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Spatial and Temporal Delineation of Ecological Features of the Evangeline-Cape Blomidon-Minas Basin Ecologically and Biologically Significant Area (EBSA)

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

The southern arm of the inner Bay of Fundy -- a macrotidal marine-estuarine system containing the Minas Channel, Minas Passage, Minas Basin and Cobequid Bay, Nova Scotia -- is an Ecologically and Biologically Significant Area (EBSA), one of a number of EBSAs identified by Fisheries and Oceans Canada. EBSA is not a legal designation; however, information on ecological features is used in sustainable management of marine resources and activities. The particularly high tides and resulting extreme currents and other associated physical conditions within the EBSA, as well the large macrotidal inland sea (Minas Basin) separated from the outer parts of the EBSA by a narrow strait, create a unique situation to which biological organisms and humans living and working here respond. This report contains a review carried out for Fisheries and Oceans Canada, Maritimes Region, in late 2016, of scientific information and studies on selected topics necessary to address data gaps identified in the process of developing the Evangeline-Cape Blomidon-Minas Basin EBSA. This report draws on earlier overviews which described the biophysical features of Minas Basin and the features of the area in relation to the EBSA criteria, as well as more recent publications and scientific research.

Délimitation spatio-temporelle des caractéristiques écologiques de la zone d’importance écologique et biologique Évangeline, cap Blomidon et bassin Minas

RÉSUMÉ

Le bras sud de l’intérieur de la baie de Fundy – un système macrotidal marin et estuarien qui comprend le chenal Minas, le passage Minas, le bassin Minas et la baie Cibequid, en Nouvelle-Écosse – est l’une des nombreuses zones d’importance écologique et biologique (ZIEB) désignées par Pêches et Océans Canada. Sa désignation en tant que ZIEB n’est pas officielle; par contre, les renseignements relatifs aux caractéristiques écologiques de cette zone peuvent servir à gérer de façon durable les ressources et les activités marines qui y sont liées. Les marées particulièrement hautes et les courants extrêmes découlant de ces marées ainsi que d’autres conditions physiques connexes au sein de la ZIEB, en plus de la grande mer macrotidale intérieure (bassin Minas) séparée des parties extérieures de la ZIEB par un détroit étroit, créent une situation unique bénéfique pour les organismes biologiques et les humains qui y habitent et y travaillent. Le présent rapport porte sur l’examen effectué à la fin de 2016, pour le compte de la région des Maritimes de Pêches et Océans Canada, concernant les renseignements scientifiques et les études menées sur des sujets ciblés en vue de combler les manques de données relevés dans le processus d’établissement de la ZIEB Évangeline, cap Blomidon et bassin Minas. Ce rapport s’appuie sur des aperçus produits antérieurement, qui décrivaient les caractéristiques biophysiques du bassin Minas et les caractéristiques de la zone en général par rapport aux critères d’établissement d’une ZIEB, ainsi que sur des publications et des recherches scientifiques plus récentes.

INTRODUCTION

The Evangeline-Cape Blomidon-Minas Basin Ecologically and Biologically Significant Area (hereafter referred to as the EBSA) is a large, complex ecosystem with a great diversity of habitats, many of which are important for very different reasons (Figure 1). The biology of marine and estuarine organisms in general is intimately entwined with the physical, chemical, and geological processes of the environment around them and with which they interact. In the EBSA, two features in particular create an environment that is significant and important ecologically. The first is that a large part of the EBSA is occupied by a shallow macrotidal inland sea (Minas Basin) separated by a narrow strait from the rest of the Bay of Fundy, which is thought to have a unique recent geological and oceanographic history (Shaw et al. 2010). The second -- and perhaps most important -- feature of the EBSA, making this area and its ecosystems unique, is the Bay of Fundy tide. Tides in parts of the EBSA are among the highest in the world, and the resulting water movements, particularly through constraining geological features such as Minas Passage and the mouths of the EBSA's many tidal estuaries, result in high currents and unique physical conditions to which organisms and ecosystems must respond. The unique tidal situation in the EBSA also causes extremes of water column mixing, distributes sediments and nutrients, causes erosion, creates extensive tidal flats, and moderates temperature and salinity, to name a few of its effects, in ways completely unlike comparable coastal areas elsewhere in the Atlantic Region. While other areas of the Bay of Fundy also experience high tides, it can be argued that the marine environment of the EBSA is the most extreme. The unique tidal aquatic regime in the EBSA is a defining feature of the area, and many of the biological and ecological features of significance derive particularly from the tides.

In addition to the tidal influence, biological features of significance are found in the EBSA. Scots Bay is one of the most important coastal herring spawning sites in the region. Minas Channel is a narrow opening to the Minas Basin and an important seasonal migratory passage for dozens of species of fish. Thousands of shorebirds feed on tiny crustaceans and other invertebrates found in the region's extensive mudflats. An isolated population of Mud-piddock clams is found here and nowhere else in Canada. Even ostensibly terrestrial species, such as bald eagles and peregrine falcons, nest in coastal parts of this EBSA and feed in marine and coastal waters. Although the Minas Basin and other areas of the inner Bay of Fundy have been a focus of research interest for decades, one of the research drivers has been the interest in potential tidal power development. Despite years of study, there remain many gaps in information on biological systems, compared to the complexity of the marine environment in the Minas Basin. There have been numerous studies of shorebirds and the mudflat organisms which are their principal food source, and more recent work to map movements of anadromous and catadromous species of conservation concern, such as Striped Bass, Atlantic Salmon, Atlantic Sturgeon and American Eel. An ecological overview of the Minas Basin (Parker et al. 2007) and a socio-economic profile (Willcocks-Musselman 2003) recently described this area in detail and are important compendiums of information about the area. For more details on the biological and physical/oceanographic features of the area, refer to Parker et al. (2007). Buzeta (2014) highlights specific features of the EBSA that are of conservation significance.

Extensive coastal development in parts of the region, particularly agricultural development, has affected the quality of coastal and freshwater habitats that many anadromous and marine species depend on (Parker et al. 2007). Fisheries of various kinds take place in the EBSA; however, agriculture, manufacturing and other industries play an important role in the economy of the area, and now tidal energy development is becoming a reality.

The EBSA criteria include the first order criteria of uniqueness, aggregation, fitness consequences and the second order criteria of resilience and naturalness. Buzeta (2014) described ecological features of the Minas Basin EBSA that correspond to the first order criteria; further review of the literature by DFO's Oceans and Coastal Management Division identified other features that may also correspond to the first order criteria (Table 1). This report provides an up to date summary of available research and information for the spatial and temporal distribution of the Minas Basin ecological features listed in Table 1. Additionally, information gaps related to those ecological features and topics where further research and information is needed are identified.

DEFINED ECOLOGICAL FEATURES FOR THE EVANGELINE-CAPE BLOMIDON-MINAS BASIN EBSA

ATLANTIC MUD-PIDDOCK (*BARNEA TRUNCATA* (SAY 1822))

Atlantic Mud-piddock (*Barnea truncata*) is one of four intertidal marine boring clam species in Atlantic Canada. It occurs only in the Minas Basin of the Bay of Fundy in Canada and is listed as Threatened under the *Species at Risk Act* (SARA). The localized distribution and low abundance of the Canadian population is restricted to exposed red-mudstone bedrock in the Minas Basin, where total available habitat is < 0.6 km^2. The species settles on this type of substrate from its planktonic post-larval stage to establish its sedentary adult stage (DFO 2010a, Hebda 2011). Sites within the Minas Basin where Atlantic Mud-piddock clams occur are separated from one another by areas of mud-flats, except in areas associated with headlands and areas of stable sand and coarse sediment in the mid-Basin. Changes or disturbances to this sediment type are a key threat for the species (Hebda 2011). Distribution of Atlantic Mud-piddock in the Minas Basin based on multi-year field surveys is depicted in Figure 2.

Temporal Distribution

The presence of Atlantic Mud-piddock in the Minas Basin, which has a well-documented warm water regime compared with the Bay of Fundy, suggests that, overall, the species has warmer water preferences (warm water basin endemic, Bousfield and Leim 1958) and requires warmer temperatures for reproduction and development. Research on Atlantic Mud-piddock populations occurring along the Virginia and Delaware coast suggest spawning occurs between April and November and in-lab studies indicate metamorphosis takes place over 35 days (as cited in DFO 2010a). Fertilization of eggs occurs in the water column and planktonic larvae are dispersed throughout the Basin by the tidal current until they reach a post-larval juvenile (spat) stage and settle to the red-mudstone substrate, where they attach and begin boring. As filter-feeders, the species requires habitat free of any significant or rapid accumulation of sediments. Rate of growth appears to be dependent on food availability, which is a potential additional factor restricting the species to the Minas Basin (as cited in DFO 2010a).

Spatial Distribution

The Atlantic Mud-piddock clam is documented to occur at 14 discrete sites in intertidal portions of the Minas Basin where firm red-mudstone substrate exists and no significant sediment accumulation occurs (Figure 3; DFO 2010a). The species may also be present sub-tidally where suitable substrate exists free of sediment accumulation, and future research to map the red mudstone substrate throughout the EBSA may identify previously unknown areas of its spatial distribution (T. Pelrine, DFO, pers. comm, 2017). Three habitat types associated with the red-mudstone substrate are documented to support the Atlantic Mud-piddock clam (DFO 2010a):

- Embedded under a more-resistant “capstone” substrate.
- Associated with more-resistant bedrock features such as large cobbles or other exposed rock material.
- In exposed surfaces including rock pools where resistant rock has been eroded (probably through ice scour or movement of lithic materials during tidal exchange).

Data Gaps

There is a notable lack of information and completed research for this species in the eastern Atlantic. The distribution of Atlantic Mud-piddock has been determined based on relatively limited sampling mostly in nearshore, shallow areas and, consequently, the observed occurrences are intertidal (mid-tidal range), but it is also possible that it can occur in the sub-tidal and upper-intertidal range. Furthermore, comprehensive habitat requirements for Atlantic Mud-piddock are not clearly defined (COSEWIC 2009, DFO 2010a). Field work is scheduled for the 2017 summer season to determine spatial distribution of the Mud-piddock throughout the EBSA area by mapping red mudstone substrate, including sub-tidal regions (T. Pelrine, DFO, pers. comm. 2017).

Timing of fertilization and development, as well as life span for the Minas Basin Atlantic Mud-piddock population is unknown. Additionally, the process of larval attachment for borers is not well known, even in species where the question has been examined. For species that bore into limestone or corals (e.g. *Hiatella arctica* (Trudgill and Crabtree 1987); *Petricola pholadiformis* (Ansell 1970)), it is thought that the early attachment and boring may involve use of enzymes and acid excretions to dissolve the substrate. However, for Atlantic Mud-piddock, and for borers that utilize rock types other than easily dissolved by acid (i.e. limestone or coral), the mechanism is not known.

Changing climate characteristics including increased frequency and severity of storms, rising sea levels and storm surges, increased rainfall (floods), and rafting ice could contribute to negative changes in sediment deposition, erosion or ice scouring that could diminish habitat and/or smother individuals. Temperature regime changes may also negatively impact life cycle stages. While firm substrate requirements for successful establishment are clear as are warm water conditions that are required for reproduction, additional habitat requirements are still unknown. Industrial development activities in the Minas Basin could also alter physical conditions, of which impacts to the population may not be adequately predicted based on the absence of biological information and monitoring activity.

REGULAR USE BY ATLANTIC SALMON (*SALMO SALAR*)

Atlantic Salmon are known to occupy at least 13 rivers of the Minas Basin watershed (Figure 4) (DFO 2013). The highest densities of Atlantic Salmon are found in the Stewiacke and Gaspereau Rivers, which are both contributing and recipient rivers for the Live Gene Bank Program (Amiro 2003, Parker et al. 2007, R. Jones, DFO, pers. comm. 2016). As repeat spawners, all Atlantic Salmon life history stages are present at one time or another in the Minas Basin watershed, including tidal and freshwater portions of river migration corridors at various times throughout their life cycle (Table 2; Figure 5). Kelts may be in the EBSA in the spring to early fall; smolts are only in marine waters of the EBSA for a short time (late April to early September); adults moving in for spawning are present from May to October but peak migration is generally in September. The EBSA is an important migration route between spawning and nursery areas in freshwaters and maturation areas in the outer Bay of Fundy. The importance of the Bay of Fundy for maturation and feeding aspects of the life history is not fully understood (DFO 2013).

The inner Bay of Fundy (iBoF) population of Atlantic Salmon is listed as Endangered under SARA. Approximately eight to 10 rivers in the EBSA system are recipient rivers for the DFO Live Gene Bank Program for iBoF Atlantic Salmon. Approximately 600 parr are collected annually, raised to maturity and crossed to produce hundreds of thousands of juveniles. The juvenile Atlantic Salmon (as unfed fry) and any sexually mature non-targeted adults not used for the pedigree based mating plan are then released back into the rivers the following fall (R. Jones, DFO, pers. comm. 2016, Gibson et al. 2003).

Individual river populations of Atlantic Salmon within the inner Bay of Fundy have similar basic life history characteristics:

1. early age at maturity;
2. repeat spawning; and
3. “local” sea migration (i.e. not migrating far from the Bay of Fundy and returning to spawn typically as one-sea-winter (1SW) salmon (grilse) (DFO 2013).

Some iBoF Salmon from the Gaspereau River return for first spawning as two-sea-winter salmon (2SW) (Amiro 2003). “Early maturity, prolonged successive annual spawning, local migration and distinct genetic profiles characterize at least two distinct stocks within the iBoF, one in the rivers of the Minas Basin and another in the rivers of the Chignecto Bay” (Amiro 2003).

Eggs are present over winter (October to April), hatch in April, and young (*alevins*) remain in the gravel substrate of the river until May and June. As fry, the young move from the gravel substrate into the water column remaining there until they reach the *parr* stage in late summer. Parr remain in the river system for two to four years before migrating into the Minas Basin as smolts.

Smolt and Post-smolt Seasonality and Distribution

Smolts remain in freshwater habitat for two to four years before they migrate out of the tidal rivers. Smolt habitat consists of tidal portions of rivers where acclimation to salt water occurs typically between the most upstream point of salt water intrusion and a line drawn between the headlands at the rivers’ mouth. Smolt runs are known to occur through the migration corridors over a short time period but have been observed spending extended periods of time inside the Minas Basin. Data collected from the Gaspereau, Stewiacke and Shubenacadie Rivers indicate the runs occur between early May and late June (Marshall 2014).

As post-smolt migrate through the Minas Basin and out of the Bay of Fundy, it is likely that the extensive tidal water movements in shallow water distribute them widely. Feeding is thought to occur in the Minas Basin through June to September (DFO 2013). Post-smolt movement outside of the EBSA may be more along the north shore as occurs with other fish species, which follow the residual current pattern. They are known to reach the mid-bay gyre (outside the EBSA) by late spring-early summer.

Adult Atlantic Salmon and Kelts Seasonality and Distribution

Adult Atlantic Salmon returning to natal rivers from the sea are known to migrate into the Minas Basin during May to October, based on historical commercial and recreational fishery data, but peak migration occurs from July to September; outside of this period, adult Atlantic Salmon are rarely in marine waters of the EBSA. Cobequid Bay and the tidal portions of the Shubenacadie River form a migration route for adult salmon to upstream spawning areas. July and August are important months in these areas, and May through August is an important period in the Minas

Channel, Central Basin, and Southern Bight for the Atlantic Salmon population from the Gaspereau River, as supported by data from earlier commercial fisheries in these areas. Temperature (<14 °C), decreasing salinity and absence of predators are important contributing factors for salmon returns to natal river habitat to spawn. The Minas Basin provides important habitat for adult staging, most probable during June to August for the Gaspereau River population (DFO 2013). Return movements of adults to the EBSA after wintering at sea are probably mainly in open water until they reach the mid-bay region of the Minas Channel when they move closer to the Minas Channel (Kings County) shore (Dadswell 2004).

Spawning in rivers occurs during October and November. Typically, adult Atlantic Salmon in the EBSA are 1SW fish (grilse) and they move through the area quickly to get into the streams, probably in as little as a few days.

Movement of kelts out of the EBSA is primarily in the spring, although migration also occurs in the fall (DFO 2013, Lacroix 2013). Pop-up satellite archival tagging of kelts from inner Bay of Fundy rivers documented migratory movement of the kelts mostly to within 300 km of their home river, and they remained in the Bay of Fundy and Gulf of Maine over winter (Lacroix 2013).

Data Gaps

There is limited information on feeding behavior and year-round residency in the Bay of Fundy for all life history stages, as well as limiting factors, in particular for 2SW Atlantic Salmon and kelts, and during overwintering (November to April).

There is no specific biological data covering the outer southwest coastal portion of the EBSA (i.e. 'Area 8' as defined in DFO 2013).

Kelt habitat, feeding behavior, staging habitat requirements, as well as sources of mortality in river and coastal estuaries are data gaps.

There is need for re-analysis of existing marine distribution data for iBoF Salmon once existing kelt data are available and to link it to environmental factors, changes in the physical oceanography of the Gulf of Maine, possible changes in the composition of the ecosystem over time through overfishing, potential availability of prey and predators and, threats to habitat potentially limiting survival or recovery (DFO 2013).

IMPORTANT FEEDING AREA FOR ATLANTIC STURGEON (*ACIPENSER OXYRINCHUS*)

Significant numbers of Atlantic Sturgeon use the Minas Basin in spring-summer-fall for feeding (Dadswell et al. 2016). The species is designated as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and it is currently under review for protection under SARA. Presence of Atlantic Sturgeon as a seasonal mixed stock feeding aggregation in the Minas Basin has been well documented (Wehrell et al. 2008, McLean 2013, McLean et al. 2014, Dadswell et al. 2016), and movement through the Minas Channel and Passage has also been documented (Stokesbury et al. 2016). Atlantic Sturgeon, mainly from the Saint John, New Brunswick, and Kennebec, Maine, river populations, aggregate to feed each year in the Minas Basin, generally from May to October, with some observed as early as April and extending into November. Peak abundance occurs from June to September (Dadswell et al. 2016). Sturgeon are relatively abundant and are commonly caught in intertidal weirs within the Minas Basin – up to 1000 animals a year (as cited in Dadswell et al. 2016). They were occasionally present in low numbers in a weir study from late-May to mid-August or later (Baker et al. 2014); noted anecdotally to peak from June to July (D. Porter, pers. comm. from Baker et al. 2014) (Southern Bight Minas Basin-Bramber); and found to be rare in weirs from mid-May to mid-June (north shore Five Islands) (Baker et al. 2014). Use of the Minas Basin waters by sturgeon was also documented by acoustic detection off Kingsport of five Atlantic Sturgeon with acoustic transponders tagged between 2010 and 2012. The records were from a boat equipped with acoustic listening equipment used to track an Atlantic Sturgeon off Kingsport in September 2012 (Logan-Chesney 2013). The sturgeon detections also provided depth information at detection (approximately 20 m ± 6 m; N=34). Stokesbury et al. (2016) documented Atlantic Sturgeon moving in and out of the Minas Basin using acoustic transmitters from 2010-2014, demonstrating that the sturgeon used the southern portion of Minas Passage significantly more than the northern portion as they moved through (N=132). A population estimate for the Minas Basin based on mark-recapture data by using external tags (Logan-Chesney 2013) was 10,283. The species has been reported to feed on soft-bodied invertebrates, in particular polychaete worms common to the Minas Basin (McLean et al. 2012, Pearson et al. 2007).

Mark and recapture weir and trawling data collected over 12 years included over 1400 tagged Atlantic Sturgeon. Data collected from four intertidal weirs in the Minas Basin, and trawl captures from the southern shore near Walton as well as the Southern Bight, demonstrate movement and local occurrence of Atlantic Sturgeon throughout the entire basin during the feeding aggregation months. The sturgeon appear to occupy the north shore of the Basin during the spring and are more abundant along the south in the summer with some individuals appearing to remain in the central Basin for extended periods (Stokesbury et al. 2016, Dadswell et al. 2016). The pattern of movement from north to south from spring to summer also suggests migration in and out of the Basin is clockwise, following the residual current structure (Dadswell et al. 2016). Atlantic Sturgeon are demersal feeders associated with coastal and shelf regions and mostly occupy shallow depths from 6 to 81 m. Observations of movement into and out of the Basin through Minas Passage in the spring and again in the fall means the species are present in Minas Passage only periodically, and no individuals have been detected during winter months. Despite being known for spending some time in the water column, Stokesbury et al. (2016) reported the first observations of Atlantic Sturgeon moving pelagically through the Minas Passage area mostly between depths of 15 and 45 m; however, it is still unclear whether this is common for the sturgeon or how this method may be related to the macro-tidal environment.

Currently, there is no evidence of over-wintering sturgeon in the Minas Basin, based on tagged fish monitoring in the Passage, which may be due to avoidance of sub-zero water temperatures during the winter months (McLean et al. 2013, Stokesbury et al. 2016). However, the species is known to occupy near-bottom environments in overwintering areas in the Bay of Fundy outside of the EBSA, including the mouth of the Saint John River, at depths of 76 to 82 meters (Taylor et al. 2016). The species is not under any threat of extinction or extirpation in the EBSA. Atlantic Sturgeon sampled from the Minas Basin exhibit life history characteristics consistent with those of northern populations in terms of growth rate. Small, juvenile individuals sampled from the Minas Basin (<80 cm, 4-10 years) suggest that the Basin may serve as a nursery before at-sea migration as northern Atlantic Sturgeon are known to migrate at sizes greater than 80 cm and at approximately 10 years old (Dadswell et al. 2016).

Data Gaps

Further research on Atlantic Sturgeon over-wintering habitat, migration patterns and movement between Minas Basin and Chignecto Bay is required, as currently, there is little information available.

Further research is needed to determine if feeding aggregation areas exist in other areas of the Bay of Fundy, outside of the Minas Basin, in order to determine the relative importance of the Basin and EBSA for feeding.

The status of the Atlantic Sturgeon stock/population or the main factors supporting it are not well known and, therefore, the species' ability to respond to environmental change is not well understood.

ATLANTIC HERRING (*CLUPEA HARENGUS*) SPAWNING AND NURSERY AREAS

The outer Minas Basin-Minas Passage-Minas Channel system in the EBSA supports important spawning areas for Atlantic Herring (*Clupea harengus*). There are two spawning populations of herring that use the EBSA: a spring spawning population within the Basin, and a summer spawning population that is found in an area extending from the Minas Passage area to the Bay of Fundy outside the EBSA (Figures 6 and 7). The spring spawning area extends from approximately Cape Sharp on the eastern end of Minas Passage to Five Islands and is used in spring (April-May) by a localized and unique spring-spawning population (Bradford and Iles 1992, Stephenson et al. 2001). The summer-spawning stock (end June to late August) (Singh et al. 2016), known as the Scots Bay stock[1] (Figures 6 and 7), exists in the Minas Passage and Channel as well as the Bay of Fundy beyond Île Haute (although the fishery is not localized in the geographic location commonly known as Scots Bay). Herring in pre-spawning condition belonging to the Scots Bay stock may mix with individuals in the spring-spawning Minas Basin group, and go on to spawn in outer parts of the EBSA later (R. Bradford, DFO pers. comm. 2016). Individual spawners and young-of-the-year from spawning beds in the Minas Basin can occur throughout and are important in the Basin following spawning. No updated information on the spring-spawning population (i.e. since the early 1990s) is available, however, owing to the presence of a commercial weir fishery and occurrence of juveniles in the Minas Basin, continued use of the site for spawning is suspected (R. Bradford, DFO pers. comm. 2016). In the outer parts of the EBSA, DFO conducts surveys where spawning occurs regularly, though the location of spawning within the survey area may vary somewhat from year to year (Figure 8).

Both the commercial Scots Bay purse seine fishery and the weir and gill net fishery in the Parrsboro to Five Islands area, depend on adult fish moving into the area and aggregating to spawn. Spawning activity on grounds is thought to be more or less constant on each ground over the season, with individual spawning groups in 'waves' continuously arriving, spawning and then leaving within 10-12 days or less (Singh et al. 2016). Herring are bottom spawners, laying their eggs on surfaces including bottom substrate, seaweeds, debris, weir structures, wharves, nets etc. In the EBSA, due to its high tides, spawn may be deposited in places that are exposed at low tide, and observed by fishers and other observers. By their nature, the location of spawning grounds is diffuse, so some spawning is likely to occur anywhere in the EBSA from the outer Minas Basin to the outer Minas Cannel where pre-spawning fish occur, but the intensity is concentrated in general vicinity of the main grounds, typically down to 10 m and perhaps deeper for spring and summer spawners (Stewart and Arnold 1994, R. Bradford, DFO, pers. comm. 2016). No studies have been done to delineate spawning beds (R. Singh and R. Bradford, DFO, pers. comm. 2016) and information on location is often anecdotal based on where greatest concentration of spawn is seen (R. Bradford, DFO, pers. comm. 2016).

Juvenile herring tend to remain in, and move through, coastal areas throughout the year until they mature and join the adult population (Stewart and Arnold 1994). As adults they become migratory, with individuals from all Bay of Fundy stocks overwintering off the Nova Scotia Atlantic coast (Mouland et al. 2003) (Figure 9). Larvae are distributed in the Minas Basin in

[1] It is important to note the difference between the Scots Bay Herring Stock which refers to herring founds in the Minas Channel outward; Scots Bay itself is geographically near Cape Split.

summer, metamorphosing to a later stage there in about four months (Bradford and Iles 1993) under conditions which suggest the Minas Basin is a retention area for the species (Bradford and Iles 1993) (Figure 10). Atlantic Herring juveniles from spawning beds in the Minas Basin-Minas Passage and Scots Bay are found throughout the EBSA. Juvenile herring (young-of-the-year = spawned in April-May) are abundant on the south shore of the Minas Basin (Bramber) in June to August; and on north side (Five Islands) mid-June through early August, from captures in weirs (Baker et al. 2014). Juvenile alosids (i.e. Gaspereau, Atlantic Herring, Shad, Blueback Herring) occur through the summer in research seine catches on the north shore from Parrsboro to Masstown (Bradford et al. 2015; R. Bradford, DFO, pers. comm., 2016). Larvae and juveniles (brit) form dense schools in the inner Bay of Fundy including the EBSA (Dadswell 2010).

Data Gaps

Modeling could be carried out to determine dynamics of water movement and turnover in central Minas Basin, in relation to its role as a potential larval retention area.

The Minas Basin spring-spawning population has not been scientifically assessed since early 1990s.

REGULAR USE BY AMERICAN EEL (*ANGUILLA ROSTRATA*)

The American Eel (*Anguilla rostrate*) is designated as Threatened by COSEWIC (COSEWIC 2012a) because of a decline in abundance over its range. The species is common to abundant in most of the rivers in the EBSA (Dadswell 2010) and there are eel fisheries (both adult and ‘glass eels’) in many of the rivers draining into the Minas Basin. In the Shubenacadie River eels are gathered as part of a Mi’kmaq ceremonial food fishery. Eel mature as elvers in freshwater over a number of years. Maturing adults are trapped in commercial fisheries through the summer beginning mid-April to September and ‘glass eels’ -- the juvenile stage migrating from the sea -- are trapped in rivers in mid-April to early May. During this time, the species appears to be restricted in distribution to rivers and estuaries, and, for example, were not captured in intertidal weirs, April to August 2013, at Bramber and Five islands (Baker et al. 2014). Fully mature adults (‘silver eels’) leave the rivers in mid-September to mid-November and after a short period of time, leave the Minas Basin via Minas Passage (Redden et al. 2014).

Tagged migrating ‘silver eels’ from the Gaspereau River were shown to spend as little as three days reaching Minas Passage and thereafter leaving the area, but mostly took about a month (average 24 days (2011) and 36 days (2012)) to leave, during which they were in the Minas Basin. Silver eels typically leave during mid-September to mid-November, with movements occurring primarily in the southern half of Minas Passage. Once in Minas Passage, they pass through quickly (1-6 days) and mostly at night during ebb tide (Redden et al. 2014). As expected, since adult eels migrate to the Sargasso Sea to spawn, one eel tagged in the Gaspereau River was detected south of Browns Bank, 24 days after release (Redden et al. 2014).

American Eel were found in all restored salt marshes in monitoring of salt marsh restoration projects in southern Minas Basin (St. Croix River, Cheverie Creek, Walton River and Cogmagun River) recently carried out by Nova Scotia Transportation and Infrastructure Renewal (see Table 12) (Bowron et al. 2013a and b, 2014a and b). Eels of various ages used the marshes in summer, from glass eels (newly entering freshwater) in the Walton River marsh to individuals up to 50 cm standard length in a marsh at St. Croix on the St. Croix River.

Data Gaps

Studies on the biology of American Eel in coastal rivers have focused on populations in rivers in Atlantic coastal watersheds (e.g. Jessop 1996). A variety of factors have been suggested to be important in the species' decline, including dams and human interference (COSEWIC 2012). Issues affecting survival in the EBSA may differ, as well as the conditions resulting from the exceptional tidal regime in the area. There are no population studies to provide information on stability and trends in abundance of American Eel in the EBSA.

NURSERY/JUVENILE AREA FOR MULTIPLE FISH SPECIES

Eggs and larvae from spawning by marine, estuarine and freshwater fish in the EBSA, as well as from egg and larval stages brought into the area by water movements, grow and develop here (Table 3). Species represented are generally a cross-section of those in coastal areas of Nova Scotia and the Scotian Shelf, but because of the unusual physical and biological conditions in the Minas Basin (due to extreme tides and currents, relatively warmer water temperatures, and other conditions which affect fish), their communities, seasonality, and developmental cycles here might be expected to have some unique characteristics compared with other coastal areas. For example, the spring spawning population of Atlantic Herring is unique in the inner Bay of Fundy (Bradford and Iles 1992). Another example is Striped Bass, for which Minas Basin and the Shubenacadie River system supports the only sustainable population in the inner Bay of Fundy. Less is also generally known of the biology of non-commercial species, many of which occur in the EBSA, and for many of which little or no information on biology is available.

Of a list of 49 fish and shellfish[2] species that commonly occur in the EBSA and potentially grow and mature there (see Table 62 of Dadswell 2010), 33 species or 67% are exclusively marine and the remaining 18 (33%) are diadromous (i.e. either anadromous or catadromous). Of the anadromous species, those that have a predominant freshwater stage (e.g. salmonids) grow and mature in freshwater, leaving only as larger juveniles (smolts) either to inhabit nearshore waters (e.g. Brook Trout) or to move through the EBSA to an entirely marine lifestyle (e.g. Atlantic Salmon). These account for approximately one-third of the fish species occurring in the EBSA. Many anadromous species, although still a relatively small proportion of the total, spawn in freshwater (e.g. Striped Bass, Atlantic Tomcod) and mature to a certain stage of development there, but they move into estuarine waters along the coast and river estuaries as juveniles for their early development. American Eel is the sole catadromous species, maturing in fresh and estuarine waters and breeding at sea.

Most fish found in the EBSA, however, are strictly marine, and juveniles may grow and mature here as a result of different reproductive strategies of the various species. Some benthic species spawn locally, likely in small numbers under suitable conditions (e.g. skate, snailfish, lumpfish). Some species spawn in large numbers in specific locations (e.g. Atlantic Herring in beds in northern Minas Passage-Minas Basin and Scots Bay; Atlantic Menhaden, Economy Point (Dadswell 2010)). Another important group of fish species using the EBSA relies on the diffuse settlement of pelagic eggs and larvae, as in the case of many groundfish species, for which eggs and larvae arrive after drifting from remote spawning grounds and develop here. Parts of the EBSA were historically important spawning areas for groundfish (e.g. Haddock grounds on the south side of Minas Channel from Scots Bay westward) (Graham et al. 2002)

[2] American Lobster is included in the list because of its mobility and its occurrence in a commercial fishery in the EBSA.

and release of pelagic eggs and larvae would have led to their distribution throughout the area. The water circulation pattern in the Minas Basin has been suggested to provide a mechanism for retaining pelagic larvae of various fish species, particularly Atlantic Herring, in the area, thereby assisting in larval and juvenile development (Bradford and Iles 1993) (Table 3). Larvae of American Shad, Atlantic Silverside, and Gaspereau, as well as other species, have been found in central Minas Basin (Bradford and Iles 1993).

Fish spawning, and subsequent egg and larval/juvenile development, can take place at different times of the year and, consequently, juvenile development and use of the EBSA as a nursery area can take place throughout the year, depending on species. The macrotidal nature of the Minas Basin causes juveniles of many of the species, particularly species inhabiting primarily coastal waters, to be distributed widely in the Minas Basin (R. Bradford, DFO pers. comm. 2016). Factors such as turbidity or salinity gradients also may affect the distribution and dynamics of some of these species (R. Bradford, DFO pers. comm. 2016). Marine gadids such as cod and Haddock, which can spawn in the inner Bay of Fundy, reproduce in winter (e.g. late December to February) and juveniles develop in coastal areas thereafter. Tomcod spawn above the head of tide in late fall to early winter, with juveniles moving down to mature in coastal waters of the Minas Basin in summer. Rainbow Smelt, another common coastal species found in the EBSA, enter estuaries in late fall and winter, spawning in rivers during March to May. Their pelagic larvae are present in coastal waters from May to August, and juveniles are present year-round (Dadswell 2010). Salmonids spawn in late fall to early winter (i.e. September to early November). Anadromous species in the herring family (*Alosidae*) spawn in freshwater during spring and summer, with Alewife, American Shad, and Blueback Herring in rivers during April to May. Larvae and juveniles develop over the summer, and occur in coastal waters of the EBSA year round. Sea Lamprey spawn in rivers from April to July and juveniles live entirely in the freshwaters around the Minas Basin until they mature after up to seven years (Dadswell 2010). Eggs and larvae of Atlantic Sturgeon can be present in rivers after spring spawning (May-July) and inhabit local estuaries as they mature. The important and endangered Striped Bass population in the Shubenacadie River-Grand Lake system has a May to June spawning period in the Stewiacke River, and juveniles mature and develop in the coastal waters of the Minas Basin for several years (Bradford et al. 2015). Small coastal estuarine fish such as Atlantic Silverside, Mummichogs, and Banded Killifish, spawn in spring-summer (Mummichogs spawn April-June) and young develop later in the same areas. Sticklebacks typically spawn in coastal estuaries or some populations in freshwater in spring to early summer (April-July) (Dadswell 2010).

