COSEWIC
Assessment and Status Report

on the

Atlantic Mud-piddock
Barnea truncata

in Canada

THREATENED
2009

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

COSEWIC. 2009. COSEWIC assessment and status report on the Atlantic Mud-piddoc *Barnea truncata* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 42 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Production note:
COSEWIC would like to acknowledge Derek S. Davis and Andrew J. Hebda for writing the provisional status report on Atlantic Mud-piddock *Barnea truncata,* prepared under contract with Environment Canada. The contractors' involvement with the writing of the status report ended with the acceptance of the provisional report. Any modifications to the status report during the subsequent preparation of the 6-month interim and 2-month interim status reports were overseen by Robert Forsyth, COSEWIC Molluscs Specialist Subcommittee Co-chair.

For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment Canada
Ottawa, ON
K1A 0H3

Tel.: 819-953-3215
Fax: 819-994-3684
E-mail: COSEWIC/COSEPAC@ec.gc.ca
http://www.cosewic.gc.ca

Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur la pholade tronquée (*Barnea truncata*) au Canada.

Cover illustration/photo:
Atlantic Mud-piddock — Beach Shell from the Minas Basin. Photo by Christina McCorry.

Catalogue No. CW69-14/594-2010E-PDF
ISBN 978-1-100-15127-4

Recycled paper

COSEWIC
Assessment Summary

Assessment Summary – November 2009

Common name
Atlantic Mud-piddock

Scientific name
Barnea truncata

Status
Threatened

Reason for designation
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 facies 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.

Occurrence
Atlantic Ocean

Status history
Designated Threatened in November 2009.

COSEWIC
Executive Summary

Atlantic Mud-piddock
Barnea truncata

Species information

The Atlantic Mud-piddock, *Barnea truncata,* is an intertidal bivalve mollusc belonging to the family Pholadidae. It is one of only two species of its family in Atlantic Canada. The shell is 3–5 cm long and well adapted to burrowing in firm substrates.

Distribution

Where substrates allow, the Atlantic Mud-piddock is found along the eastern coast of the Atlantic Ocean from Senegal, Western Africa, to South Africa. In the western Atlantic, it is sporadically found from southern Brazil to the U.S. Gulf states. It occurs in most Atlantic coastal states from southern Maine to Florida. With the exception of one population in Puerto Rico, this species does not occur on any oceanic island or sea-mount. The only Canadian population is located in the Minas Basin of the Bay of Fundy, approximately 350 km from the nearest Maine population. In Canada the Atlantic Mud-piddock occurs at three locations, where it inhabits red-mudstone in the Minas Basin.

Habitat

This is an intertidal marine species. In southern populations, it has been recorded burrowing into substrates including marine peats, firm muds, and (rarely) wood, but in Canada the species is restricted to settling on and burrowing in a single geological formation, red-mudstone that is associated with Jurassic-age sandstones in the Minas Basin. This habitat type is very limited in extent; the total area is less than 0.6 km^2.

The Minas Basin has a large tidal range (up to 19 m) that results in highly oxygenated waters with considerable particulate food resources for this species. These habitats are characterized by a large fluctuation in annual and seasonal water temperatures. This contrasts with cooler, less productive portions of the rest of the Bay of Fundy, effectively acting as a barrier and isolating this northern population.

Biology

Sexes are separate and fertilization is external. After a brief (ca. 35 day) planktonic stage the larvae settle and begin burrowing. Individuals grow while burrowing a conical burrow into the substrate. They become trapped in their burrows and are completely dependent on suspended food (likely plankton and organic particulate matter) and the overall quality of the water for food, respiration and other physiological functions.

Population sizes and trends

There are no previous quantitative data available and population trends are unknown. The total population size is unknown because of the restrictions of accessing the low tide zone and the habitat of the species (boring into mud-stone under hard capstones). Additionally, one potentially significant habitat unit was not accessible during field surveys. There are contemporary field-based indications of localized loss and gain of sites over short periods.

Limiting factors and threats

The occurrence of the Atlantic Mud-piddock in the Minas Basin is limited by the availability of the mudstone substrate in the intertidal zone. The species is immobile when adult, and any subtle or substantive changes in sediment deposition can result in the loss of individuals or sites through smothering. In addition, changes in winter conditions can also result in habitat loss through ice scour and crushing. The species is prevented from using deeper water substrates in the Minas Basin by the presence of stable bodies of subtidal sands and gravels.

Storms are known to have caused the shift and re-deposit of large volumes of sediments and increase the amount of eroded materials discharged into the basin by streams. The frequency and severity of storms is expected to increase due to climate change, which can quickly cause serious disruption in shallow estuarine ecosystems and make required habitat less stable as the frequency and severity of storm events increase.

Additional threats include the movement of ice that can scour habitat, the building of structures (barrages, causeways, tidal power projects) that will change water circulation in the basin and affect sedimentation, dredging the bottom for mineral exploration, surface water discharge from agricultural or urban areas that may introduce chemicals or additional sediments, and oil spills.

Special significance of the species

The Atlantic Mud-piddock is the only species of *Barnea* in Canada. The Canadian population, which is the most northerly population in the world and separated by over 350 km from the nearest U.S. population, is likely a remnant of a warm-water, post-glacial, marine fauna and is of scientific interest. Canadian *B. truncata* show environmental adaptations that, coupled with the high improbability of genetic exchange with southern populations, suggests that this could be a Canadian endemic. If not a distinct species, the Minas Basin population could be potentially important in terms of genetic variability of the species.

Existing protection

The Atlantic Mud-piddock and its habitat are protected under the federal *Fisheries Act*. There is no provincial legal protection.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2009)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment Canada | Environnement Canada
Canadian Wildlife Service | Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

on the

Atlantic Mud-piddock
Barnea truncata

in Canada

2009

TABLE OF CONTENTS

List of Figures

List of Tables

SPECIES INFORMATION

Name and classification

Scientific name: *Barnea truncata* (Say, 1822)
English common name: Atlantic Mud-piddock
French common name: pholade tronquée

The currently accepted classification of this species is:

Phylum Mollusca
  Class Bivalvia
    Subclass Heterodonta
      Order Myoida
        Superfamily Pholadoidea
          Family Pholadidae
            Genus *Barnea*
              Barnea truncata

There is considerable variation in the vernacular names of the species. 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 2006a), Truncated Piddock (Rogers 1936) and Truncated Angel's Wings (Vilas and Vilas 1952).

Morphological 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 (Figures 1–4). 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 (Figure 2). 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 structures that project from underneath the umbones inside each valve.
The anterior dorsal area of the shell is protected by a thin plate known as the protoplax, an important diagnostic feature.

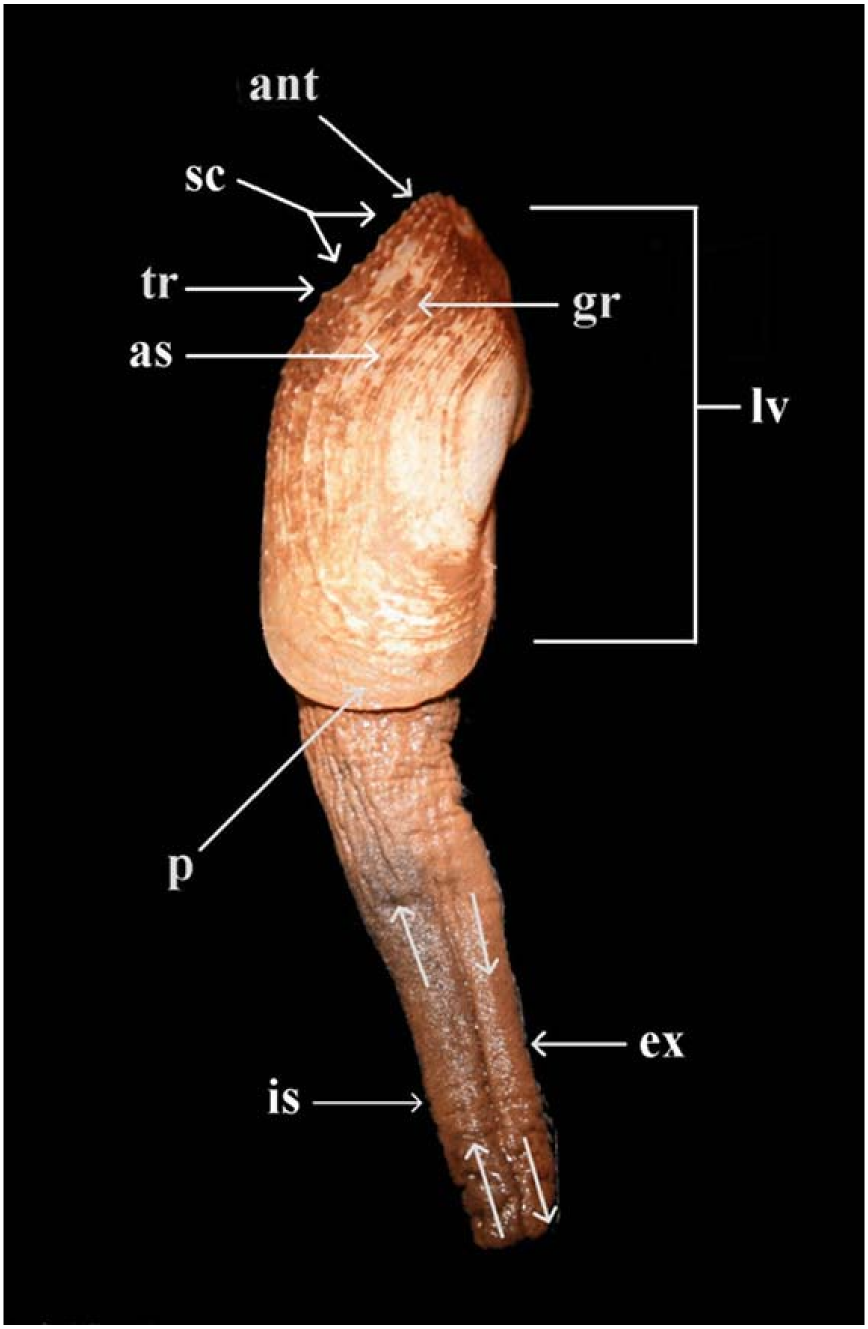

Figure 1. Lateral view (left side) of *Barnea truncata.* Adult specimen collected alive, Noel Bay, Hants County, Nova Scotia. Left valve (*lv*), inhalant siphon (*is*), exhalant siphon (*ex*), shell sculpture (*sc*), growth rings (*gr*), anterior slope (*as*), tooth ridges (*tr*), beaked anterior end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

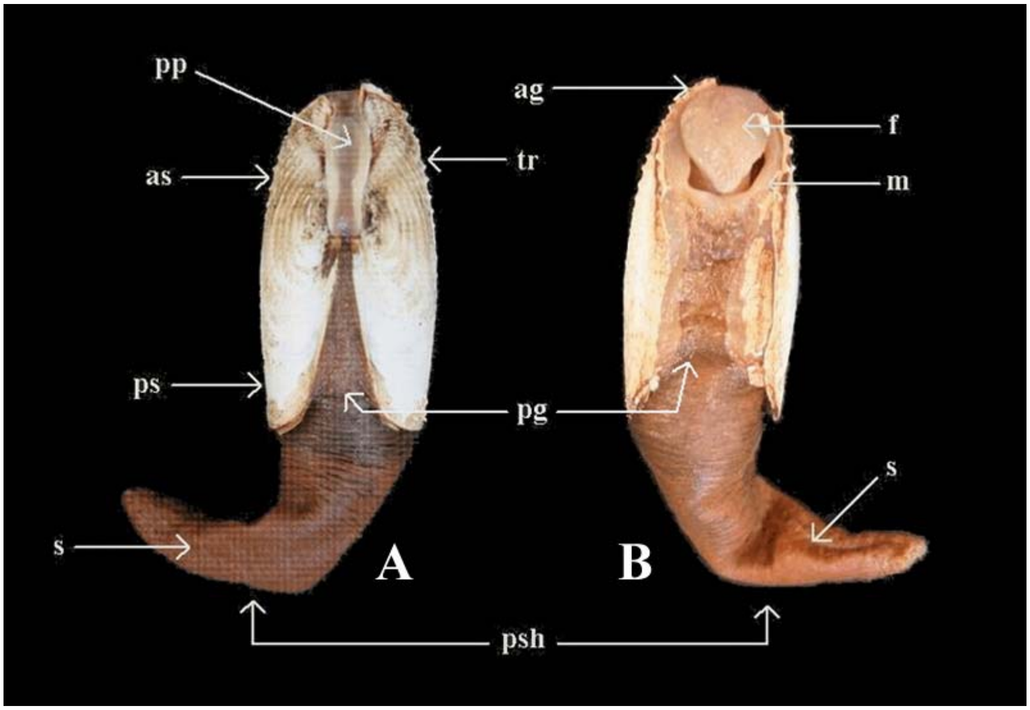

Figure 2. Dorsal (A) and ventral (B) views of *Barnea truncata.* Adult specimen collected alive, Noel Bay, Hants County, Nova Scotia. Anterior gape (*ag*), posterior gape (*pg*), protoplax (*pp*), anterior slope ridges (*as*), smooth posterior slope (*ps*), tooth ridges (*tr*), siphons paired in periostracal 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.)

