Ecological Overview of St Anns Bank

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ABSTRACT

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The Ecological Overview of St Anns Bank was written to summarize what is known about the St Anns Bank Area of Interest (AOI) ecosystem and how it functions, to inform the development of Conservation Objectives and management measures should the site be established as a Marine Protected Area under Canada's *Oceans Act*.
The report covers the physical, chemical, and biological oceanography of the St Anns Bank AOI. Annual research surveys, dedicated scientific work in the AOI, and published literature are used to characterize the St Anns Bank ecosystem. It also describes in detail the basic biology, status, ecological role, and likely distribution within St Anns Bank for common species in the ecosystem. Key ecosystem components identified included *Calanus* spp., areas of high sponge and sea pen concentrations, snow crab, an area of high fish diversity on the slope, Atlantic cod, Atlantic halibut, Atlantic wolffish, redfish, smooth skate, white hake, witch flounder, herring, sharks especially porbeagle, the migration route to the Gulf of St. Lawrence for cetaceans, harp seals, grey seals, high use areas for leatherback turtles, and seabirds, especially storm-petrels, Northern Fulmars, shearwaters, and Northern Gannets.

RÉSUMÉ

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L'examen de l'écosystème du banc de Sainte-Anne vise à résumer les renseignements disponibles au sujet de l'écosystème de la zone d'intérêt du banc de Sainte-Anne et son fonctionnement dans le but d'appuyer l'élaboration d'objectifs de conservation et de mesures de gestion si le site est désigné comme zone de protection marine en vertu de la *Loi sur les océans*.

Le rapport traite de l'océanographie physique, chimique et biologique de la zone d'intérêt du banc de Sainte-Anne. Des relevés de recherche annuels, des travaux scientifiques spécialisés dans la zone d'intérêt et des publications scientifiques permettent de caractériser l'écosystème du banc de Sainte-Anne. Le rapport décrit aussi en détail la biologie fondamentale, l'état, le rôle écologique et l'aire de répartition probable des espèces courantes dans l'écosystème du banc de Sainte-Anne. Voici les principales composantes écosystémiques déterminées : des *Calanus* spp.; des zones présentant des concentrations élevées de plumes de mer et d'éponges; des crabes des neiges; une zone ayant une grande diversité de poissons sur le talus; des morues de l'Atlantique; des flétans de l'Atlantique; des loups atlantiques; des sébastes; des raies à queue de velours; des merluches blanches; des plies grises; des harengs; des requins, en particulier des requins-taupes communs; la voie de migration vers le golfe du Saint-Laurent pour les cétacés; des phoques du Groenland; des phoques gris; des zones très fréquentées par les tortues luth; et des oiseaux de mer, en particulier des océanites cul-blanc, des fulmars boréaux, des puffins et des fous de Bassan.

EXECUTIVE SUMMARY

1. INTRODUCTION

St Anns Bank was identified in 2009 as a candidate Area of Interest (AOI) through a Marine Protected Area (MPA) regional protected area planning exercise using the conservation planning tool, Marxan. The site contributed to a large number of conservation goals set in this analysis, including both habitat representation goals and ecologically distinctive and significant area goals. On June 8, 2011, it was announced publicly as an AOI for the Maritimes Region, the first step in designating a MPA under the *Oceans Act*.

2.1 PHYSICAL OCEANOGRAPHY

The physical oceanography of the St Anns Bank area is mainly influenced by outflow from the Gulf of St. Lawrence along the south side of the Laurentian Channel. Warm freshwater outflow from the Gulf overlies deeper, cold, saltier water in the AOI, which promotes stratification in the water column; the western portion of St Anns Bank has some of the most stratified summer waters around Nova Scotia. Sea ice may cover the AOI in winter/spring, with maximal annual extent occurring in mid-March. Ice will cover St Anns Bank every 4–6 years out of 10, while the northern Laurentian Channel area of the AOI will be covered up to 8 out of 10 years.

2.2 CHEMICAL OCEANOGRAPHY

The chemistry of the St Anns Bank area is strongly influenced by outflow from the Gulf of St. Lawrence. In mid-winter, the highest concentrations of surface nitrate on the Scotian Shelf exist over the Cabot Strait and St Anns Bank AOI. Cadmium and dissolved copper contaminants have been observed in higher concentrations in the St Anns Bank area than on most of the Scotian Shelf.

3.2 PLANKTON

Phytoplankton communities in the AOI are typical of those on the Eastern Scotian Shelf (ESS), dominated by diatoms and dinoflagellates, and showing an increase in overall biomass over the last 15 to 20 years. Compared with the Scotian Shelf as a whole, the St Anns Bank AOI has an extended period of reproduction and growth for the ecologically important zooplankton species *Calanus finmarchicus*. In the deep water portion of the Laurentian Channel, large numbers of late-stage *Calanus* accumulate at depth during summer and fall. This portion of the site is also likely to contain moderately high concentrations of krill (*Meganyctiphanes norvegica*), another important forage species.

3.3.1 Classification of Benthic Habitats and Communities

The St Anns Bank AOI has been included in benthic habitat and community classification schemes by several authors. The classification generated by World Wildlife Fund (WWF-Canada 2009) divides the site into three classes (Inner Scotian Shelf, Middle Scotian Shelf, Laurentian Channel). A classification by Kostylev and

Hannah (2007) was also considered – the full range of natural disturbance levels from this model are represented in St Anns Bank.

3.3.2 Benthic Communities of St Anns Bank

At least three different community types emerge from photo and video sampling in St Anns Bank: the shallowest (Scatarie Bank), dominated by red algae; the mid-depth bedrock/cobble communities (featuring encrusting sponges and algae with a high diversity of small invertebrates); and the deep, muddy-substrate communities (dominated by tube-building worms). Based on ecosystem surveys, species composition is driven to a large degree by depth. Bank, shelf, and slope communities appear to be distinguishable from one another, with considerable overlap in the species distribution. However, it is also clear that community patterns are more patchy than this simple depth-based classification. Substrate may be an important factor.

3.4.1 Invertebrate Diversity

Relative to the ESS as a whole, the AOI appears to have about average diversity for invertebrates caught in the snow crab survey. A few shallow stations on the western edge of the AOI show significantly higher than average diversity.

3.4.2 Corals and Sponges

Soft corals (Alcyonacea), gorgonian corals (Gorgonacea) and sea pens (Pennatulacea) are found within the boundaries of the AOI, as are a variety of sponge species. Seapens are fairly common in the deeper part of the site and a regionally significant concentration of seapens has been identified in the southeast corner of the site. Significant concentrations of sponges have also been identified in the centre of the site. There have been no observations that indicate high densities of structure-forming corals in the AOI.

3.4.3 Lobster

There is relatively little lobster habitat in St Anns Bank (below 50 m) in the summer, but more (approximately 50–100 m depth) in the winter, when lobsters are found in deeper water. The area shallower than 50 m, adjacent to Scatarie Island, is actively fished.

3.4.4 Snow Crab

St Anns Bank is not an area of particularly high abundance for snow crab on the ESS, though they are the most important commercial species in the AOI and one of the most common species in the ecosystem.

3.4.5 Whelk

St Anns Bank is not an area of high whelk abundance in the snow crab survey, but in test fishing off Cape Breton, the area near Scatarie Island (in or near the western edge of the AOI) was found to have commercially-viable densities of whelk.

3.4.6 Other Invertebrates

Some common invertebrates not being considered in detail in this report include toad and lyre crabs, northern and striped shrimp, and all echinoderms, especially sea stars and sea urchins. These are all among the most abundant animals in the site, but St Anns Bank is not a particularly high area of abundance on the ESS for any of these groups.

3.5.1 Fish Diversity

About half of the fish species found on the Scotian Shelf in the research vessel (RV) survey have been found in St Anns Bank. Species diversity for fish is highest along the slope. In order from high to low, the five most frequently caught fish species in St Anns Bank were American plaice, Atlantic cod, witch flounder, Atlantic redfish (spp.), and thorny skate. The five fish species with the highest average biomass per tow were redfish spp., Atlantic cod, white hake, pollock, and haddock. Relative to the ESS as a whole, the slope area of the AOI appears to have significantly higher than average diversity for fish caught in the RV survey.

3.5.3 American Plaice

American plaice in St Anns Bank are likely comprised of a local 4Vn population year-round (described as Sydney Bight American plaice), with 4T plaice overwintering in the area. American plaice are quite common and widespread on the ESS, being the most frequently caught species in the AOI in the RV survey and the second most frequently caught species in the AOI in the snow crab survey. About 5% of preferred habitat for American plaice on the ESS was found to be in the St Anns Bank AOI.

3.5.4 Atlantic Cod

Southern Gulf of St. Lawrence (4TVn) Atlantic cod overwinter in 4Vn, including in the AOI, though the highest concentrations of overwintering cod are to the north and south. Resident 4Vn cod spawn in Sydney Bight but can be found in the SAB area during much of the year. Atlantic cod from the 4VsW stock occur in the SAB area at all times of the year, with older cod being found in this area more often, but a fairly small proportion of the overall stock would probably be found in the AOI. Overall, 25% of the preferred summer habitat for cod on the ESS is in SAB (based on Horsman and Shackell 2009).

3.5.5 Atlantic Halibut

Atlantic halibut are consistently found in St Anns Bank, but there is no evidence to suggest that St Anns Bank is particularly important for this species. However, very little is known about the reproductive ecology of Atlantic halibut in the northwest Atlantic. The halibut fishery is one of the more active commercial fisheries in St Anns Bank.

3.5.6 Atlantic Wolffish

Atlantic wolffish have been consistently caught in the St Anns Bank area on the Laurentian Channel slope (in the RV survey) and on St Anns Bank itself (in the halibut, 4Vn sentinel, and snow crab surveys). Approximately 50% of preferred habitat for Atlantic wolffish on the ESS (for time period 1994–2006) was found within the AOI boundaries. It is not known how wolffish use the area, but they do appear to use it consistently.

3.5.7 Redfish

Unit 1 redfish are found in the AOI from November to May and Unit 2 redfish are found there during the rest of the year. The proportion of these populations found in 4Vn is uncertain but appears substantial for Unit 1 and less so for Unit 2. Redfish had the highest abundance of any fish recorded in the RV survey in the AOI. The slope area within the AOI includes a significant portion of preferred habitat for redfish (11%) based on Horsman and Shackell (2009).

3.5.8 Smooth Skate

Smooth skate have been consistently caught in St Anns Bank in the RV survey over the 40-year time series. St Anns Bank is not an area of preferred habitat for smooth skate in Horsman and Shackell (2009), but smaller juveniles are not well captured by this survey and not directed for in a fishery, so their distribution is hard to assess. Large catches of skate purses in the snow crab survey have occurred in the southeast corner of the AOI; based on other records from this area, they are likely smooth or thorny skate purses. This feature requires further study.

3.5.9 White Hake

White hake population dynamics are complex and not well understood, but it is likely that white hake in the St Anns Bank area are members of both 4T and 4VW populations. The slope into the Laurentian Channel appears to be an important area for this species on the ESS. White hake abundance in 4VW is highly variable, but is currently somewhat depressed. The status of white hake in 4Vn is poor.

3.5.10 Witch Flounder

Stock structure of witch flounder in the Gulf/Scotian Shelf is uncertain; witch in the St Anns Bank area are likely a mixture of 4T east, 4Vn resident, and 4VW fish. The St Anns Bank area contains some areas of preferred habitat for witch flounder, on the slope and on the edge of the Glace Bay Hole. Witch flounder are the third most frequently caught species in the RV survey in St Anns Bank, and are widely distributed within the site.

3.5.11 Capelin

Capelin seem to migrate to and from the ESS depending on water temperature. When capelin are present, they are abundant and have been caught in the AOI.

3.5.12 Herring

There is extensive mixing of herring populations from around the Atlantic region in the St Anns Bank area. There is overwintering of southern Gulf herring in the area (for upwards of half the year), and there is spawning of coastal herring in The Big Shoal, the shallow area in the northwest corner of the site. Coastal spawning components in this area are believed to be at much reduced abundance.

3.5.13 Mackerel

Mackerel migrate through the area into the Gulf of St. Lawrence in June, migrating out in October/November. Limited commercial fisheries occur during the time that they are in the St Anns Bank area.

3.5.14 Sharks

The Laurentian Channel is part of the mating area for porbeagle, and there is occasional commercial fishing of porbeagle in this area. Other sharks that may be common here are blue sharks, basking sharks, shortfin mako, and spiny dogfish. None are known to aggregate or undertake any critical life history processes in the area. Several basking sharks were spotted here in an aerial survey in 2007, and they are known to aggregate on the west coast of Cape Breton.

3.6.1 Cetaceans

Information about cetacean use of the St Anns Bank area is mainly limited to opportunistic sightings. There are no known high use areas for cetaceans in the AOI. However, the AOI likely encompasses an important migration route for baleen whales, including blue whales, fin whales, right whales, etc. travelling through the Cabot Strait to and from the Gulf of St. Lawrence. Most cetaceans likely occur in the area seasonally or as transients. It is not known if there are resident populations of cetaceans that occur in the St Anns Bank area, but some species, particularly pilot whales, may use the area throughout the year.

3.6.2 Seals

Grey, harp and harbour seals are likely to be found in the AOI. Harp seals may pup in the AOI in years of heavy ice cover and there is some evidence that this has occurred in recent years. Hay Island is the largest grey seal colony on the ESS, with about 3,000 pups born annually. Grey seals from Hay Island use the St Anns Bank area for foraging. Tagging indicates that grey seals from the Gulf of St. Lawrence and from the Sable Island also forage in this area, as part of their large foraging areas.

3.7 Sea Turtles

The leatherback turtle is listed as endangered under the *Species at Risk Act* (*SARA*), and the western Atlantic population has been declining since the 1990s. Leatherbacks forage for jellyfish in Canadian waters each summer. St Anns Bank has been identified as an area of high use for leatherbacks, with turtles likely found in the area from July through October. Loggerhead sea turtles are unlikely to be found in the AOI, as they are rarely found inshore.

3.8 Seabirds

Seabird species observed during surveys that occur in high densities within and around the St Anns Bank AOI include storm-petrels, great black-backed and herring gulls, northern fulmars, great shearwaters, sooty shearwaters, and northern gannets. For most of these species, concentrations are believed to be of migrating individuals, though gulls and storm-petrels present may include nesting birds foraging in the area. Species nesting on and near Scatarie Island include more coastally-associated common eider, double-crested and great cormorants, black guillemot, common and arctic terns, as well as the typically more pelagic Leach's storm-petrel and black-legged kittiwake.

4.1 Migration in St Anns Bank

A large number of species are known to migrate through the Cabot Strait annually, to feed in the Gulf of St. Lawrence in summer or to overwinter in the Cabot Strait. For species from the Gulf of St Lawrence known to overwinter in the Cabot Strait, an assumption that about 50% of each fish stock overwinters in the Cabot Strait would indicate a migration of up to half a million tons of total biomass. This is probably conservative and does not include cetaceans or anadromous fish, which also migrate through this area.

4.2 Long-term Changes

This section summarizes multiple hypotheses for the changes observed in the Scotian Shelf ecosystem over the last 40–50 years. One point of agreement among these hypotheses is that overfishing on demersal species has generated a fundamental change in the functioning of the ecosystem. Also, top down effects due to removal of the larger fish are interpreted to have generated a transition to an alternate state favouring small fish and with less energy reaching the benthos. However, there is still no consensus on the importance of predation by grey seals in maintaining the low abundance of Atlantic cod and other groundfish in the ESS system.

4.3 Data Gaps and Sources of Uncertainty

As in most of the Scotian Shelf, there are a number of systematic limitations to data collection in the St Anns Bank area. For example, most sampling is through trawl surveys, which do not sample the entire ecosystem, and occur only during the summer and early fall. Some features have been noted that warrant further research to determine their significance, including potentially regionally high concentrations of krill, whelks, and skate purses in different parts of the site.

4.4 Key Ecosystem Components

This section summarizes key components of the St Anns Bank ecosystem that were identified throughout this report. A subset of these components will be used to derive conservation objectives and management measures of the site.

1. INTRODUCTION AND CONTEXT

On June 8, 2011, St Anns Bank was announced by the Minister of Fisheries and Oceans Canada (DFO) as an Area of Interest (AOI) in the Marine Protected Areas Program (DFO 2011a). This is the first step in a multi-phased process to legally designate a Marine Protected Area (MPA) under the *Oceans Act*.

The St Anns Bank AOI is located east of Cape Breton Island, immediately east of Scatarie Island (Figure 1-1). The AOI includes Scatarie Bank, most of St Anns Bank, and part of the western slope of the Laurentian Channel. The boundaries of the AOI encompass approximately 5100 km^2, and effectively represent a study area in which to conduct assessments and planning efforts.

The MPA establishment process requires DFO to complete several planning steps prior to designation, including an ecological overview and assessment. This report provides the ecological overview component, presenting an in-depth description of the ecological features and conservation priorities of the AOI. It includes an overview of the physical and biological oceanography of the site, as well as profiles of common and important species of the St Anns Bank AOI and surrounding region (including their conservation status, vulnerabilities, and overall utilization of the area). This overview will serve as a key information source for designing the MPA, including directing the ecological assessment component, defining the conservation objectives, and delineating boundaries and zones.

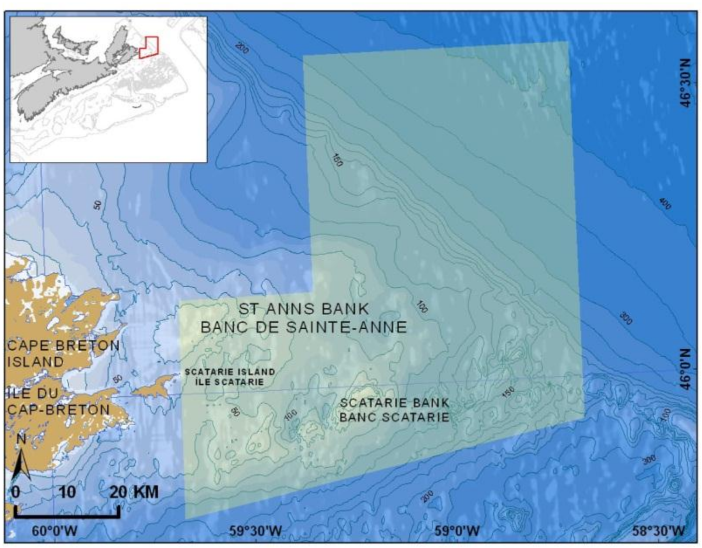


Figure 1.1. Location of St Anns Bank AOI. Boundary is for evaluation purposes only and does not reflect a proposed MPA boundary.

1.1 IDENTIFICATION OF ST ANNS BANK AS AN AREA OF INTEREST

The Health of the Oceans (HOTO) initiative was introduced in 2007 to further conservation efforts in Canada's oceans. This initiative includes the designation of six new *Oceans Act* MPAs within existing Large Ocean Management Areas (LOMAs) across the country. DFO Maritimes Region is responsible for advancing St Anns Bank as one of these sites, contributing to the broader network of MPAs for the region and the country. Canada has made several national and international commitments to networks of MPAs, which are summarized in the National Framework for Canada's Network of Marine Protected Areas (Government of Canada 2011).

The St Anns Bank AOI was identified as part of a broader analysis in 2008–2009 to identify areas of conservation interest for the offshore portions of the entire Scotian Shelf bioregion (described in detail in Horsman et al. 2011). A region-wide approach was used in order to identify a cohesive set of individual sites that all together could address multiple objectives. The ecological objectives were derived from a variety of existing efforts, including national and international scientific guidance for MPA network design.

The broad goals for this analysis were (a) to protect examples of all habitat types in the region, and (b) to protect ecologically distinctive or significant areas in the region. This is consistent with scientific guidance from the Convention on Biodiversity (CBD) for selecting areas for MPA networks (CBD, COP 9 Decision IX/20, Annex II). Over 100 data layers were used to meet these goals under the following general categories: seabed features, benthic features, significant fish and invertebrate species, depleted species, biodiversity hot spots, natural refuge areas, coral locations, and endangered whale habitat. Data sources are described in Horsman et al. (2011).

Once the data layers were collected and the objectives defined, the conservation planning tool Marxan was used to identify priority areas to meet these objectives. Marxan identifies the most spatially efficient way to meet a suite of quantitative conservation targets. St Anns Bank was consistently selected by Marxan as it met a number of region-wide goals and targets, including representation of a variety of habitat types (shallow water bank to deep water channel) and abundance and diversity of both commercial and depleted species (see Table 1-1).

From the areas of the Eastern Scotian Shelf identified by Marxan, a short list of candidate AOIs was selected. Three of these sites were included in a nine-month consultation process in 2009–2010 to gather input from stakeholders and the public. More information about this process is available from DFO Maritimes Region[1]. From the candidate AOIs, St Anns Bank was selected due to its high ecological value, alignment with criteria for MPA designation under the *Oceans Act* (see below), and because it had the highest level of support during public consultation.

[1] http://www.mar.dfo-mpo.gc.ca/e0010385

Table 1.1. Marxan targets partially met by St Anns Bank.

Feature Type		Feature	Area (planning units[1])	% of target (entire SS) in SAB
Habitat representation	Natural disturbance	Natural disturbance low medium	125.342	16.0
		Natural disturbance medium	128.107	9.3
		Natural disturbance low	34.03	2.8
		Natural disturbance high	9.593	1.9
	Scope for growth	Scope for growth very low	156.851	35.4
		Scope for growth low	50.355	5.1
	Seabed features	Inner Scotian Shelf	98.683	29.2
		Laurentian Channel	99.393	27.7
		Middle Scotian Shelf	108.753	14.5
Ecologically distinctive or significant areas	Biodiversity indices	RV survey biodiversity hot spots (rare species only)	63	5.7
	Depleted spp	Cod 4Vn	137	66.1
		Atlantic wolffish	50	12.1
	Sig species	*Sebastes* Unit 2	94	65.4
		White hake 4VW	116	64.7
		Witch flounder	83	33.9
		Plaice 4VW	30	7.3
	Invertebrates	Sponges	108	80.1
		Sea urchins	56	65.3
		Soft coral	79	48.6
		Anemones	9	11.3
		Snow crab	24	4.6
		Shrimp	13	3.8
		Crabs and lobsters	15	3.8
		Whelks	9	2.0
		Sea stars	4	1.3
	Topo roughness index	High topographic roughness	6	0.4

[1]"Planning units" refers to a grid used as the units of analysis in Marxan. They vary in size but each is approximately 10 km^2. See Horsman et al. 2011 for details.

In addition to its contribution to region-wide conservation goals, St Anns Bank meets multiple purposes for individual MPA designations under the *Oceans Act*, namely:

- Conservation and protection of commercial and non-commercial fishery resources, including marine mammals, and their habitats
    - Important habitat for Atlantic cod, redfish, American plaice, sea urchins, white hake, witch flounder, sea anemones, sponges, and sea pens
- Conservation and protection of endangered or threatened marine species, and their habitats

    - Important habitat for depleted species such as Atlantic wolffish, Atlantic cod, and leatherback turtles
- Conservation and protection of unique habitats
    - Only major bank on the Inner Scotian Shelf
- Conservation and protection of marine areas of high biodiversity or biological productivity
    - St Anns Bank contains biodiversity hot spots on the Eastern Scotian Shelf (ESS) for invertebrates and fish

1.2 REPORT ORGANIZATION AND CONTENT CONSIDERATIONS

This report is organized in three general sections: Physical Setting, Biological Description, and Trophic Levels and Ecosystem Components. Concerning the biological description, inclusion of species and species groups was based on a combination of analysis, expert opinion, and previous selection in efforts to prioritize species in the region, that is, ecologically significant species.

Most of the benthic invertebrate groups and groundfish considered in detail were identified because they have preferred habitat (defined in Section 3.5.2) in the St Anns Bank AOI and therefore contributed to the selection of St Anns Bank by Marxan (Table 1-1). The main data sources for these groups in the Marxan analysis were DFO research trawl surveys described in Section 3.1 below. Most of the groups considered in the report are poorly sampled, if at all, by this survey (plankton, pelagic fish, marine mammals, sea turtles, and seabirds), so expert opinion was used to identify which species to consider. Generally speaking, species were considered if St Anns Bank was an area of particularly high abundance for that species, or if the area was considered to be important to a life history process of the species (such as reproduction or migration).

The report concludes with a general overview of ecosystem components that provide the basis for selecting conservation priorities for St Anns Bank. Further evaluation of the ecological importance of the area and its contribution to the ESS ecosystem was provided in the January 2012 Canadian Science Advisory Secretariat (CSAS) meeting.

2. PHYSICAL SETTING

2.1 PHYSICAL OCEANOGRAPHY

The oceanographic attributes of the St Anns Bank area are predominantly influenced by the outflow from the Gulf of St. Lawrence. However, this flow is in turn influenced by a number of freshwater sources including the St. Lawrence and other rivers, and the relatively fresh, cold, marine Labrador Shelf water that flows into the Gulf of St. Lawrence through the Strait of Belle Isle between Newfoundland and Labrador. The Gulf is also influenced by Newfoundland Shelf water that squeezes around the western tip of Newfoundland through the Cabot Strait, and warm salty water from deep off the continental shelf that moves into the Gulf of St. Lawrence along the bottom of the Laurentian Channel. As shown in Figure 2.1-1, there is a complex series of upwellings and gyres that mix these various source waters while they are in the Gulf of St. Lawrence.

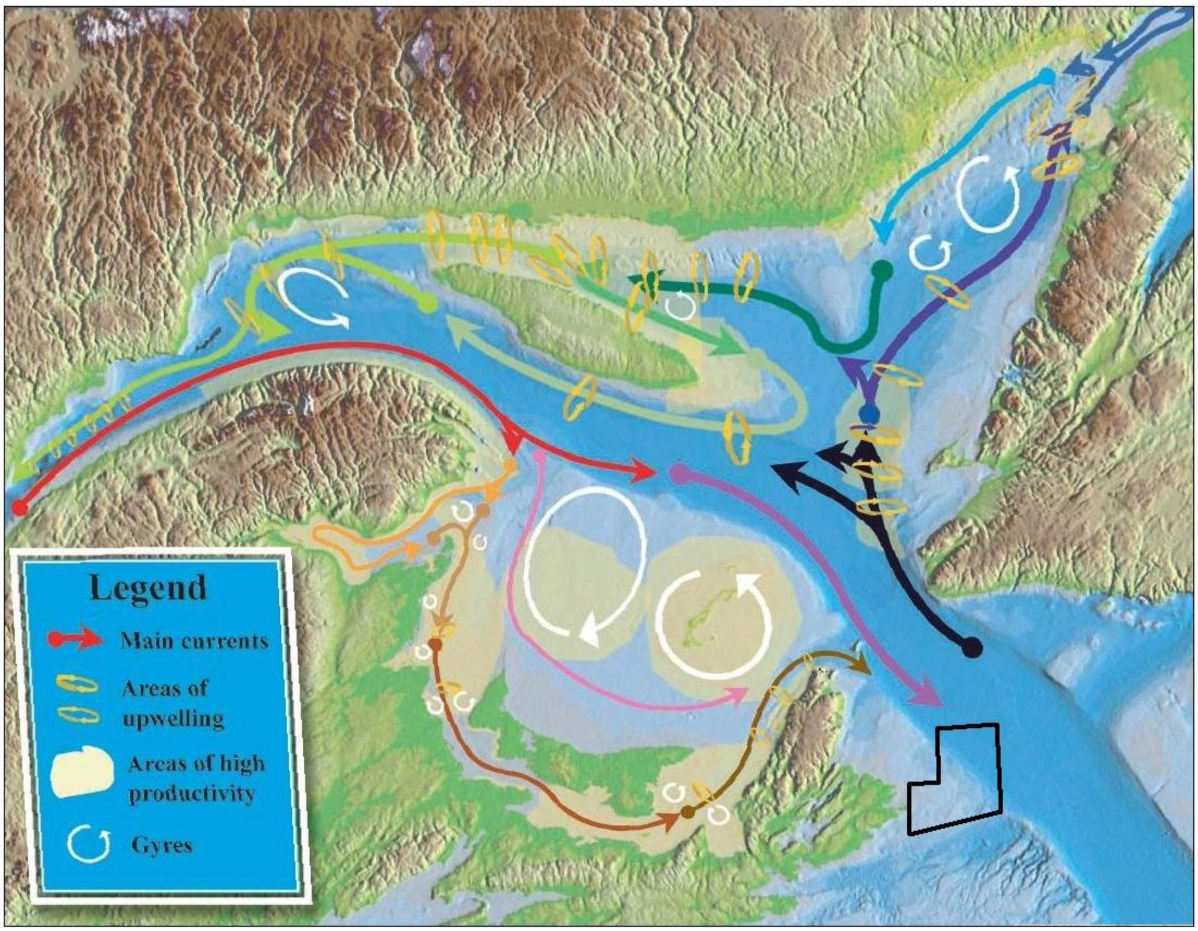


Figure 2.1-1. Depiction of the main circulation patterns of the Gulf of St. Lawrence. St Anns Bank AOI shown in black. Note the northern inflow and southern outflow in the area of St Anns Bank and the upwelling along the western coast of Cape Breton that brings nutrient rich waters to the surface (Source: DFO 2005a).

At the Cabot Strait and St Anns Bank AOI, inflow from the Atlantic Ocean toward the Gulf of St. Lawrence dominates the north (Newfoundland) side of the Laurentian Channel. In contrast, outflow dominates the south side of the Channel (Cape Breton and St Anns Bank). This outflow is a combination of a nearshore current that moves north along the western shoreline of Cape Breton through what is known as the Cape Breton Trough, and a deeper flow that follows the slope of the Laurentian Channel. The shallow part of the outflow flows through the AOI and turns southwest to become the Nova Scotia Current, while the deeper current follows the slope around Banquereau Bank and merges with the shelfbreak current (Figure 2.1-2; Source: Brickman and Drozdowski 2012).

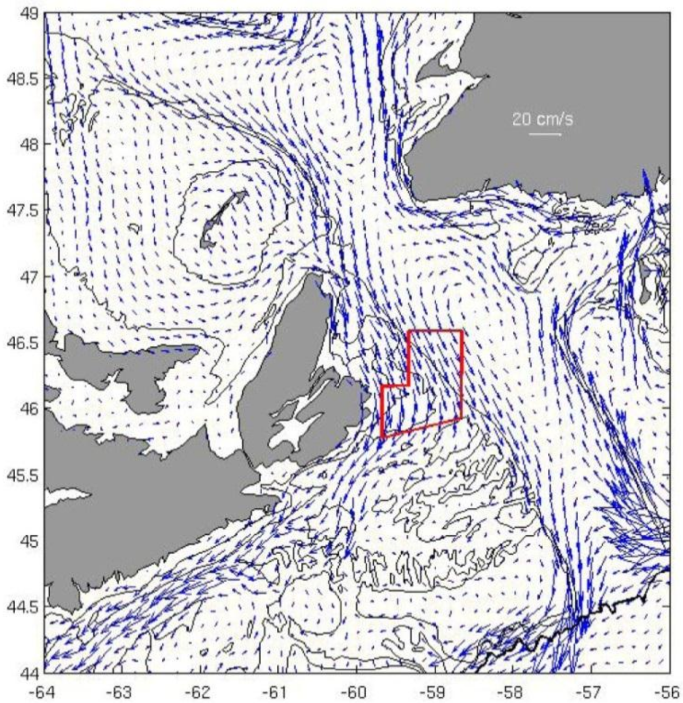


Figure 2.1-2. Annual mean depth-averaged currents in St Anns Bank region, from numerical circulation model (Source: Brickman and Drozdowski 2012).

Within the Gulf of St. Lawrence, St. Lawrence estuary water from the river, Labrador Shelf water coming through the Strait of Belle Isle, and Labrador Slope water coming in through the Laurentian Channel all come together and begin to mix. At all locations the estuary water is constrained to the upper 200 m, as its lower salinity makes it less dense than highly saline marine water. Labrador Shelf water content is greatest at about 100 m depth. Being relatively cold and fresh, it sits atop the more dense, warm, salty Labrador Slope water, which is the dominant constituent below 200 m. As much of the St Anns Bank AOI is less than 150 m deep, it is primarily the St. Lawrence estuary water and Labrador Shelf water that flows across the AOI and onto the relatively shallow Eastern Scotian Shelf (Houghton and Fairbanks 2001). However, portions of all three source waters flow eastward along the deeper Laurentian Channel past the St Anns Bank AOI.

On a more localized scale, the morphology of Sydney Bight influences current patterns, creating gyres and upwelling. Particles from within Sydney Bight area tend to follow two different tracks; one southwestward over St Anns Bank and along the Nova Scotia Current, the other slightly more offshore, following the slope of the Laurentian Channel toward Misaine Bank. Wind can be an important determinant in the direction and speed of these surface water movements to a depth of 2.5 m both through the Cabot Strait and southwestward onto the Scotian Shelf (Chassé 2001) in the St Anns Bank area.

The proximity of St Anns Bank to the mainland means that tidal currents play an important role in the AOI. There are relatively strong depth-averaged tidal current amplitudes over the St Anns Bank area, as much as 20 m/s for the M2 tidal component and stronger for the K2 component (Chassé 2001). Both the winds and tidal currents are likely to promote vertical mixing within the AOI.

As noted, a large portion of the outflow across St Anns Bank area turns southwestward along the Nova Scotia coast, forming the Nova Scotia Current, and carrying Gulf of St. Lawrence water all the way to the Gulf of Maine and eventually into the Bay of Fundy (Houghton and Fairbanks 2001). The sea level difference between North Sydney and Halifax forms a pressure gradient that can be related to the strength of the Nova Scotia Current. The difference in sea level can change over time, and this difference has generally been greater than normal from about 1984 to the mid-2000s (end of the assessed period). This suggests that relatively more Gulf of St. Lawrence water would have moved across St Anns Bank and onto the Eastern Scotian Shelf during this period (DFO 2003a).

The circulation model results of Brickman and Drozdowski (2012) were analyzed to get an idea of the variability in flow in the St Anns Bank region. Their model was forced with atmospheric variables representing the annual cycle of weather patterns in Maritime Canada, so that the model response represents the (daily) climatologically varying circulation in the region. In general, the variability in the flow in the AOI was dominated by changes in the magnitude of the velocity rather than the direction, although numerous flow reversals were observed. The annual average disturbance kinetic energy (the root mean squared difference between the daily and annual mean velocities, averaged over a year of model output) shows that the southwest part of the AOI is a region of high flow variability (Figure 2.1-3), while the majority of the AOI has average disturbance kinetic energy (KE). Areas of high disturbance KE are expected to be regions of (for example) high mixing and low retention. On a seasonal basis, there is more energy and variability in the flow during fall and winter, with more quiescent conditions during spring and summer. With respect to retention, particle tracking experiments (in the surface layer) indicate that in this region the time scale for 50% retention of particles is expected to be about 7 +/- 4 days.

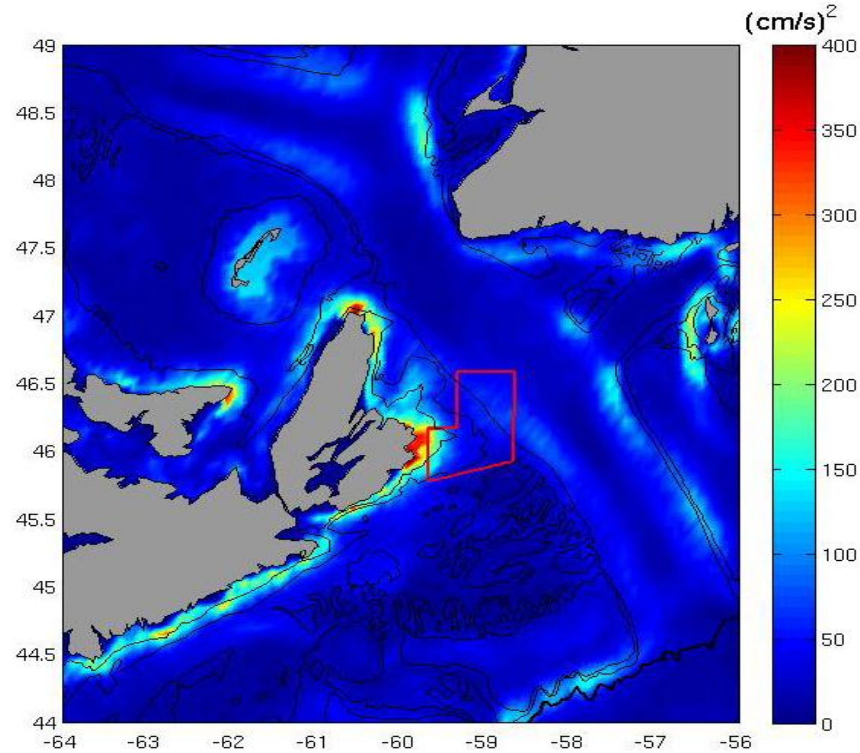


Figure 2.1-3. Annual average root mean square (RMS) disturbance kinetic energy. The AOI boundaries are shown in red.

Currents are generally driven by differences in salinity and temperature that cause one body of water to be heavier or lighter than another. In the Cabot Strait Region there are large changes in both temperature and salinity with depth (Head and Pepin 2007). Especially in summer, this area is influenced by the warmer fresher waters that flow from the Gulf of St. Lawrence (Davis and Browne 1996). Just west of St Anns Bank, in Sydney Bight, the late August surface salinity of 28–29 Practical Salinity Units (PSUs) marks the annual low and corresponds with the pulse of the spring freshet that occurred in the St. Lawrence River watershed several months earlier finally reaching the Bank area. In contrast, bottom salinity is approximately 33.5 PSUs at the same time. Winter salinities in the area will approach 31.5 PSUs at the surface and 34 PSUs in the deeper waters. Through fall, the increase in surface water salinity is due to more intense vertical mixing (Petrie et al. 1996). The salinity of the shallow nearshore bottom waters of the St Anns Bank AOI are typically about 31 PSUs. These bottom waters show a similar level of salinity year-round. Regional trends show that between the 1990s and early 2000s, freshwater discharge across the St Anns Bank area and onto the Scotian Shelf decreased relative to earlier years (DFO 2003a).

In the St Anns Bank AOI, July bottom temperatures tend to increase towards the shallower, nearshore regions as well as towards the deeper Laurentian Channel. The coldest bottom temperatures tend to be on St Anns Bank, in between these two features (Drinkwater et al. 1997). Near-bottom temperatures get warmer in the southwest corner of the AOI close to Scatarie Island, reaching up to 8^{o}C in September. Bottom water on

St Anns Bank, toward the edge of the Laurentian Channel, is around 2–3^{o}C (Drinkwater and Pettipas 1996). This water reflects the Cold Intermediate Layer (CIL) that comes from within the Gulf of St. Lawrence, and which is defined as waters with temperatures < 4^{o}C (Petrie et al. 2009). With greater depth into the Laurentian Channel bottom water temperatures again increase to around 5–6^{o}C (see Figure 2.1-4), even in January (Drinkwater et al. 1997).