Specific Studies

Juvenile Fish Distributions-Minas Basin Weirs: Use of the Minas Basin as a juvenile nursery area is supported by occurrences of young-of-the-year of several fish species in intertidal weirs in the Minas Basin[3]. Young-of-the-year Tomcod occurred in summer on the south shore of the Minas Basin (Bramber) in low to moderate abundance during late June through early August (Baker et al. 2014). American Shad juveniles are present in varying abundance May to August and perhaps later, peaking in late June on the north shore (Five Islands). Young-of-the-year Rainbow Smelt occur mid-August on the Minas Basin south shore at Bramber and in late July onward (north shore Five Islands) (Baker et al. 2014).

[3] The Acadia Centre for Estuarine Research carried out a study of fish catch in weirs in Minas Basin to provide baseline information for the assessment of tidal energy impacts (Baker et al. 2014). The study ran while the weirs were in operation, from May to August 2013, and therefore only represent occurrences during part of the year.

Juvenile Fish Distributions in Striped Bass Juvenile Surveys: Young-of-the-year Striped Bass, as well as juvenile alosids (undiscriminated Gaspereau, American Shad, Blueback Herring, Atlantic Herring), Atlantic Silverside, flounder, Rainbow Smelt and Mummichogs, are captured widely in beach seine samples taken annually since 1999 at several sites along the north shore of Minas Basin and Cobequid Bay, from Parrsboro to Upper Dyke, and Cobequid Bay in the Masstown area (Bradford et al. 2015). This suite of species is likely found more widely throughout Minas Basin, moving continuously with the tide (R. Bradford, DFO, pers. comm. 2016). Larvae and eggs of Striped Bass can be found in Minas Basin washed downstream from spawning in the upper Shubenacadie River and Stewiacke Rivers (Stewart and Dunston 2012, R. Bradford, DFO, pers. comm. 2016) but are unlikely to survive there due to low salinity requirements (R. Bradford, DFO, pers. comm. 2016).

Squid: Adult squid abundance typically increases inshore during the early summer due to spawning movements into nearshore waters, and the species moves off during the winter. Longfin Squid (*Doryteuthis pealeii*) were collected from a commercial intertidal weir in the southern Minas Basin (Bramber) between June and August 2014 (Keays 2015). Shortfin Squid (*Illex illecebrosus*) were also found at the site, though they represented a small proportion of the overall abundance caught. Longfin Squid typically spawn in nearshore waters, so the presence in the Minas Basin reflects a spawning movement; Shortfin Squid spawn offshore, so their presence here from May to August may be because they are feeding rather than reproducing (Keays 2015). Spawning for Longfin Squid typically occurs predominately in spring-summer, in shallow waters in water temperatures of 15.5 – 23°C (Dawe et al. 2007) and potentially could occur in the Minas Basin.

Little and Winter Skates: Spawning and juvenile development of Little and Winter skates potentially occurs in the Minas Basin. Prior to 2013, Winter and Little skates (*Leucoraja ocellata* and *L. erinacea*) had never been surveyed in the Minas Basin. Skates were sampled in an intertidal weir in Bramber over three summers (May to August 2012 – 2014) and in directed trawls (2013 – 2014) (Whidden 2013, 2015). Small and medium skates were most abundant across years, and large skates were relatively most abundant early in the season (i.e. early May). Female skates outnumbered males. Elsewhere, peak egg deposition for both species is from June to July, but a clear pattern wasn't observed in the Minas Basin, and females recently having deposited eggs or holding eggs occurred throughout the summer, suggesting spawning activity through that period. Skates remained in the Minas Basin through the summer, with marked skates recovered typically in less than 50 days and some after 60 days. Several skates moved 30 km across the Minas Basin to be recovered on the north side. Some tag recoveries suggested skate moved in cohorts or groups. Estimated Minas Basin population of Winter and Little Skate based on mark-recapture was 29,465 (24,890 – 36,100) (Whidden 2015).

Lobster: The EBSA is not known as a nursery area for American Lobster and the Basin appears to be mainly a feeding area, though some adults may overwinter there (Morrison 2014).

Data Gaps

For many species inhabiting the EBSA there are limited or no studies that explore the significance of the area to critical life history stages or habitat use (e.g. Lumpfish). Alternatively, a number of species such as Atlantic Sturgeon and Striped Bass have been studied in detail.

FEEDING AND MIGRATORY STAGING AREA FOR SHOREBIRDS

Shorebirds are a specific category of birds found seasonally in coastal and wetland areas in Atlantic Canada, where they rely on shores and flats of freshwater bodies, estuaries and the ocean during parts of the year. Two families of shorebirds -- Sandpipers (*Scolopacidae*) and

Plovers (*Charadriidae*) -- predominate in terms of numbers in the areas and are important in the EBSA. They are long-distance migrants, and mudflats in the inner Bay of Fundy are particularly important to many of the species as stopovers during which they build up fat reserves for long-distance over water flights to southerly overwintering areas.

Various shorebirds utilize coastal areas of the EBSA, primarily areas with mudflats and most abundantly during the late summer migration period, for feeding and roosting. They can occur wherever mudflats and associated sheltered coastal environments occur. The Minas Basin is one of two main areas in the inner Bay of Fundy supporting large stopovers and staging of shorebirds, the other being Chignecto Bay. For some species such as Semipalmated Sandpiper (*Calidris pusilla*), separate populations may be faithful to particular areas within the Bay of Fundy (Sprague et al. 2008, White 2013 as cited in Neima 2014[4]) . The amphipod *Corophium volutator* is the main food item for shorebirds, in particular Semipalmated Sandpiper, which is the most abundant migrant visiting the area, although the food mix can shift to include a predominance of other invertebrate species such as polychaetes worms. Semipalmated Sandpiper has recently been found to have greater flexibility in their diets, feeding not only on *Corophium* but with polychaetes and biofilm making substantial contributions to the diet (Quinn 2011, Quinn and Hamilton 2012). The inclusion of biofilm in the diet is consistent with recent observations of other calidrid shorebirds. Several Mount Allison University theses have recently focused on Semipalmated Sandpiper movements and food/habitat associations (Quinn 2011, Mann 2014, Neima 2014). In the past forty years, the timing of the shorebird migration has shifted to later in the season, and there has been increasing use of Cobequid Bay (J. Paquet, Canadian Wildlife Service (CWS), pers. comm. 2016; Figure 11). Recent radio-tagging studies suggest that stopovers may be longer by about a week than previous estimates (currently approximately three weeks versus about two weeks).

The inner Bay of Fundy is important as a staging site of hemispheric importance for Semipalmated Sandpipers within the western hemispheric shorebird reserve network. Work conducted by CWS (Allard et al. 2014) identifies locations with mudflats and other coastal habitats relevant to shorebirds, and relative density (determined by polygon and point data) compared with other parts of the Bay of Fundy and Atlantic Coastal Nova Scotia (Figures 12 and 13). Within the EBSA, highest densities of mudflats are in the Minas Basin, in particular in the Southern Bight and associated tidal river systems, while Cobequid Bay and the flats at the mouth of the Shubenacadie River are also important for shorebirds as a migratory stopover. Main mudflats in the Southern Bight of Minas Basin are Starrs Point, Evangeline Beach, the Guzzle/East Point, Avonport, and historically Cheverie, but less so now as Windsor flats also used at low tide (J. Paquet, CWS, pers. comm. 2016). In Upper Cobequid Bay, the main flats are at Old Barns/Black Rock/Shubenacadie River mouth, the mouth of the Chiganois River, Debert Beach, and Little Dyke Beach (J. Paquet, CWS, pers. comm. 2016). Allard et al. (2014) note high relative abundance of saltmarsh and mudflat, and lack of eelgrass, in the upper Bay of Fundy (including the EBSA).

Minas Basin and Cobequid Bay

Minas Basin and Cobequid Bay are important areas for shorebirds. In particular, high numbers of Semipalmated Sandpipers feed and roost annually in Cobequid Bay in numbers ranging from 50-80,000; up to 10% of the global population. Shorebird species occurring in these areas include those both common and rare such as Piping Plover (Allard et al. 2014), although the

[4] Neima (2014) observed flights of two radio-tagged Semipalmated Sandpipers back and forth between Cobequid Bay and Chignecto Bay (shown in Figures 18 and 19) but these are isolated occurrences.

latter likely uses the area only occasionally on migratory stopovers (K. Allard, CWS, pers. comm. 2017). Abundances of shorebirds, of which Semipalmated Sandpiper make up the majority, in the EBSA are relatively high compared to other areas of the Scotian Shelf Bioregion and some less common species also can occur here (Figures 14 – 17).

As a migrant, Semipalmated Sandpiper is the only species that occurs in the EBSA in these numbers and it has only recently (within the last 20 years) become prominent in Cobequid Bay (J. Paquet, CWS, pers. comm. 2016, Mann 2014). Recent radio-tagging studies of Semipalmated Sandpiper (Mann 2014, Neima 2014; Sprague et al. 2008) in the Southern Bight of Minas Basin and Cobequid Bay have provided information on regional behaviour and movements, as well as the migration out of the Atlantic region. There is little movement of radio-tagged birds from Chignecto Bay to Cobequid Bay, suggesting that separate populations may stage in different areas within the Bay of Fundy (Sprague et al. 2008, White 2013, Neima 2014). Birds tagged in the Southern Bight of Minas Basin and Cobequid Bay remained in the area during stopovers of several weeks, moving maximum distances of 15 to 22 km (Neima 2014).

Although the amphipod crustacean (*Corophium volutator*) has been considered the main prey item in the past and their distribution is a major factor in sandpiper distribution (Sprague 2002), Semipalmated Sandpiper has recently been found to have greater flexibility in its diet, feeding not only on *Corophium* but with polychaetes and biofilm making substantial contributions, consistent with recent observations of other calidrid shorebirds (Quinn and Hamilton 2012). Biofilm and polychaetes largely made up the diet of sandpipers in both Shepody Bay and the Minas Basin, though in varied quantities (Neima 2014); sandpipers can shift feeding strategy to these prey items in the absence of *Corophium* (MacDonald et al. 2012). Presence of predators such as Peregrine Falcon and Merlin also influence the local distribution of Semipalmated Sandpipers, with individuals tending to be found further from areas of the coast that provide cover for these species (Sprague et al. 2008).

Radio-tagging also indicates that Semipalmated Sandpipers tend to stay longer and move more than previously thought during stopovers, extending the duration of stay in the Bay of Fundy to approximately three weeks (22 days ± 6 days (Neima 2014). Previous estimates were approximately two weeks (Hicklin 1987, Sprague et al. 2008). Birds monitored by Neima (2014) arrived in the Minas Basin in early August with the latest birds leaving in the first week of September. Departures were concentrated over a small number of short periods, and departures were from August 30th to September 15th (Mann 2014). In the Southern Bight of Minas Basin, tagged Semipalmated Sandpiper individuals regularly moved 15 – 22 km between multiple roosting and foraging sites (Sprague et al. 2008, Neima 2014, and White 2013 from Mann 2014), though there was little mixing between Chignecto Bay and Minas Basin. Over Ocean Flocking (OOF) or airborne roosting, in which the birds fly continuously, has been observed in Cobequid Bay during high tides when normal roosting sites were submerged (Mann 2014).

The main areas used by Semipalmated Sandpiper are the mudflats on the Southern Bight of Minas Basin and the Cobequid Bay flats (Neima 2014) (Figure 18), although the specific sites used can vary between years. In Minas Basin, shifts in main feeding locations have taken place recently from the main traditional site at Evangeline Beach identified by Hicklin (1987) to Cheverie and Summerville, which were the most used foraging and roosting sites respectively (Sprague et al. 2008 from Neima 2014), and Avonport in 2012 (White 2013 from Neima 2014). In the Upper Bay of Fundy, sandpipers display year-to-year and site-to-site variability in movement and mudflat usage (Sprague et al. 2008).

Birds that stopover in both Chignecto Bay and the Minas Basin have been recently shown to fly directly to the Eastern Shore and South Shore of Nova Scotia, with the New Brunswick birds (Chignecto Bay) passing directly over the Minas Basin (Neima 2014) (Figure 19).

The longer estimates of stay of Semipalmated Sandpiper derived from radio-tracking has direct implications for population estimates of birds using the EBSA; based on peak counts and measures of duration of stay, approximately 300,000 to 480,000 sandpipers passed through the Bay of Fundy in 2013, which is significantly lower than earlier estimates, but is consistent with declines in this species observed elsewhere (Neima 2014).

Minas Passage and Minas Channel

Small numbers of shorebirds have been reported in Minas Passage and Channel at appropriate times (i.e. July to early September) during summer vessel surveys (June to September) and shore-based surveys in Minas Passage, conducted in connection with the tidal energy development (Envirosphere Consultants Limited 2010 – 2013). Occasional sightings included small flocks of Ruddy Turnstone and Red-necked Phalarope, as well as individual Red Phalarope, Sanderling, Semipalmated Sandpiper, Spotted Sandpiper and Greater Yellowlegs during those surveys.

Important Bird Areas

The EBSA contains several areas recognized for their importance to shorebirds under national and international programs, including the Cobequid Bay and Southern Bight-Minas Basin Important Bird Areas (IBA). Important Bird Areas are designated under the standardized international IBA Program, a conservation initiative coordinated by BirdLife International and in Canada by Bird Studies Canada and Nature Canada. The Cobequid Bay and Southern Bight-Minas Basin IBAs are important principally as feeding and migratory stopover areas for shorebirds, in particular for a large proportion of the world's populations of Semipalmated Sandpiper, which use the EBSA during migration.

The Cobequid Bay IBA (Figure 20) is a proposed Hemispheric Shorebird Reserve under the Western Hemisphere Shorebird Reserve Network (WHSRN). Most important species in the Cobequid Bay IBA are Semipalmated Sandpiper, but in addition, significant numbers of Black-bellied Plover occur, as well as other shorebirds including Red Knot, Sanderling, Least Sandpiper, Dunlin, Short-billed Dowitcher and White-rumped Sandpiper.

The Southern Bight, Minas Basin (IBA) (Figure 20) is designated as a Hemispheric Shorebird Reserve in the Western Hemisphere Shorebird Reserve Network (WHSRN), a RAMSAR site designated under the 1971 Convention on Wetlands of International Importance (Ramsar Convention). The Southern Bight Wetland Complex occupies 26,800 ha and supports the largest numbers of mixed species of shoreline birds during fall migration in all of North America (Nova Scotia Environment 2009[5]). The Ramsar Convention is an "intergovernmental treaty that provides the framework for the conservation and wise use of wetlands and their resources" to which Canada is a contracting party. Important species visiting, staging, and feeding in the Southern Bight of Minas Basin include Semipalmated Sandpiper, Black-bellied Plover, Red Knot, Sanderling, Short-billed Dowitcher, Least Sandpiper and Semipalmated Plover. Some areas of importance to shorebirds (e.g. roosting areas) found in NS DNR's Significant Habitats Database are shown in Figure 21.

[5] Nova Scotia Environment. 2009. Nova Scotia Wetland Conservation Policy.

Data Gaps

There is a need for determining long-term use patterns of the EBSA by shorebirds and other waterfowl, as well as continued assessment of changes in distribution and timing of shorebird movements in the EBSA to generate a better understanding of the overall importance of the EBSA in avian biology and the greater ecosystem. Dedicated surveys and use of emerging technologies should be used to determine and measure use of the EBSA by Piping Plover.

FEEDING AREA FOR RAPTORS, WATERFOWL, AND OTHER MARINE BIRDS

Raptors

Peregrine Falcon and Bald Eagle are the primary large raptors that feed in coastal areas in the EBSA. A provincially and federally protected species, Peregrine Falcon numbers are closely monitored. Bald Eagle attract public interest and the species has a wide ranging distribution throughout North America with a year-round presence in Nova Scotia, including the EBSA. The abundance of habitat and prey availability, in particular shorebirds found within the EBSA, contribute to the important role these bird species play within the EBSA ecosystem.

Peregrine Falcon: Peregrine Falcon are listed as Vulnerable under the Nova Scotia Endangered Species Act and as Special Concern under the federal SARA. Since they were returned to the area by captive breeding and nest placement programs in the 1980s, they occur widely in coastal areas of the EBSA, in particular near cliff nesting sites which include Cape d'Or, Cape Sharp and Cape Blomidon (Figure 22), but sightings extend to Cobequid Bay (Mann 2014). The birds feed principally on small birds (Cooper and Beauchesne 2007), are swift flyers, and can be found throughout the EBSA, generally arriving in March and remaining until the fall. Feeding by Peregrine Falcon on Semipalmated Sandpipers has been suggested as a factor in governing movement patterns of flocks (Sprague et al. 2008). In the area, Peregrine Falcon breed in early spring (April) and young are capable of weak flight at 40 days. The species has a strong site fidelity (Cooper and Beauchesne 2007).

Bald Eagle: Bald Eagle occupy nest sites along the coast throughout the EBSA, with particular concentrations along the Shubenacadie River and in the Wolfville area, where overwintering numbers have increased in recent decades because of availability of poultry offal (Figure 22). The species breeds in early spring.

Seabirds and Waterfowl

Harlequin Duck is listed as Special Concern under SARA. In Nova Scotia the species is protected under the Nova Scotia Endangered Species Act and is listed as Endangered. Several individuals were sighted during monitoring efforts in the Minas Passage related to tidal energy development (Envirosphere Consultants Limited 2010-2013). The south shore of the EBSA is a wintering area for the species, generally until March (Figure 22) (NSDNR, pers. comm. 2016)

Common Loon occur in the EBSA, typically overwintering in marine coastal areas and moving into freshwater habitat in the spring, including the Shubenacadie River (Figure 22).

The Boot Island National Migratory Bird Area in the Southern Bight of Minas Basin near Wolfville (Figure 23) has supported colonies of several of the common aquatic species, including Double-crested Cormorant, Great Blue Heron, Great Black-backed Gull, and Herring Gull (Table 4 and Figure 23). As of 2010, Herring Gull occupation has decreased significantly and only Great Black-backed Gull nest in significant numbers (MacKinnon and Kennedy 2014).

Waterfowl Surveys Overall

Canadian Wildlife Service and partner provinces conduct regular winter aerial surveys of the Atlantic region as part of the Atlantic Coastal Waterfowl Survey (ACWS), which includes the EBSA (Allard et al. 2014). Interpretation of maximum densities of waterfowl species in geographic subdivisions (Coastal Waterfowl Survey blocks) compared with other areas of the Scotian Shelf Bioregion show relatively high importance of the area, particularly Minas Basin, for American Black Duck, Canada Goose, dabbling ducks, and strength of Great Blue Heron colonies (Figures 24 – 27) and relatively low usage of the area by Common Eider, Atlantic Brant, scoters, mergansers, Goldeneye and sea ducks in general (Figures 28 – 34). Based on this information, the EBSA is particularly important for waterfowl species, more so than seabirds, and in particular dabbling duck species. Standard survey areas (blocks) in these illustrations were initially designed to reflect prominent coastline features that separate coastal segments, inshore bays and estuaries, and define functionally distinct habitat units for waterfowl (Allard et al. 2014).

Seabirds and Waterfowl, Outer Minas Basin, Minas Passage and Minas Channel

Waters and adjacent coastal areas of the EBSA are used by both resident and migrant bird species throughout the year. Although used by seabirds, waterfowl and other birds, the outer Minas Basin, Minas Passage and Minas Channel are not considered particularly significant in terms of their use by birds. Recent surveys for monitoring effects of tidal power development in the outer parts of the EBSA (Minas Passage and Channel) during 2009 to 2012 (Envirosphere Consultants Limited 2010 – 2013) provide an indication of occurrence and seasonal timing in the area, which reflects movements through the EBSA overall. In general, the surveys confirmed the observation by Hicklin and Smith (1984) that abundance and diversity would be lower in areas of the Bay of Fundy between the extreme inner reaches, such as the Minas Basin with its mudflats and marshes and their associated productivity and the outer Bay of Fundy upwelling areas between Brier Island and Grand Manan. Various common seabirds including Double-crested Cormorant, Herring Gull and Great Black-backed Gulls, Common Eider, and Black Guillemot are common and seasonally abundant, tending to feed in waters adjacent to breeding colonies (i.e. within foraging range of nests; variable by species) from Ile Haute and Cape-d'Or / Cape Spencer to the Parrsboro / Five Islands area (Figure 23). Peak abundances of these species occur in spring during breeding, and feeding takes place in the same general area before birds move further afield later in the season, typically to the Gulf of Maine and coastal areas of Nova Scotia. Apart from concentrating seasonally at colonies, locations such as points of land, for example Cape d'Or near Advocate Harbour, can support high concentrations of birds which aggregate there, particularly during migration. Seasonal presence and abundance of seabirds reflects local availability of food, availability of foraging habitat such as ledges and shoals, and movements of fish (e.g. Atlantic Herring). In the outer Minas Basin, Minas Passage and Minas Channel, a generally low abundance of birds reflects lower food supplies than other areas. Some detailed information on bird use of these areas is found below.

Minas Passage: The annual cycle of species composition and abundance of marine birds in Minas Passage was determined from shore-based surveys in March to December 2010 – 2012, and through vessel-based surveys in summers of 2009 – 2011 (Envirosphere Consultants Limited 2010, 2011a, 2012, 2013) (Figure 35). Forty-five species of migrants, local-breeders, and other occasionally-occurring species, were observed (Table 5). Herring Gull, Great Black-backed Gull and Ring-billed Gull, Double-crested Cormorant, Common Eider, and Black Guillemot were the most common and abundant species, and all, with the exception of Ring-billed Gull, breed in the EBSA. The 45 species recorded at the site represent about a third of marine bird species likely to occur in the Bay of Fundy, based on 154 species of marine birds in the list for Brier Island at the mouth of the Bay (Mills and Laviolette 2011). Red-throated Loon and several sea ducks (Black Scoter and Surf Scoter, and Long-tailed Duck) were the most abundant migrants. Species composition was most diverse during spring and fall migration in March – April, and October – November (19 species and 25 species per day respectively) (Figure 35), and highest daily abundance of birds occurred in April to June, and early November. Summer abundance and species diversity was low (8 – 14 species) (Envirosphere Consultants Limited 2013). Harlequin Duck, a listed endangered species, known to migrate through the EBSA and overwinter along the south shore of Minas Channel within the EBSA, was also sighted in the surveys in Minas Passage (Envirosphere Consultants Limited 2013), though numbers are lower than other coastal areas of the Scotian Shelf bioregion.

Minas Passage, Minas Channel and Outer Minas Basin: Up to 12 seabird and waterfowl species were observed per day, and sixteen species overall, during summer, day-long vessel surveys of Minas Passage and Minas Channel (two to four vessel surveys per year from July to September 2009 – 2012) (Envirosphere Consultants Limited 2010). The most common and abundant species seen were Herring Gull, Great Black-backed Gull, Ring-billed Gull, Double-crested Cormorant, Black Guillemot, Common Eider, Common Loon, and Northern Gannet. Limited information is available overall on marine bird densities in the Inner Bay of Fundy. Abundances in summer (June-September) in the Envirosphere Consultants Limited (2010) surveys were comparable to spring-summer (May-August) densities for the inner Bay of Fundy outside the EBSA, reported in Fifield et al. (2009). Lock et al. (1994) also provide abundances of seabirds vulnerable to oil pollution in the outer Bay of Fundy, as well as for the Atlantic Region as a whole, as well as abundances of coastal birds, including in the EBSA, from winter waterfowl surveys conducted by Environment and Climate Change Canada, Canadian Wildlife Service, prior to 1994.

Data Gaps

Aerial surveys through the Atlantic Coastal Waterfowl survey (ACWS) are done regularly in the EBSA. Colony surveys are done infrequently and do not provide complete coverage of the EBSA.

OTHER IMPORTANT CHARACTERISTICS OF THE EBSA

REGULAR USE BY STRIPED BASS

A year-round resident Striped Bass population occurs in the Minas Basin, Cobequid Bay and Shubenacadie River, which is distinct from a northeastern American and Canadian stock that also migrate to Minas Passage and Cobequid Bay to feed in the summer (Rulifson et al. 2008). Minas Basin supports a combined Striped Bass population of at least 10,000 fish including migrants, and there is some indication that the spawning abundance in the Shubenacadie River has increased since 2002 (DFO 2014). The resident population originating in the Shubenacadie River is the only and last confirmed spawning population remaining in the Bay of Fundy, and spawns within the Stewiacke River, a tributary of the Shubenacadie River (Bradford et al. 2012). Other former spawning populations were located outside the Minas Basin EBSA in the Annapolis River and the Saint John River, New Brunswick, but evidence of spawning in these locations has not been observed in over 30 years (DFO 2014; Bradford et al. 2015). Genetic assessment and mark-recapture data (Bradford et al. 2012) indicate the geographic range of Bay of Fundy Striped Bass includes all of the Bay of Fundy and extends from the Gulf of Maine to the southern Atlantic coast of Nova Scotia (DFO 2014, Bradford et al. 2012). Striped Bass are known to over-winter in Grand Lake on the Shubenacadie River system while some also migrate southward along the eastern coast of the United States (Rulifson et al. 2008). Recent tracking studies using acoustic tagging methods have also confirmed adult and sub-adult Striped Bass overwintering in the Minas Passage area, which is the first documented evidence of an extended northern range for the resident species (Keyser et al. 2016).

The species is fished recreationally in tidal waters year-round and in inland waters during the sport-fishing season, in particular on the Shubenacadie River between Rines Creek and Caddell Rapids. Striped Bass is also used locally for food and ceremonial purposes by the Mi'kmaq. Threats to Bay of Fundy Striped Bass were assessed by DFO (2006) and COSEWIC (2012). Shubenacadie River Striped Bass are susceptible to exploitation from recreational fishing, Aboriginal food, social or ceremonial (FSC) fisheries, bycatch in commercial fisheries (e.g. Shad and Gaspereau), and from poaching. They are also sensitive to acidity, with a pH of 5.9 or less considered to be lethal (Buckler et al. 1987). Bay of Fundy Striped Bass are designated as Endangered (2012) by COSEWIC and are presently under consideration for inclusion on the SARA Schedule 1 as Endangered (Bradford et al. 2015).

Temporal Distribution

Seasonal distribution varies for Bay of Fundy Striped Bass throughout the Minas Basin. Beginning in late April or early May, downstream migration to the Shubenacadie River from overwintering freshwater habitat within Grand Lake takes place (Bradford et al. 2012). Spawning occurs during May and June in the tidal freshwater area of the Stewiacke River and is initiated when water temperatures reach about 15 °C and salinity is low (< 1 to 2 ppt). Egg densities can exceed 1000 eggs per cubic meter (Duston 2010). Fertilized eggs disperse with the water current and hatch after two or three days, depending on water temperature and environmental conditions. Variance in environmental conditions can result in variable timing of spawning activity among years, from onset in mid-May or in early June (as cited in Bradford et al. 2015). Spawning into July has been observed for some years (Dr. J. Dunston, Dalhousie University Agriculture Campus, Bible Hill, NS, pers. comm. as cited in Bradford et al. 2015). Larvae remain in freshwater for 5 to 15 days before yolk reserves are consumed and larvae move to the near-shore shallows of the estuary, where they begin to feed on zooplankton. The larval stage can last 35 to 50 days (Bradford et al. 2015).

Minas Basin provides nursery habitat for young, as well as a feeding area for adults. Juveniles remain in the Basin until they reach sexual maturity (3 - 4 years for males; 4 - 6 years for females) at which time they begin to move into the Shubenacadie River to spawn (May to June) (Rulifson and Dadswell 1995, Rulifson et al. 2008). Adults remain in the Basin over summer after spawning and primarily re-enter estuaries, river mouths, and at least one headwater lake (Shubenacadie, Grand Lake) at the onset of winter (Douglas et al. 2003). The young-of-the-year are thought to remain in Minas Basin year-round, and migrate to Grand Lake to overwinter by their second year (Bradford et al. 2015). Overall, Striped Bass appear to be present in near-shore areas of Minas Basin throughout spring, summer and fall but are detected more commonly during July and August (Keyser 2015). Older juveniles, Age 2+ and post-spawned adults feed as they migrate along the coast from summer into autumn.

Striped Bass larvae and recently metamorphosed juveniles forage on zooplankton and other small invertebrates, although cannibalism is known. Their diet becomes increasingly diverse with time as the Striped Bass increase in body size and may include: mysids, sand shrimp, polychaetes, crabs, Rainbow Smelt, Atlantic Silverside, Alewife, Blueback Herring, American Shad, Atlantic Herring, Atlantic Tomcod, and American Eel (Paramore 1998, Rulifson and McKenna 1987, DFO 2006).

Spatial Distribution

Tag and recapture studies of Striped Bass between 1999-2002 and 2008-2009 as well as genotyping from 1999-2006 (Bradford et al. 2012) concluded that the range extent of Shubenacadie Striped Bass includes Minas Basin, the Shubenacadie River and Grand Lake with inter-annual use of the Shubenacadie-Grand Lake system as an overwintering area by individual fish, and a relatively small marine distribution for the contingent of the population that ascends the river to overwinter in freshwater. Other surveys demonstrate that Shubenacadie River Striped Bass occur throughout the Bay of Fundy including the Saint John River, NB, and the Gulf of Maine (Bradford et al. 2015).

Striped Bass spawning is known to occur within the tidal portion of the Stewiacke River from zero to six kilometers upstream of the confluence with the tidal Shubenacadie River and is the only confirmed spawning site used annually by the species (Bradford et al. 2015) (Table 6). Eggs, suspended in the water column, occur in large numbers and hatch in two to three days; the larvae remain for five to 15 days before moving into the near shore estuary areas to continue feeding and developing throughout the summer. Eggs and larvae hatched in the Shubenacadie River can be transported by tidal flow and found in Cobequid Bay, although their survival in the high salinities is probably low (Stewart and Dunston 2012, R. Bradford, DFO, pers. comm. 2016).

Age 0+ Shubenacadie River Striped Bass use a variety of shallow shoreline habitats, in both tidal and non-tidal waters as rearing habitat, and may extend their distribution to habitats of this type beyond Minas Passage to the outer Bay of Fundy; however, there is no documented evidence of this age group in tidal river habitats within Minas Passage (Bradford et al. 2015). By the end of the first growth season, Shubenacadie River Striped Bass are known to occupy tidal portions of the Shubenacadie and Stewiacke rivers, Cobequid Bay and the inner portion of Minas Basin. Beach seined collections of fish at sites along the north shore of Minas Basin and in Cobequid Bay, from near Parrsboro (Five Islands) to the Masstown area, indicates that young Striped Bass occur widely in the waters there, and probably throughout much of the nearshore waters of the area affected by tidal water movements (Bradford et al. 2015). Young can reach outside of the EBSA into the adjacent Chignecto Bay and Age 0+ Striped Bass with Shubenacadie River origins were captured in a research trapnet installed near the head of tide in the Petitcodiac River, NB, (Dr. Paul Bentzen, Dalhousie University, Halifax, NS, as cited in Bradford et al. 2015).

Spatial distribution of tagged Striped Bass varied seasonally within Minas Basin, as determined by an acoustic tagging study and acoustic receiver data from May to August 2011 and May to October 2012, collected at low intertidal sites including Walton, Economy, the lower Southern Bight, and Minas Passage (Keyser 2015). Detections were more frequent near Walton and the Passage during June and more frequent in the lower Southern Bight, Walton and Minas Passage during July. During August to October, detections were predominantly in the lower Southern Bight. Tag detections suggested a preference for the Southern Bight area with some fish apparently exclusive to the area, but detection of fish in Minas Passage, Walton and Economy were also consistent with no distinct pattern of movement throughout the Basin. Detections noticeably declined in October, indicative of fall migration to Grand Lake or to the outer Bay of Fundy. The study also noted that larger fish appeared to move throughout a larger range (Keyser 2015).

Within the Minas Passage, acoustic receiver data (collected in 2010, 2011 and 2012 - 2013) along intertidal areas as well as in line transects across Minas Passage and the FORCE study area (10 receivers clustered at the FORCE test site) found sub-adult and adult fish spanning the width of the Passage, with back and forth movements but no evidence of a population-wide pattern in spatial distribution (Keyser 2015, Broome 2014). Acoustic receiver data collected for 79 Striped Bass from July to November 2010 recorded fish occurring at greater depths during flood tides and shallower during ebb tides (Broome 2014). The fish were detected up to depths of 96 meters during the summer, fall and winter months, with detections most frequent during summer months and in the top 50 meters of the water column. During winter months, depth distribution was shallower, primarily detected between 15 - 35 meters. Year-round detection data indicate that during daylight hours, Striped Bass are deeper in the water column (25 – 65 m spring to fall; 20 - 35 m winter) while detections at night were closer to surface (within 20 m spring to fall; 10 - 30 m winter) suggesting a relationship between vertical migration and water temperatures (Keyser et al. 2016). This study is the first documentation of the unexpected over-wintering of Striped Bass in Minas Passage where low temperatures are considered near-lethal, as well as, the extension of the northern marine range for the species (Keyser 2015, Keyser et al. 2016). The overall proportion of the population overwintering in the Passage is likely small and future research on winter behavior in the Passage and the associated risks is recommended (Keyser 2015, Keyser et al. 2016, R. Bradford, DFO, pers. comm. 2016).

