events. Where cap-stone loss has occurred, there is evidence that some individuals persist for a period of time. In field work, it was noted that many empty valves in these areas showed evidence of shell erosion at the siphonal end, but that some growth continued (pallial line was modified to match the contemporary margin of the shell, even when slightly eroded). This would suggest that in the absence of further catastrophic physical events, the individuals could survive, providing there was no change in food supply or major change in prevailing energy regime.

Loss through old age is expected to occur if there are no other significant alterations to substrate, food or other environmental factors. It is noted that age of maturity, fecundity and life-span are not know, although examination of archived material could provide some insight. As well, total mortality is not possible to estimate for the same reasons as noted in the **Abundance** section (above).

Loss through sedimentation of existing sites may be the most important factor in limiting the population. As was noted earlier (see **Basic Biology** above) once the larvae have settled, and commenced boring and feeding, they are trapped within the bore-hole/burrow. (Figure 4) They do have the ability to extend their siphon, somewhat,(up to about 0.5 cm), allowing for adjustment to daily or seasonal changes in sediment deposition through part of the tidal cycle. Through the balance of the cycle, currents will usually remove most of the deposited material, especially in areas of higher current regimes. This suggests that most feeding probably occurs during slack tidal periods (most-likely high slack tide). Episodic sediment accumulation at higher rates or in areas where tidal flushing of the substrate is incomplete will probably result in the smothering of the affected individuals.

The area of occupancy by *B. truncata* at a site first noted by Medcoff in 1948 (unpublished archival records) has been reduced substantially in the intervening 62 years by the incremental accretion of muds. Persistance of the species at that site has been only in the small drainage channels that have cut down through the accumulated mud-flats to the mud-stone substrate. This has resulted in persistance of individuals at that site, albeit at a low density.

There is some evidence of episodic loss of populations within the basin. After a storm event in 2008, a large bed of *B. truncata* (with valves still embeded in the substrate) was exposed to the east of Noel Head. This area had been covered by silts and muds for the preceeding 30 years. It is not clear if the loss of this bed was a single catastrophic event, or as a result of gradual accumulation in an area of relatively low energy currents. It is noted, however, that this exposed bed was re-covered by sediments during the winter of 2009-2010, suggesting that some sites may be more subject to this kind of event. The photo (Figure 8) shows the western edge of this site, where *B. truncata* still persist, albeit at much reduced numbers at the margin of the sediments.

A bed of *B. truncata* associated with an old oyster bed in the Avon estuary (the Guzzle) was probably lost due to an episodic event. Bleakney and Davis (1983) postulated an catastrophic event causing the loss of the 3,800 year- old oyster bed. By extension, the *B. truncata* population, interbedded with the oysters, would have been lost at the same time (Bleakney, personal communication).

Recruitment

Recruitment through larval settlement is limited by several factors. One relates to the consumption of larvae within the water collumn or adjacent to benthic habitats. In this context adults of the species are one of the possible ``consumers`` of larval *B. truncata*. The second loss of larvae is related to the degree of tidal flushing out of the basin (see **Dispersal** , above (Parker et al, 2007)). This flushing, tied to the counter-clockwise circulation in the Gulf of Maine could account for the appearance of *B. truncata* at Bath, Maine (Anonymous, 2006). As well, successful larval settlement is restricted by limited availability of appropriate substrate. It should be re-iterated that the types of substrates used by the species throughout the rest of its North American range are not used in Canadian waters. The reason for this is not clear, but could relate to winter conditions in intertidal portions of Canadian coastal waters.

HABITAT CONSIDERATIONS

The **Basic Biology** and **Habitat Requirements** sections of this document outline the life history stages and habitat needs for each stage. These are summarised, below for the Minas Basin populations. Ranges offered reflect regional ranges (eg. temperature requirement and tolerance in Sub-Saharan African estuarine waters may not be the same as those for Minas Basin populations – no data available in the literature.) The difficulty in defining these in a Canadian context is that this population is well outside the latitudinal range of other global populations.

ADULTS

Water

Depth – Intertidal (mid tidal range) – to possible sub-tidal range - undefined although there is some evidence of larval settlement in pools in upper intertidal zone. In this ecosystem, the majority of the populations documented appear to be just below the mid-tidal range.

Salinity – 16-30 ppt (inferred).

