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INFORMATION ON POTENTIAL SENSITIVE BENTHIC AREAS IN THE BAY OF FUNDY: HEAD HARBOUR/WEST ISLES/PASSAGES AND THE MODIOLUS REEFS, NOVA SCOTIA SHORE

Context

In 2012, a number of Ecologically and Biologically Significant Areas (EBSA) were identified in the Bay of Fundy through the DFO Maritimes Region Science Advisory Process (DFO 2012; Buzeta 2014). In 2013, Resource Management requested DFO Science advice on the following question, "What coordinates would enclose the portions of the EBSAs listed below that meet the criteria for sensitive benthic areas (SBAs) (as described in the Sensitive Benthic Areas Policy)?

- Head Harbour/West Isles/Passages
- Modiolus Reefs, Nova Scotia Shore"

A Science Response process was used to respond to this request, as this response was only intended as a summary of the available information on the characteristics of each EBSA that would warrant its consideration under the SBA Policy.

A review of the available information indicates that the Head Harbour/West Isles/Passages EBSA has a number of features that support its consideration under the SBA Policy. Vulnerable structure-forming invertebrates, which have significantly declined in the Bay of Fundy, are present. A fragile tube-dwelling anemone is present. A new, endemic species of encrusting sponge has been recorded in the area. Geographically rare sponge species and a rare anemone species are present. While there is some information available on the predicted distribution of upright and massive sponges, many of which are not considered to be vulnerable to bottom contact fishing, there is a lack of spatial data on vulnerable benthic species. For this reason, precise coordinates for a potential SBA could not be provided at this time. Research is required to further understand the relationship between the predicted sponge distribution and the distribution of vulnerable species in order to more precisely map an SBA within the Head Harbour/West Isles/Passages EBSA.

A review of the available information suggests that the Modiolus Reefs, Nova Scotia Shore EBSA has features, specifically the reef feature and associated benthic community, that support its consideration under the SBA Policy. Information on the location of horse mussel (*Modiolus modiolus*) reefs in this area has been inferred through visual inspection of multibeam bathymetry and backscatter strength maps, as well as some analysis of visual and physical sampling collected in 2011.

This Science Response Report results from the Science Response Process of 17 June, 2014, on the Delineation of Sensitive Benthic Areas in the Bay of Fundy.

Background

The Policy for Managing the Impacts of Fishing on Sensitive Benthic Areas (herein referred to as the SBA Policy) was published in 2009 as part of DFO's Sustainable Fisheries Framework. It was intended to help DFO manage fisheries to mitigate impacts of fishing on SBAs or avoid impacts of fishing that are likely to cause serious or irreversible harm to sensitive marine habitat, communities or species. SBAs are areas that are vulnerable (i.e. at risk of serious or irreversible harm) to a proposed or ongoing fishing activity (including direct impacts, such as bottom contact, and indirect impacts, such as sediment resuspension) and are ecologically or biologically significant. The SBA Policy outlines processes for assembling information on benthic habitat, communities and species; assessing that information to determine the ecological and biological significance of the benthic features and to determine the risk of serious or irreversible harm from fishing; and taking appropriate management decisions, using an ecosystem approach and applying a Precautionary approach. Evaluating an areas' degree of sensitivity and susceptibility to fishing activities will be determined based on the level of harm that the fishing activity may have on the benthic area by degrading ecosystem functions or impairing productivity.

In the initial application of the SBA Policy, sponges have been accorded national priority for risk assessment. However, in addition to sponges, this response also summarizes information on other sensitive marine habitats, communities or species.

The SBA Policy is consistent with the United Nations Resolution 61/105 to provide enhanced protection to marine habitats that are particularly sensitive (referred to as vulnerable marine ecosystems or VMEs). To assist in the implementation of this resolution, International Guidelines for the Management of Deep-Sea Fisheries in the High Seas (FAO 2009) provided criteria for the identification of VMEs based on the characteristics that it possesses. The following five criteria were recommended to be used when assessing an area as a VME: i) Uniqueness; ii) Functional significance of the habitat; iii) Fragility; iv) Life-history traits of component species that make recovery difficult; and v) Structural complexity. Species classified as a VME indicator meet the criteria based on traits related to functional significance (e.g., form structural habitats), fragility, and the life-history traits of component species that produce a slow recovery from disturbance (Murillo et al. 2011). Benthic qualities of an EBSA that meet the VME criteria are considered here to be indicative of an SBA.

Analysis and Response

Head Harbour/West Isles/Passages

The Head Harbour/West Isles/Passages area (Figure 1, Table 1) was identified as an EBSA (DFO 2012) for a variety of reasons, including high levels of benthic biodiversity; aggregations of zooplankton, fish, birds, and marine mammals; the presence of juvenile fish, avian and mammalian species; and the associated fitness consequences (Buzeta 2014). The Head Harbour/West Isles/Passages area also supports several species at risk (harbour porpoise, North Atlantic right whale, Atlantic wolffish) and ecologically significant species (rockweed, krill). The persistent structural, environmental, and oceanographic features that support a complex food web are not generally found elsewhere in the Bay of Fundy (Buzeta 2014). The Head Harbour/West Isles/Passages EBSA is characterized by estuaries and islands with a complex hydrological and geological regime (Brooks et al. 1999) encompassing a large tidal range, complex benthic topography, strong currents, and upwelling. This region of the outer Bay of Fundy supports a rich pelagic food web, and contains rock walls supporting dense epifauna (Lawton 1992; Thomas 1994), including rare and previously undescribed sponge species (Ginn et al. 2000) and diverse assemblages of invertebrates. Given that the Head Harbour/West Isles/Passages EBSA includes qualities that are not benthic or likely to be vulnerable to the impacts of fishing, it is unlikely that the entire Head Harbour/West Isles/Passages EBSA will be an SBA.

Figure 1. Approximate boundaries for the Head Harbour/West Isles/Passages EBSA as described by Buzeta (2014). Underlying layers are Electronic Navigation Charts 476035, 376330 and 276260.

Table 1. Approximate latitudinal and longitudinal coordinated of the Head Harbour/West Isles/Passages EBSA.

Latitude	Longitude
44.908	-66.967
44.944	-67.006
44.976	-66.961
45.033	-66.968
45.079	-66.918
45.023	-66.831

Vulnerable Marine Ecosystem Criteria

Information on vulnerable habitats, species and communities found within the Head Harbour/West Isles/Passages EBSA is summarized according to the VME criteria (FAO 2009). This information was primarily extracted from M. Buzeta's work on EBSAs in the Bay of Fundy and includes benthic evidence as well as support for the overall uniqueness of the area (Buzeta 2014).