Data Gaps

Additional research on the overwintering behavior of Striped Bass in Minas Passage, including physiology and feeding behavior, with respect to migration and distribution ranges of the population is recommended in light of new and recent documentation of overwintering within Minas Passage despite low temperatures.

The evidence of overwintering of Striped Bass in the Minas Passage is concurrent with a period of warmer minimum sea-surface water temperatures than observed over the past 25 years (R. Bradford, DFO, pers. comm. 2017). Further research may help determine the influence of changes in the water temperature profile on the geographic distribution of Striped Bass and how this may change with time.

The resident Striped Bass population originating in the Shubenacadie River is the only confirmed spawning population remaining in the Bay of Fundy. There is some evidence of spawning in other locations; however, it is unknown if this spawning is successful. Further investigations may reveal existing or developing spawning habitat (R. Bradford, DFO, pers. comm. 2017).

MIGRATION ROUTE USED BY MULTIPLE SPECIES

Minas Channel and Minas Passage is a significant migratory route, connecting Minas Basin and the outer Bay of Fundy, utilized by dozens of fish and bird species as they migrate between inner bay, shoreline and freshwater areas and the outer Bay of Fundy and open sea. Many migratory species move in and out of the Bay during particular life history stages, coming from nearby coastal waters, inner freshwater rivers, as well as from distant areas, such as fish stocks from the Northeast Coast of the United States. Dadswell (2010) compiled a list of 77 fish species that occur or are expected to occur in the Minas Basin, Minas Passage and Minas Channel based on studies and observations carried out since the 1800s. Also, recent studies using bio-telemetry technology in the Minas Passage have been carried out for several species of economic and/or ecological importance to assemble information on the spatial and temporal use of the region in relation to tidal energy development (i.e. commercial-scale tidal in-stream energy conversion (TISEC) devices). Species including Atlantic Salmon, Striped Bass, Atlantic Sturgeon, American Shad, Gaspereau, Atlantic Herring, American Eel, shark species and lobster are among the list of fish species that pass through the Channel during a life cycle. Important migratory seabird, waterfowl and shorebird species also migrate through the Minas Basin EBSA. Species occurrence in different parts of Minas Basin often indicates seasonal migratory movements; Baker et al. (2014) summarize the importance and information of the 12 most important fish species in weir catches.

Migrations of Seabirds and Waterfowl

Seabirds, waterfowl and shorebirds make up an important component of the marine ecosystem in the EBSA, and are diverse and abundant in this part of the Bay of Fundy. The Minas Channel and Basin is a migratory corridor for some migrant bird species including Black Scoter, Surf Scoter, White-winged Scoter, Common Eider, Long-tailed Duck, and Red-throated Loon, which move through the area during the spring and fall migration periods. The Bay of Fundy, geographically, acts as a funnel for northerly spring migratory movements of water-associated birds (Cameron 2014) making Minas Channel, Minas Passage and Minas Basin a migratory route as birds are channeled through the region. The northern summer shift into Atlantic coastal waters for oceanic species such as shearwaters and petrels can result in birds of many kinds entering the mouth of the Bay of Fundy, which then reach the Minas Basin EBSA. Occurrences of Northern Gannet, Cory's, Great and Sooty Shearwaters in Minas Passage (e.g. Envirosphere Consultants Limited 2013) may be examples of the funneling effect.

Migrations of Fish and Invertebrates

Dadswell (2010) highlighted 77 species of marine and estuarine fish potentially using Minas Passage, Minas Basin and Minas Channel. Of these, 49 are relatively common and important, and are presented in Table 7, broken down into several artificial categories describing type of migration and summarized in terms of relative important in Figure 36. *Migratory* includes:

1. fish large enough to readily move beyond the limits of the EBSA and which do so as a required part of their life cycle;
2. *local migratory* species, which live nearshore in coastal marine/estuarine waters and move seasonally short distances into coastal estuaries and freshwaters for some of their life cycle (e.g. Rainbow Smelt, Atlantic Silverside); and
3. *freshwater migratory*, which move significant distances from coastal waters of the EBSA into freshwater systems for part of their life cycle and may also spend significant time there (e.g. Brook Trout, American Eel).

Some fish have a combination of migratory patterns, for example both moving large distances in marine waters to get into the EBSA, and subsequently moving up into freshwater systems to spawn (e.g. Atlantic Salmon, Alewife). *Nursery* is included in Table 7 to indicate species for which juveniles develop and mature in coastal estuarine or marine waters in the EBSA, some of which migrate out of the area at the end of the maturation period (e.g. Atlantic Herring). *Feeding* refers to fish moving into the area seasonally in relatively large numbers (e.g. Atlantic Sturgeon) presumably focused on feeding; and *casual/seasonal* reflects movements into the EBSA of fish which are widespread on the continental shelf and commonly have seasonal offshore-onshore movements for spawning or feeding and maturation as part of their life cycles and commonly enter the EBSA (e.g. haddock). The relative number of species in each migratory/use group in Table 7 is illustrated in Figure 36.

Small, typically benthic fish (e.g. snailfish, lumpfish) aren't expected to be wide-ranging as adults[6], and live and breed in the EBSA. Some fish have a combination of migratory types, summarized in Table 7 (e.g. American Shad and Atlantic Sturgeon), in which the local

[6] Biology of non-commercial benthic fish is not well known in general, and in the EBSA in particular.

populations migrate into the EBSA principally to spawn and to provide a nursery area for juveniles, while other populations from outside the EBSA move seasonally through as part of coastal feeding migrations.

Tidal portions of at least 13 freshwater rivers and riverine estuaries of Cobequid Bay and Minas Basin provide important migratory corridors for anadromous species. From May to June, smolt and adult Atlantic Salmon migrate through the rivers and estuaries, in particular the Shubenacadie River, as well as the nearshore coastal region of Minas Basin, along which a number of species (e.g. Atlantic Sturgeon and Striped Bass) move during the summer. The Shubenacadie River is considered an important migratory route for inner Bay of Fundy Atlantic Salmon, Rainbow Smelt, American Eel and Striped Bass between freshwater streams (i.e. Shubenacadie and Stewiacke Rivers) and the Minas Basin, and all the life stages are commonly found in the EBSA.

Striped Bass in the Bay of Fundy include several migratory populations as well as a resident Bay of Fundy population (Shubenacadie River in the EBSA). Spatial and temporal patterns are not clear; however, adult and sub-adult Striped Bass are documented as occurring broadly throughout Minas Basin and Passage from the surface to greater than 95 meters year-round (Broome et al. 2015, Keyser et al. 2016). Atlantic Salmon migrate from the inner Bay of Fundy to the open sea multiple times throughout their lives, beginning as smolts descending from tidal portions of freshwater rivers into the Basin at two to four years of age, and eventually returning from over-wintering at sea to the riverine estuary staging areas where they ascend rivers to spawn (DFO 2013). Atlantic Sturgeon populations, primarily from Saint John, New Brunswick and Kennebec, Maine Rivers migrate to the Minas Basin annually, occupying the area from April to November to feed. Weir and trawling data indicate a clockwise migration pattern by the sturgeon, moving along the north shore in the spring and occupying the south shore area in the summer before migrating through the Minas Passage and Channel in the fall (Stokesbury et al. 2016). Atlantic Sturgeon sub-adults captured in intertidal weirs and acoustically tagged and tracked, entered Minas Basin (summer feeding grounds) in the spring. They made sporadic use of the Minas Passage throughout the summer, prior to exiting to the outer Bay in the fall (Redden et al. 2014). Sturgeon detections in the Passage were more concentrated in the southern region. Although Atlantic Sturgeon were detected at all water depths, their movements in and near the FORCE site showed a preference for depths ranging from 15 to 40 m. The highest estimated travel speed (current assisted), between receiver lines, was 3.2 m/s (Redden et al. 2014).

Little information exists to indicate whether there are particular local routes through the EBSA that fish use to access particular target locations. The Minas Basin is relatively small, roughly 30 x 70 km, and can rapidly be crossed by fish moving actively or transported by tidal flows. Acoustic tagging studies in the past decade are starting to provide information to complement historical traditional tagging information, to look for local movement patterns. Recently, studies of Atlantic Sturgeon suggest the species uses the southern part of Minas Passage to access the Minas Basin (Stokesbury et al. 2016). A counter clockwise movement of some species out of the Minas Basin has been suggested but not proven based on the existence of a tidal residual current, which would help to move individuals in that direction (e.g. Dadswell 2004).

Some recent studies of catch in weirs (Baker et al. 2014), as well as an acoustic and trawl survey of Minas Passage (Figure 37) (CEF Consultants Ltd. 2011), conducted to provide baseline information for tidal energy development, have also provided information on migratory seasonal use of the Minas Basin part of the EBSA. Baker et al. (2014) summarized summer captures at weirs in Five Islands and Bramber (Table 8), and reported 26 species, listed in Table 9. Generally, occurrences and abundance were similar. Keays (2015) assessed populations of squid from weir catches in Bramber. Whidden (2013, 2015) studied Little and Winter Skate, based on weir and some trawl catches.

Lobster: A recent study used acoustic tags to investigate movements of lobster in the outer Minas Basin and Minas Passage (Morrison 2014). Some adult lobster may over winter in the Minas Basin, and a seasonal movement out of the Basin through Minas Passage prior to early December has been suggested based on recovery of tags and movement patterns of acoustically tagged individuals, including berried females, and an opposite movement in early spring is also thought to occur (Morrison 2014).

Squid: Longfin and Shortfin Squid (*Doryteuthis pealeii* and *Illex illecebrosus*) move into the Minas Basin from the continental shelf off Nova Scotia in summer, the former as part of a coastwide spawning movement, and the latter a summer feeding movement (Keays 2015, Dawe et al. 2007). Squid of both species, with the Longfin Squid most numerous, were captured on the south side of the Minas Basin near Bramber from May to August (Keays 2015).

Skates: Two skates found in the Minas Basin are not particularly migratory. Winter Skate (*Leucoraja ocellata*) typically occurs widely on the continental shelf offshore and can occur in winter in Passamaquoddy Bay (Scott and Scott 1988) but has a year-round presence in the Minas Basin (Dadswell 2010). The species is common in summer (Dadswell 2010) and occurred in moderate numbers in a southern Minas Basin weir catch in 2014 (Whidden 2013 and 2015). Little Skate (*L. erinacea*) is sympatric with Winter Skate (shares similar distribution and habitat) and shows similar seasonality (Scott and Scott 1988, Dadswell 2010). It is common in summer (Wehrell 2005, Dadswell 2010) and is expected to occur in Minas Passage (Dadswell 2010).

Seasonal Presence of Fish in Minas Passage

Various common fish species occur in the water column in the Minas Passage-Minas Channel during the summer to fall (June to October) based on trawl and acoustic surveys conducted for tidal energy environmental monitoring (CEF Consultants Ltd. 2011). Timing of the surveys (i.e. summer to fall) precluded representation of species having major inward spring migratory movements into Minas Basin but captured Atlantic Herring that spawn in the EBSA within that period. Atlantic Herring dominated the catch, especially in June and early July, with Atlantic Herring, Dollarfish, Atlantic Mackerel, Gaspereau, Rainbow Smelt, and Lumpfish caught most consistently (Tables 10 and 11). Atlantic Tomcod, Silver Hake, Red Hake, and Pollock, were caught in low numbers, inconsistently, and were generally small (<10 cm fork length). Some predominately bottom species caught high in the water column included Sea Raven, Summer Flounder, and Winter Skate. Although Atlantic Herring were not as abundant in catch after July, they were captured later in the season (October) when they are not expected to be present; at that time, the species still made up the largest single component in most tows, although only about 7% of their peak abundance (CEF Consultants Ltd. 2011). Some large Striped Bass and Dogfish were caught in September and October indicating possible migratory or feeding movements in that area at that time.

The CEF Consultants Ltd. (2011) trawl study locations were arranged to represent nearshore areas of Minas Passage as well as central channel areas, with a view to detecting differences in abundance and composition relative to movements of migrating species such as Atlantic Salmon, which have been suspected of moving closer to shore. Numbers of most species, were fairly evenly distributed across Minas Passage, although greater numbers were caught in the deep, central trough area, where percentage of total catch ranged between 45 and 55% (Table 12). Exceptions were Dollarfish, which were more concentrated nearshore, and Gaspereau, which appeared to be more abundant in the central area of the Passage. Acoustic biomass estimates, also indicated a relatively even distribution with little spatial differences. Depth preferences were observed for some species, but trends were not statistically significant. The major components of finfish biomass in Minas Channel appear to be adult Atlantic Herring moving into the channel in June, followed by young Atlantic Herring in later July and August, Gaspereau in September, and a broader mix of species leaving the upper Bay of Fundy in October (CEF Consultants Ltd. 2011).

Data Gaps

Most species in the EBSA have not been studied enough to provide detailed, local, life cycle information. Information on seasonal occurrence and movements is often biased towards spring-summer-fall, when the main fisheries are active and field studies are typically undertaken; therefore, the availability of winter data for most species presented is a major data gap. It is an open question whether American lobster spawn in the Minas Basin and whether the area supports significant populations of larvae and juveniles.

KELP BEDS

Subtidal animal and plant communities have been documented occasionally in parts of the Southern Bight of Minas Basin at extreme low tides, but no surveys have been conducted recently. The occurrence of kelp beds off Blomidon, initially reported by Gratto and Bleakney (1985) (Figure 38), was highlighted in Buzeta (2014) as a feature of possible significance in the EBSA. Bleakney and Mustard (1974) earlier found sponge communities at the extreme low water mark in the same general area that are also associated with water with low particulate levels. No new information is available on the kelp beds reported by Gratto and Bleakney (1985). Water clarity in outer Minas Basin is probably sufficient to support growth of seaweeds in areas in which these kelp beds were documented (Tao 2013, Envirosphere Consultants Limited 2011b, Figures 39 and 40). In Minas Passage, analysis of video of the seabed near the tidal energy site in Minas Passage has shown seaweed communities comparable to those expected on similar bottom types in the Bay of Fundy (Envirosphere Consultants Limited 2009). On a gravel to cobble seabed at the site, the shallower subtidal areas are occupied by sparse development of *Fucus sp.* (Rockweed) (Figure 41). At greater depths, marine plants including Dulse (*Palmaria palmata*) and coralline algae encrusting on rock surfaces occur. Anecdotal information indicates Dulse is occasionally harvested on Black Rock (a basalt island located along the north shore of Minas Passage west of Cape Sharp), and the island has an intertidal population of rockweeds (P. Stewart, Envirosphere Consultants Limited, personal observations).

Data Gaps

Despite the known occurrence of kelp beds in the area, no comprehensive surveys have been completed to map the distribution of macroalgae in the EBSA. It would be important for long term management objectives to have information on distribution and diversity of macroalgae because of the potential importance for the ecosystem.

SALT MARSH, SIGNIFICANT ESTUARIES AND SEA CLIFFS

Salt marsh (the fringing intertidal coastal marshes dominated by cord grass, *Spartina alterniflora* and *Spartina patens* found in the EBSA mainly throughout Minas Basin), are an important ecosystem component, providing habitat for waterfowl and wildlife, important habitat and nursery areas for coastal fish, and a carbon source for detrital food chains in the EBSA and adjoining areas of the Bay of Fundy. Particular significance is attached to salt marshes in the inner Bay of Fundy due to historic losses of natural marshes to agriculture; in one estimate 65% of Atlantic coastal marshes including those in the Bay of Fundy, have been lost (Environment

Canada 1991). Despite these losses, salt marshes still occur here in greater numbers and higher densities than other parts of the Scotian Shelf Bioregion (Allard et al. 2014).

The EBSA is important both in focusing attention on the residual marshes, and on large salt marsh restoration projects, which have been carried out along rivers and estuaries here (Bowron et al. 2013a and b, 2014a and b). Remaining salt marshes can be in a largely natural state where levels of coastal development are low. In Minas Basin, there are approximately 3855 ha of salt marsh, predominately in the Southern Bight and Cobequid Bay (Parker et al. 2007, F. Mackinnon, NSDNR 2016)[7]. Currently efforts are underway to further update the salt marsh inventory for the area (D. van Proosdij, Saint Mary's University, NS, pers. comm. 2017). Approximate distribution of salt marshes in the EBSA based on NSDNR mapping is shown in Figure 42, and distribution based on shorebird, seabird and waterfowl surveys done by CWS (Allard et al. 2014) is presented in Figure 43.

Salt marsh restoration projects have been completed in four estuaries in the Minas Basin beginning in 2005 by Nova Scotia Transportation and Infrastructure Renewal (NSTIR), including Walton River, Cogmagun River, Cheverie Creek and St. Croix River, and nearby reference rivers and streams (Bowron et al. 2013a and b, 2014a and b). Associated monitoring studies provided information on biological features including vegetation species composition, birds (Colpron 2008), benthic invertebrates and fish, as well as detailed physical information on the affected marshes. Up to 12 common fish species dominated by Atlantic Silversides (*Menidia menidia*) and Mummichog (*Fundulus heteroclitus*) were found in the four restored salt marshes in southern Minas Basin (Table 13).

Coastal estuaries in the EBSA that have been shown to be particularly important for wildlife have been identified by the Province of Nova Scotia (NS Significant Habitats Database 2016) (Figure 42). Similarly some prominent sea cliffs identified by Nova Scotia Department of Natural Resources (NSDNR) that provide habitat or potential habitat for cliff-nesting birds are also shown in Figure 42.

INTERTIDAL FLATS

Extensive areas of intertidal flats, which include mudflats and sand flats, are distinctive features of the Minas Basin and are important in both the physical and biological dynamics of the ecosystem there (Parker et al. 2007) (Figure 44). In the Minas Basin, the intertidal zone occupies a comparatively large proportion of the total area; from 53 to 59% in the Southern Bight of Minas Basin and Cobequid Bay respectively, and 15% in outer parts of Minas Basin (Prouse et al. 1984, Parker et al. 2007). The large relative area affects a number of physical properties of the oceanographic system such as water temperature, mixing and nutrient balance; but also affects biological features such as primary productivity as well as exposure of organisms to solar radiation, desiccation, and temperature extremes, to name a few. Various studies of mudflats and other intertidal flats in the EBSA in the mid-1970s to early 1980s related to sedimentology (Amos and Mosher 1985, Amos et al. 1992) and biofacies (biological communities with physical impact on geological processes and that left geological markers such as tracks, tubes and shells) (e.g. Risk et al. 1977); as well as biological processes related to shorebird feeding (e.g. Hicklin 1981, Boates 1980); and productivity of mudflats (e.g. Hargrave et al. 1983). These studies contributed to the development of baseline information to be used in assessing potential impacts of tidal energy development (Gordon and Dadswell 1984). In addition to these studies, primarily geological studies of sand bars and mudflats in Minas Basin,

[7] Another cycle of wetland mapping is planned to occur (F. MacKinnon, NS DNR, pers. comm., 2016)

and in particular Cobequid Bay (Figure 45), were also done at that time (e.g. Dalrymple 1977, Knight 1977, Knight 1980, Zaitlin 1987) as the importance of the area was recognized in describing the dynamics of tidal delta sand bar systems, which occur worldwide.

Mudflats have an important biological role in the EBSA, documented by a number of early studies focused on the role of primary production by diatoms as a food supply for other organisms on the inner Bay of Fundy mudflats (Daborn 1991, Daborn et al. 1993, Sutherland et al. 1998). DFO studies in the late 1970s to early 1980s, conducted in Cumberland Basin and Shepody Bay of Chignecto Bay (which is structurally analogous to the Minas Basin and situated between Nova Scotia and New Brunswick with similar intertidal flats and tidal ranges), showed that most of the primary production there was derived from the mudflats and supporting benthic microalgae and salt marsh habitat (Prouse et al. 1984). Measurements of benthic diatom production were done on mudflats both there and in Cobequid Bay (Hargrave et al. 1983). Although mudflat production contributes only a small proportion of primary production of the Bay of Fundy as a whole (approximately 1%, Prouse et al. 1984), it is important locally, and about half of benthic primary production in areas such as Minas Basin is due to benthic production on mudflats (Prouse et al. 1984).

More recently, interest has focused on the role of diatoms and the chemical compounds they generate, such as carbohydrates, that lead to the formation of “biofilm” and help to stabilize the mudflats, affect grainsize composition (Garwood et al. 2013 and 2015, Garwood 2014), and are a component of the diet of shorebirds feeding on the flats (MacDonald et al. 2012, Quinn and Hamilton 2012). Processes affecting the formation and stability of mudflats, in particular in relation to the effects of changes in tidal current regimes due to future tidal energy development, have also been the focus of a number of recent studies (Van Proosdij et al. 2013a and b).

Gerwing (2015) and Gerwing et al. (2015) studied physical and biotic influences on mudflat infaunal communities, as well as sandpiper diet using recombinant DNA technology, at locations in Chignecto Bay and Minas Basin (Moose Cove, Starrs Point and Avonport). Infaunal communities exhibited statistically significant but small changes over winter (between December and March), and change was only weakly correlated to winter stressors (i.e., scour density and depth, variance in drift ice cover) and sediment oxygen content. Gerwing (2015) measured community composition of mudflat invertebrate communities, diatom biomass (chlorophyll a), shorebird density, and influencing physical factors (tidal exposure time, sediment penetrability, depth of redox potential discontinuity (RPD)) and volume-weighted mean particle size, and concluded that community and population structure were relatively uncoupled from biotic and abiotic factors, presumably because of high concentrations of resources (benthic diatoms and detrital organic matter) (Gerwing 2015).

Gerwing (2015) also showed, using PCR (polymerase chain reactions) techniques on Sandpiper feces, that the diet of one of the most important shorebird species in the area (Semipalmated Sandpiper) includes organisms from marine (pelagic and intertidal), freshwater, and terrestrial ecosystems, the latter previously unknown.

The extensive tidal sand flats that characterize Cobequid Bay in the inner portions of Minas Basin are distinctive geological features that form sand bars in Cobequid Bay and a unique tidal delta system (Zaitlin 1987), which is a dominant feature of the intertidal environment there (Figure 45).

Data Gaps

No recent mapping and characterization of intertidal habitat types in the EBSA, particularly in Minas Basin, have been carried out. Information gained from such assessments would be valuable in assessing the overall importance of the different areas in biological productivity.

BENTHIC COMMUNITY

Several recent studies of the seabed and benthic communities have been conducted in outer Minas Basin, Minas Passage and Minas Channel, to provide baseline information for tidal energy development (summarized in Stewart 2009) and to meet academic (Morrison 2012, 2014) and federal government research objectives (e.g. *CGCS Hudson* research cruise 2013-13[8]) (Envirosphere Consultants Limited 2009; Table 14). The baseline studies produced the first significant systematic collection of images, and some of the first samples of the seabed, in northern Minas Passage, revealing both new and previously unseen geological features and benthic communities that occur under a unique combination of conditions including depth, substrate, water column stratification, and current (Stewart 2009). Morrison (2012) analyzed some of the baseline images in order to classify bottom types and habitats, focusing on the tidal energy development site on the north side of Minas Passage. Morrison (2014) mapped seabed geology and features based on sediment data and photographs from *CGCS Hudson* Cruise 2013-13, to determine lobster habitat distribution and suitability.

Species identified in images were all commonly found elsewhere in the Bay of Fundy and Gulf of Maine system (Stewart 2009, Morrison 2012, 2014). A low to moderate diversity of approximately 25 species of surface-dwelling animals, as well as several fish species (blenny unidentified and Longhorn Sculpin), were seen in baseline images at the site (Stewart 2009). Several other common benthic species in various taxa were identified from benthic grab samples (Table 15) including polychaetes, amphipod crustaceans, hydroids, molluscs (horse mussel spat, jingle shells and limpets). Communities of organisms in the area were shown to be associated with major geological features (Figures 46 and 47). In particular, a community dominated by three species -- Breadcrumb sponge, (*Halichondria panicea*), blood star (*Henricia sanguinolenta*) and northern red sea anemones (*Urticina felina*) -- is associated with a shallow (30 – 40 m) basalt bedrock platform exposed to the highest tidal currents and forming a prominent physical feature of Minas Passage (Stewart 2009). Species in this community are typically only found in deeper waters of the Bay of Fundy and Gulf of Maine, and, therefore, their occurrence here (probably largely due to the unique well mixed water column conditions) represents an extension or oasis of the community into a nearshore area and is an important feature of the area (Stewart 2009). Adjacent areas of outer Minas Basin also can exhibit some of the same species, with one of the sponges (Yellow Breadcrumb Sponge) found on bedrock at the lower tidal extent off Cape Blomidon (Bleakney and Mustard 1974), presumably reflecting the contiguity of water masses in that area with Minas Passage through the large tidal water mass excursion. The basalt bedrock platform is one of a chain of similar features in the area that may also support this community stretching through Minas Passage from Cape Sharp to Cape Split, but which has not been surveyed. Some of the sedimentary bedrock (mudstone) surveyed in Minas Passage also displays holes that resemble burrows of boring clams, but the identity of the holes could be verified. Fossil burrows of the rock-boring clam *Zirphaea crispata*, which occurs in the EBSA, have also been found in sandstone outcrops located in rock strata above extreme low water in the Blomidon Area (Bleakney and Janes 1983).

The benthic communities observed here, and the geological features with which they are associated, represent unique and previously undescribed elements of the benthic environment of the Bay of Fundy, in particular due to the high currents under which they exist. Deepwater hard bottom benthic environments have not been widely inventoried in Atlantic Canada to allow comparisons, so there may be similar or parallel communities elsewhere, but it is unlikely they

[8] Two technical reports on DFO surveys and analysis are in preparation (Dr. Brent Law, DFO, pers. Comm. 2017).

occur under similar current conditions. Apart from the basalt bedrock platforms, extensive areas of sedimentary bedrock outcrops and troughs occur widely in Minas Passage. The benthic communities in these areas are not well defined, and they may be the dominant communities for the area. Volcanic basalt platforms in the area have smaller localized distribution. Several occur on the outer fringes of the study area and are potentially more significant in terms of unique occurrence of species and habitat conservation value.

Data Gaps

Bathymetry and seabed characteristics have not been adequately assessed in the outer Minas Basin. Habitat classification coupled with multi-beam mapping would highlight seabed features and relative importance to organisms.

OTHER CHARACTERISTICS TO INVESTIGATE

AMERICAN LOBSTER (*HOMARUS AMERICANUS*)

The EBSA is not known as a nursery area for American Lobster, and Minas Basin appears to be mainly a summer feeding area, although some adults may overwinter there (Morrison 2014). There are unconfirmed accounts from fishers, however, of the presence of planktonic and juvenile lobster in Minas Basin. Minas Basin has a small but locally important lobster fishery (Coffen-Smout et al. 2013) with relatively high catch per unit effort (Figures 48 and 49), although composite catch weight standardized by square kilometer in the Minas Basin is low compared to the rest of the Bay of Fundy region as well as the South Shore (Figure 50) (Serdynska and Coffen-Smout 2017), reflecting fewer participants in the fishery than in many other parts of the region. Perceptions and knowledge of local fishers are an important resource for the management of the resource. Further clarification of the ecological role the area provides for lobster would enhance the EBSA as an area to develop effective resource management strategies.

REGULAR SIGHTINGS OF HARBOUR PORPOISE (*PHOCOENA PHOCOENA*)

Harbour Porpoise (*Phocoena phocoena*) are commonly found in the Minas Basin and Minas Passage often observed moving in pairs, singly, or in pods of a few animals. They are currently listed as Threatened under SARA, Schedule 2. Overall, research to date does not indicate that the EBSA is of greater importance than other parts of the Bay of Fundy for Harbour Porpoise.

Harbour Porpoise movements are thought to be primarily influenced by movements of prey, in particular Atlantic Herring, in the EBSA but also by oceanographic parameters such as temperature and depth. The number of animals that regularly use the EBSA is not known. They form a small part of the Bay of Fundy/Gulf of Maine Atlantic Harbour Porpoise subpopulation (COSEWIC 2006a), which has been estimated as 79,883 for 2011 (NOAA 2016). Occurrences in the inner Bay of Fundy, including the EBSA, have not been considered to represent an important component (Gaskin 1992) and have been largely anecdotal. Studies associated with recent tidal energy development activities (e.g. Tollit et al. 2011; Envirosphere Consultants Limited 2011a), as well as some other recent studies, show that they are a regular component although at relatively low densities. The recent studies, using passive acoustic monitoring

(PAM) technologies (C-POD and icListenHF hydrophones[9]) to measure the occurrence of porpoises in Minas Passage (Tollit et al. 2011, Wood et al. 2013, Porskamp 2015), and at two coastal locations in Minas Basin during late spring, summer and fall (Porskamp et al. 2015; Porskamp 2015) have documented seasonal trends in movement (i.e. low presence during winter with activity increasing in March and peaking in June when Atlantic Herring and other fishes are known to be regionally abundant), a higher rate of animal detection in cooler deep-water areas, and higher activity at night (Baker et al. 2014, Tollit et al. 2011, Wood et al. 2013). Land and vessel-based surveys in Minas Passage during 2010, 2011 and 2012 generally support the seasonality and occurrence trends for the Minas Passage obtained by PAM studies (Envirosphere Consultants Limited 2011a, 2012, 2013, Tollit et al. 2011).

Temporal Distribution

Data collected from PAM studies carried out between 2010 and 2014 in the Minas Passage as part of on-going research and environmental monitoring for in-stream tidal turbine developments demonstrate a peak in Harbour Porpoise presence during early spring to early summer (May – June) and again in early fall (October) (Tollit et al. 2011, Wood et al. 2013, Porskamp 2015, Porskamp et al. 2015) (Figure 51). Data obtained from the PAM studies suggest low presence in the Passage, Southern Bight and the Minas Basin north shore (Five Islands) during winter and mid to late summer months. The detection peaks during the spring and early summer coincide with the presence of Atlantic Herring and other fish species, which are abundant at this time and are a known food source for Harbour Porpoise.

Overall abundance of Harbour Porpoise has varied seasonally in Minas Passage based on shore-based surveys at the tidal energy demonstration site, with moderate numbers occurring in early March, April and November; peak numbers in late March, early July and mid-August, and low to moderate numbers in late April, May, June-August, October and late November. No data is available for January and February, as surveys were not conducted during these times (Envirosphere Consultants Limited 2013).

Spatial Distribution

PAM data collected from the lower intertidal zone near Bramber in the Southern Bight, in close proximity to a weir site, commonly detected porpoises from April to June and August to October, with peak detection during April and May, and during September and October (Baker et al. 2014; see Figure 52). In comparison, a second study site on the north shore of the Minas Basin in close proximity to a Five Islands weir site over the same period rarely detected porpoises (i.e. only eight detection positive minutes in the entire season (six months) there) (Baker et al. 2014). One and perhaps two Harbour Porpoises were recorded in the Minas Basin off Kingsport in mid-September by a broadband hydrophone mounted on an Atlantic Sturgeon caught and released off Kingsport, Nova Scotia in September 2012 (Logan-Chesney 2013), and later after the hydrophone had detached. Porpoise clicks and timing suggested that the individuals were interacting with the acoustic device, which simultaneously emitted sound and listened (Logan-Chesney 2013). The results from this and the other studies conducted in Minas Passage

[9] Hydrophone instrumentation analyze and/or record sound continuously over time in a specific area and can be specialized to detect specific sounds (i.e. porpoise click trains). C-POD hydrophones detect click trains between 20-160 kHz and have a detection range up to 300 m and optimal at 1100 m. Detections were not common at depth-averaged current speeds of >1 m/s; icListenHF hydrophones records sound from 0.01-204.8 kHz have detection range of up to 300 m, and optimal at 150 m. The frequency of porpoise echolocation click trains is between 100-160 kHz (Porskamp et al. 2015).

suggest that the majority of the Harbour Porpoise population occupies cooler, deeper waters in Minas Channel or other areas of the Bay during the summer (Wood et al. 2013, Baker et al. 2014). Detection rates recorded by C-PODs placed at four monitoring stations in Minas Passage in relation to the FORCE study site were higher at depths ranging from 40 to 84 meters and lower at shallower depths (i.e. 27 m) (Porskamp et al. 2015).

Data Gaps

Limited information is available on feeding behavior (i.e. movement in relation to prey) and presence of Harbour Porpoise in the Minas Basin and inner Bay of Fundy in relation to diel, tidal and lunar time scales, outside of research focused in the Minas Passage for in-stream tidal energy development. Wood et al. (2013) suggest future studies to deploy hydrophones in a transect arrangement from the intertidal zone to the middle of the Minas Basin to detect movements of Harbour Porpoise.

LADY CRAB (*OVALIPES OCELLATUS*)

Lady Crab (*Ovalipes ocellatus*) is a swimming crab species that has a disjunct warm-water distribution in Canada, occurring in Minas Basin and the Southern Gulf of St. Lawrence, but separated geographically from the main population located further south along the US East Coast. The species occurs commonly in the Southern Bight of Minas Basin (D. Porter, pers. Comm. 2017; C. Wood, personal communication 2017; Wood et al. 2015). It was observed in the Southern Bight of Minas Basin (Evangeline and Kingsport beaches) during the 1970s (Dr. S. Bleakney, retired, Wolfville, NS, pers. comm., 2017) and is reported in biological keys to Minas Basin (Bromley and Bleakney 1984). The first Canadian record was Bass River and Scots (“Scotsman”) Bay (Bousfield and Leim, 1958). It is common south of Cape Cod, and it occurs in estuaries but not in coastal areas around the Gulf of Maine (Burchsted and Burchsted 2006). Biological characteristics of the disjunct population occurring in the Southern Gulf of St. Lawrence are described in Voutier and Hanson (2008). The Lady Crab is pictured in Figure 53.