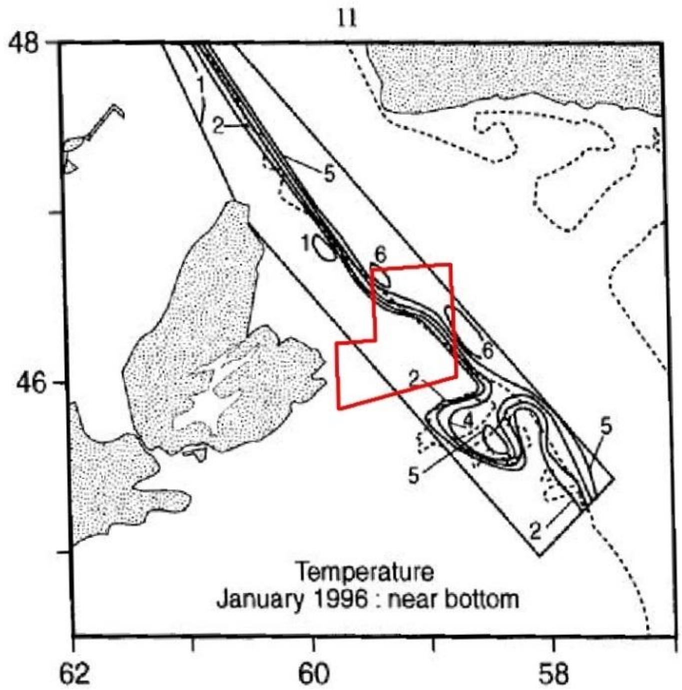


Figure 2.1-4. January 1996 near-bottom temperatures in the vicinity of St Anns Bank AOI were typical of long-term means (1961–1990), and show the increasing temperature with depth into the Laurentian Channel (Source: Drinkwater et al. 1997).

One index of the status of the marine environment that is regularly measured is the proportion of bottom water greater than 2^{o}C. In the Northwest Atlantic Fishing Organization (NAFO) 4Vn fishing zone around St Anns Bank AOI, this index dropped in the early 1970s and again beginning in 1988 (DFO 2002a). This is reflected in Figure 2.1-5, which shows the annual bottom temperature anomalies for the same area.

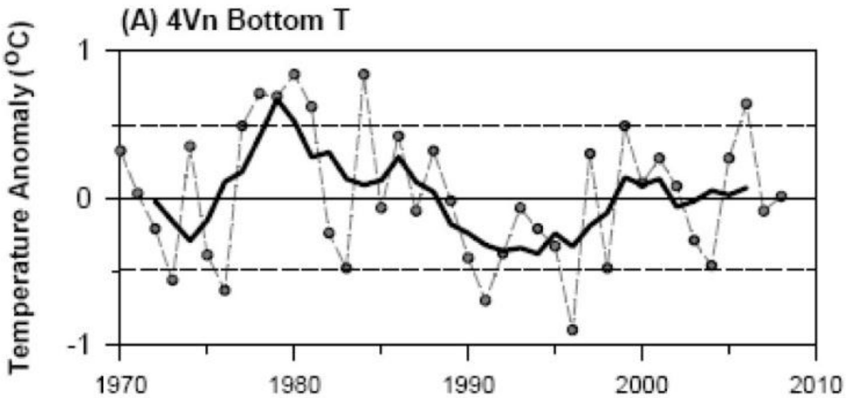


Figure 2.1-5. The yearly mean July bottom temperature in NAFO area 4Vn, which includes St Anns Bank AOI. The thick line is a five-year running mean (Source: Petrie et al. 2009).

Although there is some significant variation in bottom water temperature across the St Anns Bank AOI, surface water temperatures have a far greater range. Just west of St Anns Bank AOI, in the Sydney Bight area, the mean summer sea-surface temperature is around 17–18^{o}C (Petrie et al. 1996), and is likely similar to some of the shallow water areas in the southwest portion of the AOI. In contrast, during the winter, surface water temperatures are close to the freezing point, and have been measured to –1.7^{o}C (Chassé 2001).

The warm fresh surface water overlying the cold saltier CIL layer promotes stratification in the water column of St Anns Bank AOI. The western portion of St Anns Bank has some of the most stratified summer waters around Nova Scotia; although all areas of the Eastern Scotian Shelf are highly stratified during the summer (Breeze et al. 2002).

In winter and spring, sea ice, which moves out of the Gulf of St. Lawrence through Cabot Strait, will regularly be present in the St Anns Bank area (Davis and Browne 1996). Typically, based on a 30-year (1971–2000) period, ice first appears seaward of the Cabot Strait during late January (Petrie et al. 2005), shortly after which time it will start to cover the St Anns Bank AOI. By the beginning of February, most of the water in the Sydney Bight area is ice covered 16–33% of the time. By the beginning of March it may reach a thickness of more than 30 cm and usually remains present until the second week of April (Chassé 2001).

As shown in Figure 2.1-6, maximal annual extent of ice coverage occurs in mid-March, and ice will cover the St Anns Bank area approximately every four to six out of ten years, while the most northern area of the AOI (into the Laurentian Channel) will be covered up to eight out of ten years (Canadian Ice Service 2010).

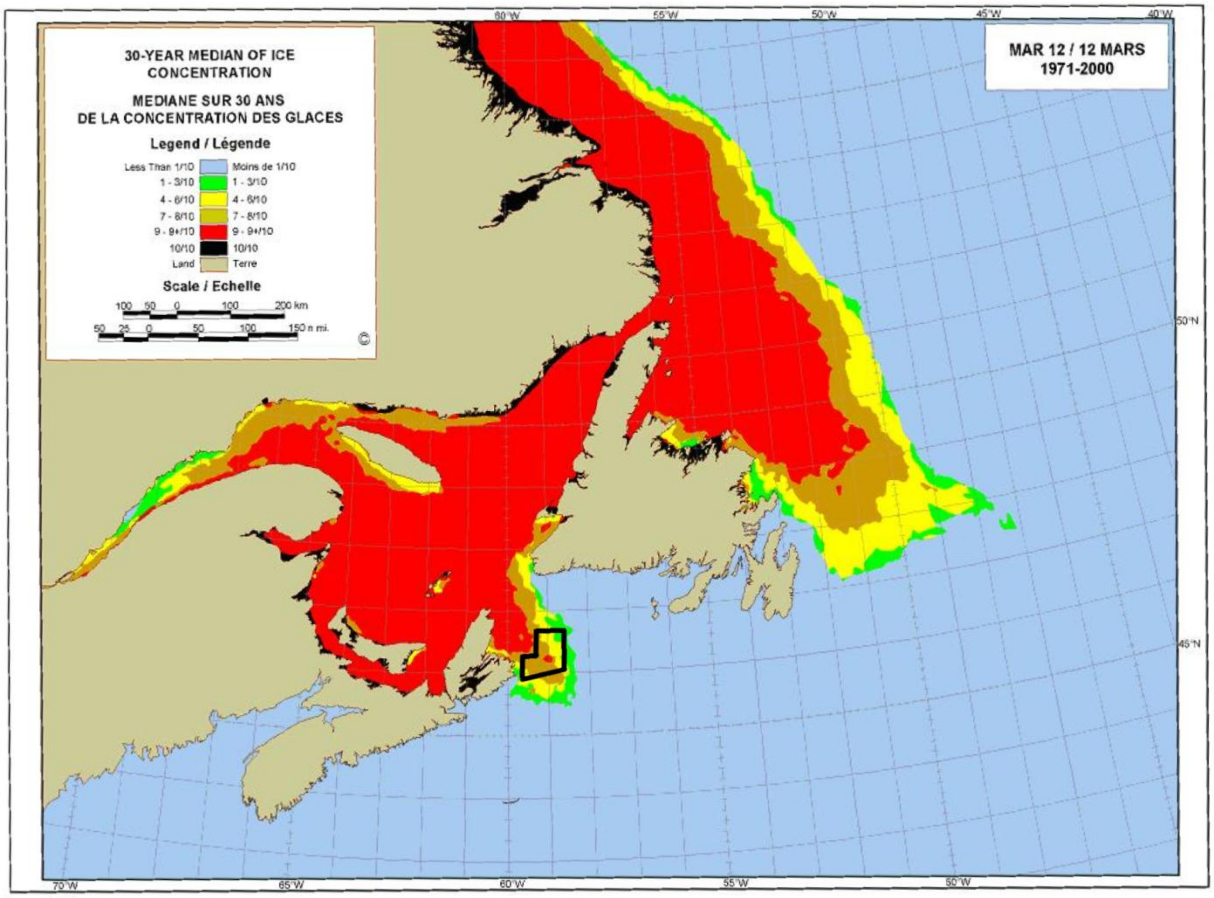


Figure 2.1-6. The week ending March 12th is the long-term (1971–2000) time of maximal extent of ice coverage. As can be seen in the 30-year median of concentration image, ice regularly covers St Anns Bank AOI (outlined in black) (Source: Canadian Ice Service 2010).

2.2 CHEMICAL OCEANOGRAPHY

2.2.1 Nutrients

The two most important sources of nutrients to productive surface waters of the Eastern Scotian Shelf are surface outflow from the Gulf of St. Lawrence and entrainment of deeper nutrient-enriched waters into the photic zone. During the winter, the Gulf of St. Lawrence is the primary source of nitrate (9300 mol· s–1) and silicate (7680 mol·s–1) found on the Scotian Shelf. In spring and summer, vertical diffusive fluxes of nitrate from deep water areas are as large as the horizontal advective ones coming from the Gulf. Concentrations of organic carbon and nitrogen are higher in the deep waters of the Shelf basins and the Laurentian Channel than on the Shelf banks and slope (Pocklington et al. 1991). Nitrogen tends to be the limiting nutrient here as in most marine ecosystems, but silicate is also critically important for diatoms and other organisms that produce silica frustules. The balance between nitrate and silicate can be an important determinant of observed species composition. The surface outflow from the Gulf is more enriched in silicate versus nitrate than the deeper waters. The nutrient climatology described by Petrie and Yeats (2000) clearly shows the importance of the St. Lawrence outflow on nutrient concentrations in the St Anns Bank area. Based on the surface nitrate distributions in winter, the concentrations over the St Anns Bank area and on the inner half of the Eastern Scotian Shelf at the onset of the spring bloom are higher than elsewhere on the Scotian Shelf (Petrie and Yeats 2000). The subsurface waters between approximately 50 and 100 m that provide more of the photic zone nutrients during the rest of the year show no differences in concentrations between St Anns Bank and the rest of the Eastern Scotian Shelf. Over the past forty years, nutrient concentrations in the surface waters in winter and in deeper (50–100 m) waters throughout the year have been decreasing on the Scotian Shelf (Yeats et al. 2010). The limited data available suggests that the multi-year trends for the St Anns Bank area are similar to those seen elsewhere on the Scotian Shelf. The temporal decrease for nitrate has been greater than that for silicate. Increased stratification would reduce vertical mixing (more important source for nitrate) and increase the importance of surface outflow (more important source for silicate).

2.2.2 Oxygen

Subsurface oxygen concentrations on the Scotian Shelf have also been decreasing with time. Gilbert et al. (2005) have documented decreasing oxygen saturation in the deeper waters of the Gulf of St. Lawrence over the past 70 years; similar but shorter duration decreases have also been observed on the Scotian Shelf (data from BioChem database). Decreasing oxygen concentrations in subsurface waters can reflect increased eutrophication and more oxygen consumption during decomposition of organic matter and/or changes in physical oceanography that either introduce offshore waters with lower oxygen concentrations or decrease ventilation of the subsurface waters. Gilbert et al. (2005) calculate that half to two-thirds of the decrease in the Gulf can be attributed to changes in water mass structure leaving one third to one half to be explained by reduced mixing and increased biological oxygen demand. Oxygen saturation levels of <~50% can be harmful to bottom dwelling fish. Based on observations taken from the DFO BioChem database, deep water oxygen saturation levels on St Anns Bank may have decreased from ~90% in the 1970s to ~80% in 2009. Deeper water saturations in the Laurentian Channel adjacent to St Anns Bank average 67% saturation. None of these should prove harmful to bottom dwelling fish.

2.2.3 pH

Changes in ocean acidity as a result of global increases in atmospheric carbon dioxide levels will be harmful to marine biological systems, such as deep-water corals that have carbonate exoskeletons. Temporal trends in pH (negative logarithm of hydrogen ion concentration) on the Scotian Shelf (Yeats et al. 2009) and the Gulf of St. Lawrence (data from BioChem database) reflect the global trend and suggest that ecological considerations on St Anns Bank should be similar to those found elsewhere. However, deeper, colder waters invariably have lower pHs than shallower warmer ones making the deep-water corals here and elsewhere potentially at risk to downward trends in pH.

2.2.4 Contaminants

There are many potential sources of contaminants on the Scotian Shelf, including dry and wet atmospheric precipitation, transport of riverborne contaminants, transport of contaminants from deep oceanic waters via shelf edge water exchange, and localized sources such as shipping, and dumped munitions or other wastes (Yeats et al. 2009). For the AOI, outflow from the St. Lawrence River is the greatest source of heavy metal contamination (Keizer and Boudreau 2002), as is the case on the Eastern Scotian Shelf generally (Yeats et al. 2009).

Sydney Harbour is also a likely source of contaminants, although contamination is believed to drop to a fairly low level even in the outer regions of Sydney Harbour (DFO 2009a), so contamination of the AOI from sources in Sydney Harbour is probably minimal. Shipping activity is quite heavy through the site, so shipping-related contaminants (such as marine debris or hydrocarbon pollution) would be expected to be higher in this area than many areas of the Scotian Shelf. Additionally, a potential source of contamination within the site is unexploded ordinance, which can, over time, break down to release heavy metals and toxic chemicals. There are two sites known to contain unexploded ordinance on the boundary of the AOI—one on the edge of the Glace Bay Hole, and one along the eastern edge of the AOI (DND UXO and Legacy Sites Program unpublished data).

In *The Scotian Shelf: An Atlas of Human Activities*, Breeze and Horsman (2005) provide maps of concentrations of various marine contaminants on the Scotian Shelf. Only concentrations of chromium in sediments and dissolved copper are mapped in the top half of the AOI (4Vn); for the other contaminants considered, only the southern portion of the AOI is shown. Cadmium levels are shown to be quite high (at the highest level for the region) in the St Anns Bank area, especially on the banks and Shelf (Figure 2.2-1), due to outflow from the Gulf of St. Lawrence. However, all cadmium levels measured were well below the Canadian marine environmental quality guidelines.

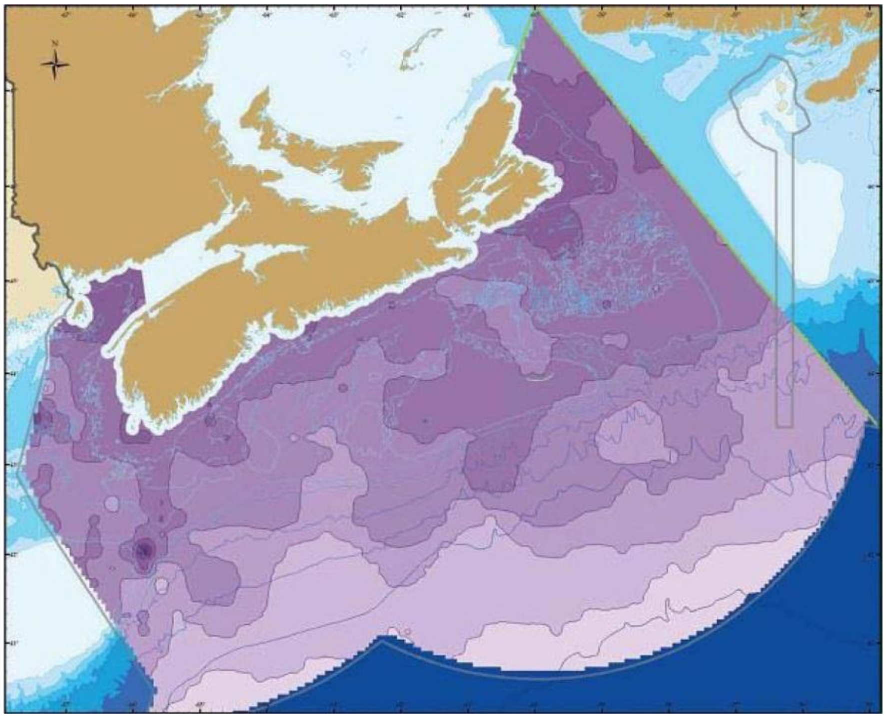


Figure 2.2-1. Dissolved cadmium concentrations on the Scotian Shelf. Range of concentrations mapped is from 0 to 0.45 nmol/L (Breeze and Horsman 2005).

Concentrations of dissolved copper are generally higher in Sydney Bight than the rest of the Scotian Shelf, and are relatively high in the bank and shelf parts of the AOI (Figure 2.2-2). These copper concentrations are related to discharges from the Gulf of St. Lawrence, and, to a lesser extent, local inputs of copper from the Sydney Harbour area. It is noted that concentrations on the Eastern Scotian Shelf may be high enough to limit the growth of certain copper-sensitive species (Breeze and Horsman 2005).

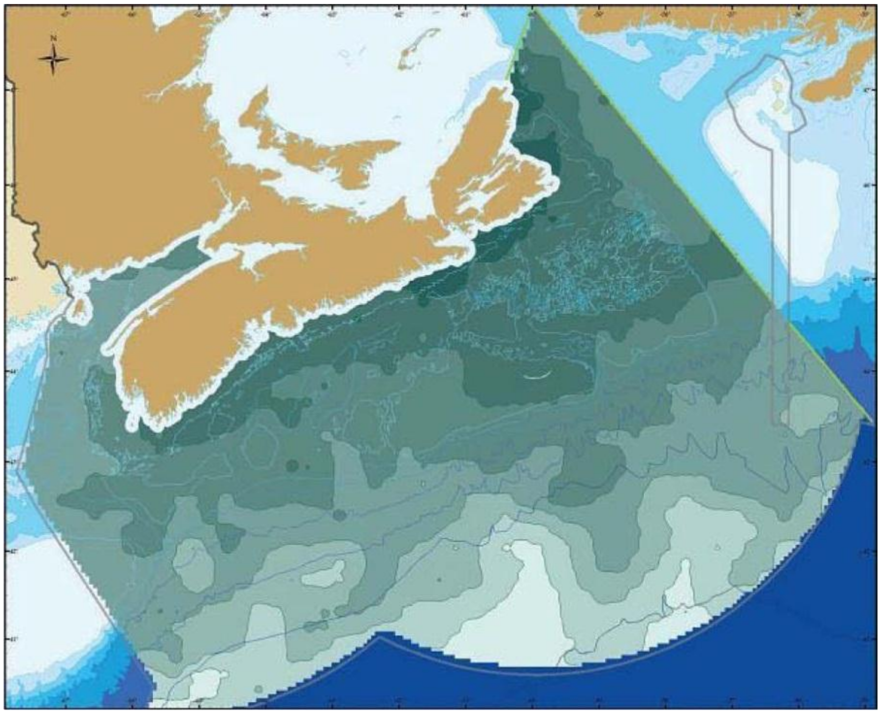


Figure 2.2-2. Dissolved copper concentrations on the Scotian Shelf. Range of concentrations mapped is from 1.2 to 5.0 nmol/L (Breeze and Horsman 2005).

For metals in sediments, copper, chromium, lead, and zinc are all generally found in higher concentrations in finer sediments, with silty, depositional areas (such as the Laurentian Channel or Shelf basins) tending to have higher levels. Copper in sediments was not particularly high in the southern portion of the AOI. Chromium, lead, and zinc were all generally found in higher concentrations on the Eastern Scotian Shelf than the west, and were medium–high or high in the southern portion of the AOI and areas southwest of the AOI, relative to the Scotian Shelf as a whole. However, very few samples, and none in the area of the AOI, were above sediment quality guidelines or probable effect levels.

3. BIOLOGICAL OCEANOGRAPHY

3.1 RESEARCH SURVEYS ON THE EASTERN SCOTIAN SHELF

3.1.1 Snow Crab Research Survey

The snow crab research survey samples approximately 400 stations on the Eastern Scotian Shelf annually, with the primary objective of estimating the extent and biomass of snow crab for the commercial fishery. The survey uses a Bigouden Nephrops trawl fitted with 40 mm mesh in the cod-end, and all species caught are identified to the lowest taxonomic level possible, with species-level identification for almost all fish and most common invertebrates. The maximum depth sampled in the site was 290 m, and the minimum depth sampled was 57 m.

The primary objective of this survey is to assess the abundance and distribution of snow crab, but the design is both extensive (going well beyond commercial fishing grounds for snow crab) and intensive (with at least one survey station in each 10 x 10 minute area) (Choi and Zisserson 2011). The survey covers areas where snow crab are not fished or even traditionally found in order to be able to monitor shifts in distribution and to sample segments of the population that have different distributions than commercially fished males, such as females and very young or old snow crab. This survey does not sample the deepest or shallowest parts of the site, or the rockiest habitats, but it does sample much of the shelf and slope habitat reasonably well. Additionally, sampling methods poorly represent organisms less than 40 mm long and large, rapidly swimming organisms. An annual report about the survey is prepared (Choi and Zisserson 2011). Survey set locations are shown in Figure 3.1-1.

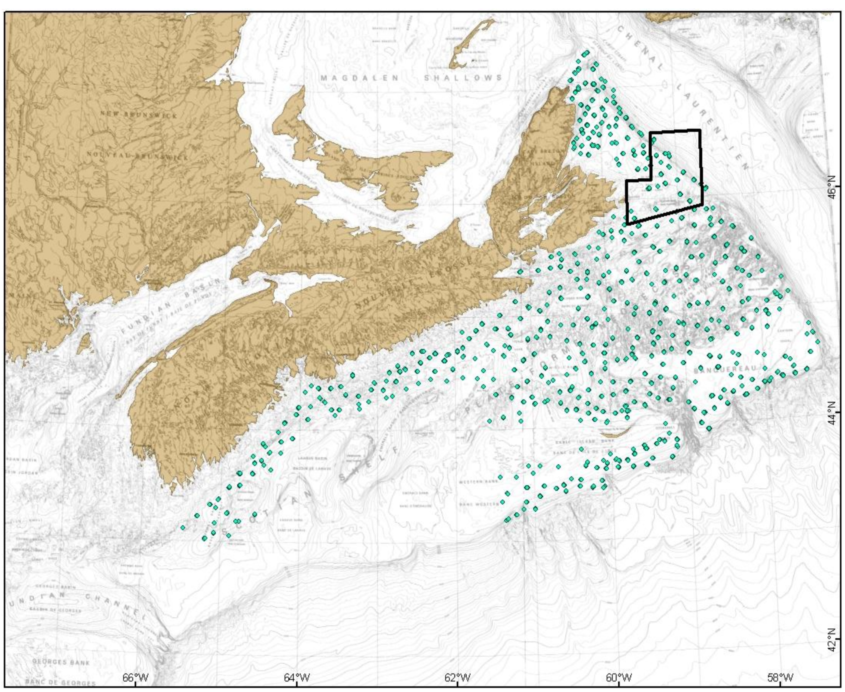


Figure 3.1-1. Set locations across the region for the Snow crab survey (2004-2010).

3.1.2 Research Vessel Survey

DFO’s Research Vessel (RV) surveys (also known as ecosystem surveys or trawl surveys) have been conducted across the Scotian Shelf and Bay of Fundy each summer (July through August) since 1970. The survey data are the primary data source for monitoring trends in species distribution, abundance, and biological condition of groundfish within the region, and findings are summarized in an annual report (Clark et al. 2010). The surveys use a Western IIA bottom trawl and a stratified random design. The strata used in the surveys are defined by depth and at least two random locations are surveyed in each stratum each year. The St Anns Bank AOI covers four survey strata from the RV survey: 440, 441, 442, and 445. At each location, temperature and salinity are recorded, as well as abundance (count) and weight for each species found. Each tow is approximately 1.75 nautical miles. For more information about the survey methods, see Chadwick et al. (2007).

All fish caught are identified and recorded. Invertebrates have been recorded consistently in the survey since 1999, but only select invertebrates (lobster, shrimp, crab, scallop, echinoderms) are recorded because they are caught regularly in the survey, are quantifiable, and may have commercial value (Tremblay et al. 2007). The survey is designed to estimate abundance trends of groundfish from about 50 m to 400 m. The maximum depth sampled in the AOI was 375 m, and the minimum was 42 m, so this survey does cover a wider range of depths than the snow crab survey. Survey set locations are shown in Figure 3.1-2.

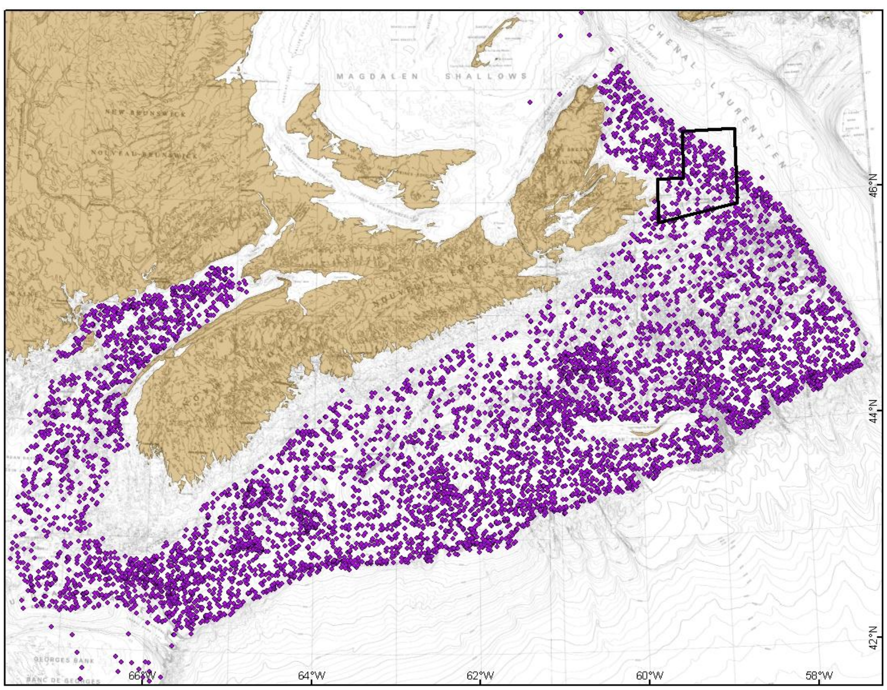


Figure 3.1-2. Set locations across the region for the summer RV survey (1970-2010).

Note that in 2004, the CCGS *Teleost* was used to conduct the RV survey since the CCGS *Alfred Needler* was unavailable; thus 2004 may not be representative.

3.1.3 Halibut Industry Survey

A joint DFO/industry longline halibut survey has been conducted on the Scotian Shelf and southern Grand Banks (3NOPs4VWX5Zc) each year since 1998. The survey provides an important source of information for a broader size range of halibut (50–230 cm) than are caught by the RV survey. In addition, it provides information on the distribution, abundance, and size structure of other species that are not well surveyed by trawl gear.

The halibut survey has a fixed station design. Commercial halibut landings from 1995–1997 were used to stratify the stock into low, medium, and high catch areas; 220 stratified random stations were allocated to these areas at a ratio of 5:7:10. In addition, 73 stations were added from 2005–2008 to increase coverage in the Bay of Fundy and north of Cape Breton. There is also a commercial index portion where participants fish at locations of their choosing using a similar protocol as the fixed stations.

The survey is conducted each year from mid-May to mid-July from vessels less than 65' (20 m). Each station is fished with one set of 1000 #14 or larger circle hooks. Each set is fished within three miles in any direction of the predetermined set location (1.5 miles before 2000), with a soak time between 6 and 12 hours. All species caught in the survey are weighed, counted, and measured. However, there is still some variation in survey protocol. For more information, see Zwanenburg and Wilson (2000). Survey points in St Anns Bank are shown in Figure 3.5.5-3, Section 3.5.5. Complete survey fixed set locations are shown in Figure 3.1-3.

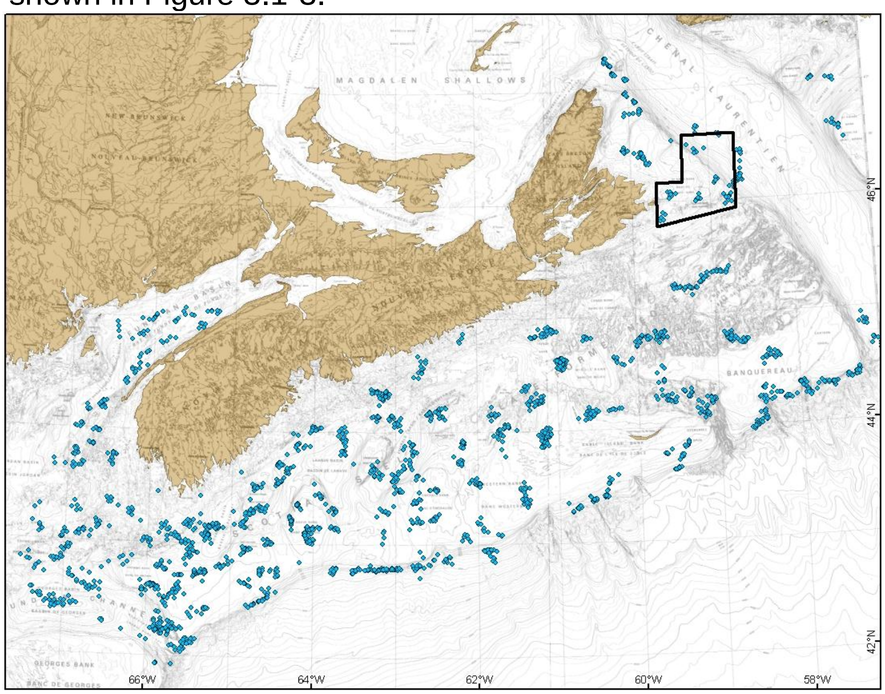


Figure 3.1-3. Set locations across the region for the Halibut industry survey (1998-2011).

3.1.4 4Vn Sentinel Survey

The 4Vn sentinel survey is a longline survey conducted by industry since 1994. The major goal of the survey is to provide an index of abundance of 4Vn cod (Figure 3.5.4-5, Section 3.5.4). As DFO's RV survey covers the entire Scotian Shelf, there are relatively few sets in 4Vn (the smallest NAFO subdivision); the sentinel survey provides a higher resolution survey of 4Vn.

The survey uses a stratified random sampling design in which the survey area is divided into three strata based on depth (< 55 m, 55–91 m, 92–183 m), and set locations are selected randomly and assigned proportionally among the strata. There was also a commercial index portion of the 4Vn sentinel survey where participants fished at locations of their choosing, but it was discontinued in 2006.

The survey has two temporal components: it is conducted for two 3-week periods (during June and September) to survey abundance of resident 4Vn cod, and two 6-week periods (during October/November and April/May) to monitor the migration of Gulf cod to and from Sydney Bight. Each set is fished by five tubs of gear, each tub containing 450–500 #12 circle hooks, with a soak time of 3 to 6 hours. However, there is some variation in gear/survey protocol amongst survey participants. A count and total weight estimate is recorded for all species, including discards. For more information, see Lambert (1995). Survey set locations are shown in Figure 3.1-4.

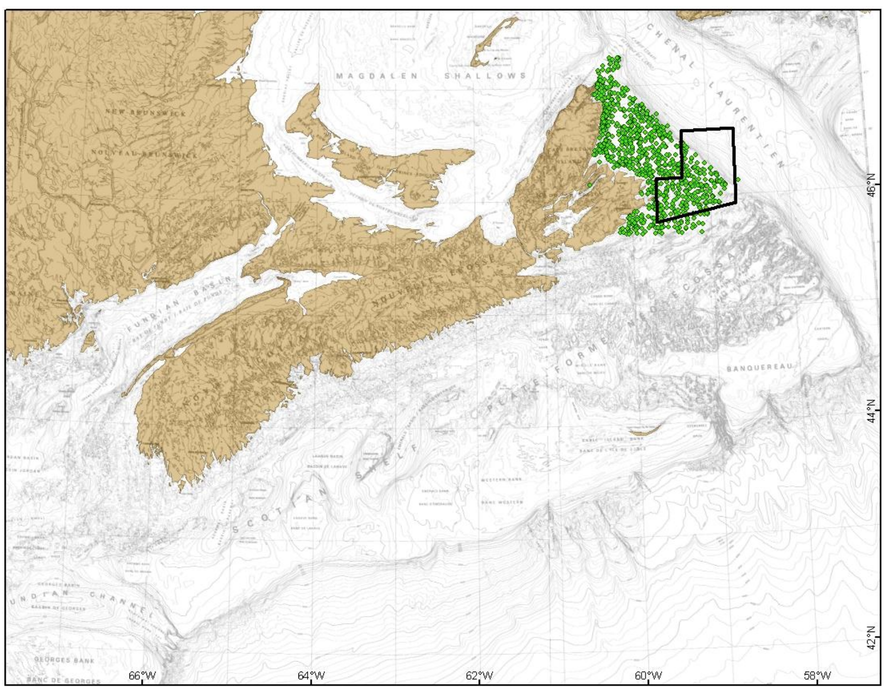


Figure 3.1-4. Set locations across the region for the 4Vn sentinel survey (1995-2010).

3.2 PLANKTON

Data from two sources were used to examine the abundance of selected plankton groups in the St Anns Bank region. The first dataset derives from sampling by means of the Continuous Plankton Recorder (CPR; Figure 3.2-1), which has been carried out since 1961[2].

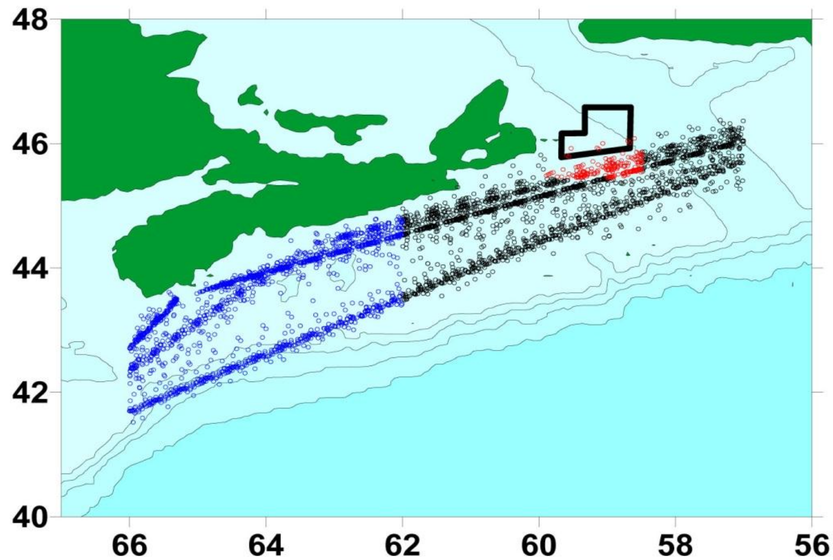


Figure 3.2-1. Positions where CPR samples were collected between 1991 and 2009 on the Western Scotian Shelf (blue circles), the Eastern Scotian Shelf (black circles), and in the area used to represent the St Anns Bank AOI (red circles). The St Anns Bank AOI is outlined in black.

Data for the ESS and Western Scotian Shelf (WSS) regions are analyzed each year and the results are reported annually in AZMP (Atlantic Zone Monitoring Program) Research Documents. CPR data for an area downstream of the AOI were analyzed and these results were compared with data for the entire ESS and WSS. Abundance values for selected plankton groups were $Log_{10}(N+1)$ transformed[3] and averaged spatially for individual month/year combinations from the three regions. These spatial averages were then averaged by month for all years sampled between 1991 and 2009 to give monthly average values (Figures 3.2-2 and 3.2-3). The average abundance of diatoms and dinoflagellates and the phytoplankton colour index in St Anns Bank are very similar to the Eastern and Western Scotian shelf (Figure 3.2-2) and St Anns Bank has a slightly higher abundance of late stages of *Calanus glacialis* and *C. hyperboreus* in the spring than the Eastern and Western Scotian Shelf (Figure 3.2-3).

[2] http://www.sahfos.ac.uk/

[3] Phytoplankton colour index (PCI) data were not transformed.

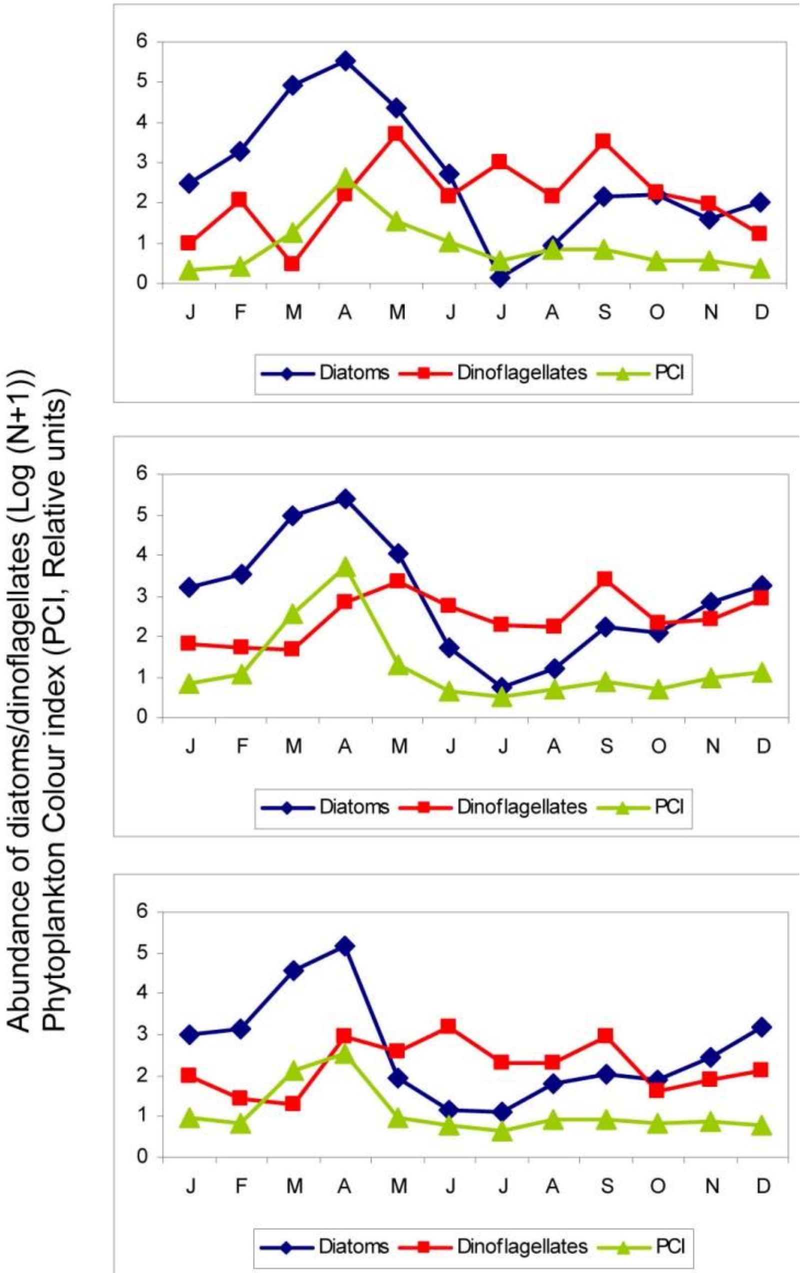


Figure 3.2-2. Average seasonal cycles (1991–2009) of abundance of diatoms and dinoflagellates and the phytoplankton colour index (PCI) for the St Anns Bank area, the Eastern Scotian Shelf (middle panel), and the Western Scotian Shelf (lower panel).