Uniqueness or Rarity

The combination of oceanographic features (strong tidal currents, turbulence and upwelling) and the high diversity of benthic fauna, marine mammals, and avifauna compacted into a small area make this area significant and ecologically unique (Gaskin 1977; Larsen 2004; P. Larsen, pers. comm.; Buzeta et al. 2003; AECOM 2011; G. Pohle, pers. comm.).

Statistical analyses of benthic survey data collected by MacKay et al. (1978a-c, 1979a, b) and MacKay and Bosien (1979) identified the West Isles as having higher than average species richness, which was significantly correlated to environmental factors (temperature, salinity) and benthic complexity (Greenlaw et al. 2007a-b). This led to the conclusion that these persistent features, as well as additional factors (current speed, dispersal and colonization processes), provide suitable habitat for more species (Buzeta 2008). This highly diverse benthic community does not appear to be generally distributed throughout the Bay of Fundy (P. Larsen, pers. comm.; MacKay et al. 1978c; Lawton 1992, 1993; Buzeta 2008).

A new species of encrusting sponge (*Hymedesmia canadensis*), currently only recorded from the Head Harbour/West Isles/Passages region, was described by Ginn (1997), Ginn et al. (1998) and Ginn et al. (2000). This species was frequent in occurrence (25-49 individuals observed per 30 min dive), where it was recorded at depths ranging from 7 – 23 m, inhabiting the shells of barnacles (*B. crenatus*). Limited information is available on the spatial distribution and life history of this rare, endemic sponge species.

There are a number of geographically rare species found in the Head Harbour/West Isles/Passages area, including three species of sponges: *Myxilla fimbriata*, *Hymeniacidon heliophila*, *Hemigellius* sp. aff. *flagellifer* (Ginn et al. 1998), and a deep-burrowing anemone, *Edwardsia elegans* (MacKay et al. 1978a, b; M. Strong and M-I Buzeta, unpublished dive and video logs). The Head Harbour/West Isles/Passages area is the only known location in the Bay of Fundy for *Myxilla fimbriata*, *Hymeniacidon heliophila*, *Hemigellius* sp. aff. *flagellifer*, although they are known in the areas stretching from the Arctic to Cape Cod (Ginn et al. 1998).

Functional Significance of the Habitat

Two of the larger ascidian species, the sea peach (*Halocynthia pyriformis*) and the sea squirt (*Boltenia ovifera*), are possible ecologically significant species. For each group, it is the dense aggregations (beds/fields) that are considered to be VME in order to establish functional significance. Locations of high local population densities provide additional habitat and a protective canopy for juvenile cod (*Gadus morhua*; M. Strong and M-I Buzeta, unpublished dive and video logs; D. Methven, pers. comm.). *B. ovifera* spawns in early January, and recent settlers have been observed on stalks of adults in February (Lacalli 1980). The species is also colonized by various small invertebrates (Plough 1969, 1978). In the nearshore Scotian Shelf, Francis et al. (2014) found 22 species of invertebrate and algal taxa growing on specimens of *B. ovifera*. The stalk and tunic of an individual provide a firm substrate for epibiotic algae and filter-feeding invertebrates (e.g., sponges, anemones, and hydroids) that also may benefit from increased water flow by being elevated above bottom (Francis et al. 2014). The small cactus tunicate (*Boltenia echinata*) was found on *B. ovifera* by Francis et al. (2014). Francis et al. (2014) also found that polychaetes occurred in the holdfasts of some specimens of *B. ovifera*, suggesting the holdfasts provide shelter for these and other small invertebrates (Ackley and Witherell 1999; Stevens 2003). Larger specimens of *B. ovifera* hosted more epibiont species, likely due to their greater age and increased surface area and holdfast size for colonization.

Modiolus modiolus (horse mussel) can form significant, long-lived structures (mussel reefs). Their longevity, and byssal attachment mode leads to the formation of a cohesive matrix of gravels, cobbles, and boulders which may help increase the resilience of these habitats to physical disturbance (P. Lawton, pers. comm.). Modiolus also provide habitat for other species, and are expected to house > 50 species living externally on a Modiolus reef (M. Owen, pers. comm.) Again, it is the dense aggregations (beds/fields) that are considered to be VME in order to establish functional significance.

Removal of *Cerianthus borealis* fields may disrupt benthic assemblages as cerianthid predation of scallop and sabellid worm larvae has been hypothesized as an important factor in controlling their spatial distribution (Langton and Robinson 1990).

Simpsons Island Cove is rich in benthic finfish, including small aggregations of winter flounder (*Pseudopleuronectes americanus*), juvenile cod, juvenile and ripe redfish (*Sebastes fasciatus*), and spawning and spent lumpfish and their egg masses. Aggregations of juvenile groundfish species (cod, redfish, cunner) are observed among the islands (Mowatt, Sandy, Casco, Simpsons) within Head Harbour/West Isles/Passages area where they occupy rock wall and cave habitats (M. Strong and M-I Buzeta, unpublished dive and video logs). The presence of juvenile and ripe redfish, spawning and spent lumpfish and their egg masses at Simpson, Mowatt, Sandy, and Casco Islands is known locally and was verified during spot dives (M. Strong and M-I Buzeta, unpublished dive and video logs). Spawning of lumpfish is known to occur in shallow water on rocky substrates and the males guard the egg mass for 6-8 weeks (Daborn and Gregory 1983). Local knowledge, surveys, and video observations suggest the Head Harbour/West Isles/Passages area may contribute to the life cycle of a high number of species.

Sponge species form thick encrustations, mounds, and branched, barrel or fan-like shapes that influence near-bottom currents and sediment patterns. They provide substrate for other species and offer shelter for associated fauna through the provision of holes, crevices and spaces (DFO 2010). In laboratory studies, juvenile cod mortality was lower (50%) on cobble habitat with sponges habitat than on bare cobble, with density more important than height (Lindholm et al. 1999). Cod survivorship was lowest on habitats that emulated chronic fishing impacts to the bottom, and highest for the habitat with the highest density of structures. Within the Head Harbour/West Isles/Passages EBSA areas of higher current velocity are expected to have the highest abundance of large sponges, due to the lack of sedimentation on hard substrates (Bell and Barnes 2000). In Little L'etete Passage, Ginn et al. (2000) identified 16 sponge species. Increased upright (e.g., *Haliclona oculata*) and massive (e.g., *Myxilla* spp.) sponge cover in the Quoddy Region was positively correlated to depth (up to 25 m), current velocity (up to 75-125 cm/s) and topography (hard bottom, vertical rock slope, boulder sides, and cliff sides). Buzeta (2008) also showed that areas within the EBSA with vertical orientation were found to have higher sponge diversity.