Temperature – 2 - 30° C (inferred) – need temperature change to induce spawning.

Current – adequate (during each tidal cycle) to prevent sediment accumulation (speeds undefined).

Turbidity - unknown, although food items (planktonic and other particulates) must be adequate.

Oxygen – due to its confinement in substrate (inability to move), it has a requirement for well-oxygenated waters.

Substrate

Composition – firm mud (mudstone facies in Jurassic age sandstone assemblage have this texture and density until they are de-watered, at which time they become very hard). This is a possible reason why upper-intertidal habitats are poorly colonised. There is tolerance of minor amounts of sands into mudstone matrix, but sandier mudstones do not appear to sustain adults).

Location – Must not be subject to significant variation in sediment deposition – there is some evidence that gradual re-positioning of sediment plumes from rivers, as evidenced in aerial photographs, can change sedimentation patterns in the long-run.

Must have a degree of protection from scouring by currents (especially at highest current speeds), from moving lithic material (cobbles, coarse sand etc.) as well as from moving and resting ice, especially in late winter.

LARVAE

Water

There is a lack of knowledge for the requirements of larval (trochophore and veliger) stages in Canada, although it is expected that basic requirements are well-oxygenated water and adequate food availability for the duration of the larval period (believed to be around 35 days (Chanley, 1965).

Substrate

Settlement is thought to occur at high-slack tide, so substrate of appropriate texture and density is required. Larvae are not able to start boring in hard or complex substrates containing hard elements (sands).

Since successful settlement is dependent on sufficient time to initiate boring and derive protection from the bore-hole/burrow before de-watering with the falling tide, it appears that, ideally this would be from mid-tidal point and lower. Successful establishment has been noted in tide pools in upper intertidal areas, but such areas tend to be subject to factors limiting the persistence of adults.

SPATIAL EXTENT OF AREAS LIKELY TO HAVE THESE PROPERTIES

There is only a narrow band of habitats in the mid-low or even sub-tidal portions of the Minas Basin where one finds substrate suitable for settlement. Except for several areas where there are greater exposed surface areas, the majority of sites are at points where this mud-stone facies is exposed under firmer rock beds. There are only 42 ha of surveyed substrate that fit into this category, with a possible additional 15 ha which were inaccessible during field surveys (Table 1).

Elements relating to water quality are relatively constant (in the mid-low intertidal zone) for much of the Minas Basin, although there are some minor differences among the sub-basins.

Habitats along the south shore of the basin tend to exhibit more cap-stone-like features than those of the north side. The three largest sites on the north side of the basin offer other forms of protection in tide-pool type habitats, ranging from cobble to large rock protection, still maintaining adequate water movement and flushing.

SPATIAL CONSTRAINTS

Except in areas associated with headlands, most of the sites with populations of *B. truncata* are isolated from each other by areas of mud-flats or, in the mid-basin, stable masses of sands and other coarse sediments. However, since the species is not mobile in its adult form and larvae are carried throughout the basin and further by tidal currents, this is not a barrier.

SUPPLY OF HABITAT MEETING DEMANDS

At present, the populations of *B. truncata* in the basin are relatively stable. There is some loss of sub-populations and some constraint at margins of others. However, due to the relative refreshing of substrates at some sites and evidence for ongoing recruitment/ settlement at most sites, there is an adequate supply of habitat to maintain the present populations within the basin unless there are catastrophic changes (eg. storm or pollution events) or long-term degradation to the ecosystem.

HABITAT ALLOCATION OPTIONS

As was outlined in **Status and Trends** (**Abundance**), it would appear that the most important habitats from the point of recruitment and persistence of the species in the basin are probably the sites with populations associated with cap-stone habitats, followed by those deriving protection from other features such as cobble beds etc., with open pool-type habitats being the least significant (or persistent). In the presence of such a limited amount of habitat, allocation options may be limited. Ultimately, aside from recruitment potential, the most essential habitats may be those exhibiting “cap-stone” characteristics in an energy regime that would, ultimately, be least susceptible to sedimentation events.

RESIDENCE REQUIREMENTS

SARA defines a residence as a: "Dwelling place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating". Residence is interpreted by DFO as being constructed by the organism. Under these uses the Mud-piddock's bore holes/burrows are residences, but there is a one to one correspondence between the individual and its burrow for all its’ post larval life. This means that the distribution of residences is an exact copy of the distribution of the post settlement population and not a sub-area of the distribution.