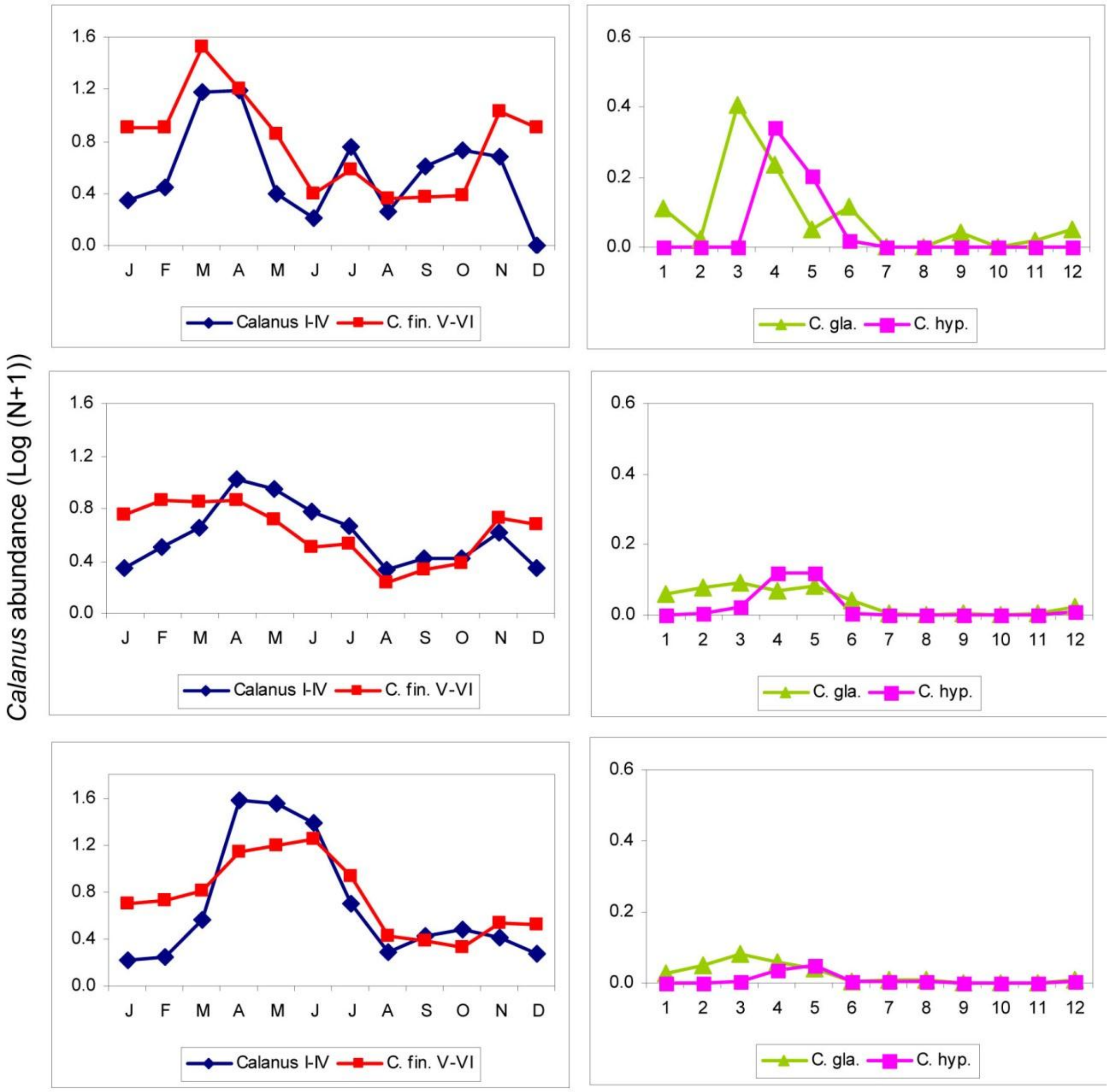


Figure 3.2-3. Average seasonal cycles (1991-2009) of *Calanus finmarchicus, C. glacialis* and *C. hyperboreus* for the St. Anns Bank area (upper row), ESS (middle row) and WSS (lower row). Early (stages I-IV) of all three species and late (stages V-VI) stages of *C. finmarchicus* are shown in the left-hand column; late stages of *C. glacialis* and *C. hyperboreus* are shown in the right-hand column.

The second dataset was compiled from AZMP cruises that have taken place in spring, summer and fall since 1999 (DFO 2011b). None of the AZMP standard lines have stations in the AOI around St Anns Bank, but there are stations upstream on the western end of a section across Cabot Strait (Cabot Strait Line, stations CSL1–3, Figure 3.2-4), and downstream on the inshore portion of a section that runs from Cape Breton to the shelf break (Louisburg Line, stations LL1–3). These lines have been sampled in spring (April) and fall (October) since the fall of 1999. Samples are also collected in the region during groundfish survey cruises, which are conducted in July. All AZMP zooplankton samples are collected by means of vertical tows from near bottom to the surface.

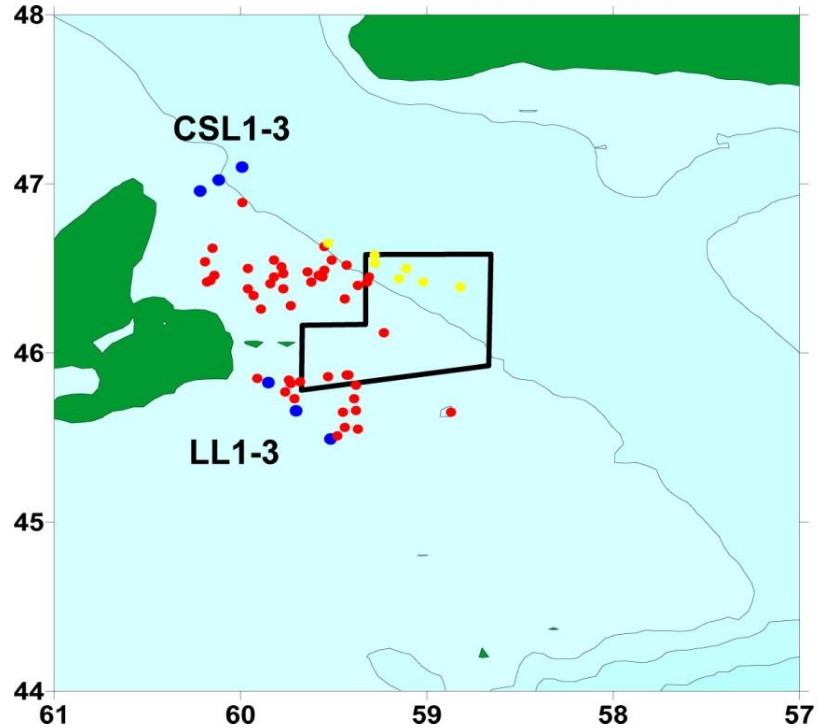


Figure 3.2-4. Positions of sampling stations on the Cabot Strait Line (CSL) and Louisburg Line (LL) of the AZMP standard sections that provided data in spring and fall between 1999 and 2010 (blue circles). Positions of stations sampled on groundfish survey cruises in summer between 1999 and 2010, grouped into shelf stations (red circles), and deep Laurentian Channel stations (yellow circles).

Five stations along a section across the AOI were sampled on the fall AZMP cruise for the first time in 2011. These stations will be incorporated into standard AZMP sampling, although sample analysis will be dependent on special funding. No data are available from the fall 2011 sampling at the time of writing this document.

3.2.1 Phytoplankton and Other Microbes

Although the phytoplankton community structure in the St Anns Bank AOI is not known in detail (Zwanenburg et al. 2006), we do know a great deal about some aspects of the microbial community, including phytoplankton, in the Scotian Shelf–Gulf of Maine ecoregion as a whole (Li et al. 2011). Diatoms and dinoflagellates dominate phytoplankton biomass. Spring blooms on the Shelf are comprised principally of diatoms that decrease in importance in summer and fall when nanoflagellates and picophytoplankton (e.g., *Synechococcus*) become more prevalent (Figure 3.2-2). Because of the complex mixture of water masses on the Scotian Shelf, arctic, temperate and subtropical forms occur on the Shelf at various times (Head and Harris 2004).

Phytoplankton in this area comprise eukaryotic microalgae that include Bacillariophyceae, Dinophyceae, Prymnesiophyceae, Prasinophyceae, Trebouxiophyceae, Cryptophyceae, Dictyochophyceae, Chrysophyceae, Eustigmatophyceae, Pelagophyceae, Synurophyceae, and Xanthophyceae, as well as numerous genera of prokaryotic cyanobacteria. Bacteria include the dominant SAR11 phylotype cluster, and other abundant phylotypes such as SAR86-like cluster, SAR116-like cluster, *Roseobacter*, Rhodospirillaceae, Acidomicrobidae, Flavobacteriales, *Cytophaga*, and unclassified Alphaproteobacteria and Gammaproteobacteria clusters. Heterotrophic, eukaryotic protists include Dinophyceae, Alveolata, Apicomplexa, amoeboid organisms, Labrynthulida, and heterotrophic marine stramenopiles. Ciliates include *Strombidium*, *Lohmaniella*, *Tontonia*, *Strobilidium*, *Strombidinopsis*, and the mixotrophs *Laboea strobila* and *Myrionecta rubrum* (ex *Mesodinium rubra*). Viruses are largely cyanophages and bacteriophages, including podoviruses; additionally, there is some evidence of Mimivirus and Chlorovirus.

Results of new analyses on data from the Continuous Plankton Recorder, covering the Scotian Shelf back to the 1960s, show that phytoplankton levels were higher in the 1990s and 2000s than in previous decades (Head and Pepin 2009). The complex nature of the physical oceanographic features of the Scotian Shelf influences the patterns of abundance of phytoplankton. There is a great amount of variability in both where and when phytoplankton biomass changes may occur on the Scotian Shelf. Since 1992, spring blooms start earlier in the year, are more intense, and last longer (Zwanenburg et al. 2006; Head and Pepin 2009). The trend of early spring blooms continued into 2010 (Johnson et al. 2012). Although several studies have indicated that phytoplankton biomass levels have increased, the ratio of primary production to total ecosystem biomass has seemingly decreased (Bundy et al. 2009). This change is due primarily to increases in the biomass of seals, small pelagic fish, and invertebrates.

Much of the increase in phytoplankton has been documented through the indicators of diatom abundance and the phytoplankton colour index. These indicators show increases in the winter months (January–March), although peak periods have remained in April for decades. Although phytoplankton levels on the Scotian Shelf remain higher than in the 1960s and 1970s, all three phytoplankton indicators (diatom and dinoflagellate abundance and the phytoplankton colour index) have recently decreased relative to their highest values, which were in the late 1990s.

Chlorophyll-a is used as an index of phytoplankton biomass, where higher concentrations of chlorophyll indicate higher biomass of phytoplankton. The mean maximum phytoplankton bloom approaches 8–10 $mg \cdot m^{-3}$ of chlorophyll-a in the St Anns AOI as shown in Figure 3.2-5. The Sydney Bight area, immediately east of St Anns candidate area, has been noted as an important area of high phytoplankton productivity year-round (Breeze et al. 2002; Figure 3.2-6), and the prevailing circulation is from the Bight towards the AOI.

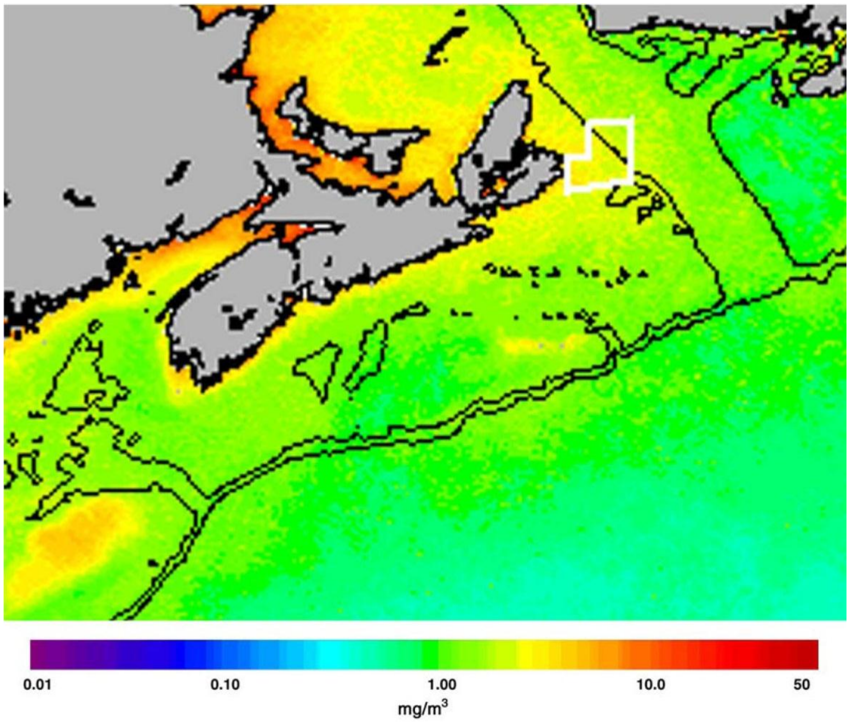


Figure 3.2-5. Average chlorophyll concentration during spring blooms from 1997–2007 on the Scotian Shelf and environs. Chlorophyll is higher in the St Anns Bank area (outlined in white) than on most of the Scotian Shelf.

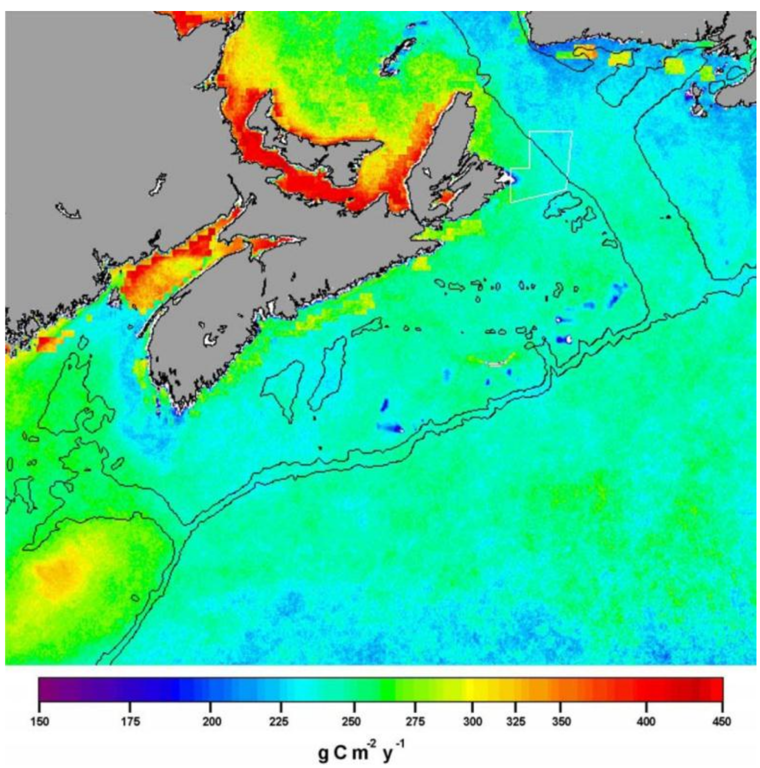


Figure 3.2-6. Average annual primary productivity on the Scotian Shelf over the period 1998–2004.

Direct measurements of chlorophyll-a upstream of the AOI at the western end of the AZMP Cabot Strait Line and downstream at the inshore end of the Louisburg Line indicate a multi-year decline since 1997 in both the spring and autumn. However, it is notable that the decrease in total phytoplankton biomass inferred from chlorophyll-a (Figure 3.2-7A) may not be uniform across all component taxa. There is an apparent increase in the abundance of the picoeukaryotic algae in spring (Figure 3.2-7B), and an apparent increase of the picocyanobacterium *Synechococcus* in autumn (Figure 3.2-7C). These presumptive changes in phytoplankton biomass and community structure may have consequences for energy flow to higher trophic levels.

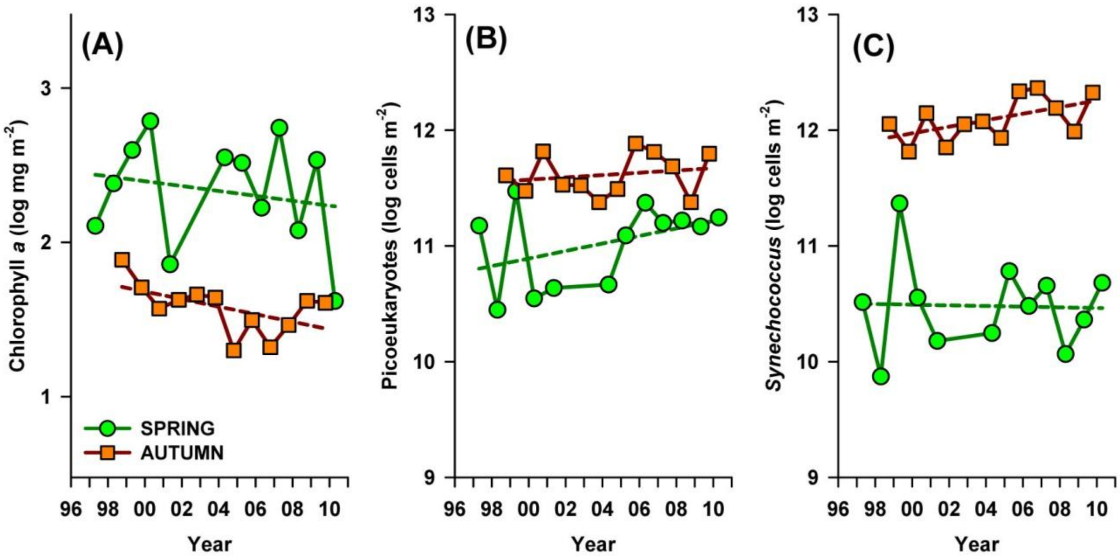


Figure 3.2-7. Phytoplankton trends at AZMP stations upstream (CSL-1,2,3) and downstream (LL-1,2,3) of St Anns Bank in the spring and in the autumn from 1997 to 2010. Values indicate station averages of the logarithmic transform of abundances integrated over the upper 100 m of the water column.

Song et al. (2011) modeled interannual variability in phytoplankton blooms and plankton productivity on the Scotian Shelf. They concluded that annual productivity on the Shelf was controlled by a combination of light and nutrient limitation, which offset one another and are of nearly equal importance. They also found that overall annual variations in primary productivity and mesozooplankton productivity were moderate. They argue that the shifts in fisheries productivity and recruitment that have been observed on the Scotian Shelf and Gulf of Maine are more likely related to changes in the timing of annual plankton blooms than changes in annual primary productivity.

3.2.2 Zooplankton

The St Anns Bank AOI encompasses shallow and deep water regions that are both influenced by the outflow from the Gulf of St. Lawrence (GSL), which has an important influence on the zooplankton species composition. More than 60% of the mesozooplankton biomass of the St Anns Bank region in spring is accounted for by large copepods of the genus *Calanus* (Head and Harris 2004). There are three species, one boreal species, *Calanus finmarchicus*, and two arctic species, *C. glacialis* and *C. hyperboreus*. All three share similar life history characteristics (Conover 1988). They all spend part of the year, when surface conditions are unfavourable, at depth in a dormant state, and they all come to the surface to feed on the spring bloom in March/April (Figure 3.2-3). The arctic species descend again in late May, as soon as surface temperatures start to warm up. They are adapted to a short growing season and take two or three years to reach adulthood. In the St Anns Bank region most *C. finmarchicus* have a one-year life cycle. They spend the winter as pre-adult copepodites (stage CV) and mature to adulthood, mate, and start to reproduce when they arrive in the surface layers in spring. The offspring develop from eggs through six naupliar stages and four copepodite stages to reach the pre-adult CV stage. These then descend to repeat the cycle. In the study region, the *C. finmarchicus* reproductive and growth seasons last into the fall. As individuals migrate to depth to enter dormancy they are swept from the shallow shelf regions into deeper waters (e.g., shelf basins, slope waters, and the Laurentian Channel) where they accumulate at high concentrations.

For all three *Calanus* species the main upstream springtime source populations for the study region are those that have spent the winter at depth in the Gulf of St. Lawrence (Sameoto and Herman 1992). Because the arctic species spend such a short time in the surface layers, they are abundant only in the areas of the Scotian Shelf most affected by the GSL outflow (i.e., St Anns Bank region, northeast Scotian Shelf, Nova Scotia Current) and mainly in spring. *C. finmarchicus*, by contrast, is more broadly distributed over the Scotian Shelf and may have other springtime sources as well as the GSL (Head et al. 2001). In central and western regions, late winter/spring temperatures are warmer, and the *C. finmarchicus* annual growth cycle starts and ends earlier, and is more intense but of shorter duration (Figure 3.2-3). The effects of the differences in sources and seasonal dynamics can be seen by comparing results of sampling in April at a station in the Nova Scotia Current off Halifax[4] (Stn HL2) with those from a station off Louisburg (Stn LL1). At LL1 there are ~9000 *C. finmarchicus* per m^2, while at HL2 there are ~42,000 per m^2, due to earlier reproduction at HL2. The corresponding numbers for the arctic species *C. glacialis* and *C. hyperboreus* are 10,000 per m^2 (LL1) versus 3500 per m^2 (HL2), and 21,000 per m^2 (LL1) versus 7,500 per m^2 (HL2), respectively. These latter differences are due to the relative distances of the stations from the source populations in the GSL.

Calanus finmarchicus is a key species in the ecosystems of the Scotian Shelf and Gulf of St. Lawrence because its eggs and early (naupliar) stages are important food items for larval fish (e.g., cod, haddock, sand lance) and its later copepodite stages are prey for juvenile groundfish and pelagic fishes (e.g., cod, haddock, mackerel, herring) as well as planktivorous birds (e.g., kittiwakes) and whales (e.g., right whales). In the St Anns Bank region, reproduction, growth and development persist until fall, with young stages reaching the pre-adult stage and retreating to depth throughout the summer and fall. Thus, eggs, nauplii, and young stages are available to a variety of predators throughout

[4] HL2 data analyzed over the 1999–2006 period and reported by Head and Pepin (2007, 2008).

spring and summer. This is in contrast to areas of the Scotian Shelf to the southwest, where relatively few young stages are found in the surface layers after July.

As the late *Calanus* stages descend to enter dormancy, they accumulate in deep waters such as the area of the Laurentian Channel included in the St Anns Bank AOI. Here, they provide important food sources for fish such as hake and redfish. Late stage *C. glacialis* do not accumulate in large numbers, but in fall late stage *C. finmarchicus* and *C. hyperboreus* abundances reach 40,000 per m^2 and 20,000 per m^2, with biomass levels of 6.6 g/m^2 dry weight (~30 g/m^2 wet weight) and 10.1 g/m^2 dry weight (~50 g/m^2 wet weight), respectively.

As well as the three *Calanus* species, there are several small copepod species that are common in the study region. Species of the genera *Pseudocalanus* and *Oithona* are evenly distributed throughout the study region with more-or-less equal abundances in spring and fall (roughly 20,000 per m^2 and 50,000 per m^2, respectively) and higher levels in summer (70,000 and 120,000 per m^2, respectively). *Temora*, which is generally more abundant in the GSL than on the Scotian Shelf in summer and fall, is lowest in abundance in spring (5000 per m^2) and highest in fall (45,000 per m^2). Together with the *Calanus* spp. these small copepods account for > 80% of the total copepod abundance at CSL1–3 and LL1–3 in spring, > 90% in shelf and deep waters in summer, and > 80% at CSL1–3 and > 60% at LL1–3 in fall.

Euphausiids, also known as krill, are large zooplankton (up to 4 cm in length) that form a major link in the food web between plankton and large predators such as fish and other high trophic levels (Sameoto and Cochrane 1996). There are three important species of krill on the Scotian Shelf, with the largest and most important being *Meganyctiphanes norvegica*, followed by *Thysanoessa inermis* and *T. longicaudata*. *M. norvegica* primarily eat copepods and phytoplankton, while *Thysanoessa* spp. primarily eat phytoplankton. All are preyed upon by many species of fish (notably silver hake and redfish), seabirds, and whales (Sameoto and Cochrane 1996).

Sameoto and Cochrane (1996) reviewed available information about the distribution of krill on the Scotian Shelf. *M. norvegica* were primarily found where bottom depths are between 200 and 1000 m. They spend the day at depths between 100 and 300 m and migrate to the surface layers at night. Highest concentrations of krill are found in the Shelf basins, but the slope of the Laurentian Channel is also known to host high concentrations (Sameoto and Cochrane 1996). More detailed modelling of krill abundance in the Gulf of St. Lawrence indicated that a band of high abundance of vertically migrating krill was seen along the Laurentian Channel slope just north of the AOI (Sourisseau et al. 2006). The model did not extend into the slope area of the AOI. The authors also noted that the distribution of large whales in the Gulf of St. Lawrence appears to be highly correlated with locations where krill abundance is high.

Overall, compared with the Scotian Shelf as a whole, the St Anns Bank AOI has an extended period of reproduction and growth for the ecologically important species *Calanus finmarchicus*. It is also an area where copepods characteristic of the Gulf of St.

Lawrence are especially abundant (e.g., large arctic *Calanus* species in spring and small *Temora* spp. in fall). In addition, it includes a deep water portion of the Laurentian Channel, where large numbers of late stage *Calanus* accumulate at depth during summer and fall. Relatively high abundances of the euphasiid *M. norvegica* may also been found along the Laurentian Channel slope (> 200 m). Thus, it is an area that provides a variety of feeding regimes for higher trophic levels throughout the year.

3.3 BENTHIC HABITATS AND COMMUNITIES

3.3.1 Classification of Benthic Habitats and Communities of the Scotian Shelf

Several authors have described and classified benthic communities of the Eastern Scotian Shelf, including the St Anns Bank area. Unfortunately, this has been based on fairly little benthic sampling in St Anns Bank and the Cabot Strait (Breeze et al. 2002). Breeze et al. (2002) summarized previous classifications of benthic communities on the Scotian Shelf, starting with Nesis (1962), who described dominant communities of some parts of the Eastern Scotian Shelf and the Grand Banks based on Soviet research performed in 1954 and 1958–1960.

Steele et al. (1979) include the Cabot Strait in their classification of benthic communities created for Parks Canada. In that classification, the St Anns Bank AOI spans four classes: communities dominated by modiolus-rodophytes (horse mussels and red algae), modiolus-ophiopholis (horse mussels and brittle stars), macoma (*Baltic macoma* clam), and corals, moving from inshore to offshore. Shallow inshore modiolus-rodophytes communities include a range of species in addition to horse mussels (*Modiolus modiolus*) and red algae (Rodophytes). Modiolus-ophiopholis communities are found on coarse (rocky) sediments at moderate depths, and are less diverse, dominated by horse mussels, daisy brittle stars, sea scallops, lobster, and Arctic lyre crabs. *Macoma* communities are found slightly deeper on soft sediments, and are dominated by *Baltic macoma*, soft-shelled clams, green crabs, and polychaete worms. Deep-water, coarse substrate communities that were described as coral communities also featured basket stars in addition to corals.

The Natural History of Nova Scotia (Davis and Browne 1996) and WWF-Canada (2009) produced very similar classifications of this portion of the Eastern Scotian Shelf, essentially dividing the Cabot Strait into the Inner Shelf (above 100 m), the Middle Shelf (100–200 m), and the Bank Edges, Saddles and Channels or Laurentian Channel (below 200 m), though *The Natural History of Nova Scotia* divides Sydney Bight from the rest of the Inner Shelf. According to *The Natural History of Nova Scotia*, communities of the Inner Shelf/Atlantic region typically include horse mussels, sea cucumbers, sea stars, amphipods, barnacles, crabs, lobsters, sea scallops, ocean quahogs, and sea urchins (Davis and Browne 1996). The fauna of the Middle Scotian Shelf region contains both fauna characteristic of banks (ocean quahog, Arctic surf clam, sea scallop, horse mussel, brittle star, lobster, toad crab, sand dollar, amphipod) and basins (brittle star, heart urchin, mud star, northern shrimp, sea pen, snow crab, Jonah crab, tusk shell, and polychaete worms) (Davis and Browne 1996). Below 200 m, in the Laurentian Channel, the sediment is mostly soft and muddy with abundant marine life including sea pens, cup corals, and anemones (WWF-Canada 2009). The WWF classification was adopted in the Marxan analysis used to identify the St Anns Bank AOI (Figure 3.3.1-1).

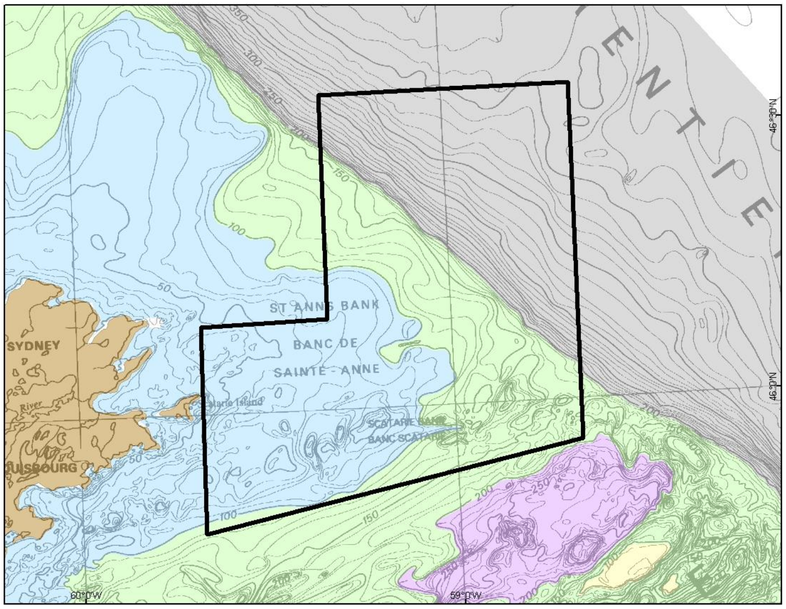


Figure 3.3.1-1. Seabed feature classes from WWF-Canada (2009). Blue areas are the Inner Scotian Shelf, green areas are Middle Scotian Shelf, and grey is the Laurentian Channel.

Roff et al. (2003) also used geophysical factors to classify habitats on the Scotian Shelf. They classified pelagic and benthic seascapes, and then overlaid them to produce a map of Scotian Shelf seascapes. The benthic seascape classification divides the St Anns Bank AOI into only two seascape types: cold water, potentially exposed, mostly sand seabed above 50 m depth, and cold water, low slope, mostly sand below 50 m depth. Overlaying the pelagic classes gives a total of seven seascape classes in this part of the Cabot Strait, based on variation in depth and the degree of water mixing. The Glace Bay Hole (north of St Anns Bank proper) creates an area of well-mixed water, as does the complex topography in the southeast corner of the site. They note that there is insufficient sampling of benthic communities on the Scotian Shelf to predict community associations with their seabed classes; communities may vary at a finer spatial scale than these classifications, especially at depth.

Kostylev and Hannah (2007) also classified habitats of the Scotian Shelf based on physical features, with the intent of predicting associated biological communities and their characteristics. Their classification scheme had two axes: natural disturbance (defined as exposure to mechanical disturbance of the sediment) and scope for growth (severity of environmental conditions). As different organisms are adapted to deal with different degrees of these environmental conditions, different biological communities should be present at different combinations of the variables. For example, areas with low scope for growth and low natural disturbance might be expected to have low migration rates and great longevity, typified by cold-water corals. Areas with low scope for growth but higher natural disturbance would be expected to show higher levels of migration or movement, and to have lower longevity, typified by quahogs. Kostylev and Hannah (2007) preferred to express the axes as gradients, reflecting the gradation in natural communities over space. However, for the Marxan analysis used to select the AOI, these axes were converted to five scope for growth and five natural disturbance classes across the region. The most inshore parts of the site were not included in the classification, and areas below about 200 m were not included in the modelling of scope for growth (Figure 3.3.1-2). In the parts of the site covered by the model, all four natural disturbance levels are represented (Figure 3.3.1-2a). However, only the very low and low scope for growth regions are represented (Figure 3.3.1-2b). While they showed that the model predicts similarity of biological communities better than just distance between samples, no descriptions of expected biological communities has been generated based on this model.

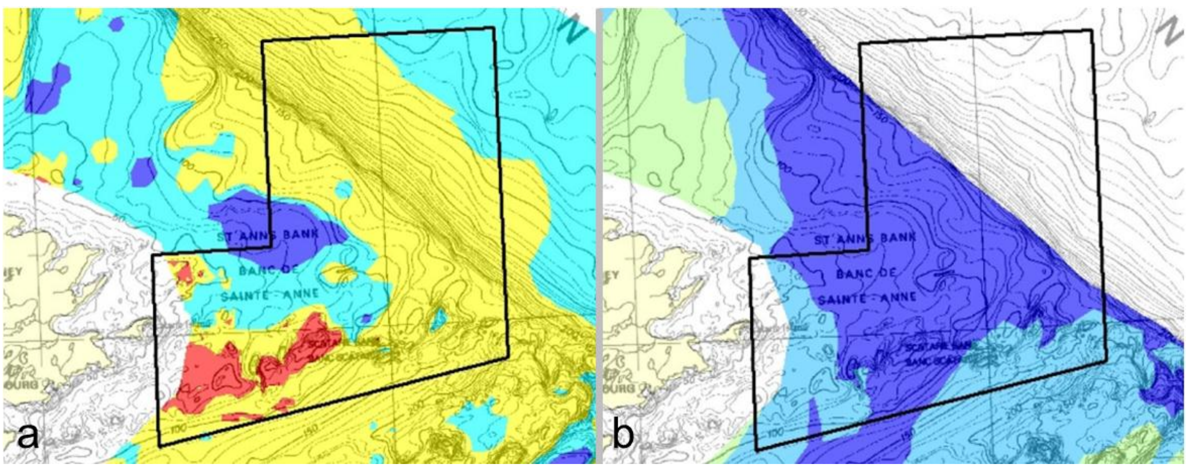


Figure 3.3.1-2. Natural disturbance and scope for growth regions represented in the St Anns Bank region. a) Natural disturbance regions included range from high natural disturbance (red) through moderate (yellow), low (light blue) and very low (dark blue). b) Light blue areas represent low scope for growth and dark blue areas are very low scope for growth.

3.3.2 Benthic Communities of St Anns Bank

There has not been comprehensive biological sampling that would allow a detailed description of benthic communities of the St Anns Bank AOI. However, there are a variety of sources of information that can be used to improve our understanding about the benthic communities of the AOI.

Sampling of benthic communities directly in the AOI has been limited, but there has been some photo and video sampling, and two DFO research surveys, the summer RV survey and the snow crab survey, occur here annually. In addition, there are fisheries observer records of coral caught in the area. This section reviews what can be learned about benthic communities of St Anns Bank from these four data sources. The data from photo and video sampling have not been analyzed or published previously. Annual reports are written about both research surveys (Choi and Zisserson 2011; Clark et al. 2010).

Not all parts of the site are sampled equally and data gaps should be kept in mind. In particular, there is no benthic sampling from any of the data sources cited in the northeast corner of the site deeper than 375 m. This is approximately 8% of the AOI. The snow crab survey mainly avoids the shallower, rockier parts of the site, though these were sampled to a limited degree by the RV survey and in photo and video sampling. The photo and video techniques sample very different organisms than the research surveys. While these techniques are complementary to some extent, they also show how much of the ecosystem is missing if only one technique is considered. The benthic community described for the southern parts of the site from photos and video has not been described for the northern half of the AOI, or from nearshore parts of the AOI.

Photo and Video Sampling

Photo and video sampling was done on two science cruises: a 2009 DFO/NRCan research cruise on the *Hudson*, and a 2010 DFO research cruise on the *Matthew*. The 2009 *Hudson* cruise sampled four stations within SAB with Campod (09-64 to 09-67, Figure 3.3.2-1).

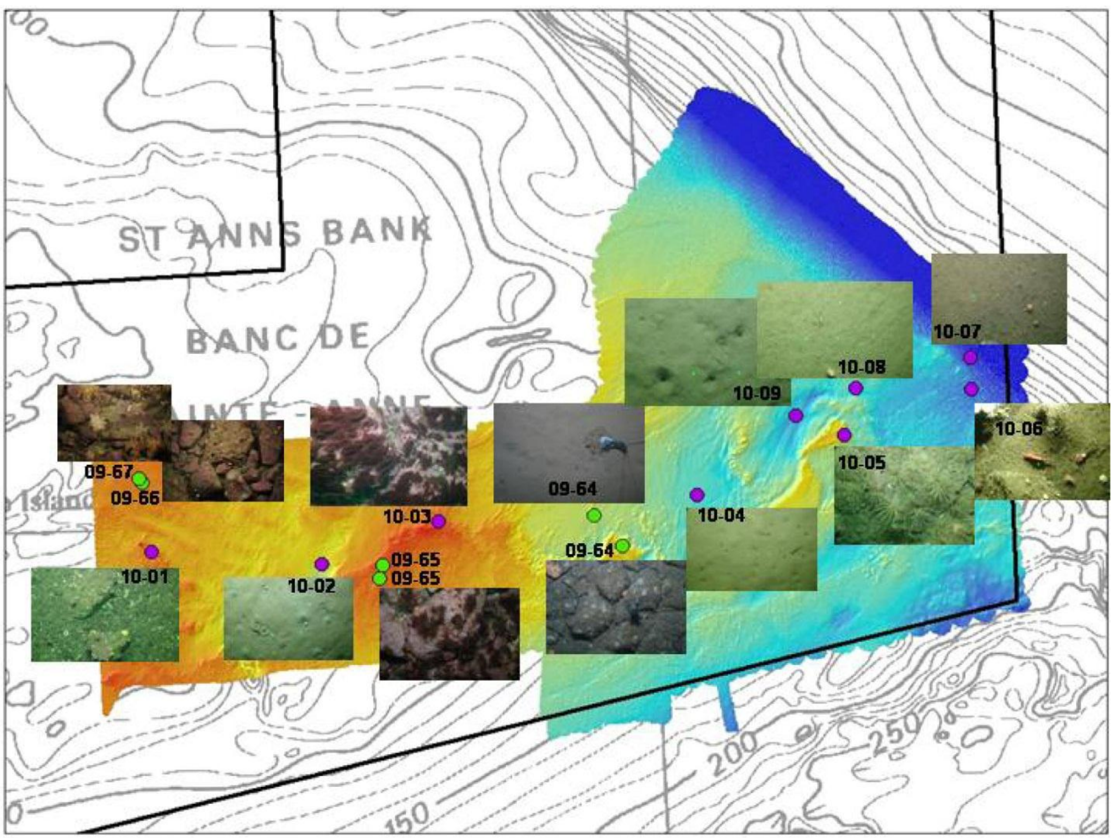


Figure 3.3.2-1. Photo and video sampling on St Anns Bank in 2009–2010. Photos from sampling stations show a range of habitat types and associated communities.

To date, organisms have been identified to the lowest taxonomic category possible for only the two stations furthest west, Stations 09-66 and 09-67 (Figure 3.3.2-1). These two stations form an almost continuous transect in a north to northwesterly direction. This is a relatively shallow area (around 50 m depth), about 16 km east of Scatarie Island. The station largely consists of cobble and boulders, covered with encrusting sponges and coralline algae, and a range of worms, hydrozoans, tunicates, bryozoans (Ectoprocta), and soft corals.

Data from the remaining two stations have not been processed. However, the dominant biota and the habitat type can be described generally. Station 09-65 is on Scatarie Bank, at a depth of 40–45 m (Figure 3.3.2-1). There are 31 photos from this station and all are similar, showing large cobble and boulders, covered in encrusting coralline algae, unidentified red algae, and some kelp (*Agarum nodosum*) (Figure 3.3.2-1). Many types of anemones, sponges, and other invertebrates can be seen, similar to the fauna of the stations that have been described in detail (09-66 and 09-67). This station also appears to be similar to Station 10-03, sampled in 2010. Station 09-64 is a long transect (3.8 km) running northwest and covering a varied topography, from 70 m depth to almost 130 m. The shallower parts of this transect are cobble covered by fine sediment, supporting a variety of invertebrates including sponges, sea stars, and tubeworms, as well as some redfish. The deeper parts of the station are covered with a very fine sediment, and very few species can be seen in the photos.