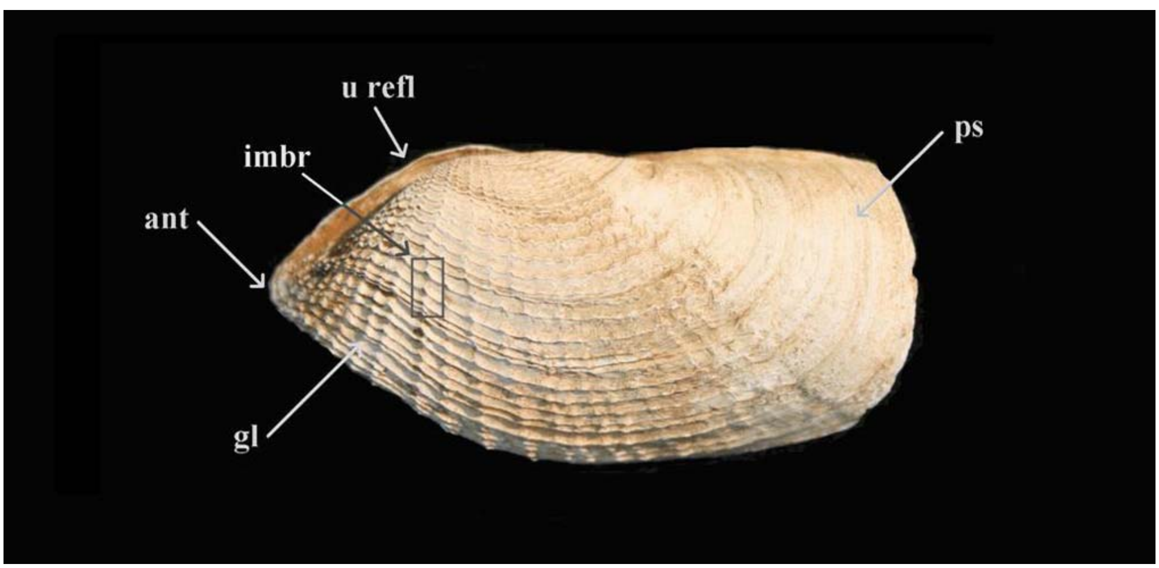

Figure 3. *Barnea truncata.* Beach shell from the Minas Basin, Nova Scotia. Exterior of left valve showing concentric growth line (*gl*), anterior radial sculpture, truncate posterior end and smooth posterior slope (*ps*), beaked anterior end (*ant*), imbrications (*imbr*) where concentric and radial sculpture intersect (important in burrowing), umbonal reflection (*u refl,* closed posteriorly, open anteriorly). (Photo by Christina McCorry.)

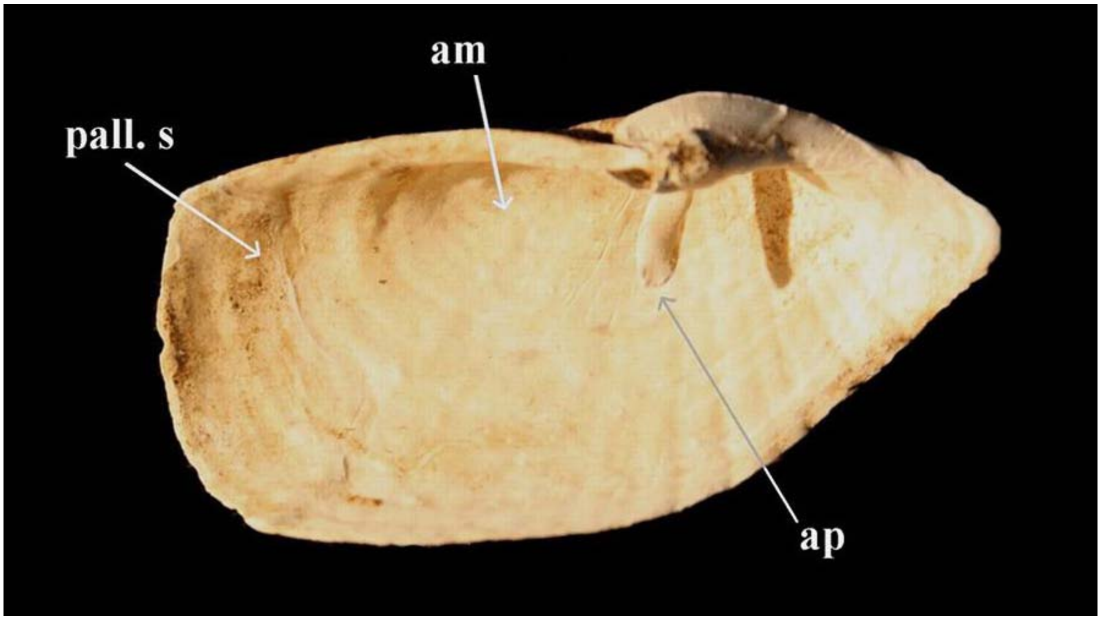

Figure 4. *Barnea truncata.* Beach shell from Minas Basin, Nova Scotia. Interior of left valve showing projecting apophysis (*ap*). The pallial sinus (*pall. s*) and the adductor muscle scars (*am*) are present but not clearly seen in the photograph. (Photo by Christina McCorry.)

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 in *B. truncata*. The protoplax is longitudinally divided (Figure 2A).

The body cannot be entirely 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* [Family Petricolidae]). The muscular foot is visible through the anterior gape in the shell (Figure 2B).

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 *Zirphaea crispata* (Family Pholadidae), 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).

Although the sexes are separate, there is no sexual dimorphism evident in the external appearance of the shells.

Larval *B. truncata* are characterized by a swimming structure called a velum (Figure 5), 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.

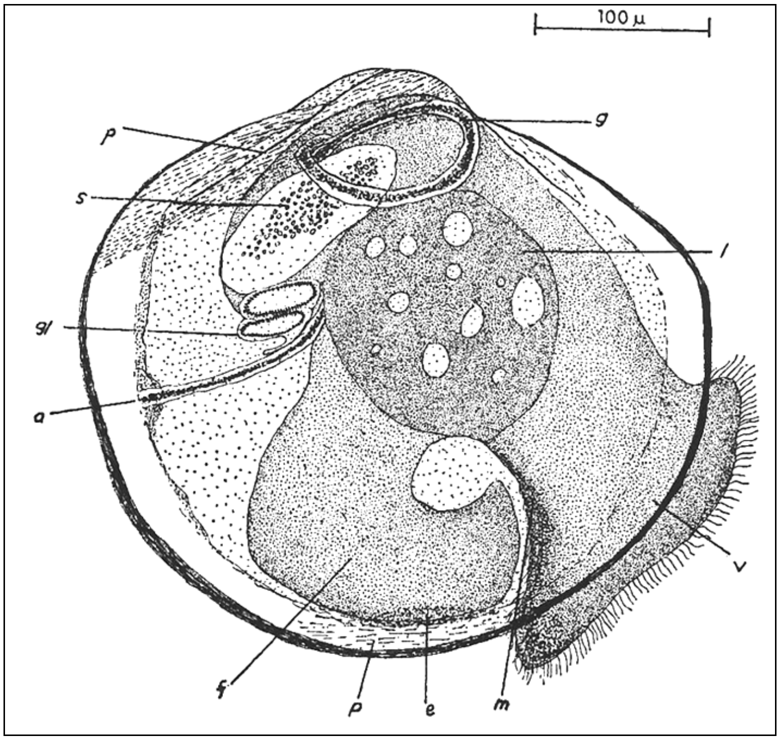

Figure 5. Prominent features in the internal anatomy of the *Barnea truncata* larva. Anus (*a*), granular swelling in mantle (*e*), foot (*f*), gut (*g*), Gills (*gl*), liver or digestive gland (*l*), mouth (*m*), pink or purple shell colour (*p*), stomach (*s*), velum (*v*). (Reproduced from Chanley (1965) with permission of Springer Science and Business Media.)

Genetic description

There are no published data on the genetic structure of *B. truncata*. Data on the genetics of the Canadian, American and other populations would assist in clarifying the relationships among these populations and give insight into the potential for rescue of the Minas Basin population.

Due to the water circulation within the Minas Basin (Greenberg 1983) and reproductive strategy of *B. truncata* (see **Life cycle and reproduction**) it is suspected that this Canadian population is of relatively uniform genetic composition. The counter-clockwise nature of the prevailing currents within the Bay of Fundy and Gulf of Maine (Scarratt 1982; Davis and Browne 1996) makes it unlikely that there has been any importation of genetic material from the nearest population in southern Maine in recent times. However, because of the volume of water exchanged during tidal cycles between the Bay of Fundy and the Gulf of Maine, the potential of the Canadian population contributing to the Gulf of Maine population cannot be ruled out.

Designatable units

Because all locations of *B. truncata* in Canada are believed to form a single, presumably genetically homogenous population within a small area, there are no designatable units.

DISTRIBUTION

Global range

Overall, *B. truncata* is restricted to Atlantic Ocean margins (Figure 6). It has been recorded from tropical and subtropical habitats in the eastern Atlantic from 15°N to 34°S latitude, including Senegal, the Democratic Republic of Congo, Namibia, and South Africa. There is one additional collection record from Port Elizabeth, South Africa, on the western margin of the Indian Ocean. It is probably continuous in distribution throughout this area where substrate allows, although surveys in this region are incomplete.