Fragility

The structure-forming invertebrates *Boltenia ovifera* (sea squirt) and *Modiolus modiolus* (horse mussel) are expected to be at risk of serious or irreversible harm from bottom-contact fishing. These species have significantly declined in the Bay of Fundy over a 30 year period, from 1966-67 to 1997, due to the cumulative impacts of bottom-contact fishing in the area (Kenchington et al. 2007).

Boltenia ovifera (sea squirt) are structure-forming invertebrates that attach to the sea bottom by a stalk which raises them off the sea floor (>5 cm) and consequently makes them vulnerable to bottom-contacting fisheries. In Head Harbour, analysis of remotely-operated video survey transects revealed high local densities of *Boltenia ovifera* (G. Pohle, pers. comm.). Similar observations have been obtained using other remotely-operated video surveys in the Head Harbour/West Isles/Passages area (P. Lawton, unpublished video logs).

From 1971 until the mid-1980s, large horse mussels were regularly collected in this region during drags on rocky substratum; however, surveys conducted in 2011 around Greens Point and the ledges adjacent to Whitehorse Island did not yield any horse mussels (M. Owen, pers. comm.). Their absence may be interpreted as an indicator of repeated disturbance of the benthic substrata by drag fisheries, as they remain reasonably common in vertical rock walls (M. Owen, pers. comm.).

Cerianthus borealis (tube dwelling anemone) protrude up to 20 cm above the seafloor and are known to be easily damaged by bottom contact fishing gear (Langton and Robinson 1990; Fuller et al. 2008).

Life-History Traits of Component Species that Make Recovery Difficult

Boltenia ovifera are functionally fragile with poor regeneration abilities (>20 years) and are listed as a VME indicator species (Murillo et al. 2011).

Modiolus modiolus is considered long lived (up to 100 years; MacDonald 1996). In the Irish Sea, no recovery was evident after one year for horse mussels when only a single trawl was conducted and significantly fewer infaunal taxa (polychaetes, malacostracans, bivalves and ophuroids) were recorded (Cook et al. 2013). Contributing to Modiolus' longevity are slow growth rates and a late age of maturity. In the North Sea, the fastest growth rate of *Modiolus* was 110 mm within 10 years, while the slowest achieved a shell length of 43 mm at eight years old. Mussels did not reach sexual maturity until they reached about 35-40 mm in shell length, when they were four and six years old (Jasim and Brand 1989). In advance of sexual maturity, mussels were able to devote a greater proportion of their energy resources to rapid somatic growth. However, these small but fast-growing mussels were selectively consumed by a variety of benthic predators particularly crabs and starfish. Only when the mussels had escaped predation by effectively growing beyond the size range most vulnerable to attack was energy redirected towards reproductive development. Thereafter, these larger slower-growing, essentially predator-free, mussels then survived for many years (Anwar et al. 1990).

A list of known sponge species present in the Head Harbour/West Isles/Passages area (Table 2) was compiled to assess their VME characteristics. A review of their characteristics indicated that most of these sponges are relatively fast growing with a well-developed ability to regenerate after physical damage (O. Tendal, State Natural History Museum, University of Copenhagen, pers. comm.). Again, little information is available on the life history of *Hymedesmia canadensis*. There is some evidence that *Cliona* spp. may exhibit life-history traits that make recovery difficult. *Cliona* spp. is in decline elsewhere in the Bay of Fundy, (Kenchington et al. 2007). Similar to *Boltenia ovifera* and *Modiolus modiolus*, this decline may be associated to the cumulative impacts of bottom-contact fishing in the area. The lifespan of *Ceranthius borealis* is also unknown.

Structural Complexity

Modiolus modiolus (horse mussel) can form significant, long-lived structures (mussel reefs) creating high levels of physical complexity which supports a diverse epifaunal community (hydrozoans, bryozoans, and barnacles), as well as, a rich infauna, epifauna, and crevice fauna of 200-300 species (M. Owen, pers. comm.; Cook et al. 2013). Localized areas within the Head Harbour/West Isles/Passages have extensive reef formations (G. Pohle, Unpublished video logs). In shallower sub-tidal areas, even though they may not form extensive reef systems, horse mussels still play a role as “ecosystem engineers” in coastal cobble boulder habitats (P. Lawton, unpublished video logs).

Ceranthius borealis are larger in size and form dense aggregations, and occurrence on relatively featureless sandy or muddy bottoms, renders them key structure-forming species (Fuller et al. 2008). Late juvenile redfish have been associated with dense patches of cerianthid anemones in the Gulf of Maine. The fish may use cerianthid habitats on an encounter basis or they may serve as a protective corridor for moving between boulder sites (Auster et al. 2003).

Generally, the Passages have complex vertical walls rich in biota (Thomas 1983) demonstrated by video surveys along Big Letete Passage (Lawton 1992, 1993).

The high level of benthic species diversity, including several species of sponges (Table 2), has been suggested to be a result of availability of substrate, higher complexity, and the distribution of this substrate within a matrix of soft sediments (Hubbell 2001). Both topographic complexity, and species richness estimated from abundance data along benthic transects (MacKay et al. 1978a-c, 1979a, b; MacKay and Bosien 1979), were higher in this region than in adjacent regions (Buzeta and Singh 2008), with a strong correspondence between the two (Greenlaw et al. 2007a-b).

Location Information

Hymedesmia canadensis was recorded at depths ranging from 7 – 23 m, inhabiting the shells of barnacles (*B. crenatus*) (Ginn 1997, Ginn et al. 1998, and Ginn et al. 2000). Limited information is available on the spatial distribution and life history of this rare, endemic sponge species. Little information is also known about the distribution of *Cliona*, and the geographically rare sponge species *Myxilla fimbriata, Hymeniacidon heliophila*, *Hemigellius* sp. aff. *flagellifer*.

B. ovifera has been found on hard substrates at 30 – 320 m of depth (Plough 1969, Murillo et al. 2011). The strong association of *B. ovifera* with bedrock and boulders reflects the species requirement of hard substrata for settlement and attachment (Witman 1985, Kenchington 1999).

