

Identification of Atlantic Mud-piddock Habitat in Atlantic Canadian Waters

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ABSTRACT

Clark, C.M., Hebda, A., Jones, G., Butler, S., and Pardy, G. 2019. Identification of Atlantic Mud-piddock Habitat in Canadian Waters. DFO Can. Tech. Rep. Fish. Aquat. Sci. 3295. iv + 42 p.

The primary purpose of this study is to delineate areas containing current and potential Mud-piddock habitat (red mudstone) to support the identification of critical habitat in the upcoming recovery strategy for Atlantic Mud-piddock. This is done by delineating areas containing live Mud-piddock observations and currently viable habitat; these areas incidentally captures areas of red mudstone where Mud-piddock are not currently present but could settle if conditions become suitable (i.e. potential habitat). Thirteen extant sites are delineated by foot surveys followed by applying the bounding box methodology. Extant sites exhibit red mudstone in the intertidal and subtidal zones including the following habitat feature subtypes: tide pools, rivulets, resistant capstones, boulders/cobbles, and patches. Biophysical functions, features, and attributes of the habitat are described. Extant sites from Tennycap to Mungo Brook are identified as core sites; Port Williams (Starr's Point) and Spencer Point are identified as peripheral but stable sites; all other extant sites are identified as peripheral. The total habitat area available is less than 1.84 km².

Désignation de l'habitat de la pholade tronquée dans les eaux canadiennes de l'Atlantique

RÉSUMÉ

Clark, C.M., Hebda, A., Jones, G., Butler, S., and Pardy, G. 2019. Désignation de l'habitat de la pholade tronquée dans les eaux canadiennes de l'Atlantique. DFO Can. Tech. Rep. Fish. Aquat. Sci. 3295. iv + 42 p.

Cette étude vise principalement à délimiter les zones renfermant un habitat actuel ou potentiel de la pholade tronquée (mudstone rouge) pour appuyer la désignation de l'habitat essentiel dans le cadre de la stratégie de rétablissement à venir pour cette espèce. La désignation est effectuée en délimitant la répartition actuelle des pholades tronquées adultes et des larves déposées et métamorphosées, ainsi que les zones de mudstone rouge où il n'y a pas de pholades tronquées actuellement (habitat potentiel). Treize sites existants sont délimités au moyen de relevés à pied suivis de l'application de la méthode de cadre englobant. Les sites existants présentent du mudstone rouge dans les zones intertidales et infralittorales, notamment dans les sous-éléments d'habitat suivants : cuvettes de marées, ruisseaux, fonds rocheux résistants, roches/pierres et hauts-fonds. Les fonctions biophysiques, les caractéristiques et les paramètres de l'habitat sont décrits. Les sites existants de Tennycap à Mungo Brook sont désignés comme des sites principaux; Port Williams (Starr's Point) et Spencer Point sont désignés comme étant des sites périphériques, mais stables; tous les autres sites existants sont désignés comme étant des sites périphériques. La superficie de l'habitat total disponible est inférieure à 1,84 km².

1. INTRODUCTION

The Atlantic Mud-piddock, *Barnea truncata*, is a species that – in Canada – is found only in the Minas Basin, Nova Scotia (Figure 1). As an inlet of the Bay of Fundy, the Minas Basin experiences a tidal range of up to 19 m (COSEWIC 2009). It is approximately 80 km long and 30 km wide. Major rivers that flow into the Minas Basin include the Shubenacadie River, the Cornwallis River, the Avon River, the Gaspereau River, and the Salmon River. Outside of Canada, Mud-piddock's nearest location is 475 km away in southern Maine (DFO in press). Knowledge about its life history is limited. It is an intertidal bivalve mollusk, 3 to 5 cm long, which grows while burrowing conically into the substrate (Figure 2). As a result of this growth pattern, Mud-piddock become trapped and are reliant on suspended food and local water quality (COSEWIC 2009).

Throughout its range, Mud-piddock are found intertidally, with only one sub-tidal occurrence recorded in Florida (COSEWIC 2009). They are always found in soft muds, mudstones, or peats, with one exception: a single report of valves retrieved from a sample of submerged wood (Frank 2009; Jacobsen and Emmerson 1961). The species is limited in Canada to a specific geological formation: red mudstone substrate interbedded with sandstone that occurs only within the intertidal zone of the Minas Basin (COSEWIC 2009). The total extent of exposed red mudstone was estimated in COSEWIC (2009) as 0.6 km².

In 2009, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) recommended a threatened status for the Atlantic Mud-piddock. Mud-piddock was listed as Threatened on Schedule 1 of the *Species at Risk Act* (SARA) in 2017. Designation reasons included: its restriction to a single population in Canada; limited available preferred habitat; and the potential for changes in sediment deposition from increased frequency and severity of storms, erosion from rising sea level, increased rainfall, and coastal development. Rapid sediment deposition can smother Mud-piddock; this is the greatest threat to the species.

This study was undertaken to provide information supporting the identification of critical habitat for Mud-piddock. Critical habitat is defined under SARA as the habitat that is necessary for the survival or recovery of a listed wildlife species and is identified within a recovery strategy or action plan for the species (SARA s. 2[1]). For Threatened species, SARA requires the posting of a proposed recovery strategy on the Species at Risk Public Registry within two years of listing (SARA s. 42[1]); therefore the proposed recovery strategy for the Atlantic Mud-piddock is expected to be posted in 2019.

This study maps all current Mud-piddock habitat accessible by foot, at previously identified sites by:

1. mapping “areas containing live observations” of settled metamorphosed larval and adult-stage Atlantic Mud-piddock that are visible to the naked eye (not eggs or early stage larvae) to determine habitat that is currently occupied; and,
2. mapping “areas containing currently viable habitat” (red mudstone that is not currently occupied but that Mud-piddock could inhabit in its current state).

Sites that are extant and those that have recently been extirpated are identified. Sites that contain a large amount of habitat and high numbers of live Mud-piddock (core and major sites) are noted. This study uses consistently applied methods adapted from the Assessment of Methods for the Identification of Critical Habitat for Freshwater Mussels (DFO 2011) and offers a complete data set of the species' distribution in the Minas Basin. The biophysical functions, features, and attributes of Mud-piddock habitat are described. The information in this report can contribute to the identification of critical habitat as defined in the national Guidelines for the Identification of Critical Habitat for Aquatic Species at Risk (DFO 2015).⁴

2. METHODS

Methods used to delineate areas containing current and potential Mud-piddock habitat are described in detail below: selecting sites to survey by foot (section 2.1), researching habitat types to enable their identification in the field (section 2.2), surveying sites by foot (section 2.3), and then delineating areas using the bounding box approach (section 2.4). In addition to delineating habitat, qualitative comparisons of habitat extent and Mud-piddock occupancy are made between this survey and past surveys (section 2.5) and functions, features, and attributes (section 2.6) are described as a requirement under SARA.

2.1. SITE SELECTION

Previous data regarding metamorphosed larval and adult-stage Atlantic Mud-piddock distribution fit into two timeframes:

1. Historical (incidental) efforts from 1948-1995, when incidental sampling and surveys were undertaken at intertidal and sub-tidal portions of the coast; and,
2. Directed surveys from 2007-2008, which were undertaken to confirm the presence of the species within the Minas Basin and its persistence in historically identified sites.

The sites that were identified based on incidental historical observations and directed surveys up to 2008 were included in COSEWIC (2009). COSEWIC's Assessment and Status Report (2009) lists 14 extant sites, three recently extirpated sites, and two "other" sites where Atlantic Mud-piddock are or have been found in the Minas Basin. All 14 sites identified in COSEWIC (2009) as extant, one site identified in COSEWIC (2009) as extirpated (Evangeline Beach), and Kingsport were surveyed for this study. Evangeline Beach was surveyed opportunistically, and Kingsport was surveyed based on a report to the Nova Scotia Museum from the public about a Mud-piddock observation at that site.

Two sites listed by COSEWIC (2009) as extirpated (Salter Head, Walton Cove) and the two sites listed as "other" (The Guzzle and a site between Shad Creek and

⁴ Fisheries and Oceans Canada. 2015. Species at Risk Act (SARA) Guidelines for the Identification of Critical Habitat for Aquatic Species at Risk. Unpubl. Report, January 2015, Ecosystem Management Branch, Ottawa, Canada, 43 pp.

Sloop Rocks) were not surveyed because they were presumed to be extirpated. No suitable red mudstone habitat was observed during surveys in 2007-2008. The Guzzle and the site between Shad Creek and Sloop Rocks were assumed to be extirpated because although red mudstone habitat was uncovered in the past, storms have subsequently recovered them in sand and silt.

Maitland and Five Houses Road were excluded from COSEWIC (2009) due to uncertainty about whether or not reports of Atlantic Mud-piddock shells at these sites represented occupancy (A. Hebda, pers. comm.) and thus were re-assessed as extirpated but not visited or surveyed for this study.

2.2. HABITAT DESCRIPTION

The descriptions of Mud-piddock habitat and habitat limitations in DFO (2010) and Hebda (2011), and field observations from the 2007-2008 field survey were used to identify metamorphosed larval and adult-stage Atlantic Mud-piddock habitat at each site surveyed by foot. The following habitat types that are suitable for Mud-piddock residency in their present state (“currently viable habitat”) are described in DFO (2010) and Hebda (2011): tidal pools, boulders, capstone, and rivulets. These viable habitat types are composed of red-mudstone that is associated with water at high tide. Red mudstone that is not one of these habitat types and thus not currently suitable for Mud-piddock residency (e.g. red mudstone that is dry at low tide) was not included. It is important to note that red mudstone that is unsuitable now could be classified as “currently viable habitat” in the future (e.g. by erosion) and is therefore considered “potential habitat”; nevertheless, defining all red mudstone in the Minas Basin was outside the scope of this study. Field observations were made to further describe these habitat types. Due to limited knowledge about Atlantic Mud-piddock biology and habitat requirements, the habitat description was limited to substrate, geomorphology, and water quality.

2.3. DATA COLLECTION

Between July 2017 and May 2018, each site (Table 1) was surveyed at low tide at least once. Three sites were surveyed over multiple visits because they were too large to be surveyed completely on a single tide: Sloop Rocks twice, Mungo Brook twice, and Burntcoat Head West five times.

Mud-piddock occur in the mid to low intertidal zone (COSEWIC 2009) rather than the subtidal zone; therefore, the extent of the red mudstone habitat was surveyed on foot. At least two surveyors participated in each survey. Surveys began by establishing the outer extent of the survey area, based on visual observation of red mudstone. Given the local knowledge of the Minas Basin held by two of the authors (Hebda and Jones), there is a high degree of confidence that currently viable Mud-piddock habitat areas have been captured in this determination. Both of these authors participated as surveyors at each site.

To determine the boundaries, a foot survey was initiated from an access point on land (Figure 3). The surveyors walked toward the low water level, following a path defined by the presence or absence of red mudstone (Figure 4) that is roughly perpendicular to the shore. After following the low water mark until no red mudstone

was visible, surveyors followed the extent of the red mudstone closest to the low tide mark. They then walked back toward shore to capture the opposite outer edge, and then along the extent of the red mudstone closest to the high tide mark. Red mudstone that was not a defined habitat type and thus not currently viable (e.g. dry red mudstone) was not recorded.

The distance between surveyors varied between sites according to the size of the formation (sites range from $<5\text{ m}^2$ to several hectares), but was always small enough that habitat and Mud-piddock between surveyors was visible. A lack of red mudstone within the surveyors' field of view defined the outer limit of the survey area. Red mudstone beyond the field of view was not captured by the survey, but may be present.

At the same time as the outer extent of the survey area was established on foot, red mudstone habitat types and live Mud-piddock observations within the surveyors' field of view were recorded using GPS. Live Mud-piddock and red mudstone habitat types (Figures 5 and 6 respectively) were visually identified along the outer extent of the survey area and within the outer boundary and marked with Garmin GPSMAP 78s and Garmin GPSMAP 64st with GLONASS. Where a habitat type (e.g. tide pool) was larger than $3 \times 3\text{ m}^2$, the 'corners' of the feature were marked. If the habitat type was linear (e.g. rivulet or undercut), two points were marked at its beginning and end. In Figures 7 to 19, two or more points may represent one large feature, such as the beginning and end of one rivulet, rather than two rivulets.