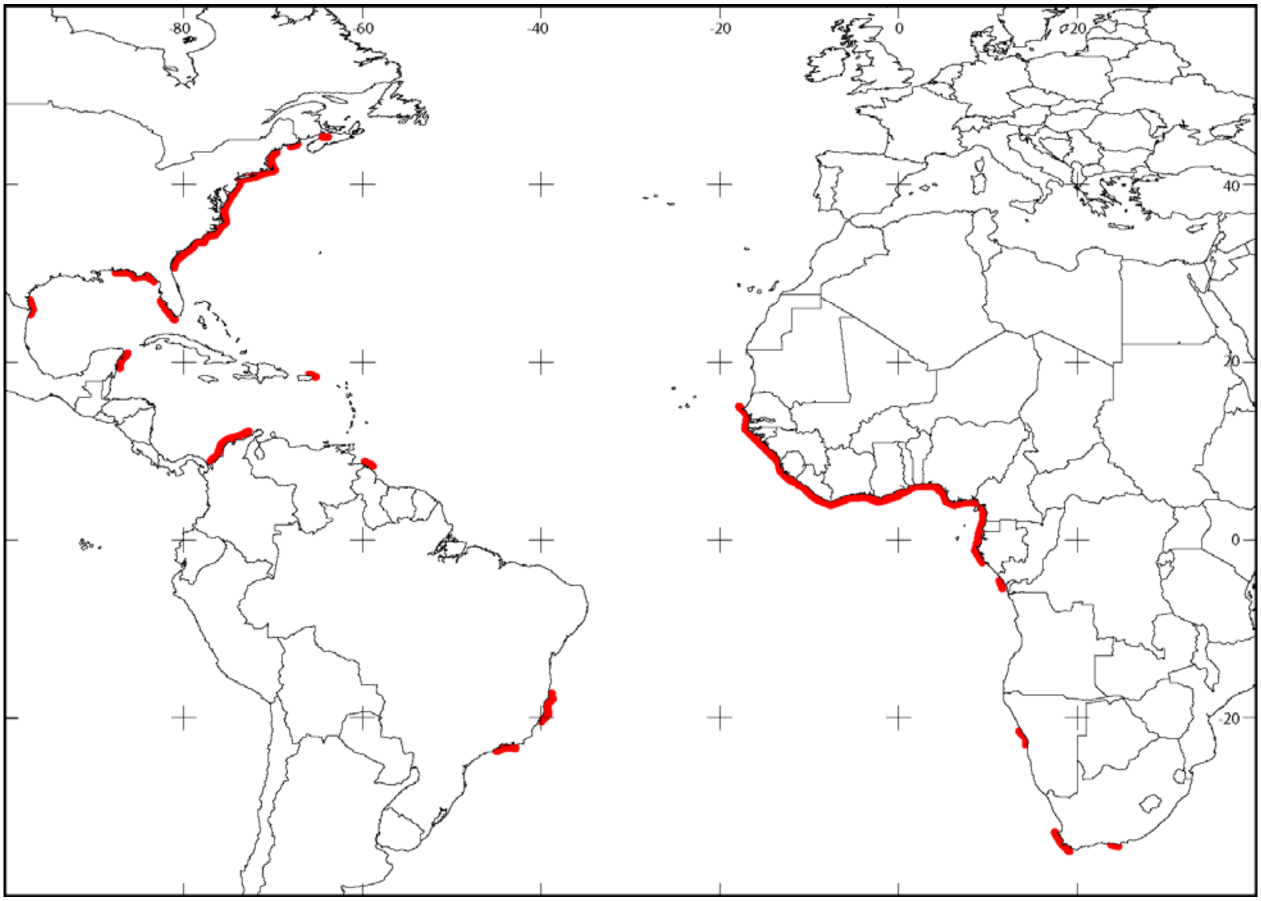

Figure 6. Global distribution of *Barnea truncata* (in red).

It is not found north of Dakar, Senegal (von Cosel pers. comm. 2007) and, consequently, is absent from the Mediterranean Sea or coasts of Europe. There is a single listing from a commercial shell supplier indicating a specimen from Western Sahara, although this has not been recorded in the scientific literature. It is not recorded from any oceanic islands in the north, central or south Atlantic Oceans or from the Azores in the mid-Atlantic (Avila 2000).

In the western Atlantic, *B. truncata* is distributed from 24°S to 45.4°N. It has been recorded from southeastern Brazil (west of San Paulo), Guyana, Colombia (von Cosel pers. comm. 2007), the east coast of Yucatan, and in the U.S., most Gulf of Mexico and all Atlantic American states from Florida to Maine. It is not recorded from any island in the Gulf of Mexico or the Caribbean Sea, except for a single collection from Puerto Rico (Warmke and Abbott 1961). In Maine, there is one disjunct population (Anonymous 2006a), and Turner (1954) noted that specimens in southern Maine are exceedingly rare. The only records north of Maine are from a single population within the Minas Basin, Nova Scotia (approximately 350 km north and east of the nearest Maine record).

It is reported from the Eastern Pacific Ocean in the species profile from the Integrated Taxonomy Information System (ITIS 2009). This unattributed citation is probably in error and likely a reference to *B. subtruncata*, a species from the west coast of North, Central and South America (see Turner 1954; Olsson 1961; and Abbott 1974). Turner (1954) noted a close similarity between the two species with potential for intergrades but outlined important morphological differences that make the two species distinct.

Canadian range

In Canada, *B. truncata* is only known from around the shores of the Minas Basin, Nova Scotia. This occurrence is disjunct from the nearest, also disjunct site located about 350 km south in the southern Gulf of Maine (Maine). However, it is not clear if this Canadian population became disjunct during the little ice age between AD 1200 and 1800 (Davis and Browne 1996) or whether its presence reflects bouts of colonization going back several thousand years.

Prior to 2007, records of *B. truncata* in Canadian waters were limited to a handful of sites within the Minas Basin, with no records in any other part of the Bay of Fundy or other portions of the upper Gulf of Maine. Historically, information concerning Canadian distribution was limited to institutional records. These include collection of empty valves in areas near Parrsboro, Five Islands Provincial Park, and Bass River (Cumberland County), Spencer Point (Colchester County), Maitland, Noel Bay (Bousfield and Leim 1959) and Walton (Hants County) and Evangeline Beach, Port Williams/Starrs Point (Kings County) (Figure 7). There are sites noted in the literature or observed in the field that are no longer occupied by *B. truncata* (Figure 7).

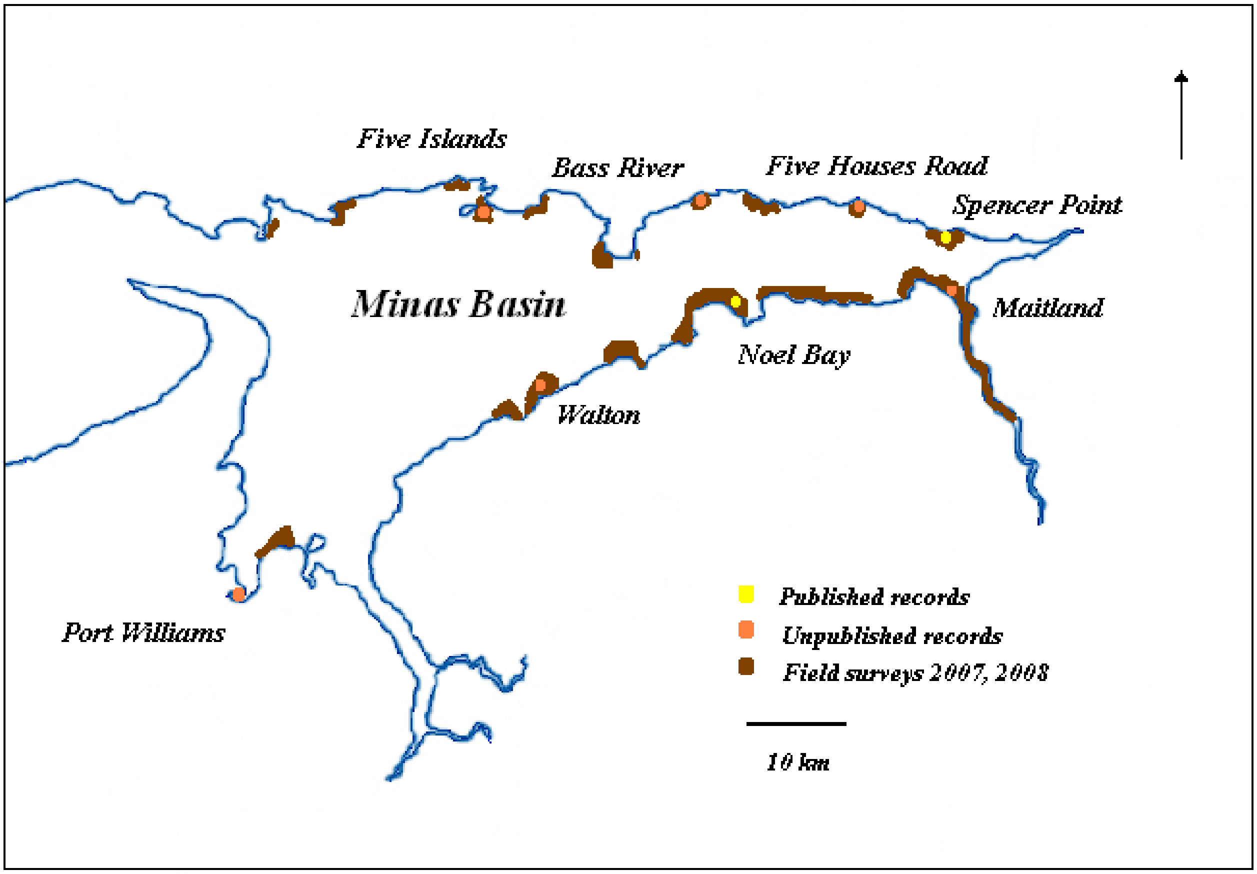

Figure 7. Summary of historical records and survey effort in 2007 and 2008.

Contemporary survey work (Hebda *et al*. in press) has confirmed the presence of *B. truncata* at 14 separate sites within the Minas Basin of Nova Scotia (Figure 8 and Table 1). These form three locations (Figure 8) based on the most likely threat (see **LIMITING FACTORS AND THREATS**). *Barnea truncata* is not recorded in the Bay of Fundy south and west of the Minas Channel (Bousfield 1958) and does not occur within Chignecto Bay to the northeast. Consequently, it is not found in any intertidal areas of New Brunswick. It is not recorded from the Gulf of St. Lawrence (Clarke 1962; Brunel *et al.* 1998). The known occurrence in Canada can be summarised as the mid-lower region of the Minas Basin (Hants, Colchester, Kings and Cumberland counties) at 45° 22’ N, 64° 07’ W.

Table 1. Extant and historical sites of *Barnea truncata* in Canada

Locality name (all Nova Scotia)	Latitude	Longitude	Habitat type	Area[†]	Abundance*	Remarks
Extant sites						
Parrsboro (Wasson's Bluff), Cumberland County	45° 23' 22.08" N	64° 13' 25.97" W	tide pool	2 ha	15%	associated with large cobble (reported from local knowledge -Eldon George and Ken Adams)
Five Islands (Provincial Park), Colchester County	45° 23' 14.95" N	64° 03' 55.90" W	tide pool	4 ha	30%	in zone between the "Old wife" and Moose Island (archival record-Bohlmann, Bleakney)
Economy Point and southwest headlands (Thomas Cove), Colchester County	45° 21' 01.73" N	63° 53' 46.47" W	tide pool	10 ha	10%	in protected zone between mid-tide line and offshore reefs (new)
Economy Point east headland, Colchester County	45° 20' 57.79" N	63° 52' 59.76" W	undercut	< 1 m^2	< 5%	mid-intertidal in an isolated, eroded "flower-pot" outcrop
Bass River (Saints Rest), Colchester County	45° 23' 42.73" N	63° 46' 51.20" W	drainage channel	< 1 m^2	80%	old bed covered with mud-only small remnant remaining (archival record-Medcoff 1948)
Spencer Point, Colchester County	45° 23' 08.47" N	63° 37' 53.99" W	tide pool and undercut	1 ha	20%	along east side of point-mid-tide range (historical-Bousfield)
Lower Selma (Mungo Brook Cove Reef), Hants County	45° 19' 06.04" N	63° 37' 42.52" W	tide pool and undercut	1.5 ha	15%	in exposed reef and tide pools to the east of reef (new)
Noel Shore (Shad Creek Cove Reef), Hants County	45° 19' 12.59" N	63° 40' 14.76" W	tide pool and drainage channels	4 ha	15%	mostly in drainage channels (new)
Noel Head (Sloop Rocks), Hants County	45° 19' 30.51" N	63° 43' 03.60" W	tide pool and undercut	10 ha	5%	mostly in undercut with some in tide pools and minor amount in drainage channels (new)
Noel Bay, Hants County	45° 18' 49.37" N	63° 45' 36.24" W	tide pool and undercut	1.5 ha	5%	in substrate on edges of tide pools-no cap-rock protection (historical-Bousfield)
Burntcoat Head (north section), Hants County	45° 19' 07.98" N	63° 47' 08.75" W	tide pool and undercut	2 ha	5%	mostly in undercut with some marginally in tide pools, lower intertidal (new)
Burntcoat Head (Lighthouse Point), Hants County	45° 18' 43.07" N	63° 48' 35.39" W	undercut	3 ha	10%	heavily riddled under capstone, lower intertidal (new)
Tennycape (west of headland), Hants County	45° 16' 48.23" N	63° 53' 44.29" W	tide pool	2 ha	< 5%	mid-low intertidal with approximately 5 ha of apparently appropriate substrate with no settlement
Port Williams (Cornwallis River estuary), Kings County	45° 06' 08.93" N	64° 22' 38.38" W	undercut	1 ha	80%	in bank (mid-tide) of Cornwallis River estuary
Recently extirpated sites						
Salter Head, Hants County	45° 20' 12.44" N	63° 32' 22.20" W	tide pool	ca. 2 ha		evident under 2-5 cm of soft muds and organic sediments — total area unknown
Walton Cove, Hants County	45° 14' 26.81" N	64° 00 20.83" W	not recorded	not recorded		intact empty valve noted in 1976 — all firm and hard substrate now occupied by barnacles
Evangeline Beach, Hants County	45° 08' 22.32" N	64° 19' 47.42" W	tide pool	< 0.5 ha		intact empty valves recovered imbedded in substrate covered with organic (mid-tidal)
Other sites						
Site between Shad Creek and Sloop Rocks, Hants County	45° 19' 13.38" N	63° 40' 40.62" W	tide pool	ca. 75 ha		area exposed after winter storm 2007/8, initially covered with soft muds — lower intertidal
The Guzzle, off Evangeline Beach / Boot Island, Kings County	45° 09' 34.87" N	64° 17' 37.63" W				extent of *B. truncata* not documented — found in ancient oyster bed (3,800 BP)

[†]Total area of all extant locations = 42 ha. There are 15 ha of potential un-surveyed habitat.
*Abundance defined as percentage of area of available suitable substrate with live *B. truncata* present.