In 2010, nine stations in the southern portion of the AOI were sampled, covering a range of depths and habitat types (Figure 3.3.2-1). Six of the stations had a primarily silty, very fine substrate type, while the other three (10-01, 10-03, 10-05) were a combination of pebbles, cobble, and boulders or bedrock (Table 3.3.2-1). These are also the shallower stations, as shallow as 33 m in the case of Station 3 on Scatarie Bank. All stations deeper than 100 m were depositional and predominantly covered by fine sediment.

Table 3.3.2-1. Average percent cover by substrate type for stations sampled in 2010 and average depth in metres.

STATION	FINE SEDIMENT /MUD	SAND	GRANULE	PEBBLE	COBBLE	BOULDER	BEDROCK	APPROX DEPTH (m)
10-01	3.2	0.1	7.22	33.76	41.74	13.88	0.1	56
10-02	99.62			0.33	0.05			108
10-03			4.45	20.78	60.55	13.04	1.18	33
10-04	96.97							148
10-05	14.70		5.18	29.27	20.19	2.01	28.64	75
10-06	83.00		9.25	0.98	5.37	1.4		187
10-07	91.91		6.29	0.89	0.77	0.14		216
10-08	96.84		1.94	0.29	0.82	0.10		153
10-09	100							171

The three shallow stations (10-01, 10-03, and 10-05, all less than 50 m depth) all show a fairly high percent cover from encrusting coralline algae and encrusting sponges (Appendix B–Part 1). Other small sponges, bryozoans and tunicates are also common features of all three shallow, rocky locations. Soft corals were also common at the most westerly station, 10-01. At the shallowest station on Scatarie Bank (10-03) a red algae was the most common species in the photos and video, with 51 percent cover. The same red algae is a dominant species in the photos from Scatarie Bank from 2009 (Station 9-65). Station 10-05, on a plateau or ledge close to the shelf break, was dominated by crinoids, with an average of 46.6 crinoids per photo.[5]

Of the other six stations surveyed, stations 10-04 and 10-09 were silty and featured very little visible macrofauna in the photos or video, though quite a few burrows could be seen (28 and 18 burrows per photo, respectively). Stations 10-06, 10-07, and 10-08 are all fairly deep (> 150 m), soft, muddy stations near the shelf break, with similar fauna. The benthic community at each station is dominated by tube-building worms and amphipods, brachiopods, and anemones, with encrusting sponges where rocks emerge from the mud. The final station, 10-02, is a mid-depth (~100 m) station to the west (inshore) of Scatarie Bank. This station was dominated by brittle stars, toad crabs, and soft coral.

Snow Crab Survey

The snow crab survey (see 3.1 above for details), included 112 sets in 21 survey stations in St Anns Bank from 2004 to 2010 (Figure 3.3.2-2). A total of 100 taxa were recorded in the AOI over seven years. The most common species caught in St Anns Bank (by frequency of occurrence) were snow crab, American plaice, and redfish (Table 3.3.2-2), and the largest numbers of individuals caught were of heart urchins, sponges,

[5] Photo sizes are not standard, covering approximately 0.75–1.5 m^2.

and redfish (Table 3.3.2-2). In St Anns Bank, the average number of species recorded per tow was 18, and the maximum number in a tow was 29.

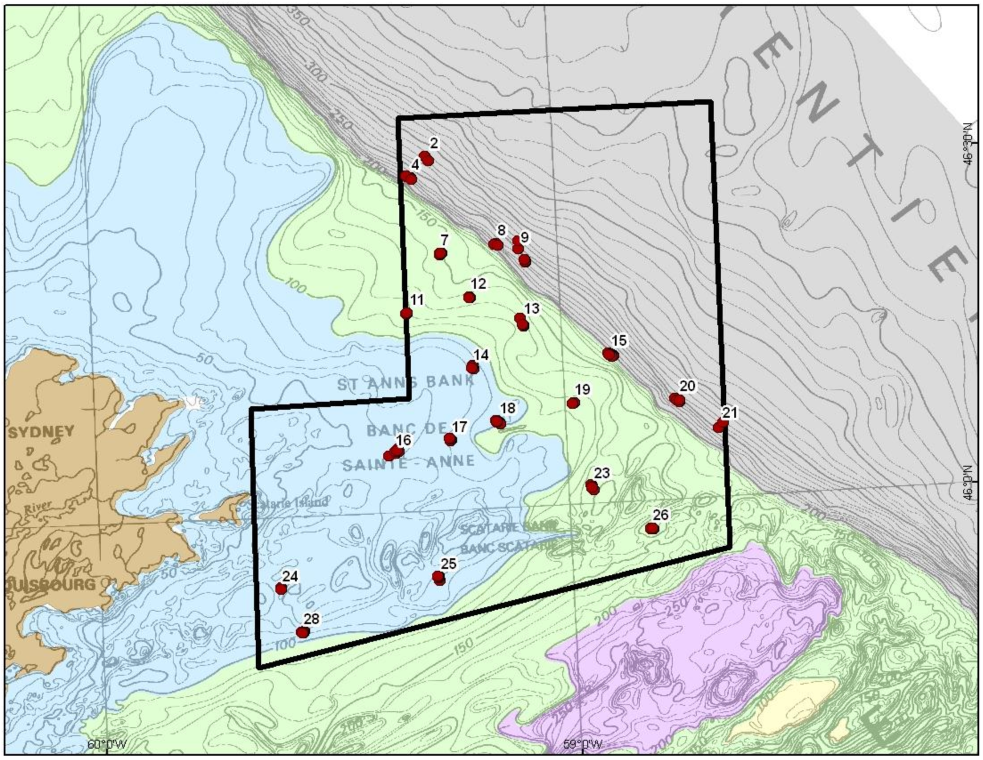


Figure 3.3.2-2. Snow crab survey locations in SAB, 2004–2010. Numbers are stations referred to in the text, and most were sampled 5–7 times over 2004–2010. The background is the seabed feature classification developed by WWF-Canada (2009); blue represents Inner Scotian Shelf (referred to as “bank” habitat in the text), green represents Middle Scotian Shelf (or “shelf”), and grey represents Laurentian Channel (or “slope”) habitat. Pink (south of the AOI) represents a Middle Scotian Shelf Basin and yellow represents a Middle Scotian Shelf Bank.

Table 3.3.2-2. The ten most commonly observed taxa in SAB, plus heart urchins (which had the largest number of individuals caught). The complete set of species caught is in Appendix B.

Species	**# Sets (112 total)**	**# Stations (21 total)**	**# Individuals (summed over 7 years)**
Snow crab	112	21	3612
American plaice	106	21	4074
Redfish	86	20	6087
Atlantic cod	79	16	1004
Witch flounder	76	18	3746
Thorny skate	74	19	326
Asteroidea unk.	68	21	305
Sponges	66	17	7724*
Sea anemone	66	17	614
Smooth skate	65	17	326
Heart urchin	12	4	9554

* may represent pieces of animals rather than whole sponges

Using the seabed feature classification developed by WWF-Canada (2009), the stations have been divided into bank (14, 16, 17, 18, 24, 25, 28), shelf (7, 11, 12, 13, 15, 19, 23, 26), and slope (2, 4, 8, 9, 20, 21) stations (Figure 3.3.2-2). While some species such as snow crab and American plaice are found at every station or almost every station, there are differences in the overall community composition across depths (Figure 3.3.2-3).

On bank stations, Atlantic cod and American plaice are very common fish species, and striped shrimp, basket stars, and sponges show up as common invertebrates in several stations (Figure 3.3.2-3). The set of true bank species, rarely found below 100 m, is fairly small (Figure 3.3.2-3). These bank species include striped shrimp, sea potato, lyre crabs, and unidentified sculpins. Seven of the 21 stations are shallower than 100 m, so this small number and catch of shallow water species may reflect lower abundance of these species in the AOI rather than just sampling effort.

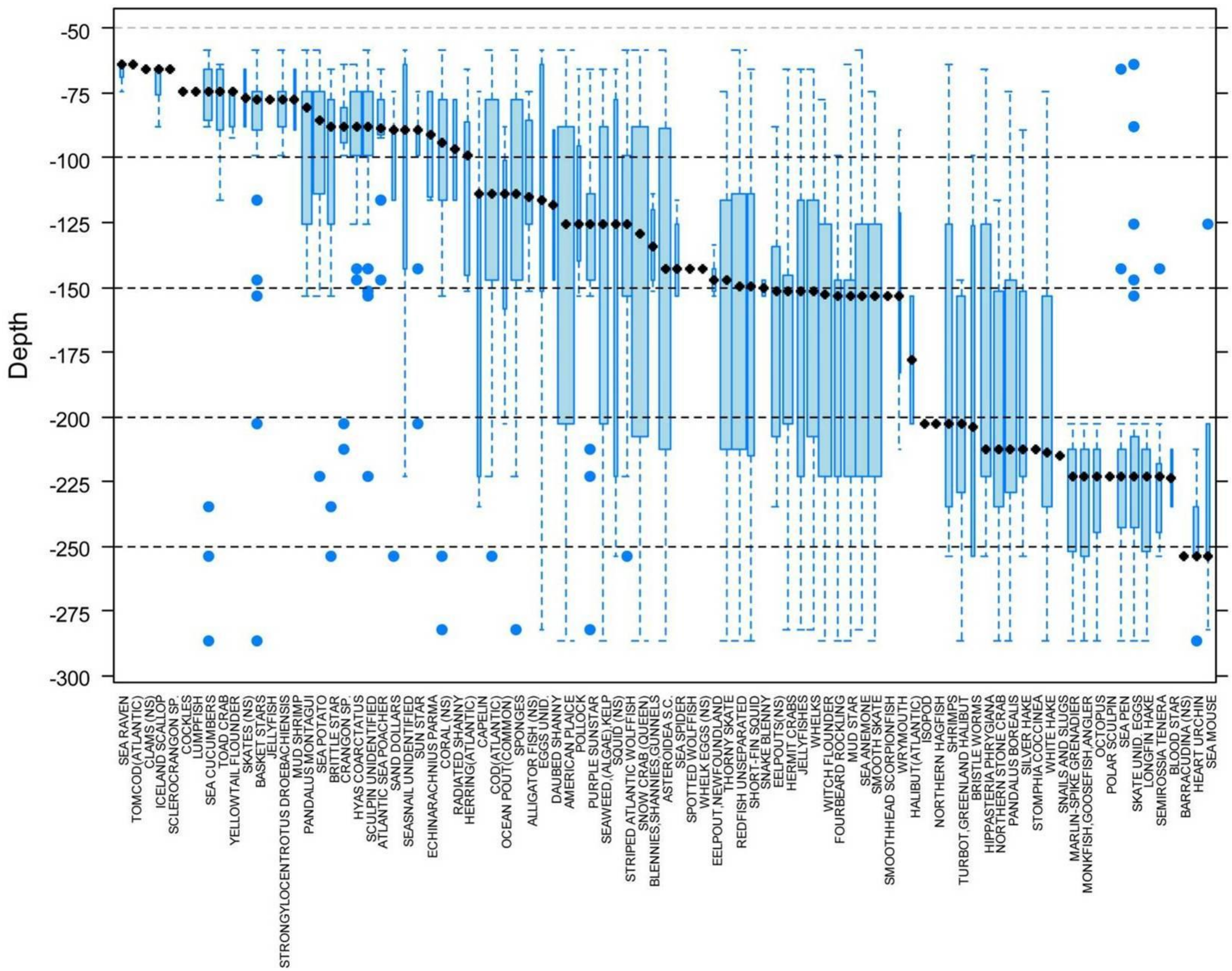


Figure 3.3.2-3. Distribution of taxa recorded in the snow crab survey by depth. Black circles indicate the median depth, and width of bars is proportional to total catch of that taxa. Blue dots represent outliers.

In mid-depth shelf stations, witch flounder are found frequently among the most commonly sampled species, along with redfish, American plaice, Atlantic cod, sponges, and snow crab (Figure 3.3.2-3). Overall, the most abundant species sampled in St Anns Bank are primarily found at these depths, 100 to 150 m (Figure 3.3.2-3). Common species whose distribution is centred at 100–125 m include Atlantic cod, sponges, American plaice, Atlantic wolffish, and snow crab. Moving down the shelf, common species whose distribution is centred around 150 m include redfish and thorny skate, whelks, witch flounder, mud stars, sea anemones, and smooth skates.

There is a distinct break in the species composition moving down onto the slope (200 m and below), though many shelf species are found at a wide range of depths. Along the slope, northern shrimp, redfish, witch flounder, sea pens, and snow crab are the most abundant species in most slope stations over time (Figure 3.3.2-3). Heart urchins and skate eggs are found in large numbers at stations 20 and 21 respectively. Species that can be found at a range of depths, but which are found most frequently below 200 m, include northern shrimp, northern stone crab, and white hake (Figure 3.3.2-3). In the deepest part of the site, there are taxa that are rarely found above 200 m, including marlin-spike grenadier, sea pens, longfin hake, and skate eggs.

Non-metric multidimensional scaling was used to look for grouping of species and stations (using the metaMDS function and the “vegan” package in R). Looking only at invertebrates, some groupings that appear to be related to depth can be seen (Figure 3.3.2-4). Shallower invertebrates found in bank habitats, such as sea cucumbers, basket stars, and sea potato tunicates, generally group together (on the upper left of Figure 3.3.2-4). Shelf invertebrates from intermediate depths such as sea anemones and whelks group together in the lower part of the plot, with stations in the 100–150 m range. Invertebrates primarily associated with deep-water habitats, such as sea pens, heart urchins, and northern shrimp, also group together (in the upper right-portion of Figure 3.3.2-4).

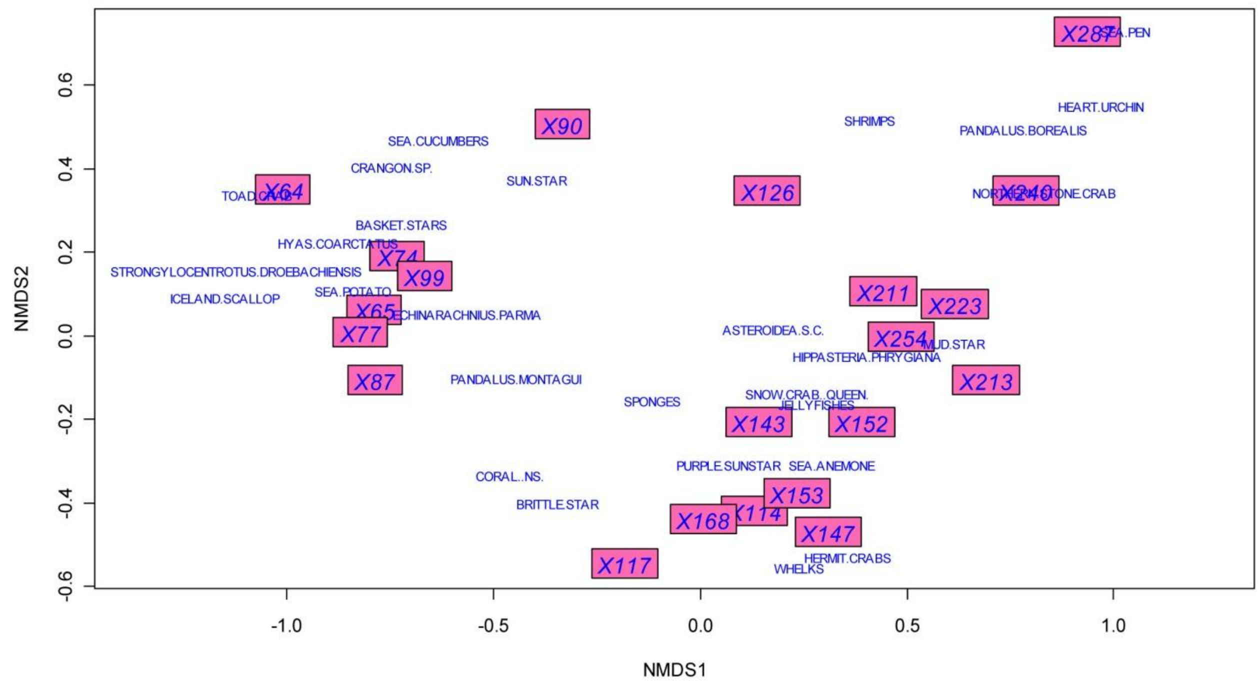


Figure 3.3.2-4. Results of non-metric multidimensional scaling analysis showing the invertebrate species and the stations from the snow crab survey in St Anns Bank. The depth of each station is shown in the pink boxes. For example, X287 in the upper right represents Station 2, which has a depth of 287 m.

Similarly, in Figure 3.3.2-4 some stations group together, representing a similar species composition in sampling for those stations. The stations labeled X87 (i.e., depth is 87 m), X77, X65, and X99 are stations 14, 17, 16, and 18 respectively, which are geographically close on St Anns Bank itself (Figure 3.3.2-2). The station labeled X74, station 25, also groups with those stations. It is a shallow water station further south on Scatarie Bank, but with similar species composition. Some other stations that group together are labeled X168, X114, X147, and X153, at the bottom of Figure 3.3.2-4. These are stations 19, 11, 23, and 26. These stations are not all close together in the site, but are at similar depths across the slope. Similarly, the stations labeled X211, X223, X254, and X213 are stations 4, 8, 21, and 15, which are stations that are at similar depths but not closely grouped in space in the AOI.

<u>RV Survey (Invertebrates Only)</u>

DFO’s RV surveys, described in detail above at Section 3.1, have only recorded invertebrates consistently since 1999. Only select invertebrates (lobster, shrimp, crab, scallop, echinoderms) are recorded because they are caught regularly in the survey, are quantifiable, and may have commercial value (Tremblay et al. 2007). Therefore what is reported here does not provide a complete picture of the invertebrates in St Anns Bank. This summary uses RV sets only from within the AOI boundaries, and only reports on the invertebrates recorded. Both “Summer” and “Summer Teleost” series are used here as Tremblay et al. (2007) reported that catch rates of invertebrates from the two vessels used over the time series (*Needler* and *Teleost*) were not consistently different. The maximum depth sampled in the AOI was 375 m, and the minimum was 42 m, so this survey does cover a wider range of depths than the snow crab survey.

The St Anns Bank AOI covers four survey strata from the RV Survey: 440, 441, 442, and 445 (Figure 3.3.2-5). There were 62 sets within SAB from 1999–2009, and a total of eleven invertebrate species were recorded within the AOI (Table 3.3.2-3), including shrimp, crabs, scallops, and echinoderms.

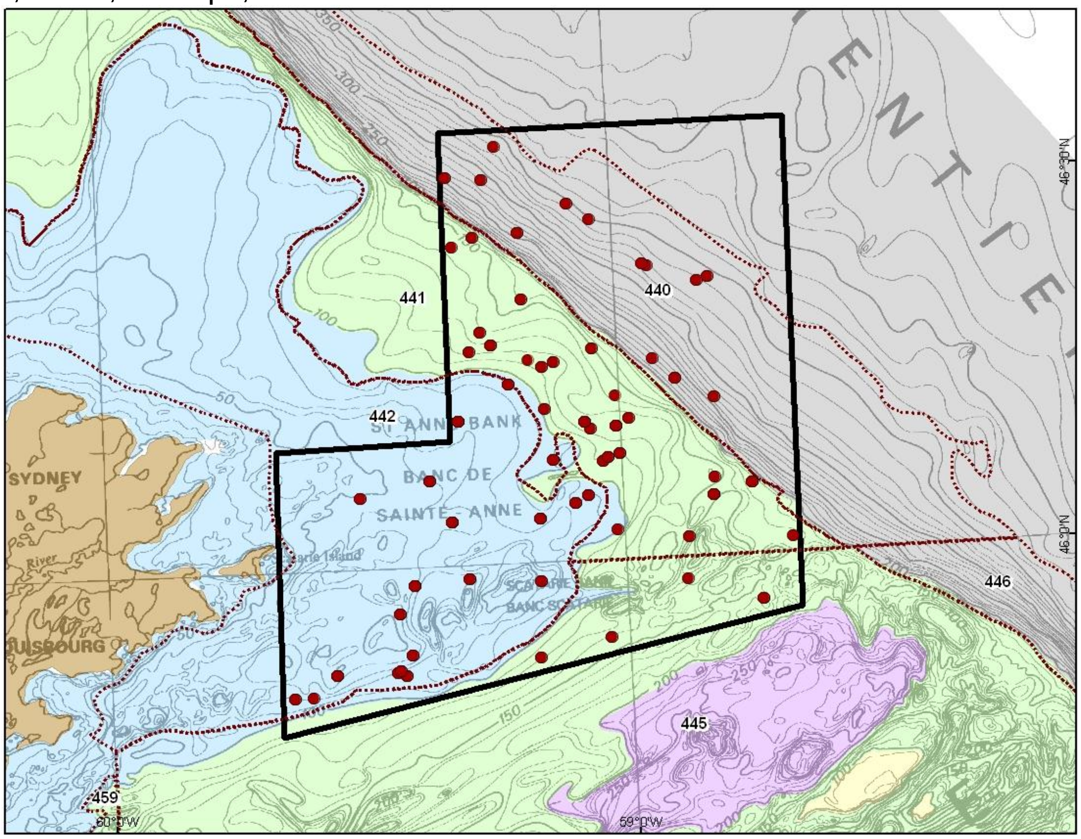


Figure 3.3.2-5. RV survey sets in St Anns Bank (1999–2009) with RV survey strata in dashed lines. Numbers are labels for the survey strata (e.g., 440). The background is the seabed feature classification (bank, shelf, and slope) developed by WWF-Canada (2009), as in Figure 3.3.1-1.

The most common species caught in St Anns Bank (by frequency of occurrence) were *Asteroidea* spp., snow crab, striped shrimp, and Arctic lyre crab (Table 3.3.2-3). The species with most individuals caught in SAB were striped shrimp, northern shrimp, and *Asteroidea* spp., while the species caught in St Anns Bank with the greatest weights were *Asteroidea* spp., northern shrimp, and snow crab. *Asteroidea* spp. includes all species of starfish, with brittle stars generally not recorded (Tremblay et al. 2007). The species included in this category are varied and span a variety of habitats, as can be seen in some of the starfish identified to species in the snow crab survey (Figure 3.3.2-3).

Table 3.3.2-3. The eleven invertebrate species recorded in the RV survey in St Anns Bank, ordered by number of sets present. All fields are summed for ten years (1999–2009).

Species	# Sets (62 total)	# Individuals	Total weight (kg)
Asteroidea spp.	55	1081	88.0
Snow crab	41	366	36.2
Striped shrimp	25	13,612	35.3
Arctic lyre crab	25	474	33.1
Green sea urchin	21	504	28.9
Sea cucumber	18	74	30.1
Northern shrimp	17	12,687	77.7
Northern stone crab	14	31	7.0
Toad crab	13	79	4.8
Iceland scallop	10	56	1.8
Sand dollar	6	8	5.1

The RV survey sets were further broken down into bank, shelf, and slope areas of the AOI, based on the seabed feature classification developed by WWF-Canada (2009). These classes match the survey strata distinctions closely in most cases (Figure 3.3.2-5).

There were 21 sets on the bank, 28 on the shelf, and 13 on the slope, so the slope has somewhat fewer samples than the rest of the site. Sea cucumbers were recorded mostly on the bank. *Asteroidea* spp. were recorded in most bank sets, as well as Arctic lyre crab and green sea urchin (these two were also recorded in fewer sets on the shelf/slope). Toad crabs were recorded in half of the bank sets, with very few recorded in the shelf/slope sets. Striped shrimp were recorded in almost half of the bank sets. All species recorded in St Anns Bank were present in the bank sets, except northern stone crab.

All of the eleven invertebrate species recorded in St Anns Bank were found in the shelf sets. *Asteroidea* spp. were recorded in almost all shelf sets. Striped shrimp and snow crab were recorded in most of the shelf sets. The rest of the species were found in less than half of all the shelf sets (Table 3.3.2-4).

Table 3.3.2-4. The eleven invertebrate species recorded in the RV survey in SAB, divided into bank, shelf, and slope areas of the AOI. All fields are summed for ten years (1999–2009).

Species	**Bank**		**Shelf**		**Slope**	
	# Sets (21 total)	# Individuals	# Sets (28 total)	# Individuals	# Sets (13 total)	# Individuals
Striped shrimp	8	3111	17	10,501	-	-
Arctic lyre crab	18	452	6	21	1	1
Asteroidea spp.	18	221	25	360	12	500
Green sea urchin	15	362	5	141	1	1
Iceland scallop	8	54	2	2	-	-
Northern shrimp	1	17	4	149	12	12,521
Northern stone crab	-	-	7	14	7	17
Sand dollar	3	5	3	3	-	-
Sea cucumber	15	68	3	6	-	-
Snow crab	16	128	19	229	6	9
Toad crab	10	75	2	3	1	1

Although there were fewer sets on the slope, *Asteroidea* spp. were found in most of them. Northern shrimp were recorded most often in the slope sets; they were found in fewer sets on the bank and shelf. Northern shrimp also had the highest number of individuals and highest weight recorded of all species found on the slope. Northern stone crabs were recorded in half of the slope sets, higher than in the bank/shelf sets. Snow crabs were also recorded in about half of the slope sets. Four of the eleven species recorded in St Anns Bank were not found in the slope sets (striped shrimp, Iceland scallop, sand dollar, and sea cucumber).

In general, *Asteroidea* spp. appear to be found everywhere; they are present in most of the sets on the bank, shelf, and slope. This is likely due, at least in part, to this category including a range of species—12 *Asteroidea* species caught in the RV survey are listed in Tremblay et al. (2007). Snow crabs are recorded throughout the site, though they are present in fewer sets on the slope. There appear to be differences in the shrimp species in the site, with striped shrimp being recorded more often on the bank/shelf, and northern shrimp being recorded most often on the slope and not at all on the bank.

<u>Combining Datasets: Patterns in Community Composition</u>

It seems apparent that there are different benthic communities across the site, and that these are driven at least in part by the combination of depth and substrate type. In the southern part of the site, where photo and video sampling has been done, shallow areas appear to be rocky while deeper areas are muddy and depositional. Given this combination, different communities would be expected in different parts of the site, and to an extent this can be seen in all the data sets examined. However, some species (such as American plaice, witch flounder, and snow crab) appear to be very widely spread throughout the site and across depths. Also, some species such as redfish and snow crab are known to spend different parts of their life history in different habitat types (Choi and Zisserson 2011; COSEWIC 2010a), which may partly explain why they are found to be more widely distributed in research surveys than in their commercial fisheries.

Though many fewer invertebrate species are considered in the RV survey, the two research surveys considered show some commonalities. Patterns in distribution of northern and striped shrimp and of the crab species caught in both surveys are similar. Green sea urchins and sea cucumber are primarily found on the banks in both surveys. While many species are found throughout the site in both surveys, there do appear to be distinct bank and slope communities. Shelf communities appear to be intermediate in species composition, with most species in the AOI occurring on the shelf at least some of the time.

Overall, it appears useful to consider the benthic communities by seabed feature class (bank, shelf, slope). The shallow bank areas (shallower than 100 m) that have been sampled are generally on hard, rocky substrates covered in encrusting coralline algae and encrusting sponges, along with small sponges, bryozoans, and tunicates. Macroinvertebrates characteristic of bank communities include lyre crabs, snow crab, basket stars, green sea urchins, sea potato, sponges, and sea cucumbers. The most common fish species on the banks in the snow crab survey are American plaice, Atlantic cod, and sculpins.

Shelf species are more difficult to characterize. In the video and photo sampling, shallower rocky shelf areas appear quite distinct from slightly deeper, depositional areas, which are muddy. Rocky areas supported crinoids, sponges, anemones, sea stars, and tubeworms, while on muddy sites, tube-building worms and amphipods are dominant, if any organisms are visible at all. In the surveys, snow crab, starfish, sponges, whelks, and anemones are common macroinvertebrates. American plaice and Atlantic cod are still the most common fish, followed by witch flounder, redfish, and smooth and thorny skate.

Finally, slope communities seem easier to characterize based on the data considered. From photos and videos, tube worms and burrows are the most common organisms or features in the two slope stations (10-06 and 10-07). Northern shrimp and snow crab are very common invertebrate species in these depths, along with sea pens and localized high concentrations of heart urchins. Redfish, witch flounder, and hake are also commonly caught on the slope.

This simple classification glosses over variation in benthic communities at a finer spatial scale. For example, the high concentrations of crinoids documented in photo and video sampling (Station 10-05) appear to occupy only a small portion of shelf habitat and are related to a finer-scale habitat feature. The bank communities include very shallow areas of Scatarie Bank, which support lush growth of red algae despite being about 40 km offshore. The bank area of the AOI also includes deeper holes, such as Station 10-02, which are muddy and have fauna more similar to other muddy shelf stations. There also appear from the snow crab survey to be single stations where high concentrations of particular species (such as wolffish and heart urchins) are found repeatedly, suggesting finer-scale habitat and community variation. Finer-scale sampling with the goal of describing benthic communities, as was done for Browns Bank (Todd et al. 2006) and German Bank (Todd and Kostylev 2011), would be needed to describe the habitats and associated communities of St Anns Bank at this level.

3.4 INVERTEBRATES

3.4.1 Diversity

Invertebrate biodiversity hot spots were identified on the Eastern Scotian Shelf using the annual snow crab survey (2004–2010). The survey catches a range of species, including many fish. Only invertebrate species were considered in this analysis.[6]

The number of unique species/taxa per survey set were counted, and then a hot spot analysis tool in ArcGIS was used to calculate the Getis-Ord Gi* statistic for each set.

The Gi* statistic indicates whether features with high values or features with low values tend to cluster in a study area by looking at each feature within the context of neighbouring features. The Gi* statistic is actually a Z score, which is a measure of standard deviation. For statistically significant positive Z scores, the larger the Z score is, the more intense the clustering of high values, and the more likely that the clustering is not random. For statistically significant negative Z scores, the smaller the Z score is, the more intense the clustering of low values. For this analysis, statistically significant positive Z scores ($\geq$ 1.96) were considered biodiversity hot spots for invertebrates. The Z score results of the hot spot analysis were then interpolated to create a more generalized surface (Figure 3.4.1-1).

[6] Invertebrate species appear to be recorded with varying levels of accuracy; several generic taxa (identified only to class, family, etc.) were removed from the dataset prior to analysis to prevent double counting. This means the number of individuals of some taxa could be underestimated.

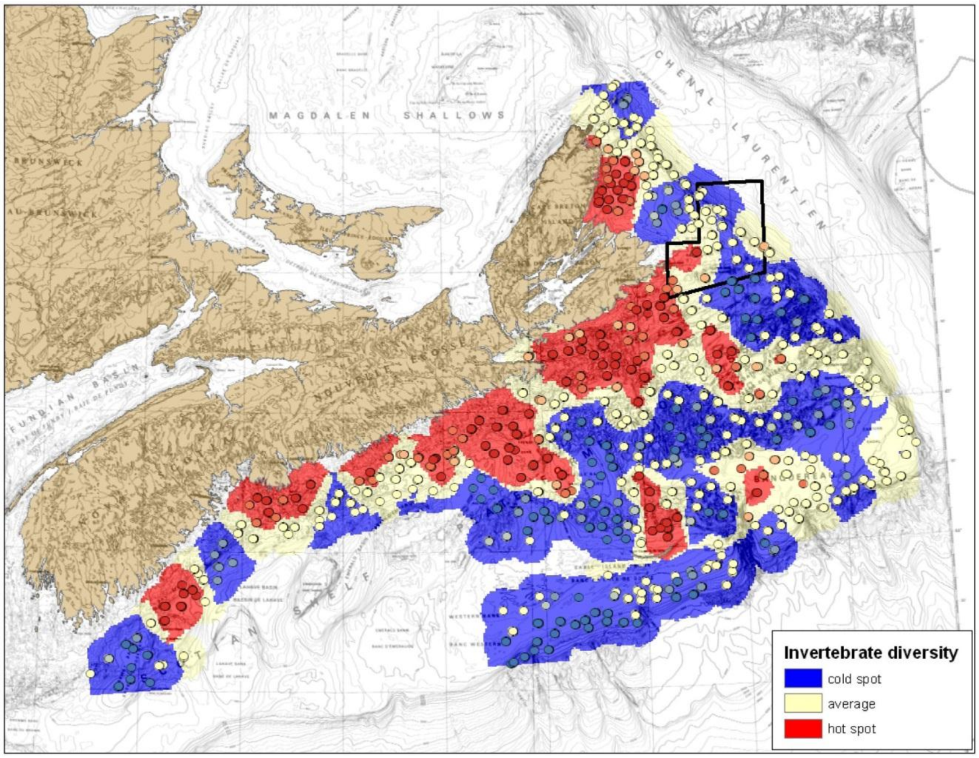


Figure 3.4.1-1. Invertebrate biodiversity hot spots on the Eastern Scotian Shelf (based on the snow crab survey). Both the point results from the Getis-Ord hot spot analysis and the interpolated surface are shown. As Z scores are either statistically significant or not, only three colours are used for the interpolated surface—red (statistically significant hot spot), blue (statistically significant cold spot), and yellow (not statistically significant).

The results show invertebrate biodiversity hot spots in patches along the east coast of Nova Scotia, near Sable Island and Banquereau banks, Sydney Bight, and partially in St Anns Bank in the southwest near Scatarie Island. The hot spot in St Anns Bank appears to mostly be driven by Station 15, one of the shallowest stations in St Anns Bank (see Section 3.3.2 for map and description). Most of St Anns Bank appears to have average invertebrate diversity.

3.4.2 Corals and Sponges

Soft corals (Alcyonacea), gorgonian corals (Gorgonacea), and sea pens (Pennatulacea) are found within the boundaries of the AOI, as are a variety of sponge species. While there are a small number of records that indicate that St Anns Bank may have large gorgonian corals, there have been no observations that indicate high densities of structure-forming corals. Sea pens are fairly common in the deeper part of the site and a significant concentration of sea pens has been identified in the southeast corner of the site. Significant concentrations of sponges have also been identified in the centre of the site.

Introduction

In recent years, there has been much interest in coral- and sponge-dominated benthic communities in temperate waters of the North Atlantic (see, e.g., Breeze et al. 1997; MacIsaac et al. 2001; Gass 2002; Mortensen et al. 2006; Gordon and Kenchington 2007; Cogswell et al. 2009; Fuller 2011). This interest is due in part to i) a greater understanding of the role played by benthic communities in overall ecosystem health, ii) the vulnerability of these animals to human activities, and iii) a desire by management agencies to promote an ecosystem approach to management. In addition, United Nations General Assembly Resolution 61/105 committed nations fishing on the high seas (including Canada) to identify and to protect vulnerable marine ecosystems. Fisheries and Oceans Canada recently published guidance on developing ecosystem objectives for marine management that identified structure-providing species such as corals and sponges as species of particular importance (DFO 2006). The ecological function of corals and sponges and their vulnerability to fishing was further documented in a 2010 DFO Science report (DFO 2010a), and areas with high densities of corals and sponges were described by Kenchington et al. (2010). DFO Maritimes Region published a Coral Conservation Plan in 2006 (ESSIM 2006) and fisheries closures have been put in place to protect two areas on the Scotian Shelf with high densities of structure-forming corals. Recently, a voluntary fisheries closure was put in place to protect a unique community of sponges known as Russian hats (*Vazella pourtalesi*). As a result, the distribution and status of sponge and coral communities are of importance both for better understanding the ecosystem and developing appropriate management measures.

General Description of Corals Off Nova Scotia

The term coral is used to describe several different taxonomic groups within the phylum Cnidaria. Two subclasses of corals—the Hexacorallia and the Octocorallia—occur in the waters off Nova Scotia. The subclass Hexacorallia houses members of the order Scleractinia (stony corals or hard corals) including colonial reef-building corals, such as *Lophelia pertusa*, and solitary corals, such as the cup coral (*Flabellum alabastrum*). This subclass is also parent to the order Antipatharia (black corals), which are also present mostly in the deep waters of the shelf break. The Octocorallia include the sea fans, sea pens, sea whips, and the species known as "soft corals". The World Registry of Marine Species[7], the preferred online taxonomic authority of Fisheries and Oceans Canada, specifies three orders of octocorals that are particularly useful for understanding the vulnerabilities of corals to human activities: the Gorgonacea (which includes the sea fans), the Alcyonacea (the soft corals), and the Pennatulacea (sea pens). There is some debate among taxonomists about whether to maintain Gorgonacea as a separate order or to group the sea fans with the Alcyonacea (Daly et al. 2007). However, off Nova Scotia many of the sea fans traditionally found in the order Gorgonacea grow to much larger sizes than the species traditionally considered Alcyoncea, and are thus likely more important as habitat for other species. For that reason, this description groups the traditional "gorgonian" corals separately from the other Alcyonacea (Cogswell et al. 2009 takes a similar approach).

[7] www.marinespecies.org

There is no general consensus on the cold-water coral species that should be considered the most important structure-providing species. However, it is generally agreed (see, e.g., Fuller et al. 2008a; Freiwald et al. 2004) that *Lophelia pertusa*, large octocorals, and large antipatharian corals are important in providing habitat for other corals. The most recent Coral Conservation Plan for the Maritimes Region identifies certain corals as particularly vulnerable to human activity due to their size, morphology, and life history characteristics (ESSIM 2006). These are the large gorgonian corals, such as *Paragorgia arborea*, *Paramuricea* sp., and *Primnoa resedaeformis*, and the reef-building coral *Lophelia pertusa*.

<u>Biology and Habitat Preferences of Corals</u>
Corals are filter feeders that attach themselves to the ocean bottom and feed off zooplankton and other nutrients suspended in the water column. Most species recorded off Nova Scotia are colonial organisms, with multiple tiny polyps sharing a common skeleton. Other corals are in solitary forms, such as the cup corals *Flabellum alabastrum* and *Desmophyllum dianthus*. The Scleractinian corals of Nova Scotia’s temperate waters do not have the symbiotic zooxanthellae that many of their tropical cousins have. However, some species, such as *Lophelia pertusa*, are still able to form reefs, albeit at a much slower rate than reef-building corals of the tropics (Wilson 1979; Gass and Roberts 2006).

The large gorgonian coral species are found attached to hard substrates, such as cobble, boulder and consolidated sandstone, and in high current (see, e.g., MacIsaac et al. 2001; Mortensen and Buhl-Mortensen 2005). Most other coral species are also found on hard bottoms, except for a few species such as sea pens that prefer soft or clay bottom habitats (Mortensen and Buhl-Mortensen 2005).

<u>General Description of Sponges Off Nova Scotia</u>
Sponges are a diverse group of organisms from the phylum Porifera. They are found from coastal areas to the deep sea, on a variety of sediments. Certain species can be found in dense aggregations; on the Pacific coast of Canada, globally unique glass sponge reefs (Class Hexactinellida) occur. Sponges range in form from thin, encrusting species to animals that form large mounds. The surface characteristics of the sponge, the size of ostia (channels that lead to the sponge’s central cavity), and the size of the sponge itself are considered important in determining what role the sponge plays as habitat to other organisms (Fuller et al. 2008a).

Most sponge species in the North Atlantic occur as isolated individuals; however, in some areas, they can form dense, multispecies communities (ICES 2009), providing habitat for many other species. These sponge grounds are primarily made up of large erect sponges. An International Council for the Exploration of the Sea (ICES)/NAFO working group identified 25 sponge species that are structure-forming in certain environments. Unfortunately, most of the information on sponges from St Anns Bank does not identify sponges to the genus or species level. For that reason, a general distribution of sponges in the area is provided.

Biology and Habitat Preferences of Sponges

Sponges are filter feeders and have complicated interior canal systems to filter food from the water (Bergquist 1978). They are usually found on hard bottom habitats, such as cobbles, gravel and corals, although a few species have specialized spicules that allow them to live on soft, muddy bottoms. Sponges differ from deep-water corals in that they do not have polyps that can close: they continuously filter. Some groups of carnivorous sponges also have modified spicules to capture prey. They can be smothered by debris in the water, which can filter into their bodies.