At all sites, GPS points were marked wherever living organisms (live observations) were found on the red-mudstone survey route. Habitat types were also recorded for living organisms.

Atlantic Mud-piddock were distinguished from other intertidal bivalves using characteristics detailed in COSEWIC (2009). Where Mud-piddock were enclosed by their burrows, they were distinguished from the False Angelwing by the close proximity of their inhalant and exhalant siphons (Figure 5). Where they were not fully enclosed due to erosion or other factors, they were identified primarily by the anterior gape of their shells.

2.4. GEOSPATIAL ANALYSIS

The points collected in the field were analyzed using the Bounding Box Approach (BBA) described in DFO (2015). A "bounding box" is defined as "the area in which critical habitat is found." In that approach, habitat includes areas within a boundary or polygon where the described biophysical feature and function it supports occurs. Therefore, the BBA includes not only red mudstone, but other substrate types as well. Although bounding boxes will form the basis for critical habitat identification, they are not critical habitat. Critical habitat will be identified in the recovery strategy for this species at a later date.

Three methods were explored to delineate a geographic area to capture habitat features are: a minimum convex hull polygon, a geographic feature envelope, and a whole waterbody approach (DFO 2011). Of the three methods, the minimum convex hull polygon was deemed the most appropriate approach for Mud-piddock. In that

method, a polygon with convex sides is drawn using the outermost distribution points. It is used for each site in this analysis because it is the minimum area that includes all known points of current occupancy. Due to the specificity of Mud-piddock's red mudstone habitat, the geographic feature envelope is not useful since this approach creates a larger polygon which includes unsuitable habitat. Similarly, the whole waterbody approach is not suitable because it includes large areas of the Minas Basin that do not contain Mud-piddock habitat.

For this analysis, GPS coordinates were plotted for each site in four parts using ArcMap 10.4.1 (ESRI 2016).

First, a bounding box was created for the areas containing live observations collected during the 2017-2018 field surveys. The points on the outer edge of the bounding box were calculated using the "minimum bounding geometry – convex hull" function that is included in ArcMap 10.4.1. A 10 m buffer was applied to mitigate any GPS calibration errors. These points define the "area containing live observations" bounding box for each site (Figures 7 to 19).

Second, a bounding box with a 10 m buffer was created to include all points collected during the field surveys using the same method described above. These boxes contain all live observations and all habitat points identified using the habitat description, and are named "areas containing currently viable habitat" on Figures 7 to 19. As noted previously, they also include some but not all red mudstone that is not currently suitable (e.g. dry red mudstone; potential habitat) but that could become classified as "currently viable habitat" in the future. Note that these areas also contain substrate other than red mudstone. For sites that include more than one area of red mudstone and in which those areas were separated significantly, more than one bounding box was used. This applied for two sites: three polygons were used at Burntcoat Head West (Lighthouse Point) and two were used at Parrsboro.

Third, the two sets of bounding boxes and the points used to create them for each site were plotted on a satellite background map in ArcGIS (Figures 7 to 19). Some areas of red mudstone within the polygons that are currently covered in sand and silt but that are uncovered and recovered periodically were identified using local knowledge (Hebda and Jones) and included on the maps as a hatched area labelled "dynamic substrate." Note that not all dynamic substrate within the polygons is defined as a result.

Finally, the "areas containing currently viable habitat" at each site, including the 10 m buffers, were calculated (Table 1). These numbers were added together to determine the total combined area of currently viable habitat throughout the Minas Basin. Note that these are overestimates of red mudstone areas due to the presence of other substrates within the areas.

2.5. QUALITATIVE COMPARISONS

The persistence of red mudstone at each surveyed site cannot be assessed by comparing the total area estimated by this study to the estimates reported in COSEWIC (2009). Although an estimate of the total area of red mudstone at each site was included in COSEWIC (2009), the total area in that report cannot be quantitatively

compared to the total area calculated in this report because different methods were used. In addition, the bounding box approach overestimates the total amount of red mudstone as noted above. Therefore, a qualitative comparison of the 2007-2008 and 2017-2018 surveys was used to determine whether each site is stable or experiencing a positive or negative trend.

Notes from the COSEWIC (2009) report for the sites were compared to current observations (e.g. using the visual observations of the number of live individuals, the amount of available habitat, and what attributes were present). Andrew Hebda, who conducted the 2007-2008 field survey, was present at all the sites and confirmed these determinations.

Sites were characterized as stable, increasing, or declining (Table 3). Sites were then characterized as “core” or “peripheral” based on their size, proximity, and apparent stability. Core sites are the largest sites that are adjacent to one another and together comprise more than 80% of Mud-piddock habitat. They are also stable in Hebda’s qualitative comparisons. Peripheral sites are all other sites outside of the core sites, and major peripheral sites are sites outside of the core sites that are stable in Hebda’s qualitative comparisons.

2.6. FUNCTIONS, FEATURES, AND ATTRIBUTES

A functions, features and attributes table (Table 4) was created following the national guidelines for identifying critical habitat (DFO 2015). The guidelines identify a function as a life-cycle process of the species that takes place in critical habitat (e.g. spawning), a feature as an essential structural component of the critical habitat where the function(s) is carried out (e.g. intertidal zone), and an attribute as a measureable characteristic of a feature (e.g. red mudstone tide pool). These guidelines were interpreted for Mud-piddock habitat collectively by a group of DFO Species at Risk Management staff with concurrence from the authors of this report.

3. RESULTS

3.1. SITE SELECTION

Overall, 16 “areas containing currently viable habitat” (which include “areas containing live observations”) were mapped and analyzed at 13 sites (Table 1; Figures 7 to 9). These include 12 of the 14 sites (Burntcoat was previously separated into two sites) assessed as extant by COSEWIC (2009), Kingsport, and Evangeline Beach which was determined to be extant rather than extirpated (Table 1). Table 2 shows the six sites in the Minas Basin where Atlantic Mud-piddock is now extirpated. Of the four sites listed as extirpated in this study, two sites listed as extant by COSEWIC (2009), Saints Rest and Economy Point East Headland, had become extirpated due to habitat loss. No red mudstone was present at either site, speculatively due to ice scour. Two sites, Maitland and Five Houses Road (not assessed in COSEWIC 2009), were not visited in this study and thus assessed as extirpated because no suitable habitat is present at these sites.

For the extirpated sites that were identified in this study and in COSEWIC (2009), the chance of re-establishment is low due to a lack of suitable substrate and the distance from extant sites.

3.2. HABITAT DESCRIPTION

Based on the description of Mud-piddock habitat and limitations affecting the species DFO (2010), Hebda (2011), and field observations during the 2007-2008 field survey, it was observed that Mud-piddock are:

- Limited to a single soft mudstone substrate: red mudstone facies found between layers of Jurassic-age sandstone formations in association with hard conglomerates, limited sub-tidally by stable masses of sands and fine gravels
- Found in five habitat types (Figure 6, also identified for each site in Table 3), all of which have water present at low tide, except “capstone, undercut” (see footnote 5):

Tidal pools	In the bottom of tidal pools > 1.0 m ² with water >0.5 cm deep
Patches	In patches in the intertidal zone covered by water, <0.5 cm deep, and much smaller in area than a tidal pool (< 1.0 m ²). Note that this habitat type is not described in DFO (2010) or Hebda (2010/2011) but was defined during field surveys
Boulders	Around the base of large cobbles or boulders where tidal scour around the base causes sediment flushing
Capstone	Adjacent to or under resistant capstone that protects underlying mudstone against scour from ice and other materials (“capstone” or “capstone, undercut”) ⁵
Rivulets	In rivulets or channels where freshwater runoff or the tide causes sediment flushing

- Found only in low-mid intertidal areas, even where appropriate substrate is present in upper intertidal areas
- Threatened by suffocation caused by accumulation of sediments, even if it is seasonally flushed clean

⁵ Mud-piddock can burrow into vertical substrate that is found under capstone edges. This habitat type is the only habitat type that may not be submerged at low tide. Mud-piddock are able to persist in this habitat type due to the retention of moisture from shade provided by the overhanging capstone.

- Present in salinity of 5 ppt to 25 ppt. Other water quality parameters for Mud-piddock in the Minas Basin (e.g. temperature or oxygen levels) are not known, beyond that we know they can survive average air and water temperatures in all seasons because they live to be five or more years old.

Red mudstone in the low- to mid- intertidal zone was used to identify habitat in the field. The five habitat types were also identified. Salinity was not used to identify habitat due to tidal variance, run-off, and water condition at some sites. All other parts of the habitat description were used to identify habitat in the field.

3.3. DATA COLLECTION

Live observation and habitat type data were collected at 13 sites (Table 1): Kingsport (Figure 7), Evangeline Beach (Figure 8), Port Williams (Figure 9), Tennycap (Figure 10), Noel Bay (Figure 11), Burntcoat Head (Figure 12), Sloop Rocks (Figure 13), Shad Creek (Figure 14), Mungo Brook (Figure 15), Spencer Point (Figure 16), Economy Point (Figure 17), Five Islands (Figure 18), and Parrsboro (Figure 19).

3.4. GEOSPATIAL ANALYSIS

The bounding boxes, “areas containing live observations” and “areas containing currently viable habitat”, and data points are shown in Figures 7-19. The area calculations for the “areas containing currently viable habitat” at each site are included in Table 1.

Three bounding boxes were created for Burntcoat Head to distinguish between two sections of habitat at Lighthouse Point and another section of habitat in the north. Two bounding boxes were also used at Parrsboro, where there was a clear separation between two areas of red mudstone habitat.

As a result of this methodology, some red mudstone that is not currently viable habitat for Mud-piddock is included in the bounding box, while some is excluded because it was not recorded. In other words, the bounding boxes do not necessarily capture all red mudstone, but they are expected to capture all currently viable Mud-piddock habitat.

For the 13 sites mapped in this study, the total area of exposed red mudstone reported in 2007-2008 was 0.465 km². The total bounding box areas for the 13 sites (16 “areas containing currently viable habitat”) calculated in this study is 1.836 km².

3.5. QUALITATIVE COMPARISONS

Changes noted at the sites, habitat and population trends (declining, increasing, or stable), and the status of those sites within the broader population (peripheral or core) are summarized in Table 4.

3.5.1. Trends of Sub-populations and Associated Habitat

Stable Sites: Qualitative comparisons indicate that sites from Tennycap to Mungo Brook have maintained their habitat and vigour over the last ten years.

Spencer Point and Port Williams are also stable. While there have been no studies regarding Mud-piddock population and settlement patterns, one hypothesis is that these sites sustain their own sub-populations.

Positive Trends: There is a positive trend at two of the sites surveyed: Evangeline Beach and Kingsport. Evangeline Beach was included as extirpated in COSEWIC (2009), but in 2017-2018, three individual Mud-piddock were observed at the site. Kingsport was not included in COSEWIC (2009) or in any previous surveys, but individuals were found at the site in 2017-2018. Kingsport may be a new settlement, or it may have been missed when the site was visited in previous surveys due to its small size.

Negative Trends: There is a negative trend at Economy Point Southwest Headlands and Parrsboro. Since the original survey at Economy Point in 2007-2008, there has been an increase in the presence of fine silt and sediment throughout the site as well as the loss of some of the large boulders noted in earlier surveys (only one boulder remained in the 2017-2018 sampling period). With the loss of large boulders there has been an apparent loss of some red mudstone “swept” habitats at the base of the boulders. It is not clear if the sedimentation is a seasonal phenomenon, since surveying was not undertaken in the winter and spring season in the past. At Parrsboro, there has been a decrease in the number of cobbles and boulders in the identified zone of occurrence. No enumeration of cobbles and boulders had been undertaken in the earlier sampling period, but visual observation led to the identification of the decrease. As at Economy Point, with the loss of large cobbles, there has been an apparent loss of some of the boulder or “swept” habitat site points.

Extirpated Sites: Two sites have been extirpated in the last ten years. At Saints Rest, there is now no red mudstone substrate available at the site due to cobble deposition. Only a small patch of mudstone (<1 m²) was identified 250 m from the previously extant site. The nearest current Mud-piddock site is 10.3 km away. Economy Point East Headland has lost the small sea stack formation with red mudstone habitat reported previously and is 2.7 km away from the next currently occupied Mud-piddock site. The chance of resettlement at either site is minimal.