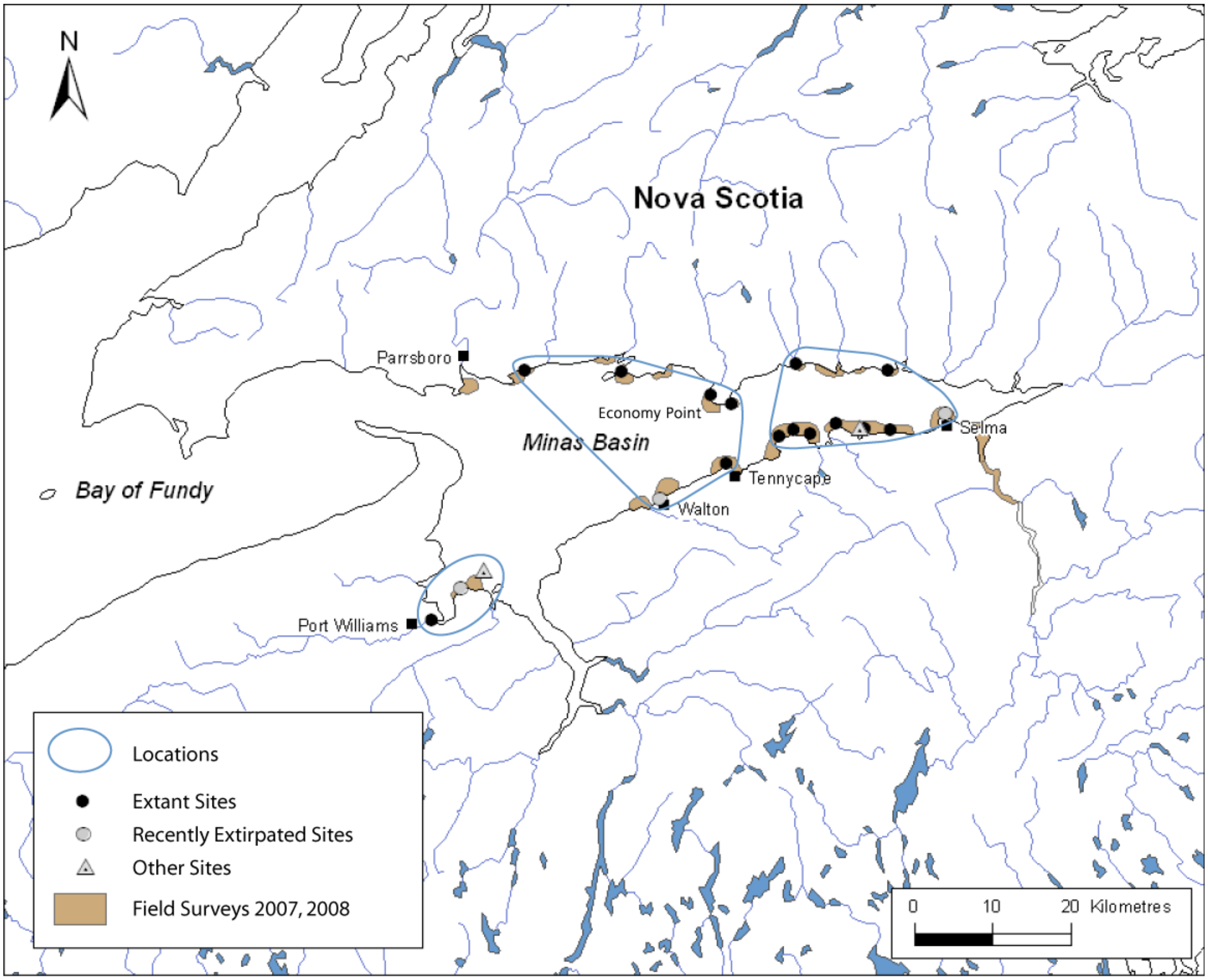

Figure 8. Canadian distribution of *Barnea truncata:* extant and recently extirpated sites, other sites, and areas covered by field surveys in 2007 and 2008. Locations are bounded by blue lines.

Locations are defined by the main threat, which is believed to be storms (see **LIMITING FACTORS AND THREATS**). The number of locations relates to the exposure to weather-related issues and erosion, suspension, and deposition of sediments. The Minas Basin can be divided into three sections, based on current regimes and the amount of shelter afforded by headlands from the prevailing west-northwest winds and wind-generated waves. Therefore, the number of locations is three (Figure 8). Because the combination of proximity to streams, sediment type, topography and adjacent areas of open water (affecting fetch) is different for each of these locations, they would be impacted differently by any single storm event.

The life history of *B. truncata,* which includes a planktonic veliger larval form that is probably freely dispersed throughout the basin (see **Life cycle and reproduction** and **Dispersal**), lends support for a single population. Because there is only one population, it cannot be severely fragmented.

The extent of occurrence (EO) is 985 km^2. The index of area of occupancy is 76 km^2 based on a 2×2 km grid.

As an intertidal species, *B. truncata* is restricted to the margins of the Minas Basin. The total area of the intertidal zone of the basin has been calculated to be 358 km^2 (Parker *et al*. 2007), but the portion of the intertidal zone that has usable substrates associated with Jurassic-age bedrock formations is possibly as little as 5% of the total intertidal zone. However, the Area of Occurrence (AO) is substantially less, because the species only lives within a specific substrate of that formation (see **Habitat requirements**). Based on these values and approximations, the limited occurrence of these red-mudstone facies (a distinctive group of characteristics within part of a rock body that differ as a group from those found elsewhere in the same rock unit) results in an area of occupancy (AO) of less than 0.6 km^2 (A. Hebda, unpublished data).

The inaccessible and unsurveyed intertidal reef and ledge complex between Economy Point and Lower Economy might yield further records of *B. truncata*; however, due to the complex mosaic of substrates, it is uncertain what the size of potential habitat is for this area. However, it is believed that there could be no more than five additional sites within the Minas Basin.

HABITAT

Habitat requirements

Habitat requirements for *B. truncata* are not clearly defined in the literature. Field observations suggest that it occurs in intertidal areas with a salinity range of 19–25 parts per thousand (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 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, *B. truncata* requires a dependable source of particulate organic matter, but is tolerant of some exposure during low tidal periods. 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, which are common in many estuaries.

The principal habitat constraint appears to be the requirement of a firm to semi-consolidated substrate for settlement of spat (post-larval juveniles). In other populations, *B. truncata* is known to bore into firm peat-muds and, rarely, submerged wood (Jacobson and Emerson 1961). In the north-eastern coastal states it is a resident of eelgrass 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 evidence to suggest that *B. truncata* uses 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*. in press; Figure 9). This substrate is limited subtidally by the presence of stable masses of sands and fine gravels. This geological formation and associated facies are absent from the Bay of Fundy and from Chignecto Bay. MacGinitie and MacGinitie (1968) classified boring bivalves by the substrate used and identified a range of substrates from soft muds to hard rock; in Canadian marine waters, *B. truncata* would fall into the category referred to as burrowing into stiff clay.

Figure 9. Red-mudstone facies, the only substrate confirmed as supporting *Barnea truncata* in Minas Basin. Note that the soft mudstones are overlain by a cap-rock of more durable sandstone. Ice-mediated collapse of the cap is evident in the foreground, and barnacle settlement is apparent on sandstone surfaces. (Photo by Gwyneth Jones.)

The Canadian population is unique in that it is not found in habitats defined as typical for the species throughout its southern range, but the apparent presence of this species in its habitat over the last 3,800 years (see **Dispersal**) in an area of relatively high energy and turbidity suggests it is using a typical substrate type but in an unusual ecological setting.

Habitat trends

The incursion of salt waters into the Minas Basin is estimated to have started approximately 5,000 years ago with rising water levels associated with the warming trend of the Hypsithermal period (Roland 1982; Bleakney and Davis 1983; Piper 1991; Davis and Browne 1996). The interaction of estuarine discharge of major rivers (Salmon, Shubenacadie, Avon and Bass rivers) with increasing water levels of this interstadial period resulted in repositioning of the principal discharge channels. The effect may be caused by changes in water flow due to change in resistance of the riverbed and estuarine bottom with increase in water level. This appears to occur over a period of several decades (based on aerial photography). The repositioning of the channel in the estuary results in a concurrent change in deposition of sediments in adjacent habitats. The result is a periodic loss of *B. truncata* at such sites. This is apparent at three sites in the basin (Salter Head, Evangeline Beach and Walton; Figure 8).

At sites that are not under such direct influence, *B. truncata* shows greater flexibility in substrate use and a broader area of occupation. This suggests greater stability of these habitats. Such sites may be subject to large-scale habitat modification associated with major storm events (see **LIMITING FACTORS AND THREATS**). These effects may be greater if these storms are coincident with seasonal tidal periodicity or storm surges. This was recorded on one occasion in 1869 with the coincidence of a major gale with a tidal surge in the basin. Areas of apparently suitable habitat were lost due to catastrophic sediment movement (creation of the Partridge Island causeway near Parrsboro). Similar rapid, although not catastrophic, changes have been proposed as causing the loss of an old oyster bed with a nested *B. truncata* association at “the Guzzle” off Evangeline Beach in Kings County (Bleakney and Davis 1983). A mid-winter storm event in 2007–08 exposed a previously occupied *B. truncata* site (approximately 75 ha) east of Noel Head, Hants County that had been buried under silt and sand for at least 30 years (Hebda *et al*. in press). The site was subsequently reburied by Hurricane Dan (A. Hebda pers. comm. 2009).

Continued increases in sea levels associated with climate change (Davis and Browne 1996) with resulting shifts in the position of the intertidal zone within the basin could further alter these habitats and sites where *B. truncata* occurs.

The construction of infrastructure impacts habitat. An example is the causeway and associated water control structure on the Avon River near Windsor, Hants County. Its construction in 1968–70 resulted in the rapid replacement of complex, deep, intertidal habitats with a massive, shallow, saltmarsh complex (Daborn *et al*. 2003). Daborn *et al.* (2003) also noted that changes in organic particulate dispersal due to this construction have been recorded as far as 20 km from the structure site.

Changes in dominance of other benthic and epifaunal species, such as barnacles (*Balanus* sp.) have also resulted in the elimination of some surficial habitats needed for larval settlement. Although this has been observed in only one site (Walton Cove) where substrate is somewhat harder (intermixing of sands into the mud-stone facies), such expansion of other species could result in further limiting the areas available for settlement.

Habitat protection/ownership

The Atlantic Mud-piddock is restricted to the intertidal area of a marine water body, the Minas Basin. The species falls under federal jurisdiction under the provisions of the *Fisheries Act,* specifically the sections dealing with conservation and protection of fish and fish habitat (see **EXISTING PROTECTION AND OTHER STATUS DESIGNATIONS**).