The most extensive information on sponge distribution in the Head Harbour/West Isles/Passages area to date is presented on the expected upright and massive sponge habitat map (Figure 2) created from SCUBA diving-based surveys (MacKay et al. 1978a, b; Logan 1988; Ginn 1997; P. Lawton unpublished dive logs). There has been relatively little survey effort (either at specific locations or in a geographically extensive manner) at depths greater than 25 m using other sampling approaches (e.g., remotely-operated video surveys). However, the greatest numbers of sponges are expected to be found on firm surfaces such as rocks (Ginn et al. 2000; Weaver et al. 2007), within an initial depth distribution to 25 m(Ginn 1997). The map of expected sponge habitat was created by intersecting the common areas between exposed bedrock and boulder habitat (Schumacher et al. unpublished manuscript; Figure 3), and areas between 5 and 30 meters of depth (Greenlaw et al. unpublished manuscript; Figure 3). This approach removes the bias towards historical and possibly temporally variable sampling data. These areas show a high degree of overlap with areas that have an abundance of upright and branching sponge species (Figure 4). It is possible that the available sponge habitat exceeds this depth range; however, past these depths the sea bed is expected to be soft sediment-dominated and likely supports a lower abundance of sponges. Within the box outlined in Figures 3 and 4, predictions of bedrock are less confident due to the absence of multibeam data in that portion of the region. It is expected that there will be a variety of substrate grain sizes present within this box.

The expected spatial distribution of other vulnerable features within the Head Harbour/West Isles/Passages EBSA could not be provided at this time.

The series of predicted sponge distribution maps provided in this report are not expected to coincide with the precise boundaries of an SBA, as not all sponges are considered vulnerable to fishing, and there are other non-sponge features (e.g., horse mussels and sea squirts) that are considered vulnerable to fishing but that have not been mapped. The sponge maps provided may be used when approximating SBA boundaries within the Head Harbour/West Isles/Passages EBSA in the future; however, this would require evidence that vulnerable sponge and non-sponge species follow a similar pattern of distribution. Further investigation of the spatial patterns of vulnerable benthic species in the region is required to provide precise coordinates for the portions of the Head Harbour/West Isles/Passages EBSA that would be considered an SBA.

Table 2. Sponges and structure forming invertebrates in the Head Harbour/West Isles/Passages EBSA. Details on sampling protocols for published studies may be found in the references cited. Lawton (unpublished) refers to initial species identifications from video data collected during tests of a surface-deployed video camera system. Species that met at least one Vulnerable Marine Ecosystem (VME) criteria (uniqueness or rarity, functional significance of the habitat, fragility, life-history traits that make recovery difficult, or structural complexity) are highlighted in bold. (na=not assessed, ns=not seen)

Morphotype	Ginn 1997 (Little Letete)	Logan 1988 (Head Harbour)	MacKay 1978 a-c	Lawton (unpublished)	Characteristics
Upright Sponges	*Isodictya palmata*	*Isodictya palmata*	Isodictya-like	ns	30 cm, common, subtidal, rock, broad branching (MacKay 1978c)
	Isodictya deichmannae	ns	ns	ns	unknown
	Haliclona oculata	*Haliclona oculata*	*Haliclona oculata*	*Haliclona*	50 cm, broad branching, common subtidal, rock (MacKay 1978c)
	ns	*Leucosolenia* sp.	*Leucosolenia* sp.	ns	10 cm, branching colonies, not common, subtidal under rocks (MacKay 1978c)
	ns	*Suberites* sp.	Suberites-like	ns	15 cm, bulb like or pear shaped, not common, subtidal rock (MacKay 1978c)
	ns	ns	*Scypha ciliata/ Sycon ciliatum*	ns	Grows from single holdfast, up to 8 cm long, common, underside of rocks (MacKay 1978c)
	ns	*Microciona prolifera* (red beard)	ns	ns	20 cm, branching (Biernbaum 1981)
Massive Sponges	*Eumastia sitiens*	*Pellina sitiens*	ns	*Pellina sitiens*	unknown
	Myxilla incrustans	ns	Myxilla-like	ns	30 cm, round, massive, common, subtidal rock (MacKay 1978c)
	Myxilla fimbriata	**ns**	**ns**	**ns**	**geographically rare (Ginn et al. 1998)**
	Hymeniacidon heliophila	**ns**	**ns**	**ns**	**geographically rare (Ginn et al. 1998)**
	Mycale lingua	*Mycale lingua*	ns	ns	could be very large, could live up to 20 years, common in water 35+ m, often up to 40 cm high/wide or larger (Ginn 1997)
	ns	*Tedania suctoria*	ns	ns	unknown
	Hemigellius* sp. aff. *flagellifer	**ns**	**ns**	**ns**	**geographically rare (Ginn et al. 1998)**

Table 2 (cont.). Sponges and structure forming invertebrates in the Head Harbour/West Isles/Passages EBSA. Details on sampling protocols for published studies may be found in the references cited. Lawton (unpublished) refers to initial species identifications from video data collected during tests of a surface-deployed video camera system. Species that met at least one Vulnerable Marine Ecosystem (VME) criteria (uniqueness or rarity, functional significance of the habitat, fragility, life-history traits that make recovery difficult, or structural complexity) are highlighted in bold. (na=not assessed, ns=not seen)