3.5.2. Status of Sub-populations and Associated Habitat

Core Sites: Core sites include the following six adjacent sites: Tennycap, Burntcoat Head, Noel Bay, Sloop Rocks, Shad Creek, and Mungo Brook. These sites are adjacent to one another and contain the six largest bounding boxes: 89.7% of the total areas containing Mud-piddock habitat calculated in this study. They are also stable based on Hebda’s qualitative comparisons of density and abundance of live individuals.

Peripheral Sites: All other sites are considered peripheral. Two sites on the periphery – Spencer Point and Port Williams – are still major as they are stable. Port Williams contains significant Mud-piddock populations. They are not core, though, because they are not adjacent to the core sites on the tidal reef complexes from Tennycap to Mungo Brook. The remaining sites – Kingsport, Evangeline Beach,

Economy Point, and Five Islands – are also peripheral. They are either declining or small and increasing, and distanced from the core sites.

3.6. FUNCTIONS, FEATURES, AND ATTRIBUTES

Table 4 summarizes the functions, features, and attributes found at the sites and necessary for the BBA as defined in DFO (2015). Due to the limited knowledge available about the life history of Atlantic Mud-piddock, and the consistency of habitat features between sites, all of the sites were grouped in this table. Small variations in geomorphological attributes in the red mudstone between sites are shown in Figures 7 to 19 and described in Table 3.

4. DISCUSSION

Since the last survey ten years ago, core and major peripheral Atlantic Mud-piddock habitat appear to have been stable. The core sites and major peripheral sites are very similar to 2007-2008, meaning that 92% of habitat at the 13 sites is stable. Two sites have been extirpated – Saint's Rest and Economy Point East Headlands, but two sites have established or reestablished: Evangeline Beach and Kingsport.

4.1. HABITAT TYPES AMONG SITES

All points identified as habitat in the field were red mudstone substrate, but the type of red mudstone differs between and within sites. This study showed that larger stable sites have more habitat types than smaller sites. The smallest sites, Evangeline Beach and Kingsport, were each restricted to a single habitat type: patches. The declining sites, Economy Point and Parrsboro, had fewer habitat types compared to other sites (e.g., tide pools, patches, and cobbles/boulders). The most extensive set of sites, from Tennycap to Mungo Brook, had the most diverse habitat types, with all habitat types present: tide pools, patches, rivulets, capstone, and some cobbles/boulders.

Port Williams had extensive capstone. While Port Williams's red mudstone is attached to its bank rather than a reef formation, the Cornwallis River Estuary has similarly eroded the bank and exposed red mudstone. Rivulets, tide pools, and some cobbles/boulders are also present at Port Williams. The other major peripheral site, Spencer Point, does not have capstone like Port Williams, but does have tide pools, a large rivulet, and some cobbles/boulders.

4.2. MINAS BASIN GEOLOGY

All of the core Mud-piddock sites are on the south side of the Minas Basin on a single tidal reef complex that is part of the Evangeline Member of the Wolfville Formation (Sues and Olsen 2015). The Wolfville Formation is part of the Triassic Lowlands (Davis and Browne 1995). Port Williams, a major peripheral site, is also part of the Wolfville Formation (Sues and Olsen 2015). The geology within this formation varies considerably and there has been no geological survey to identify the red mudstone in the area, which could be a useful tool for identification of Mud-piddock habitat.

4.3. LIMITATIONS

4.3.1. Data Collection Methods

Due to the time and tidal constraints and the extremely small size of Mud-piddock burrows and settlement, some live individuals and small habitat types (i.e., patches) within the bounding box may have been missed while conducting foot surveys. Also, because this study mapped only currently viable habitat and live observations, not red mudstone that is not currently available as Mud-piddock habitat (e.g. dry red mudstone, potential habitat), the full extent of red mudstone in the Minas Basin is not known and may extend beyond the bounding boxes. In addition, changing sedimentation patterns may uncover or recover habitat in the future. Foot surveys do not address underlying geology and therefore covered red mudstone areas could be missed and not included within the bounding boxes. Furthermore, only settled metamorphosed larvae and adult Mud-piddock are observable with the naked eye; younger individuals are not observable with the methods in this study. These limitations mean that live individuals and habitat marked within the bounding box do not represent all habitat and all individuals within the box or at the site. However, with the exception of red mudstone covered in sediment that is outside the bounding box, the study does provide the bounds of areas of currently viable habitat and live observations, which was its goal.

A final limitation was that this study did not measure area in the same way as previous studies did, and therefore the changes in habitat areas could not be compared quantitatively. This limitation means that only qualitative comparisons were possible, yielding an estimation of the trend but not a specific numerical value or percentage representing the changes.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSIONS

The overall status of Atlantic Mud-piddock habitat on the Minas Basin appears to be stable over the last ten years, which is consistent with the suggestion in COSEWIC (2009) and DFO (2010) that the population is stable. The core and major peripheral sites, accounting for more than 90% of bounding box areas, have not decreased in area or vigour. There have been approximately equal gains and losses in peripheral sites with two sites – Economy Point East Headland and Saints’ Rest – being extirpated, but two sites – Evangeline Beach and Kingsport – establishing or re-establishing. This indicates that Atlantic Mud-piddock habitat in the Minas Basin is presently stable. However, habitat is not a proxy for population abundance or distribution, so due to Mud-piddock’s small size and limited habitat it remains vulnerable to changes in habitat.

5.2. RECOMMENDATIONS

Atlantic Mud-piddock habitat and individuals likely exist at Brick Kiln (DFO 2010); however, it cannot be accessed safely on foot because it is a rocky tidal island. If a remote or otherwise safe method can be found, this area should be surveyed.

Extirpated sites identified in 2007-2008 (Salter Head, Walton Cove, The Guzzle and site between Shad Creek and Sloop Rocks) could also be visited in the future to determine if red mudstone has become exposed and if recent settlement has occurred.

A geological survey would be useful to better understand the extent of red mudstone facies in the Minas Basin. Foot surveys like the one in this study are limited in scope due to time and tidal constraints; however if future foot surveys are conducted, recording the outer perimeter of all red mudstone (not just currently viable habitat) at each site to capture all potential habitat is recommended. Visual observations are also limited because red mudstone could be hidden due to seasonal sedimentation or periodic cobble coverage. A sedimentation study could also determine patterns, such as what red mudstone habitat may be covered or exposed by sedimentation.

To better understand the species, as well as the functions, features, and attributes of the sites, additional life history information about Atlantic Mud-piddock would be useful. Projects related to habitat could include:

1. Spawning studies to determine the timing of Mud-piddock spawning, the water temperature at which they spawn, and their mobility and preference within intertidal habitat (i.e. whether larvae use their cilia to move from unsuitable substrate to red mudstone, or whether they are limited by the tide). This study could be based on Chanley (1965), whose methods could be adapted and repeated for the Minas Basin. A study of the distribution of eggs and unsettled larvae could also be conducted, as that distribution was outside of the scope of this study.
2. Ageing studies to determine the lifespan of the species and the age structure of the population to show how long adults use the substrate
3. Genetics studies to determine the interrelatedness of the sites, and to test hypotheses (e.g. older and larger sites are self-maintaining while newer and smaller sites are settled by eggs and larvae from other sites)

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8. TABLES

Table 1. Extant Atlantic Mud-piddock sites mapped in this study. Coordinates and visual estimates of exposed red mudstone are from COSEWIC (2009). Visual estimate of exposed red mudstone areas (2007-2008) are an estimate of only red mudstone, while bounding box areas are an estimate of the areas that contain all currently viable red mudstone habitat as well as other habitat types included incidentally as a result of the methodology.

Site	Coordinates	2017-2018 Survey Date	Visual estimate of exposed red mudstone, 2007-2008	Bounding box area, 2017-2018
Kingsport , Kings County (Figure 7)	45°09'57.6"N 64°20'45.6"W	September 2017	Not reported	0.009 km ²
Evangeline Beach , Hants County (Figure 8)	45°08'22.32"N 64°19'47.42"W	September 2017	< 0.005 km ²	0.003 km ²
Port Williams (Cornwallis River estuary), Kings County (Figure 9)	45°06'08.93"N 64°22'38.38"W	February 2018	0.01 km ²	0.031 km ²
Tennycap (west of headland), Hants County (Figure 10)	45°16'48.23"N 63°53'44.29"W	May 2018	0.02 km ²	0.206 km ²
Noel Bay , Hants County (Figure 11)	45°19'07.98"N 63°47'08.75"W	March 2018	0.02 km ²	0.149 km ²
Burntcoat Head , ¹ Hants County (Figure 12)	45°18'43.07"N 63°48'35.39"W	July 2017, February and March 2018	0.03 km ²	0.38 km ²
Sloop Rocks (Noel Head) Hants County (Figure 13)	45°19'30.51"N 63°43'03.60"W	July 2017 and March 2018	0.155 km ²	0.26 km ²
Shad Creek Cove Reef (Noel Shore), Hants County (Figure 14)	45°19'30.51"N 63°40'14.76"W	November 2017	0.04 km ²	0.356 km ²
Mungo Brook Cove Reef (Lower Selma), Hants County (Figure 15)	45°19'06.04"N 63°37'42.52"W	November 2017 and March 2018	0.015 km ²	0.295 km ²

Site	Coordinates	2017-2018 Survey Date	Visual estimate of exposed red mudstone, 2007-2008	Bounding box area, 2017-2018
Spencer Point , Colchester County (Figure 16)	45°23'08.47"N 63°37'53.99"W	February 2018	0.01 km ²	0.018 km ²
Economy Point and Southwest headlands (Thomas Cove), Colchester County (Figure 17)	45°21'01.73"N 63°53'46.47"W	December 2017	0.1 km ²	0.076 km ²
Five Islands Provincial Park , Colchester County (Figure 18)	45°23'14.95"N 64°03'55.90"W	June 2018	0.04 km ²	0.02 km ²
Parrsboro (Wasson's Bluff) ² , Cumberland County (Figure 19)	45°23'22.08"N 64°13'25.97"W	January 2018	0.02 km ²	0.032 km ²
TOTAL AREA			0.465 km ²	1.836 km ²

Notes:

1. Three areas containing red mudstone were mapped at Burntcoat Head.
2. Two areas containing red mudstone were mapped at Parrsboro

Table 2. Extirpated Atlantic Mud-piddock sites in Minas Basin. First column indicates if sampled during this study (Y) or assessment based on earlier surveys (N).

Surveyed in 2017-2018	Site	Coordinates (COSEWIC 2009)	First Confirmed Presence	COSEWIC (2009) assessment	Year surveyed and Observations	Potential for reestablishment
N	Walton Cove Hants County	45°14'26.81"N 64°00'20.83"W	1975-1976	Extirpated	1975-1976 – valves report by Dr. Derek Davis 2007-2008 direct survey -- Whole area occupied by barnacle assemblage, with no exposed mudstone substrate present within 5 km of site.	Very low. No suitable substrate. Barnacles require firm substrate, not mudstone. Next available substrate is at Tennycap, 9.7 km ENE.
N	Salter Head Hants County	45°20'12.44N 63°32'22.20"W	2007-2008	Extirpated	2007-2008 direct survey -- Apparent loss of surficial mudstone layer, with bottom portions of burrows present in sandstone/mudstone.	Very low. Substrate possibly lost due to scouring. Nearest available substrate is at Mungo Brook, 8.5 km WSW.
N	Maitland Hants County	45°19'25.23"N 63°30'07.47"W	1975-1976	Not assessed	1975-1976 – valves reported by Dr. Derek Davis; 2007-2008 direct survey -- Intertidal area covered by soft sediments with margin of hard rock substrate present at lower end of low tide.	Very low. Historical report is of an intact valve with apophysis at a shipyard. No substrate present. Nearest available substrate is at Mungo Brook, 11.5 km W.
N	Five Houses Road Colchester County	45°23'43.27"N 63°44'01.41"W	2000	Not assessed	2000 -- Intertidal area covered with soft sediments. Only a valve was reported, not habitat.	Very low. Nearest available substrate is at Spencer Point, 8.1 km E
Y	Saints Rest Colchester County	45°23'42.73"N 63°46'51.20W	1948	Extant	1948 – secure site (COSEWIC, 2009) 2007-2008 direct survey – present in drainage cuts through new salt marsh 2017-2018 direct survey – no substrate present due to cobble deposition.	Very low at initial site. Small patch of mudstone (< 1m ²) identified nearby at 45°23'39.12"N, 63°46'58.61W -- .25 km away.