SABELLARIA REEFS

Sabellaria vulgaris is a reef-building suspension feeding polychaete that constructs tubes from coarse sand and, in addition to using mollusc shells as substrate, can expand and stabilize areas of the seabed by forming reefs (Kinner and Maurer 1978; Zimmer et al. 2012). This species has a temperate distribution in eastern North America and reaches its northern limit of distribution “in warm water enclaves” of western Nova Scotia and the Bay of Fundy (Pocklington 1989). Although not listed as occurring in the Estuary and Gulf of St. Lawrence (Brunel et al. 1998), it was found on the Northumberland Strait shore of northern New Brunswick (Cape Pele and Botsford) and Prince Edward Island (Fishing Cove) in surveys for ocean disposal permits in the early 1990s (Stewart et al. 1999) and so appears to fit the zoogeographic pattern of a warm water species that moved into the area in a period of warm climate conditions after the last glaciation (Davis and Browne 1997), and has since remained in warm water enclaves. Specimens have been found in Minas Basin and Chignecto Bay (Pocklington 1989, Appy et al. 1980, Bromley and Bleakney 1984, Zaitlin 1987). The existence at one time of a large area of *Sabellaria* reefs near the Guzzle Channel and off Kingsport in southern Minas Basin was identified by Dr. Sherman Bleakney and Dr. Glenys Gibson of Acadia University (H. Breeze, DFO, pers. comm. 2017). However, the present occurrence or distribution is unknown. The species was not found in a survey covering coastal areas throughout Minas Basin (Westhead 2005). *Sabellaria* reefs have been reported along the US coast (e.g. Delaware Bay (Curtis 1975, Kinner and Maurer 1978)). The occurrence of reefs of this species may be unique in Atlantic

Canada and, therefore, significant in terms of the ecological significance criteria for the EBSA. It is recommended that the site of previous occurrence of the reefs should be surveyed to determine if reefs are present and, if so, to determine the extent.

SPECIES AT RISK

Several at-risk species protected under SARA or with a COSEWIC designation occur occasionally within the EBSA. While there are occasional occurrences of White Shark, Shortnose Sturgeon, Leatherback Sea Turtle, North Atlantic Right Whale, and Fin Whale in the EBSA, these species are not known to directly inhabit the area for their complete life cycle. The relationship between the EBSA and these occasional occurrences is currently unclear, but it unlikely that the EBSA is of particular importance to these species. It is likely that other marine areas, where these species regularly occur, are more important for supporting the species. Species at risk for which the EBSA is particularly important are described earlier in the document.

CONCLUSIONS

The coastal marine system encompassed by the Evangeline-Cape Blomidon-Minas Basin EBSA is significant in many ways, in particular because of the existence there of a macrotidal environment and oft-cited highest tides and tidal currents in the world, but also because of a unique combination of estuarine environments; geological features including extensive mud and sand flats; relatively small size and overall shallowness in relation to its size, which affects temperature regime and productivity; use by the full spectrum of marine associated birds, marine mammals and fish; and the constant mixing caused by the tide.

As is the case of many complex coastal ecosystems, a full understanding of the processes taking place is limited. Academic interest, tidal energy development, and science-based management initiatives have focused attention on the ecological importance of the Minas Basin. In particular, the importance of the EBSA to life history stages of a variety of species has emerged, such as the seasonal occurrence of a major segment of western hemisphere shorebirds that rely on the mudflats, and its importance as a coastal migratory stopover for various pelagic fish and feeding area for other species. Recent technological developments, in particular acoustic tagging and tracking of fish and shorebirds, and passive listening for marine mammals, have added to research efforts, has led to major advances in understanding movements and behaviour of these groups, and to defining the ecological importance of the area.

Although it is known that the EBSA is important ecologically and commercially, with respect to some fisheries as well as to its use by the Mi’kmaq, current knowledge still does not provide a complete picture of the complex interactions that exist in the Minas Basin and EBSA or provide a complete view of the importance of the area within the Scotian Shelf Bioregion. Efforts to identify information gaps will help to focus studies in such a way as to increase the understanding of the importance of the EBSA, and lead to better management and protection of the resources and organisms within.

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TABLES

Table 1. List of ecological features for the Evangeline-Cape Blomidon-Minas Basin Ecologically and Biologically Significant Area. The shaded areas represent other characteristics of the EBSA that may be considered as ecological features, derived from literature reviews and expert opinion.

Features of the EBSA, used in identifying it as an EBSA	DFO EBSA Criteria				
	U	A	FC	R	N
Mud-piddock clam	x	-	x	-	-
Important area for multiple life-history stages of inner Bay of Fundy (iBoF) Atlantic Salmon	-	-	x	-	-
Important feeding area for Atlantic Sturgeon	-	-	x	-	-
Spawning area for Atlantic Herring	-	x	X	-	-
Nursery area for Atlantic Herring	-	x	X	-	-
Concentration of habitat used by American Eel	-	-	-	-	-
Nursery/juvenile area for multiple fish species	-	x	x	-	-
Important feeding area for migrating shorebirds	-	x	x	-	-
Important feeding area for migrating and overwintering waterfowl, raptors, other marine birds	-	-	x	-	-
Other important characteristics of the EBSA that may also correspond to the first order EBSA criteria:					
Important area for multiple life-history stages of Striped Bass	-	-	-	-	-
Migration route used by multiple species	-	-	-	-	-
Kelp beds	-	-	-	-	-
Salt marsh	-	-	-	-	-
Intertidal flats	-	-	-	-	-
Other characteristics of the EBSA to investigate:					
Nursery area for American Lobster					
Regular sightings of Harbour Porpoise					
Occurrence of Lady Crab					
Occurrence of *Sabellaria* reefs					

DFO EBSA Criteria:
U – Uniqueness: the degree to which the characteristics of areas are unique, rare, distinct, and have few or no alternatives.
A – Aggregation: of individuals of a species, of different species, of structural features, of oceanographic processes.
FC – Fitness Consequences: the degree to which the area is required by a population or species for various life stages and activities.
R – Resilience: the degree to which the area is required by a population or species for various life stages and activities.
N – Naturalness: degree to which areas are pristine and contain native species.

Table 2. Summary of the biophysical functions, features, attributes and location of marine and estuarine habitat important to inner Bay of Fundy Atlantic Salmon (DFO 2013, DFO 2016a, Marshall 2014). The information below is an excerpt for Areas 2 and 8 from the complete table in DFO (2013); Areas 2 and 8 occur all or in part in the EBSA (see Figure 5).

Geographic Location of Habitat	Life-stage	Function and Timing	Features	Attributes
Minas Basin, Chignecto Bay and coastal estuaries (Area 2)	Post-smolt	Migration to outer BoF (May-Jun)	Migration corridor to outer BoF	Salinity increases to 31 ppt; predators; temperature
		Feeding (May-Sept)	Food availability	Pelagic prey includes copepods, amphipods, euphausiids, fish larvae (Key forage species not known for this area)
	Adult	Migration to freshwater (May-Oct)	Migration corridor to freshwater	Temperatures ≤14°C while awaiting cues for river entry <Salinity; temperatures <14°C while awaiting cues for river entry Predator abundance
		Staging (Jun-Oct, river specific)	Estuaries	Temperatures ≤14°C while awaiting cues for river entry <Salinity; temperatures <14°C while awaiting cues for river entry
		Feeding (extent unknown)	Food availability	Pelagic prey includes amphipods, euphausiids, fish larvae
	Kelt	Migration to the outer BoF and reconditioning, (winter/spring)	Migration corridor to outer BoF	>Salinity for re-acclimation to salt water Depth/volume Predator abundance
		Feeding (winter/spring)	Food availability	Forage: Minas Channel/Basin with juvenile herring, juvenile White Hake, Winter Flounder, adult and juvenile 3-spine Stickleback.
Bay of Fundy coastal NS, Port George-Hall's Harbour (Area 8)	Post-smolt	Feeding (Jul into Sept)	Food availability Upwelling of bay water cooler than center gyre	Forage of copepods, includes *Calanus* sp., amphipods, euphausiids, fish larvae, sand lance and larval herring SSTs <14°C; rich cool waters
	Adult	Staging (Jun-Aug)	Upwelling of bay water	SSTs <14°C; rich cool waters
		Feeding (extent uncertain)(Jun-Aug)	Food availability	Forage: amphipods, euphausiids, fish larvae, sand lance and spawning herring
	Kelt	Unknown		

Table 3. Fish larvae detected in ichthyoplankton surveys in Minas Basin, Minas Passage and Minas Channel in 1983 and 1984 (from Bradford and Iles 1993).

Common Name	***Scientific Name***
American Sand Lance	*Ammodytes americanus*
Atlantic Herring	*Clupea harengus*
Lumpfish	*Cyclopterus lumpus*
Atlantic Snailfish	*Liparaus atlanticus*
Inquiline Snailfish	*Liparus inquilinus*
Grubby	*Myoxocephalus aenaeus*
Rainbow Smelt	*Osmerus mordax*
Winter Flounder	*Pseudopleuronectes americanus*
Windowpane Flounder	*Scopthalmus aquosus*
Radiated Shanny	*Ulvaria subbifurcata*

Table 4. Seabird colonies in the Minas Basin EBSA. Source: NS DNR (2016)

Location	**Species**
Spencer’s Island (1984)	Great Blue Heron, Double-crested Cormorant, Black Guillemot, Common Eider
Cape Split Pinnacle (2011)	Double-crested Cormorant
Black Rock (2011)	Black Guillemot
Pinnacle Island	Great Blue Heron
Egg Island (2011)	Double-crested Cormorant
Brick Kiln Island (2011)	Double-crested Cormorant
Boot Island (2011)	Double-crested Cormorant, Great Blue Heron, Great Black-backed Gull, Herring Gull

Table 5. Scientific and common names of water associated birds found in Minas Passage and Channel (2009-2012) from monitoring studies carried out in connection with tidal energy development (Envirosphere Consultants Limited 2010-2013).

Family	Species
Phalacrocoracidae (Cormorants)	Double-crested Cormorant (*Phalacrocorax auritus)* Great Cormorant (*Phalacrocorax carbo)*
Laridae (Gulls and Terns)	Great Black-backed Gull (*Larus marinus*) Herring Gull (*Larus argentatus)* Iceland Gull (*Larus glaucoides*) Laughing Gull (*Larus atricilla*) Lesser Black-backed Gull (*Larus fuscus*) Ring-billed Gull (*Larus delawarensis*) Mew Gull (*Larus canus*) Black-legged Kittiwake (*Rissa tridactyla*) Black Tern (*Chlidonias niger*) Bonaparte's Gull (*Larus philadelphia)**
Podicipedidae (Grebes)	Horned Grebe (*Podiceps auritus*) Red-necked Grebe (*Podiceps grisigena*)
Sulidae (Gannets)	Northern Gannet (*Bassanus morua*)
Alcidae (Auks)	Atlantic Puffin (*Fratercula arctica*) Black Guillemot (*Cepphus grylle*) Common Murre (*Uria aalge*) Thick-billed Murre (*Uria lomvia*) Razorbill (*Alca torda*)
Procellariidae (Shearwaters)	Cory's Shearwater (*Calonectris diomedea*) Greater Shearwater (*Puffinus gravis*) Sooty Shearwater (*Puffinus griseus*) Northern Fulmar* (*Fulmarus glacialis*) Parasitic Jaeger* (*Stercorarius parasiticus*) Long-tailed Jaeger* (*Stercorarius longicaudus*)
Gaviidae (Loons)	Red-throated Loon (*Gavia stellata*) Common Loon (*Gavia immer*) Pacific Loon (*Gavia pacifica*)
Anatidae (Ducks and Geese)	American Black Duck (*Anas rubripes*) Common Goldeneye (*Bucephala clangula*) Common Eider (*Somateria spectabilis*) King Eider (*Somateria spectabilis*) White-winged Scoter (*Melanitta fusca*) Surf Scoter (*Melanitta perspicillata*) Black Scoter (*Melanitta nigra*) Northern Shoveler (*Anas clypeata*) Red-breasted Merganser (*Mergus serrator*) Common Merganser (*Mergus merganser*) Harlequin Duck (*Histrionicus histrionicus*) Long-tailed Duck (*Clangula hyemalis*) Mallard (*Anas platyrhynchos*) Canada Goose (*Branta canadensis*)
Scolopacidae (Sandpipers and Phalaropes)	Sanderling (*Calidris alba*) Semipalmated Sandpiper (*Calidris pusilla*) Spotted Sandpiper (*Actitis macularia*) Greater Yellowlegs (*Tringa melanoleuca*) Ruddy Turnstone (*Arenaria interpres*) Red-necked Phalarope (*Phalaropus lobatus*) Red Phalarope (*Phalaropus fulicaria*)
Storm-Petrels (Hydrobatidae)	Wilson's Storm Petrel* (*Oceanites oceanicus*)

*Additional species observed in Minas Passage during vessel surveys and species seen outside of survey time limits.

Table 6. Summary of features, functions, and attributes of Bay of Fundy Striped Bass habitat (DFO 2014).

Population – Shubenacadie River				
Geographic Location	**Age from Egg Deposition**	**Function**	**Features**	**Attributes**
Stewiacke River 0 km to 6 km from confluence	Adults	Spawning (May-June)	Saltwater/Freshwater interface	Temperature: 13°C - 24°C Salinity: ≤ 1 ppt Water velocity: moderate current Dissolved oxygen: > 5 mg/L
	Eggs (0-3 days)	Incubation of pelagic eggs (May-June)	Saltwater/Freshwater interface Current to maintain eggs in suspension	Temperature: 13°C - 24°C Salinity: ≤ 1 ppt Water velocity: moderate current Dissolved oxygen: > 5 mg/L
	Larvae (0-7 days to first feeding)	Early development (May)	Saltwater/Freshwater interface Current to maintain eggs in suspension	Temperature: 15°C - 26°C Salinity: ≤ 6 ppt Dissolved oxygen: > 5 mg/L Prey: zooplankton
	Larvae and recently metamorphosed juveniles (8-30 days)	Metamorphoses (May-July)	Waters under tidal influence in the Stewiacke and Shubenacadie rivers.	Temperature: 15°C - 26°C Salinity: < 10 ppt 8-17 days, 1-30 ppt 18-30 days. Dissolved oxygen: > 5 mg/L Prey: zooplankton
Tidal waters of the inner Bay of Fundy	Age 0+ year (31-150 days post-hatch)	Growth (May-October)	Food availability	Temperature: ≤ 22°C Dissolved oxygen: > 5 mg/L Prey: Zooplankton

Population – Shubenacadie River				
Geographic Location	**Age from Egg Deposition**	**Function**	**Features**	**Attributes**
Tidal waters of the inner Bay of Fundy	Age 0+ year (31-150 days post-hatch)	Migration (May-December)	Corridor to/from winter habitat and spawning habitat	Temperature: ≤ 22°C Dissolved oxygen: > 5 mg/L Corridor free of obstructions that prevent/delay migration
		Over-wintering (October–May)	Inner portions of estuaries	Temperature: ≥ -1.5°C Dissolved oxygen: > 5 mg/L Water circulation that promotes retention
Tidal waters of Bay of Fundy including Saint John River, Shubenacadie River and lakes	All Age 1+ year and older	Growth (April-October)	Food availability	Dissolved oxygen: > 5 mg/L Prey: mysids, *Crangon*, polychaetes, crabs, small, medium, and large fishes
		Migration (October-November)	Corridor to/from winter habitat	Temperature: ≥ -1.5°C (tidal waters) Dissolved oxygen: > 5 mg/L
		Overwintering (October–May)	Marine/estuarial	Temperature: ≥ -1.5°C Dissolved oxygen: > 5 mg/L Water circulation that promotes retention

Population – Shubenacadie River				
Geographic Location	**Age from Egg Deposition**	**Function**	**Features**	**Attributes**
Tidal waters of Bay of Fundy including Saint John River, Shubenacadie River and lakes	All Age 1+ year and older	-	Freshwater	Lakes/embayments with low susceptibility to flushing Dissolved oxygen: > 5 mg/L
	Adults Males: Age 3+ years and older Females: Age 5+ years and older females	Spawning	See 'Eggs'	Temperature: ≥ 15°C (onset of spawning activity) Light: generally at dusk See 'Eggs'
			Corridor to spawning grounds	Free of obstructions that prevent/delay migration Dissolved oxygen: > 5 mg/L
		Migration (October-November)	Corridor to/from winter habitat	Temperature: ≥ -1.5°C (tidal waters) Dissolved oxygen: > 5 mg/L
		Overwintering (October-May)	Marine/estuarine	Temperature: ≥ -1.5°C Dissolved oxygen: > 5 mg/L Water circulation that promotes retention
			Freshwater	Lakes/embayments with low susceptibility to flushing Dissolved oxygen: > 5 mg/L

Table 7. Migratory characteristics and use as a nursery area for 49 fish species extracted from a list of 77 species compiled by Dadswell (2010) that commonly occur in the Minas Basin Ecologically and Biologically Significant Area[10].

Species	Resident Non-Migratory	Local Migratory	Freshwater Migratory / Life-Cycle	Spawning	Nursery	Feeding	Casual / Seasonal
Alewife	-	-	✓	✓	✓	✓	-
American Eel	-	-	✓	-	✓	-	-
Atlantic Halibut	-	-	-	-	-	✓	✓
American Lobster	-	-	-	-	✓?	✓	-
American Mackerel	-	-	-	-	-	✓	-
American Shad	-	-	✓	✓	✓	✓	-
Atlantic Cod	-	-	-	-	-	-	✓
Atlantic Herring	-	-	-	✓	✓	-	✓
Atlantic Salmon	-	-	✓	✓	-	-	-
Atlantic Silverside	-	✓	-	-	✓	-	-
Atlantic Sturgeon	-	-	✓	✓	✓	✓	-
Atlantic Tomcod	-	✓	-	-	✓	-	-
Banded Killifish	-	✓	-	-	✓	-	-
Blueback Herring	-	-	✓	✓	✓	-	-
Brook Trout	-	✓	✓	-	-	-	-
Brown Trout	-	✓	✓	-	-	-	-
Butterfish	-	-	-	-	-	-	✓
Fourbeard Rockling	✓	-	-	-	✓	-	✓
Haddock	-	-	-	-	-	✓	✓
Inquiline Snailfish	✓	-	-	-	✓	-	✓
Little Skate	✓	-	-	✓?	✓?	-	✓

[10] American Lobster is also included because of its mobility, occurrence in a commercial fishery, and potential ecological significance for the area.

Species	Resident Non-Migratory	Local Migratory	Freshwater Migratory / Life-Cycle	Spawning	Nursery	Feeding	Casual / Seasonal
Longfin Squid	-	-	-	✓?	✓?	-	✓
Longhorn Sculpin	✓	-	-	-	✓	-	✓
Lumpfish	✓	-	-	-	✓	-	✓
Monkfish	✓	-	-	-	✓	-	✓
Mummichog	-	✓	-	-	✓	-	-
Pollock	-	-	-	-	-	-	✓
Porbeagle Shark	-	-	-	-	-	✓	✓
Radiated Shanny	✓	-	-	-	✓	-	-
Rainbow Smelt	-	✓	✓	-	✓	-	-
Red Hake	-	-	-	-	✓	-	✓
Rock Gunnel	✓	-	-	-	✓	-	-
Sand Lance	-	-	-	-	-	-	✓
Sea Lamprey	-	-	✓	✓	-	-	-
Sea Raven	✓	-	-	-	✓	-	-
Shortfin Squid	-	-	-	-	-	✓	✓
Shorthorn Sculpin	✓	-	-	-	✓	-	-
Silver Hake	-	-	-	-	-	-	✓
Smooth Flounder	-	-	-	✓	✓	-	✓
Smooth Skate	✓	-	-	-	✓	-	✓
Spiny Dogfish	-	-	-	-	-	✓	✓
Sticklebacks	✓	-	-	-	✓	-	-
Striped Bass	-	✓	✓	✓	✓	-	-
Thorny Skate	-	-	-	-	-	-	✓
White Hake	-	-	-	-	-	-	✓
Windowpane	✓	-	-	✓	✓	-	✓

Species	Resident Non-Migratory	Local Migratory	Freshwater Migratory / Life-Cycle	Spawning	Nursery	Feeding	Casual / Seasonal
Winter Flounder	-	-	-	✓	✓	✓	✓
Winter Skate	✓	-	-	✓?	✓?	-	✓
Yellowtail Flounder	-	-	-	-	-	✓	✓

Table 8. Summer occurrence (May – August) of important fish species in Minas Basin weirs in Five Islands and Bramber in 2013 (Baker et al. 2014).

Species	**Occurrence**
Atlantic Herring (*Clupea harengus*)	*Bramber:* Present in varying abundance from early April to August and perhaps later with spawning adults in April to May and juveniles (young of year) from July to August. *Five Islands:* present in varying abundance early May to August and perhaps later with high abundance of adults in May and juveniles (young of year) abundant from mid-June to early August and perhaps later.
Tomcod (*Microgadus tomcod*)	*Bramber:* Adults early April to mid-May. Juveniles in low to moderate abundance late June through early August. *Five Islands:* Occasionally present at least early May to early August and perhaps later.
Alewife (*Alosa pseudoharengus*)	*Bramber:* Spawning mid-April to early May (spawning adults captured enroute to rivers). Abundant in June; present in varying abundance in summer (i.e. to mid-August) though smaller fish. *Five Islands:* Abundant in June; present in varying abundance in summer (i.e. to mid-August) though smaller fish.
Blueback Herring (*Alosa aestivalis*)	*Bramber:* Present in varying abundance May to August and perhaps longer with high abundance mid-May. *Five Islands:* Present in varying abundance May to August and perhaps longer with high abundance in late June.
American Shad (*Alosa sapidissima*)	*Bramber:* Adults and juveniles present in varying abundance mid-April to August and perhaps later with peaks in late April (large adults only present) and June (adults and juveniles). *Five Islands:* Adults and juveniles present in varying abundance May to August and perhaps later, peaking in late June.
Atlantic Mackerel (*Scomber scombrus*)	*Bramber:* Present mid-June to early August, peak early July. *Five Islands:* Occasional from late May to late July, peak mid- to late June.
Rainbow Smelt (*Osmerus mordax*)	*Bramber:* present at least from early April to mid-August or later, highest later in the season (i.e. mid-August), comprised of adults with young-of-the-year. *Five Islands:* Present at least from early May to early August, mainly adults with or young-of-the-year in late July onward.
Winter Flounder (*Pseudopleuronectes americanus*)	*Bramber:* Present at least from early April to mid-August or later, peaking in June with spawners present April to early May. *Five Islands:* Present at least from early May to early August or later, peaking in June.
Windowpane (*Scophthalmus aquosus*)	*Bramber:* Present at least from early April to mid-August or later, peaking in June. *Five Islands:* Occasionally present at least from early May to early August or later.
Smooth Flounder (*Liopsetta putnami*)	*Bramber:* Present at least from early April to mid-August or later, most abundant May to July. *Five Islands:* Rare at least from early May to early August or later (north shore Five Islands).

Species	Occurrence
Striped Bass (*Morone saxatilis*)	*Bramber:* Present at least from early April to mid-August or later, most abundant in May. *Five Islands:* Occasionally present at least from early May to early-August or later, and most abundant in May.
Atlantic Sturgeon (*Acipenser oxyrhinchus*)	*Bramber:* Occasionally present in low numbers from late May to mid-August or later, and may peak June – July (D. Porter, pers. comm. 2016). *Five Islands:* Rare from mid-May to mid-June (north shore Five Islands).

Table 9. Twenty-six species captured in weirs at Five Islands and Bramber, Minas Basin in 2013 (Baker et al. 2014)

Species	**Scientific Name**
Alewife	*Alosa pseudharengus*
American Shad	*Alosa sapidissima*
Blueback Herring	*Alosa aestivalis*
Atlantic Herring	*Clupea harengus*
Winter Flounder	*Pseudopleuronectes americanus*
Rainbow Smelt	*Osmerus mordax*
Windowpane Flounder	*Scophthalmus aquosus*
Striped Bass	*Morone saxatilis*
Atlantic Mackerel	*Scomber scombrus*
Butterfish	*Peprilus triacanthus*
Sea Raven	*Hemitripterus americanus*
Longhorn Sculpin	*Myoxocephalus octodecemspinosus*
Atlantic Sturgeon	*Acipenser oxyrinchus*
Smooth Flounder	*Liopsetta putnami*
Winter Skate	*Raja ocellata*
Atlantic Tomcod	*Microgadus tomcod*
Red Hake	*Urophyscis chuss*
Silver Hake	*Merluccius bilinearis*
Spiny Dogfish	*Squalus acanthias*
Northern Pipefish	*Syngnathus fuscus*
Brown Trout	*Salvelinus fontinalis*
Pollock	*Pollachius virens*
Monkfish	*Lophius americanus*
Cunner	*Tautogolabrus adspersus*
Bluefish	*Pomatomus saltatrix*
White Perch	*Morone americana*

Table 10. Abundance and composition of fish catch in a trawl survey in Minas Passage, June 19, 2010, (CEF Consultants Ltd. 2011).

Quantity	Species	Length (cm)
1	Dollarfish	10
2	Silver Hake	18
1	Sea Raven	30
1	Herring	30
1	Mackerel	20
3	Tomcod	8, 10, 25*
1	Gaspereau	30
3	Summer Flounder	25
2	Winter Skate	35
***note: a single length indicates all fish were the same length**		

Table 11. Seasonal breakdown of fish catch in trawl and acoustic surveys in the Minas Passage, June – October 2010 (CEF Consultants Ltd. 2011).

Month	Herring	Dollarfish	Mackerel	Gaspereau	Smelt	Lump Fish
June	8096	1	9	0	4	1
July	5749	151	20	17	31	0
August	1047	431	167	100	173	5
September	1335	36	55	24	12	6
October	582	13	42	8	3	7

Table 12. Numbers of fish captured in trawls in Minas Basin – Minas Channel, versus location relative to shore and main channel, June – October 2010 (CEF Consultants Ltd. 2011).

Species/Size	Central Deep Area	Other Areas	Percent Deep (%)
Herring, young	2,153	2,161	49.91
Herring, adult	2,511	2,019	55.43
All Herring	4,664	4,180	52.74
Dollarfish	244	387	38.67
Mackerel	133	145	47.84
Gaspereau	130	57	69.52
Lump Fish	10	8	55.56

Table 13. Fish species captured in salt marshes on the southern shore of Minas Basin in monitoring of salt marsh restoration projects (Bowron et al. 2013a and b, 2014a and b).

	Cheverie Creek (2004-2009)	Cogmagun River (2009-2013)	St. Croix River (2007-2013)	Walton River (2005-2012)
Atlantic Silversides (*Menidia menidia)*	X	X	-	X
Alewife (Gaspereau) (*Alosa pseudoharengus)*	X	X	-	X
Three-spine Stickleback (*Gasterosteus aculeatus)*	X	-	-	X
Four-spine Stickleback (*Apeltes quadracus)*	X	-	-	X
Nine-spine Stickleback (*Pungitius pungitius)*	X	X	X	X
Mummichog (*Fundulus heteroclitus)*	X	X	X	X
Killifish (*Fundulus diaphanous)*	-	-	-	X
Tomcod (*Microgadus tomcod)*	X	X	X	X
Rainbow Smelt (*Osmerus mordax)*	X	X	-	X
American Eel (*Anquilla rostrata)*	X	X	X	X
Striped Bass (*Morone saxatilis)*	X	-	X	X
Brook Trout (*Salvelinus fontinalis)*	X	-	-	-
Rainbow Trout (*Oncorhynchus mykiss)*	X	X	X	-

Table 14. Benthic communities in the Minas Passage study area (Envirosphere Consultants Limited 2009).

Community/Area	**Depth (m)**[1]	**Substrate**	**Seaweeds**	**Macrofauna**
Unconsolidated Sediments				
Coastal Platform – Intertidal	HWM to MLW	Level gravel to occasional cobble and boulder.	Patchy rockweed (*Fucus* sp) and *Ulva lactuca* on flats. Includes *Ascophyllum* in tide pools.	Low abundance of amphipods, periwinkles, barnacles.
Coastal Platform – Subtidal	MLW – 6.5 m	Gravel to cobble.	Coralline algae, occasional rockweed (*Fucus).*	Barnacles, bryozoans (*Flustra),* rock surface community.
Slope and toe of Coastal Platform	6.5 – 25 m	Stable gravel to cobble.	Coralline algae, occasional rockweed (*Fucus).*	Rock surface community (tube builders).
Shallow Nearshore (Cobble/Boulder)	25 – 50 m	Cobble to boulder, occasional gravel, minor sand.	No seaweeds.	Breadcrumb sponge, sea stars (*Asterias),* bryozoans (*Flustra*), rock surface community (tube builders), mobile epifauna (e.g. hermit crabs).
Bedrock				
Offshore Sandstone Bedrock ridges	45 – 50 m	Rough sandstone/ mudstone ridges separated by bands of cobble and boulder.	No seaweeds.	Breadcrumb sponge, seastars (*Asterias, Henricia*), rock surface community (tube builders (e.g. amphipods, *Jassa* sp), hydroids, attached bivalves (e.g. *Anomia*).
Offshore Volcanic Bedrock Plateau	31 – 34 m	Rough basalt commonly overlain by smooth basalt boulders.	No seaweeds.	Breadcrumb sponge, encrusting sponges, barnacles, sea anemones (*Stomphia),* seastars *Henricia* sp, patchy surface tube builders (amphipods/polychaetes), barnacles.

[1]Depth below mean low water (MLW)

Table 15. Benthic organisms found on rocks dredged in sedimentary outcrops Stations 1 and 7, August 19 and 20, 2009 (number or organisms in brackets) (Envirosphere Consultants Limited 2009).

Station	**Benthic Organisms**
Station 1	Bryozoan: *Flustra foliacea* Hydroid: *Eudendrium arbusculum*? Ascidian: *Ascidia callosa*
Station 7 (Sandstone Cobble)	Hydroid Unidentified Amphipods: *Jassa falcata* (23); *Corophium insidiosum* (1) Barnacles: *Semibalanus balanoides* (43) Snails (Jingle shells): *Anomia squamula* (1); *Anomia simplex* (1) Clams: Horse mussel spat - *Modiolus modiolus* (1) Encrusting sponge: white (1); brown (1) Polychaete worms: *Lepidonotus squamatus* (1); *Terebellidae* (1); *Goniadidae* (1); *Maldanidae* (1); *Spirorbis* (1); *Ampharetidae* (1)
Station 7 (Basalt Cobble)	Bryozoan unidentified Amphipods: *Jassa falcata* (4) Hydroid: *Eudendrium*? sp Polychaete worm fragment Bivalve spat (2)

FIGURES

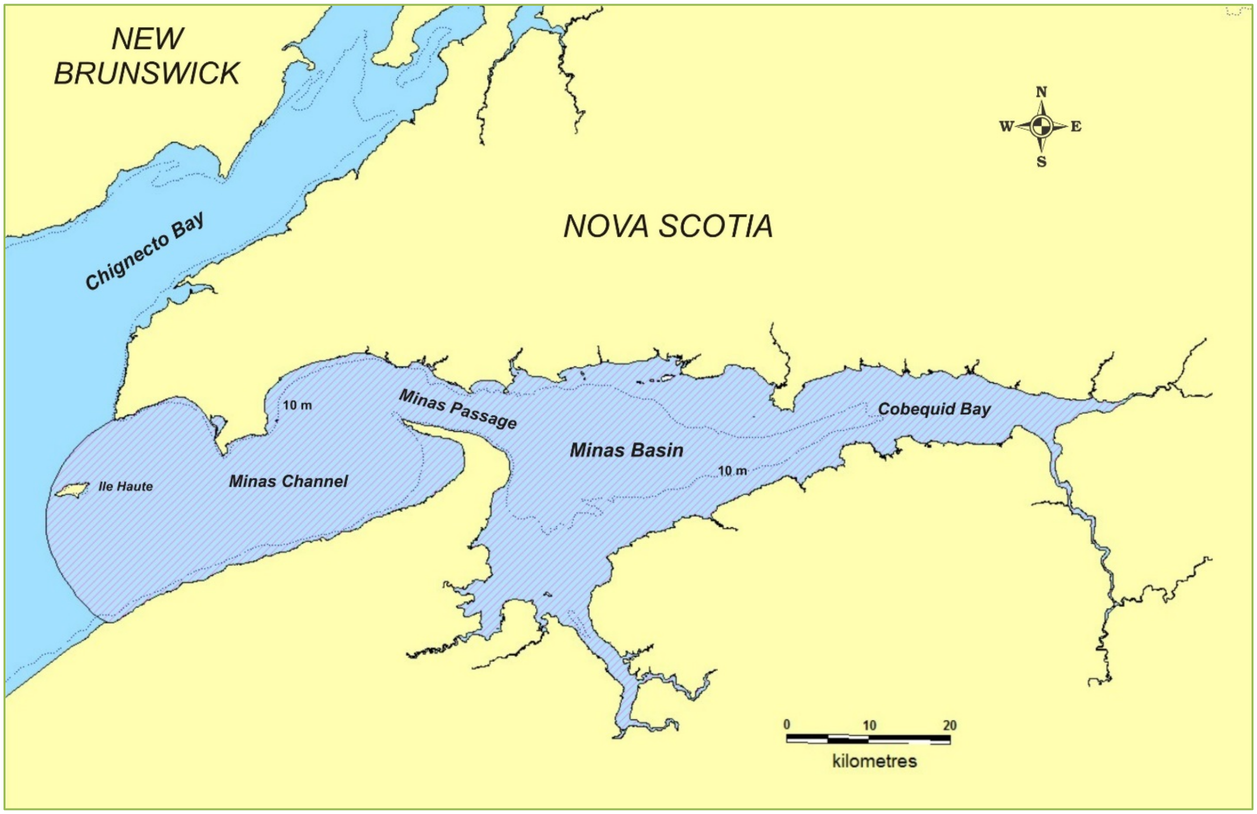


Figure 1. The Evangeline-Cape Blomidon-Minas Basin Ecologically and Biologically Significant Area.