THREATS

A series of potential threats and potential sources of mortality was identified in the COSEWIC (2009) Status Report and COSEWIC Species Assessment for the Atlantic Mud-piddock. These are discussed in the sequence presented in the Status Report. Additional threats were identified during the Assessment process, and threats, current protection and protection if listed under *SARA* are shown in Table 2. (from DFO, Oceans, Habitat and Species at Risk Branch).

Noted impacts that predict changes in sedimentation as outcome infer loss of population through substrate smothering. This includes both loss of individuals as well as the decrease in availability of useful substrate (for future larval settlement).

TEMPERATURE CHANGE

The upper ranges of temperatures encountered in the Minas Basin are well within the normal ranges encountered by the species throughout its range. However, with this being the most northerly occurrence of the species, winter temperatures may be a critical limiting factor, possibly explaining atypical substrate use in the Minas Basin. Water temperatures can approach -2° C and air temperatures routinely approach -20° C in the winter. If absolute temperatures are limiting, any changes in temperature regimes, including greater oscillation around annual means or decreased winter temperatures, could have a negative impact on persistence of the population in the Minas Basin. - ***Magnitude Unknown but could affect whole basin populations – temperature – related mortality.***

ICE MOVEMENT IN LATE WINTER

Ice rafting in late winter – early spring is probably one of the most significant factors in the modification of populations of *B. truncata* within the Basin, be it through scour of unprotected areas or pressure-induce collapse of cap-stones protecting populations. If there is a climate-change induced change (specifically increase) in volume and persistence of rafting ice within the basin, then most populations could be impacted. – ***Magnitude Unknown – throughout whole basin – both physically-protected and unprotected sites.***

INCREASED FREQUENCY AND SEVERITY OF STORM EVENTS

With changes in weather patterns, possibly associated with global climate change, there are predictions of more as well as more severe weather events (hurricanes) affecting Canadian East Coast near-shore waters. The movement of such major storms, in conjunction with high tides and storm surges through the Bay of Fundy/Minas Basin could result in major siltation events throughout the estuary as well as increased ice damage during winter storms. – ***Magnitude Unknown, but potentially severe and Basin-wide – Sedimentation effects.***

INSTALLATION OF WATER CONTROL STRUCTURES OR IN-STREAM ELECTRICAL GENERATORS

The modification of currents within the basin by the construction or alteration of structures such as aboideaus, barrages or causeways has been noted to result in major changes in proximal intertidal ecosystems (Daborne *et al*. 2003). Such an effect was predicted in the evaluation of potential impacts of barrage construction on Minas Basin in-fauna but had not been examined in the context of lithophagous species. Similarly, installation of suites of “in-stream” turbines for power generation could have similar effects. - ***Magnitude Unknown but with projected modelling proposing extraction of between 5 and 30% of available energy from the tides, both near-field and far-field effects on habitats could be substantial. Based on this scale of development this could adversely affect all non-cap-stone sites – sedimentation effects.***

MINING OF MINERALS IN RIVER AND BASIN SEDIMENTS

The discovery of a titanium within the surficial and deeper sediments of the basin resulted in experimental dredging of lower portions of the Shubenacadie River (inflow to the Minas Basin)

(Percy 2001). Impacts of this dredging activity on sediment loads and deposition patterns within the basin are not clear. Although this experimental dredging program proved to be uneconomical, similar exploratory or extraction activity could have negative effects on the species by siltation of habitat and smothering. - ***Magnitude Locally Moderate to Severe-sedimentation effects.***

SURFICIAL DRAINAGE FROM ADJOINING WATERSHEDS

The Minas Basin receives runoff from the two most productive agricultural areas within Nova Scotia: the Annapolis Valley and the Shubenacadie drainage basin. Both these regions also support growing urban zones with concurrent generation of agricultural and urban runoff. There is no documented effect of either of these on the water quality of the receiving waters. However, there was one incident in 1986 when a fire destroyed a pesticide and agri-chemical warehouse in the lower part of the Annapolis Valley (Canning, Nova Scotia) that resulted in the release of substantial volumes of fertilizer and pesticides into the Avon Estuary of the Minas Basin (Percy *et al.*1989). – ***Magnitude Locally Moderate to Severe- primarily chemical effects.***