Surveyed in 2017-2018	Site	Coordinates (COSEWIC 2009)	First Confirmed Presence	COSEWIC (2009) assessment	Year surveyed and Observations	Potential for reestablishment
Y	Economy Point East Headland Colchester County	45°20'57.78"N 63°52'59.76"W	2006	Extant	2006 – single spot reported at base of “flower-pot” formation in a random survey by Leslie Pezzack 2017-2018 – small sea stack formation reported by Andrew Hebda as no longer present; basal substrate scoured away.	Very low. Nearest available substrate is at Economy Point Headlands (Thomas Cove), 2.7 km W.
N	The Guzzle Kings County	45°09'34.87"N 64°17'37.63"W	1979	Other	1979 – presence noted as part of larger research project related to fossil oyster bed nearby (Bleakney and Davis, 1983) 2007-2008 direct survey – no suitable substrate from south of the reported collection point to the upper intertidal zone at Evangeline Beach.	Very low. Nearest available substrate is at Evangeline Beach, 3.3 km W.
N	Site between Shad Creek and Sloop Rocks Hants County	45°19'13.38"N 63°40'40.62"W		Other	2007-2008 – area exposed during storm and recovered with soft muds	Low due to red mudstone being covered by sediment

Table 3. Observations and status of extant Mud-piddock sites mapped in this study.

Site	Coordinates	First Confirmed Presence	Observations at sites over time	Status of Sub-population in 2017-2018 Survey	Habitat type
Kingsport Kings County (Figure 7)	45°09'57.6"N 64°20'45.6"W	2017-2018	Not previously reported. 2017 direct survey – four live individuals found in <5 m ² of red mudstone substrate	Peripheral, perhaps incidentally settled from another site	Patch
Evangeline Beach Hants County (Figure 8)	45°08'22.32"N 64°19'47.42"W	2007-2008	COSEWIC (2009) – tide pool, <0.5 m, recently extirpated, with only intact empty valves. 2017 – three live individuals found in <5 m ² of red mudstone substrate	Peripheral, perhaps incidentally settled with spat from another site	Patch
Port Williams (Cornwallis River estuary) Kings County (Figure 9)	45°06'08.93"N 64°22'38.38"W	2007-2008	COSEWIC (2009) – undercut, 1 ha, in mid-tide bank of Cornwallis River Estuary. 2018 direct survey – very similar; a major site	Peripheral but stable	Capstone, rivulet, tidal pool
Tennycap (west of headland) Hants County (Figure 10)	45°16'48.23"N 63°53'44.29"W	2007-2008	COSEWIC (2009) – tide pool, 2 ha, mid-low intertidal, additional 5 ha appropriate substrate with no settlement. 2018 direct survey – very similar; large site but not as densely populated as other large sites like Burntcoat Head.	Peripheral	Capstone, tidal pool, boulder, patch
Noel Bay Hants County (Figure 11)	45°19'07.98"N 63°47'08.75"W	2007-2008	1959 – valves recovered by Bousfield and Leim at Noel Bay (COSEWIC 2009) – tide pool and undercut, 1.5 ha, no capstone or rock protection. 2017-2018 direct survey -- mix of all habitat types with section of dynamic substrate (sedimentation) with possible mudstone underneath.	Core	Capstone, rivulet, tidal pool, patch

Site	Coordinates	First Confirmed Presence	Observations at sites over time	Status of Sub-population in 2017-2018 Survey	Habitat type
Burntcoat Head Hants County (Figure 12)	45°18'43.07"N 63°48'35.39"W	2007-2008	COSEWIC (2009) – capstone and undercut, 3 ha. at Lighthouse Point; tidepool and undercut, 2 ha. at north section 2017-2018 direct survey – very similar; tide pools associated with capstone; with Burntcoat (Lighthouse Point), it is the most extensive site and component of red mudstone reefs from Burntcoat to Mungo Brook	Core	Capstone, rivulet, tidal pool, patch
Sloop Rocks (Noel Head) Hants County (Figure 13)	45°19'30.51"N 63°43'03.60"W	1959	Sloop Rocks (COSEWIC 2009) -- in undercut, some tide pools, drainage channel, 10 ha Site between Shad Creek and Sloop Rocks (COSEWIC 2009) -- -- area exposed after winter storm 2007/2008, initially covered with soft muds in lower intertidal; tide pool, 75 ha 2017-2018 direct survey -- very similar; extensive site, particularly at Sloop Rocks; part of reef complex from Burntcoat to Mungo Brook	Core	Capstone, rivulet, tidal pool, patch
Shad Creek Cove Reef (Noel Shore) Hants County (Figure 14)	45°19'30.51"N 63°40'14.76"W	2007-2008	COSEWIC (2009) – drainage channels, tide pool, 4 ha 2017 – very similar; smaller site but part of the reef complex from Burntcoat to Mungo Brook	Core	Habitat types not recorded
Mungo Brook Cove Reef (Lower Selma) Hants County (Figure 15)	45°19'06.04"N 63°37'42.52"W	2007-2008	COSEWIC (2009) – exposed reef and tide pools, undercut, 1.5 ha 2017 – very similar; part of the reef complex from Burntcoat to Mungo Brook	Core	Capstone, rivulet, tidal pool, patch
Spencer Point Colchester County (Figure 16)	45°23'08.47"N 63°37'53.99"W	2007-2008	COSEWIC (2009) – mid-tide tide pools and undercut, 1 ha	Peripheral but stable	Tidal pool, rivulet, patch

Site	Coordinates	First Confirmed Presence	Observations at sites over time	Status of Sub-population in 2017-2018 Survey	Habitat type
Economy Point and Southwest headlands (Thomas Cove) Colchester County (Figure 17)	45°21'01.73"N 63°53'46.47"W	2007-2008	COSEWIC (2009) – tide pool, 10 ha, protected zone between mid-tide line and offshore reef. 2017 direct survey – Increase in fine silt and sediment throughout site; loss of some boulders and associated habitat (1 remaining)	Peripheral, declining	Tidal pool, boulder, patch
Five Islands Provincial Park Colchester County (Figure 18)	45°23'14.95"N 64°03'55.90"W	1980s	1980s – archival record from Bohlmann and Bleakney COSEWIC (2009) – tide pool, 4 ha 2018 direct survey – very similar; two large tidepools and rivulet	Peripheral	Tidal pool, rivulet
Parrsboro (Wasson's Bluff) Cumberland County (Figure 19)	45°23'22.08"N 64°13'25.97"W	2007-2008	Date unknown – shell in personal collection of Eldon George COSEWIC (2009) – tide pool, 2 ha, associated with large cobbles. 2018 direct survey – qualitative loss of large cobbles and some habitat	Peripheral, declining	Tidal pool, patch

Table 4. Summary of the biophysical functions, features, attributes of Atlantic Mud-piddock habitat, based on information from COSEWIC (2009) and DFO (2010). Note the geographic location for all life stages is at various locations within the Minas Basin, Nova Scotia.

Life Stage	Functions	Features	Attributes
Egg	Egg incubation and growth	Water in intertidal and subtidal zones	<ul style="list-style-type: none"> • Salinity: 2 to 25 ppt • Temperature and oxygen levels within natural range of variation (0° to 21°C and ~5 mg/L)^{3,1} • Sufficient water quality
Trochophore Larva	Growth	Water in intertidal and subtidal zones	<ul style="list-style-type: none"> • Salinity: 2 to 25 ppt • Temperature and oxygen levels within natural range of variation (0° to 21°C and ~5 mg/L) • Sufficient water quality
Veliger Larva	Settlement	Water in the intertidal zone	<ul style="list-style-type: none"> • Salinity: 2 to 25 ppt • Temperature and oxygen levels within natural range of variation (0° to 21°C and ~5 mg/L) • Sufficient water quality • High slack tide for settlement • Sufficient water quality
		Red mudstone ² in the intertidal zone where water is present at high and low tide and is associated with the following habitat types: tide pools, rivulets, resistant capstones ³ , boulders/cobbles, patches	<ul style="list-style-type: none"> • Available red-mudstone surfaces to settle upon
Sub-adult (post-larva stage that has not reached maturity) ⁴	Boring and growth	Red mudstone in the intertidal zone where water is present at high and low tide and is associated with the following habitat types: tide pools, rivulets, resistant capstones, boulders/cobbles, patches	<ul style="list-style-type: none"> • Available red-mudstone within which to bore and mature • No rapid or significant accumulation of sediments
		Water in the intertidal zone	<ul style="list-style-type: none"> • Salinity: 2 to 25 ppt • Temperature and oxygen levels within natural range of variation (0° to 21°C and ~5 mg/L) • No rapid or significant accumulation of sediments • Sufficient water flushing to remove waste • Sufficient water quality

Life Stage	Functions	Features	Attributes
Adult	Growth	Red mudstone in the intertidal zone where water is present at high and low tide and is associated with the following habitat types: tide pools, rivulets, resistant capstones, boulders/cobbles, patches	<ul style="list-style-type: none"> Red-mudstone of sufficient depth (~5 cm) in which to grow No rapid or significant accumulation of sediments
		Water in the intertidal zone	<ul style="list-style-type: none"> Salinity: 2 to 25 ppt Oxygen levels within natural range of variation (~5 mg/L) Suitable temperature for external fertilization (exact temperature unknown) No rapid or significant accumulation of sediments Sufficient water flushing to remove waste Sufficient water quality
	Reproduction	Red mudstone in the intertidal zone where water is present at high and low tide and is associated with the following habitat types: tide pools, rivulets, resistant capstones, boulders/cobbles, patches	<ul style="list-style-type: none"> Available mudstone from which to reproduce No rapid or significant accumulation of sediments
		Water in the intertidal zone	<ul style="list-style-type: none"> Salinity: 2 to 25 ppt Temperature and oxygen levels within natural range of variation (0° to 21°C and ~5 mg/L) No rapid or significant accumulation of sediments Sufficient water quality Tidal flushing to allow egg fertilization and distribution
All (except egg)	Feeding	Food supply	<ul style="list-style-type: none"> Sufficient quality and quantity of food (plankton and particulates)

Notes:

1. Greenberg, 1982; Kendal et al. 2018

2. Veliger larva can settle on any substrate but can only successfully bore into red mudstone.

3. Mud-piddock can burrow into vertical substrate that is found under capstone edges. This habitat type is the only habitat type that may not be submerged at low tide. Mud-piddock are able to persist in this habitat type due to the retention of moisture from shade provided by the overhanging capstone.