BIOLOGY

Life cycle and reproduction

The sexes are separate, and while male and female internal organs are distinct, it is not possible to differentiate sex by external features. Fertilization is external. Ova and sperm are released 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 are dropping in the fall. In his larval studies Chanley (1965) spawned adult *B. truncata* from Virginia in mid-May as well as through August and September. He 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 initially measure 18 μm, but larvae with a functional velum grow to 315 μm (Figure 5). The rate of growth is dependent on the availability of food (Chanley 1965) suggesting a limiting factor in deeper oceanic habitats (Bay of Fundy vs. Minas Basin) where particulate food may be less abundant and temperatures are lower.

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.

Once they have settled they begin the process of boring into the substrate. Within the Pholadidae, this process varies from species to species and 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*. in press) 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, this results in a conical bore-hole. Consequently, the adult animal is trapped for life inside its burrow.

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 or five years old. Examination of valves from field studies by Hebda *et al.* (in press) suggests a life span of up to nine years, with sexual maturity possibly as early as two years. Consequently, the estimated generation time is four to five years.

Food and feeding

There are no specific published data on the feeding of *B. truncata.* However, as with all sessile marine bivalves, it is probably a generalist feeder, 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 have 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 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.

Physiology

The physiology of this genus is not well defined, although there have been some efforts to delineate limiting factors such as salinity tolerances. 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 as might be expected for an intertidal species (Turner 1954). At sites occupied by *B. truncata* in the Minas Basin, mid-summer salinities of between 27–30 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 freshets, salinities may decrease to as low as 14–15 ppt.

Dispersal

The distribution of *B. truncata* on both a local (Canadian) and global scale suggest two possible mechanisms at play in the dispersal of the species. The first relates to dispersal associated with reproductive activity, the release of planktonic larvae, 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. Greenberg (1983) illustrates modelling of residual tidal currents in the basin (Figure 10). While it is probable that these planktonic larvae disperse 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.

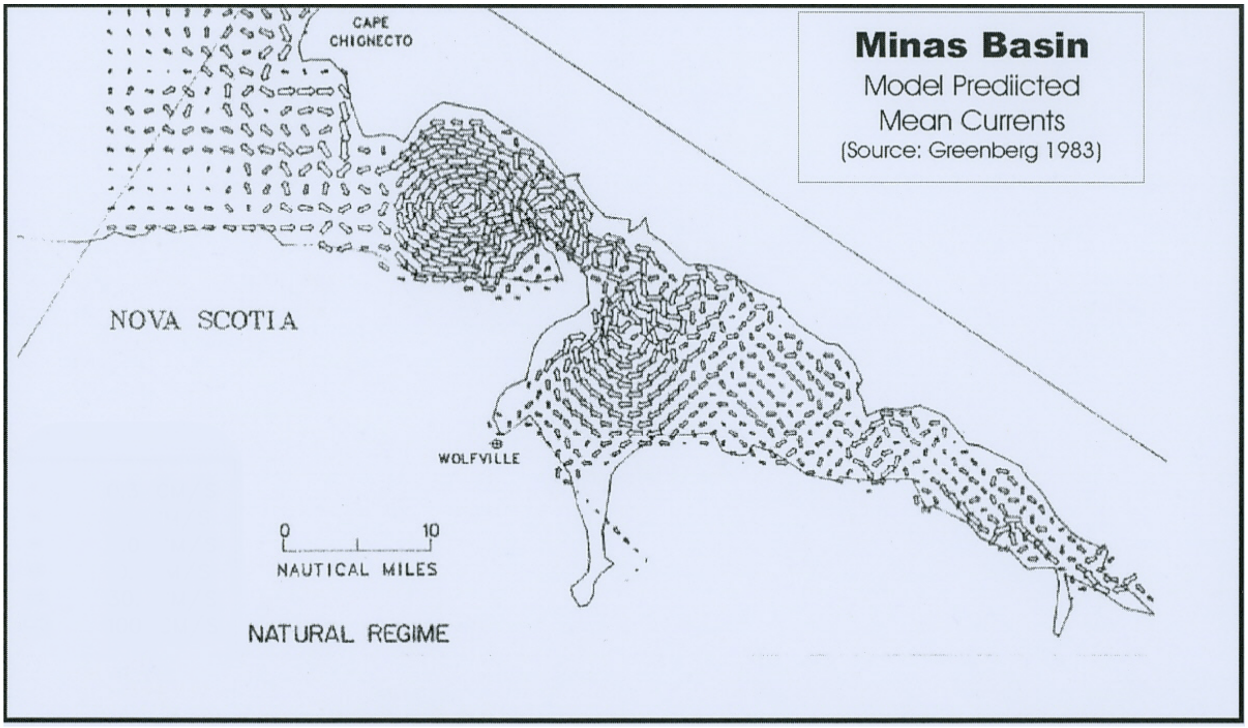

Figure 10. Prevailing local counter-clockwise circulation in Minas Channel at the entrance to Minas Basin limits the outward movement of *Barnea truncata* larvae.

With the production of large numbers of larvae and high tidal flushing out of the basin (3 billion cubic metres 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 thepresence of factors restricting its establishment in habitats outside of the Minas Basin. 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. While this same circulation might also be responsible for possible sporadic recruitment of larvae from larger populations off Massachusetts, circulation patterns, distance and larval period make it very unlikely that recruitment from U.S. populations is possible. Genetic evaluation of the Gulf of Maine and Minas Basin populations of *B. truncata* could determine the validity of this interpretation.

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 within the North and South Atlantic, although amphi-Atlantic planktonic dispersal is possible in some molluscs, such as the gastropod *Cymatium parthenopaeum* for which oceanic stages may persist for months (Gofas *et al*. 1989). With the exception of Puerto Rico, a review of records from the Azores, Bermuda, and islands in the South Atlantic Ocean and Caribbean Sea did not reveal the presence of *B. truncata* on oceanic islands. The single account on persistence of the larval form of *B. truncata* observed that cultured larvae metamorphosed in approximately 35 days (Chanley 1965), which is an insufficient time frame for trans-Atlantic larval dispersal but adequate for coastal dispersal.

It is unknown if transport of larvae via ballast water, or adults with firm or high-density ballast, is possible, but the historical use of peats or firm muds for ballast in ocean-going vessels is not documented. The occurrence of the species within an ancient oyster bed (3,800 ybp), in the Minas Basin appears to predate the arrival of vessels carrying ballast (Bleakney pers. comm. 2008). Reference to the presence of this species 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.

Interspecific interactions

Due to their lithophagous life style, established individuals are relatively immune to the action of other species. The only exception may be pyramidellid gastropods, which are parasites of marine bivalves (Fretter and Graham 1962). Although *Boonea bisuturalis* co-occurs with *B. truncata* in the Minas Basin (Bousfield and Leim 1959), it has not been recorded parasitizing the *B. truncata*.

Principal interactions may be restricted to the free-swimming larval and larval settlement phases of the life cycle. As free-swimming larvae, they become a portion of the planktonic community, which is an important food source for planktivorous organisms such as coelenterates, larval fish and other molluscs. At time of settlement, competition for surfaces for settlement may occur with other attached epifauna, including bryozoans, barnacles and *Petricolaria pholadiformis*, although the former two groups tend to use firmer- or coarser-grained substrates for settlement. *P. pholadiformis* has been noted to use similar substrates and co-occurs with *B. truncata,* especially where protective structures such as more erosive resistant cap-rocks are absent. As well, *P. pholadiformis* uses a similar reproductive strategy to *B. truncata* although its peak larval production has been recorded as early to midsummer (Sullivan 1948). Valves of *P. pholadiformis* have been found nested inside empty *B. truncata* valves in burrows. This has also been noted for *B. truncata*, and nesting in other empty *B. truncata* valves (Hebda *et al*. in press) suggests competition for even these limited microhabitats.

Adaptability

Throughout its range, *Barnea truncata* demonstrates flexibility in substrate use, although the Minas Basin population is inflexibile in using only one type of substrate. In relatively protected low energy habitats along the north shore of the basin, *B. truncata* is found primarily in bore-holes in tide pools. These sites are not exposed to the scour of strong tidal currents.

In habitats along the south shore of the basin they may be found in tide pools but more frequently occur in bore-holes that are fully immersed in drainage channels (caused by tidal fall at the lower end of the tidal cycle). Because these channels are eroded into the red-mud substrate the bore-holes are also not exposed to ice scour. These individuals may be exposed to substantial fluctuations in salinity due to influence of draining freshwater, especially after rainfall.

Unique to the Minas Basin is the use by the species of firm red-mudstones under erosion-resistant rock. Settlement of larvae on such undercut vertical surfaces suggests the ability to move along surfaces because settlement is usually a passive process (driven by gravity) at periods of slack tide. The occurrence of bore-holes oriented horizontally or even angled upward may suggest further adaptation in the use of the muscular foot (see **Life cycle and reproduction**). A thigmotactic response (boring at right angles to settlement surface irrespective of its orientation) may confer an element of protection in a high energy habitat and a harsh climate (scouring from rafting ice) that allows for persistence at this northern latitude. These are the most physically protected habitats within this northern ecosystem.

Although evidence was encountered for greater prevalence in tide pool and drainage channel habitats in the past (Hebda *et al*. in press), these are subject to more extreme environmental conditions, i.e., temperature and periodic scouring by ice, especially in late winter and spring.

POPULATION SIZES AND TRENDS

Search effort

Historical surveys

Literature and extant museum and other collection records were examined for information concerning the distribution and abundance of *B. truncata* in Canada. Aside from archival collections (see **COLLECTIONS EXAMINED**) only two publications exist (Bousfield and Leim 1959; Davis and Browne 1996). Neither of them contains information on abundance or inferred distribution. Additional searching was undertaken using web-searchable metadata sources, including Malacolog (Morris and Rosenberg 2005) and Global Biodiversity Information Facility – GBIF (several portals). These revealed one earlier (unpublished) collection at the Atlantic Reference Centre (Saint Andrews, N.B.).

Field studies were undertaken in the 1970s to determine potential impacts of a large-scale tidal power installation in the Minas Basin. These concentrated on the benthic (soft-substrate) infauna. Consequently, no data were collected about *B. truncata*, although the presence of one lithophagous bivalve, *Petricolaria pholadiformis,* was observed (Tunnicliffe pers. comm. 2008).

Recent surveys

Given the lack of systematic historic surveys, field studies by the Nova Scotia Museum (NSM) in 2007 and 2008 were undertaken to determine the distribution of the species (Hebda *et al.* in press). Surveys involved the walking of approximately 25 km of intertidal habitats within the Minas Basin on falling tides, and conducting a boat-based reconnaissance of an additional 7 km of estuarine area (Shubenacadie River). Appropriate substrate types were searched for evidence of burrows. Where bore-holes were found, holes were examined for live animals or empty shells. Voucher specimens were collected of bore-holes in substrate, empty valves and live animals. Substrate types were recorded and estimates were made of total areas of usable habitat.

These studies confirmed the existence of *B. truncata* at 14 sites (Figure 8, Table 1), and provided evidence that three sites (one from each location) were recently extirpated: Evangeline Beach, Walton and Salter Head (Figure 8, Table 1). A previously occupied site that had been covered by sediments for more than 30 years (see **Habitat trends**) was noted between Noel Head and Shad Creek, Hants County (Table 1). At 11 of 14 occupied sites, there was evidence of recent spatfall in the form of small, new bore-holes, suggesting ongoing recruitment.

Fieldwork was constrained by the limited period of time in the tidal cycle when safe access was possible to potential lower intertidal habitats. Because of the extreme tidal range (up to 19 m), complex habitats (mosaics of soft muds with occasionally emerged firmer substrates), and limited access to shoreline, this is a challenging environment to survey.

Abundance

It is not possible to make an accurate population estimate. Although the numbers of individuals inhabiting shallow tide pool habitats could be estimated, as could the number of individuals occurring in the drainage courses (submerged even during low tide), the greatest population densities seem to be in the heavily riddled substrates under resistant capstone formations. Most of these formations are undercut and numbers of individuals cannot be quantified without destructive habitat manipulation. Although visible, bore-holes may not contain live animals. The number of individuals generally increases lower down in the intertidal zone and access to these lowest intertidal areas is restricted to short periods during specific tides in the spring and the fall. The low visibility and high current conditions associated with rapid tidal fluctuations prevent the use of SCUBA or other survey methods. A potentially important intertidal reef and ledge complex west of Economy Point to Lower Economy was inaccessible.