Morphotype	Ginn 1997 (Little Letete)	Logan 1988 (Head Harbour)	MacKay 1978 a-c	Lawton (unpublished)	Characteristics
Encrusting Sponges	*Halichrondria panacea*	*Halichrondria panacea*	*Halichrondria panacea*	*Halichrondria panacea*	30 cm, encrusting, common, intertidal, subtidal, rock, mud, under rocks, shells (MacKay 1978c)
	Haliclona loosanoffi	*Haliclona loosanoffi*	ns	ns	unknown
	Haliclona canaliculata	*Haliclona canaliculata*	ns	ns	unknown
	***n*s**	***Cliona* sp.**	***Cliona* sp.**	**ns**	**In decline, variable size, encrusting, not common, subtidal, rock (MacKay 1978c; Kenchington et al. 2007)**
	ns	*Iophon pattersoni*	*Iophon* sp.	ns	Not common, 3cm, encrusting on Brachiopods (MacKay 1978b)
	Prosuberites epiphytum	ns	ns	ns	unknown
	Halichondria bowerbanki	*Halichondria bowerbanki*	Ns	ns	unknown
	Crella rosea	ns	ns	ns	Only recorded location in western Atlantic (Ginn et al. 1998) and possibly invasive (T. Theriault, pers. comm.)
	ns	*Microciona prolifera*	ns	ns	20 cm, encrust shells and pilings (Biernbaum 1981)
Structure-forming Cnidarians	na	*Tubularia* sp (Pink-hearted)	*Tubularia* sp (Pink-hearted)	na	6-10 cm, common, single polyps forming large clusters, rock (MacKay 1978c)
	na	*Campanularia*	*Obelia* hydroid	na	Common, 1 cm, branching stalks with small terminal polyps (MacKay 1978c)
	na	*Gersemia rubiformis*	*Gersemia* (soft coral)	na	8-10 cm, branching, common and abundant on rocks and tide pools (MacKay 1978c)
	na	*Halecium* sp	*Antennularia*	na	Common, 10-15 cm, single stalk with short branching, usually in clusters on rocks. Doesn't like strong currents (MacKay 1978c)
	na	ns	*Clava*	na	Not common, 5 mm, individual polyps in clusters (MacKay 1978c)
	na	*Corymorpha pendula*	*Corymorpha pendula*	na	5-6 cm, solitary polyp with root-like holdfast, common and abundant mud and sand (MacKay 1978a)
	na	ns	*Lucernaria quadricornis*	na	Not common, 6 cm, solitary, intertidal, rock (MacKay 1978c)

Table 2 (cont.). Sponges and structure forming invertebrates in the Head Harbour/West Isles/Passages EBSA. Details on sampling protocols for published studies may be found in the references cited. Lawton (unpublished) refers to initial species identifications from video data collected during tests of a surface-deployed video camera system. Species that met at least one Vulnerable Marine Ecosystem (VME) criteria (uniqueness or rarity, functional significance of the habitat, fragility, life-history traits that make recovery difficult, or structural complexity) are highlighted in bold. (na=not assessed, ns=not seen)

Morphotype	Ginn et al. 1997 (Little Letete)	Logan 1988 (Head Harbour)	MacKay 1978 a-c	Lawton (unpublished)	Characteristics
Structure-forming Hydroids	na	ns	*Hydractinia*	na	5 mm, not common, found on shells of Pagurus sp., subtidal (MacKay 1978c)
	na	***Cerianthus* sp. (*borealis*)**	***Cerianthus borealis***	**na**	**Not common, VME indicator species, fragile, tube dwelling in soft substrate of sand, up to 40 cm with tube, up to 20 cm above seafloor (MacKay 1978b; Fuller et al. 2008)**
	na	*Metridium senile*	*Metridium senile*	na	Abundant, 30 cm, growth rate 9cm/mo, like moderate to high currents (MacKay 1978c; Bucklin 1987)
	na	*Alcyonium digitatum*	*Alcyonium digitatum*	na	Common, 10cm soft coral, sand, mud, rock, large distribution (MacKay 1978c)
	na	ns	*Edwarsia elegans/ sipunculoides*	na	Geographically rare tube dwelling anemone, 9cm, sand (MacKay 1978c; Buzeta 2012)
Structure-forming Protochordates	**na**	***Boltenia ovifera***	***Boltenia ovifera***	**na**	**Abundant, VME indicator species, 30 cm, root-like holdfast, rocky (MacKay 1987c; Murillo et al. 2011)**
	na	***Boltenia echinata***	***Boltenia echinata***	**na**	**Common, hairy, usually covered with silt, 3 cm, rock (MacKay 1978c)**
	na	ns	*Halocynthia pyriformis*	na	Abundant, 10 cm, barrel shapes, rock (MacKay 1978c)
	na	ns	*Molgula*	na	2.5 cm, encrusted, ball shapes, rock (MacKay 1978c)
	na	*Dendrobeania*	ns	na	Common
	na	*Caberea ellisii*	ns	na	Common
	na	*Electra* sp	ns	na	Unknown
	na	*Bugula simplex*	ns	na	3 cm, colonies, not so common
Structure-forming Mollusca	**na**	***Modiolus modiolus***	***Modiolus modiolus***	**na**	**Common, long lived (up to 100 years), fragile, slow to recover, abundant, rock, mud, sand (MacKay et al. 1978a-c, MacDonald 1996, Cook et al. 2013)**