EXCAVATION OF SALT DOMES FOR LIQUIFIED GAS STORAGE

A recent development was registered under the Environmental Assessment Review Process (EARP) in Nova Scotia for excavation of salt domes near the Shubenacadie estuary for creation of caverns for storage of liquefied natural gas. The development proposed to discharge up to 400 T of anhydrites into the river on a daily basis for a period of three years. Modeling for impacts of salt discharge did not take into account the potential impact of such concentration of salts in falling tidal waters on intertidal molluscs. – ***Magnitude Unknown, but potentially locally Moderate to Severe – primarily chemical (salinity) effects.***

BULK PETROLEUM MOVEMENT IN GULF OF MAINE

With bulk movement of petroleum by sea throughout the Gulf of Maine and Bay of Fundy to four seaports with oil refineries in Maine and New Brunswick, there is a risk of oil spills within this estuarine area. Although there is little movement of bulk vessels into the Minas Basin and the basin is considered at low risk for coastal spills, oil entering from lower reaches of the Fundy Basin could cause significant impacts on intertidal habitats and pose considerable problems in cleanup (Owens 1977). – ***Magnitude Unknown but potentially could be Severe.***

It is noted that with the lack of historical data on extent of populations of *B. truncata* and any estimate of densities it is not possible to determine effect of activities of the past on populations. Likewise, it is important to have adequate survey data in order to be able to evaluate future impacts. Table 2 list some additional threats, i.e. non point source pollution and the proposed development of tidal power generation from the Minas Channel. It also lists the current protection and management measures afforded by legislation, and what additional protection would be afforded by listing the Atlantic Mud-piddock under Schedule 1 of *SARA*.

RECOVERY OBJECTIVES

Barnea truncata was designated as threatened due to its small population size rather than evidence of a declining population. At present the population appears to be stable with local variability, and is not expected to increase beyond current levels. The present limiting factor is the availability of suitable substrate (red-mudstone habitat). Due to this, a possible recovery target would be to maintain the current status and prevent the loss of suitable habitat due to human activities in the Minas Basin. The most serious threats involve changes in sediment deposition patterns that could smother present occupied areas.

RESEARCH AND ANALYSIS REQUIRED

At present there are substantial gaps in our knowledge of the species, its habitat use and our understanding of why it uses habitats (in Canadian waters) that are so different from those within the rest of its global range. However several questions should be addressed in order to place management of the species or threats to the species on firmer ground. These include:

1. confirmation of life history traits - life span, age to sexual maturity, time of reproductive activity;
2. confirmation of presence or absence of the species in approximately 15 ha of isolated habitats;
3. evaluation of field sites with current silt loading (mud flats) overlaying mud-stone facies to determine if there are other sites within the basin that have been lost due to siltation events; and
4. genetic analysis to confirm relationship between nearest sustaining populations (Massachusetts) and southern populations – is this one species or a species complex with intergrades?.

CONCLUSIONS

The population of *Barnea truncata* in Canada is a small disjunct, relic population. It is unlikely to re-establish naturally from other populations.

In Canada *Barnea truncata* is restricted to a single type of substrate, red-mudstone, within the Minas Basin, Nova Scotia.

The limited occurrence of these red-mudstone facies result in an area of occupancy (AO) of less than 0.6 km^2.

At present there are no data on trends in abundance, but the population appears to be stable. The population is not expected to increase beyond current levels. Recovery would be to maintain the current population status.

Barnea truncata's life history of a planktonic larval phase with the adult boring into the substrate, with the hole increasing in diameter and depth as it grows, means it is immobile and susceptible to smothering by sediment movement.

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Table 1. Extant and historical locations of Barnea truncata in Canada (Modified from COSEWIC 2009).