Fluctuations and trends

Field evaluations undertaken by the NSM in 2007 and 2008 identified several sites where loss of sites has occurred (Hebda *et al.* in press). As noted in **Habitat trends,** oscillation in river discharge has resulted in the siltation and loss of three sites (Evangeline Beach, Walton, and Salter Head), and a substantive reduction of another site (Bass River/Saints Rest). Based on field investigations, these comprise less than 5% of known or suspected sites. The exposure of a large, previously occupied site east of Noel Head with intact valves (no erosion of valves and intact apophyses) suggests an episodic loss of that site of possibly an additional 5% of known or suspected sites. These investigations suggest that in the long term the total population of *B. truncata* in the Minas Basin is probably stable but locally can demonstrate substantial natural variation.

Rescue effect

The Canadian population of the *B. truncata* is isolated from the nearest American population by a distance of approximately 350 km. To determine if natural recovery is possible and genetic exchange may occur, it would be helpful to know if this population became disjunct during the little ice age between AD 1200 and 1800 (Davis and Browne 1996) or whether its presence reflects bouts of colonization going back several thousand years. The counter-clockwise nature of prevailing circulation within the Gulf of Maine (moving south down the coast of Maine) makes the possibility of natural dispersal from this population north into Canada highly unlikely (see **Dispersal**), but larvae from Massachusetts populations, about 650 km from the Minas Basin, would be more likely to reach Canada by drifting east and north with the same circulation. This opens up the possibility, albeit remote, for some of these larvae to enter the Bay of Fundy, then on into the Minas Basin.

If it can be determined that long-distance dispersal is by means of drift of colonized structures such as waterlogged wood, then natural recovery from secure and well-established populations in the southern Gulf of Maine might be possible.

LIMITING FACTORS AND THREATS

The principal limiting factor for successful settlement and establishment of *B. truncata* appears to be the amount of substrate suitable for larval settlement and sustainability. Because the only substrate in which it appears to persist in the Minas Basin is a red-mudstone inter-bedded in Jurassic sandstone formations, its distribution within the basin is limited to this small portion of the intertidal zone.

In subtidal portions of the basin, otherwise suitable substrates are unavailable for colonization due to the presence of relatively stable overlying masses of sands, gravel and muds (Figure 11). These deposits are the result of the lower current regimes associated with this deep-water zone in spite of the large tidal range within the basin. There appears to be little scope for development of sites of *B. truncata* subtidally in the Minas Basin.

Figure 11. Deep water sand intrusion limiting subtidal substrate use by *B. truncata*. Note the harder sandstone bedrock with barnacle settlement, the narrow bed of red-mudstone and maximum edge of advance of deep water sand mass. (Photo by Gwyneth Jones.)

As noted in **Habitat trends**, the periodic repositioning of depositional plumes at the mouths of rivers emptying into the basin limits the utility of such areas for settlement of larvae and maintenance of long-term, stable sites (even with appropriate substrate).

There is a general scientific consensus that the world is now undergoing human-induced climate change, with the effects including more variable weather, sea-level rise, and increased storm severity and frequency (e.g., Houghton *et al.* 2001; Copenhagen Diagnosis 2009).

While the effects of climate change on *B. truncata* are likely to be complex, climate change is expected to be the most serious threat to the persistence of *B. truncata* in the Minas Basin, where storm events could cause serious disruption in shallow estuarine ecosystems. Within the basin, observed effects include the movement and re-deposition of large volumes of sediments from fine silts and clays to sands, gravels, and even cobbles.

The episodic deposition of such materials is probably the most significant factor in the loss of *B. truncata* at specific sites (see **Habitat trends**). Although 2008 field surveys found three sites that were recently uncovered by storm events (see **Search effort**), and this would seem to suggest new habitat for the species for resettlement, by September 2009, one of these sites (ca. 75 ha, near Noel Head between Shad Creek Reef and Sloop Rocks) was re-covered by sediments following Hurricane Dan (Hebda pers. comm. 2009). It could be inferred that sites might become less stable as the frequency and severity of storms increase.

The timing of storm events also can be critical with respect to impacts on this population. A storm event lasting more than six hours will have an impact on both upper and lower intertidal ecosystems. A storm event at high tide, coupled with a storm surge (as occurs frequently with late summer tropical depressions and hurricanes) can result in the deposition of large volumes of freshly eroded materials throughout low-energy portions of the basin. If there is an increase in the occurrence of such storm events, as has been predicted in some climate change models, there would be an expected increase in smothering events, potentially putting the sites at greater risk.

Temperature regimes in the Minas Basin population may play a role in limiting the sustainability of *B. truncata*. Surficial temperatures may reach 26°C with incoming tidal water passing over heated intertidal muds (Percy 2001). In mid-winter, water temperatures as low as –2°C, and air temperatures as low as –20°C, are not uncommon (Hebda *et al.* in press). The upper temperatures are well within the range encountered by the species throughout southern and equatorial portions of its distribution. However, the winter temperatures are substantially lower than those found anywhere else including the nearest populations in Maine. 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.

The movement of ice in mid- to late winter is probably another important factor affecting habitat use by *B. truncata* in the Minas Basin. With a tidal range of up to 19 m, strong tidal currents and presence of rafted freshwater and marine ice in the winter and early spring could have a negative effect on occupied habitat. Sites may be subject to both substantive ice scour and the collapse of protective cap-rock under the weight of ice after water retreat at low tide. This effect is evident at Burntcoat Head where the underlying mudstones are extensively riddled (Figure 12), weakening the support for the harder sandstone and conglomerate cap-rock. The resulting loss of occupied habitat and organisms at such edges appears to expose new mud surfaces for colonization and as such may be playing a role in providing refreshed surfaces for settlement and colonization.

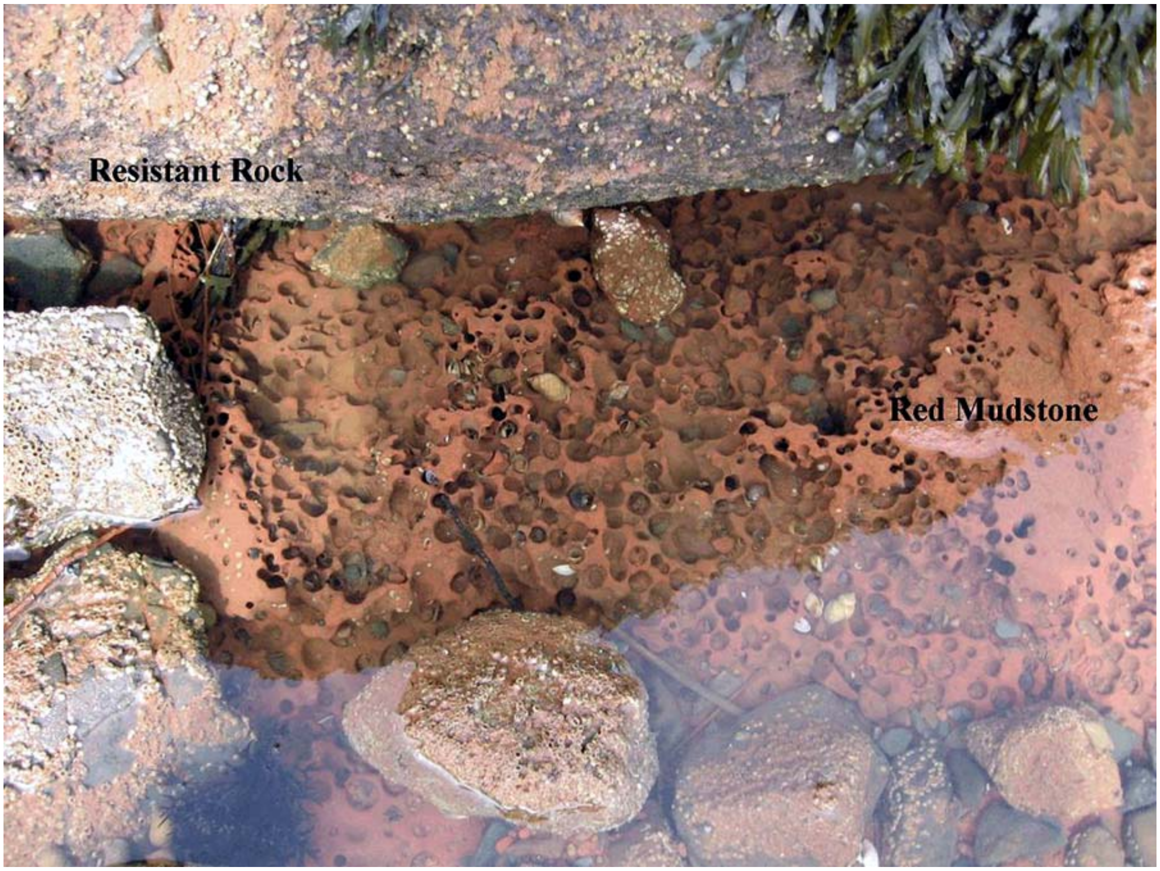

Figure 12. Weakening of underlying mudstone by burrowing of *Barnea truncata* adults can result in collapse of harder overlaying cap-rock under the weight of ice rafting and settlement. (Photo by Gwyneth Jones.)

More long-term effects of climate change are also expected. The rise in sea-level has increased at a faster rate than what was previously expected with an upper limit of ~ 2 m by 2100 (Copenhagen Diagnosis 2009). Rising sea level is likely to increase shore erosion and beach migration (Forbes *et al.* 1997; Ashmore and Church 2001; NRCAN 2009b). Additionally, climate change has the potential to alter substantially the flow of rivers by increasing the frequency of floods that result in erosion. The Copenhagen Diagnosis (2009) notes "Recent changes have occurred faster than predicted by some climate models, raising the possibility that future changes will be more severe than predicted". The Atlantic coastal river systems will be among the most affected systems in Canada (NRCAN 2009a). According to Ashmore and Church (2001), "In coastal Nova Scotia, small decadal changes in precipitation produce large changes in flood frequencies." The implication is that increased erosion in rivers entering into Minas Basin, and along the shoreline of the Basin itself, could deposit higher than historic levels of sediment into the estuarine Basin, which in turn suggests an increased likelihood that required habitat for *B. truncata* would be sedimented over.

The modification of currents within the basin by the construction or alteration of structures — such as aboideaus (devices installed in dykes for allowing discharge of freshwater during a falling tides but preventing incursion of saltwater on incoming tides) barrages or causeways — has been noted to result in major changes in proximal intertidal ecosystems (Daborne *et al*. 2003). This may occur both above as well as below the structures, with measurable changes at considerable distances within the basin. As previously noted, this could result in critical alteration of substantial areas of habitat. Such an effect was predicted in the evaluation of potential impacts of barrage construction on Minas Basin infauna but had not been examined in the context of rock-boring species (Risk pers. comm. 2007; Tunnicliffe pers. comm. 2008). Subsequently, a preliminary evaluation of potential impacts of in-stream turbine installations in the Minas Basin has noted *B. truncata* under "environmental issues" (Anonymous 2006b).

The discovery of 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.

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 agrichemical warehouse in the lower part of the Annapolis Valley (Canning, Nova Scotia), which resulted in the release of fertilizer and pesticides into the Avon Estuary of the Minas Basin (Percy *et al.*1989).

Several proposed industrial developments within the estuary could also pose threats to intertidal organisms in the Minas Basin. Because *B. truncata* is an intertidal species with the majority of the population inhabiting the mid- to lower intertidal zone of the basin, it is vulnerable to potential anthropogenic alterations of tidal regimes as well as changes in discharges into estuarine channels.

Two such, proposed, developments with direct potential impact on the estuary include installation of experimental tidal turbines within the Minas Channel (outflow from the Minas Basin) and excavation of salt domes near the Shubenacadie estuary for creation of caverns for storage of liquefied natural gas.

The proposed experimental tidal power installation includes three bottom-anchored turbines extracting energy during both phases of the tidal cycle. This pilot-scale development could be the precursor to the installation of up to 200 such turbines within the channel with theoretical extraction of 30–40% of tidal energy. Impacts of this form of extraction of tidal energy on tidal flushing and modification of estuarine and intertidal ecosystems are not clear at this time although this scale of potential ecosystem modification could have wide implications for intertidal organisms.