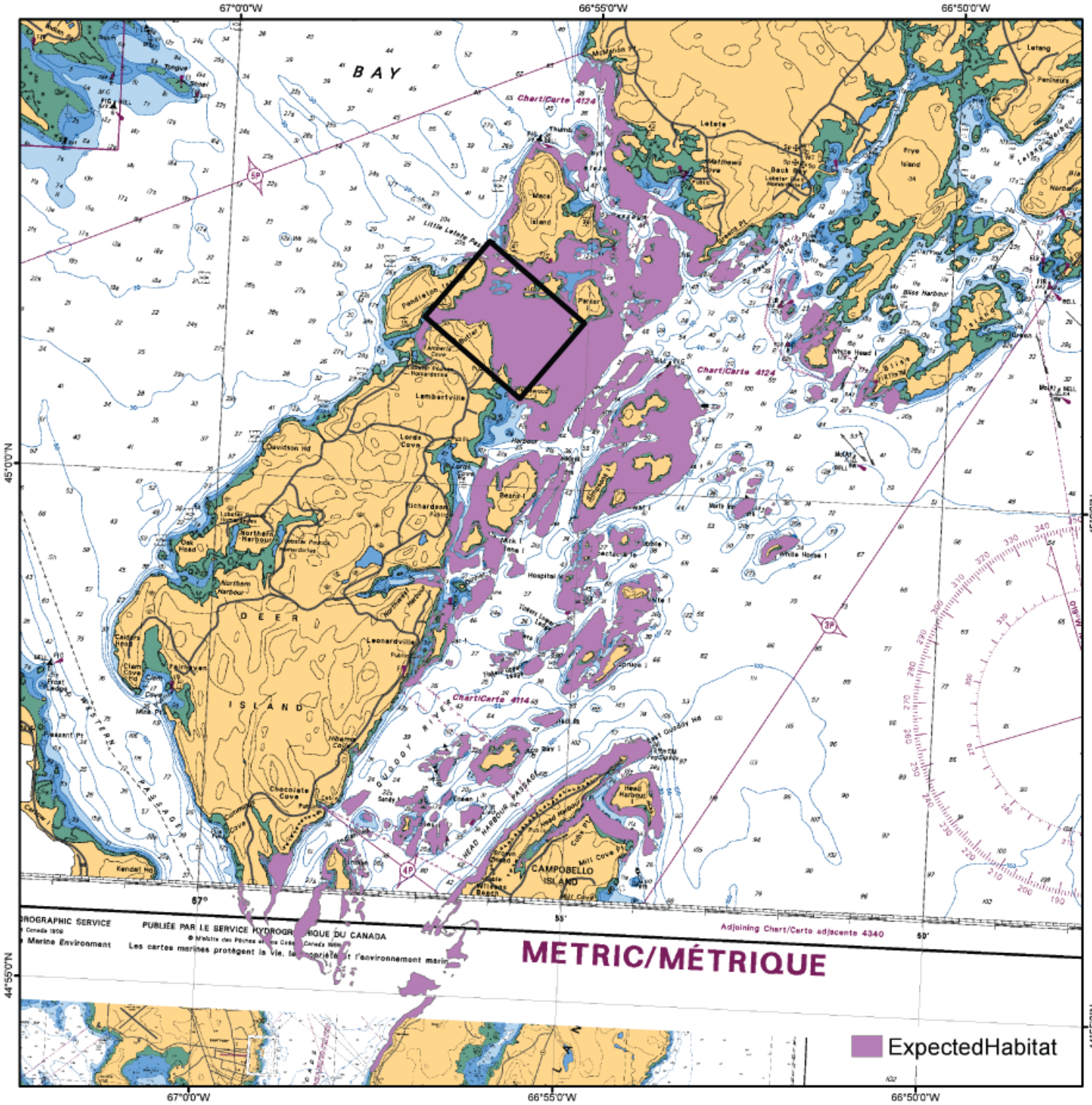

Figure 2. Expected significant upright and massive sponge habitat map, created by taking the area in common between exposed bedrock and boulder habitat (Schumacher et al. unpublished manuscript), and areas between 5 and 30 meters of depth (Greenlaw et al. unpublished manuscript). The black box outlines the area that is less confident in the prediction of bedrock, due to the unavailability of multibeam data in that area.

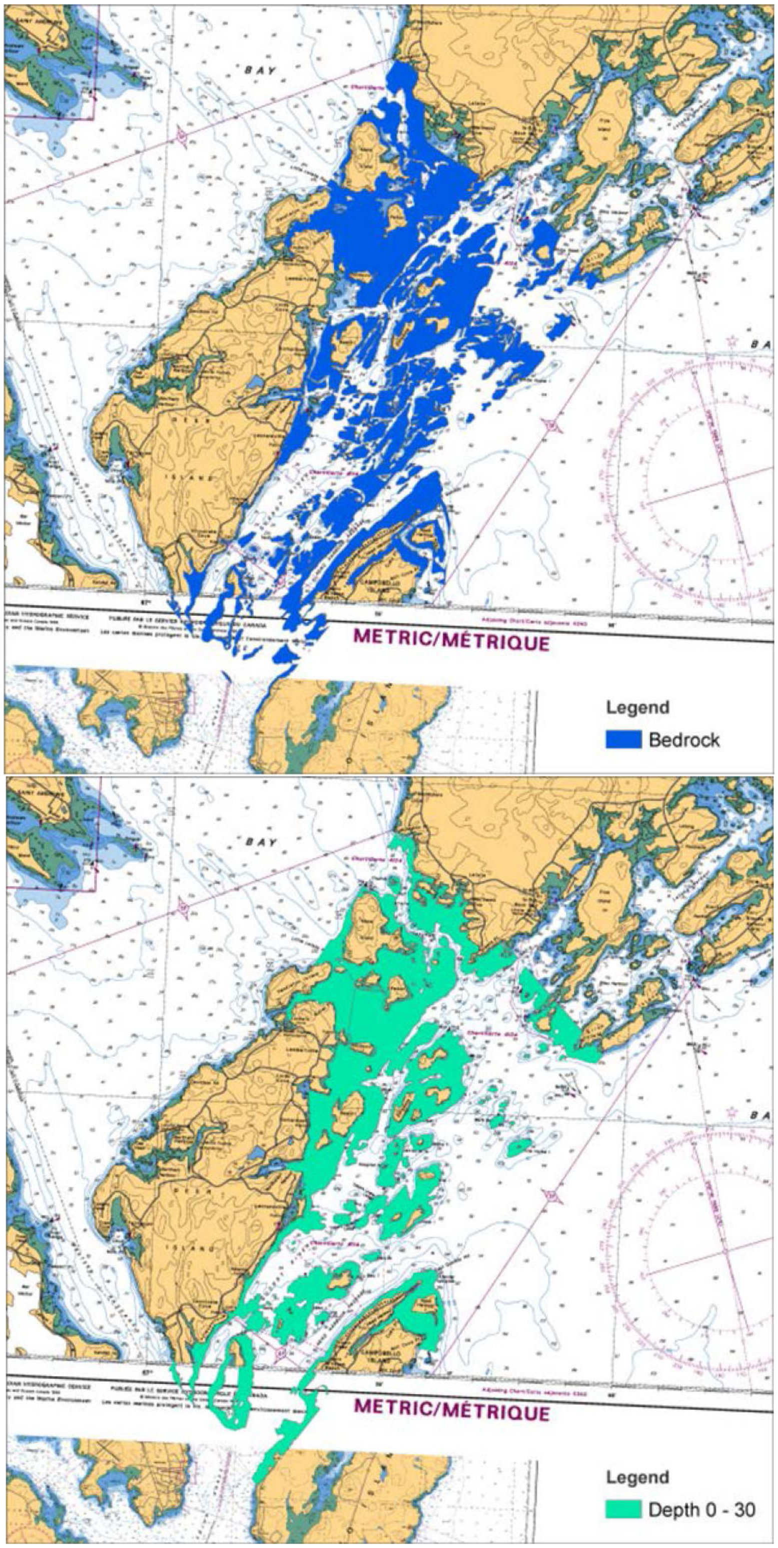

Figure 3. Bedrock (top) and depth from 0 – 30 m (bottom) layers were intersected to create the expected upright and massive sponge habitat map (Figure 2).