4. The duration of the sub-adult stage is unknown.

9. FIGURES

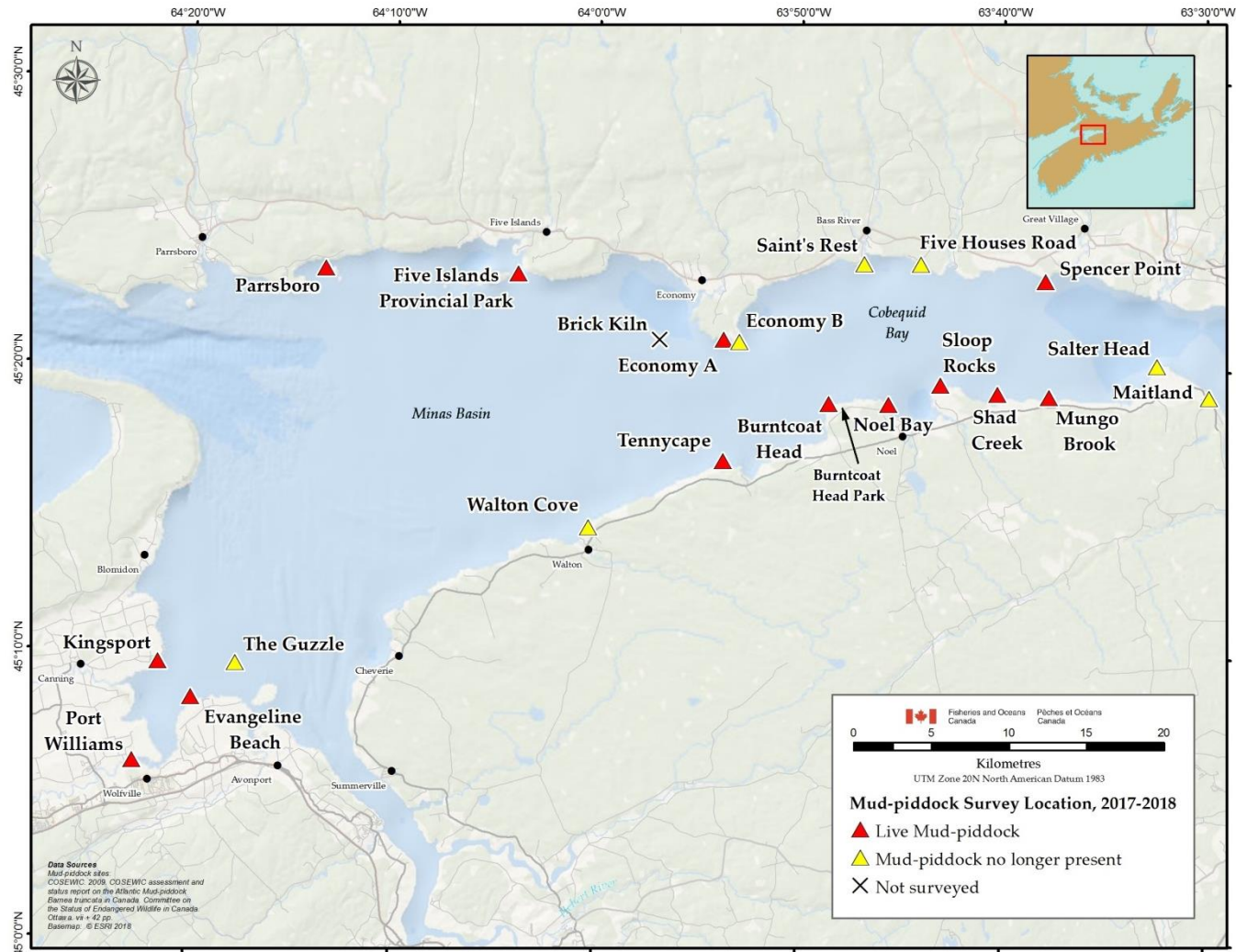


Figure 1. Extant and extirpated sites of Atlantic Mud-piddock habitat in the Minas Basin.

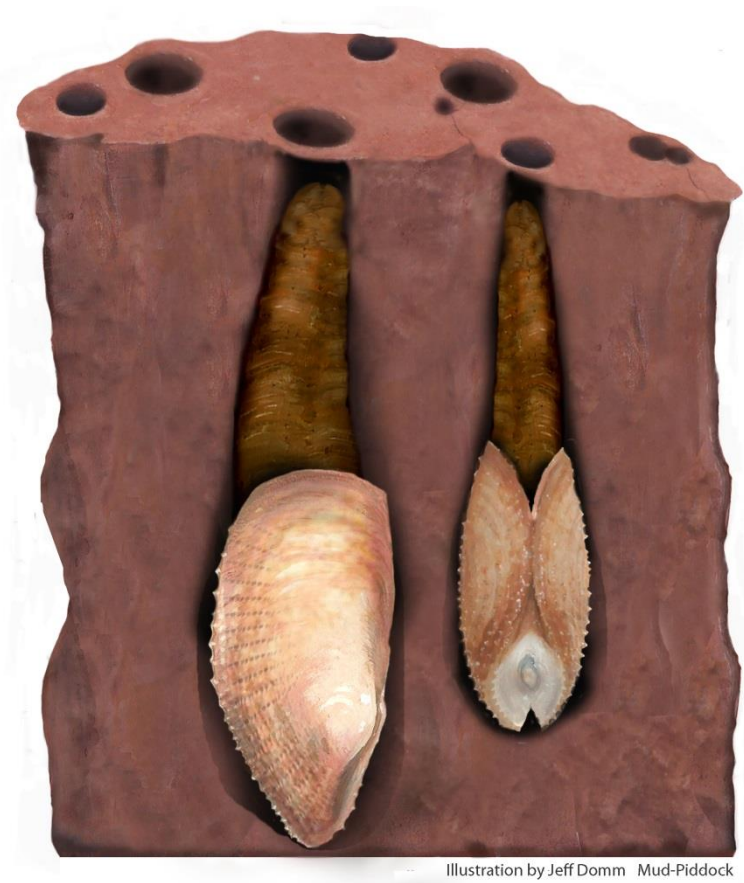


Figure 2. Atlantic Mud-piddock in-situ in conical burrows in red mudstone substrate.



Figure 3. Example search pattern for three people surveying for Atlantic Mud-piddock current occupancy and potential habitat. Pictured: Noel Bay (Google Maps 2018).

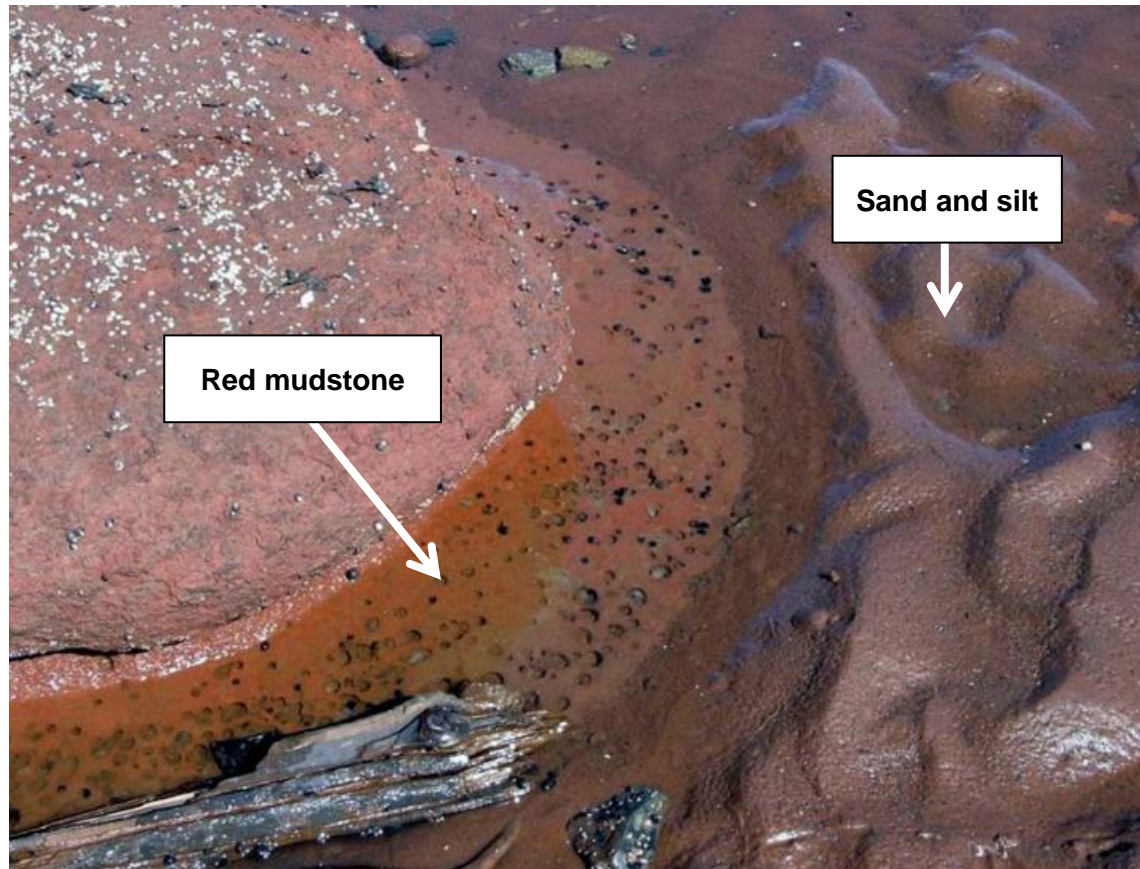


Figure 4. Example of the boundary between red mudstone facies (left) and sand (right). (Photo by G. Jones)

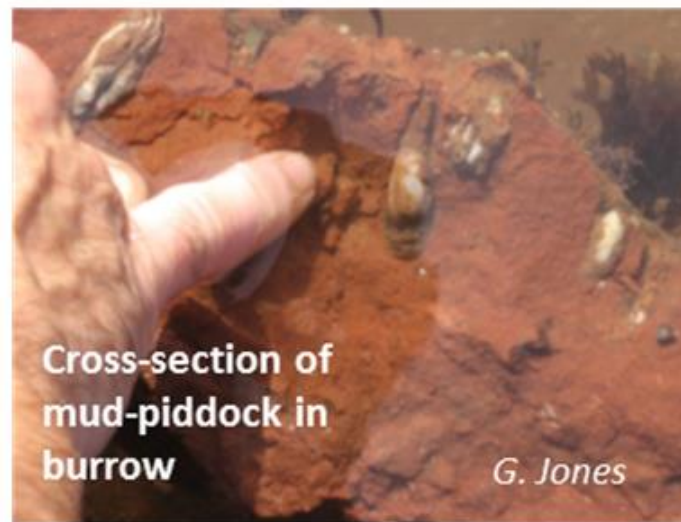


Figure 5. Atlantic Mud-piddock in-situ, showing siphons and burrows.



Figure 6. Red mudstone habitat types used by the Atlantic Mud-piddock.

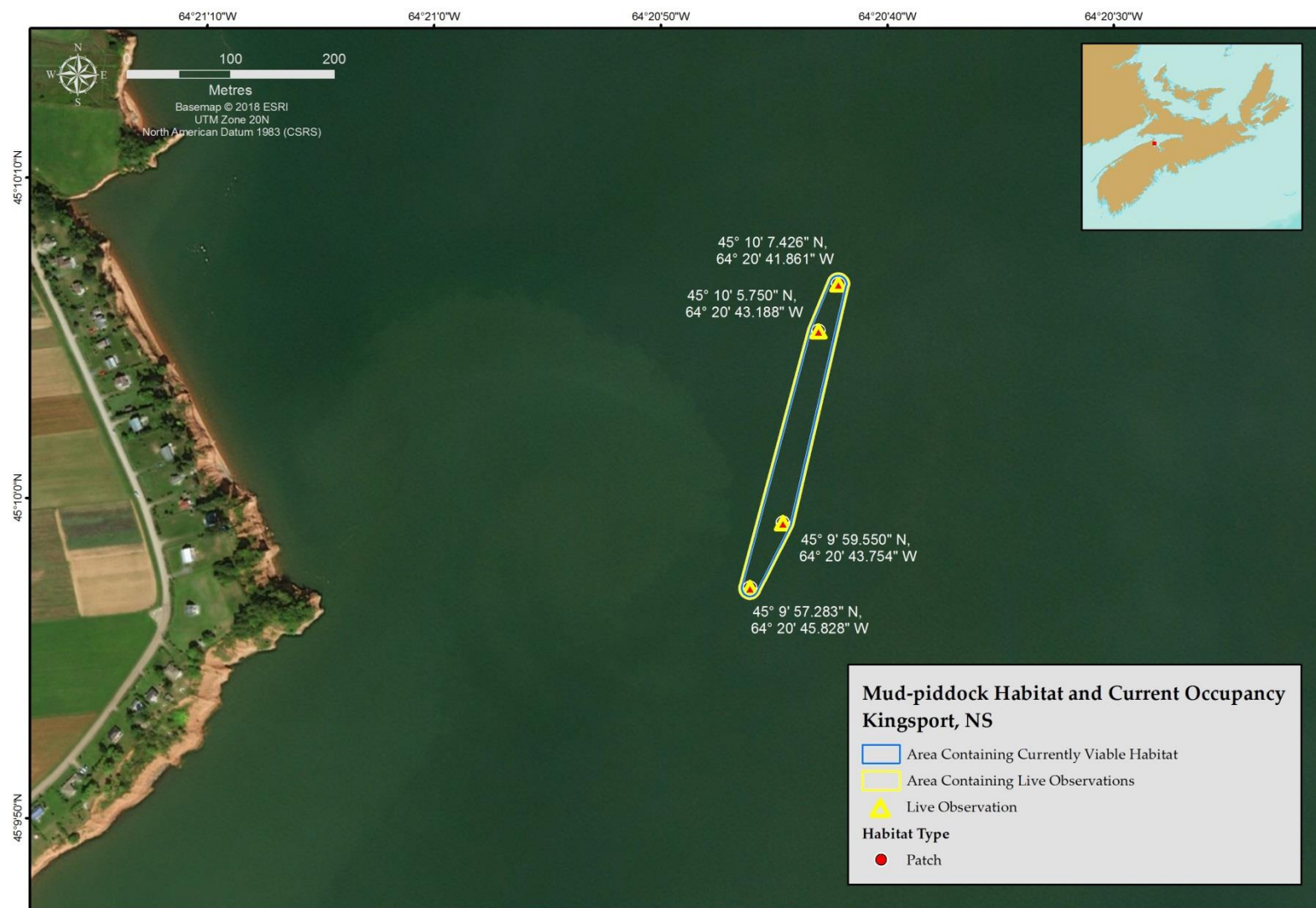


Figure 7. Current Mud-piddock occupancy and habitat (red mudstone) at Kingsport.