The excavation of salt domes could result in the release of approximately 400 T of anhydrites into the basin on a daily basis for a period of three years. It is not clear as to what the impact of such a prolonged discharge would be on intertidal molluscs, so it is not clear whether this would pose a risk to the population of *B. truncata*.

Finally, 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).
The occurrence of the sole Canadian population of *B. truncata* in this small area in intertidal habitats may be problematic.

SPECIAL SIGNIFICANCE OF THE SPECIES

This is the only species of *Barnea* in Canada. The single Canadian population within the Minas Basin is the most northern occurrence *B. truncata* in the world (Figure 6). This population is separated by over 350 km from the nearest American population, itself disjunct from populations further south. *Barnea truncata* is probably one of the few marine faunal remnants of a warm-water post-glacial period in the Maritimes (Bousfield and Thomas 1975; Davis and Browne 1996; Bleakney pers. com. 2008). If so, the population may represent a more widespread fauna affected by natural climate change and as such may be a useful model for monitoring such processes. Canadian *B. truncata* show environmental adaptations (see **Habitat requirements**) that, coupled with the high improbability of genetic exchange with southern populations (see **Dispersal**), suggests that this could be a Canadian endemic. If not a distinct species, the Minas Basin population could be potentially important in terms of genetic variability of the species.

Mi'kmaq First Nations elders are aware, through international contact, that the species has significance for indigenous peoples in Brazil. However, *B. truncata* does not appear to have a similar significance to First Nations here (Gloade pers. comm. 2008).

Although there is record that the species is edible (Turner 1954), there is no evidence at this time of its consumption by First Nations (McNeely pers. comm. 2008).

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

Barnea truncata and its habitat are protected under the federal *Fisheries Act*. The *Fisheries Act* provides Fisheries and Oceans Canada with powers, authorities, duties and functions for the conservation and protection of fish and fish habitat (as defined in the Act). The Act contains provisions that can be applied to regulate flow needs for fish, fish passage, killing of fish by means other than fishing, the pollution of fish bearing waters, and harm to fish habitat. There is no provincial statutory protection.

There are no status designations (sub-national ranks) available for either Maine or Massachusetts, or any other American state within the range of *B. truncata*.

TECHNICAL SUMMARY

Barnea truncata
Atlantic Mud-piddock pholade tronquée
Range of occurrence in Canada (province/territory/ocean): Nova Scotia, Atlantic Ocean

Demographic Information

Generation time Estimated, based on a life span of up to nine years, with sexual maturity possibly as early as two years.	4–5 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Unknown
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased?	N/A
Are there extreme fluctuations in number of mature individuals?	Unknown

Extent and Occupancy Information

Estimated extent of occurrence	985 km²
Index of area of occupancy (IAO) Biological AO < 0.6 km^2.	76 km²
Is the total population severely fragmented? There is only one population.	N/A
Number of "locations∗" See **Canadian range** for how these are defined.	3
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	Unknown
Is there an inferred continuing decline in number of populations?	No
Is there an [observed, inferred, or projected] continuing decline in number of locations? There is some loss of habitat, but evidence of continued settlement in newly exposed areas of appropriate substrate.	Unknown
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat? There is some loss of habitat, but evidence of continued settlement in newly exposed areas of appropriate substrate.	Unknown
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

∗ See definition of location.

Number of Mature Individuals (in each population)

Population (1)	N Mature Individuals
Minas Basin	Unknown
Total	Unknown

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	N/A

Threats (actual or imminent, to populations or habitats)

Changes in sediment depositional regimes (causing smothering):

- Increased frequency and severity of storms due to climate change, which shift and re-deposit sediments or introduce new sediments from land-based erosion
- Construction of barrages, causeways and tidal energy projects, which have the capacity to alter current and depositional patterns

Other Threats:

- Industry – tidal turbine installation; excavation of salt domes and potential release of anhydrites into the basin
- Oil spills
- Discharge of chemicals from agricultural or urban runoff

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? Not ranked (see below).	
Is immigration known or possible?	Highly unlikely
Would immigrants be adapted to survive in Canada?	Unknown
Is there sufficient habitat for immigrants in Canada? New habitat can become exposed; exposed surfaces exist in already-occupied habitat.	Yes
Is rescue from outside populations likely?	Unknown, but not likely

Current Status

COSEWIC: Threatened (November 2009)

Status and Reasons for Designation

Status:	Alpha-numeric code:
Threatened	D2

Reasons for designation:

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 facies 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.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. The total number of mature individuals is unknown.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. The current IAO (76 km^2) and the number of locations (3) meet the thresholds for Endangered (IAO: < 500 km^2; locations: ≤ 5), but there is no known continuing decline in EO, IAO, area, extent or quality of habitat, number of locations, and number of mature individuals.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. The number of mature individuals is unknown.
Criterion D (Very Small or Restricted Total Population): Meets D2 Threatened because the number of locations is 3 (≤ 5) and the population is prone to the effects of severe storms that can bury and smother habitat.
Criterion E (Quantitative Analysis): Not applicable. No data are available.

ACKNOWLEDGEMENTS AND AUTHORITIES CONSULTED

The co-operation of the following is acknowledged in the provision of access to relatively inaccessible habitats for field verifications: John McLellan and Jeannie Van Dyk (Noel Shore), Carol Macomber and Doug Lynch (Noel Shore), and Phillip and Lori Vroegh (East Noel). Insight of the following is acknowledged for reports of possible sites in the Bay of Fundy and the Minas Basin: Ken Adams (Director, Fundy Geological Museum), Eldon George, and Greg and Sharon Laska. Assistance of the following individuals is acknowledged in the conduct of field investigations: Dr. Gwyneth Jones, Anne Moyce and Leslie Pezzack. Field sites and insitu populations were photographed by Dr. Gwyneth Jones, and all laboratory-based specimen photographs and associated graphics were undertaken by Christina McCorry and Katherine Ogden. The assistance of Lynda Silver, Nova Scotia Museum Librarian, is gratefully acknowledged.

INFORMATION SOURCES

Abbott, R.T. 1974. American Seashells: The Marine Mollusca of the Atlantic and Pacific Coasts of North America. 2nd edition. Van Nostrand Reinhold Company, New York. 663 pp.

Anonymous. 2006a. Report on strange clam off Bath, southern Maine region. Maine Municipal Shellfish News, Department of Marine Resources. Web site: http://www.maine.gov/dmr/crd/smd/reg_off/r1_news.htm [accessed February 2009].

Anonymous. 2006b. Instream Tidal Power in North America, Environmental and Permitting Issues EPRI-TR-007-NA, prepared for the Electric Power Research Institute Inc., Paulo Alto, California, by Devine Tarbell & Associates Inc., Portland Maine, June 2006.163 pp.

Ashmore, P. and M. Church. 2001. The impact of climate change on rivers and river processes in Canada. Geological Survey of Canada, Bulletin 555:58 pp. Web site: http://geopub.nrcan.gc.ca/moreinfo_e.php?id=211891 [accessed 15 September 2009].

Avila, S.P. 2000. Shallow-water marine molluscs of the Azores: Biogeographical relationships. Arquipélago. Life and Marine Sciences. Supplement 2(A): 99-131.

Bleakney, J.S., pers. comm. 2008. *Verbal correspondence with A.J. Hebda*. March 2008. Professor Emeritus of Biology, Acadia University, Wolfville, NS B4P 2R0.

Bleakney, J.S. and D.S. Davis, 1983. Discovery of an undisturbed bed of 3800 year old oysters (*Crassostrea virginica*) in Minas Basin, Nova Scotia. Proceedings of the Nova Scotia Institute of Science 33:1-6.

Bleakney, J.S., S.M. Robinson and J.C. Waugh. 1980. Endolithic fauna of vacated *Zirfaea crispata* L. burrows in Blomidon shale, Minas Basin, Nova Scotia. Proceedings of the Nova Scotia Institute of Science 30:55-63.

Bousfield, E.L. 1958. Littoral marine arthropods and mollusks collected in western Nova Scotia, 1956. Proceedings and Transactions of the Nova Scotia Institute of Science 24 (3):303-325.

Bousfield, E.L. 1960. Canadian Atlantic Sea Shells. National Museum of Canada, Ottawa. 72 pp.

Bousfield, E.L. and A.H. Leim. 1959. The fauna of the Minas Basin and Minas Channel. Contributions to zoology, 1958. National Museum of Canada Bulletin 166 (Biological series 61):1-30.

Bousfield, E.L. and M.L.H. Thomas. 1975. Postglacial changes in distribution of littoral marine invertebrates in the Canadian Atlantic region. Proceedings of the Nova Scotia Institute of Science 27(Supplement 3):47-60.

Bromley, J.E.C. and J.S. Bleakney. 1984. Keys to the Fauna and Flora of the Minas Basin. Acadia University, Wolfville, Nova Scotia. 366 pp.

Brunel, P., L. Bosse and G. Lamarche. 1998. Catalogue of the marine invertebrates of the estuary and Gulf of Saint Lawrence. Canadian Special Publication of Fisheries and Aquatic Sciences 126: 405 pp.

Chanley, P.E. 1965. Larval development of a boring clam, *Barnea truncata*. Chesapeake Science 6(3):162-166.

Clarke, A.H. 1962. Sublittoral molluscs and brachiopods from the Gulf of St. Lawrence. In: Contributions to zoology (1960-1961). National Museum of Canada, Bulletin 183:6-10.

Copenhagen Diagnosis. 2009. Updating the World on the Latest Climate Science. I. Allison, N.L. Bindoff, R.A. Bindschadler, P.M. Cox, N. de Noblet, M.H. England, J.E. Francis, N. Gruber, A.M. Haywood, D.J. Karoly, G. Kaser, C. Le Quéré, T.M. Lenton, M.E. Mann, B.I. McNeil, A.J. Pitman, S. Rahmstorf, E. Rignot, H.J. Schellnhuber, S.H. Schneider, S.C. Sherwood, R.C.J. Somerville, K. Steffen, E.J. Steig, M. Visbeck, and A.J. Weaver. The University of New South Wales Climate Change Research Centre, Sydney, Australia. 60 pp. Web site: http://www.copenhagendiagnosis.org/ [accessed: 30 November 2009].

Cox, L.R., N.D. Newell, C.C. Boyd, C.C. Branson, R, Casey, A. Chavan, A.H. Coogan, C. Deschaseaux, C.A. Fleming, F. Haas, L.G. Hertlein, E.G. Kauffman, A.M. Keen, A. La Rocque, A.L. McAlester, R.C. Moore, C.P. Nuttall, B.F. Perkins, H.S. Puri, L.A. Smith, T. Soot-Ryen, H.B. Stenzel, E.R. Trueman, R.D. Turner and J. Weir. 1969. Treatise on invertebrate paleontology (R.C. Moore, ed.), Part N, volume 2, Mollusca 6, Bivalvia. Geological Society of America and University of Kansas, Lawrence, Kansas. 443 pp.

Daborne, G.R., M . Brylinsky and D. van Proosdij. 2003. Ecological studies of the Windsor Causeway and Pesaquid Lake, 2002. Acadia Centre for Estuarine Research Publication No. 69. Wolfville, Nova Scotia. 112 pp.

Davis, D.S. and S. Browne. 1996. The Natural History of Nova Scotia, volume I (Topics and Habitats). Nova Scotia Museum & Nimbus, Halifax. 518 pp.

Davis, D.S. and R.P. van Ingen. 1992. Truncated or Fallen Angel Wing *Barnea truncata* (Say, 1822). Species Status Sheet 8, Nova Scotia Museum, Halifax. 2 pp.

Duval, D.M. 1963a.The biology of *Petricola* Lamarck (Lamellibranchiata: Petricolidae). Proceedings of the Malacological Society of London 35:89-100.

Duval, D.M. 1963b. Observations on the annual cycle of *Barnea candida* (Class Lamellibranchiata, Family Pholadidae). Proceedings of the Malacological Society of London 35:101-102.