Locality name (all Nova Scotia) and date surveyed	Latitude	Longitude	Habitat type	Area[†]
Extant populations				
Parrsboro (Wasson's Bluff), Cumberland County, 3 Oct. 2007	45° 23' 22.08" N	64° 13' 25.97" W	tide pool	2 ha
Five Islands (Provincial Park), Colchester County, 23-24 May 2008	45° 23' 14.95" N	64° 03' 55.90" W	tide pool	4 ha
Economy Point and Headlands (Thomas Cove), Colchester County, 31 Oct. 2008	45° 21' 01.73" N	63° 53' 46.47" W	tide pool	10 ha
Bass River (Saints Rest), Colchester County, 23 May. 2008	45° 23' 42.73" N	63° 46' 51.20" W	drainage channel	< 1 square m
Spencer Point, Colchester County, 23 May 2008	45° 23' 08.47" N	63° 37' 53.99" W	tide pool and undercut	1 ha
Lower Selma (Mungo Brook Cove Reef), Hants County, 2 Sep. 2007	45° 19' 06.04" N	63° 37' 42.52" W	tide pool and undercut	1.5 ha
Noel Shore (Shad Creek Cove Reef), Hants County, 3 Sep. 2007	45° 19' 12.59" N	63° 40' 14.76" W	tide pool and drainage channels	4 ha
Noel Head (Sloop Rocks), Hants County, 16 Sep. 2007	45° 19' 30.51" N	63° 43' 03.60" W	tide pool and undercut	10 ha
Noel Bay, Hants County, 11 Aug. 2007	45° 18' 49.37" N	63° 45' 36.24" W	tide pool and undercut	1.5 ha
Burntcoat Head (north section), Hants County, 26 Sep. 2007	45° 19' 07.98" N	63° 47' 08.75" W	tide pool and undercut	2 ha
Burntcoat Head (Lighthouse Point), Hants County, 9 Sep. 2007	45° 18' 43.07" N	63° 48' 35.39" W	undercut	3 ha
Tennycape (west of headland), Hants County, 23 Sep. 2007	45° 16' 48.23" N	63° 53' 44.29" W	tide pool	2 ha
Port Williams (Cornwallis River estuary), Kings County, 17 Jun. 1999	45° 06' 08.93" N	64° 22' 38.38" W	undercut	1 ha
Recently extirpated locations				
Salter Head, Hants County, 3 Sep. 2007	45° 20' 12.44" N	63° 32' 22.20" W	tide pool	c 2 ha
Walton Cove, Hants County, 10 Oct. 2007	45° 14' 26.81" N	64° 00' 20.83" W	not recorded	not recorded
Evangeline Beach, Hants County, 27 Oct. 2007	45° 08' 22.32" N	64° 19' 47.42" W	tide pool	< 0.5 ha

Table 2. Threats, Potential Impacts and Protection and Management Measures – Atlantic Mud-piddock (DFO, Oceans, Habitat and Species at Risk Branch).

Potential Anthropogenic Threats	**Potential Biophysical or Chemical Changes**	**Potential Impact on Atlantic Mud-piddock**	**Current Protection and Management Measures**	**Potential Protection and Management Measures Under *SARA***
Climate Change	-Storm events could cause serious disruption to sediments in shallow estuarine ecosystems -Change in temperature regimes -Changes to the movement of ice in mid to late winter -Rising sea level -Increased rain could increase the frequency of floods substantially altering the flow in rivers	Storms – smothering of Mud-piddock habitat -Temperature – greater oscillation of temperatures around annual means or decreased winter temperatures could harm the population -Ice – habitat could be destroyed due to substantive ice scour and the collapse of protective cap-rock under the weight of ice after water retreat at low tide -Rising sea level – likely to destroy habitat due to an increase in shore erosion and beach migration -Rainfall – a greater amount of sediment could be carried from the rivers into the Basin resulting in smothering of Mud-piddock habitat		- Climate change mitigation measures are outside of DFO jurisdiction and mandate. - Periodic site surveys to monitor the distribution and status of the Atlantic Mud-Piddock to be undertaken using protocols developed by the Nova Scotia Museum of Natural History.
Construction or alteration of shoreline or watercrossing structures (e.g., aboiteaus, dams causeways wharves, boat slips)	-Modification of currents -Destruction of fish habitat -smothering of habitat via sedimentation	-Changes in currents could result in the alteration of nearby intertidal fish habitat due to the movement of sediment, erosion, etc. (possibly critical alteration of substantial areas of habitat which could include Mud-piddock habitat) -Activities associated with shoreline structures could result in the destruction of Mud-piddock habitat	-Compliance with existing legislation as set out under the *Fisheries Act* (Federal), *Canadian Environmental Assessment Act* (F), Beaches Act (Provincial), etc. -DFO to continue to review development proposals under the referral process established with the Nova Scotia Department of Natural Resource (NSDNR) to determine the compliance requirements in relation to the Habitat Protection Provisions of the *Fisheries Act*.	-Certain activities under “shoreline development” fall within the “Low Risk Guidelines”. DFO does not currently receive proposals for these activities from NSDNR for review and comment. If the Atlantic Mud-Piddock is listed under *SARA*, DFO would initiate discussions with the Province of Nova Scotia to ensure that protection of this species and its habitat are considered when reviewing project proposals that fall under the “Low Risk Guidelines”. -Mud-piddock habitat could be identified and these areas could be designated Critical Habitat (CH). Activities that could lead to CH destruction would be prohibited under *SARA*, if an Order is made under *SARA* section 58.
Exploratory or extraction activities in nearby rivers	-Disturbance of sediments (e.g., resuspension and migration of sediments)	-Smothering of Mud-piddock habitat	-Compliance with existing legislation as set out under the *Fisheries Act* (F), *Canadian Environmental Assessment Act* (F), *Crown Lands Act* (P), *Beaches Act* (P), etc.	Atlantic Mud-Piddock habitat could be identified and these areas could be designated as Critical Habitat. Activities that could lead to CH destruction would be prohibited under *SARA*, if an Order is made under *SARA* section 58.