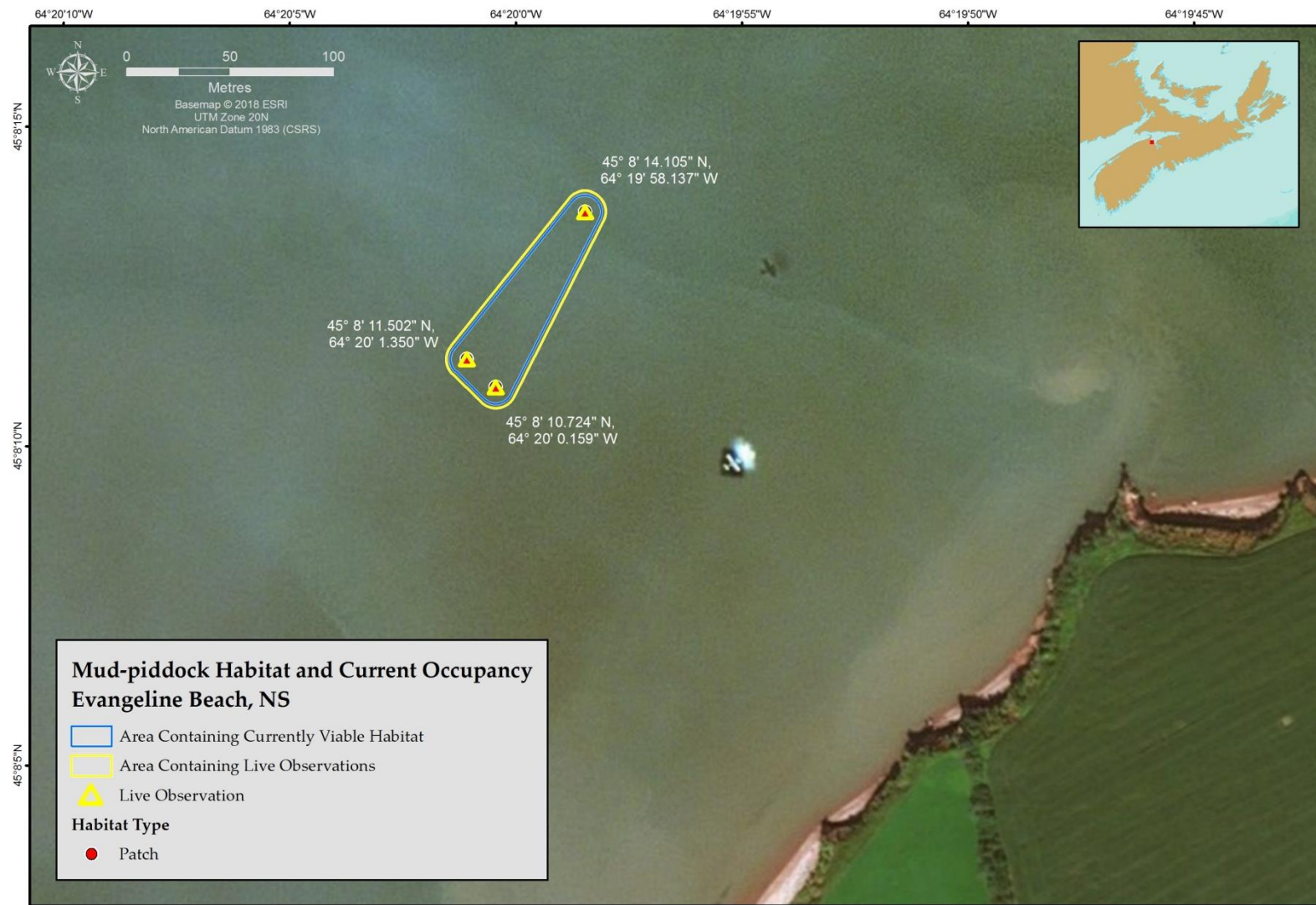


Figure 8. Current Mud-piddock occupancy and habitat (red mudstone) at Evangeline Beach.



Figure 9. Current Mud-piddock occupancy and habitat (red mudstone) at Port Williams.

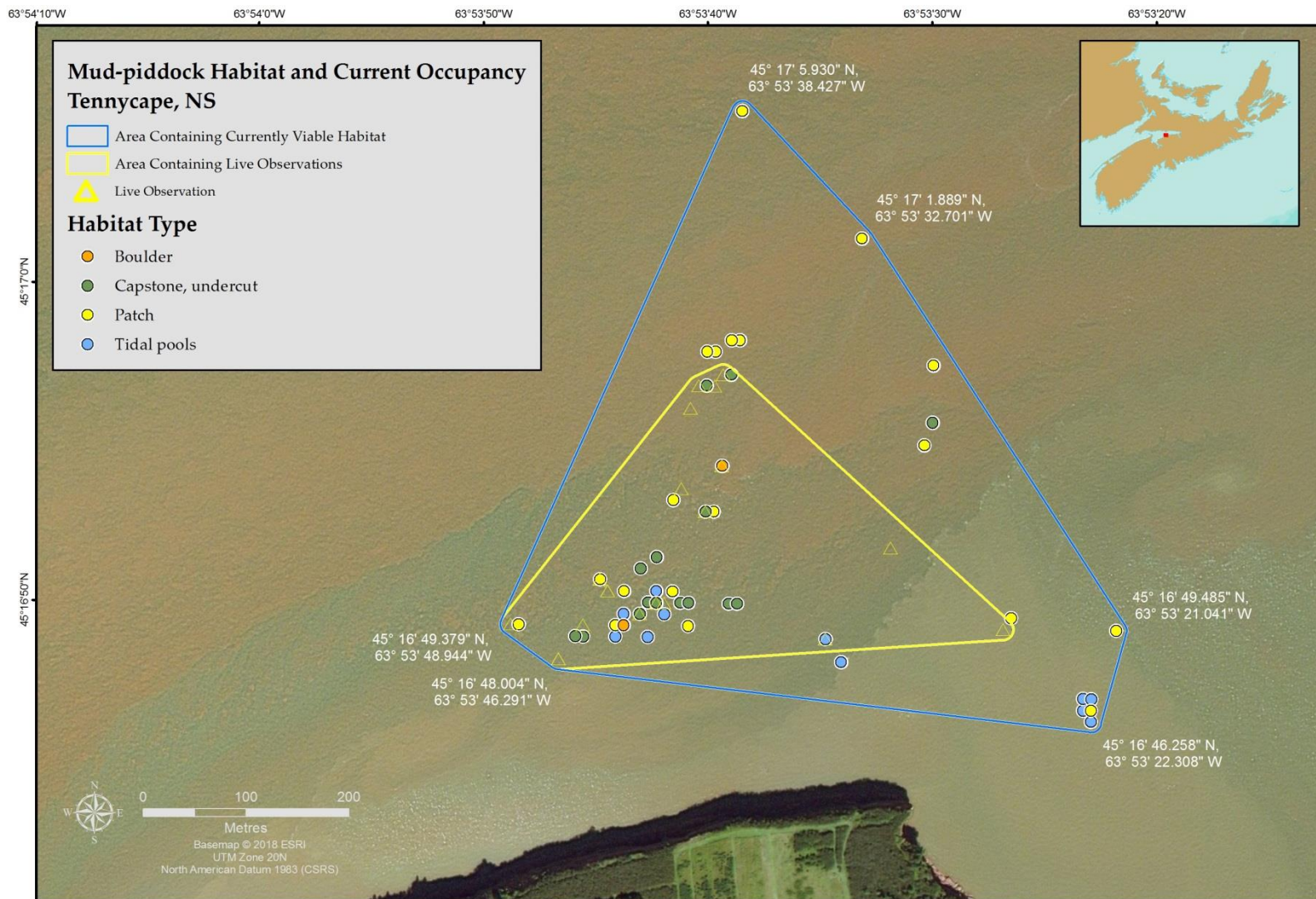


Figure 10. Current Mud-piddock occupancy and habitat (red mudstone) at Tennycape.

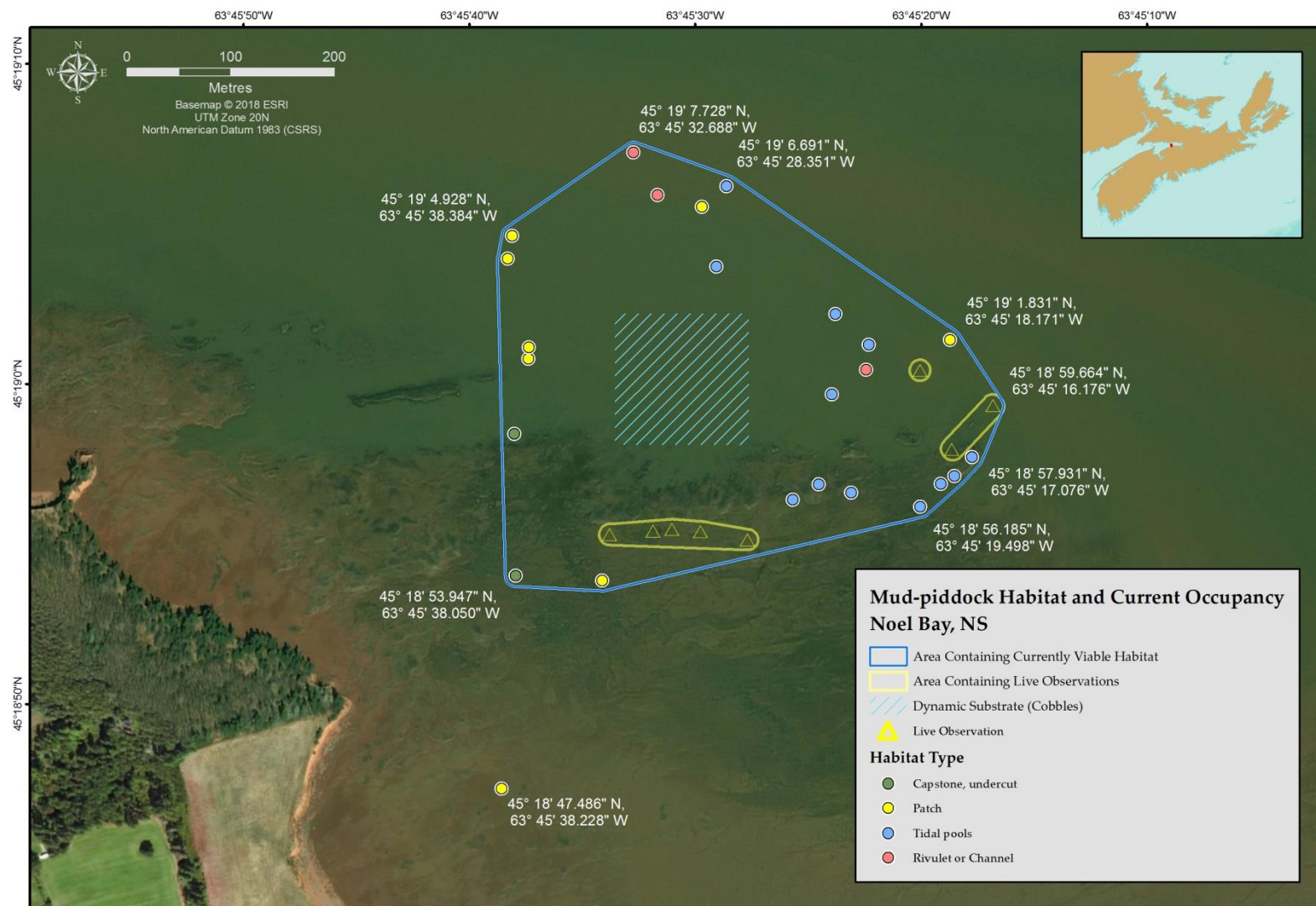


Figure 11. Current Mud-piddock occupancy and habitat (red mudstone) at Noel Bay. Dynamic substrate denotes an approximate area of receding and accumulating sedimentation and cobbles that could have mudstone underneath.