Sources of information

There is little published information on the corals and sponges of St Anns Bank. As a result, most of the information found here was taken from records of recent scientific missions to the St Anns Bank area. More information on those missions can be found in Section 3.3.2. Other information was taken from the Maritimes Region coral and sponge database described in Cogswell et al. (2009). Catches of corals and sponges in the snow crab survey are also described, though these taxa are not identified to species in this survey.

Distribution of corals and sponges

The variety of habitats within the St Anns Bank area supports a variety of species of corals and sponges. Soft corals (Alcyonacea), gorgonian corals (Gorgonacea), and sea pens (Pennatulacea) have been reported within the boundaries of the AOI, as have a variety of sponge species.

The coral and sponge database maintained by DFO Maritimes and described in Cogswell et al. (2009) contained 68 records of corals and sponges in the St Anns Bank area as of July 2011, representing 102 individual specimens. This does not include records in the database from local ecological knowledge, which are described later in this section. The records are incidental catches from research trawl surveys and records from commercial fishing trips with observers. Records from two recent research missions have not yet been entered into the database (Andrew Cogswell, DFO Science, personal communication, July 2011) Table 3.4.2-1 (below) lists the taxa, the number of specimens caught, and the source of the record.

Table 3.4.2-1. Records of coral and sponges in the St Anns Bank area from fisheries observer and research vessel reports. Database described in Cogswell et al. (2009).

Taxa	**Common name**	**Source of Information**	**Number of specimens***
Anthozoa (coral)**		Fisheries observer	42
Anthozoa (coral)		Research vessel survey	4
Gersemia rubiformis	Sea strawberry (soft coral)	Research vessel survey	8
Neptheidae unidentified	Soft coral	Research vessel survey	5
Paragorgia arborea	Bubblegum coral (gorgonian)	Research vessel survey	1
Pennatula borealis	Sea pen	Research vessel survey	3
Pennatulacea unidentified	Sea pen	Research vessel survey	14
Porifera unidentified	Sponge	Research vessel survey	24
Lophelia pertusa	Spider hazards (hard/stony coral)	Research vessel survey	1

*Some records did not indicate the number of specimens; those records were counted as one specimen.
**Some records only identified the taxa to the class Anthozoa, while indicating that it was thought to be a coral.

Records of sea strawberries and other soft corals are throughout the AOI, mostly from depths above 150 metres (Figure 3.4.2-1). Records of unidentified anthozoa are similarly distributed. The sole record of *Paragorgia arborea* is from an area near the southwestern part of St Anns Bank (Figure 3.4.2-1). The record of *Lophelia pertusa* is considered questionable, as it is from a bank habitat that does not match the preferred preferences of the species. A subsequent benthic research mission to the area visited the location and did not find *Lophelia pertusa* (Andrew Cogswell, personal communication, 14 July 2011).

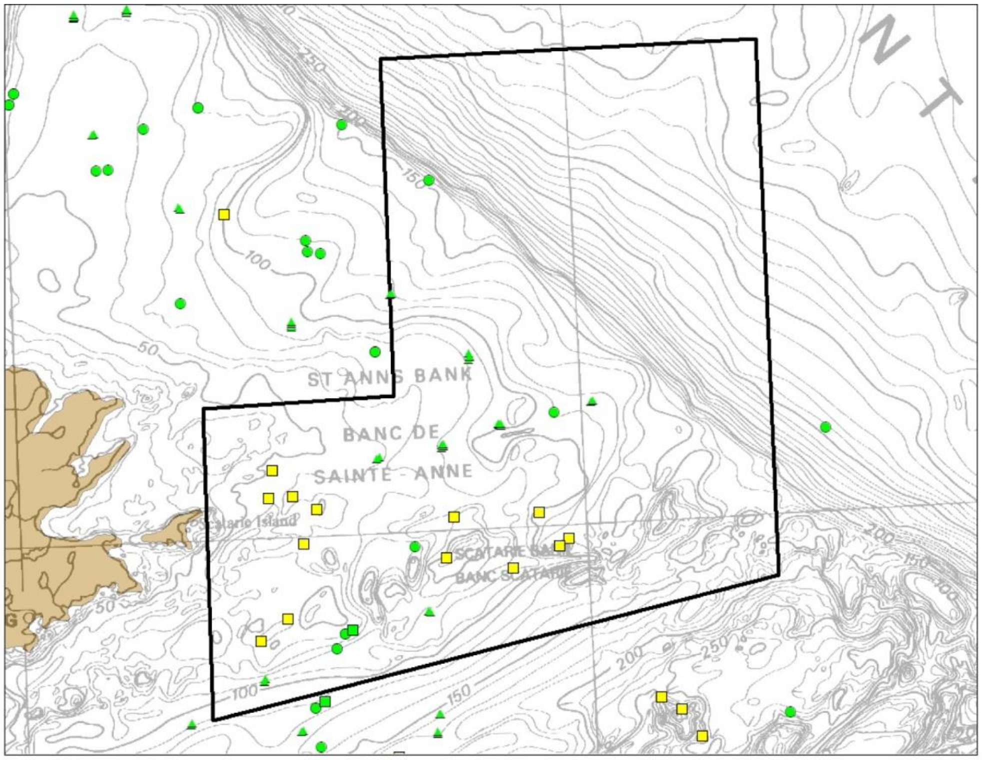


Figure 3.4.2-1. Coral records (other than sea pens) from the Maritimes Region coral and sponge database. Triangles indicate records identified only as “corals” or “anthozoa”, circles indicate soft corals, and squares indicate hard corals. Green records were identified by fisheries observers or on science cruises while yellow records were identified by fishermen interviewed by Gass (2002).

A study that looked at the distribution of cold-water corals in Atlantic Canada using scientific and local knowledge identified the edge of St Anns Bank as an area with corals, based on fishermen’s knowledge (Gass 2002; Gass and Willison 2005). In general, fishermen identified the large gorgonian corals as trees and did not identify particular species. However, fishermen identified both trees in general and the large gorgonian *Primnoa resedaeformis* specifically from the St Anns Bank area. In general, the local ecological knowledge (LEK) records from St Anns Bank appear to follow the 100-metre isobath (also shown in Figure 3.4.2-1).

The sea pen records are distributed from the edge of St Anns Bank into the Laurentian Channel, though the majority of records are along the slope, around 150 m depth or below (Figure 3.4.2-2). Kenchington et al. (2010) identified a significant concentration of sea pens in the southeast corner of the AOI (Figure 3.4.2-2), based on catches in the RV survey. As noted in Section 3.3.2, some large numbers of (unidentified) sea pens have also been caught in the deep water stations of the snow crab survey (Figure 3.4.2-2). They were the most common species caught in one station on the slope, Station 9 (see Section 3.3.2 for maps), with a total of 2910 sea pens recorded over five years.

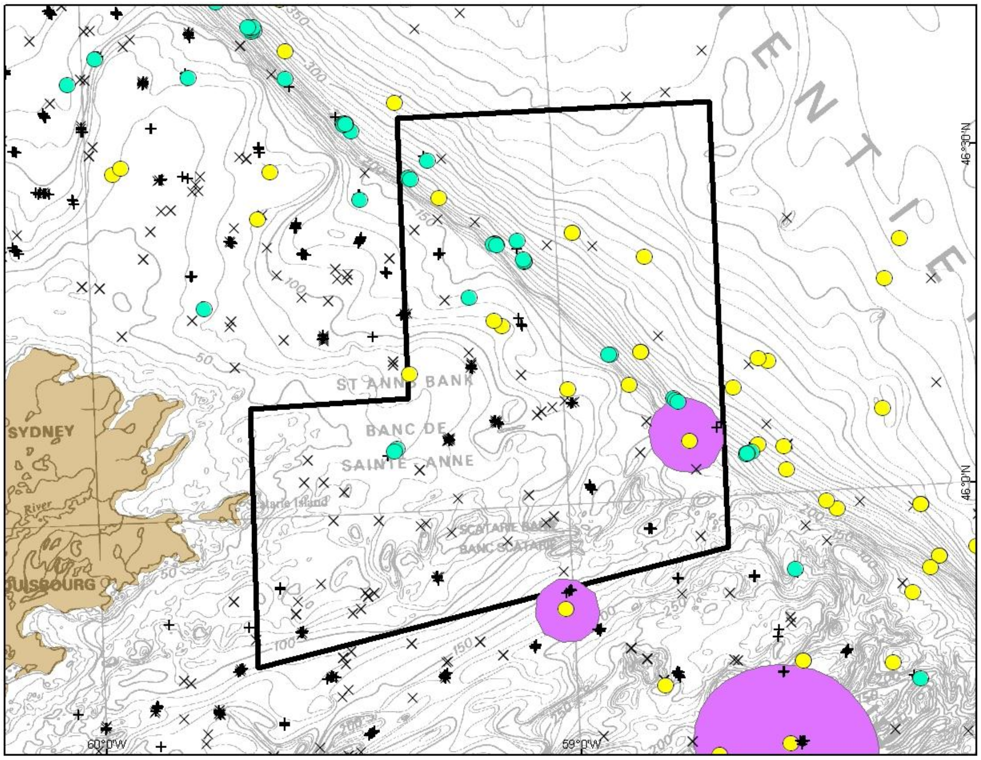


Figure 3.4.2-2. Sea pen catches recorded in the snow crab survey (green circles, crosses represent sets with no sea pens) and those in the Maritimes Region coral and sponge database (yellow circles, X's represent records of other taxa in the database). Areas with significant concentrations of sea pens identified by Kenchington et al. (2010) are shown in pink.

Sponges (Porifera) are distributed throughout the area, from bank habitats to the Laurentian Channel. In total, more than 30 different sponges were identified in the preliminary analysis of the stations within the AOI; most have not yet been identified to the species level. S. Fuller (personal communication, August 2012) suggests that there are areas of dense sponge populations in the AOI; Demosponges and possibly *Mycale spp*. similar to other patches of sponge found in similar depths and bottom substrate off Yarmouth (Kenchington et al. 2007).

Kenchington et al. (2010) identified areas of significant sponge concentration in the Maritimes Region. Although large, structure-forming sponges have not been identified in the AOI, significant amounts of sponges in the AOI were identified, based on catches in the RV survey (Figure 3.4.2-3). This area of the St Anns Bank AOI also appears to have among the highest catches of sponges in the snow crab survey (Figure 3.4.2-3).

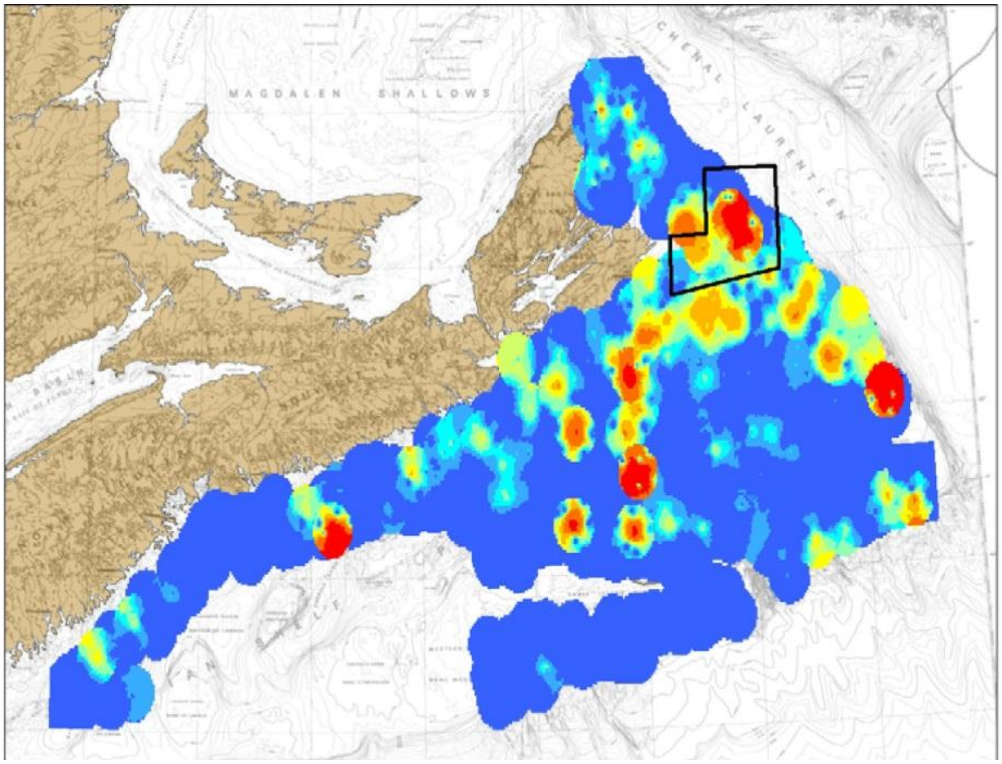


Figure 3.4.2-3. Sponge catches in the snow crab survey, interpolated as described in Section 3.4.1 (DFO unpublished data).

In addition to these published records, preliminary analysis of video and photos of two recent research cruises have added to our knowledge of the corals and sponges of the area. Taxa were identified to the lowest level possible for each station from photographs taken during a 2010 research mission (DFO unpublished data – stations and locations described in Section 3.3.2). An encrusting sponge was among the top ten taxa at six of the nine stations sampled, while an unidentified sponge was among the top ten taxa at two of the stations and an unidentified stalked sponge was common at one station. Soft corals from the family Nephtheidae were common at two of the nine stations; both of these stations were shallow bank habitats.

Photographs from two stations from a 2009 research mission to St Anns Bank have been analyzed. Both stations were relatively shallow (< 50 m) and in the western portion of St Anns Bank. Sponges were among the more common marine invertebrates and were observed in every photo. Preliminary results suggest that fifteen different sponge taxa were observed at those stations. They have not yet been identified as to species. Soft corals from the family Nephtheidae were also relatively common, with most being *Gersemia* spp. (sea strawberries). Fourteen individual sea pens (*Anthoptilum grandiflorum*) were identified at the two stations. Skeletal fragments of the large gorgonian coral *Primnoa* were identified at one of the stations.

Role as Habitat
A DFO report (2010a) concluded that “Corals and sponges form complex, three-dimensional biogenic structures that directly and indirectly influence the occurrence and abundance of many fish and invertebrate species.” Corals form complex, three-dimensional habitat, and provide shelter from predators or from high current regimes for many other species.

Particular species associated with the corals and sponges of St Anns Bank are not known. Buhl-Mortensen and Mortensen (2005) described a diverse fauna associated with deep-water gorgonian corals (*Primnoa resedaeformis* and *Paragorgia arborea*) from several areas of Atlantic Canada. These organisms lived on the surface of the corals and inside the skeleton. The corals were found to provide substrate on which other organisms could attach and were also used as a refuge from currents and predators. The fauna was dominated by suspension feeders. While there are a couple of records that indicate that St Anns Bank may have large gorgonian corals, such as those that provide important habitat, there have been no observations from directed research of dense concentrations of structure-forming corals.

Status and Trends
There is no information available on the overall status of corals and sponges of St Anns Bank, or on any recent population trends. Fishermen report general decreases in abundances of coral on the Eastern Scotian Shelf (Gass and Willison 2005).

Sources of Uncertainty
Little is known about the benthic communities of the deeper parts of the AOI. As well, the benthic research that has recently taken place has not been fully analyzed. This research did not cover the entire AOI and took place at depths of 200 metres and above. Most coral records from off Nova Scotia come from deeper depths. It is likely that research in deeper parts of the AOI would increase the number of records and the number of species recorded for the AOI.

3.4.3 Lobster
Lobsters are large, long-lived marine crustaceans that support the most valuable commercial fishery in Canada.

Geographic Range and Habitat Preferences
The Atlantic lobster (*Homarus americanus*) is found from Long Island Sound to the southern part of the Labrador Sea, from the intertidal zone to the edge of the continental shelf. Most of the lobster fishery takes place in shallow water, less than 30 m deep, where lobsters are more concentrated. But lobster are also found and fished in much deeper water, down to 450 m depth (DFO 2009b).

Lobster is found in waters ranging between –1.5 and 24 ºC (DFO 2009b). In summer they move to shallower, warmer waters; in winter, most move to deeper water to avoid ice, cold, and winter storms. Lobsters use a wide range of habitats, including sand, gravel, and cobble seabeds, but prefer bottom types with boulders and larger grain sizes (Tremblay et al. 2009).

Population or Stock Definitions

From a management perspective, St Anns Bank is within lobster fishing area (LFA) 27, the lobster fishery management unit encompassing most of eastern Cape Breton. The recent framework assessment for lobster on the Atlantic coast of Nova Scotia identified three assessment units: LFA 27, LFAs 28–32, and LFA 33 (Tremblay et al. 2011).

Coastal lobster populations are generally believed to be “locally self-sustaining, with replenishment through reproduction rather than dispersal” (Bowlby et al. 2008). In particular, long-distance, directional movements by adult lobsters are rarely seen in tagging studies (Bowlby et al. 2008) in the southern Gulf of St. Lawrence and along coastal Nova Scotia. Lobsters are likely to move longer distances in the Gulf of Maine (Tremblay et al. 2011). However, it is known that larval lobster can disperse over long distances, such that there are likely to be genetic connections between lobster populations at scales larger than the LFA (Chassé and Miller 2010).

Lobster is fished primarily in inshore waters less than 30 m, with some fishing occurring up to 50 m depth, on the western edge of the AOI. This largely reflects the distribution of the species during the fishing season (May 15–July 15). During the fall and winter, lobster in the St Anns Bank area may move further into the AOI, though their distribution in the site would likely be limited by cold water below 50 to 100 m depth (John Tremblay, DFO Science, personal communication, August 2011) (Figure 3.4.3-1).

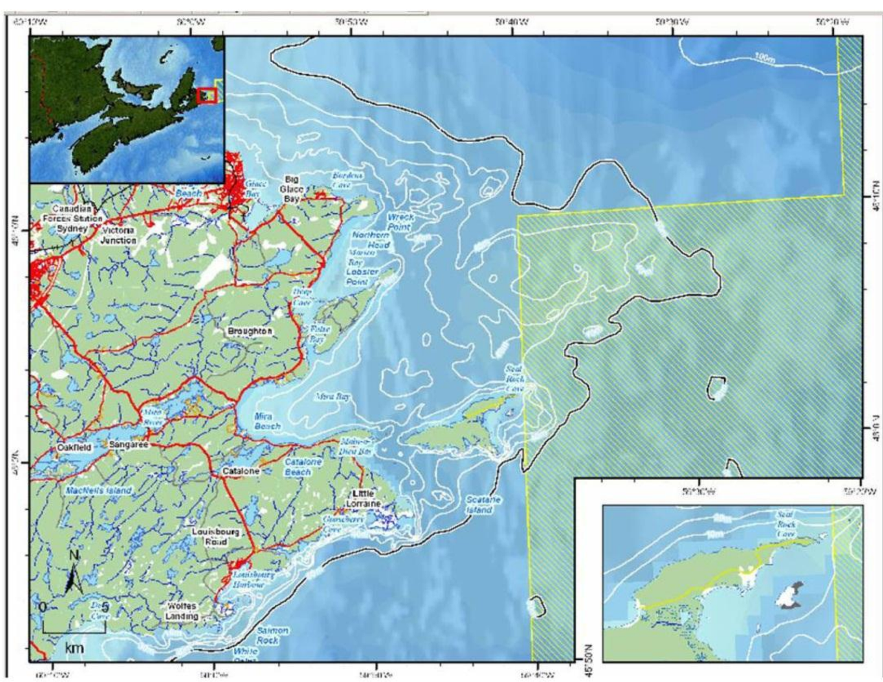


Figure 3.4.3-1. The coastal area adjacent to St Anns Bank, with yellow hatching representing the St Anns Bank AOI. The dark line is the 50 m contour, representing the limit to lobster fishing and the likely summer lobster distribution in the AOI.

Biology

Productivity
Lobsters in Maritimes Region generally take 8–10 years to reach the legal size of 82.5 mm carapace length (DFO 2010b). Females reach reproductive maturity at different sizes and ages through their range. In LFA 27, recent estimates of the size at which 50% of the females are mature range from 71 to 76 mm carapace length (Reeves et al. 2011). Mature females produce eggs every two years on average, and eggs are carried by females for nine to twelve months (Tremblay et al. 2011). The number of eggs produced varies greatly and increases with the size of the female, ranging between a few thousand and tens of thousands.

Natural Mortality
Natural mortality (M) has been estimated for some nearshore populations and is generally assumed to be between 10 and 15% for all fully recruited, legal-sized lobsters and, in most models is assumed to be the same over time and for all size groups. However, in reality, this could vary greatly depending upon habitat, predator abundance, and lobster size (Tremblay et al. 2011).

Ecosystem Interactions
Predator-prey relationships of lobster have been modeled in the southern Gulf of St. Lawrence. Hanson (2009) found that predation on planktonic stages of lobster was rare and predation upon benthic stages of lobster was also uncommon, and was primarily due to shorthorn sculpin or cannibalism. A number of other species, including cod, cunners, flounder, sculpin, wolffish, ocean pout, monkfish, and dogfish have been documented to prey on lobsters, though fully grown lobsters are believed to be eaten fairly rarely (DFO 2009b).

Around 50% of the prey of larger (> 40 mm) lobster in the southern Gulf of St. Lawrence was rock crab or moulted rock crab carapaces (Hanson 2009). Small sea stars and smaller lobsters or moulted lobster carapaces were also common prey items, and a minimum of 35% of the lobster prey biomass was from scavenging. In southwestern Nova Scotia, a different dietary pattern was found, with mussels being the most common prey item out of a broad range of molluscs, crustaceans, echinoderms, and polychaetes (Elner and Campbell 1987).

Fisheries and Other Human Activities
In 2009, there were a total of 524 licences in LFA 27 out of 2992 in the Maritimes Region (DFO 2010b). The fishery is effort-managed rather than quota-managed, with a limited number of licences and a trap limit of 275 traps per fisher. A minimum legal size and restriction on retention of females with eggs is also in place. The season runs from May 15 to July 15 (DFO 2010b). Overall landings peaked around 1990, at 3790 t, but recent landings have been strong compared to the long-term average with recent years (2008–2010) averaging over 2500 t per year (DFO 2011c).

Other human activities in the coastal zone, including exploration for oil and gas and harbour dredging, have raised concerns about potential effects on various life history stages.

Status and Trends

Stock Status

Recent landings in LFA 27 are less than the peak in the late 1980s/early 1990s, but about 1.3 times the mean for the period 1985–2004 (DFO 2011c). In general, the recent increases in catch are believed to represent a significant increase in lobster abundance over the long-term mean (Tremblay et al. 2011; Boudreau and Worm 2010).

Abundance /Biomass in the AOI

Over the last ten years, LFA 27 has generally had the third highest landings of LFAs in the Maritimes Region (DFO unpublished data; also note that LFAs vary considerably in size). From 1999 to 2009, the catch from LFA 27 represented between 6 and 9% of the overall lobster catch in the Maritimes, an average of 1763 t per year. Recently fishers have begun to record their catch by grid cells, a series of strips along the coast (Figure 3.4.3-2). The lobster fishing area of St Anns Bank is within grid cell 350. Reporting by grid cell has been recently implemented and a small proportion of landings may be misreported or not reported by grid cell, but 5.4 to 6.9% of the landings with a grid cell recorded in LFA 27 from 2008 to 2010 were from grid cell 350. The area to the immediate north, grid cell 351, is a much more important lobster fishing area within the LFA.

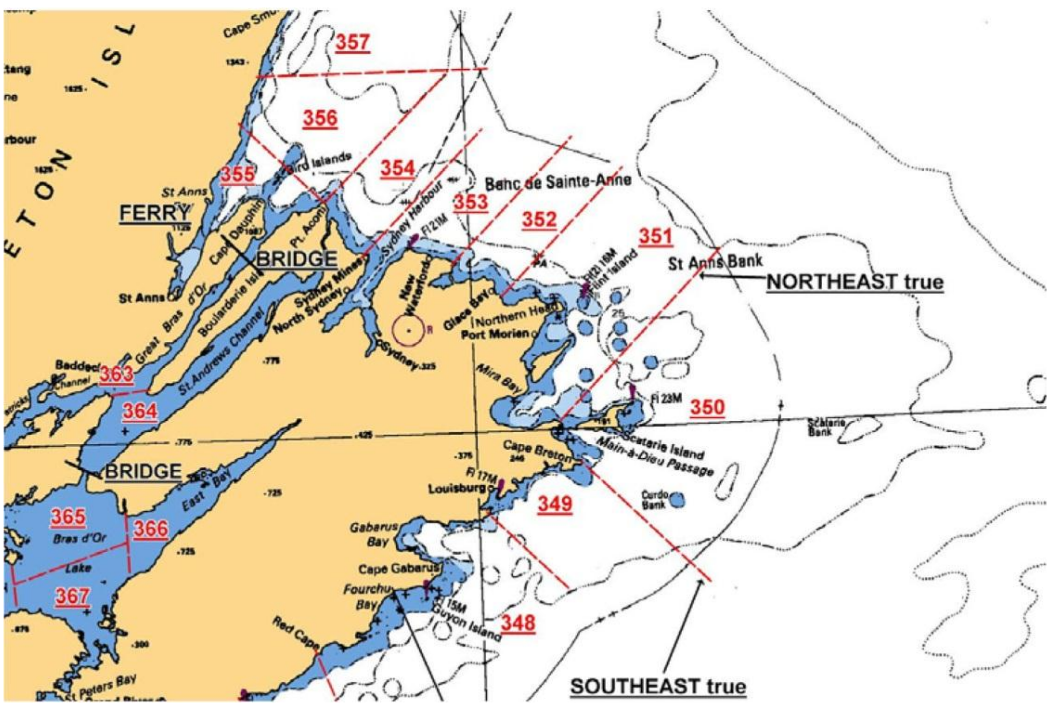


Figure 3.4.3-2. Lobster grid cells in the area of the St Anns Bank AOI.

Other than this coarse information based on the fishery, there is no information (such as from surveys, etc.) that would allow evaluation of the importance of the St Anns Bank AOI to lobster populations in LFA 27.

Sources of Information
Most information used to monitor and assess lobster populations and the fishery in the Maritimes comes from the fishery (Tremblay et al. 2011). There is also a significant partnership between DFO and the Fishermen & Scientists Research Society (FSRS). Through the FSRS, a significant number of fishermen throughout the province, including LFA 27, fish a number of scientific lobster traps along with their commercial traps. These traps retain undersized lobsters, which are counted and measured as an index of future recruits to the fishery (FSRS 2011; Tremblay et al. 2011).

Sources of Uncertainty
The use of the AOI, particularly deeper areas, by lobster in the winter is unknown, and currently there are no data sources that could be used to resolve this question (J. Tremblay, personal communication, August 2011).

3.4.4 Snow Crab

Snow crab are large cold-water crabs that support an important commercial fishery on the Eastern Scotian Shelf. They are sexually dimorphic, with only the larger males being caught in commercial fisheries (carapace width of 9.5 cm and over). Females are generally too small to be available to the gear (DFO 2009c).

Geographic Range and Habitat Preferences
In the northwest Atlantic, snow crab range from northern Labrador to the Gulf of Maine. They are more common in colder waters of the Eastern Scotian Shelf than they are further south, on the Western Scotian Shelf for example.

Snow crab are broadly distributed on the Scotian Shelf, but they prefer soft, muddy habitats, and depths between 60 and 280 m (Choi and Zisserson 2011). There are differences in distribution by sex and life history stage, with young juveniles and female snow crab found in shallower areas (as in the more inshore parts of St Anns Bank) and commercially fished males found in deeper areas. They also prefer temperatures between -1 and 6 ºC. Temperature is thought to be a major determinant of their distribution in this region and of their recent increase in abundance in the region (Boudreau et al. 2011).

Populations or Stock Definitions
Snow crab on the ESS are assessed in three management units: Northern–Eastern Nova Scotia (N–ENS), Southern–Eastern Nova Scotia (S–ENS), and Crab Fishing Area 4X (Figure 3.4.4-1). However, these are fishery management units based on political, economic, and historical factors and have little biological basis (Choi and Zisserson 2011). Choi and Zisserson (2011) consider that snow crab on the Scotian Shelf are likely a single, autonomously reproducing population, though population dynamics can differ on a more local scale, depending upon temperature conditions and exploitation patterns.

The St Anns Bank AOI is mainly within the N–ENS management area, north of Scatarie Island, but the southern part of the AOI is in the S–ENS management area (Figure 3.4.4-1). Because trends in the N–ENS and S–ENS management areas have differed in recent years, they will be considered separate ecosystem components for the purposes of the Ecological Overview.

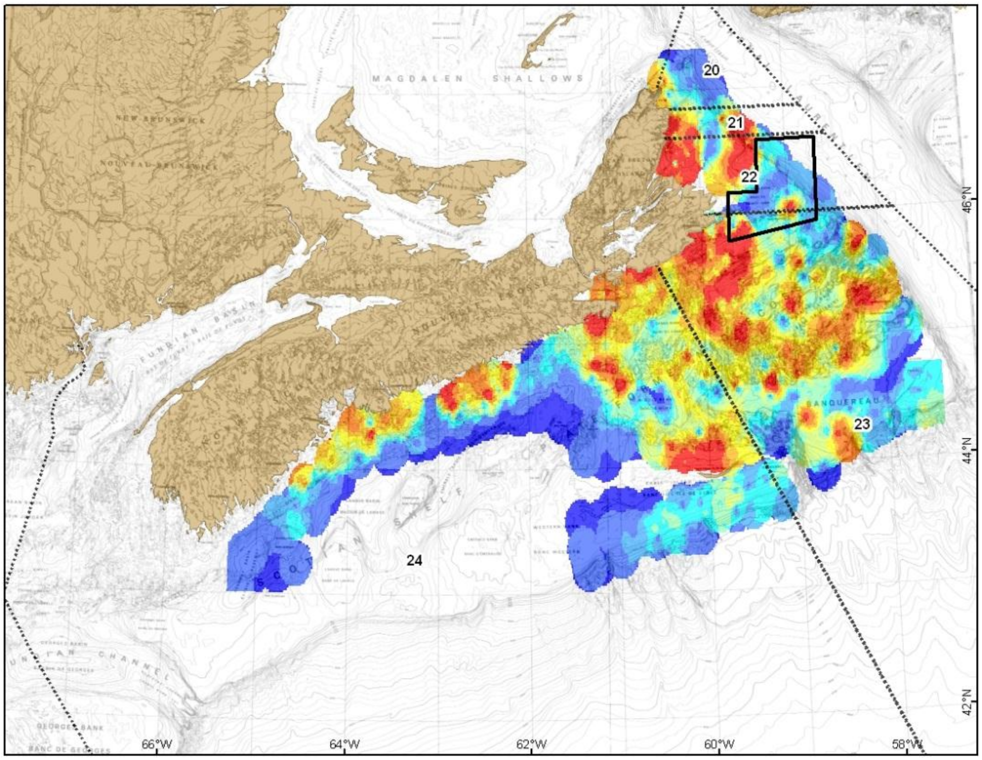


Figure 3.4.4-1. Distribution of snow crab on the Eastern Scotian Shelf based on the snow crab survey from 2004 to 2007. Areas with highest catch are shown in orange-red.

<u>Snow Crab in St Anns Bank</u>

Snow crab are very widespread within the AOI. For example, they were found in every set of the snow crab survey inside the AOI from 2004 to 2010 (see Section 3.1 for details), and also in 41 of the 62 summer RV survey sets in St Anns Bank from 1999 to 2009.

Overall, St Anns Bank is not a very important habitat for snow crab on the Scotian Shelf (Figure 3.4.4-1). However, there is an area in the southeastern corner of the site that has high densities of snow crab on a regular basis.

The Glace Bay Hole deserves mention with respect to snow crab and St Anns Bank. This refers to an area of deeper water just north of the AOI. This is historically an area of high abundance for snow crab and an important snow crab fishing area. This area can be seen as an area of high abundance immediately northwest of the site in Figure 3.4.4-1 and as an area of snow crab catch in Figure 3.4.4-2.

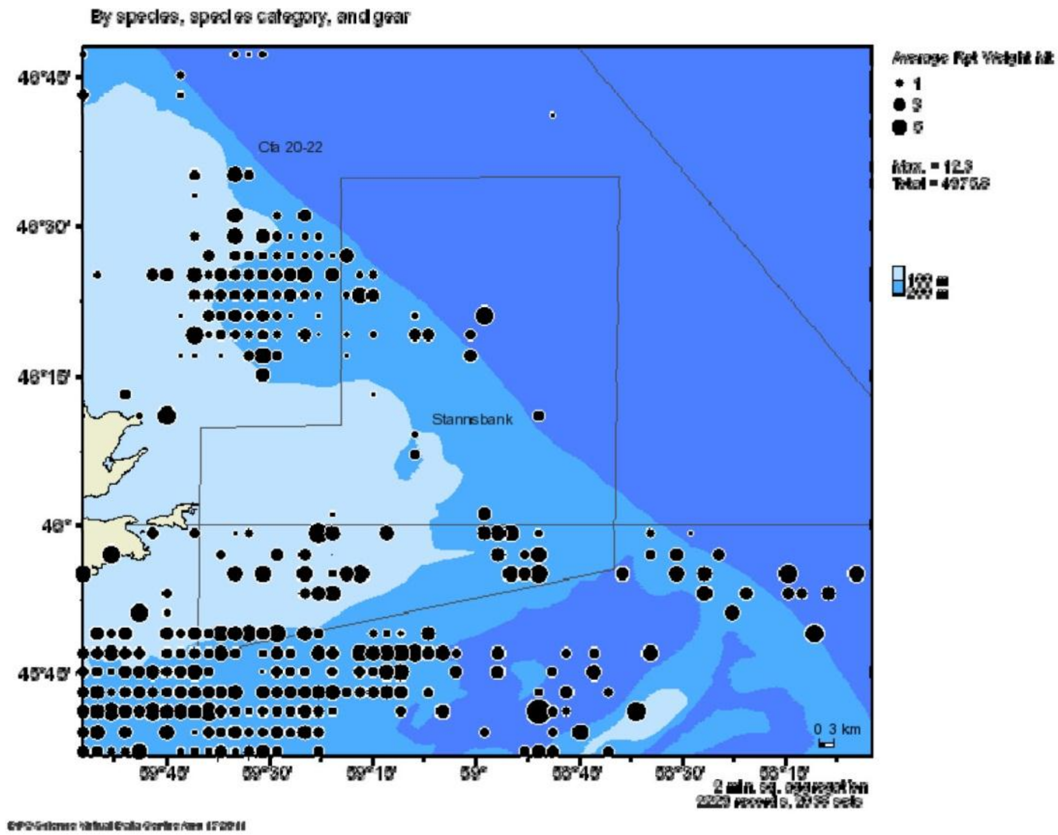


Figure 3.4.4-2. Reported snow crab catch from commercial fisheries in the St Anns Bank area from 2002 to 2011 (DFO MARFIS database).

Biology

Productivity

Snow crab are highly fecund, with as many as 100,000 eggs being carried by a female in some cases (Choi and Zisserson 2011). After fertilization, the eggs are brooded by the female for up to two years. They are thought to carry two broods in a lifetime on average (Sainte-Marie 1993). Maturation is at approximately 10–12 years for males while females mature earlier at 4–6 years (DFO 2009c).

Natural Mortality

Wade et al. (2003) suggested that instantaneous mortality rates for southern Gulf of St. Lawrence snow crab > 95 mm carapace width are within the range of 0.26 to 0.48. At earlier life history stages, this mortality rate is likely to be much higher (Kuhn and Choi 2011).

Ecosystem Interactions

The primary prey of snow crab are shrimp, fish (capelin and lumpfish), starfish, sea urchins, worms, detritus, large zooplankton, other crabs, ocean quahog, molluscs, sea snails, and sea anemones (DFO 2010c).

Snow crab are preyed on mainly by groundfish. Historically, the most important predators have been Atlantic halibut, skates (especially thorny skate), Atlantic cod, seals, American plaice, squids, and other crabs, in that order (Bundy 2004). The fish species found to most frequently prey upon snow crab was the Atlantic wolffish (3.5% of the guts sampled since the year 2000 contained snow crab, n=253 guts) (Choi and Zisserson 2011). However, because of their overall low numbers, it is unlikely that wolffish predation is an important mortality source for snow crab.

Snow crab have been a dominant macro-invertebrate on the Eastern Scotian Shelf since the decline of groundfish in the early 1990s (DFO 2010c). Their overall importance to the ecosystem is not clearly understood, but due to their high abundance, it is likely that they are an important predator in benthic systems in this region (Choi and Zisserson 2011). Also, because they eat detritus, they may represent an important link moving energy from the seafloor back into demersal systems. Another hypothesis related to the importance of snow crab is that the high abundance of juvenile snow crab may be a factor in the increase in lobster abundance in the Eastern Scotian Shelf since lobster are known to prey on juvenile snow crab (Choi and Zisserson 2011). Higher local densities of some groundfish are also found in areas where small immature crab are found in high densities (such as the southeast corner of St Anns Bank), possibly because of the food source represented by the crab (Choi and Zisserson 2011).

Fisheries and Other Human Activities

Snow crab supports the second most valuable fishery in Atlantic Canada and the third most valuable in Nova Scotia (DFO 2010c). Catches on the Eastern Scotian Shelf increased from about 1750 t in 1997 to a peak of 11,428 t in 2009 (Choi and Zisserson 2011). The fishery includes 203 licences, of which 78 are in the N–ENS region and 116 in the S–ENS region (Choi and Zisserson 2011). The fishery is prosecuted with conical traps. Only mature male snow crabs are retained and very low bycatch is observed (Choi and Zisserson 2011). Since 2005, about 10–30 t per year of snow crab have been caught in the St Anns Bank area in the commercial fishery (DFO MARFIS database).

There is some bycatch of snow crab in other fisheries in the region. Lobster traps and Danish seines are known to catch snow crab in some cases, though neither are quantified (Choi and Zisserson 2011). Snow crab share habitat with northern shrimp to a large extent, and though few or no snow crab are retained in the trawl due to the use of separator grates, some unrecorded mortality may occur (Fisheries Diversification Program 2001).

There are several other potential sources of mortality for snow crab. In particular, bitter crab disease, caused by a parasitic dinoflagellate infection (*Hematodinium* sp.), results in both mortality of snow crab and meat with a bitter taste. The disease has been found in Atlantic Canada but does not seem to have affected the population or the fishery in this region yet, as it has in other parts of the world such as Alaska (Choi and Zisserson 2011; Mullowney et al. 2011).

Status and Trends
Estimates of fishable biomass have generally been low in N–ENS in recent years and increasing in S–ENS (Figure 3.4.4-3). In N–ENS, representing most of the AOI area, landings increased over the years 1995–2002 (Figure 3.4.4-4), after which fishable biomass and the TAC (total allowable catch) declined considerably. Most recently, fishable biomass increased in 2008 to 4836 t in N–ENS, though it declined again to 1342 t (95% C.I.: 946–2059 t) in 2009.