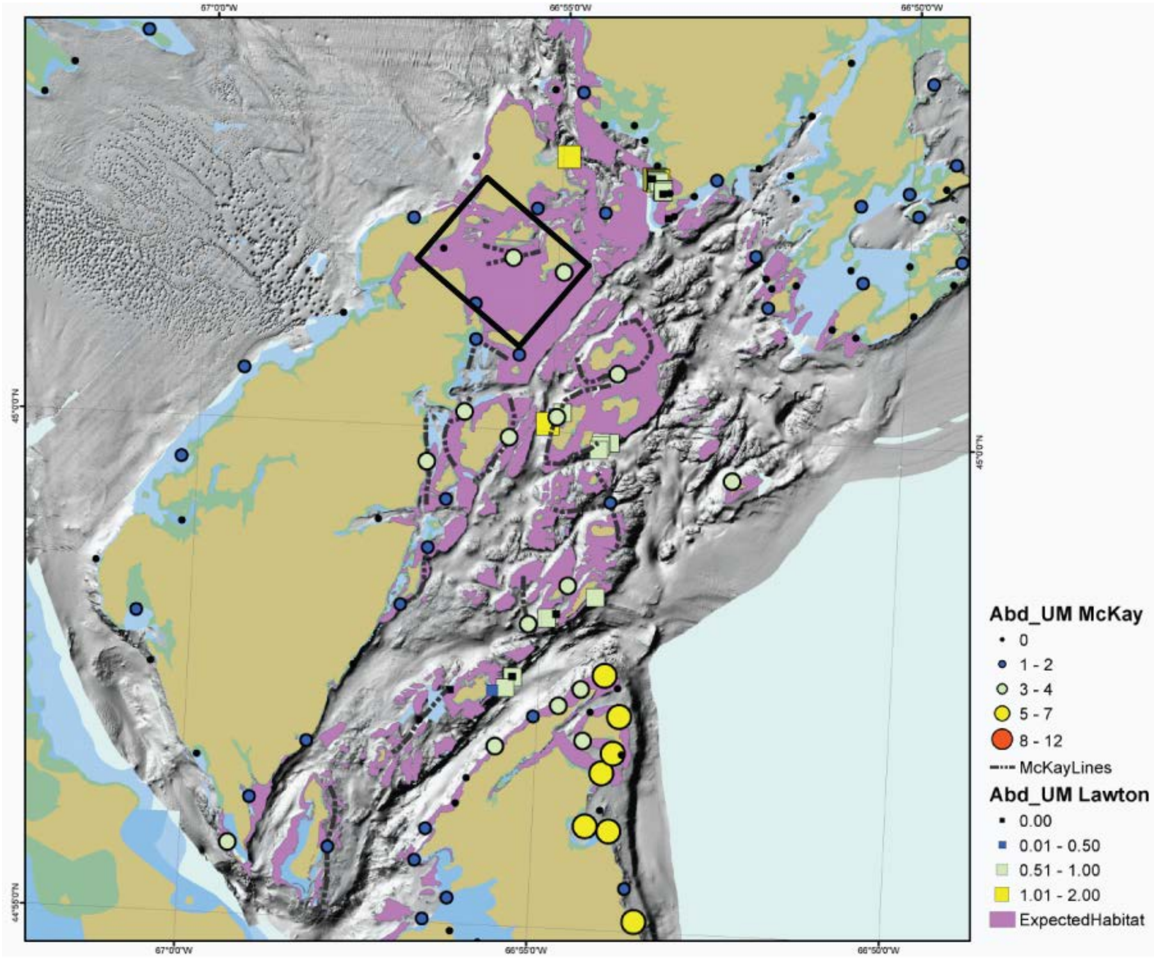

Figure 4. Expected upright and massive sponge habitat and the distribution and abundance (additive abundance) of upright and massive sponges that have been found in the McKay et al. (1978a, 1978b) and Lawton (2000) samples. The scale in the legend corresponds to the additive abundance of the McKay et al. (1978a, 1978b) and Lawton (2000) sponges, which were calculated by adding together relative abundance values (McKay: 0 to 3; Lawton: 0 to 2) for each species of upright and massive sponge characterized (McKay: Haliclona oculata, Scypha cilate and Myxilla-like; Lawton: Haliflona oculata and Pellina sitiens). The black box outlines the area that is less confident in the prediction of bedrock, due to the unavailability of multibeam data in that area.

Modiolus Reefs, Nova Scotia Shore

The *Modiolus* reefs off the Nova Scotia Shore (Figure 5) were identified as an EBSA (DFO 2012) for a variety of reasons, including the morphological uniqueness and sensitivity of the mussel reef feature; the aggregation of seabirds, lobsters and hydroid communities; as well as fitness consequences related to fish spawning (Buzeta 2014). It is the *Modiolus* reef feature and associated benthic community that is of particular relevance in terms of its identification as a potential Sensitive Benthic Area.

Vulnerable Marine Ecosystem Criteria

Characteristics of *Modiolus modiolus* (horse mussel) are summarized according to the VME criteria (FAO 2009) below.

Functional Significance of the Habitat

Modiolus modiolus (horse mussel) can form significant, long-lived structures (mussel reefs). Their longevity, and byssal attachment mode leads to the formation of a cohesive matrix of gravels, cobbles, and boulders which may help increase the resilience of these habitats to physical disturbance (P. Lawton, pers. comm.). Modiolus also provide habitat for other species, and are expected to house > 50 species living externally on a Modiolus reef (M. Owen, pers. comm.) It is the dense aggregations (beds/fields) that are considered to be VME in order to establish functional significance.

Life-History Traits of Component Species that Make Recovery Difficult

Modiolus modiolus is considered long lived (up to 100 years; MacDonald 1996). In the Irish Sea, no recovery was evident after one year for horse mussels when only a single trawl was conducted and significantly fewer infaunal taxa (polychaetes, malacostracans, bivalves and ophuroids) were recorded (Cook et al. 2013). Contributing to Modiolus' longevity are slow growth rates and a late age of maturity. In the North Sea, the fastest growth rate of *Modiolus* was 110 mm within 10 years, while the slowest achieved a shell length of 43 mm at eight years old. Mussels did not reach sexual maturity until they reached about 35-40 mm in shell length, when they were four and six years old (Jasim and Brand 1989). In advance of sexual maturity, mussels were able to devote a greater proportion of their energy resources to rapid somatic growth. However, these small but fast-growing mussels were selectively consumed by a variety of benthic predators particularly crabs and starfish. Only when the mussels had escaped predation by effectively growing beyond the size range most vulnerable to attack was energy redirected towards reproductive development. Thereafter, these larger slower-growing, essentially predator-free, mussels then survived for many years (Anwar et al. 1990).