Forbes, D.L., J. Shaw and R.B. Taylor. 1997. Climate change impacts in the coastal zone of Atlantic Canada. Climate Change and Climate Variability in Atlantic Canada, Occasional Report of Environment Canada 9:37-58.

Frank, B. 2009. *Barnea truncata* (Say 1822) Atlantic Mud-piddock. Jacksonville Shell Club. Web site: http://www.jaxshells.org/btrun.htm [accessed March 2009].

Fretter, V. and A. Graham. 1962. British Prosobranch Molluscs. The Ray Society, London. 755 pp.

Gagnon, J.-M., pers. comm. 2007. *Email correspondence to A.J. Hebda*. November 2007. Chief Collection Manager, Invertebrate Collections (and Interim for Vertebrates) Canadian Museum of Nature, P.O. Box 3443 Station D, Ottawa, ON K1P 6P4.

GBIF (Global Biodiversity Information Facility) Data Portal. Web site: http://www.gbif.org [accessed Feb 2009].

Gloade, G., pers. comm. 2008. *Verbal correspondence with A.J. Hebda*. June 2008. Mi'kmawey Debert Public Information Officer, The Confederacy of Mainland Mi'kmaq, P.O. Box 1590, Truro, NS B2N 5V3.

Gofas, S., J. Pinto-Alfonso and M. Brandao. 1989. Conchos e moluscos de Angola. Universidade Agostinho Neto/ Elf Acquitaine, Angola. 144 pp.

Gould, A.A. 1870. Report on the Invertebrata of Massachusetts, published agreeably to an order of the Legislature, 2nd edition, comprising the Mollusca, edited by W.G. Binney. Wright and Potter, Boston. 524 pp.

Greenberg, D.A. 1983. Modeling the mean barometric circulation in the Bay of Fundy and Gulf of Maine. Journal of Physical Oceanography 13:886-904.

Hebda, A.J., D.S. Davis, G.M. Jones and L. Pezzack. In press. The Atlantic Mud-piddock, *Barnea truncata*, in Nova Scotia. Nova Scotia Museum Curatorial Report.

Houghton, J.T., Y. Ding, D.J. Griggs, M. Nouger, P.J. van der Linden, X. Dai, K. Maskell and C.A. Johnson (eds.). 2001. Climate change 2001: the scientific basis: contribution of Working Group I to the third assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK. 881 pp.

ITIS (Integrated Taxonomy Information System). 2009. Web Site: http://www.cbif.gc.ca/pls/itisca [accessed March 2009].

Jacobson, M.K. and W.K Emerson. 1961. Shells of the New York City Area. Argonaut Books, Larchmont, New York. 142 pp.

MacGinitie, G.E. and N. MacGinitie. 1968. Natural History of Marine Animals. 2nd edition. McGraw-Hill, Toronto. 523 pp.

Matthews, T.G. and P.G. Fairweather. 2004. Effect of lowered salinity on the survival, condition and reburial of *Soletellina alba* (Lamarck, 1818) (Bivalvia: Psammobiidae). Austral Ecology 29:250-257.

McNeely, J. 2008. *Verbal correspondence with A.J. Hebda*. October 2008. Regional Facilitator, Species at Risk Ikanawtiket, Box 8, 172 Truro Heights Road, R.R. #1, Truro, NS B2N 5A9.

Miner, R.W. 1950. Field Book of Seashore Life. G.P. Putnam and Sons, New York. 888 pp.

Morris, P.A. 1957. A Field Guide to the Shells of Our Atlantic Coasts. Houghton Mifflin, Boston. 190 pp.

Morris, P.J. and G. Rosenberg, 2005. Search interface and documentation for Malacolog, an online database of Western Atlantic marine Mollusks. Online database (version 4.1.0). Web site: http://www.malacolog.org/helpfindingsnails.html [accessed March 2009].

NRCAN (Natural Resources Canada). 2009a. The atlas of Canada. Sensitivity of river regions to climate change. Web site: http://atlas.nrcan.gc.ca/site/english/maps/climatechange/potentialimpacts/sensitivityriverregions/1 [accessed 15 September 2009].

NRCAN (Natural Resources Canada). 2009b. The atlas of Canada. Coastal sensitivity to sea-level rise. Web site: http://atlas.nrcan.gc.ca/site/english/maps/climatechange/potentialimpacts/coastalsensitivitysealevelrise/1 [accessed 15 September 2009].

Olsson, A.A. 1961. Mollusks of the tropical Eastern Pacific, particularly from the southern half of the Panamic-Pacific faunal province (Panama to Peru). Paleontological Research Institution, Ithaca, New York. 574 pp.

Owens, E.H. 1977. Coastal environments, oil spills and clean-up programs in the Bay of Fundy, economic and technical review, report EPS 3-EC-77-9, Environment Canada, Ottawa.175 pp.

Parker, M., M. Westhead and A. Service. 2007. Ecosystem overview report for the Minas Basin, oceans and coastal management report 2007-05. Fisheries and Oceans Canada, Dartmouth, Nova Scotia. 179 pp.

Percy, J.A. 2001. Fundy's Minas Basin, Fundy Issues No. 19. Web site: http://www.bofep.org/minas1.htm [accessed March 2009].

Percy, R., W. Ernst, H. Samant, P. Hennigar, L. Trip, and F. Potter. 1989. Response and environmental monitoring during the Canning pesticide warehouse fire, In: Canada, Canadian Chemical Producer's Association, Proceedings: Dangerous Goods Emergency Response '89, Nova Scotia, Canada. The Canadian Chemical Producer's Association, May 1989, pp. 177-212.

Piper, D.J.W. 1991. Surficial geology and physical properties 7: Paleoceanography and paleo-glaciology, in: East Coast Basin atlas series: Scotian Shelf. Atlantic Geoscience Centre, Geological Survey of Canada, Dartmouth, folios 123-124.

Pohle, G., pers comm. 2007. *Email correspondence to A.J. Hebda*. November 2007. June, 2008. Invertebrate Manager Atlantic Reference Centre, St. Andrews, New Brunswick.

Purchon, R.D. 1968. The Biology of the Mollusca. Pergamon Press, London. 560 pp.

Risk, M.J., pers. comm. 2007. *Verbal and Email correspondence to A.J. Hebda*. December 2007. Professor Emeritus School of Geography and Earth Sciences, General Science Building Room 206, McMaster University, 1280 Main Street, Hamilton, ON L8S 4K1.

Roddick, D., pers. comm. 2007. *Email correspondence to L.E. Pezzack.* August 2007. Bedford Institute of Oceanography, Fisheries and Oceans Canada, 1 Challenger Drive, P.O. Box 1006, Dartmouth, NS B2Y 4A2.

Rogers, J.E. 1936. The Shell Book. Charles T. Brandford Co., Boston. 503 pp.

Roland, A.E. 1982. Geological Background and Physiography of Nova Scotia. Nova Scotia Institute of Science, Halifax. 311 pp.

Scarratt, D.J. (ed.). 1982. Canadian Atlantic offshore fishery atlas. Revised edition. Canadian Special Publication of Fisheries and Aquatic Sciences 47: 101 pp.

Sullivan, C.M. 1948. Bivalve larvae of Malpeque Bay, P.E.I. Bulletin of the Fisheries Research Board of Canada 77: 36 pp.

Tunnicliffe, V., pers. comm., 2008. *Email correspondence with A.J. Hebda.* March 2008. Professor of Biology and Paleobiology in the Department of Biology and the School of Earth and Ocean Sciences, University of Victoria, P.O. Box 3020, Victoria, BC V8W 3N5

Turgeon, D.D., J.F. Quinn, Jr., A.E. Bogan, E.V. Coan, F.G. Hochberg, W.G. Lyons, P.M. Mikkelsen, R.J. Neves, C.F.E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F.G. Thompson, M. Vecchione and J.D. Williams. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: Mollusks. 2nd edition. American Fisheries Society Special Publication 26: ix + 526 pp.

Turner, R.D. 1954. The family Pholadidae in the western Atlantic and the eastern Pacific. Part I – Pholadinae. Johnsonia 3(33): 64 pp.

Vilas, C.N. and N.R., Vilas. 1952. Florida Marine Shells, a Guide for Collectors of Shells of the Southeastern Atlantic Coast and Gulf Coast. Bobbs-Merrill, New York. 170 pp.

von Cosel, R., pers. comm. 2007. *Email correspondence to A.J. Hebda.* December 2007. Département de Systématique et évolution, Muséum national d'histoire naturelle, CP 26, 57 rue Cuvier, 75231 Paris cedex 05, France.

Warmke, G.L. and R.T. Abbott. 1961. Caribbean Seashells. Livingston Publishing, Narberth, Pennsylvania. 394 pp.

Way, K., pers. comm. 2007. *Email correspondence to A.J. Hebda.* December 2007. Collections Manager, Higher Invertebrates Curation Group Zoology Department, The Natural History Museum, Cromwell Road, South Kensington, London, SW7 2RL, U.K.

Yonge, C.M. and T.E. Thompson. 1976. Living Marine Molluscs. Collins, London. 288 pp.

BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Dr. D.S. Davis, Curator Emeritus of the Nova Scotia Museum

Derek Davis has had a lifelong interest in natural history and landscape and has a particular interest in molluscan diversity and zoogeography. He received his B.Sc. in Geology, Zoology and Botany from the University of London in 1960. In the following five years he carried out marine surveys of electricity generating sites in the United Kingdom, continued his interest in natural history, participated in 10 km^2 mapping census of non-marine molluscs and organized nature conservation activities for youth in Britain and Northwest Europe. He immigrated to Canada in 1965 and received a PhD. in biology from Dalhousie University in 1972 for studies on the ecology of the Rough Periwinkle. He joined the Nova Scotia Museum in 1968 as Chief Curator of Science. His work included administration, management, research, and interpretive projects. Through the provincial government Committee on Land Use Policy he participated in preparation of policy and legislation related to the provincial park system, the *Special Places Protection Act* and wildlife habitat protection. A product of this work was the major two-volume resource document, The Natural History of Nova Scotia, first published in 1984 and revised in 1996. He managed the non-arthropod invertebrate collections of the museum and made significant additions of molluscs and other invertebrates from marine, freshwater and terrestrial habitats, mostly from Nova Scotia. He has published many papers and reports. He retired from the Nova Scotia Museum in 1994, became a Research Associate with the Museum, and was appointed Curator Emeritus in 1999.

A.J. Hebda, Curator of Zoology of the Nova Scotia Museum

Andrew Hebda comes to the field of natural history with a wide-ranging background. He was educated in Ottawa (B.Sc. Honours) in Biology from Carleton University and in Toronto, with a M.Sc. in Biology (Limnology) from York University. This was followed by a career in the Canadian Forces as a Medical Associate Officer, Adjutant and Company Commander. He has been a senior partner in two biological consulting companies based in Nova Scotia, co-authoring reports on over 45 studies (field and laboratory) with an emphasis on near-shore aquatic ecosystems. In his role as Curator of Zoology (since 1995), he has overseen the re-development of the zoological collections of the Nova Scotia Museum, including the finalization of the digitizing of the Museum zoological records as well as the systematic expansion of the malacological collection.

COLLECTIONS EXAMINED

No Canadian records were located in any principal international malacological collection, including the Natural History Museum (London) (K. Way pers. comm. 2007) or the Muséum national d'histoire naturelle in Paris (Rudolph von Cosel pers. comm. 2007). Specimens or records of *B. truncata* from Canada were located in only four collections:

Canadian Museum of Nature, Gatineau, Quebec: one catalogued voucher specimen (Spencers Point, N.S., collected by E.L. Bousfield (1958), first published Canadian record) (J.-M. Gagnon pers. comm. 2007).

Huntsman Marine Laboratory, Atlantic Reference Centre, St. Andrews, New Brunswick: 14 voucher specimens (Bass River, N.S., collected in 1948 by Medcoff, unpublished); Gerhard Pohle pers. comm. 2008). Additional specimens with no provenance are present at the Bedford Institute of Oceanography. Survey data from the Noel Bay site were noted (Dale Roddick pers. comm. 2007).

Nova Scotia Museum, Halifax, Nova Scotia: voucher specimens collected by NSM staff, U. Bohlman and J.S. Bleakney.

Private collection of Eldon George, Parrsboro, Nova Scotia: no collection data, unpublished.