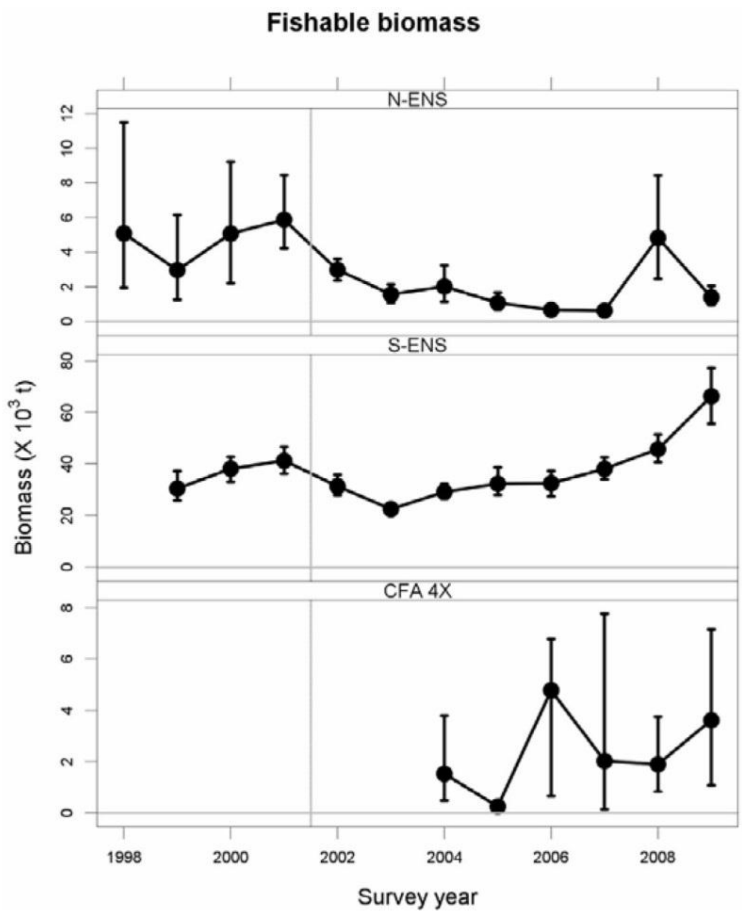


Figure 3.4.4-3. Temporal variations in fishable biomass estimates. Error bars are 95% confidence intervals about the estimated total biomass. The vertical line near 2002 indicates the period in which trawl surveys changed from a spring to an autumn sampling period (Choi and Zisserson 2011).

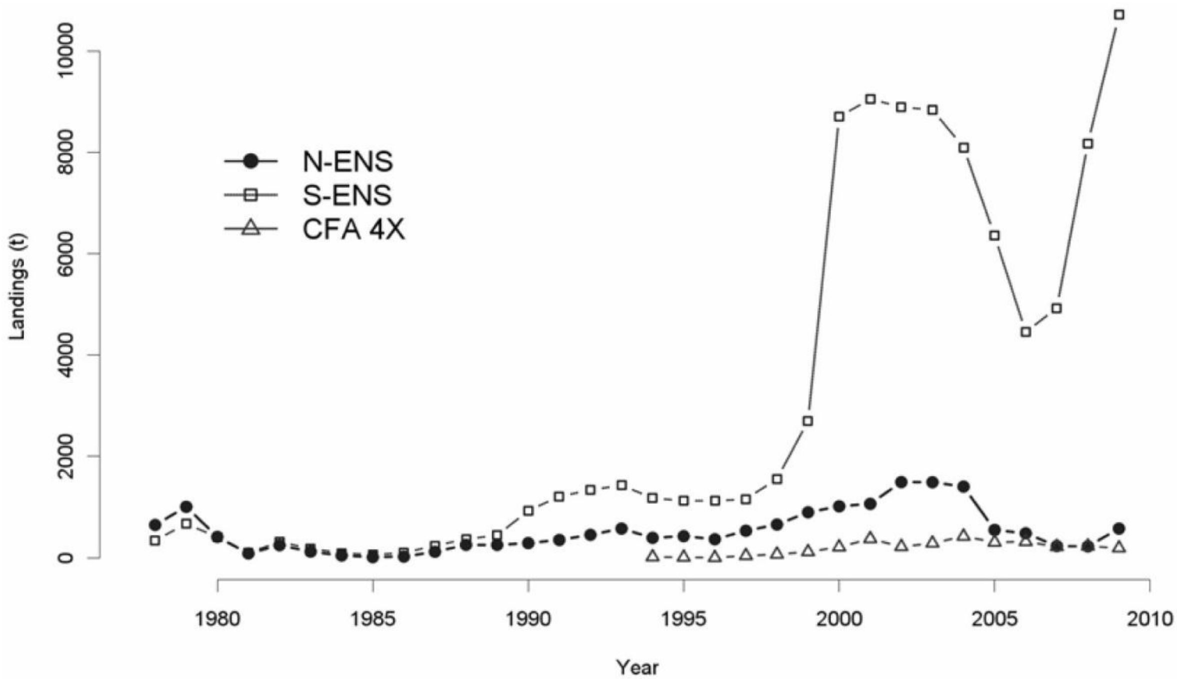


Figure 3.4.4-4. Temporal variations in the landings of snow crab on the Scotian Shelf. Note the sharp increase in landings associated with dramatic increases to TACs and a doubling of fishing effort in the year 2000 (Choi and Zisserson 2011).

In S–ENS, the fishable biomass has generally been increasing in recent years and the catch has increased markedly since 2000 (Figures 3.4.4-3 & 3.4.4-4). The fishable biomass in 2009 is the record in the time series at 66,200 t, and catch in 2009 was the record at 10,645 t. The snow crab in S–ENS is considered to be healthy and fished at a sustainable level (Choi and Zisserson 2011).

Sources of Information
The most important source of information about snow crab in this region is the snow crab survey, described in Section 3.1 and in Choi and Zisserson (2011). Snow crab are also recorded in the RV survey. Other research is undertaken sporadically to investigate particular issues related to snow crab.

Sources of Uncertainty
While the population status of snow crab on the Eastern Scotian Shelf is generally well understood, there is significant uncertainty about the earlier stages of life, particularly pelagic stages. Also, moult cycles and reproductive cycles are not well understood in this region, where snow crab are living at the southern extreme of their range.

3.4.5 Waved whelk
Waved whelk or common whelk (*Buccinum undatum*) is a large gastropod mollusc (i.e., a snail) that is commercially fished in some parts of Atlantic Canada.

Geographic Range and Habitat Preferences

In the western North Atlantic, waved whelks are broadly distributed, inhabiting subtidal habitats from New Jersey to Labrador in the northwest Atlantic (DFO 2009d). Though they are mobile, it is generally believed that overall adult dispersal is low (DFO 2009d). Females lay their eggs inside capsules, which they attach to hard structures, and the embryos emerge as miniature crawling whelks (DFO 2009d). Therefore, due to the absence of a pelagic stage, overall lifetime dispersal is much lower than in many marine invertebrates.

Waved whelks prefer colder water and tolerate salinities down to approximately 20 ppt (DFO 2009d). They can be found at depths of more than 100 m and on various types of substrates (boulders, cobbles, mud), but greatest densities have been found on muddy bottoms at 15–30 m depth (DFO 2009d).

Based on the snow crab survey, whelks (all species) are particularly abundant on Banquereau, with other localized areas of high catch in Sydney Bight and around Middle Bank (Figure 3.4.5-1). However, *Colus stimpsoni* is also found with *Buccinum* and is reported to be the more dominant species on Banquereau (Kenchington and Glass 1998). St Anns Bank was not identified as a hot spot in this survey. Within the site, higher catches of whelks have been documented on the slope in the southeast corner (Figure 3.4.5-1).

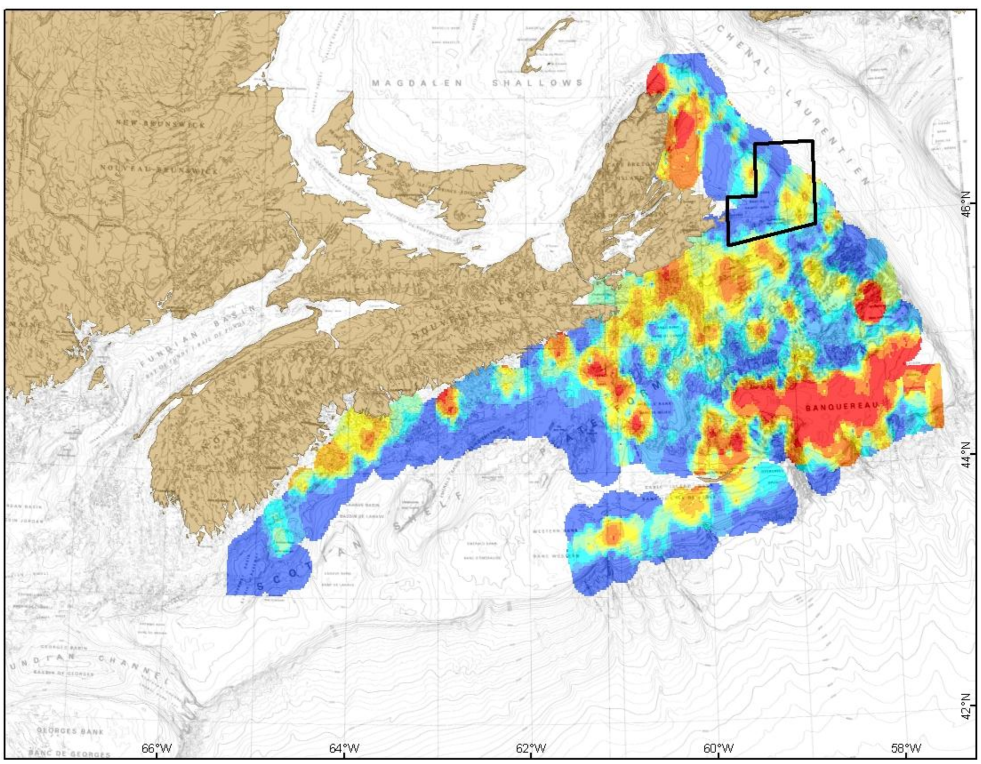


Figure 3.4.5-1. Whelk catch in the snow crab survey.

Test fishing for whelk took place in eight locations off Cape Breton and Canso in 2008 (Rawlings et al. 2009). In this experiment, catches on three trips south of Scatarie Island, inside or near the western boundary of the AOI, were much higher than at any other site. The only commercially viable concentrations of whelks sampled were in this area, indicating a much higher population of whelks in this area. Since that time, there has been no further test fishing, so it is unknown whether high densities of whelks in this location are persistent.

Populations or Stock Definitions

In general, stock or population structure of waved whelk off Nova Scotia has not been determined. However, it is believed that due to the limited dispersion of these animals, distinct populations would exist on the order of tens to hundreds of kilometres (DFO 2009d). There is differentiation in the biology of whelks (size, growth rate, sex ratios, and shell morphology) at small scales that appears to support this conclusion (Kenchington and Glass 1998). Kenchington and Lundy (1996) concluded that “[w]helks appear to form small, locally adapted stocks, and local management zones may provide a unit consistent with the nature of the resource.”

Biology

Productivity

Waved whelk mature between the ages of four and seven years, or 50–75 mm, depending on their gender and location (DFO 2009d). It is known that females do not always reproduce every year. Large numbers of eggs (an average of 340,000 per egg mass (Martel et al. 1986)) laid inside multiple capsules are laid together in a mass. Many of those eggs are unfertilized and are eaten by the embryonic whelks, so less than 1% of eggs laid hatch (Martel et al. 1986).

Natural Mortality

No estimates of natural mortality rates in *B. undatum* were found, but they are vulnerable to naturally occurring parasites, in addition to predators (DFO 2009d). Egg masses are also quite vulnerable to predation, particularly by sea urchins (Dumont et al. 2008).

Ecosystem Interactions

Whelk are predators with a broad diet. They are known to eat live animals including polychaetes and bivalves, but it is believed that remains of dead animals are also a main food source (DFO 2009d). Kenchington and Glass (1998) note that because waved whelk are a predator, they are higher on the food chain than the many filter-feeding molluscs that support large commercial fisheries, for example, scallops. Whelks might be expected to contribute to limitation of prey populations such as clams, as well as to other predators that they compete with, for example, starfish (Kenchington and Glass 1998).

Noted predators of adult whelk are sea stars, crabs, lobsters, and fish including wolffish and cod (DFO 2009d). Lobster predation has been noted, particularly in the Bay of

Fundy, while sea stars seem to be more important predators in the Gulf of St. Lawrence (DFO 2009d).

Fisheries and Other Human Activities

In the Maritimes Region, whelk fishing is in the experimental stage. Fishing trials with standard conical traps were completed off Cape Breton in 2006 and 2008, with the 2008 trials consisting of seventeen fishing trips by nine vessels. Since 2008, very little whelk fishing has occurred, for reasons related to management and processing/marketing. Commercial fisheries do occur off southern Newfoundland (mainly in subdivision 3Ps) and in the Gulf of St. Lawrence off Quebec.

Waved whelk are considered to be highly vulnerable to overexploitation due to their high catchability, slow reproduction, and limited dispersal in all life stages, and extirpation of commercially-exploited populations has occurred in Europe (DFO 2009d). Kenchington and Glass (1998) propose that permanent closed areas be established to protect broodstock and egg-laying habitat if commercial whelk fishing is pursued on the Scotian Shelf.

Other Human Activities

Waved whelks are frequently caught as bycatch in lobster fishing in southwest Nova Scotia (Kenchington and Lundy 1996). den Heyer et al. (2010) also report that waved whelk were a relatively common bycatch species in lobster traps along the Atlantic coast of Nova Scotia, but were much more frequently caught along the South Shore (LFA 33) than off Cape Breton.

Waved whelk are also known to be susceptible to contamination of marine waters by tributyltin compounds, which were used as marine anti-biofouling agents in the shipping industry until recently. Some whelks in areas exposed to these chemicals develop imposex, a condition in which male sex organs develop in the female gonad system, leading to partial or complete sterility in the female whelk. Sydney Harbour is known to be highly contaminated with tributyltin compounds, and imposex was documented in all *Nucella lapillus* snails sampled in Sydney Harbour in 1995. As far as could be determined, however, there has been no sampling of any snails or whelks in the St Anns Bank area (Prouse and Ellis 1997).

Status and Trends

There is no information on which to base any assessment of status or trends in these populations, and they have not been assessed by COSEWIC (Committee on the Status of Endangered Wildlife in Canada) or listed under the *Species at Risk Act* (*SARA*).

Sources of Information

In the Maritimes Region, there is no regular monitoring of waved whelk populations. In the fishery in Quebec Region, information from logbooks and processing plant observers is used to monitor exploited populations (DFO 2009d).

Sources of Uncertainty

The lack of baseline or any regular monitoring of waved whelk populations is a significant source of uncertainty. Also, their population structure is poorly known but believed to be complex and small scale.

3.4.6 Other Invertebrates

There are many invertebrate species whose life history and distribution in the St Anns Bank AOI are not being considered in detail, though many of them are described in Section 3.3.2, Benthic Communities of St Anns Bank. A hot spot analysis was undertaken as part of the AOI selection process (Horsman et al. 2011), which identified areas of high concentration of several invertebrate taxa based on the snow crab survey catch from 2004 to 2007. The taxa considered were anemones, brittle stars, crabs and lobsters (other than snow crab), sea cucumbers, shrimp, snow crab, sponges, urchins, whelks, soft coral, sea stars, and tunicates. Based on this hot spot analysis, St Anns Bank contains hot spots (also referred to as preferred habitat) for snow crab, sea urchins, sponges, and soft coral, and a tiny amount of preferred habitat for crabs and lobsters (other than snow crab). This generally matches the maps of invertebrate distribution based on the RV survey in Tremblay et al. (2007). Sponges, soft coral, snow crab, and lobster, and their distribution are described in detail in other sections of this report. Crabs, shrimp, and echinoderms will be briefly discussed in this section.

Crabs

There are three species of crab other than snow crab that are caught regularly in the ecosystem survey and the snow crab survey in St Anns Bank. Northern stone crab (*Lithodes maya*) are generally caught along the slope or in deep basins on the southern Scotian Shelf (Tremblay et al. 2007), including along the slope portions of St Anns Bank (Figure 3.4.6-1). Toad crabs (*Hyas araneus*) and lyre crabs (*Hyas coarctatus*) show an overlapping distribution in ecosystem surveys and on St Anns Bank (Figure 3.4.6-1), though Tremblay et al. (2007) note that they are very difficult to distinguish, so misidentification between the two may exaggerate their spatial overlap. Lyre crab is among the five most common species caught at the two shallowest snow crab survey stations in St Anns Bank (see Section 3.3.2). Over the period from 1999 to 2006, the largest concentrations of toad crabs and lyre crabs found in the ecosystem survey were in Sydney Bight, with significant concentrations on St Anns Bank (Tremblay et al. 2007).

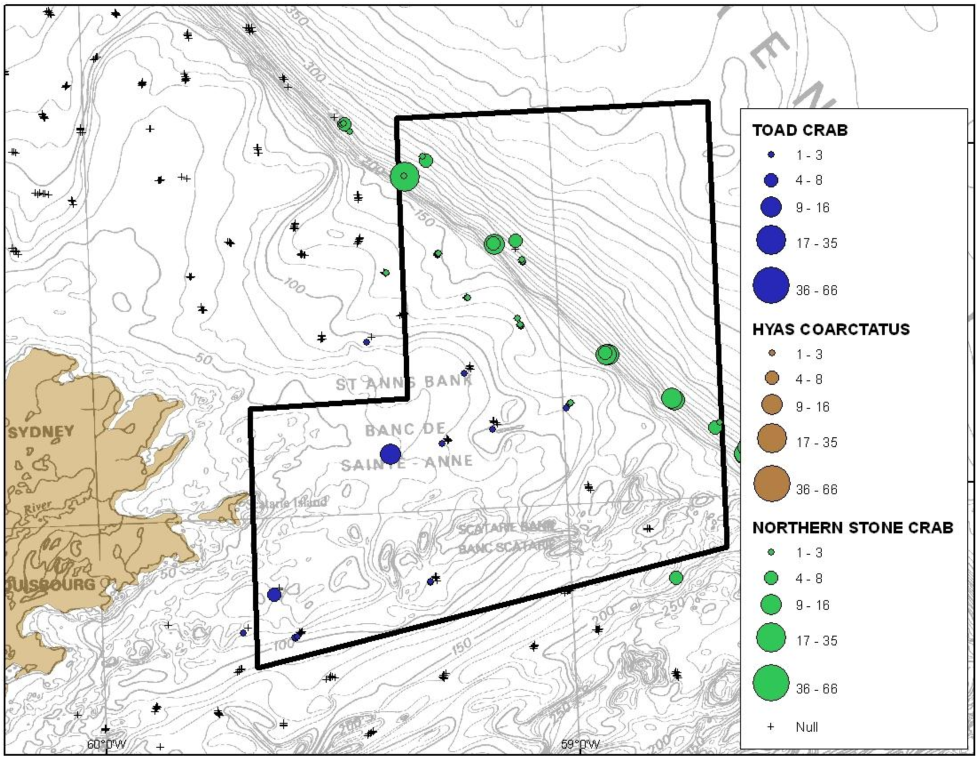


Figure 3.4.6-1. Catch of northern stone crab, toad crab, and lyre crab in snow crab survey stations in and around St Anns Bank.

Northern Shrimp and Striped Shrimp

Northern shrimp (*Pandalus borealis*) are a major prey species on the Eastern Scotian Shelf, in addition to supporting a commercial fishery. By count, they were the most abundant species recorded in the ecosystem survey from 1999 to 2006, though their individual size is very small. Tremblay et al. (2007) note that while the mean catch in positive sets on the ecosystem survey was 833 shrimp, their mean weight was 4.1 kg. Similarly, in the snow crab survey they are caught in large numbers; they are the second most numerous species in the snow crab survey on St Anns Bank, and the most or second most abundant species in almost all of the slope stations in the survey. However, St Anns Bank is not an area of high abundance for northern shrimp (Figure 3.4.6-2). The shrimp tend to be concentrated in deep "holes" on the shelf, such as the Louisburg Hole just south of the AOI. The shrimp fishery concentrates on these areas, as does the shrimp research survey used to estimate abundance of northern shrimp on the Shelf. There is no evidence that this area is of high importance to northern shrimp at any life history stage (Koeller et al. 2009).

Striped shrimp (*Pandalus montagui*) are generally more widespread but less abundant than northern shrimp on the Scotian Shelf (Tremblay et al. 2007). In the St Anns Bank AOI, striped shrimp are commonly found on St Anns Bank itself, where they are among the most numerous species in the snow crab stations. This matches the distribution mapped in the ecosystem survey, which shows high concentrations of striped shrimp further south on the Scotian Shelf, north of Sable Island. St Anns Bank does not appear to be a highly significant area for striped shrimp on the Scotian Shelf (Figure 3.4.6-2).

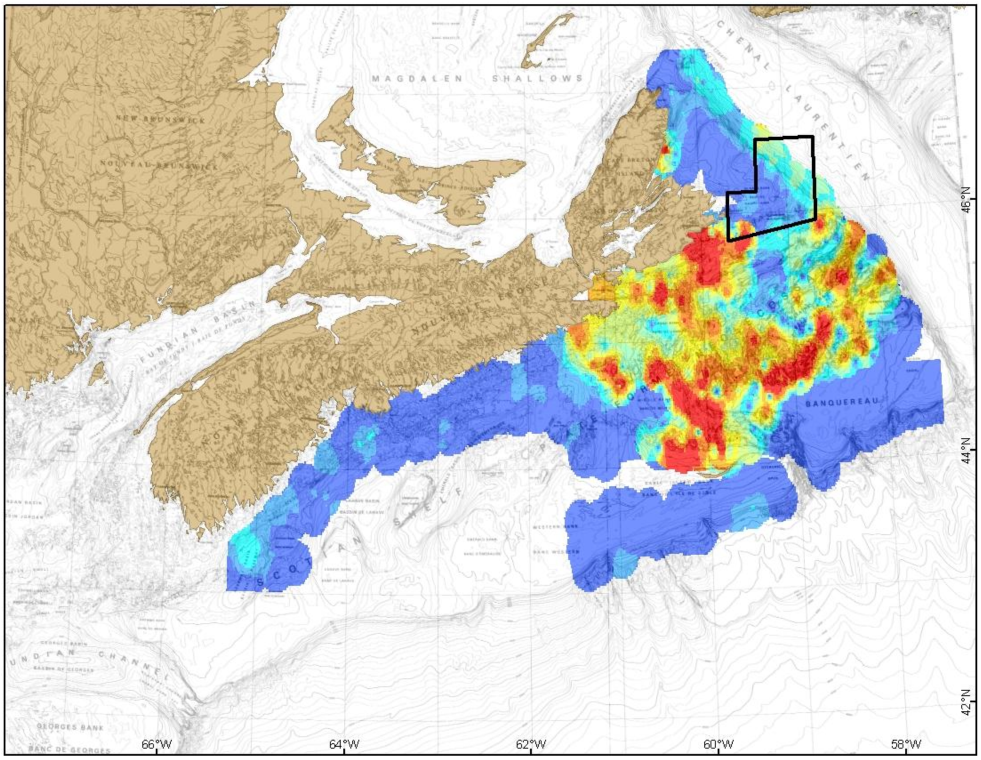


Figure 3.4.6-2. Distribution of shrimp (all species) on the Eastern Scotian Shelf (based on the snow crab survey).

<u>Echinoderms</u>

Echinoderms are another highly abundant invertebrate group that is not considered in detail in this report. Echinoderms, particularly sea stars and brittle stars, are extremely widespread and abundant on the Eastern Scotian Shelf (Tremblay et al. 2007). After snow crab, the most commonly recorded invertebrate taxa in the snow crab survey on St Anns Bank was *Asteroidea*, or unidentified sea stars. Several sea star species are generally identified in the survey, so the total frequency of sea stars would be even higher. However, this is not an area of particularly high abundance of sea stars on the Eastern Scotian Shelf (Figure 3.4.6-3).

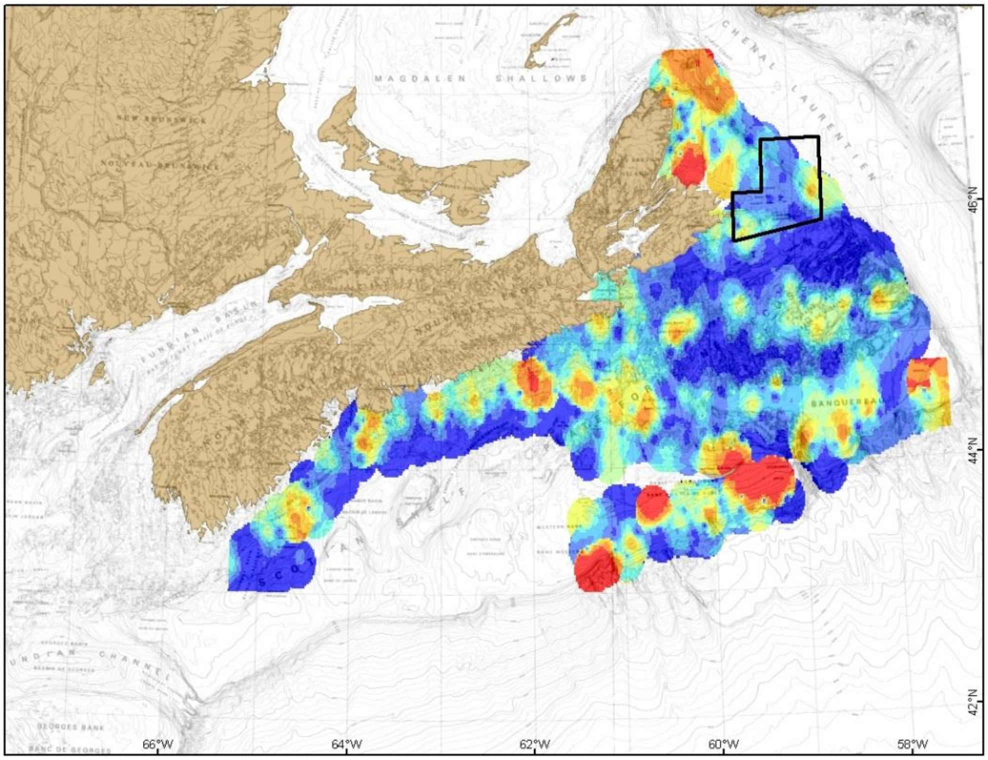


Figure 3.4.6-3. Distribution of sea stars on the Eastern Scotian Shelf based on the snow crab survey.

Heart urchins (*Brisaster fragilis*) and green sea urchins (*Strongylocentrotus droebachiensis*) are also common species in some parts of St Anns Bank. There was a huge catch of heart urchins (8820 individuals) in the southeast corner of the site in 2006, making them the most numerous species in the snow crab survey in St Anns Bank. They are a common species along the Laurentian slope part of the site. Green sea urchins were also among the most commonly caught species at a couple of bank stations in the survey. However, in general, St Anns Bank is not an important area for sea urchins on the Eastern Scotian Shelf (Figure 3.4.6-4).

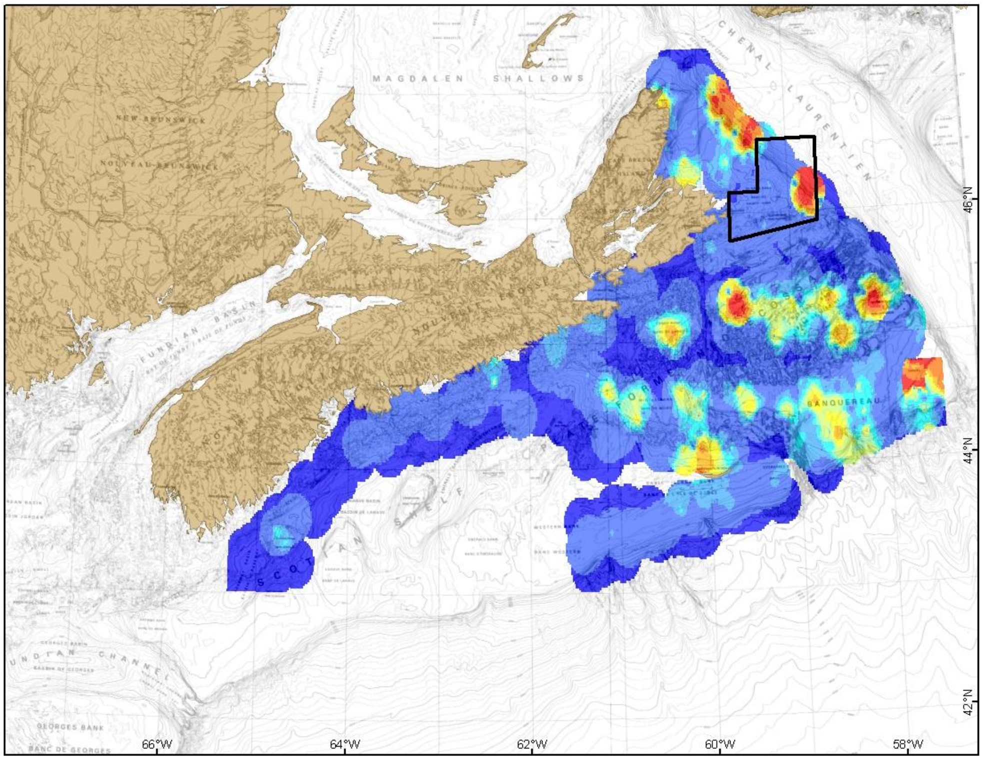


Figure 3.4.6-4. Distribution of sea urchins on the Eastern Scotian Shelf based on the snow crab survey. The hot spot in St Anns Bank is largely driven by one very large catch of heart urchins.

3.5 FISH

3.5.1 Fish Diversity

We used the RV survey conducted every July from 1970 to 2010 (described in Section 3.1 above) accessed through the Ocean Biogeographic Information System (OBIS) database[8] to characterize the finfish community of St Anns Bank. The area sampled by 190 sets represents only ~0.15% of the AOI, and the deepest parts of the site were not sampled at all (Figure 3.5.1-1). Both on land and sea, it is difficult to exhaustively sample a natural area for purposes of characterizing diversity. To address this common problem, a whole field of diversity research is devoted to developing methods to account for under sampling (Gotelli and Colwell 2001).

[8] http://www.iobis.org

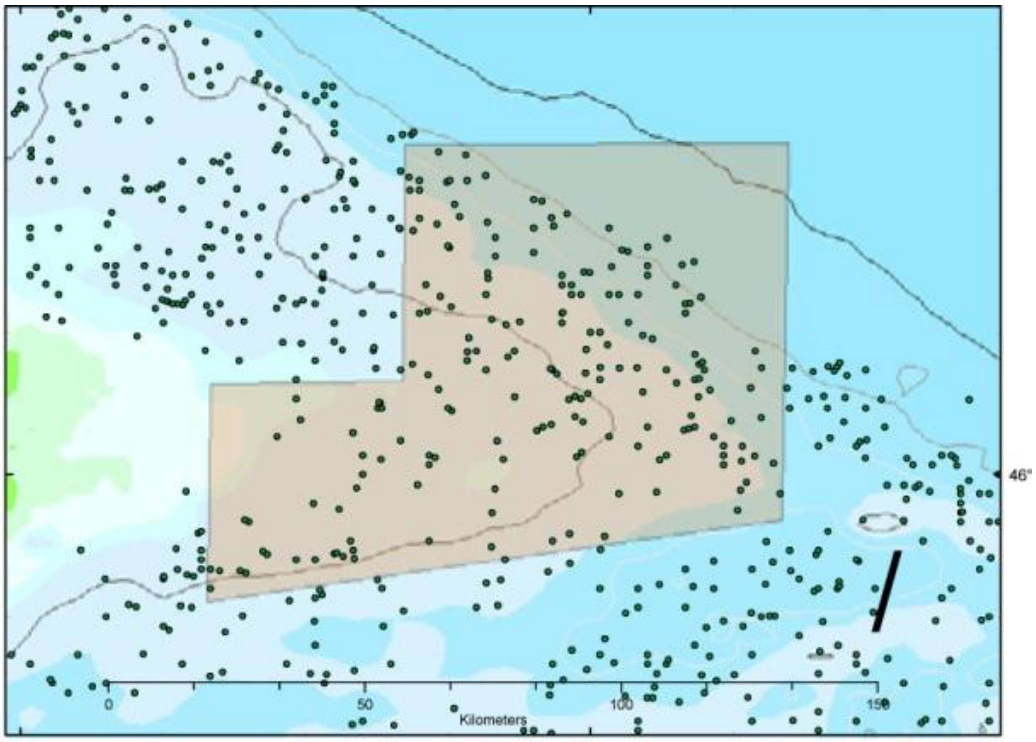


Figure 3.5.1-1. Ecosystem survey sample locations from 1970 to 2010, with St Anns Bank in grey.

In St Anns Bank, 70 species have been sampled, representing almost 50% of the 139 species sampled on the ESS. Of course, the ESS is much larger and more sampled, and so the odds of finding more species are higher. “Rarefaction” is a method to compare areas of different sample sizes by standardizing by the number of sampled individuals (Gotelli and Colwell 2001). If only 1000 individuals were sampled, 91 (+/- 5) species would be found on the ESS, compared to 49 (+/- 3) on the St Anns Bank (using package vegan in R), so St Anns Bank is estimated to host ~55% of the species on the Shelf.

The species–area relationship for the SAB shows that the rate of discovering new species slows down as the number of sets increases, but has not levelled off, indicating that the total number of species has not yet been found (Figure 3.5.1-2). Total species richness (the number of species) estimation methods have been developed to account for when the total number has not been found. Using the “Jackknife” method in package BiodiversityR in R, we would expect 86 (+/- 5) species (as compared to the observed 70) in the St Anns Bank area if more of the area had been sampled (and 162 +/-5 on the ESS).

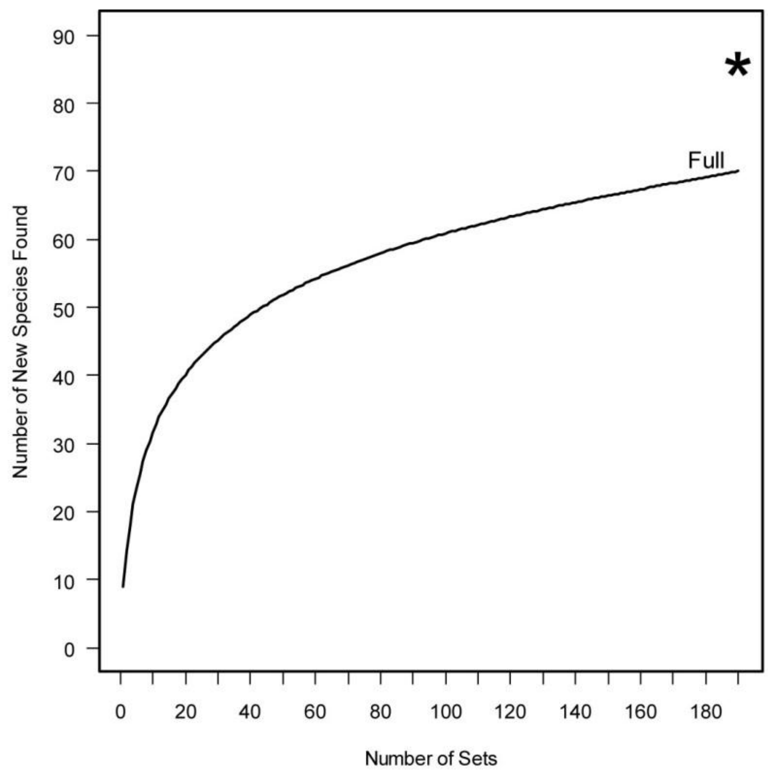


Figure 3.5.1-2. Species area curve made by re-sampling the order samples 1000 times. The asterix marks the total number of species based on the Jackknife method.

The spatial distribution of species richness (species density) shows that the most highly species-dense areas are off the bank and on the slope (Figure 3.5.1-3). This is consistent with the idea that species distribute themselves according to depth and temperature: the slope changes quickly over a short distance offering a range of habitats.

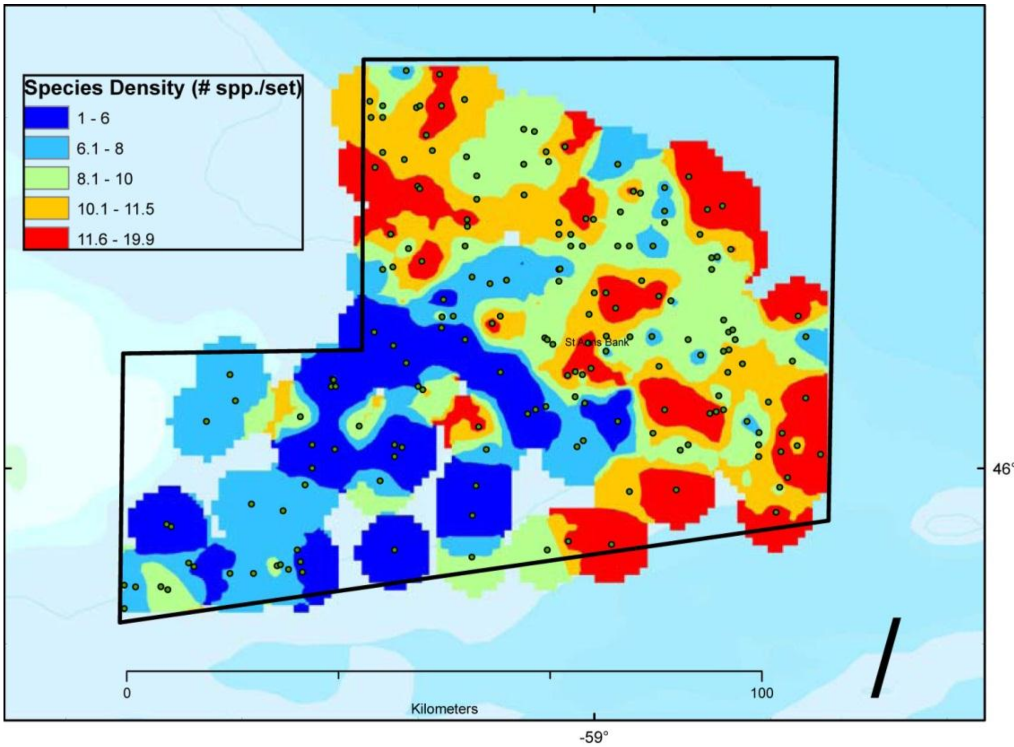


Figure 3.5.1-3. Species density in St Anns Bank (outlined in black), with spatial interpolation.

Finfish Community

In St Anns Bank, only a few species account for the majority of observations, which is typical of natural communities: 23 out of 70 species account for ~85% of all observations (Figure 3.5.1-4). American plaice was the most frequently observed species from 1970 to 2010, but not necessarily the most abundant (Figure 3.5.1-4). Indeed, some species' median biomass was high, but they were not observed as frequently as others (e.g., halibut, lumpfish, winter skate, wolffish). The same is true for species' median abundance (Figure 3.5.1-5). Finally, it is clear that for some species (e.g., capelin), biomass was not recorded but abundance was. This may be due to the former practice of not recording any weights < 250 g (Don Clark, DFO Science, personal communication, St. Andrews, NB, October 2011). Ordinarily, missing biomass entries are estimated from an assumed weight/length relationship, but not in the current version of the OBIS database (Dan Ricard, personal communication, Halifax, NS, October 2011).

Finfish Depth Preferences

On the Scotian Shelf, fish species' preferred habitat is determined by depth and temperature and to a lesser extent, sediment type (Mahon and Smith 1989). In the St Anns Bank area, fish communities are roughly defined by depth (Figure 3.5.1-6). Some species are restricted to shallow water and some to deeper waters (e.g., grenadiers), while others are observed over a wide depth range (e.g., thorny skate).

Many species are observed over a wide depth range and this may reflect the use of different depths for different life history stages. Spawning is most successful where larvae/juveniles will be retained in food-rich water masses during a critical period, such as on a bank with a circulation gyre that helps retain the larvae. Near the shelf/slope break, or in warm slope water intrusions, larvae can be swept out to the open ocean (Drinkwater et al. 2000) where they may die due to lack of food. It is also true that juveniles of several species prefer shallower water than the adults (Zeller and Pauly 2000). In effect, a range of depths provide different habitat not only for different species but also for the same species during different life history stages.