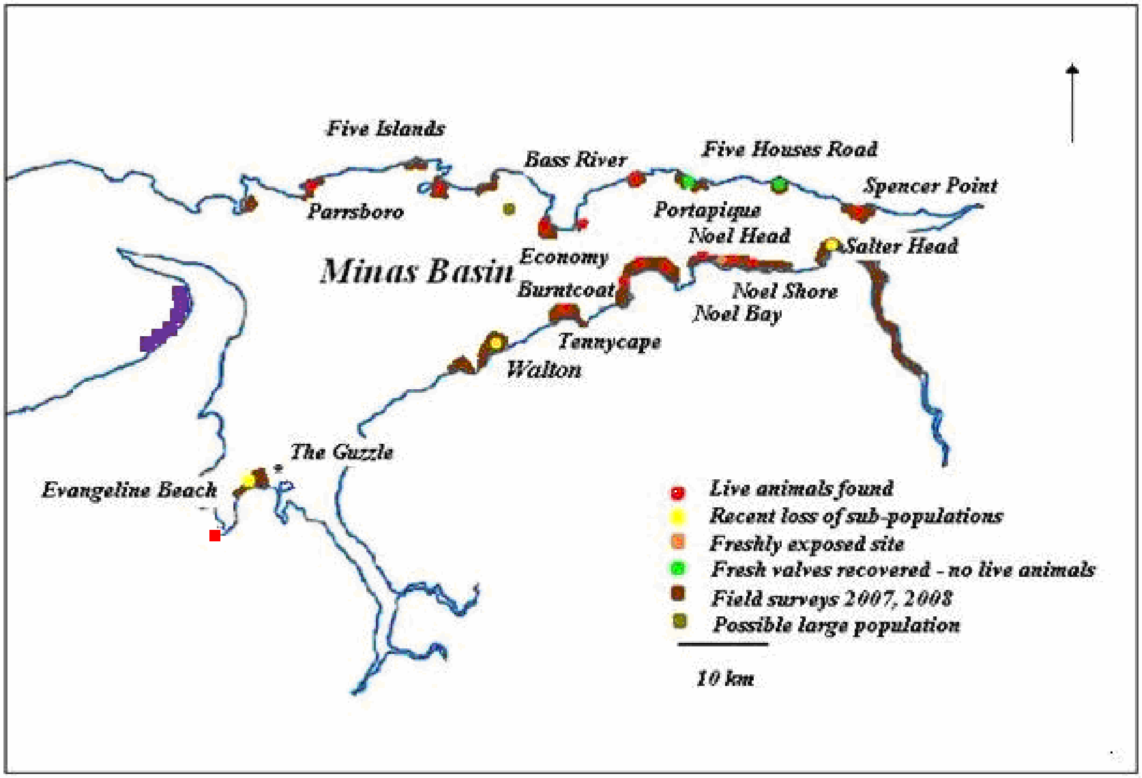


Figure 2. Summary of current and historic distribution of Atlantic Mud-piddock Barnea truncata, including search effort in 2007-2008 and 2009, 2010 (Adapted from COSEWIC 2009). Purple denotes Nova Scotia Museum 2010 field survey (DFO 2010a).

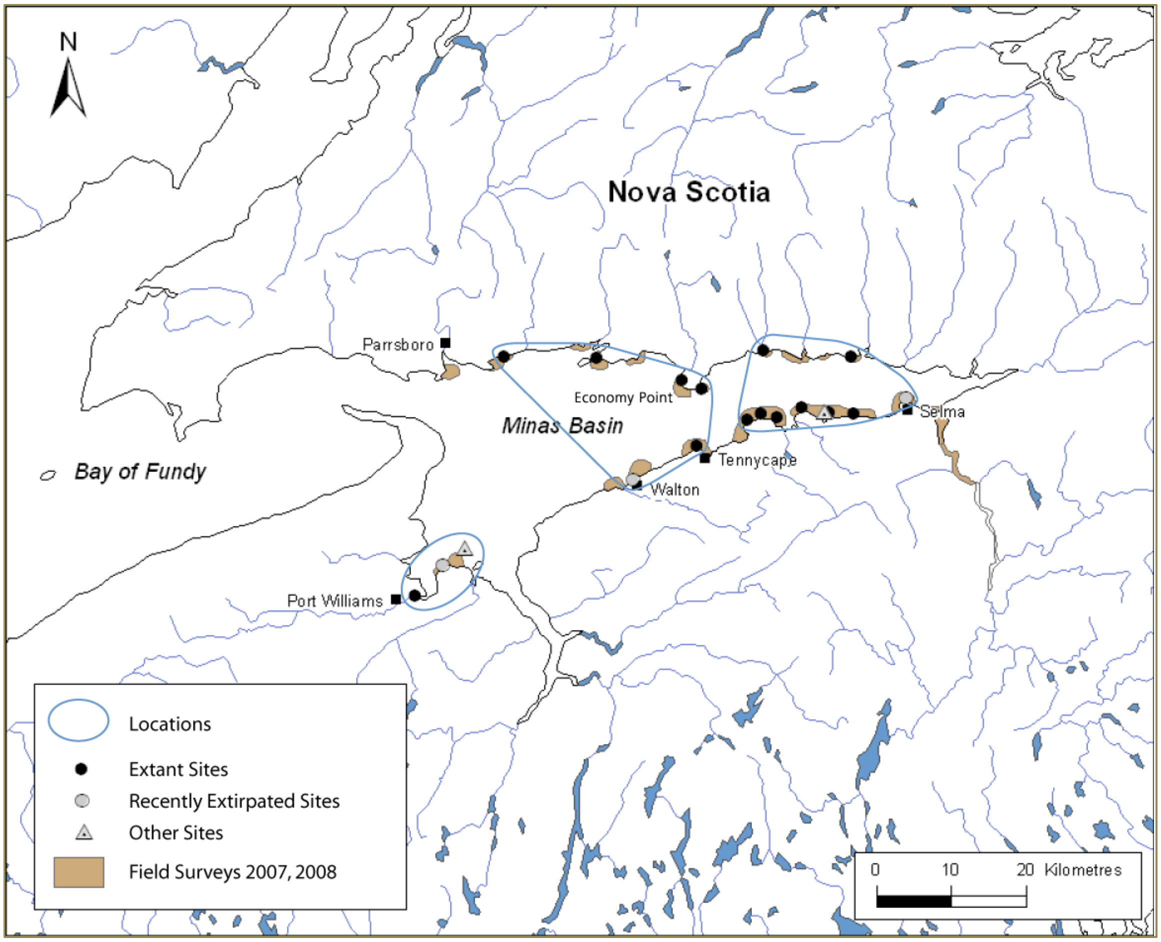


Figure 3. Canadian distribution of Atlantic Mud-piddock Barnea truncata: extant and recently extirpated sites, other sites, and areas covered by field surveys in 2007 and 2008. Locations are bounded by blue lines (from COSEWIC 2009).

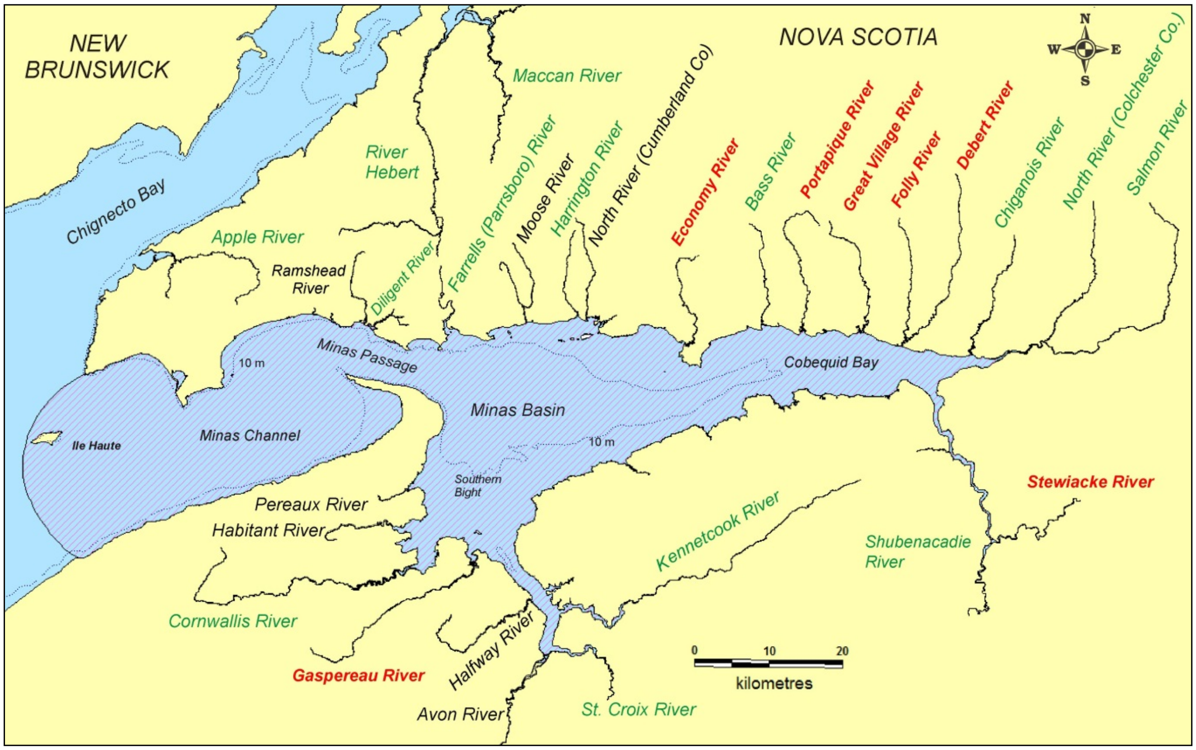


Figure 4. Map of the principal rivers in the Minas Basin Ecologically and Biologically Significant Area and in the immediate vicinity. Rivers labeled in red contain critical habitat for iBoF Atlantic Salmon (Debert, Folly, Great Village, Portapique, Economy, Gaspereau and Stewiacke rivers). Other rivers with self-sustaining populations are labeled in green (Salmon, North River, Chignecto, Bass, Harrington, Farrells, Diligent, Maccan, Apple, Heber, Cornwallis, St. Croix, Kennetcook, and Shubenacadie rivers) (DFO 2010b, DFO 2016b).

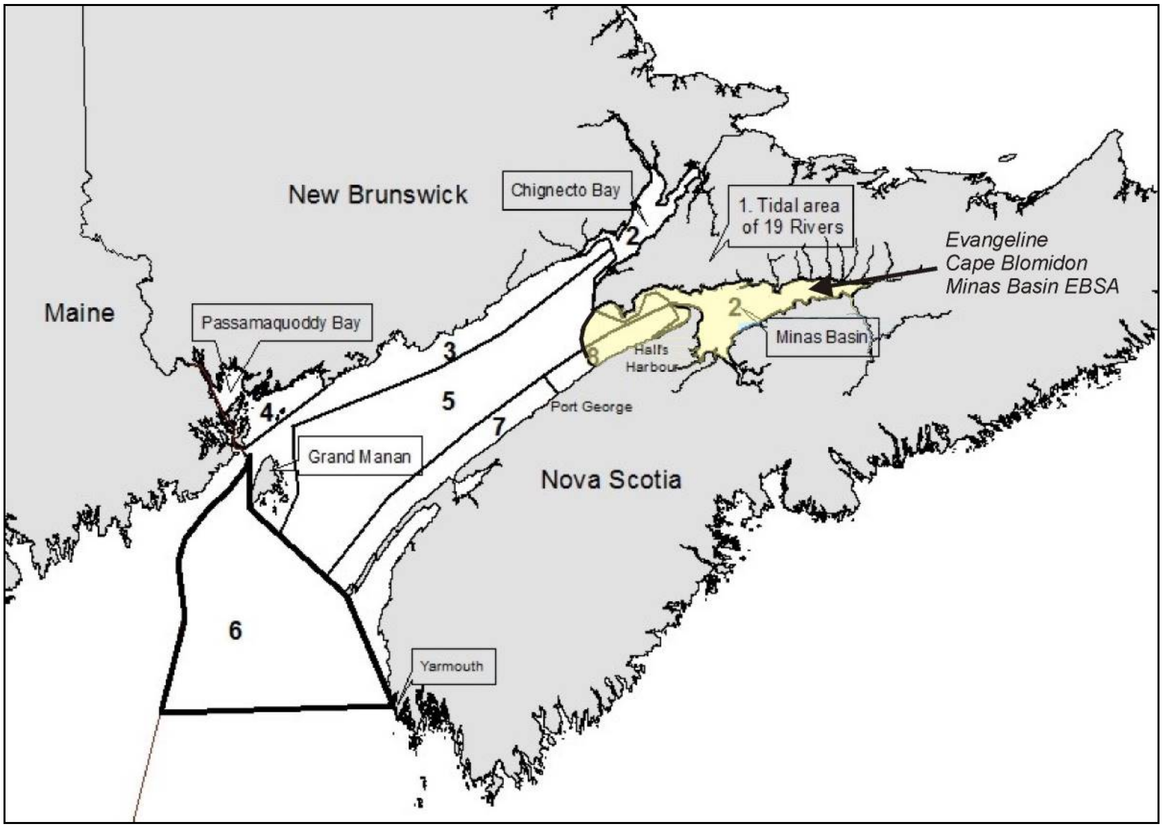


Figure 5. The Evangeline-Cape Blomidon-Minas Basin Ecologically and Biologically Significant Area (yellow shaded area) in relation to important habitat areas for inner Bay of Fundy Atlantic Salmon (DFO 2013).

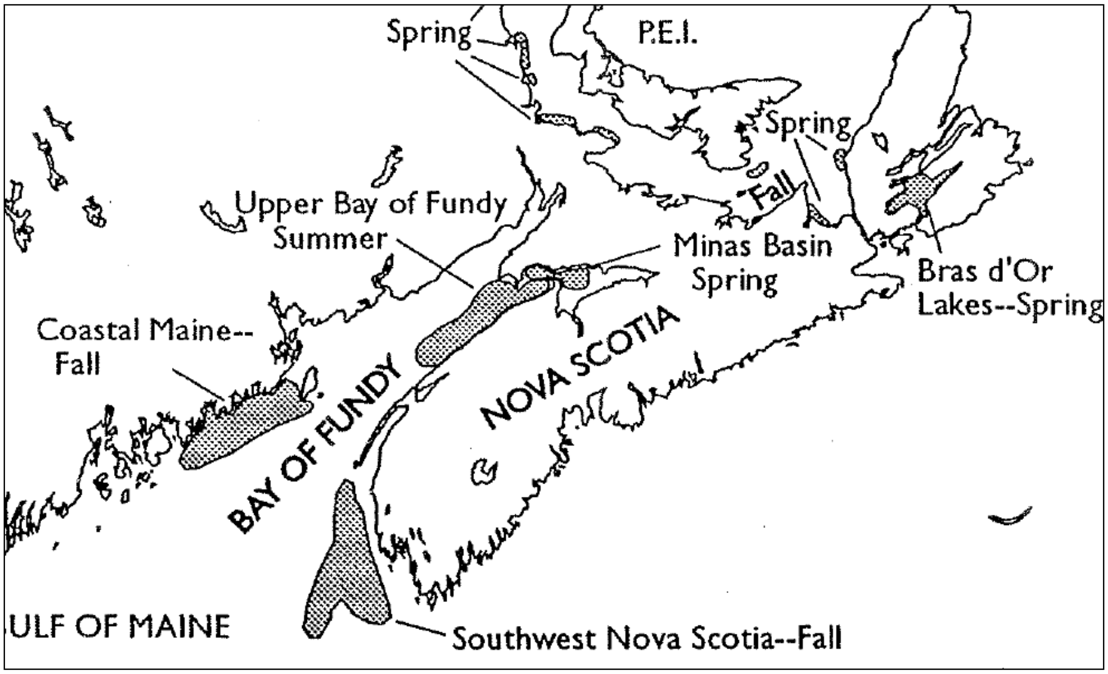


Figure 6. Atlantic Herring spawning areas in Nova Scotia and New Brunswick (Stewart and Arnold 1994). Areas shown in Minas Basin and adjacent area were taken from Haegele and Schweigert (1985).

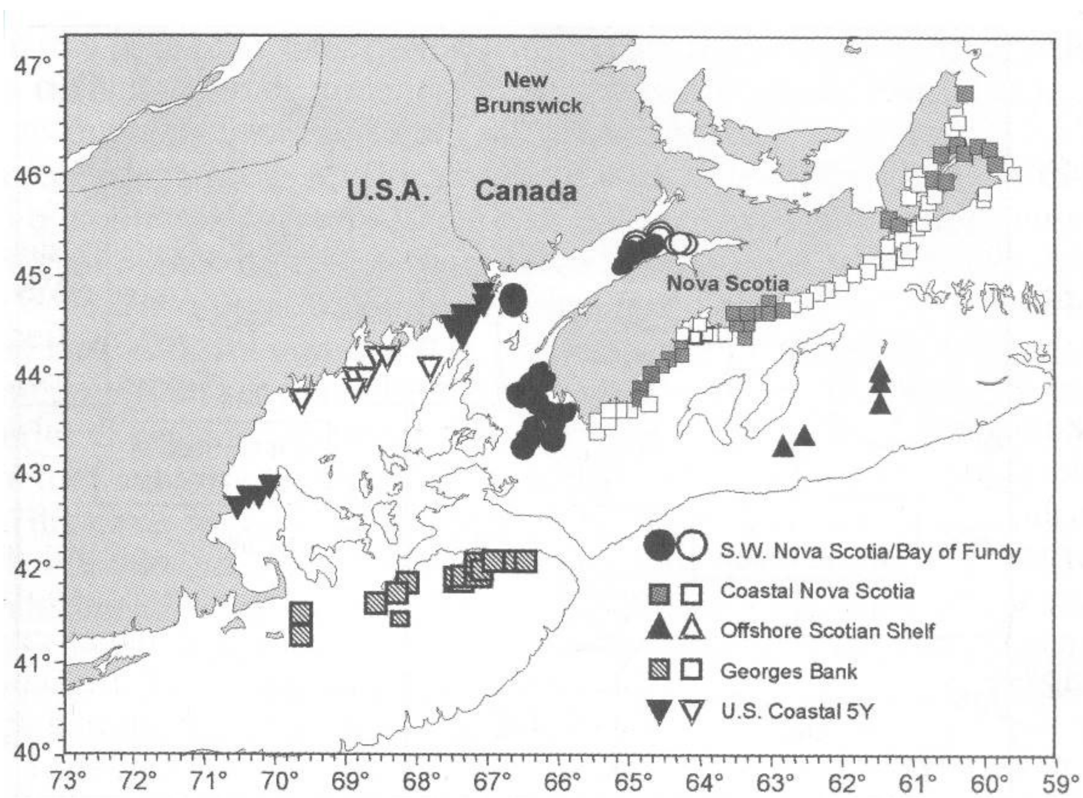


Figure 7. Atlantic Herring spawning areas in 2001 from Stephenson et al. (2001). Open symbols are those sites surveyed within previous two decades.

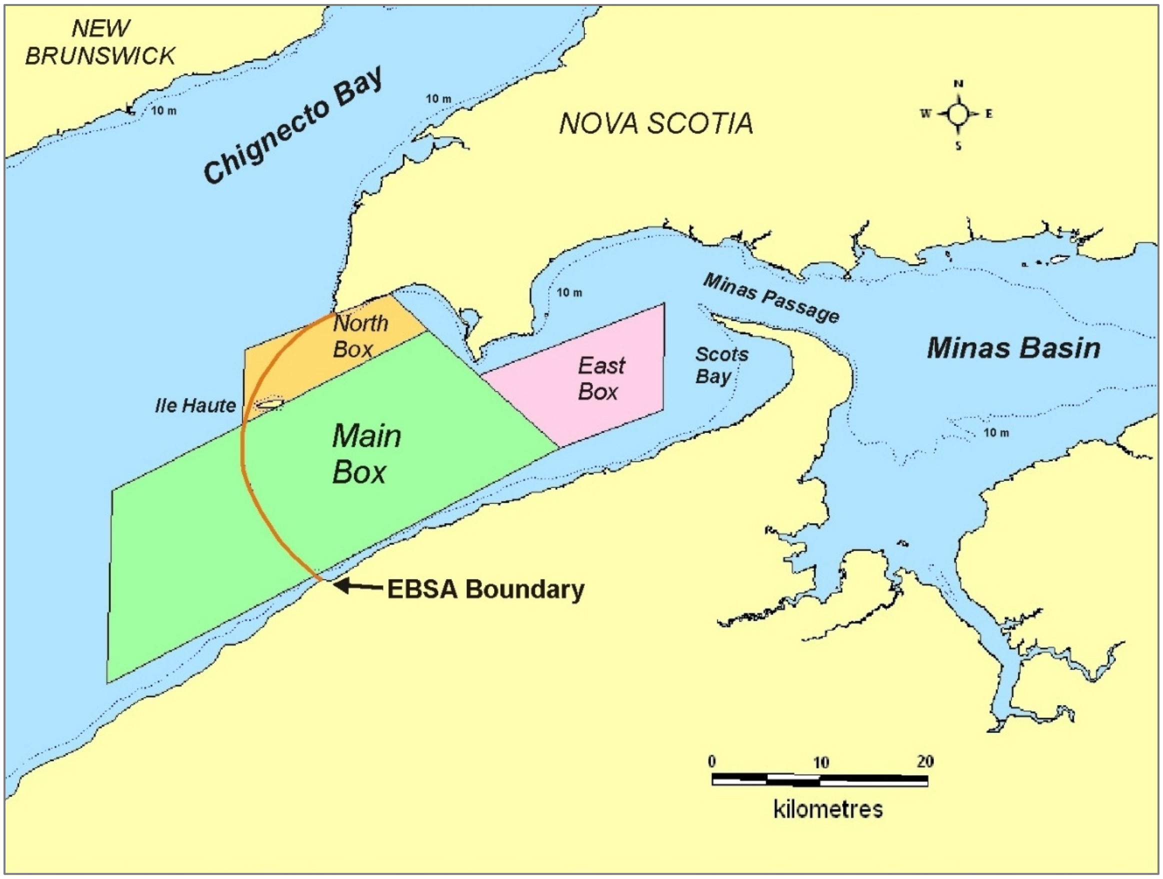


Figure 8. Atlantic Herring fishery management areas in the Minas Basin Ecologically and Biologically Significant Area (R. Singh, DFO, pers. comm. 2017).

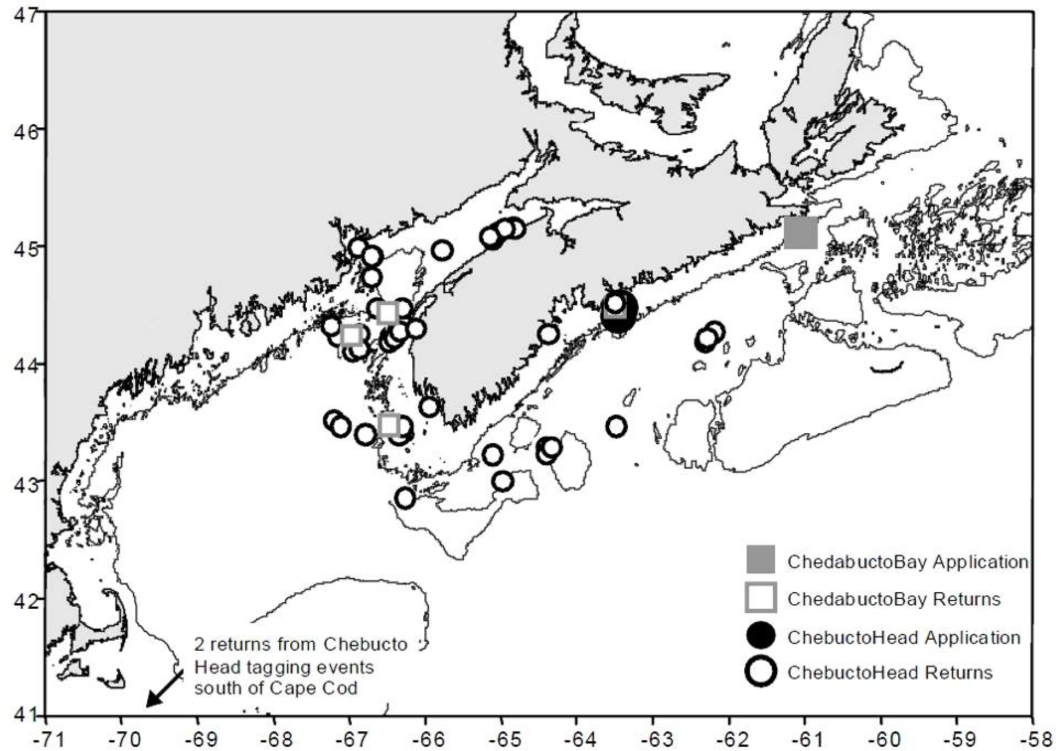


Figure 9. Recaptures of Atlantic Herring tagged in overwintering areas (from Mouland et al. 2003).

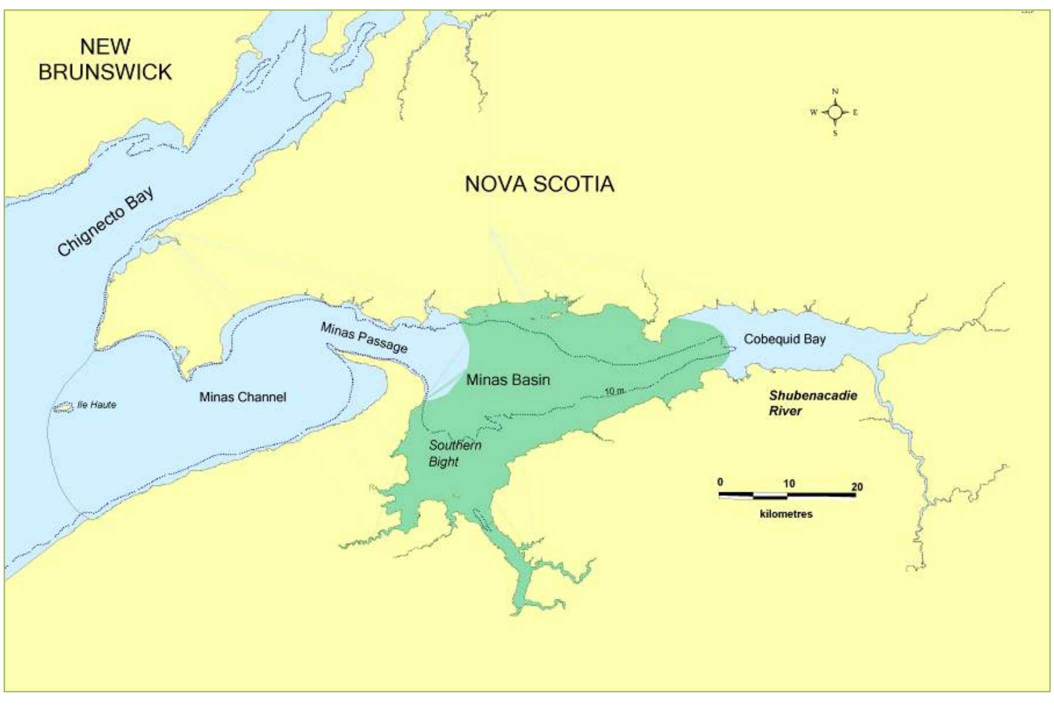


Figure 10. Suggested larval retention area for Atlantic Herring based on Bradford and Iles (1993) and approximate tidal excursion distances.

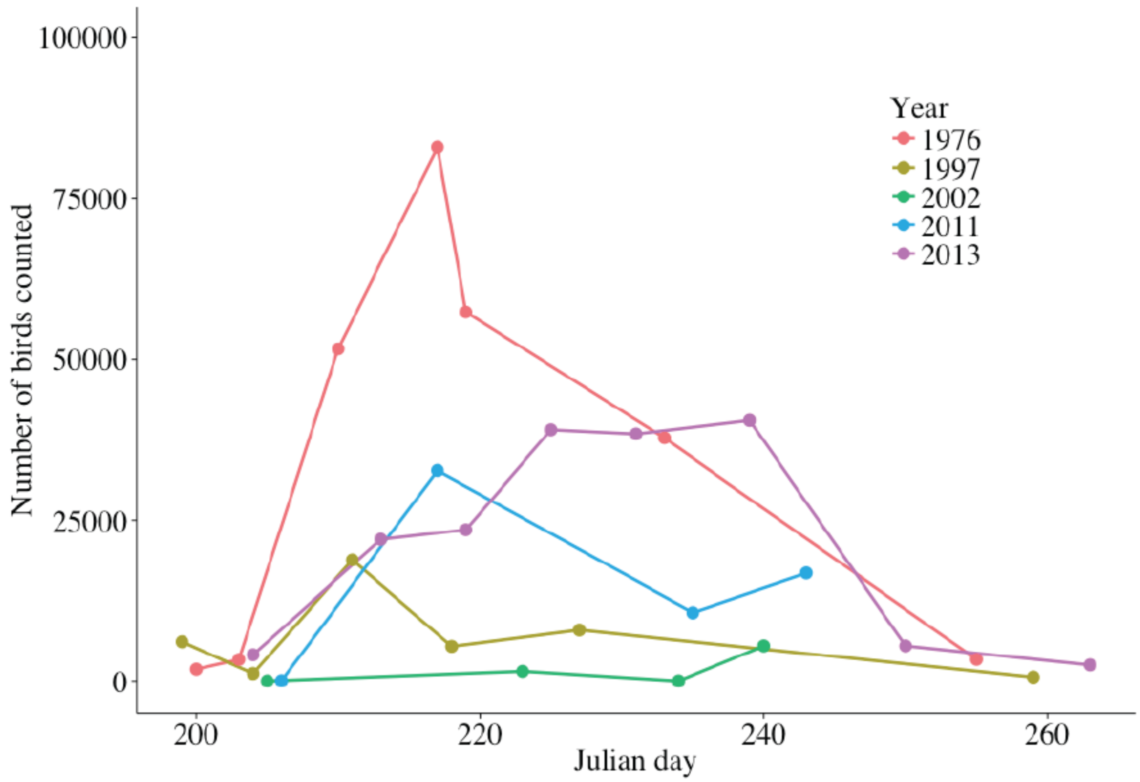


Figure 11. Semipalmated Sandpiper aerial survey counts from Cobequid Bay. Unpublished data from J. Paquet, Canadian Wildlife Service, cited in Mann (2014).

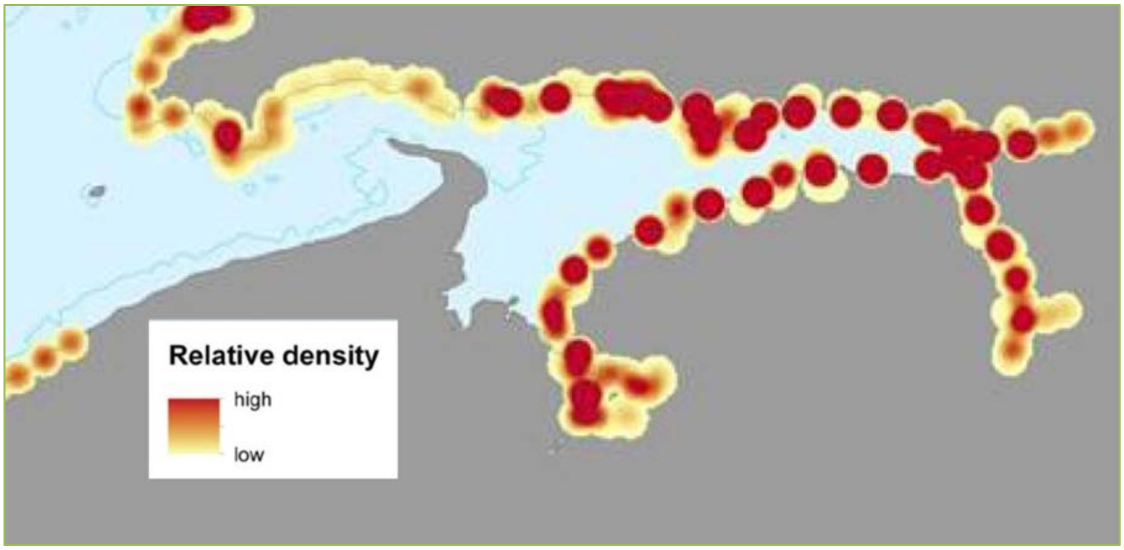


Figure 12. Depiction of mudflat relative areal density[11] occurring in a 2.5 km grid within the Minas Basin Ecologically and Biologically Significant Area, from Allard et al. (2014), compared to maximum and minimum values found for the Scotian Shelf Bioregion, using data from the Canadian Wildlife Service Maritimes Wetland Inventory Atlas Database. Scale shows the range from highest to lowest ranking for the Bioregion.