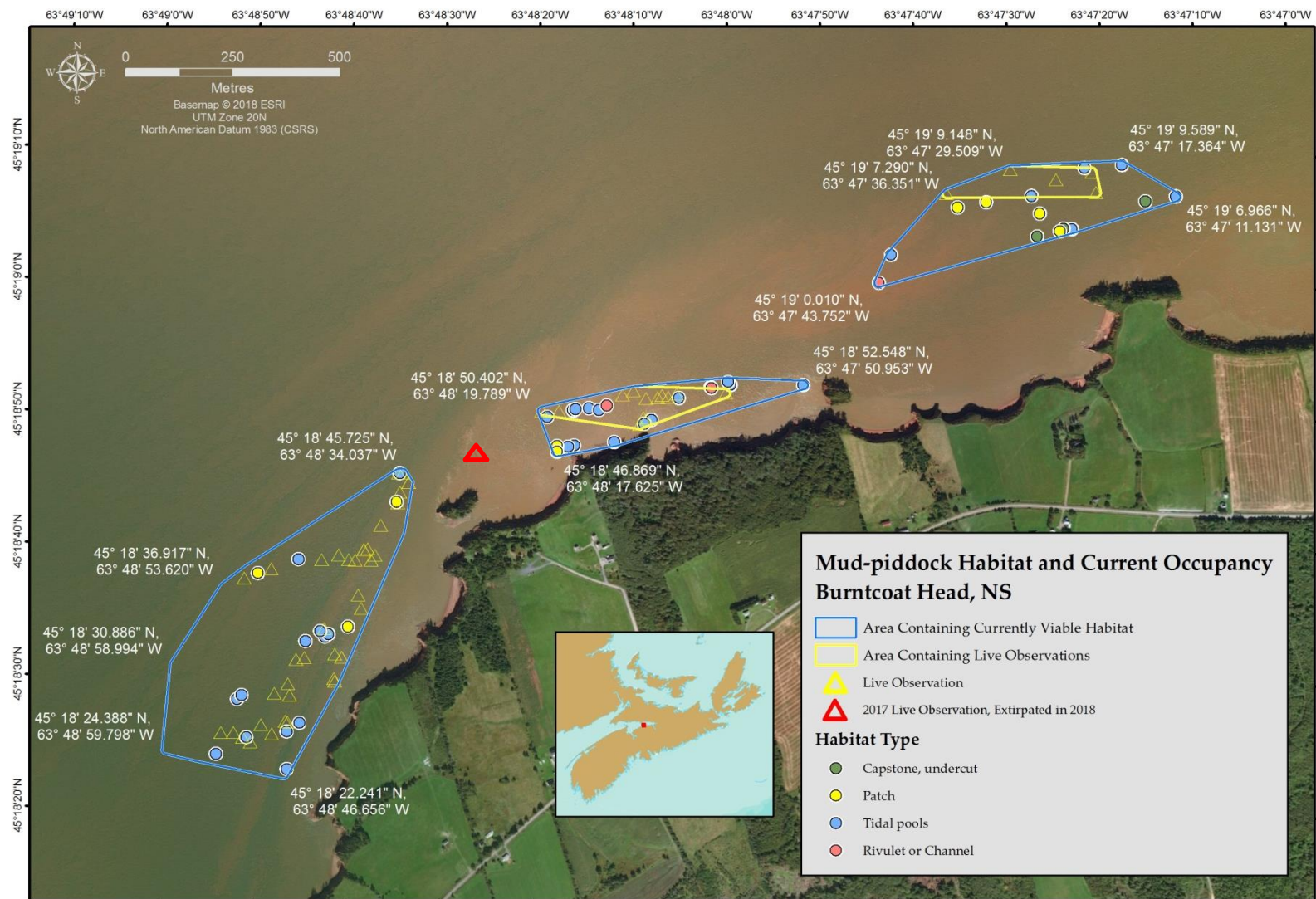


Figure 12. Current Mud-piddock occupancy and habitat (red mudstone) at Burntcoat Head (Lighthouse Point and North Section).

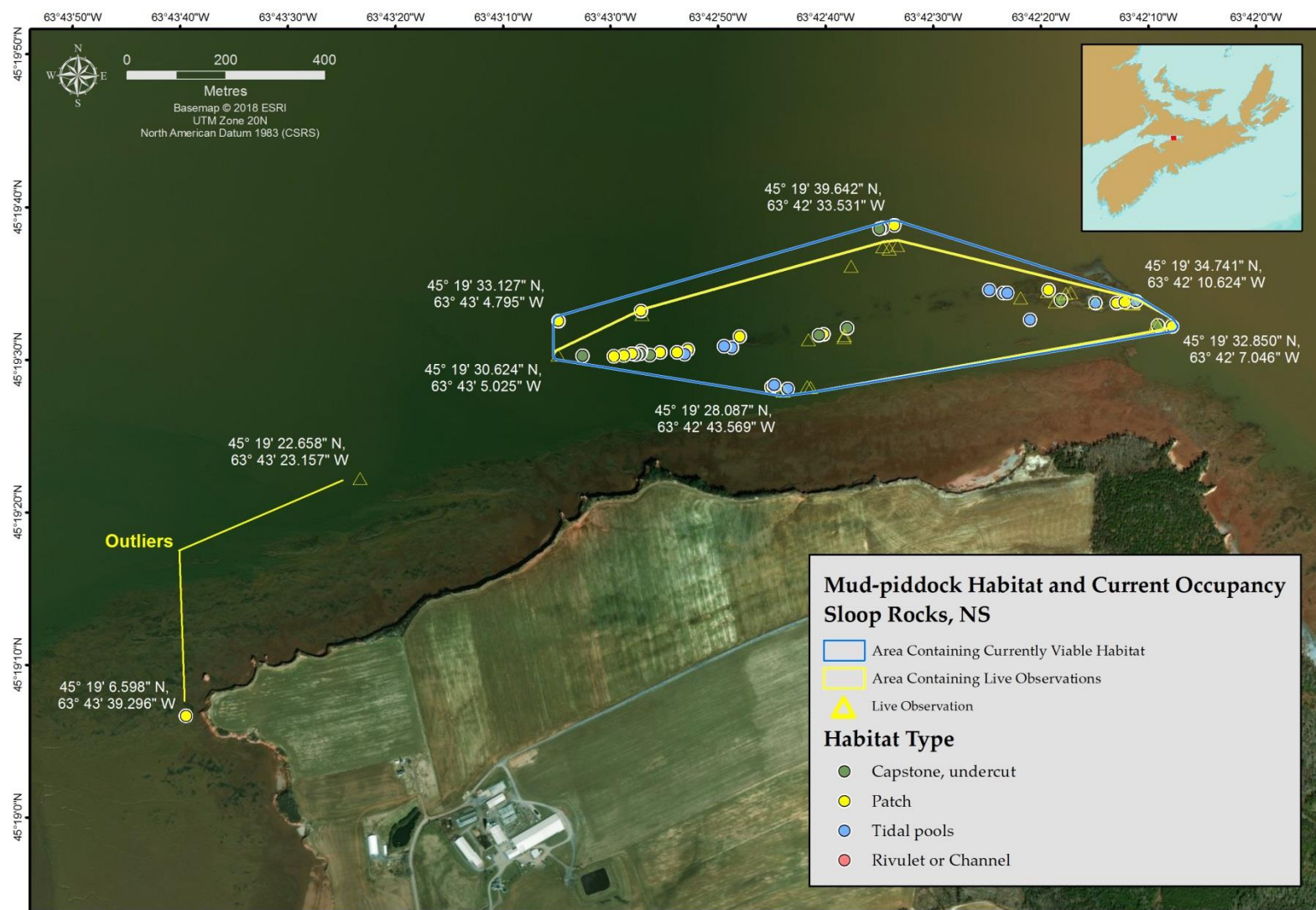


Figure 13. Current Mud-piddock occupancy and habitat (red mudstone) at Sloop Rocks.



Figure 14. Current Mud-piddock occupancy and habitat (red mudstone) at Shad Creek. Dynamic substrate denotes an approximate area of receding and accumulating sedimentation and cobbles that could have mudstone underneath.

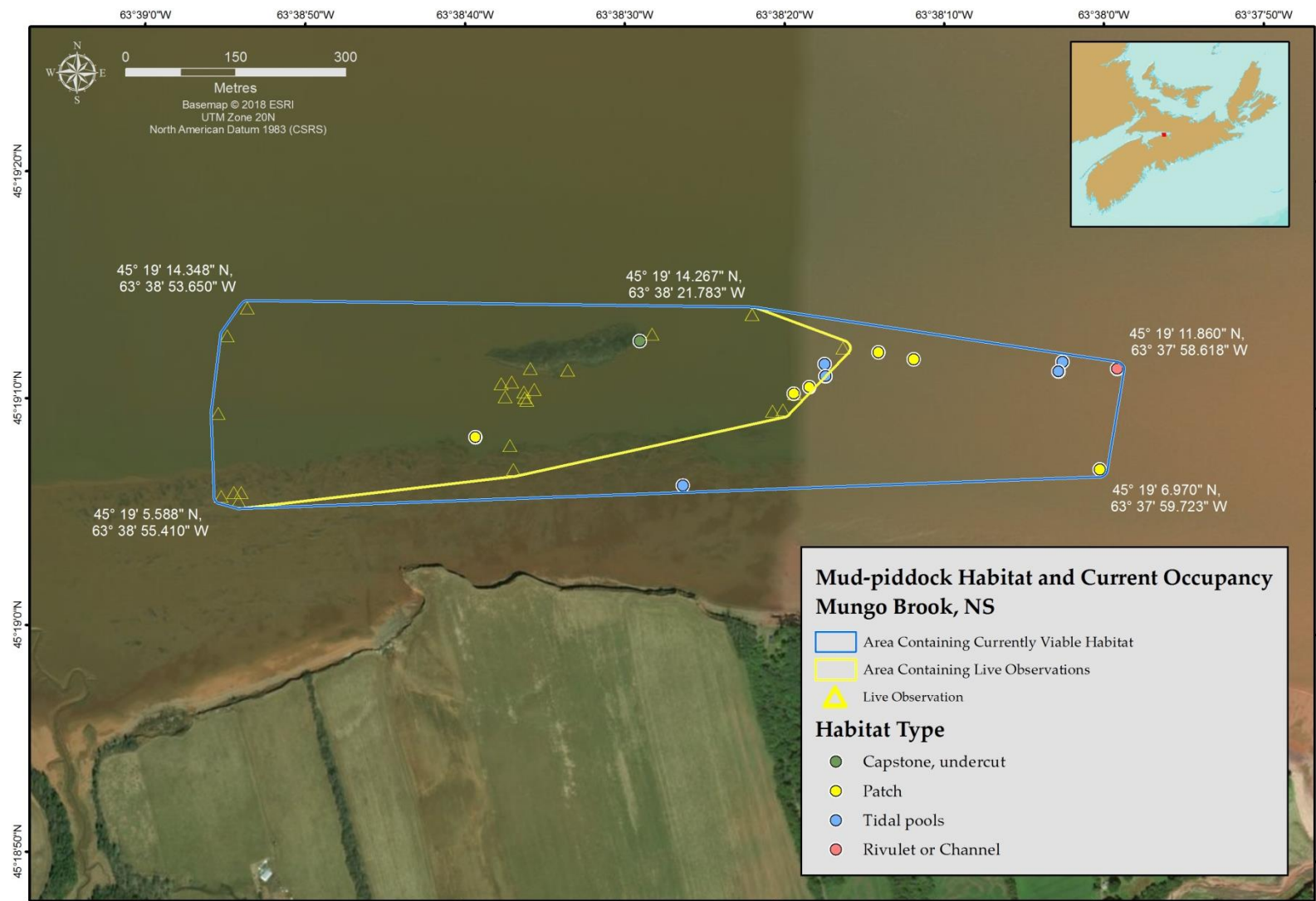


Figure 15. Current Mud-piddock occupancy and habitat (red mudstone) at Mungo Brook.