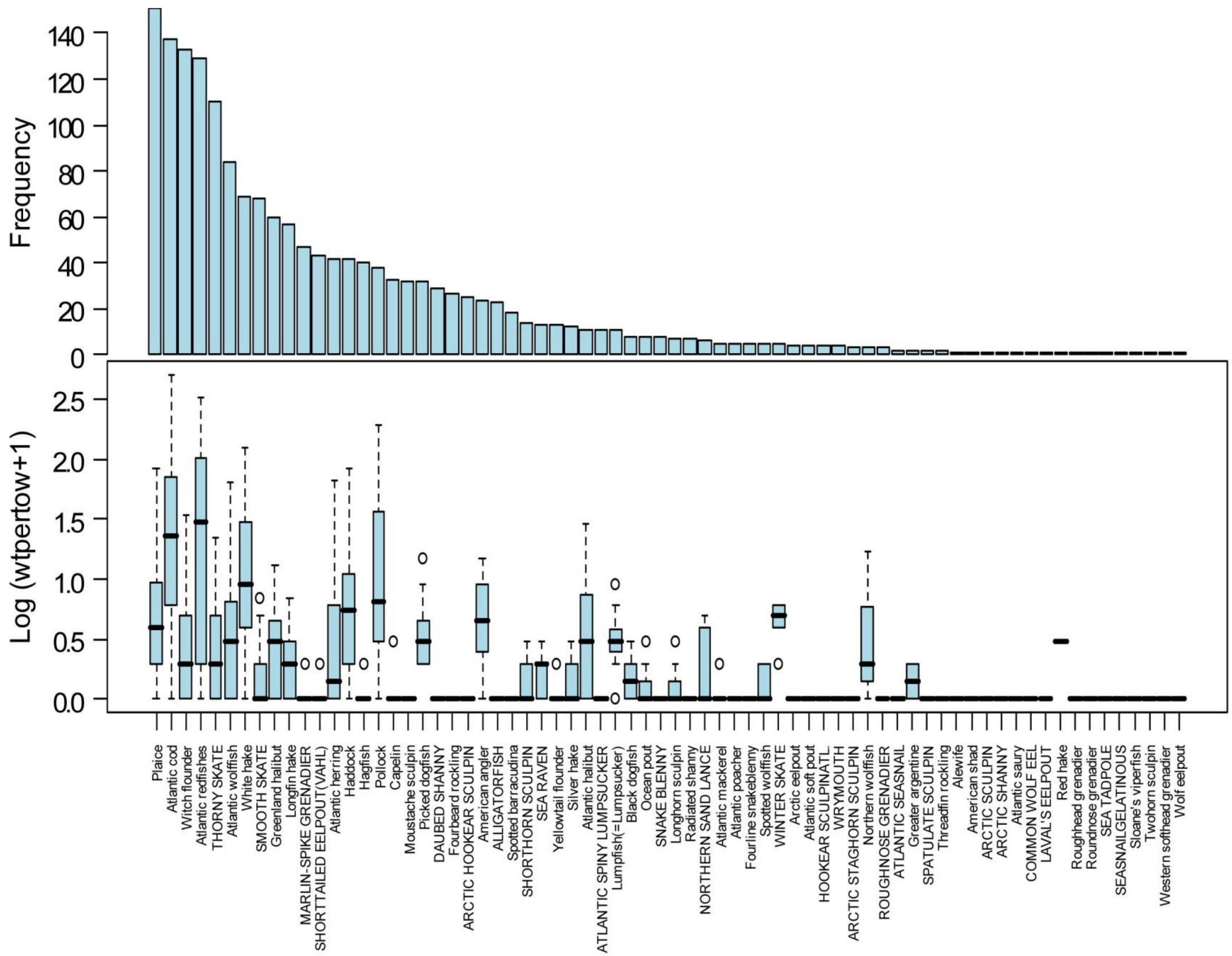


Figure 3.5.1-4. Number of observations for each species from 1970 to 2010 ordered from most frequently observed to least (top panel) and biomass (log(wtpertow+1) for each species (bottom panel). Frequency is the number of sets in which the species was observed out of 190 total sets in the AOI.

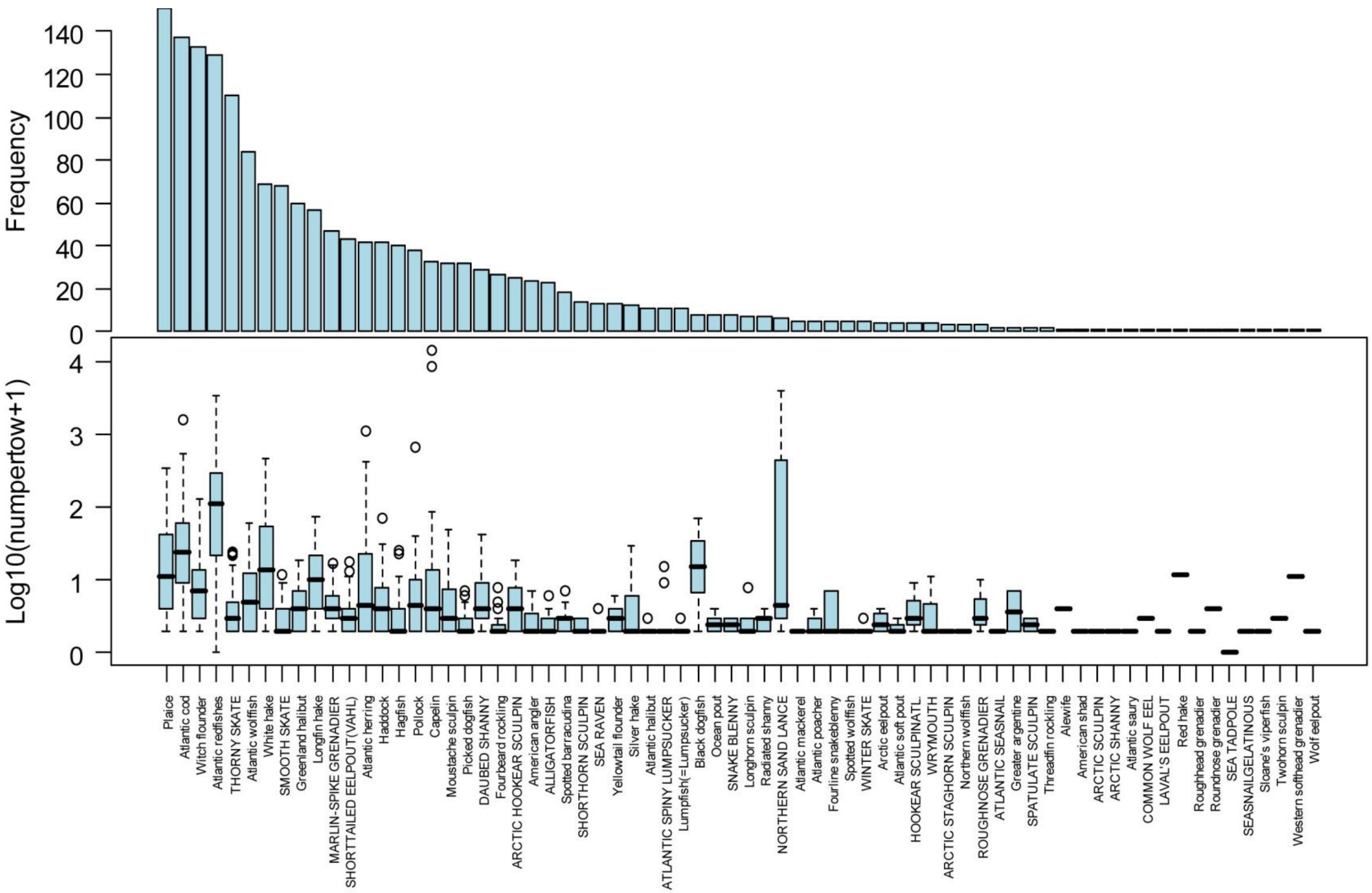


Figure 3.5.1-5. Number of observations for each species from 1970 to 2010 ordered from most frequently observed to least (top panel) and abundance (log(numpertow+1) for each species (bottom panel). Frequency is the number of sets in which the species was observed out of 190 total sets in the AOI.

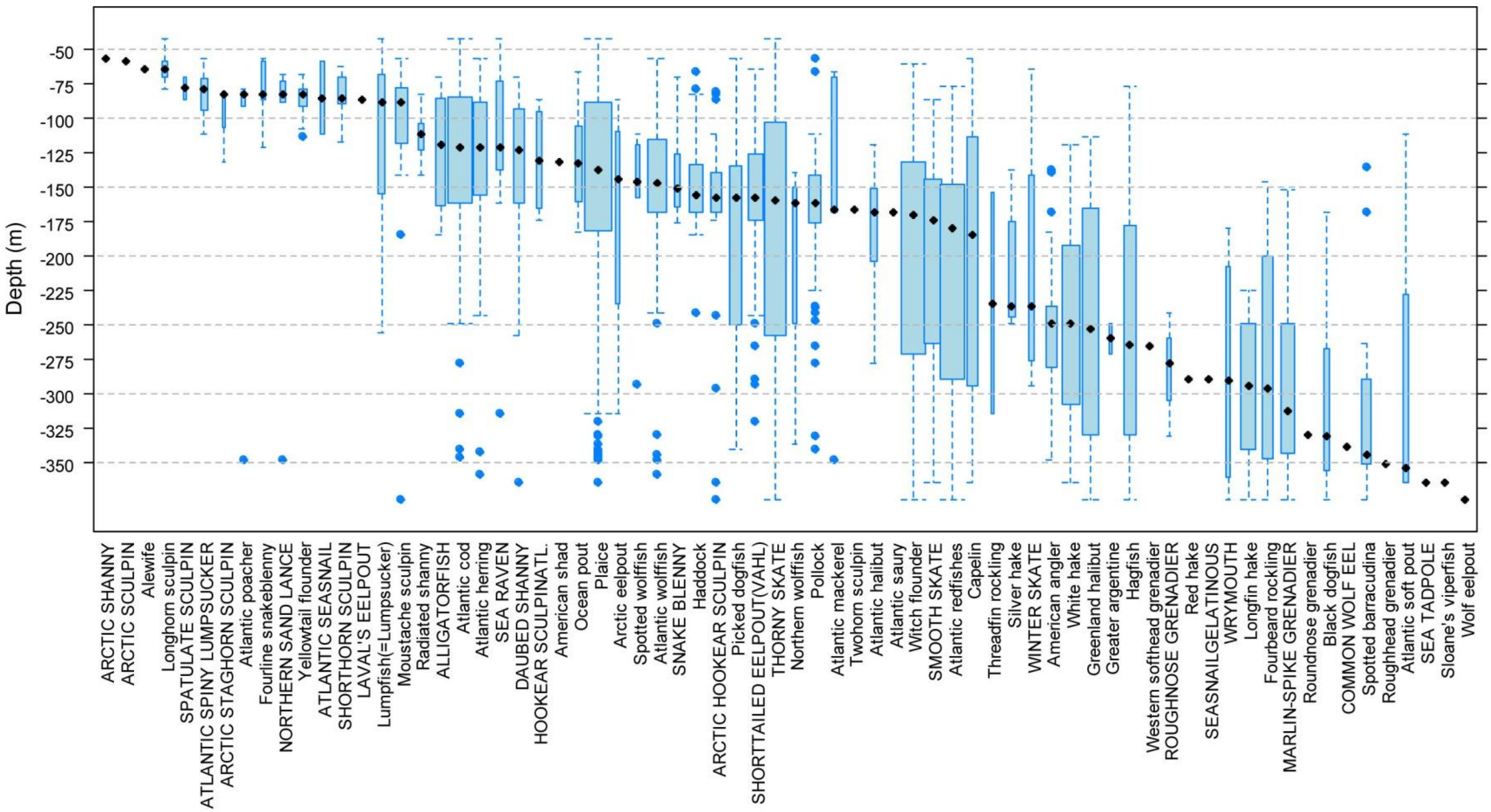


Figure 3.5.1-6. Boxplot of species by depth ordered from shallow to deep. The width of the box is proportional to the number of observations from 1970 to 2010: wider boxes indicate species that were observed more frequently.

Fish Biodiversity Hot Spots

Fish biodiversity hot spots were identified on the Eastern Scotian Shelf using the RV survey (1970–2010; see Section 3.1 above). The survey catches a range of species, including invertebrates; however, only fish species were included in this analysis. The analysis was also restricted to the ESS to evaluate fish diversity in St Anns Bank in that context. As well, the snow crab survey used to identify invertebrate diversity hot spots (see Section 3.4.1 – Invertebrate Diversity) is restricted to the ESS for the most part.

Each survey set was assigned to a 2-minute grid (used by Horsman et al. 2011), and the number of unique fish species per grid cell were counted. A hot spot analysis tool in ArcGIS was used to calculate the Getis-Ord Gi* statistic (Z score) for each grid cell (see Section 3.4.1 above for more details on the Gi* statistic/Z scores). For this analysis, statistically significant positive Z scores ($\geq$ 1.96) were considered biodiversity hot spots for fish. The Z score results of the hot spot analysis were then interpolated to create a more generalized surface (Figure 3.5.1-7).

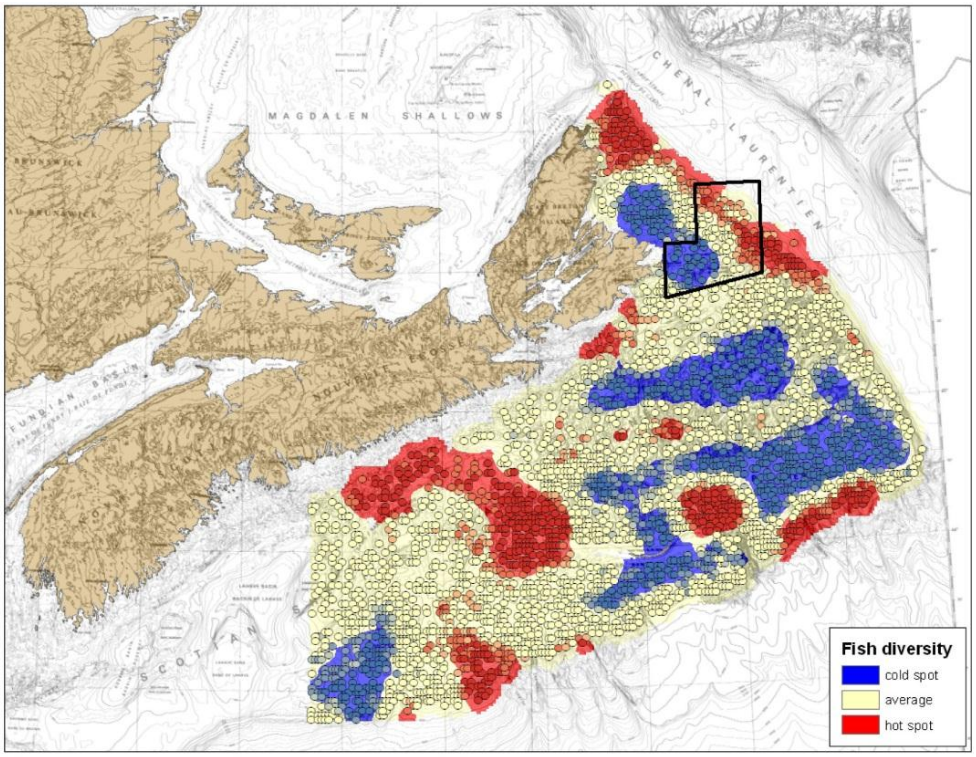


Figure 3.5.1-7. Fish biodiversity hot spots on the ESS (based on the RV survey). Both the point results from the Getis-Ord hot spot analysis and the interpolated surface are shown. As Z scores are either statistically significant or not, only three colors are used: red (statistically significant hot spot), blue (statistically significant cold spot), and yellow (not statistically significant).

The results show fish biodiversity hot spots in patches in Sydney Bight and along the slope into the Laurentian Channel, as well as in Middle Bank, the Gully Trough, parts of Western Bank, and along Shortland and Haldimand canyons. The slope portion of the

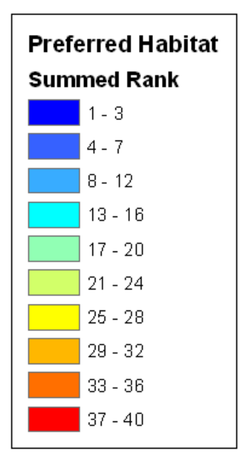
St Anns Bank AOI appears as a fish diversity hot spot, while the bank and inshore portions appear as average and a cold spot, respectively.

<u>Pelagic Fish</u>
A large number of pelagic fish use St Anns Bank as a migratory or feeding area, but only a small number of species (porbeagle sharks, herring, mackerel, and capelin) are considered in this section in detail. No anadromous fish are included in this section, though some have been found in the RV survey (e.g., alewives and American shad), and it is in the range of other anadromous species including Atlantic salmon and sea lampreys. Bluefin tuna migrate up the Atlantic coast of Nova Scotia and into the Gulf of St. Lawrence to feed, so it seems likely that they use the St Anns Bank area on their migrations. While there is little information with which to estimate the use of St Anns Bank by these highly migratory species, the Ocean Tracking Network has a line of acoustic receivers from Cape North on the northern tip of Cape Breton to St. Paul's Island, north of the AOI. Acoustically tagged animals that have been detected passing through this narrow, inshore passage north of the AOI include Atlantic salmon, Atlantic sturgeon, and bluefin tuna (OTN 2011). Although information on the distribution of sand lance, an important forage species on the Scotian Shelf, is quite limited (DFO 1996a), it does not appear that significant concentrations of sand lance are found in St Anns Bank, so this species was not considered in detail.

3.5.2 Preferred Habitat Mapping

Horsman and Shackell (2009) mapped important habitat for a number of fish species on the Scotian Shelf using the RV survey data. They divided the data into four time periods, 1970–1977, 1978–1985, 1986–1993, and 1994–2006, based on changes in fisheries management and water temperatures. Within each time period, data were interpolated over space and ranked from one through ten according to relative biomass (observed weight per tow). These ranks were then summed for all time periods to map important habitat for each species over the 40-year time series. More details on methods can be found in Horsman and Shackell (2009).

Horsman et al. (2011) used these important habitat maps to define preferred habitat for each species, which were then used in their Marxan analysis (see Introduction). Preferred habitat was defined as areas with relative biomass averaging in the 80th percentile and higher over the four time periods (rank $\geq$ 32 out of a possible 40).



Horsman and Shackell's (2009) maps are presented in each groundfish section of this report. The legend for these maps is shown to the right. In addition, for select species (thought to be well sampled by the RV survey), we calculated the percent of preferred habitat on the Eastern Scotian Shelf (shallower than 3000 m) found within the AOI boundaries. This was done for each time period to identify any trends and to indicate the AOI's importance to each species over time.

3.5.3 American Plaice

American plaice (*Hippoglossoides platessoides*) is a benthic flatfish which was at one time the most abundant flatfish in the northwest Atlantic (COSEWIC 2009). In general, plaice are slow growing and relatively long-lived (Scott and Scott 1988), growing up to 61 cm in length (COSEWIC 2009) and living up to 30 years (oldest recorded; Bowering and Brodie 1991).

Geographic Range and Habitat Preferences

American plaice are distributed throughout the western North Atlantic from Baffin Island in the north to Rhode Island in the south (Scott and Scott 1988). They are found across the Scotian Shelf from Sydney Bight to the Bay of Fundy (Bigelow and Schroeder 1953). The largest concentrations of plaice on the Scotian Shelf are usually found on Banquereau Bank (COSEWIC 2009). Distribution of plaice on the Scotian Shelf based on the summer RV surveys is shown in Figure 3.5.3-1 (Horsman and Shackell 2009; see Section 3.5.2 – Preferred Habitat Mapping for details).

Habitat Preferences

Plaice are usually associated with bottoms with firm sediment, such as fine sand and gravel (Scott 1982). Bowering and Brodie (1991) suggest that “this is consistent with the topography of the banks where they occur.” Plaice prefer depths of 100–300 m (Bowering and Brodie 1991), and are found at temperatures of 1–4^{o}C and salinities from 31–34 ppt on the Scotian Shelf, with the highest abundances at 33 ppt (Scott 1982).

Populations or Stock Definitions

American plaice on the Scotian Shelf are divided into two stocks: 4VW and 4X. However, that division is more for management purposes than biology. Fowler and Stobo (2000) suggest that 4VW plaice probably comprise three different populations: a local 4Vn population, Banquereau (4Vs) population, and seasonal contributions of 4T plaice to 4Vn. Tagging studies show that plaice from the southwest Gulf (4T) migrate to the Sydney Bight/4Vn/Laurentian Channel area for the winter, and then return to the Gulf to spawn (Busby et al. 2007). Therefore Sydney Bight (4Vn) plaice may comprise a mixed population during the winter and a smaller local population during the rest of the year.

American plaice spawn on the Scotian Shelf in April/May (COSEWIC 2009). The major spawning component of plaice on the Scotian Shelf is likely on Banquereau (COSEWIC 2009). However, Sydney Bight/4Vn plaice may spawn in another location (Busby et al. 2007).

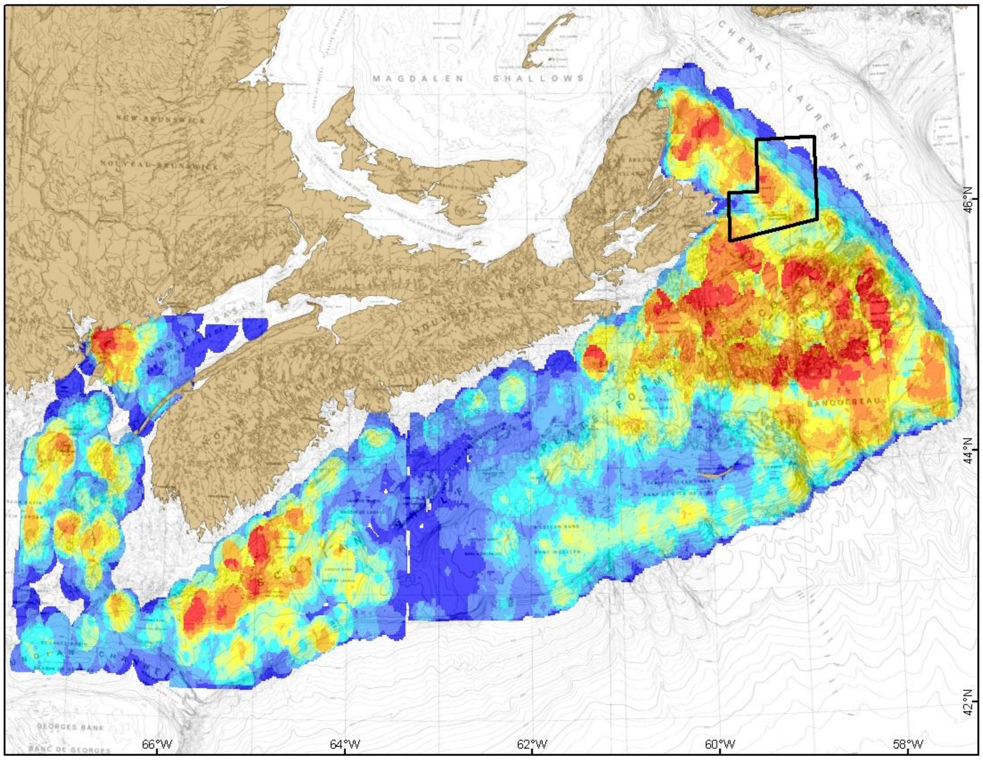


Figure 3.5.3-1. Distribution of American plaice on the Scotian Shelf (Horsman and Shackell 2009). Preferred habitat is shown in red/orange. The St Anns Bank AOI boundaries are outlined in black.

American Plaice in St Anns Bank

Within St Anns Bank, plaice appears to be concentrated on St Anns Bank itself (Figure 3.5.3-2; Horsman and Shackell 2009). However, this is based on summer survey data and so likely only shows resident 4Vn plaice, if they are in fact a separate population as suggested by Fowler and Stobo (2000). Distribution of plaice in the St Anns Bank/4Vn area may be different in winter when 4T plaice are also found in the area.

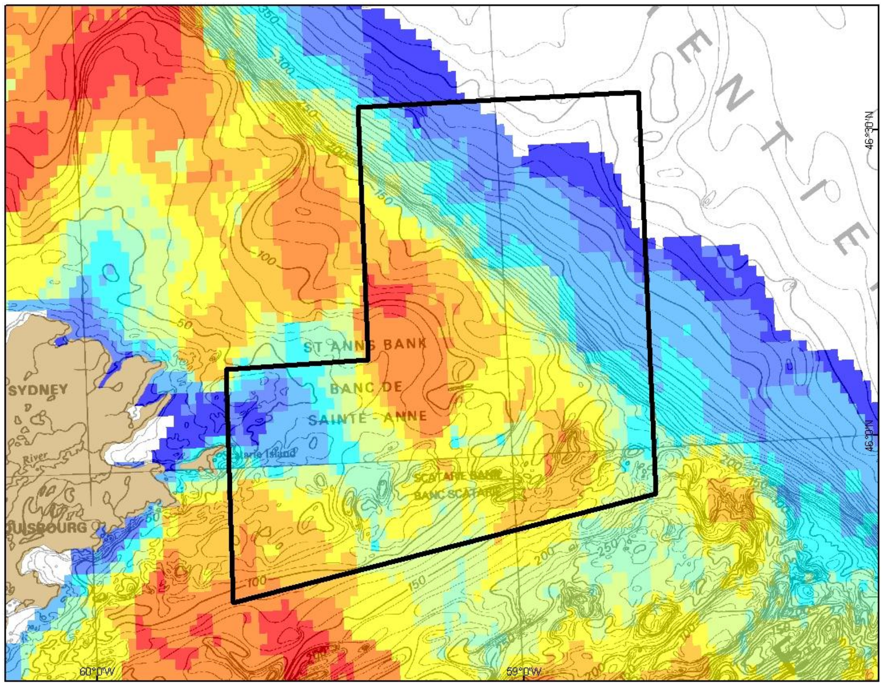


Figure 3.5.3-2. Distribution of American plaice in the St Anns Bank area (Horsman and Shackell 2009). Preferred habitat is shown in red/orange. The St Anns Bank AOI boundaries are outlined in black.

Horsman and Shackell (2009) mapped preferred habitat for plaice on the Scotian Shelf over four time periods (see Section 3.5.2 – Preferred Habitat Mapping). In both the 1978–1985 and 1995–2006 time periods (Figure 3.5.3-3), preferred habitat for plaice represented ~18% of the ESS even though plaice declined over that time period (COSEWIC 2009). In both time periods, ~5% of plaice preferred habitat on the ESS occurred in the St Anns Bank area. Again, this is based on summer survey data.

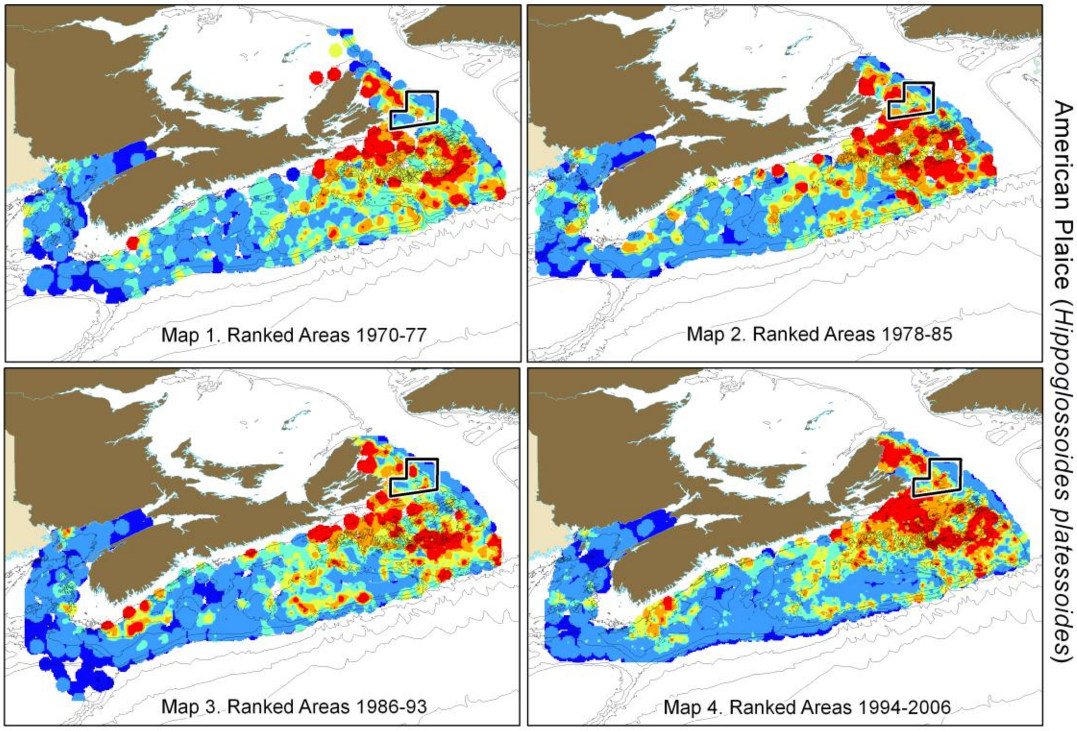


Figure 3.5.3-3. Distribution of American plaice on the Scotian Shelf for the years 1970–1977, 1978–1985, 1986–1993, and 1994–2006 (Horsman and Shackell 2009). Preferred habitat is shown in red/orange. The St Anns Bank AOI boundaries are outlined in black.

In addition, plaice were the most frequently caught species in St Anns Bank in the RV survey (1970–2010) and the second most frequently caught species in the snow crab survey (2004–2010) (see Section 3.5.1 above). Distribution of plaice caught in the snow crab survey is shown in Figure 3.5.3-4.

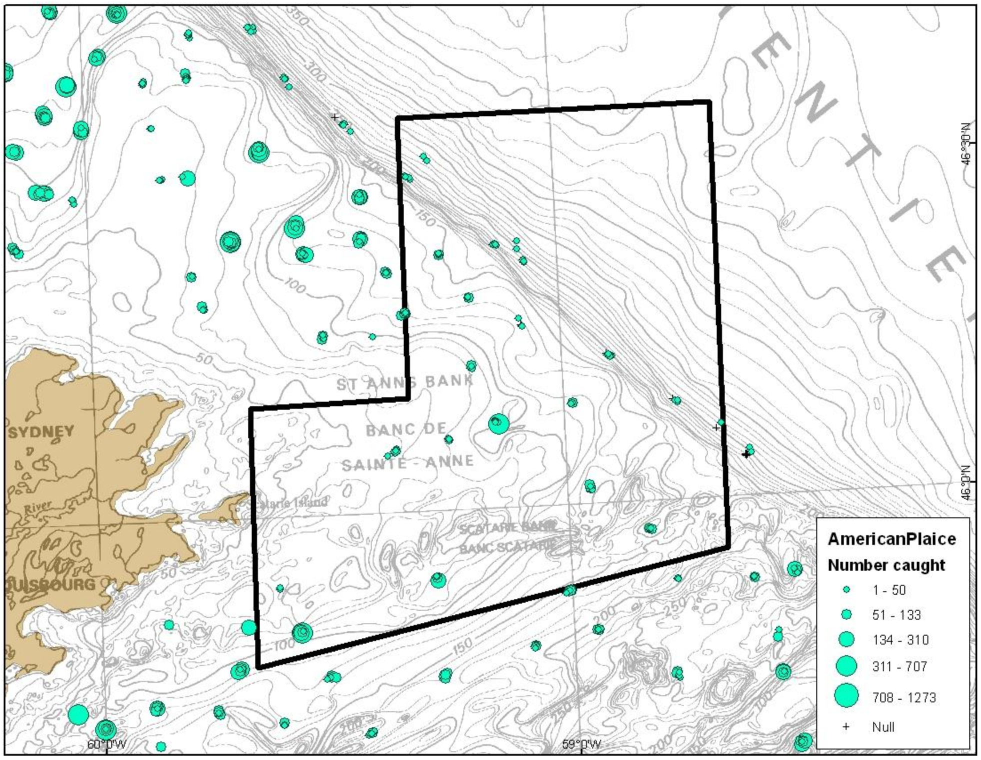


Figure 3.5.3-4. Distribution of American plaice in the snow crab survey (2004–2010), showing the number of individuals caught (weight not available).

In summary, American plaice appear to be relatively common in the St Anns Bank area, though it is not known to be a particularly important area for the species. The area probably includes spawners, but it is not a known spawning area (Mark Fowler, DFO Science, personal communication, January 2011). The proportions of different populations of plaice (4Vn, 4Vs, 4T populations) in the area at various times of year are not currently known.

<u>Biology</u>

Productivity

American plaice are sexually dimorphic; females grow faster and larger than males (Scott and Scott 1988). Recent analyses show decline in size and age at maturity for plaice. Early estimates (1959–1968) for Scotian Shelf plaice were 10.5–11.5 years (33.0–41.4 cm) for females and 4–5 years (22–23 cm) for males (Beacham 1983; Bakken 1987). By 1979, females matured at 4.7–6.7 years (27.2–30.8 cm) (Beacham 1983; Bakken 1987). Busby et al. (2007) estimated the length at 50% maturity for plaice in 4VW at 27 cm, which has declined from 37 cm in the 1960s. Busby et al. (2007) also estimated a generation time of 17 years.

Plaice are batch/serial spawners; only a portion of all eggs are spawned in a batch, and they may spawn as many as ten egg batches (Nagler et al. 1999). The eggs float near the surface, and eggs and larvae tend to be retained over the area where they were spawned (Nevinsky and Serebryakov 1973). Fecundity in American plaice increases with fish size (Zamarro 1992), but has not been studied in great detail.

Natural Mortality
Busby et al. (2007) concluded that natural mortality of plaice can vary considerably over time, but that a reasonable overall estimate of natural mortality (M) for American plaice is 0.2.

Ecosystem Interactions
Plaice are opportunistic feeders and prey upon a variety of invertebrates (polychaetes, echinoderms, molluscs, crustaceans) and small fish (capelin, sand lance, flatfish; COSEWIC 2009). Small plaice are eaten by cod (Morisette et al. 2003), and adult plaice are eaten by harp and grey seals (Benoit and Bowen 1990a & b). Both juvenile and adult plaice are also eaten by adult cod, halibut, lobster, and dogfish (Powles 1965; Scott and Scott 1988; Johnson 2004).

Fisheries and Other Human Activities
The primary factor responsible for the decline of plaice is overfishing (COSEWIC 2009). There are still directed fisheries for flatfish on the Scotian Shelf. In 4VW three species of flatfish (plaice, witch flounder, and yellowtail flounder) are managed as a multispecies stock, which is assessed in the context of the most vulnerable species. The TAC is 1000 t in 4VW. Plaice may be caught as bycatch and most of the TAC is used when directing for more valuable species (witch flounder; Busby et al. 2007). As this is a multispecies stock, there are no specific management measures for the sustainability of plaice (COSEWIC 2009). An additional concern is the potential for discarding plaice on the Scotian Shelf when targeting other species (COSEWIC 2009).

Status and Trends

Stock Status
Mature American plaice have declined by 67% on the Scotian Shelf between 1970 and 2005 (based on RV data). Further, when only 4VW is considered, plaice have declined by 70% since 1970 (COSEWIC 2009). This decline has been associated with fishery-sized fish as abundance and production of large plaice are very low: there are no trends in small plaice (DFO 2002b). Recruitment indicators have been improving, but there is no evidence of a contribution to fishable biomass (DFO 2002b). There has been no change in Design-Weighted Area Occupied (DWAO) or the minimum area containing 95% of the population (D95) over the 1970–2005 time period (Busby et al. 2007). Anomalously low temperatures are among the suspected culprits for failure of plaice to recover in terms of abundance and growth (Mark Fowler, DFO Science, personal communication, January 2011).

Species at Risk Considerations
The Maritime population of American plaice has been assessed by COSEWIC as Threatened (2009), due to large declines in mature individuals in the Gulf of St. Lawrence and on the Scotian Shelf. Plaice are not listed under *SARA*.

Sources of Information

The main source of information for American plaice on the Scotian Shelf is the summer RV survey conducted by DFO (see Section 3.1 for details). Another RV survey in March contributed to our understanding of growth and maturity, and tagging studies have provided most of our knowledge about long-term and seasonal movements.

Sources of Uncertainty

On the Scotian Shelf, long-term trends in growth and maturity of American plaice are poorly tracked. This poses a challenge to accurately apportion abundance estimates among adult and juvenile components of the population. As well, the identity of American plaice in Sydney Bight and the relationship between Scotian Shelf and Gulf of St. Lawrence plaice are not well understood.

3.5.4 Atlantic Cod

Historically, Atlantic cod was ecologically dominant on the Eastern Scotian Shelf, accounting for 28% of the total biomass in the summer RV survey from 1970–1999 (Zwanenburg et al. 2006). The dramatic declines in cod stocks on the ESS are believed by some authors to have resulted in fundamental ecological changes in this area (Bundy 2005; see Section 4.2 below). In St Anns Bank, Atlantic cod are the second most frequently caught species and have the second highest biomass in the summer RV survey over 1970–2010.

Geographic Range and Habitat Preferences

In the northwest Atlantic, Atlantic cod occur from inshore shallow water to the edge of the continental shelf. On the Canadian side of the Davis Strait, the northern limit is off Frobisher Bay and extends into Ungava Bay, while the southern limit is Cape Hatteras. Cod are abundant from the Labrador coast to Georges Bank (DFO 2011d). Cod distribution on the Scotian Shelf (based on the RV survey) is shown in Figure 3.5.4-1 (Horsman and Shackell 2009; see Section 3.5.2 – Preferred Habitat Mapping for details).

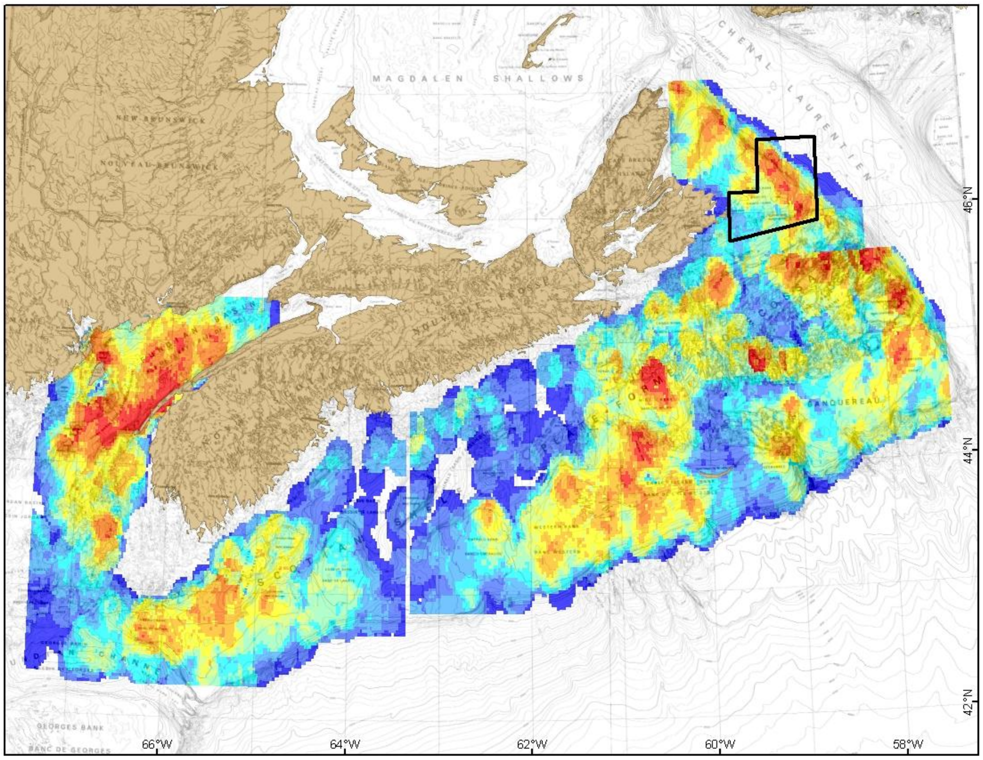


Figure 3.5.4-1. Distribution of Atlantic cod on the Scotian Shelf (Horsman and Shackell 2009). Preferred habitat is shown in red/orange. The St Anns Bank AOI boundaries are outlined in black.