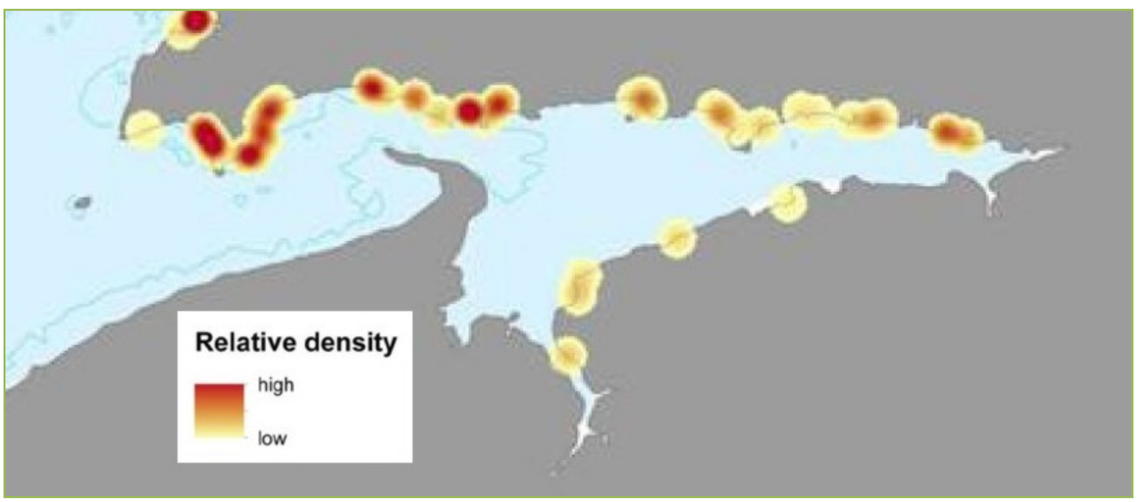


Figure 13. Depiction of the relative linear density of beaches[12] occurring in 2.5 km square grids within the Minas Basin Ecologically and Biologically Significant Area, from Allard et al. (2014), compared to maximum and minimum values found in the Scotia Shelf Bioregion, using data from the Environment and Climate Change Canada Shoreline Classification and Pre-spill Database. Scale shows the range from highest to lowest ranking in the Bioregion.

[11] Coastal areas used for comparison were the Scotian Shelf Bioregion (DFO 2009), which includes the coast in the Bay of Fundy and Atlantic coastal areas of Nova Scotia extending to Wreck Point on the northeastern tip of Cape Breton (in the Donkin area).

[12] A point data summary based on location and linear extent of beaches found in the Environment Canada Shoreline Classification and Pre-spill Database was used to generate relative linear density (Allard et al. 2014).

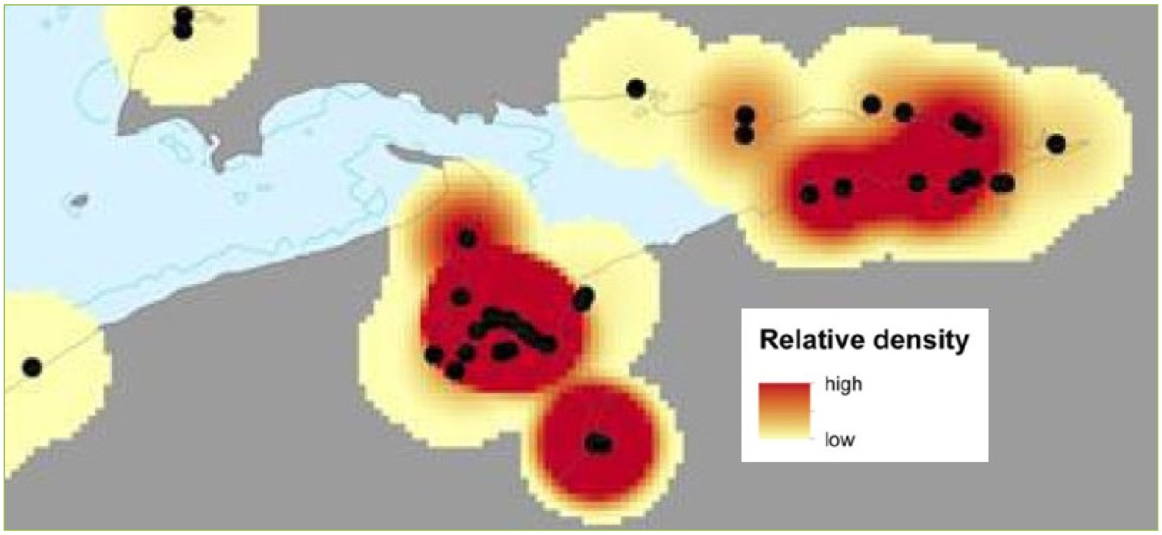


Figure 14. Depiction of maxima of shorebird numbers on surveys in the Atlantic Canada Shorebird Survey database, across species, excluding Species at Risk[13], within the Minas Basin Ecologically and Biologically Significant Area, from Allard et al. (2014). Relative point densities are densities determined for the Scotian Shelf Bioregion. Scale shows the range from highest to lowest ranking in the Bioregion.

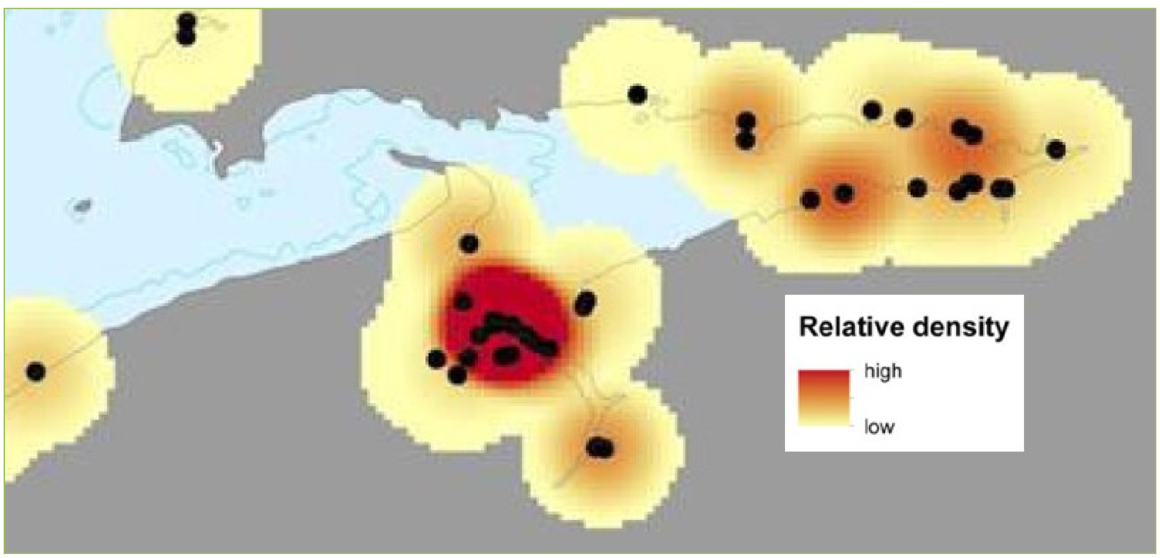


Figure 15. Depiction of proportions of the North American population of the shorebirds observed within the Minas Basin Ecologically and Biologically Significant Area (also see Figure 14), based on surveys in the Atlantic Canada Shorebird Survey database, across species, excluding Species at Risk. Relative point densities are densities determined for the Scotian Shelf Bioregion[14] (from Allard et al. 2014). Scale shows the range from areas having highest proportions to those having among the lowest for the Scotian Shelf Bioregion as a whole.

[13] A point data summary of maximum densities of shorebirds observed at standard survey sites was used to generate relative point densities (Allard et al. 2014).

[14] Bioregions are defined in DFO (2009).

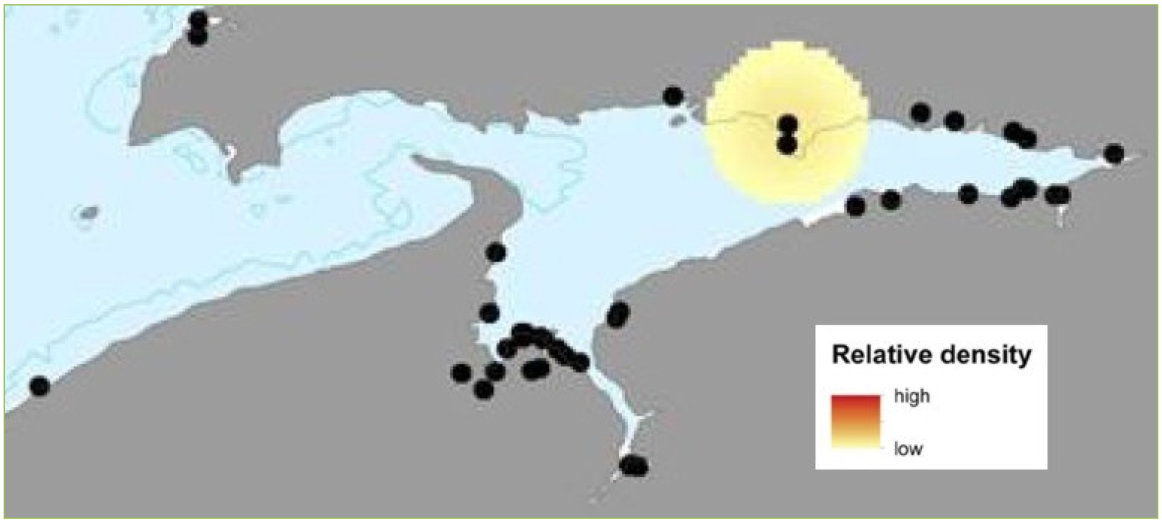


Figure 16. Depiction of maximum counts of Piping Plover numbers from surveys included in the Atlantic Canada Shorebird Survey database, within the Minas Basin Ecologically and Biologically Significant Area. Relative densities are densities determined for the Scotian Shelf Bioregion (from Allard et al. 2014). The map shows a sighting of the species and an area potentially used for staging, but is neither nesting nor critical habitat (K. Allard, CWS, pers. comm. 2016).

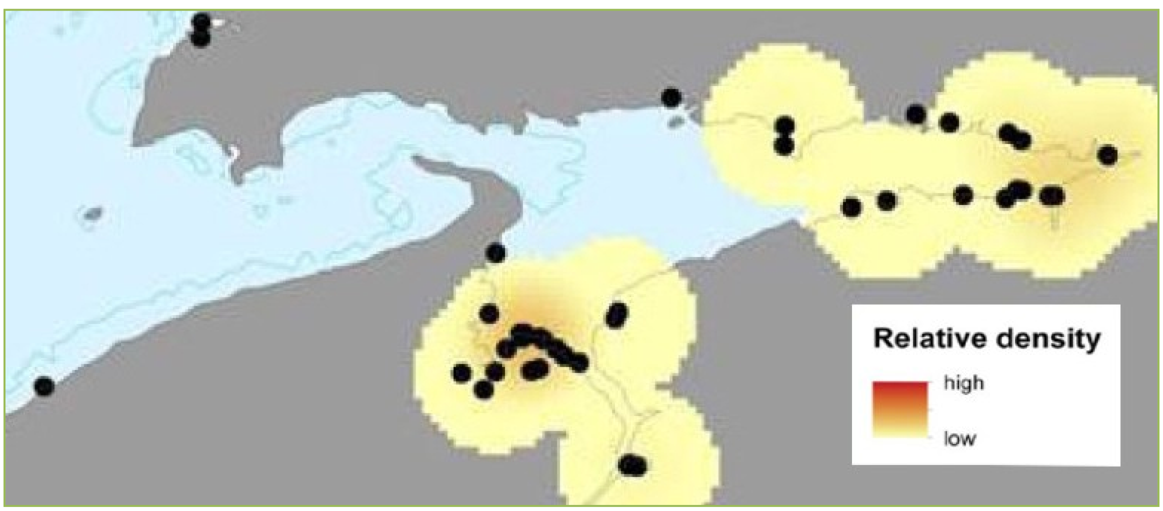


Figure 17. Depiction of maximum counts of Red Knot within the Minas Basin Ecologically and Biologically Significant Area, from surveys included in the Atlantic Canada Shorebird Survey database. Relative point densities are densities determined for the Scotian Shelf Bioregion. Scale shows the range from highest to lowest ranking for the Bioregion (Allard et al. 2014).

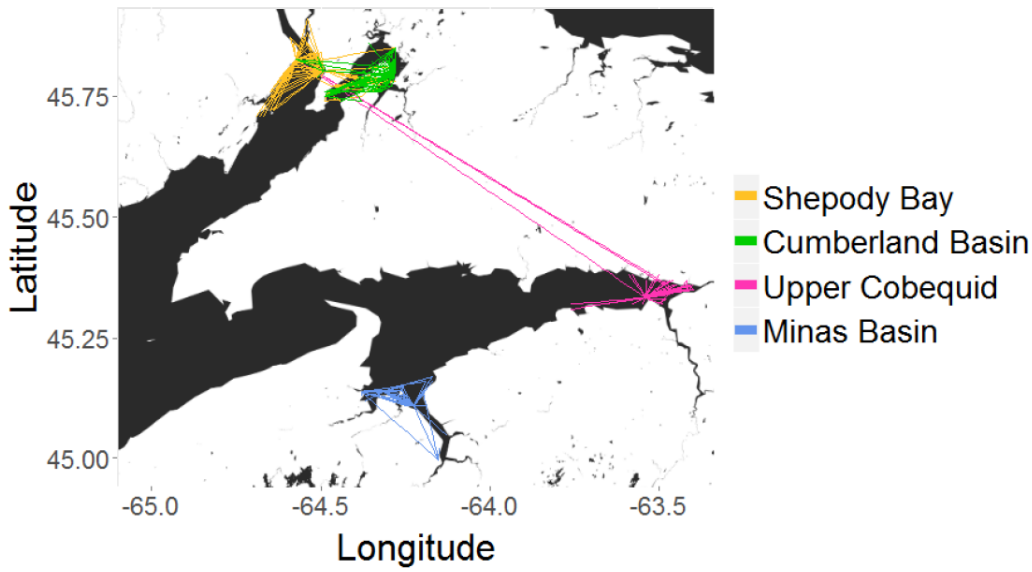


Figure 18. Map of the upper Bay of Fundy showing movements of all radiotagged Semipalmated Sandpipers from each capture area during migratory stopover (from Neima 2014).

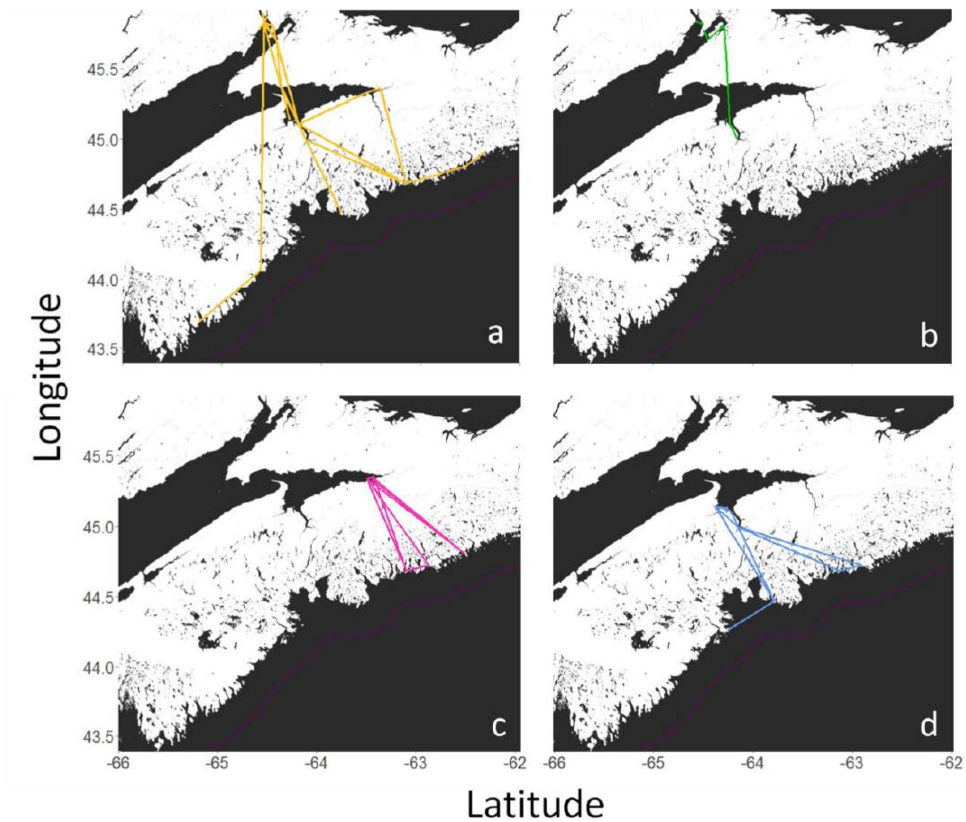


Figure 19. Maps of the Bay of Fundy and the eastern shore of Nova Scotia showing the last 24 hours of detections for each Semipalmated Sandpiper within the study area (i.e. departure routes) (from Neima 2014).

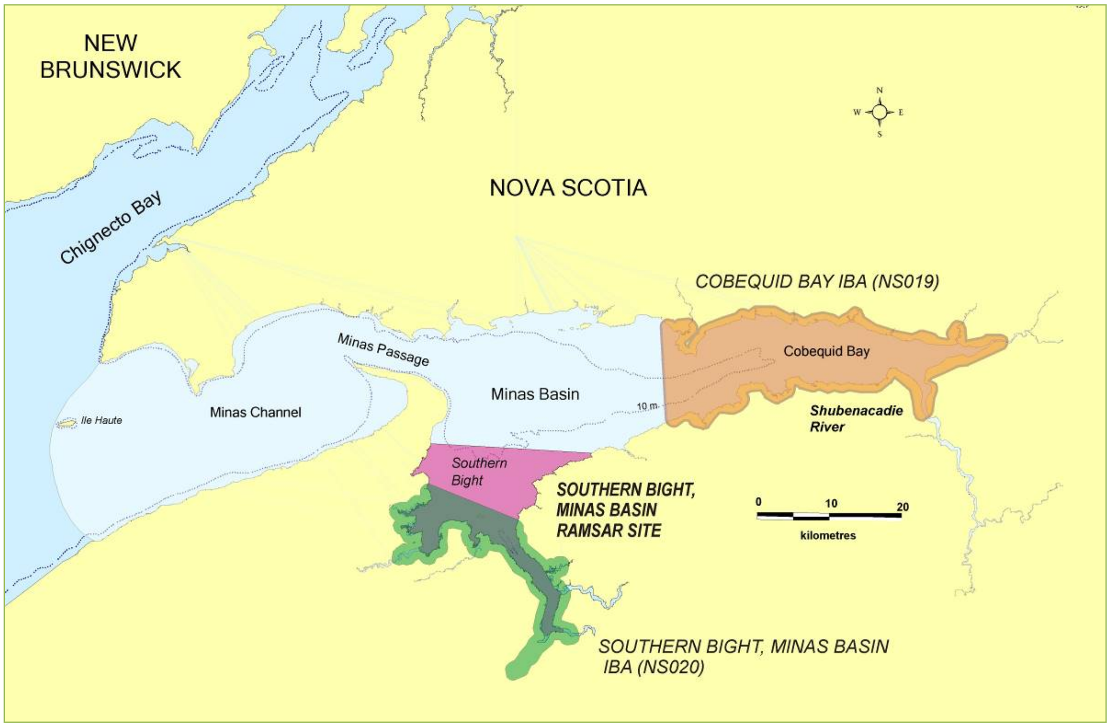


Figure 20. Important Bird Areas (IBAs) in the Evangeline-Cape Blomidon-Minas Basin Ecologically and Biologically Significant Area.

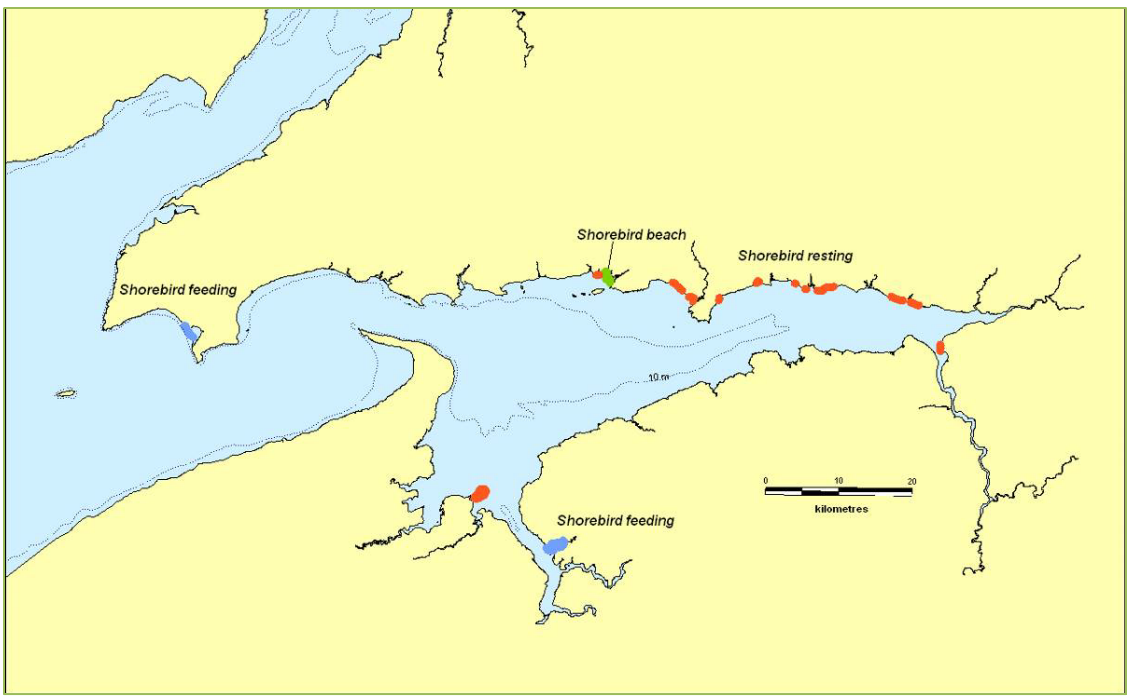


Figure 21. Areas occupied by shorebirds recorded during field activities by Nova Scotia Department of Natural Resources Regional Biologists. Red-resting; green-occupied beach; blue-active feeding (NSDNR Wildlife Division, pers. comm. 2016).

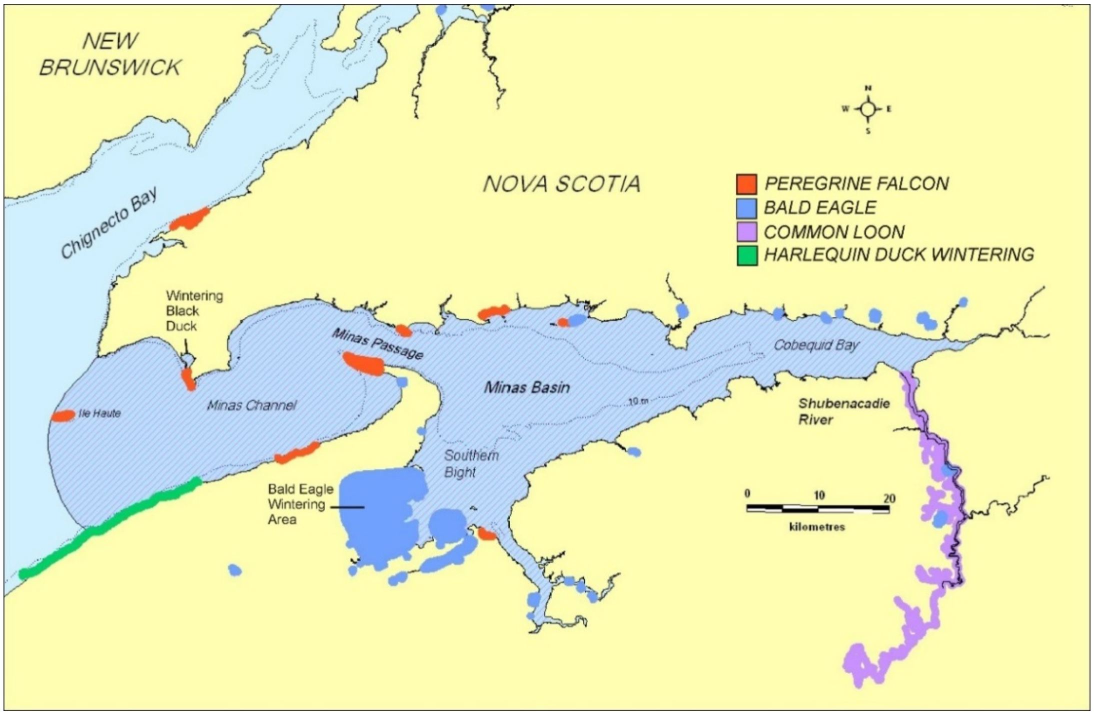


Figure 22. Areas where species at risk birds and birds with conservation importance have occurred, based on regional biologist sightings in NS DNR databases (NSDNR, pers. comm. 2016).

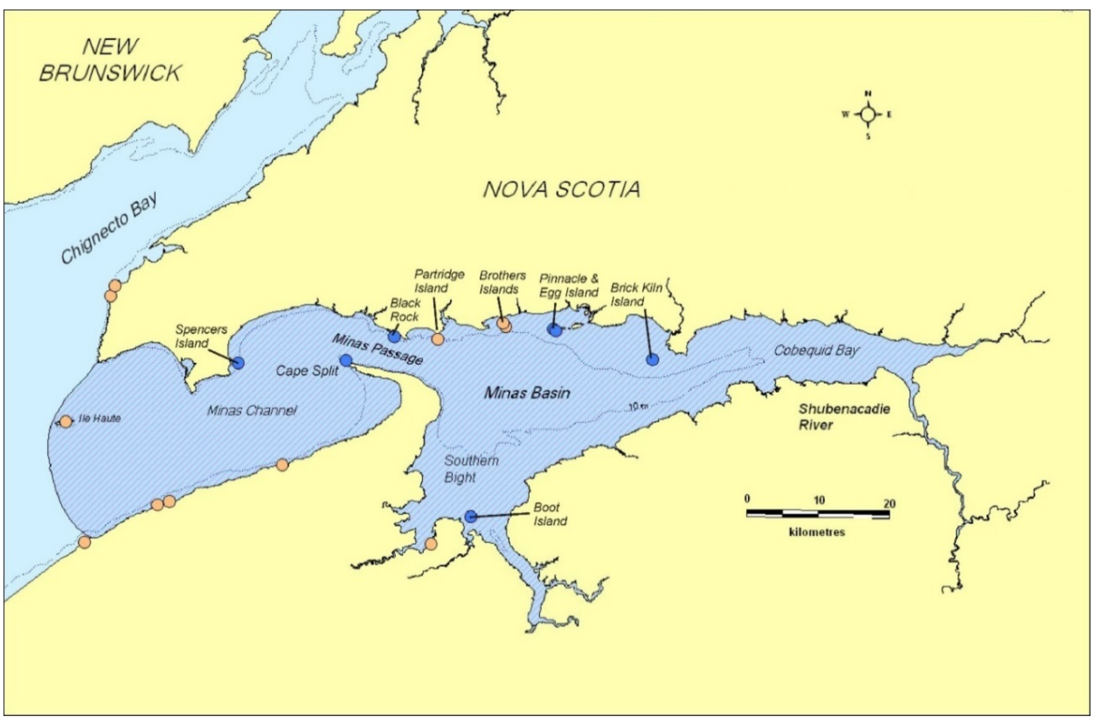


Figure 23. Seabird colony locations in the Minas Basin Ecologically and Biologically Significant Area and adjacent areas. Species occurring at colonies shown in blue are presented in Table 4. Source: Atlantic Colonial Waterbird Database (see Allard et al 2014).

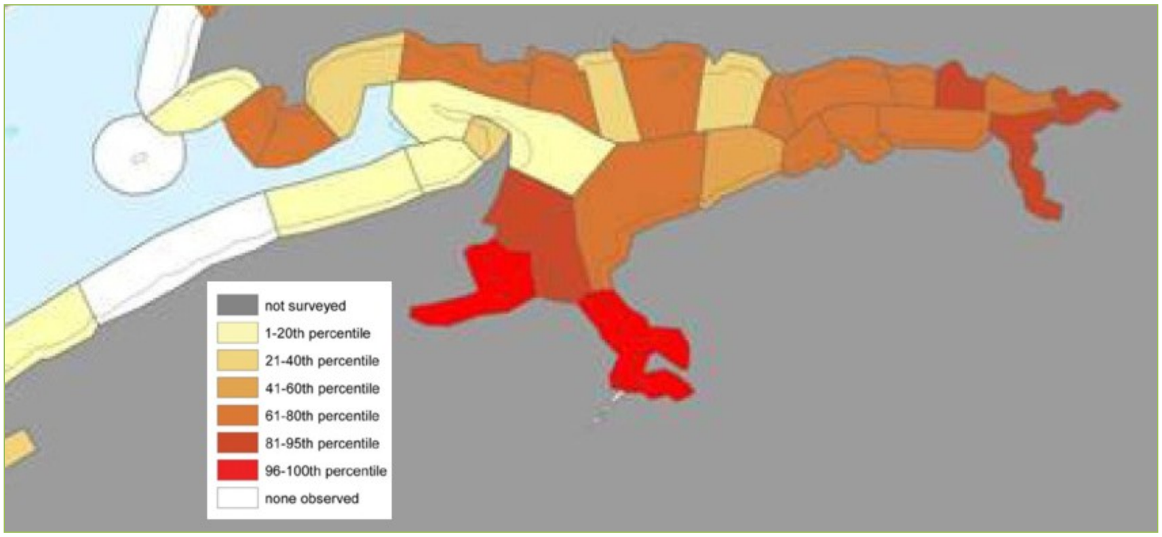


Figure 24. American Black Duck abundance (maximum density per subarea) for the Minas Basin Ecologically and Biologically Significant Area expressed in quantiles relative to abundances determined for the Scotian Shelf Bioregion (see Allard et al. 2014). Subareas shown are standard Atlantic Coastal Waterfowl Survey blocks (see text).

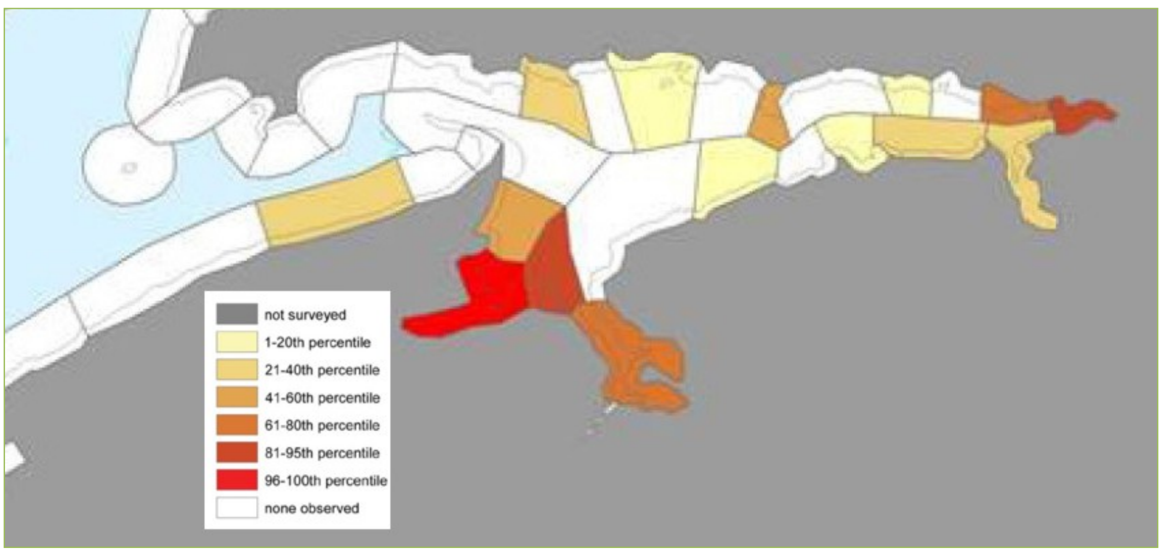


Figure 25. Canada Goose abundance (maximum density per subarea) for the Minas Basin Ecologically and Biologically Significant Area expressed in quantiles relative to abundances determined for the Scotian Shelf Bioregion (see Allard et al. 2014). Subareas shown are standard Atlantic Coastal Waterfowl Survey blocks (see text).

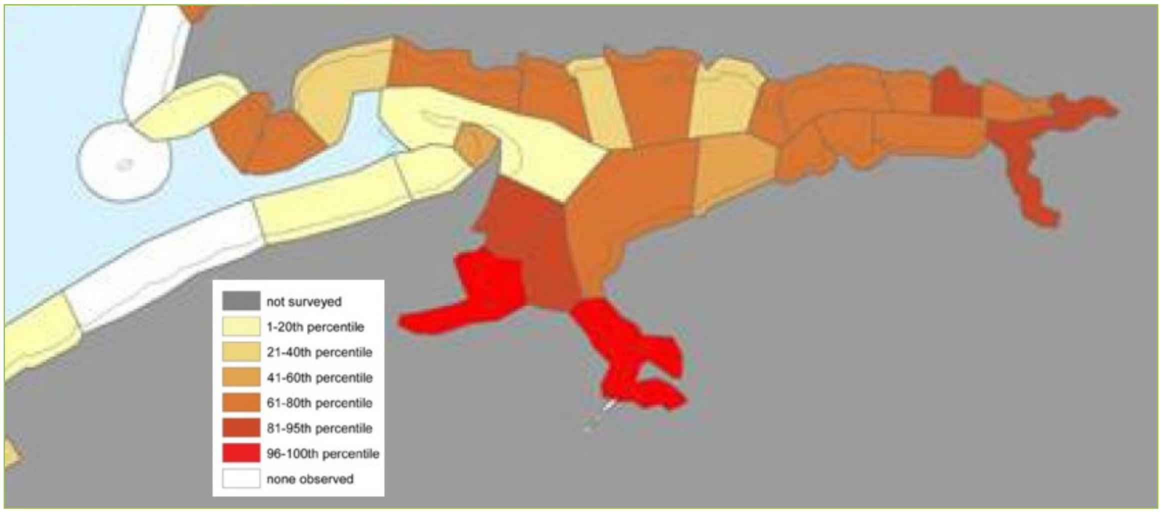


Figure 26. Dabbling duck guild abundance (maximum density per subarea) for the Minas Basin Ecologically and Biologically Significant Area expressed in quantiles relative to abundances determined for the Scotian Shelf Bioregion (see Allard et al. 2014). Subareas shown are standard Atlantic Coastal Waterfowl Survey blocks (see text).