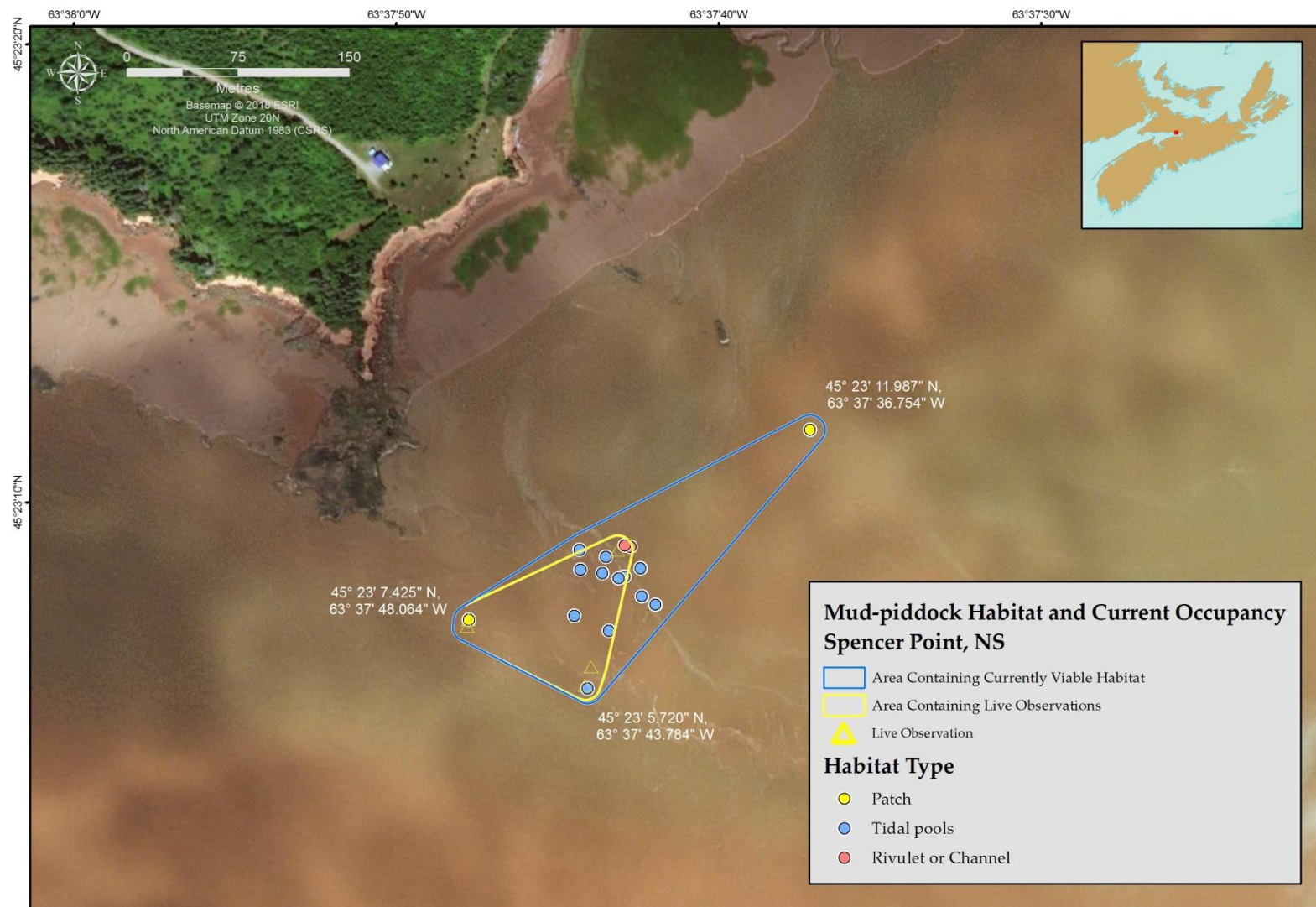


Figure 16. Current Mud-piddock occupancy and habitat (red mudstone) at Spencer Point.

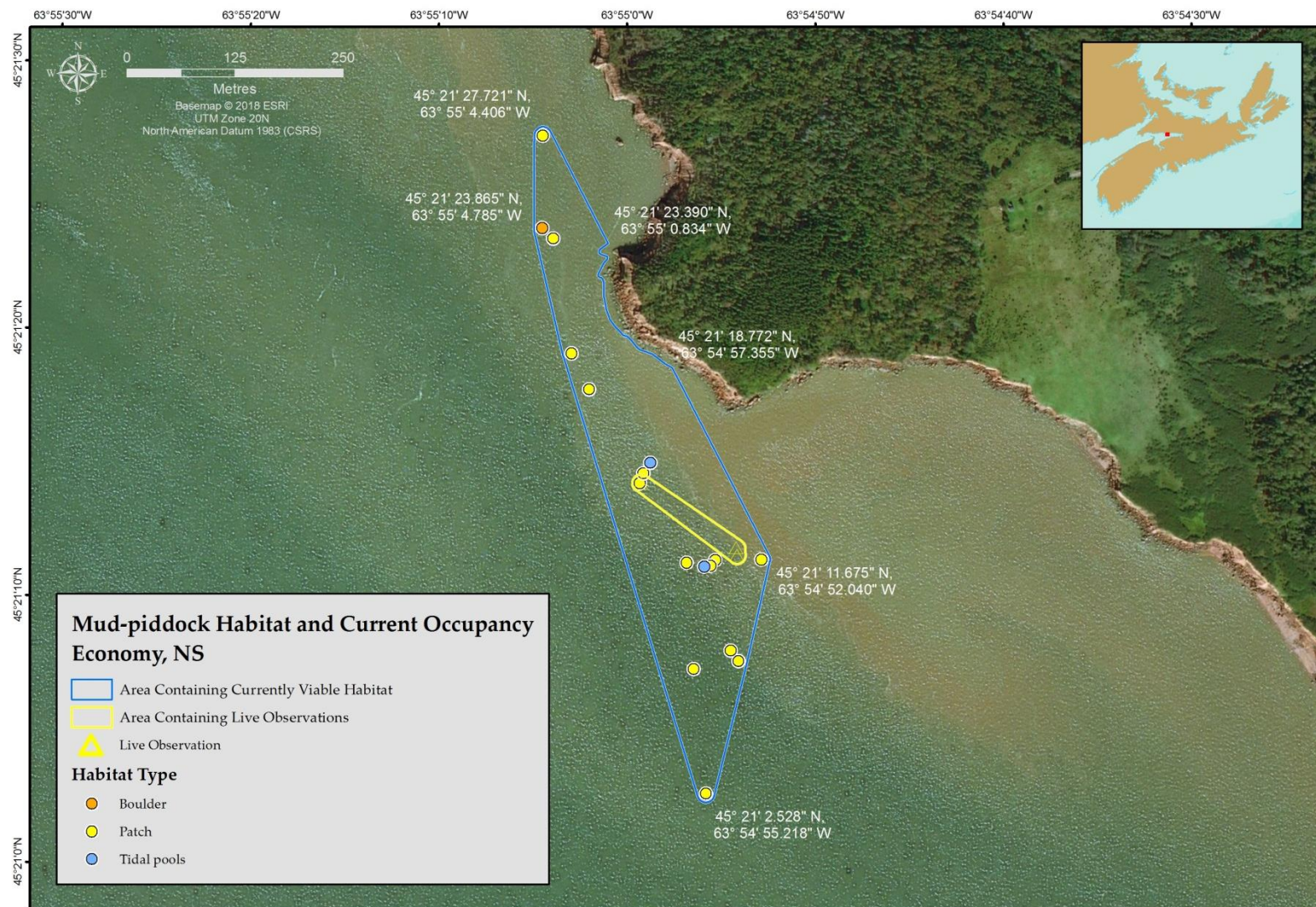


Figure 17. Current Mud-piddock occupancy and habitat (red mudstone) at Economy Point.

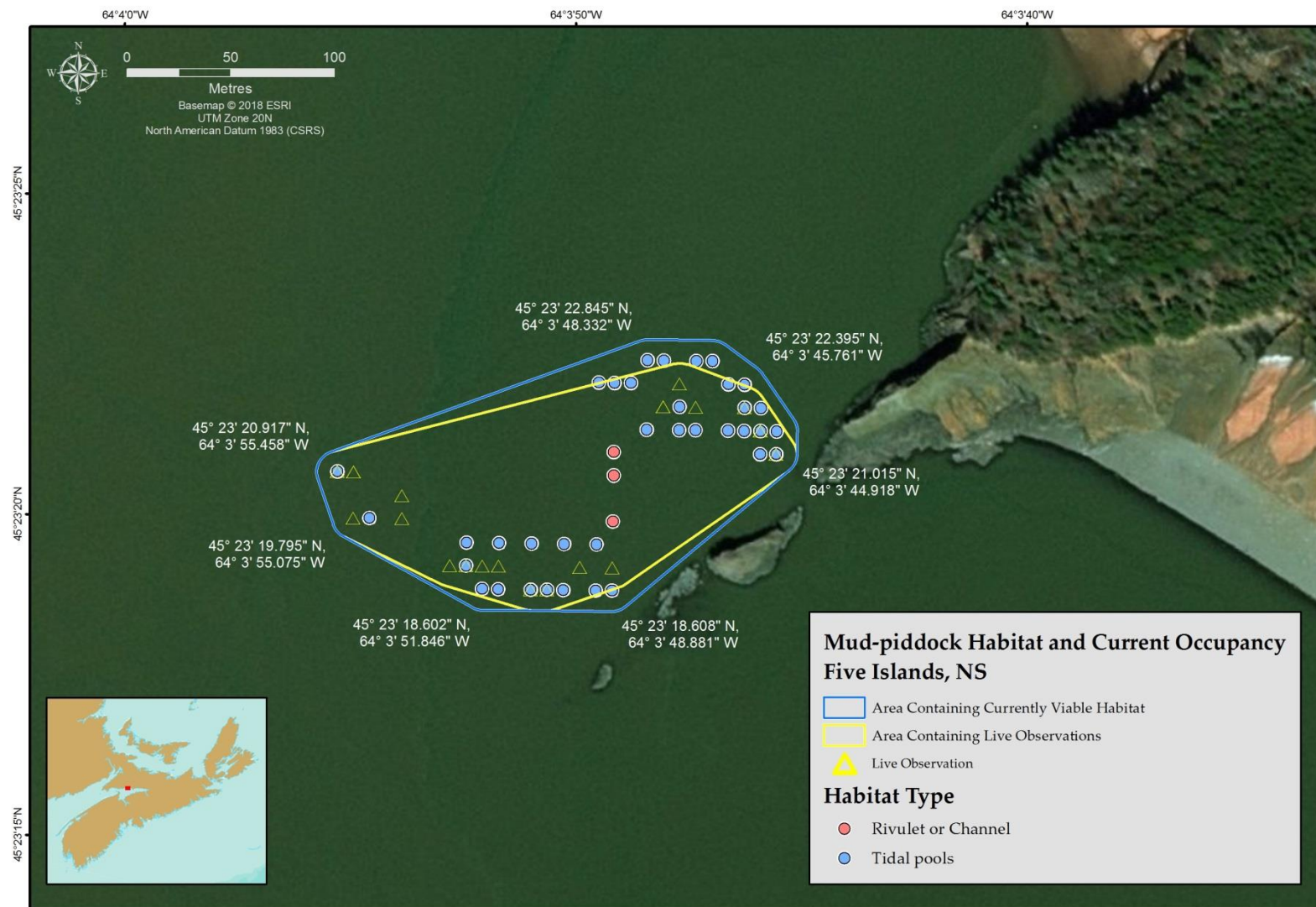


Figure 18. Current Mud-piddock occupancy and habitat (red mudstone) at Five Islands.



Figure 19. Current Mud-piddock occupancy and habitat (red mudstone) at Parrsboro.