Table 2 (continued).

Potential Anthropogenic Threats	Potential Biophysical or Chemical Changes	Potential Impact on Atlantic Mud-piddock	Current Protection and Management Measures	Potential Protection and Management Measures Under *SARA*
Non-point source pollution, i.e. agricultural and urban runoff form the Annapolis Valley and the Schubenacadie drainage basins	-Degradation of water quality due to mitigation of soil, animal waste, pesticides, etc. into the water	-Adverse health effects on Mud-piddock related to degraded water quality	Compliance with existing legislation as set out under the *Fisheries Act* (F), *Canadian Environmental Assessment Act* (F), *Environment Act* (P), *Crown Lands Act* (P), *Beaches Act* (P), etc.	-Relevant Federal and Provincial departments to continue current management measures. - Conduct public education campaigns to raise awareness about the species and its habitat. Encourage community involvement and stewardship through funding programs such as the Habitat Stewardship Program.
Developments with potential to impact the estuary – turbines	-Alteration of tidal regimes	-Unknown	- One turbine has been deployed to date. It is the tidal in-stream energy conversion (TISEC) device and is located in the Minas Channel. The TISEC device was damaged so will be removed early. Removal is planned for October 2010. - Deployment of other experimental tidal turbines is planned to take place in the Bay of Fundy over the next several years . Dates for deployment have yet to be determined. - Any future proposals will be reviewed by DFO for compliance with the *Fisheries Act* (F) and any other relevant legislation. The Developer will be required to monitor environmental effects related to the experimental turbines. -The long term plan is to commercialize the turbines.	Environmental Effects Monitoring will be more stringent to ensure any potential effects on the Atlantic Mud-Piddock are assessed.
Developments with potential to impact the estuary – underground natural gas storage project with associated release of brine into the Schubenacadie River	- Increase in the salinity level of the water over a two year period	- Unknown, likely no measurable impact in the Minas Basin due to the dilution on the brine	- This project received an environmental approval from the province of Nova Scotia. This approval outlines requirements for baseline data collection and monitoring in relation to fish and fish habitat. - The proponent is continuing to obtain any required provincial approvals\permits.- - There was no requirement for a *Fisheries Act* authorization. A Letter of Advice will be written in regards to the Habitat Protection Provisions of the *Fisheries Act*. It will provide recommendations for mitigation and monitoring. - There was no requirement for a federal environmental assessment under CEAA.	- No additional management measures required. Regulatory requirements can't be changed after a proposal has been reviewed. However, if monitoring demonstrates that federal legislation could potentially be contravened (e.g., *Species at Risk Act*, *Fisheries Act*) as a result of the project, the proponent would be requested to make changes to operating procedures
Bulk movement of petroleum by sea throughout the Gulf of Maine and Bay of Fundy to four seaports with oil refineries in Maine and New Brunswick	-Accidental oil spill – oil could enter the Basin from the lower reaches of the Fundy Basin	-Could cause significant impacts in intertidal habitats and pose considerable problems in cleanup	The *Canada Shipping Act* and associated regulations govern the transport of petroleum products by ship.	No additional management measures required. Existing legislation is considered sufficient at this time.