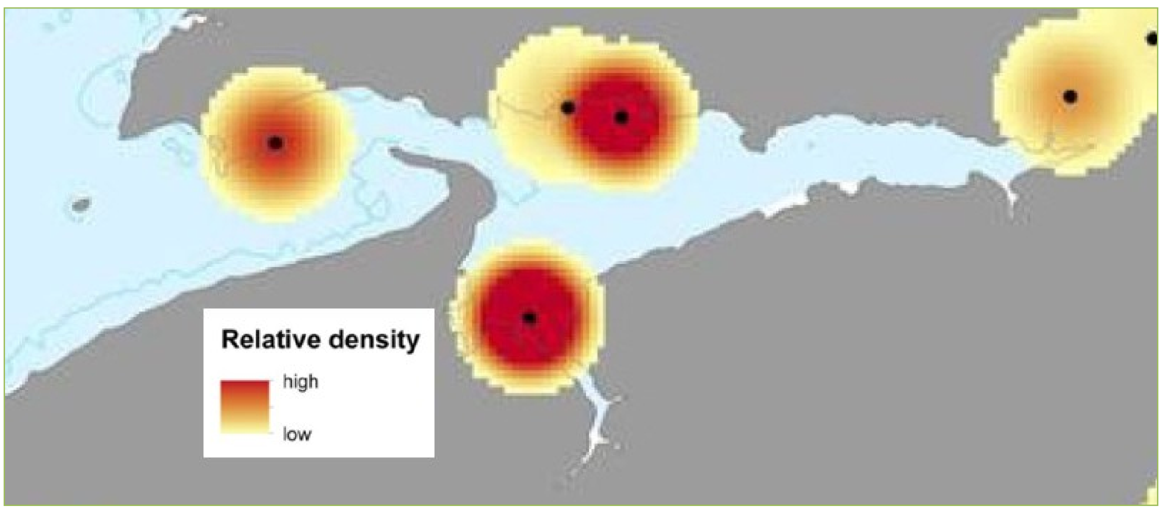


Figure 27. Great Blue Heron colony densities (maximum colony numbers since 1960) for the Minas Basin Ecologically and Biologically Significant Area expressed relative to densities determined for the Scotian Shelf Bioregion (see Allard et al. 2014).

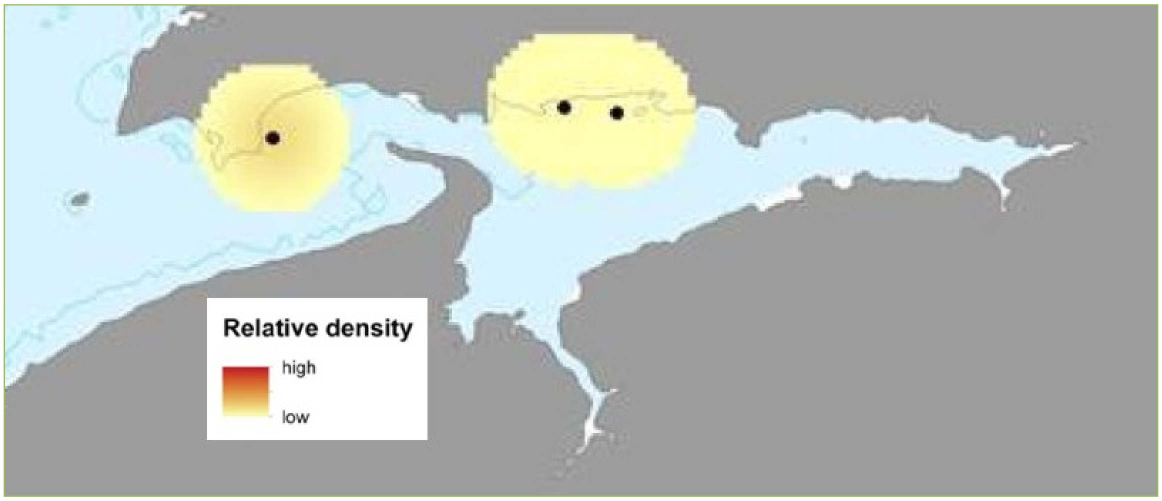


Figure 28. Common Eider colony densities (maximum colony numbers since 1960) for the Minas Basin Ecologically and Biologically Significant Area expressed relative to densities determined for the Scotian Shelf Bioregion (see Allard et al. 2014).

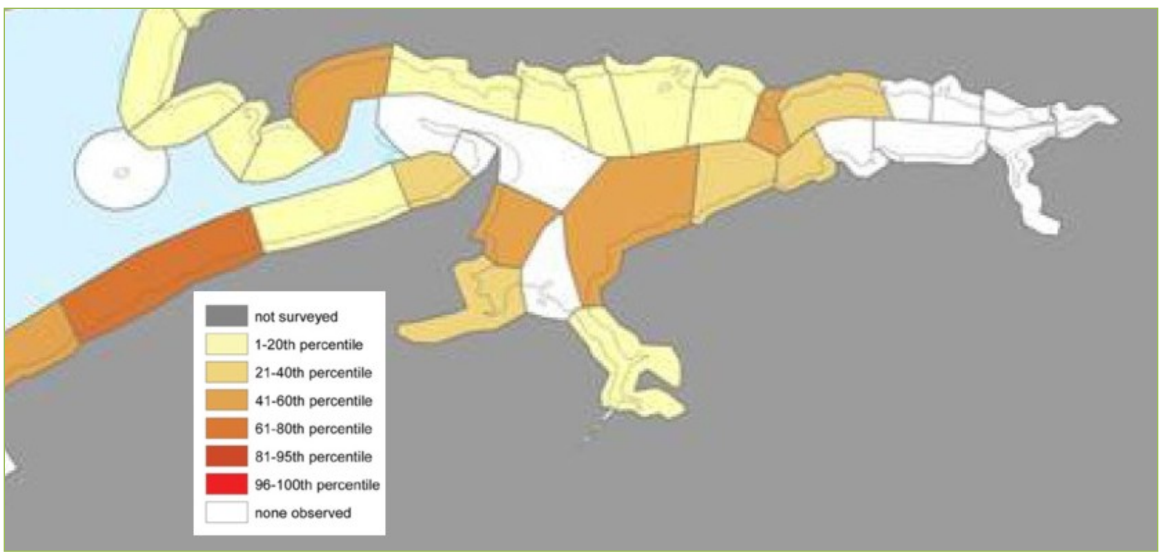


Figure 29. Eider species abundance (maximum density per subarea) for the Minas Basin Ecologically and Biologically Significant Area expressed in quantiles relative to abundances determined for the Scotian Shelf Bioregion (see Allard et al. 2014). Subareas shown are standard Atlantic Coastal Waterfowl Survey blocks (see text).

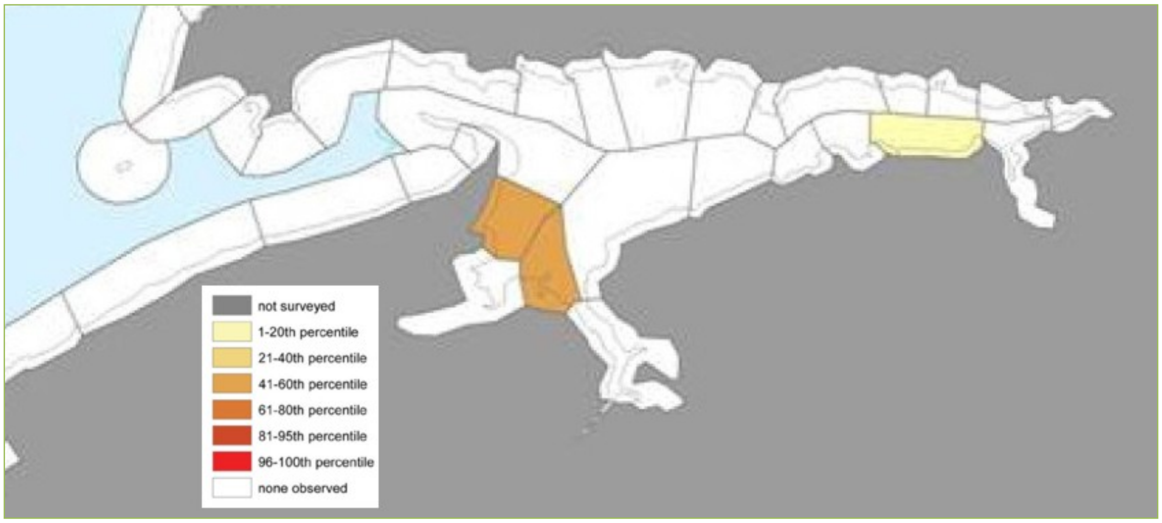


Figure 30. Atlantic Brant abundance (maximum density per subarea) for the Minas Basin Ecologically and Biologically Significant Area expressed in quantiles relative to abundances determined for the Scotian Shelf Bioregion (see Allard et al. 2014). Subareas shown are standard Atlantic Coastal Waterfowl Survey blocks (see text).

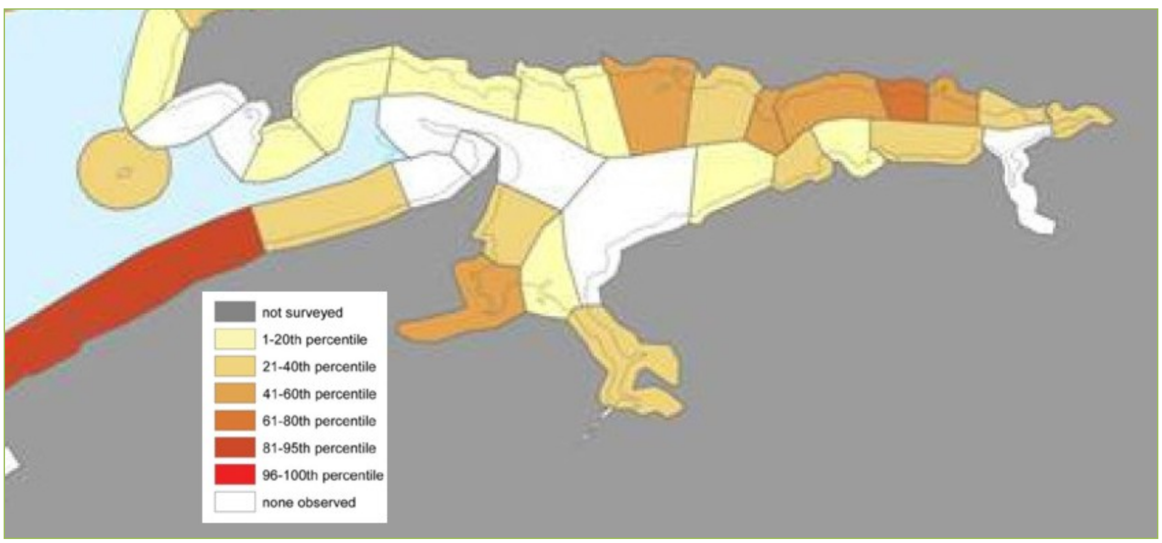


Figure 31. Scoter species abundance (maximum density per subarea) for the Minas Basin Ecologically and Biologically Significant Area expressed in quantiles relative to abundances determined for the Scotian Shelf Bioregion (see Allard et al. 2014). Subareas shown are standard Atlantic Coastal Waterfowl Survey blocks (see text).

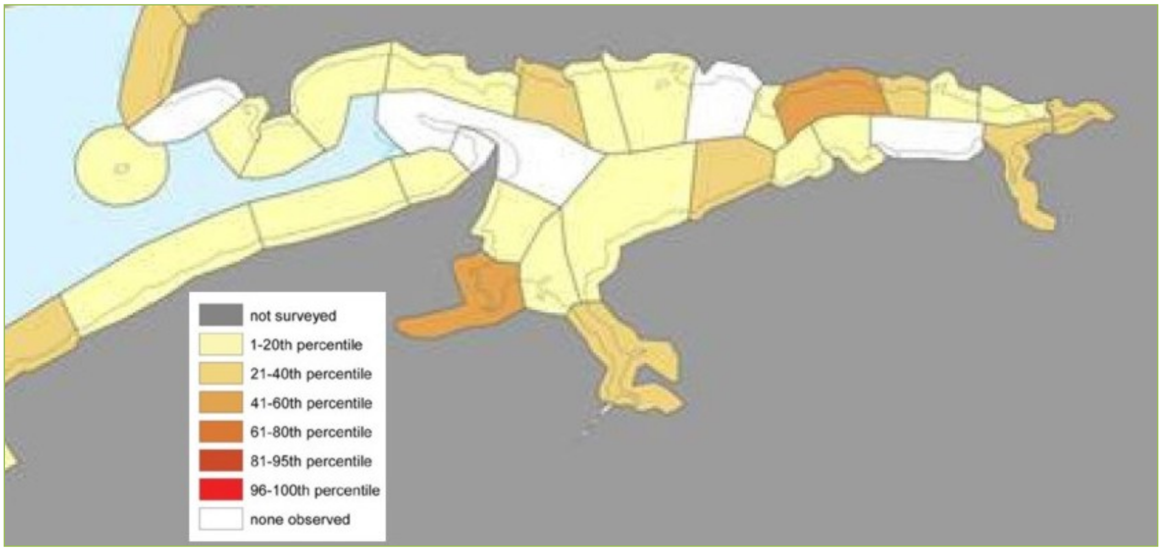


Figure 32. Merganser species abundance (maximum density per subarea) for the Minas Basin Ecologically and Biologically Significant Area expressed in quantiles relative to abundances determined for the Scotian Shelf Bioregion (see Allard et al. 2014). Subareas shown are standard Atlantic Coastal Waterfowl Survey blocks (see text).

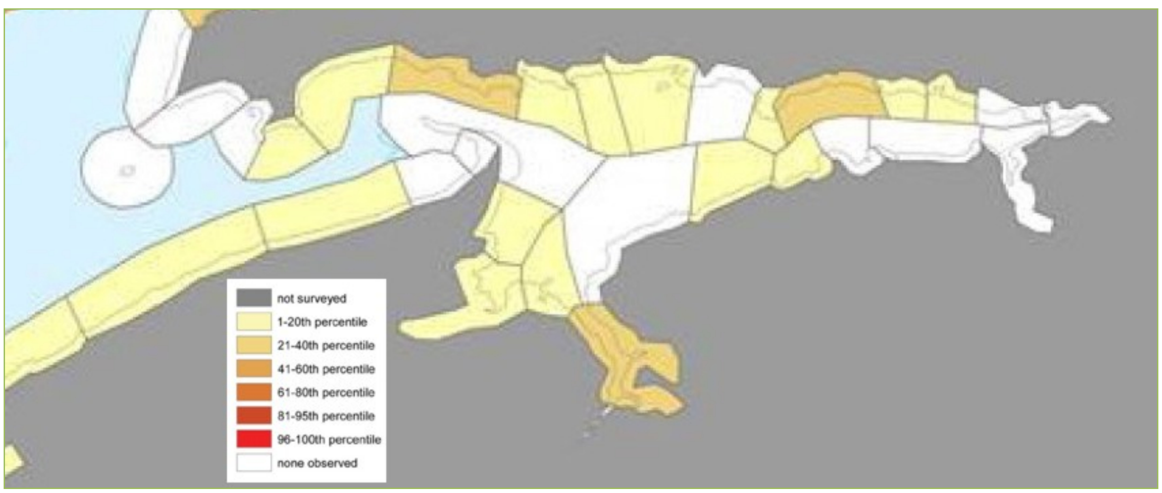


Figure 33. Goldeneye species abundance (maximum density per subarea) for the Minas Basin Ecologically and Biologically Significant Area expressed in quantiles relative to abundances determined for the Scotian Shelf Bioregion (see Allard et al. 2014). Subareas shown are standard Atlantic Coastal Waterfowl Survey blocks (see text).

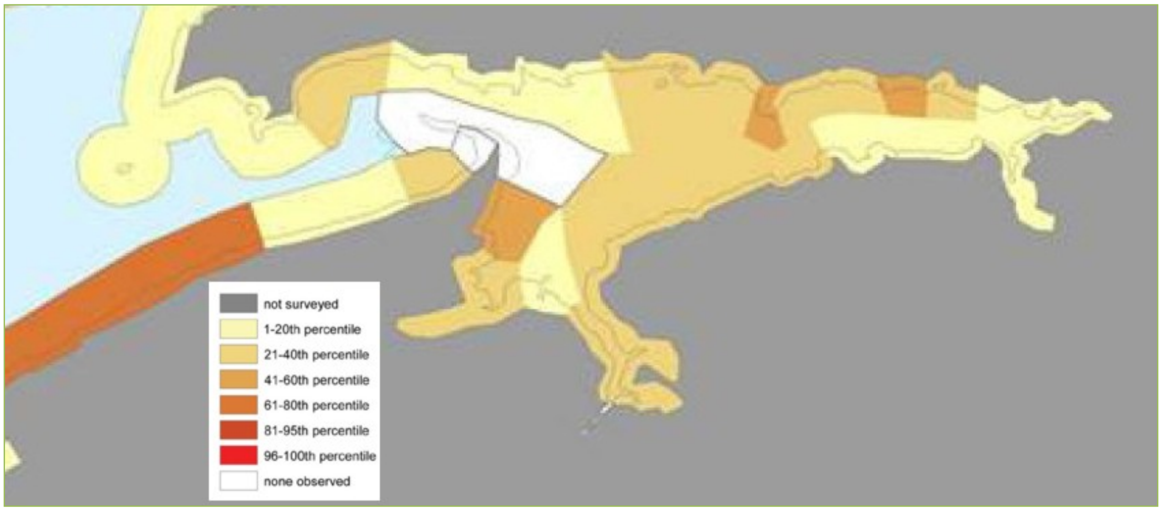


Figure 34. Sea duck guild abundance (maximum density per subarea) for the Minas Basin Ecologically and Biologically Significant Area expressed as quantiles relative to abundances determined for the Scotian Shelf Bioregion (see Allard et al. 2014). Subareas shown are standard Atlantic Coastal Waterfowl Survey blocks (see text).

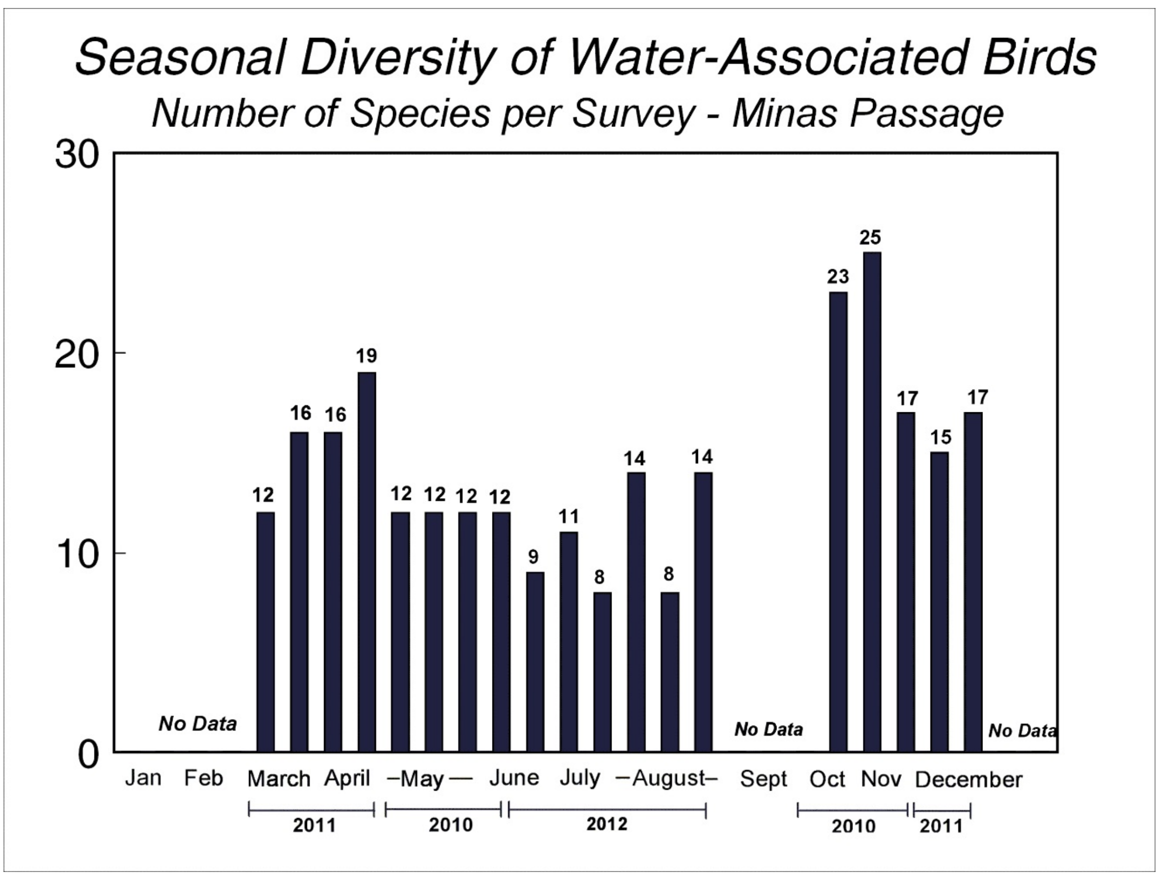


Figure 35. Seasonal diversity of marine bird species observed in shore-based daytime surveys at the Fundy Ocean Research Centre for Energy (FORCE) tidal energy demonstration site in Minas Passage, March-December, 2010-2012 (Envirosphere Consultants Limited 2013).

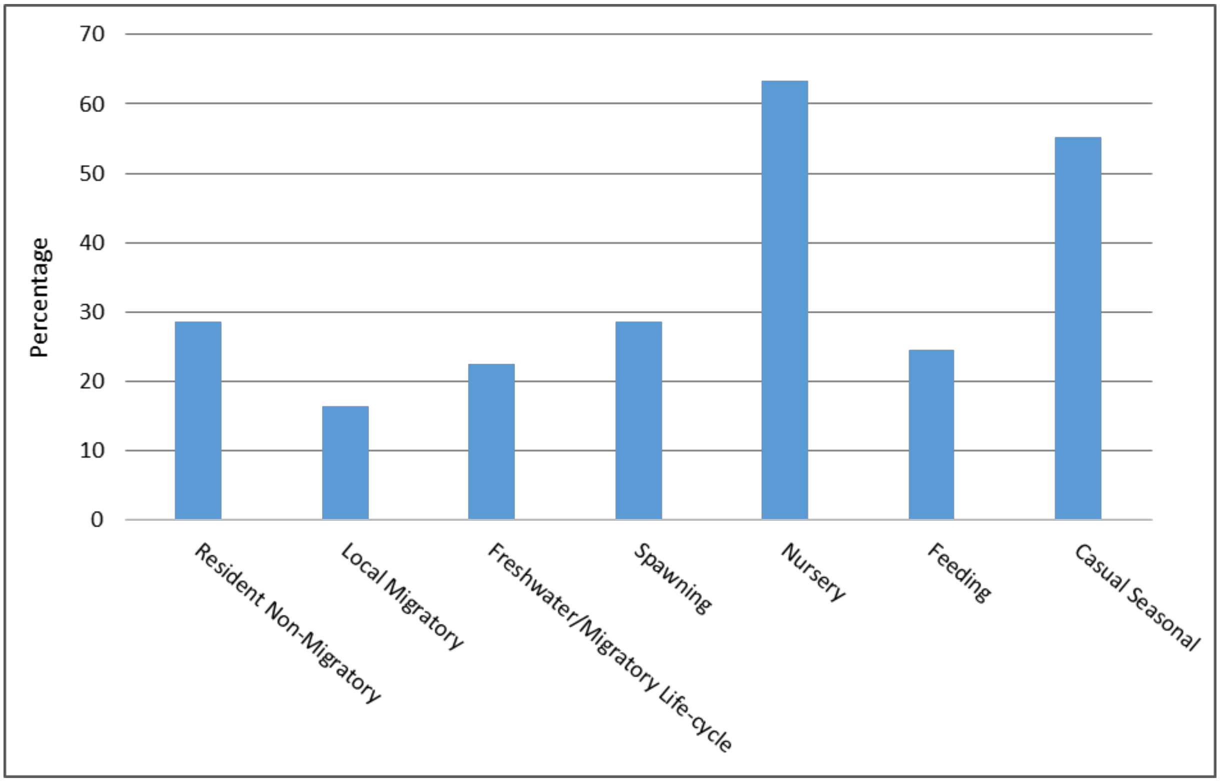


Figure 36. Proportion of migratory/life-cycle types represented by the number of common fish species to which it applies, as listed in Table 7. Definitions of types are presented in the text.

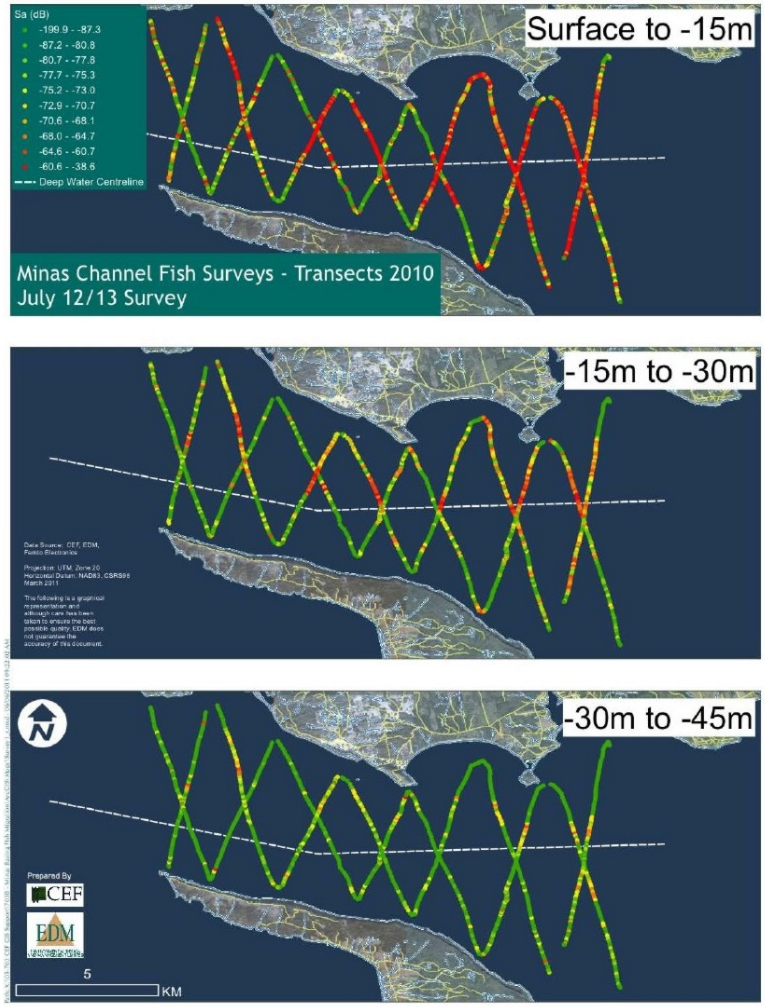


Figure 37. Locations of acoustic survey transects in June – October 2010 (CEF Consultants Ltd. 2011) survey, and distribution of acoustic backscatter for an early July 2010 survey.

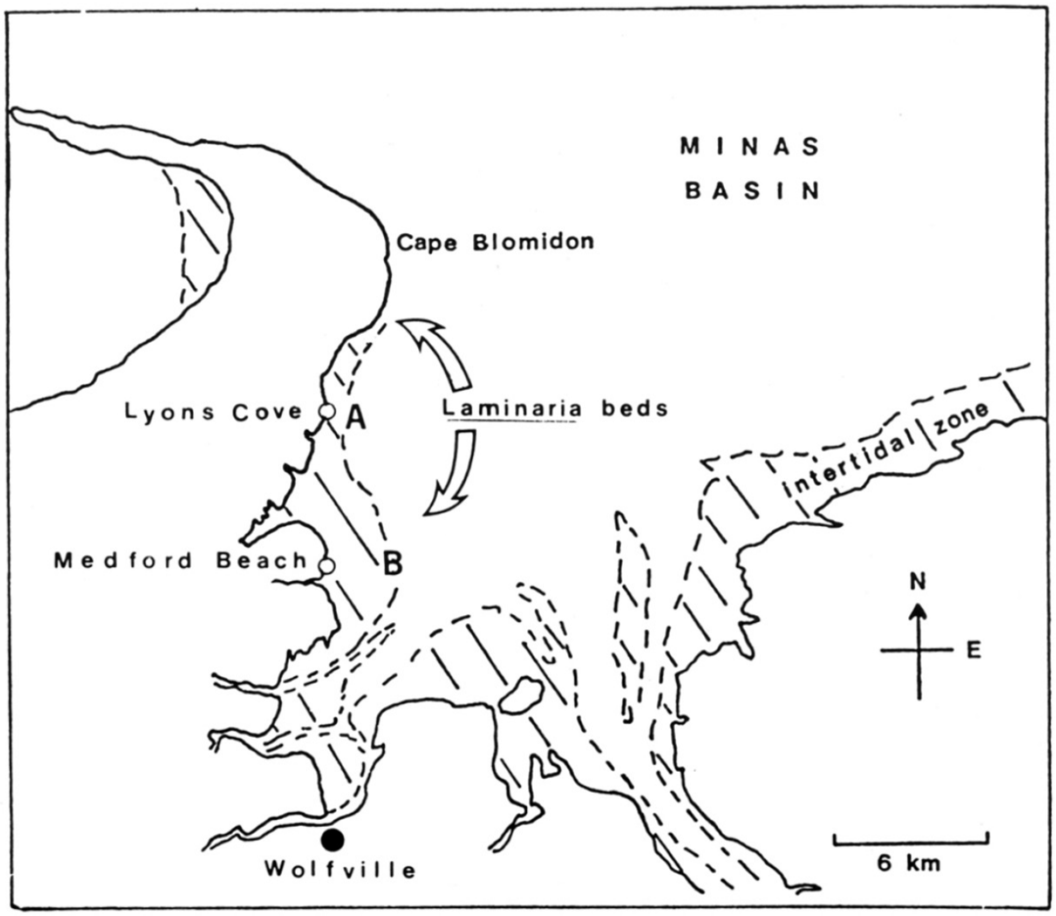


Figure 38. Location of kelp (Laminaria saccharina) beds located off Cape Blomidon (from Gratto and Bleakney 1985).

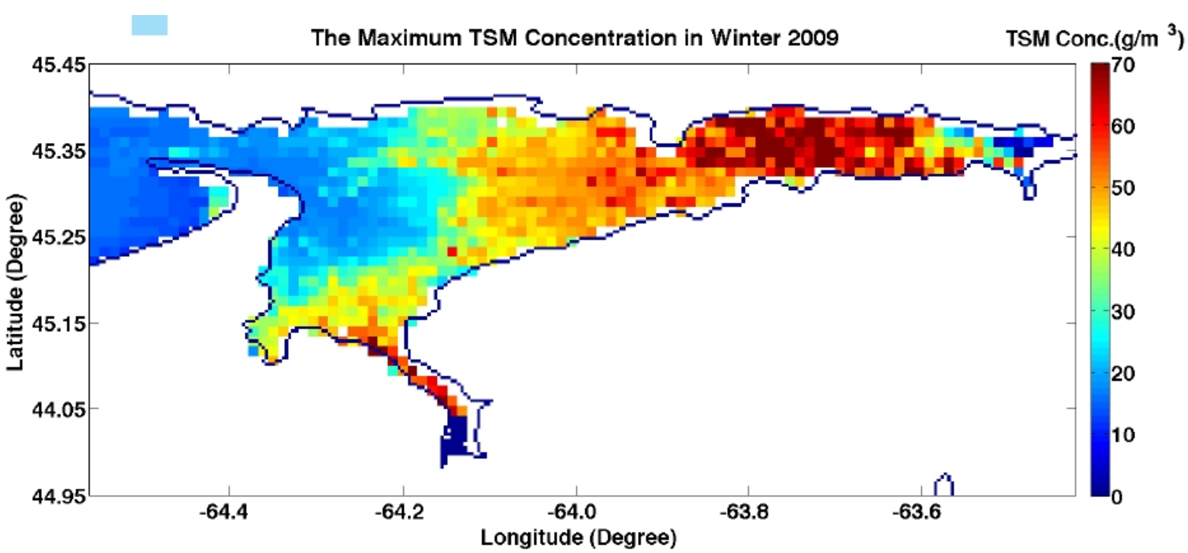


Figure 39. Winter concentration of suspended matter in surface waters of the Minas Basin Ecologically and Biologically Significant Area, based on satellite data (Tao 2013).