Structural Complexity

Modiolus modiolus can form significant, long-lived structures (mussel reefs) creating high levels of physical complexity which supports a diverse epifaunal community (hydrozoans, bryozoans, and barnacles), as well as a rich infauna, epifauna, and crevice fauna of 200-300 species (M. Owen, pers. comm.; Cook et al. 2013).

Location Information

The locations of *Modiolus* reefs within the Modiolus Reefs, Nova Scotia Shore EBSA have been inferred by visually inspecting multibeam bathymetry and backscatter strength maps. Horse mussel beds are expressed as elongated and elevated ridges with backscatter strength different than surrounding seabed (Kostylev et al. 2009; Todd et al. 2014). For further description of how the *Modiolus* reefs were mapped, refer to Todd et al. (2014).

Some visual and physical sampling was conducted within this area in 2011 to help validate the presence of *Modiolus* reef structures (Todd et al. 2014).

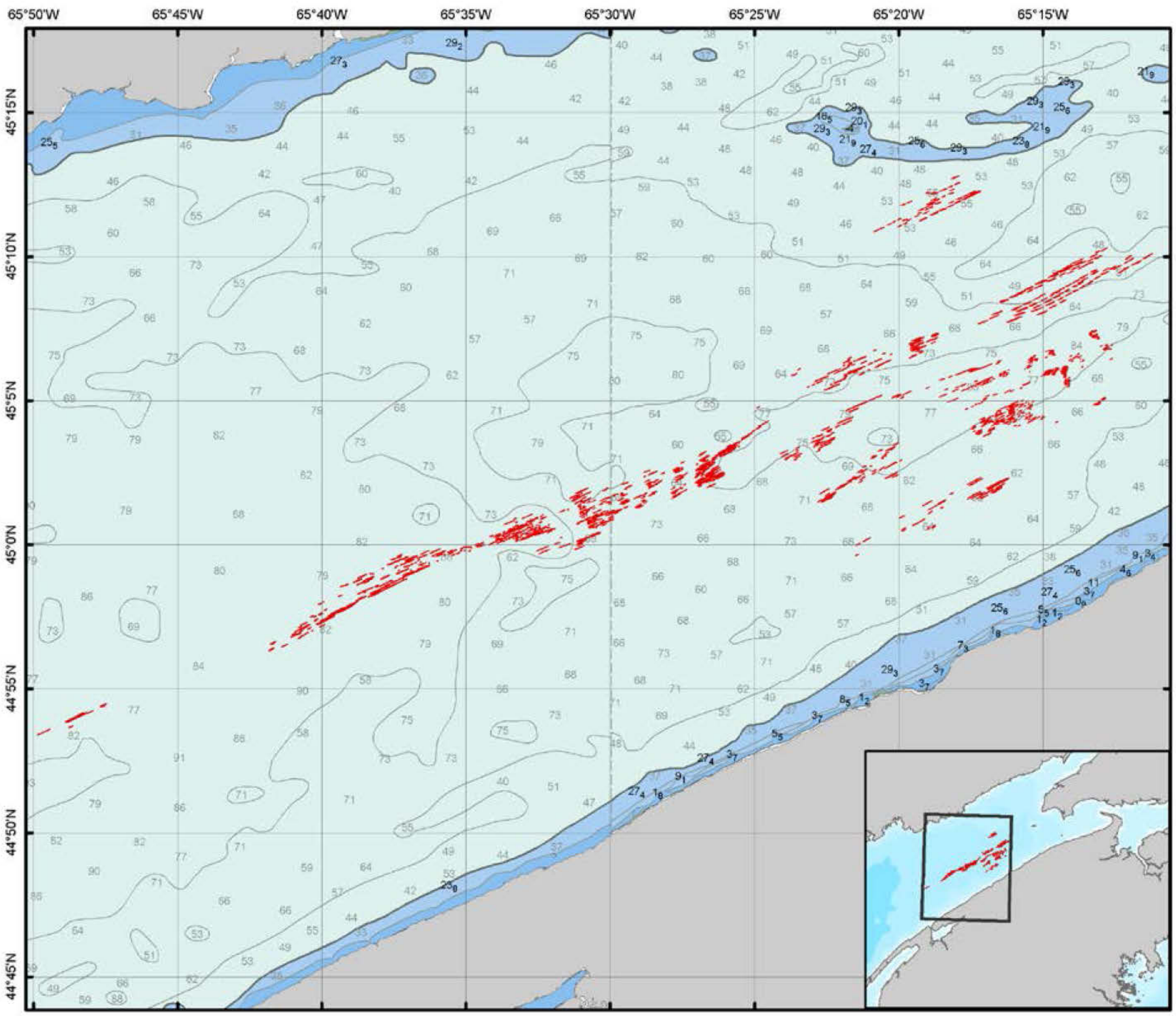

Figure 5. Approximate location of the Modiolus Reefs, Nova Scotia Shore (Table 3), as inferred from multibeam bathymetry and backscatter strength maps (Kostylev et al. 2009; Todd et al. 2014).

Conclusions

The Head Harbour/West Isles/Passages EBSA has a number of features that support its consideration under the SBA Policy. Vulnerable structure-forming invertebrates (*Boltenia ovifera* and *Modiolus modiolus*), which have significantly declined in the Bay of Fundy over a 30 year period, are present. A fragile tube-dwelling anemone (*Cerianthus borealis*), which is thought to control community structure through predation, is present. A new species of encrusting sponge species (*Hymedesmia canadensis)* is currently only recorded in the Head Harbour/West Isles/Passages region. Geographically rare sponge species (*Myxilla fimbriata*, *Hymeniacidon heliophila*, *Hemigellius* sp. aff. *flagellifer*) and a rare anemone species (*Edwardsia elegans*) are present. While there is some information available on the predicted distribution of upright and massive sponges, many of which are not considered to be vulnerable to bottom contact fishing, there is a lack of data on vulnerable benthic species. For this reason, precise coordinates for a potential SBA could not be provided at this time. Research is required to further understand the relationship between the predicted sponge distribution and the distribution of vulnerable species in order to more precisely map an SBA within the Head Harbour/West

Isles/Passages EBSA. This information could be obtained through additional fieldwork including dive, video and/or photographic surveys.

A review of the available information suggests that the Modiolus Reefs, Nova Scotia Shore EBSA has features, specifically the reef feature and associated benthic community, that support its consideration under the SBA Policy. Information on the location of horse mussel (*Modiolus modiolus*) reefs in this area has been inferred through visual inspection of multibeam bathymetry and backscatter strength maps, as well as some analysis of visual and physical sampling collected in 2011.

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