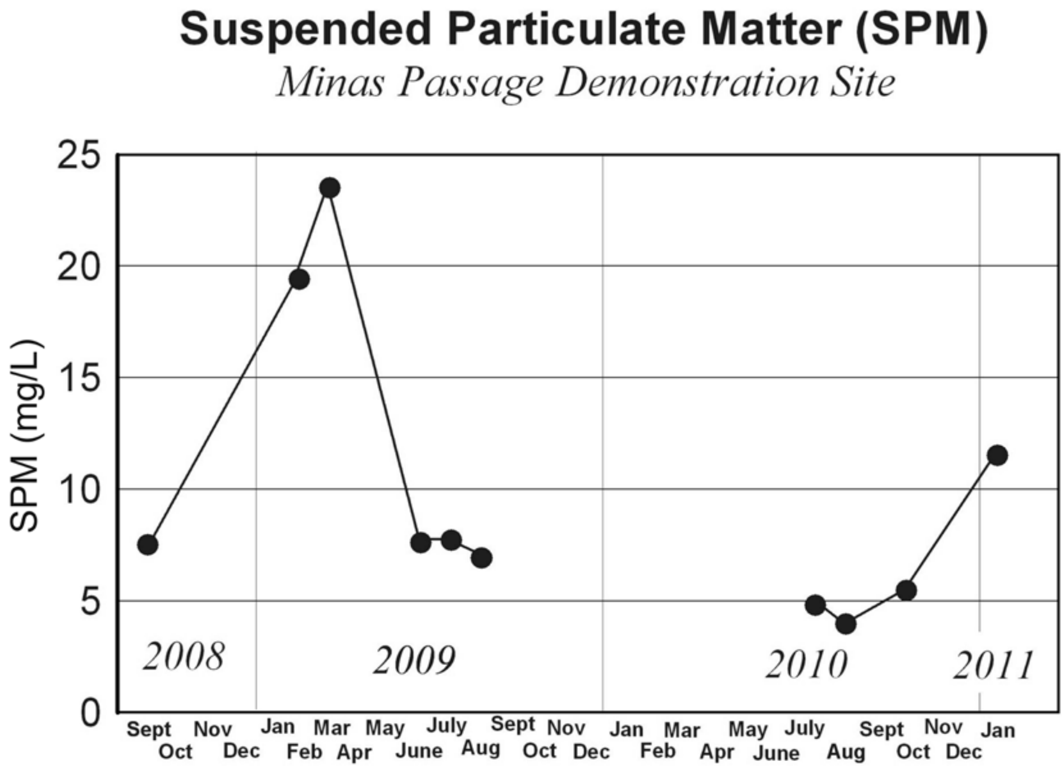


Figure 40. Seasonal pattern in suspended particulate matter (SPM) concentrations in Minas Passage, from data obtained during Fundy Tidal Energy Demonstration Project, August 2008 to January 2011 (Envirosphere Consultants Limited 2011b).

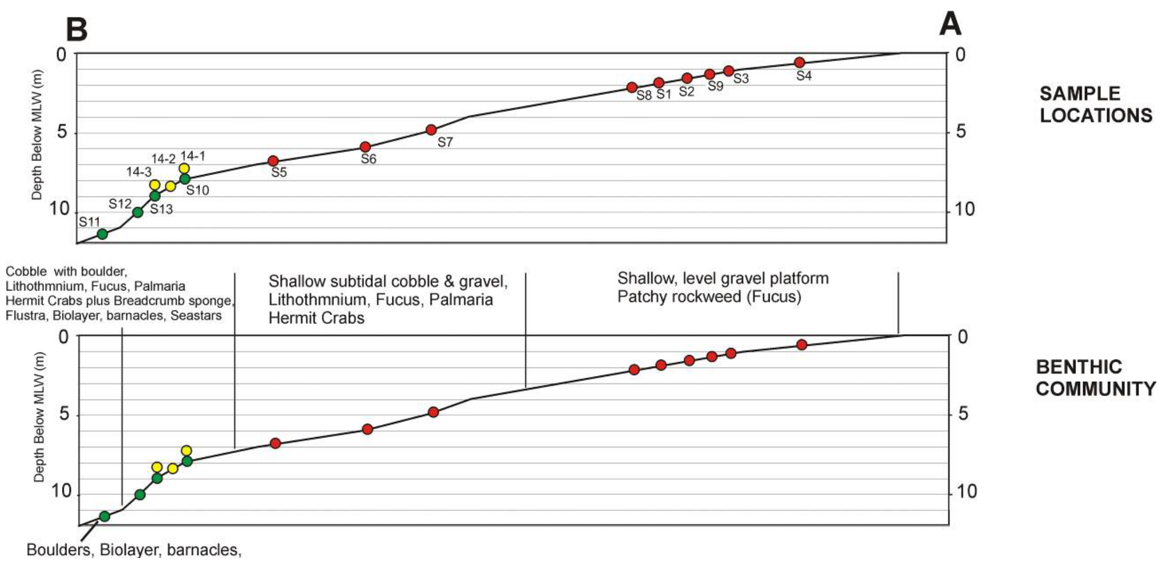


Figure 41. Seaweeds and biological community distribution with depth for a cross-section of the nearshore shelf over cobble to gravel bottom on the north side of Minas Passage in the vicinity of the tidal energy demonstration site (Envirosphere Consultants Limited 2009).

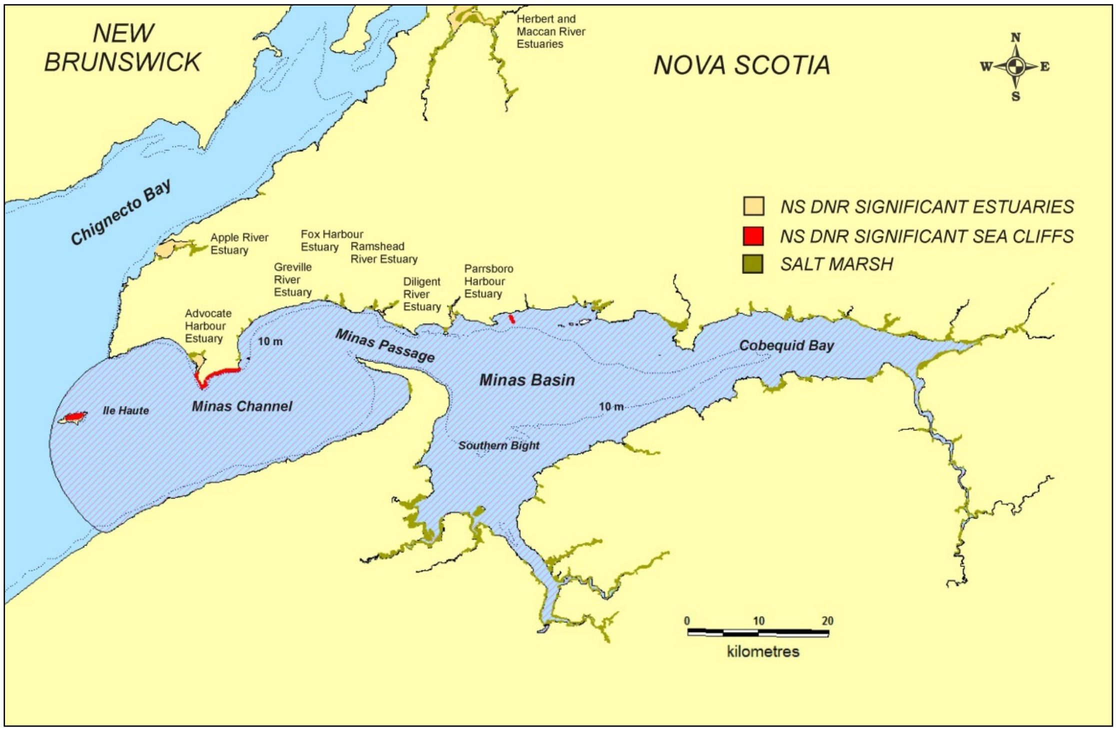


Figure 42. Important biophysical features of coastal areas in Minas Channel, Minas Basin and Cobequid Bay, based on Nova Scotia Significant Habitats Database and Nova Scotia Wetlands Vegetation and Classification Inventory (NSDNR 2016). Estuary and sea cliff features shown are those considered significant for wildlife.

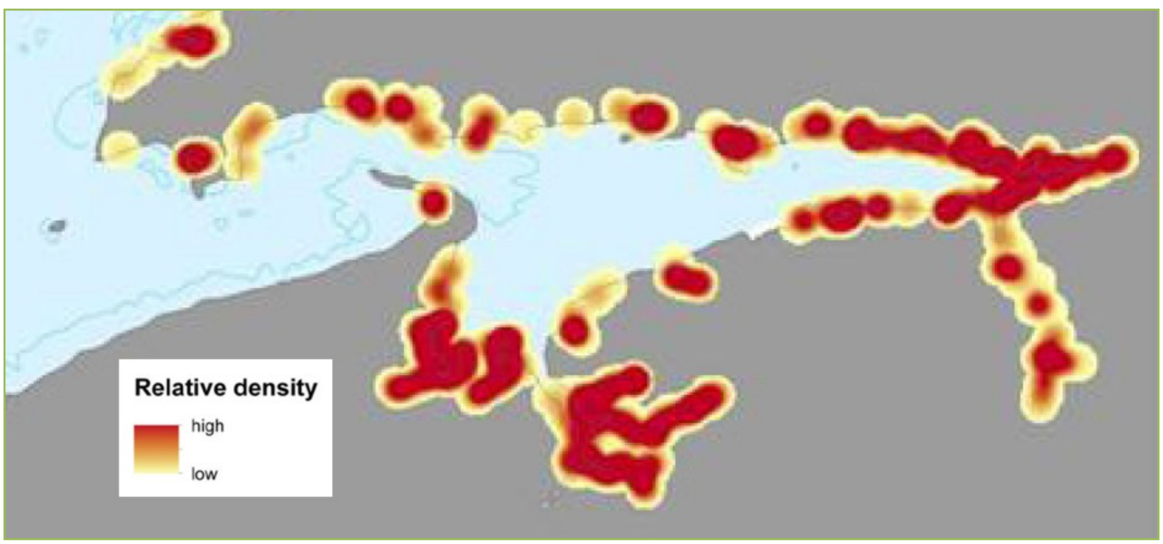


Figure 43. Depiction of salt marsh occurring in 2.5 km grid squares within the Minas Basin Ecologically and Biologically Significant Area, from Allard et al. (2014), compared to maximum and minimum values found for the Scotian Shelf Bioregion, using data from the Canadian Wildlife Service Maritimes Wetland Inventory Atlas Database. Scale shows the range from highest to lowest ranking in the Bioregion.

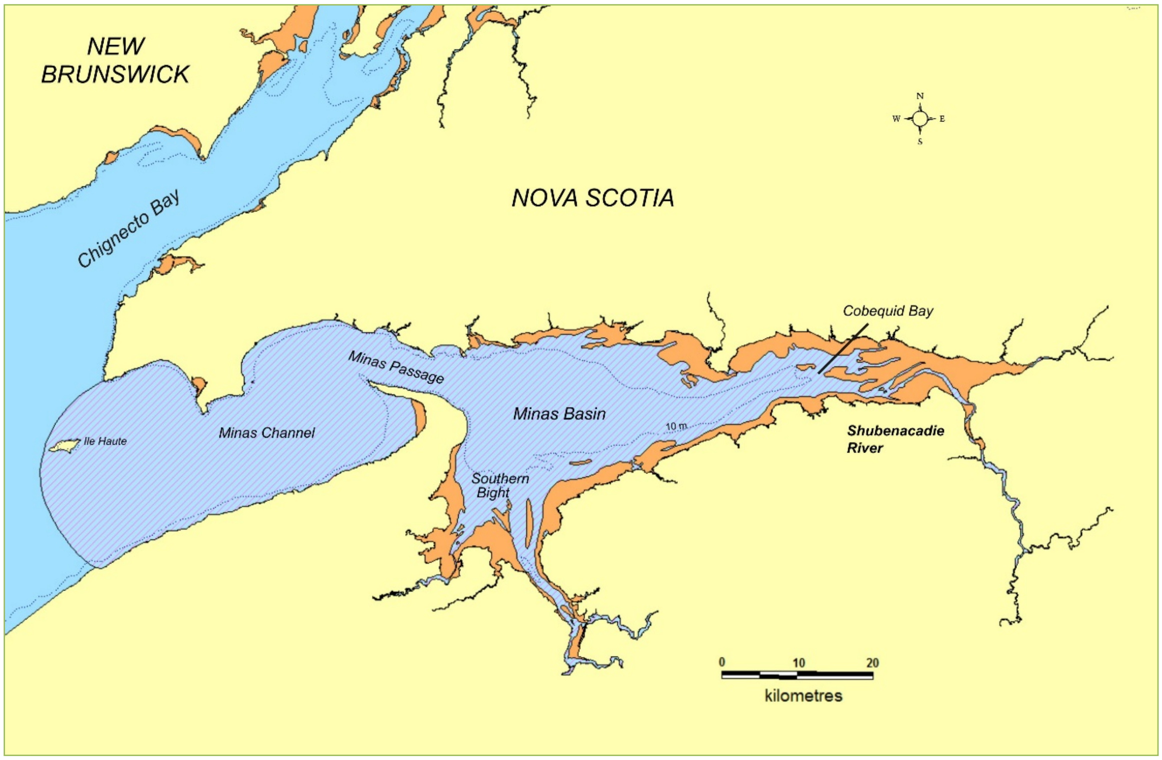


Figure 44. Extent of tidal flats in Minas Basin Ecologically and Biologically Significant Area (Sources: Parker et al. 2007, CHS Chart 4010, NTS 1:50,000 topographic maps).

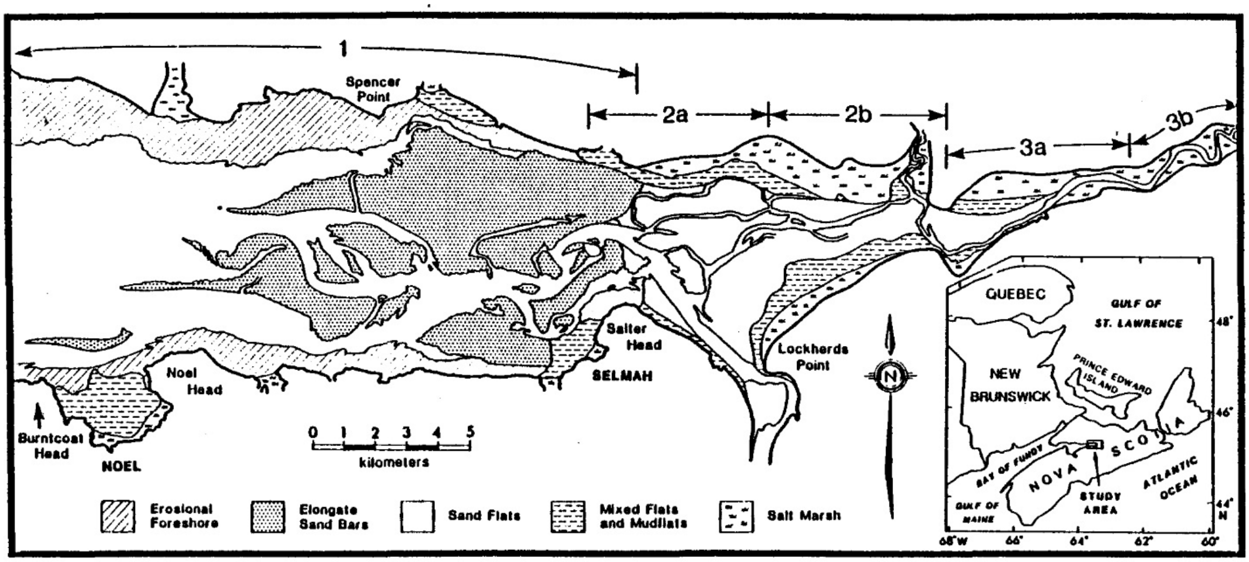


Figure 45. Distribution of mudflat, salt marsh and sand deposits in inner Cobequid Bay (Zaitlin 1987).

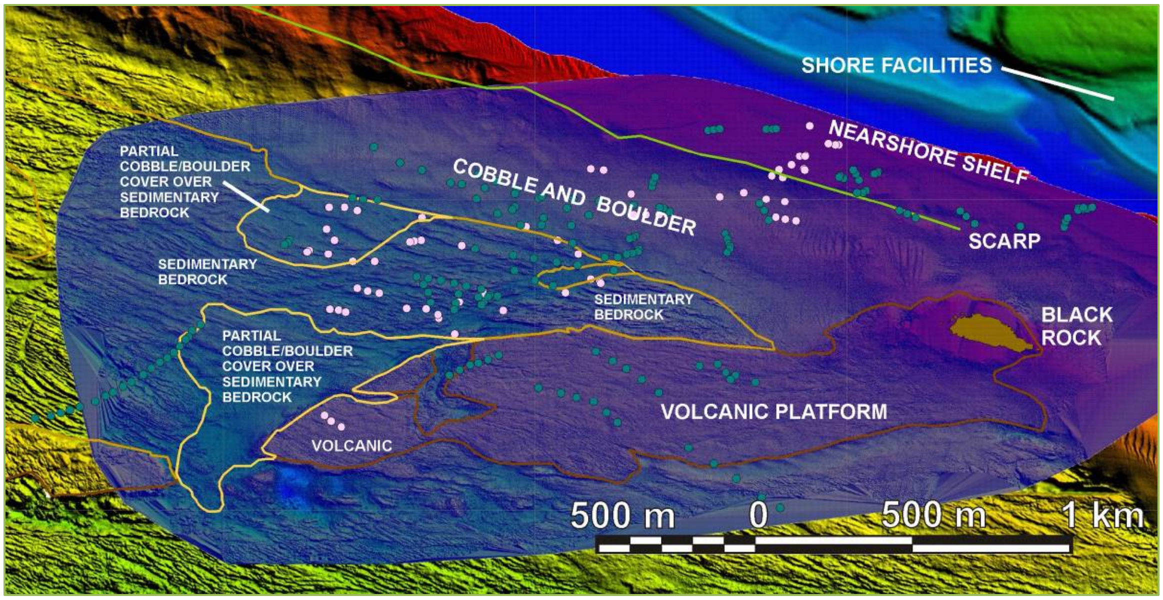


Figure 46. Geological zones in northern Minas Passage (Stewart 2009).

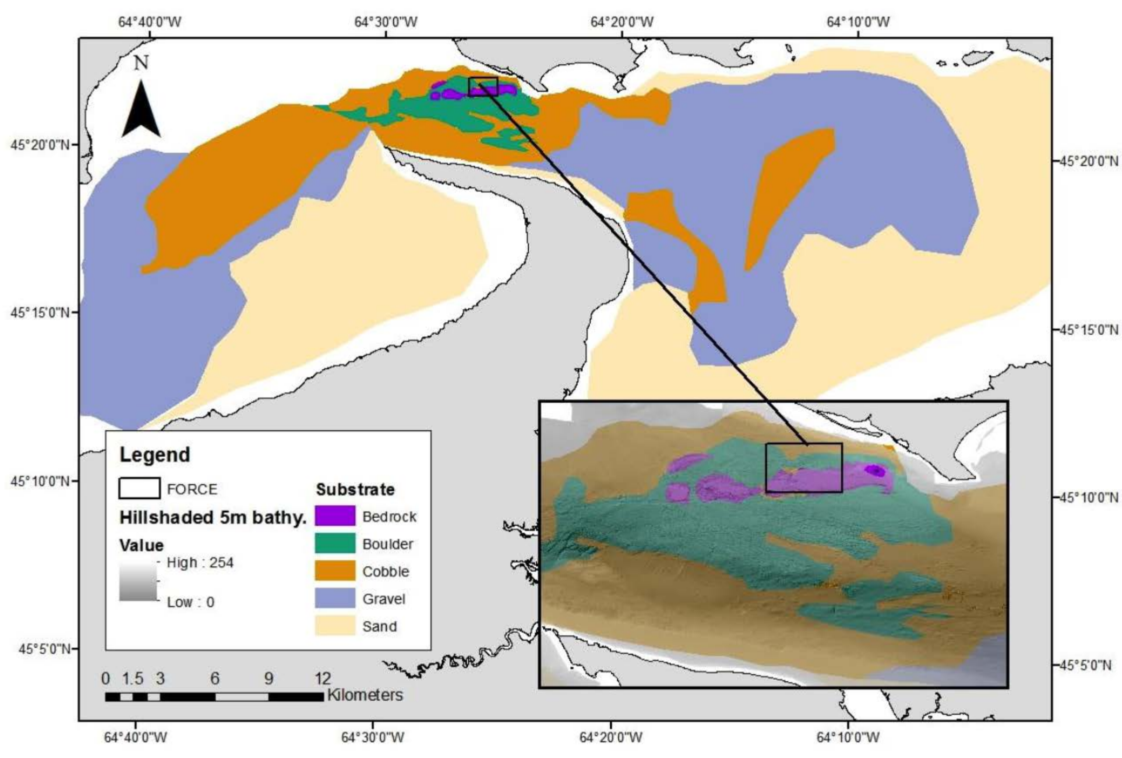


Figure 47. Interpretation of bottom types in outer Minas Basin, Minas Passage and inner Minas Channel (Morrison 2015).

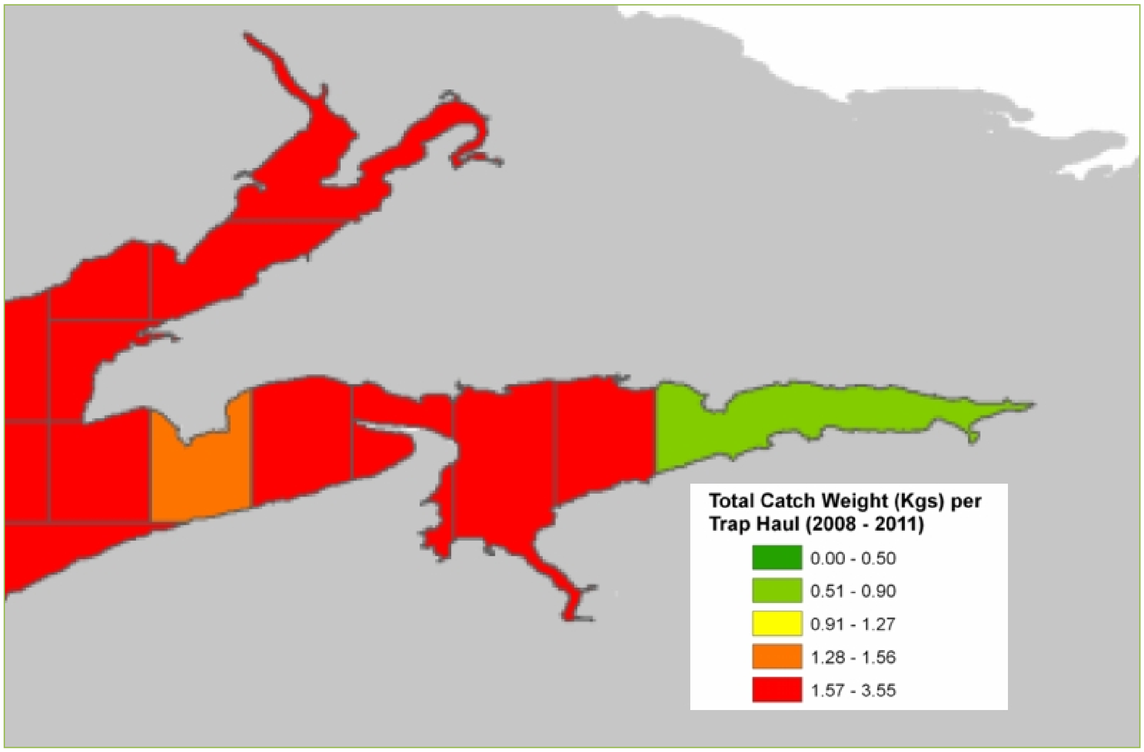


Figure 48. Catch per unit effort for American Lobster in the Inner Bay of Fundy, 2008-2011 (modified from Coffen-Smout et al. 2013).

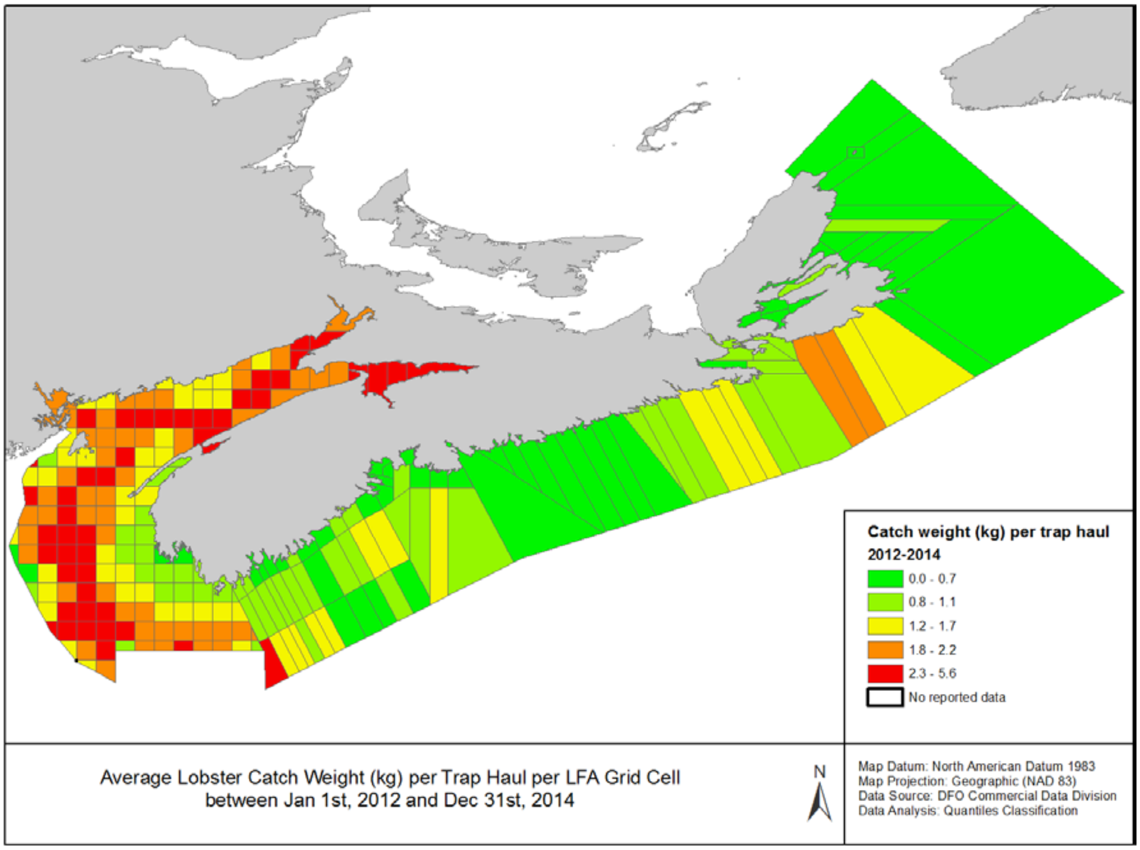


Figure 49. Composite Catch Per Trap Haul (CPUE) weight, 2012–2014 (Serdynska and Coffen-Smout 2017).

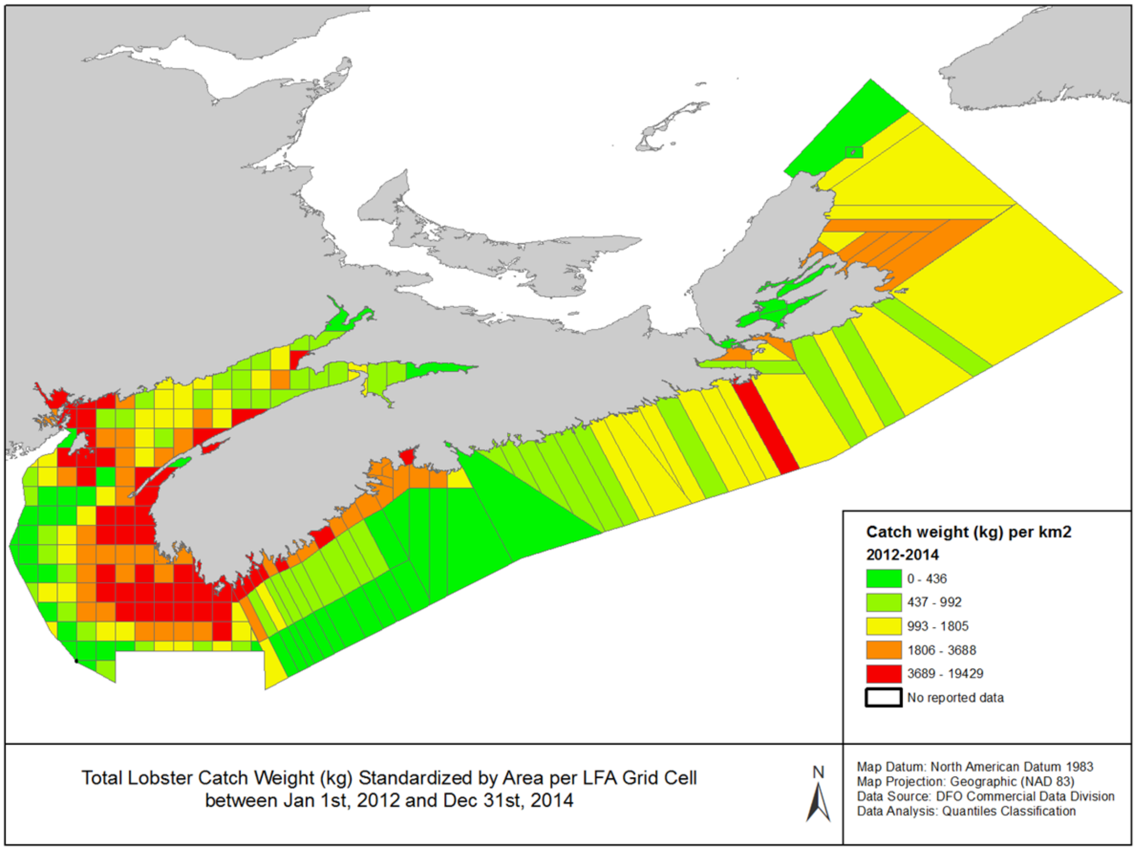
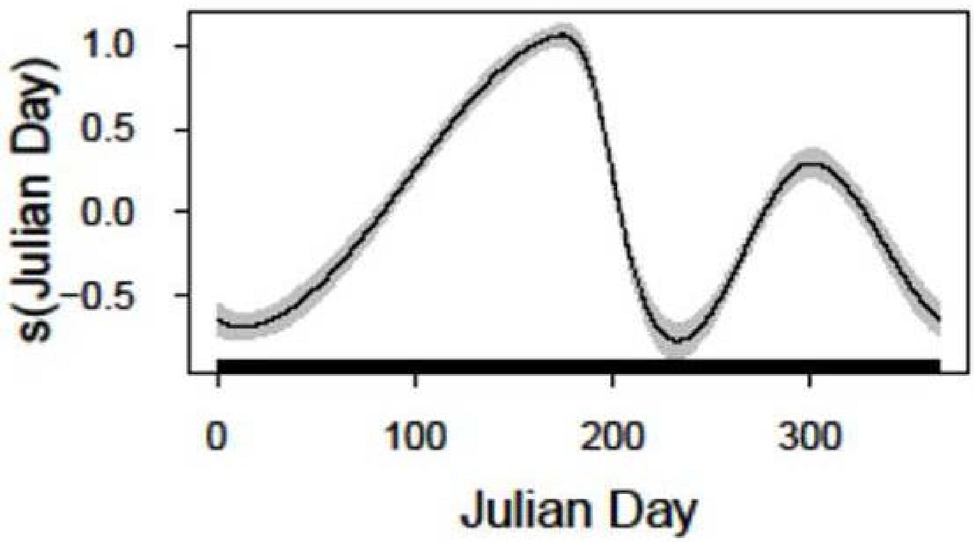


Figure 50. Composite catch weight standardized by area, 2012–2014 (Serdynska and Coffen-Smout 2017).



Julian Day Range (season)	Dates	Mean DPMp10M	SD	% of 10 MP with DPM	No. of 10MP
30-60 (winter)	30 Jan – 1 March	0.05	0.40	2.2	12563
130-160 (spring)	10 May – 9 June	0.13	0.59	6.7	42497
220-250 (summer)	8 Aug – 7 Sept	0.03	0.28	1.8	34735
280-310 (fall)	7 Oct – 6 Nov	0.09	0.55	4.1	41670

Figure 51. Modeled annual abundance of Harbour Porpoise near the tidal energy demonstration site in Northern Minas Passage, determined by Passive Acoustic Monitoring (from Porskamp et al. 2015). The illustration shows two annual peaks.

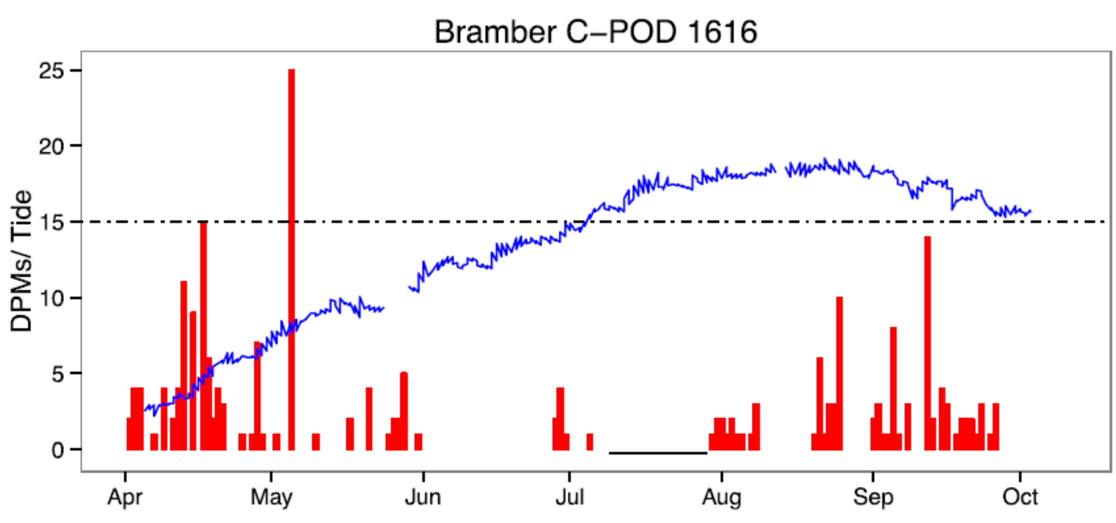


Figure 52. Detections of Harbour Porpoise in southern Minas Basin near weir at Bramber, 2013. DPM = Detection Positive Minutes. The blue curve shows water temperature (Baker et al. 2014).

Figure 53. A live Lady Crab captured and released from a weir located at Bramber, Nova Scotia, in May, 2017 (Photo: Patrick Stewart).