COSEWIC (2010b) provides an overview of the habitat preferences of cod. During the first few weeks of life, cod eggs and larvae inhabit the upper 50 m of the ocean. Factors such as water temperature, currents, and food availability influence early life history distribution. During the juvenile stage (ages 1–4), heterogeneous habitat such as eelgrass (*Zostera marina*) in nearshore waters, as in the Sydney Bight, are preferred due to both reduction in predation and enhanced growth. As cod grow into adults, while there does not appear to be a particular depth or bottom substrate requirement, they are generally observed to move into increasingly deeper, colder water with age (Sinclair 1992; Swain 1993). Campana et al. (1999) suggest that depth is not a hindrance to swimming across the Laurentian Channel, although cod from the northern and southern Gulf tend to stay on their respective sides of the Channel during overwintering. Swain (1993) suggests that habitat preference of 4T-Vn cod is density-dependent during the feeding season, reflecting an interaction between effects of density-dependent resources (i.e., food availability) and density-independent costs related to water temperature. Spawning cod are not known to have any specific habitat requirements other than currents around banks to entrain the early life history stages during their development. COSEWIC (2010b) consider that spawning habitat is highly unlikely to be limiting to the species.

Populations or Stock Definitions

The Cabot Strait is a significant mixing area for three Atlantic cod populations or stocks (DFO 2011d):

Southern Gulf of St. Lawrence	- 4T plus 4Vn (November–April)
Eastern Cape Breton	- 4Vn resident
Eastern Scotian Shelf	- 4VsW

Based upon ichthyoplankton and inshore trawl surveys, spawning of the 4Vn resident population occurs in Sydney Bight during May and June, consistent with the presence of a historical "Gutter" fishery in this area and at this time of year (Campana et al. 1995). Juveniles tend to be found inshore and move into deeper water as they grow older (Sinclair 1992; Swain 1993). During summer and autumn, about 65% of the spawning biomass of the 4Vn resident stock moves offshore but remains within 4Vn; cod tagged in 4Vn during the summer are often recovered in 4Vn (Stobo and Fowler 2006). This group moves south along the edge of the Laurentian Channel to overwinter in the southern part of 4Vn and thus in the vicinity of the AOI (Comeau et al. 2002a). In the spring, 4Vn resident cod in the offshore tend to move north along the edge of the Laurentian Channel before moving to the coastal area.

Also during the fall, the 4TVn stock move into 4Vn. Comeau et al. (2002b) describe the overwintering migration of 4TVn cod in some detail. The 4TVn overwintering migrants move south along the Laurentian Channel but do not appear to move as far south into 4Vn as the resident population, perhaps not reaching the area of the AOI (Figure 3.5.4-2). Further, where the two populations may mix, Campana et al. (1999) indicate that there is population integrity (i.e., separation) at spatial scales of less than 20 km. In the spring, the 4TVn migrants return to the Gulf, initiating their movement in April or May. Assuming that much of the stock remains in northern 4Vn during the winter, it could be assumed that 25% could intersect with the AOI.

Regarding mixing of the 4Vn resident and 4VsW stocks, Campana et al. (1995) suggest that this intrusion is of greater extent than that of the 4TVn stock. This 4Vn–4VsW stock mixing could be expected to occur throughout the year and be related to the size of each stock with it being more prevalent when the 4VsW stock is abundant.

Atlantic Cod in St Anns Bank

Based on the above data, it appears that an average of 65% of the 4Vn resident cod can be expected to inhabit the AOI and its vicinity during most of the year. There are incursions of 4TVn cod, though these predominantly occur in the northwestern area of 4Vn, outside the area of the AOI (Figure 3.5.4-2). On the other hand, incursions of 4VsW cod into the AOI could be expected throughout the year. It is not possible to state what proportion of the stock would move to this area, but given the current depressed state of the 4VsW cod stock, it could be expected to be a small fraction (< 10%) of the resource.

Horsman and Shackell (2009) mapped preferred habitat for Atlantic cod on the Eastern Scotian Shelf over four time periods. Over the years 1978–1985, 18% of the Eastern Scotian Shelf was considered preferred habitat, of which 8.4% was in St Anns Bank. Over the years 1994–2006, only 3.3% of the Eastern Scotian Shelf was preferred habitat, but 25% of this was in St Anns Bank (Figure 3.5.4-3).

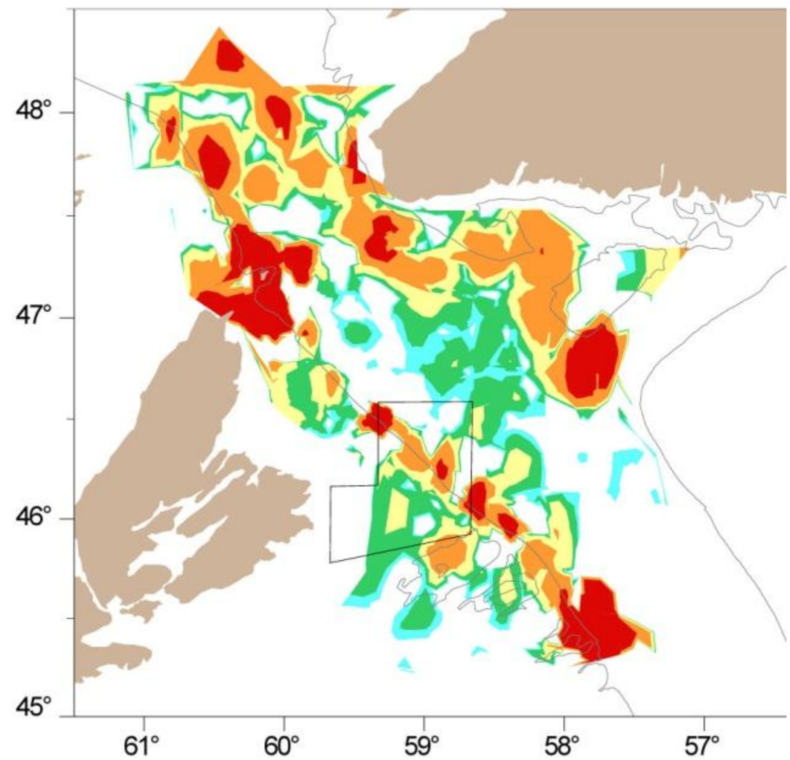


Figure 3.5.4-2. Atlantic cod observed in January surveys of the Cabot Strait in the mid-1990s, showing intermediate densities of overwintering cod in the AOI. Red indicates areas of highest abundance (≥ 190 cod/tow) and green indicates areas of lowest abundance (1–2 cod/tow) (Doug Swain, DFO Science, personal communication, September 2011). Ninety-eight percent of cod on the south side of the Channel were estimated to be 4T cod (Swain et al. 2001).

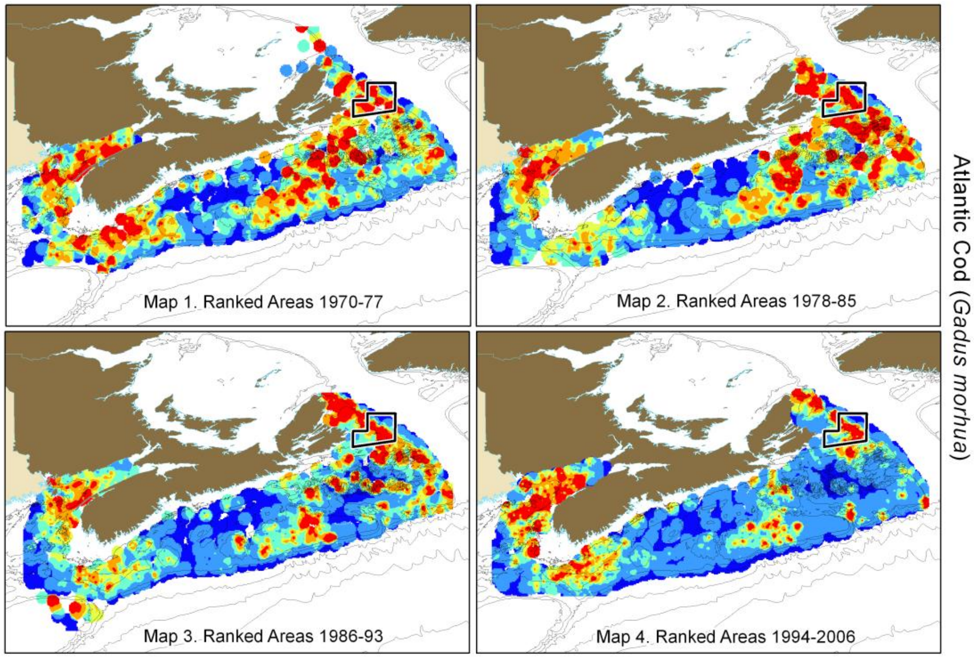


Figure 3.5.4-3. Distribution of Atlantic cod on the Scotian Shelf for the years 1970–1977, 1978–1985, 1986–1993, and 1994–2006 (Horsman and Shackell 2009). Preferred habitat is shown in red/orange. The St Anns Bank AOI boundaries are outlined in black.

Within the AOI, the most important area for cod based on the RV survey appears to be the slope, around 100–150 m (Figure 3.5.4-4). However, cod is the second most common fish species in the RV survey in the AOI, and is found across the full range of depths sampled in the AOI (see Section 3.5.1 – Fish Diversity). Cod are also caught throughout the AOI in the 4Vn sentinel and halibut industry surveys (Figures 3.5.4-5 and 3.5.4-6).

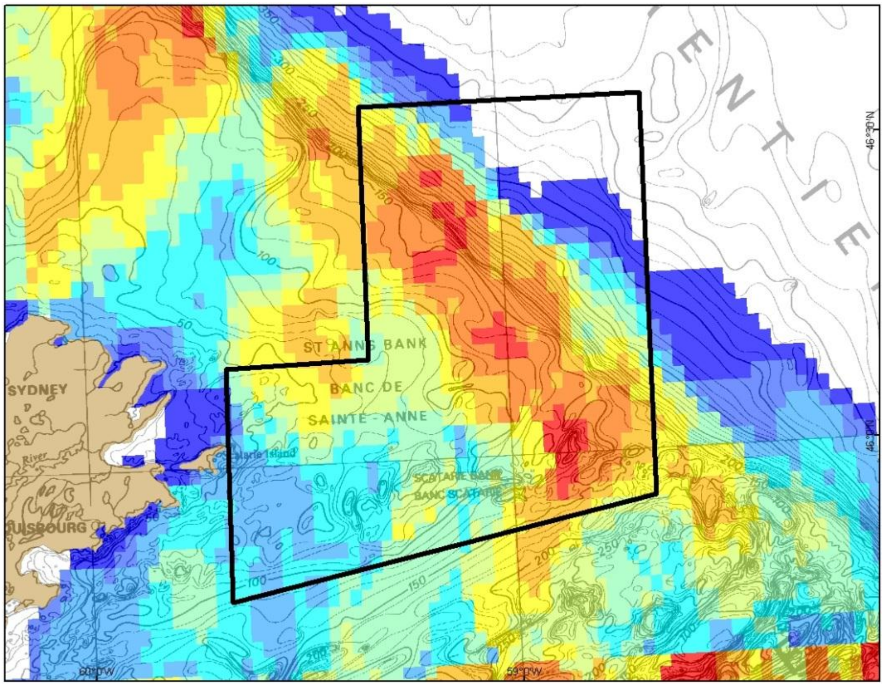


Figure 3.5.4-4. Distribution of 4Vn Atlantic cod in the St Anns Bank area in July, based on the RV survey (Horsman and Shackell 2009). Preferred habitat is shown in red/orange. The St Anns Bank AOI boundaries are outlined in black.

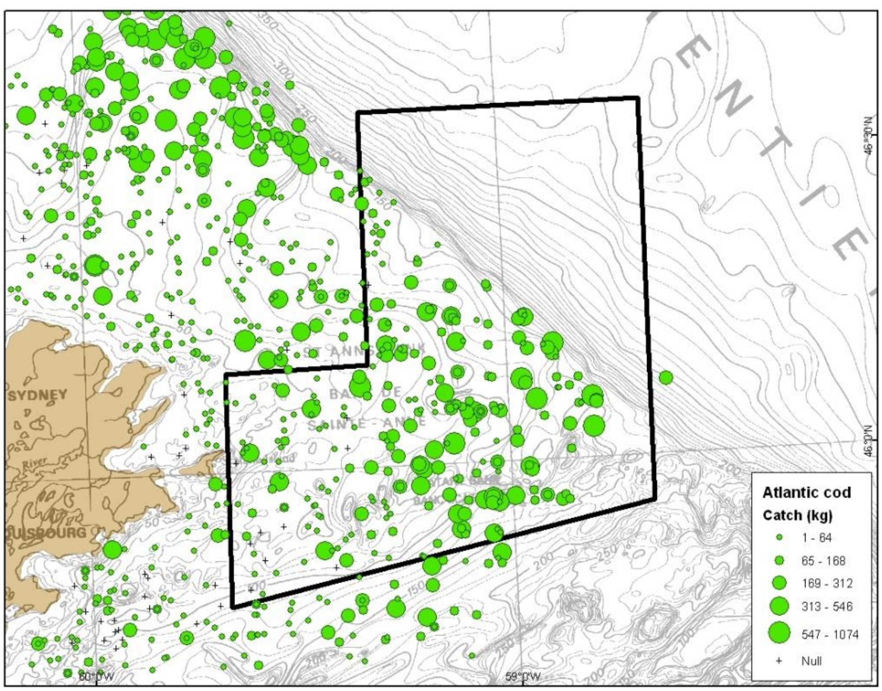


Figure 3.5.4-5. Distribution of Atlantic cod in the 4Vn sentinel survey (1994–2010; excludes commercial index and fixed stations), showing total weight caught (kg).

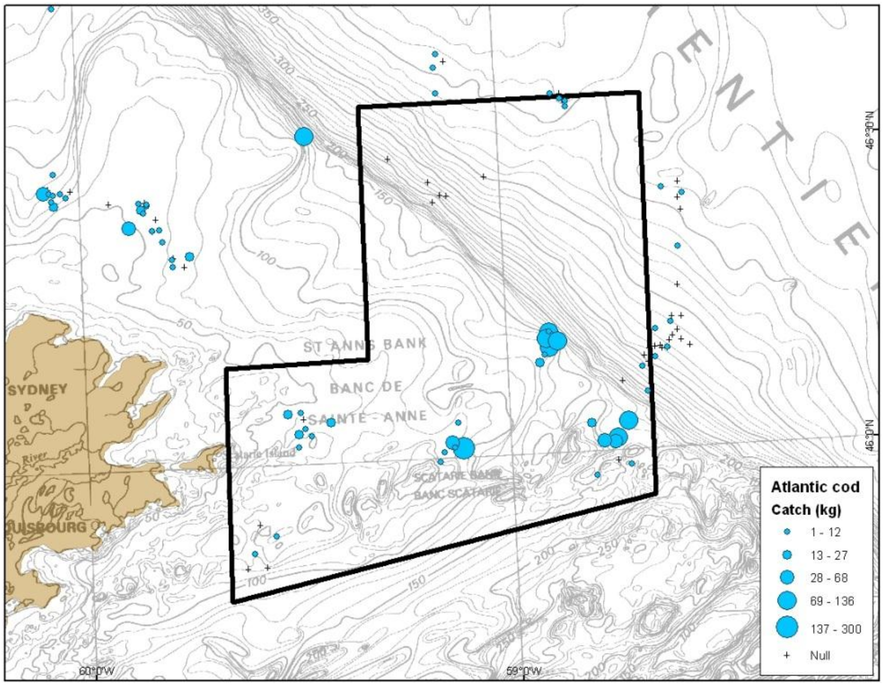


Figure 3.5.4-6. Distribution of Atlantic cod in the halibut industry survey (1998–2010; fixed stations only), showing total weight caught (kg).

Biology

Productivity
Myers et al. (1997) report that the maximum rate of population growth of 4TVn, 4Vn resident, and 4VsW cod, 0.24–0.5, is below the mean and at the low end of the range (0.24–1.15) for all stocks considered in the North Atlantic. Average age at maturity in recent decades is 3–4.5 years depending on the stock, with a generation time of 5–8 years (from Worcester et al. 2009). Maturation occurred at older ages in the 1950s and 1960s (Swain 2011). Individual growth rates of cod in these stocks declined significantly during the 1980s and 1990s (Halliday and Pinhorn 2009) and has stabilized since then.

Natural Mortality
In both the Gulf and the Eastern Scotian Shelf, natural mortality (M) has been estimated to have increased significantly since the mid-1980s, from 0.2 to 0.6 (Figure 3.5.4-7). Chouinard et al. (2005) and O'Boyle and Sinclair (2011) suggest that predation by grey seals may be a primary cause of the increase in M in the Gulf and the ESS respectively, while Trzcinski et al. (2006) believe that the increase on the ESS is due to some as yet unknown source. Recent increases in 4VsW cod biomass in the summer bottom trawl survey are consistent with declines in M since 2003.

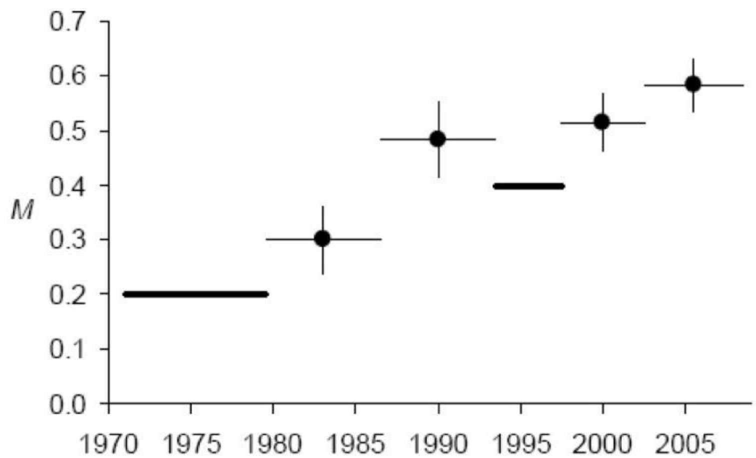


Figure 3.5.4-7. Natural mortality estimated by the model. Heavy lines are assigned values, and circles are values estimated by the model with their 95% confidence intervals (vertical lines). Horizontal lines indicate the period for which M is either assigned or estimated (from DFO 2009e).

<u>Ecosystem Interactions</u>
Benoît and Swain (2008) and Bundy (2004; 2005) provide comprehensive analyses, based on ecosystem modelling, of the role of Atlantic cod in the Gulf of St. Lawrence and Scotian Shelf ecosystems respectively. Cod is an opportunistic feeder, eating primarily macroinvertebrates at younger ages and becoming increasingly piscivorous at older ages.

In both areas, there have been significant changes in the structure and functioning of the ecosystems. Bundy (2005) shows how the trophic level of cod has changed (become higher) with the broader changes in the Eastern Scotian Shelf ecosystem:

Trophic Level	Early 1980s model	Early 1990s model
Small Cod (<=40cm)	3.36	3.64
Large Cod (>40cm)	3.68	4.01

This increase was observed to be due to an increase in the proportion of fish eaten and the portion of sand lance eaten. This study looked at the ESS as a whole and did not examine trends in particular subareas, such as 4Vn.

<u>Fisheries and Other Human Activities</u>
The fishery on 4Vn resident and 4VsW cod has been closed since September 1993. The Southern Gulf of St. Lawrence stock – 4TVn – was under moratoria from September 1993 through 1997, in 2003, and since 2009. During the periods it was not under a moratorium, it was managed using a TAC.

Status and Trends

Stock Status

4TVn
DFO (2011d) provides the most recent stock status. Year-classes produced since the late 1980s have been much weaker than those produced from the mid-1970s to the mid-1980s. The most recent year-classes (2003–2006) are estimated to be the lowest in the time series. As noted above, natural mortality in recent years (Figure 3.5.4-7) is estimated to be high (about 0.66) and increasing.

Stock growth is considered unlikely unless productivity increases well above levels observed in the past decade. The exploitation rate in 2008 is estimated at 6% (fishing mortality of 0.08), a small fraction of natural mortality, but still high and unsustainable given current stock productivity. Spawning stock biomass (SSB) is at the lowest level observed in the last 61 years (Figure 3.5.4-8). The estimate of SSB at the beginning of 2010 is 39,500 t, which is well below the limit reference point (LRP) of 80,000 t. SSB has been below the LRP since 2002.

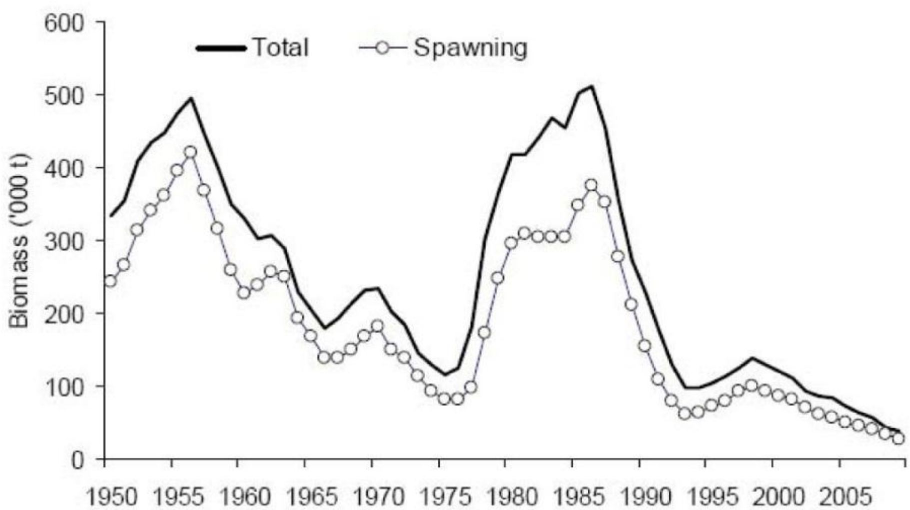


Figure 3.5.4-8. Total (ages 3+) and spawning stock biomass estimates derived from population models for cod in the southern Gulf of St. Lawrence (from DFO 2009e).

Swain and Chouinard (2008) undertook a viability analysis of the 4TVn cod stock. Unusually high natural mortality of adult cod and slow individual growth are the most significant factors in the low productivity. In contrast, recruitment rate (recruits per unit of spawner biomass), though lower than the unusually high rates observed between the mid-1970s and early 1980s, is currently relatively high compared to the rates observed in the 1950s and 1960s. Projections were conducted, taking into account recent variability in rates of recruitment and growth and uncertainty both in the natural mortality rate of adult cod and in the current levels of cod abundance at age. All projections led to the conclusion that the population is not viable at its current level of productivity.

Assuming that this low level of productivity persists into the future, the population is expected to steadily decline even with no fishery. Based on the accepted assessment model, the population is certain to be extirpated (defined here as a spawner biomass less than 1000 t) within 40 years (five generations) with no fishery and in 20 years (four generations) with a TAC of 2000 t. A substantial increase in productivity would be required for the population to be viable.

4Vn Resident

DFO (2011d) provides the most recent status of this stock. The 4Vn sentinel survey shows a general decline in abundance from 1994 to 2009 (Figure 3.5.4-9). A commercial index of traditional fishing catch rates by sentinel survey vessels was conducted from 1996 to 2006, and indicated an increase in abundance until 2001, showing no correspondence with the sentinel survey index during this period. Since 2001, the commercial index demonstrated no strong trend, with some suggestion of a slight decline.

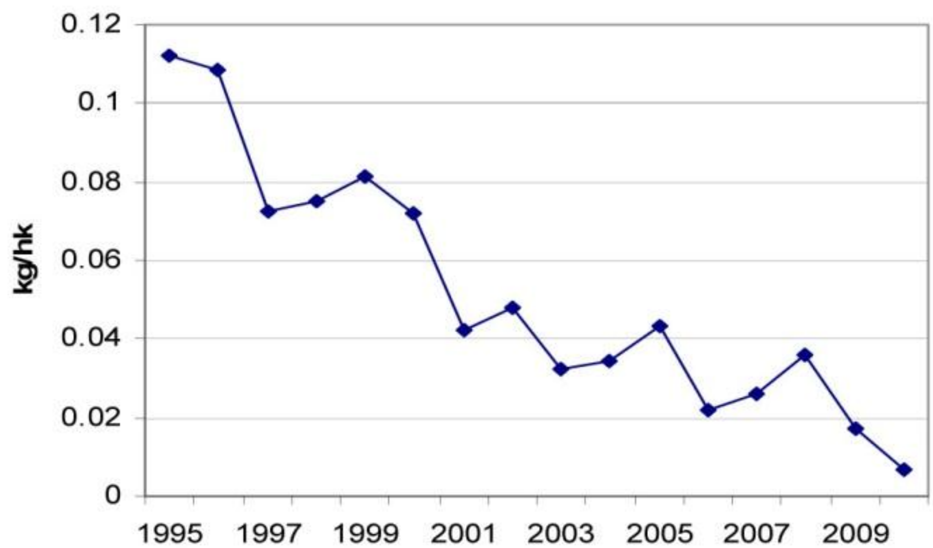


Figure 3.5.4-9. Catch rate index for 4Vn cod abundance from September sentinel fixed gear survey (DFO 2011d).

The current (2004–2009) biomass is estimated to be about 2250 t, or 25% of the LRP of 8400 t (DFO 2011d). Potential for recruitment was evidenced during 2001–2002, but did not carry through to spawning ages, and there have been no subsequent indications of a recruitment pulse.

4VsW

DFO (2011d) presents the most recent stock assessment on which the following summary is based. By the late 1980s and mid-1990s, this stock was severely depleted. The summer survey shows peak age 1+ biomass in the early 1980s with a decline to historical lows during 1995–2005 (Figure 3.5.4-11).

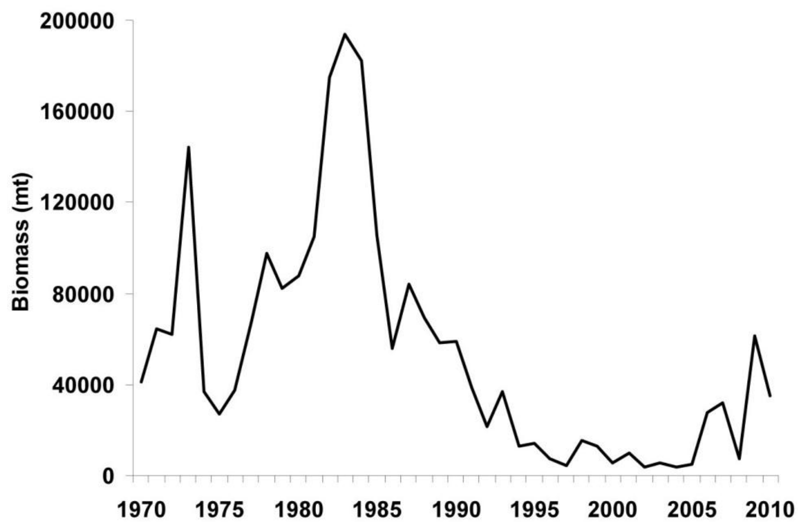


Figure 3.5.4-11. Trend in 4VsW cod summer survey age 1+ trawlable biomass during 1970–2010 (Robert Mohn, DFO Science, personal communication, April 2011).

During the overexploitation observed in the 1980s, Frank et al. (1994) report the loss of the more common spring spawning component; now only the fall component is evident in the population. This represents a significant loss in productive capacity to the population. More recently, survey biomass has increased to levels not seen since the late 1980s (DFO 2011d). This increase is still controversial and needs to be confirmed by upcoming surveys.

In 2009, the estimated biomass of this stock was 64,000 t, putting the population above the LRP of 50,000 t for the first time since 1992 (DFO 2011d).

The trends in recruitment (age 1+2) to the survey are similar to those of SSB although not as strong in the recent period (Figure 3.5.4-11). This indicates that survivorship in the late 2000s has been increasing and is consistent with declining M observed by Worcester et al. (2009).

Despite recent increases in biomass, projections indicate that under current productivity conditions, the population will likely decline below the LRP and then stabilize at a low level, even with no fishing (DFO 2011d). The focus of work to determine the recovery prospects of the 4VsW stock has been the potential impact of grey seal predation (DFO 2010d). Depending upon the cod–seal model assumed, there is a wide range of responses from no recovery to some recovery. As well, there is uncertainty as to whether or not natural mortality is declining (as suggested by the summer survey) or remaining stable and high.

Species at Risk Considerations
COSEWIC (2010b) considered 4TVn, 4Vn resident, and 4VsW cod as comprising the Laurentian South designatable unit (DU), which it assessed as being endangered. It noted that the three stocks in this DU had declined by 90% in the past three

generations. The main cause of the rapid decline in abundance during the early 1990s was overfishing. While fishing has largely ceased since 1993, increased natural mortality and small amounts of catch (in 4TVn) have caused the continuing decline.

Sources of Information
The key sources of information for these stocks are the ongoing programs that monitor the catch (both at sea and dockside) and stock abundance as well as the environment in which they inhabit (surveys). Surveys used to monitor these stocks include the ecosystem surveys in the Gulf and on the Scotian Shelf and the 4T, 4Vn, and 4VsW sentinel surveys (see Section 3.1 above for a description of the surveys).

Sources of Uncertainty
The key source of uncertainty for the three cod stocks in St Anns Bank is the source of current high natural mortality and, in the case of 4VsW, whether or not the recent increase in biomass is real or due to interannual survey variability. If the abundance of adult 4VsW cod is in fact increasing, then M is declining for this stock in the face of historically high levels of one of its predators, grey seals.

Another key uncertainty is the level of mixing amongst the three stocks in the area of the AOI. This involves intrusions of 4T cod into 4Vn from the northwest and of 4VsW cod from the southeast. Only educated guesses on the extent of these stocks into the area of the AOI could be provided here.

The last source of uncertainty is related to the general lack of ongoing monitoring in 4Vn. The current RV summer survey design allocates few sets to 4Vn and there are also relatively few observations made in the halibut survey.

3.5.5 Atlantic Halibut
Atlantic halibut (*Hippoglossus hippoglossus*) is the largest of the flatfishes, and is found throughout Atlantic Canada. They are a demersal species, living on or near the bottom, and are sexually dimorphic, with females being larger than males.

Geographic Range and Habitat Preferences
Halibut are found throughout the North Atlantic, from Virginia to Labrador in the western Atlantic (Scott and Scott 1988). Tagging studies have shown that halibut can travel long distances and move extensively throughout the North Atlantic (Stobo et al. 1988).

The distribution of halibut on the Scotian Shelf based on the RV survey is shown in Figure 3.5.5-1 (Horsman and Shackell 2009; see Section 3.5.2 – Preferred Habitat Mapping for details). The RV survey catches small halibut (30–70 cm), so this should be considered a map of juvenile distribution. The halibut survey (see Section 3.1 above) was designed to monitor the distribution and abundance of larger halibut (50–230 cm) over a wide range of depths (50–800 m), The distribution of halibut indicated by the map of the halibut survey catches (Figure 3.5.5-2) is similar to the distribution of catches in the RV survey. Figures 3.5.5-1 and 3.5.5-2 both show halibut distributed throughout the Scotian Shelf, with the exception of the Misaine Bank and Sable Island Bank areas.

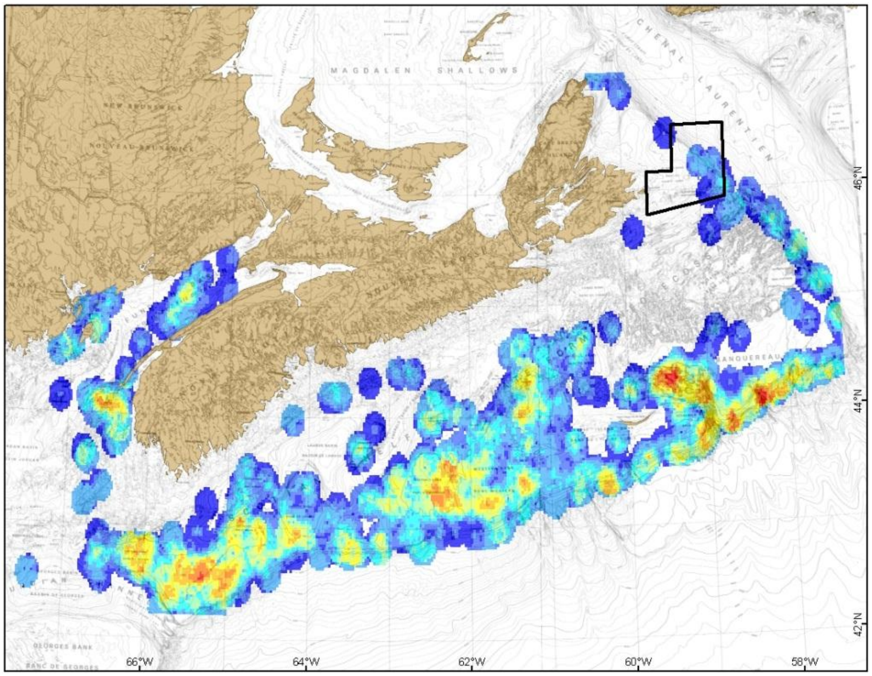


Figure 3.5.5-1. Distribution of Atlantic halibut on the Scotian Shelf based on the RV survey (1970–2006; Horsman and Shackell 2009). Preferred habitat is shown in red/orange. The St Anns Bank AOI boundaries are outlined in black.

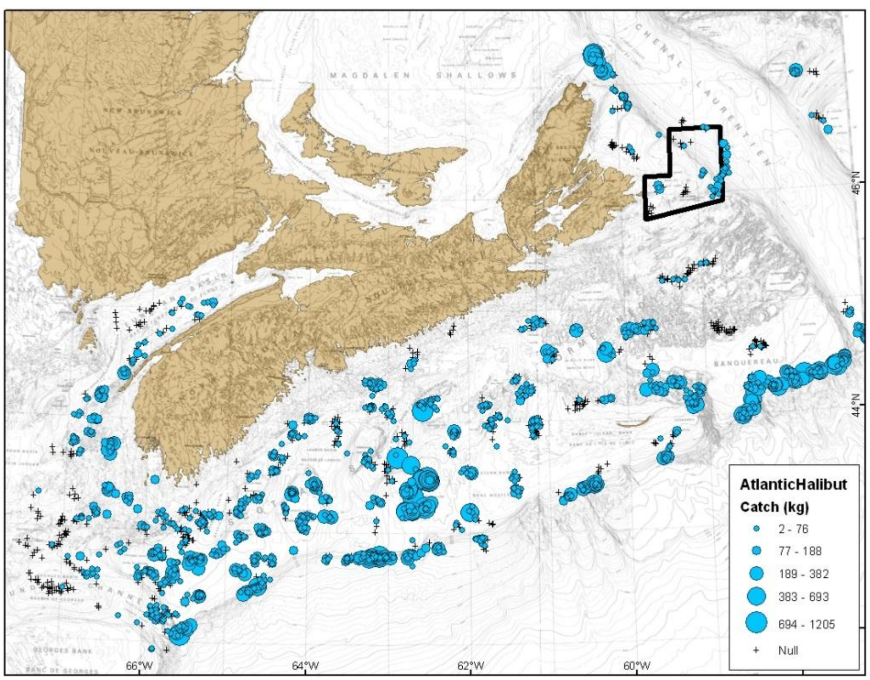


Figure 3.5.5-2. Distribution of Atlantic halibut on the Scotian Shelf based on fixed stations in the halibut survey (1998–2010). The St Anns Bank AOI boundaries are outlined in black.

Habitat Preferences
Halibut are found at temperatures within a few degrees of 5^{o}C, and are most abundant at depths of 200–500 m. They are usually found in deep water channels between banks and along the continental shelf (DFO 2011e). Males appear to be caught in deeper waters than females, but the difference (16 m) may not be biologically relevant (Trzcinski et al. 2011a).

Populations or Stock Definitions
The current management unit for Atlantic halibut is 3NOPs4VWX5Zc, encompassing the entire Scotian Shelf and southern Grand Banks. This is the largest groundfish management unit in Canadian waters (Trzcinski et al. 2011a). It was defined based on the results of tagging studies (Stobo et al. 1988).

Atlantic Halibut in St Anns Bank
There is little specific information regarding halibut in St Anns Bank. The halibut survey has several fixed stations within the St Anns Bank AOI (Figure 3.5.5-3). Most halibut survey catches are in deeper water near the slope and in the channel. Halibut are also caught in the 4Vn sentinel survey (Figure 3.5.5-4; see Section 3.1 above); most catches from that survey are also in deeper water near the slope and in the channel. Based on the halibut, 4Vn sentinel, and RV surveys, it appears that halibut are consistently found in the St Anns Bank AOI, but it is not known to be a particularly important area for this species.

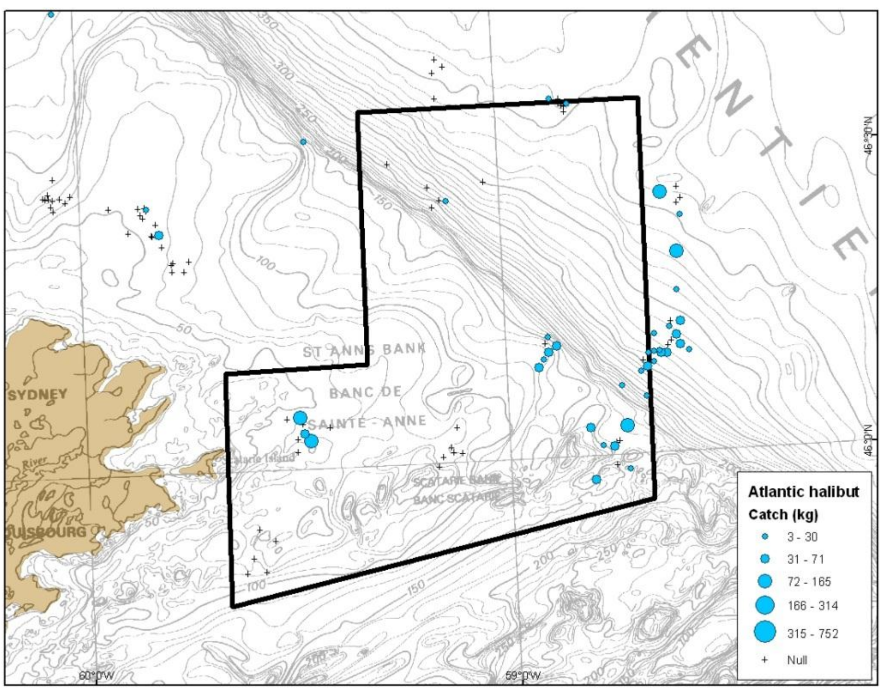


Figure 3.5.5-3. Halibut catches at fixed halibut survey stations in the St Anns Bank area. The St Anns Bank AOI boundaries are outlined in black.

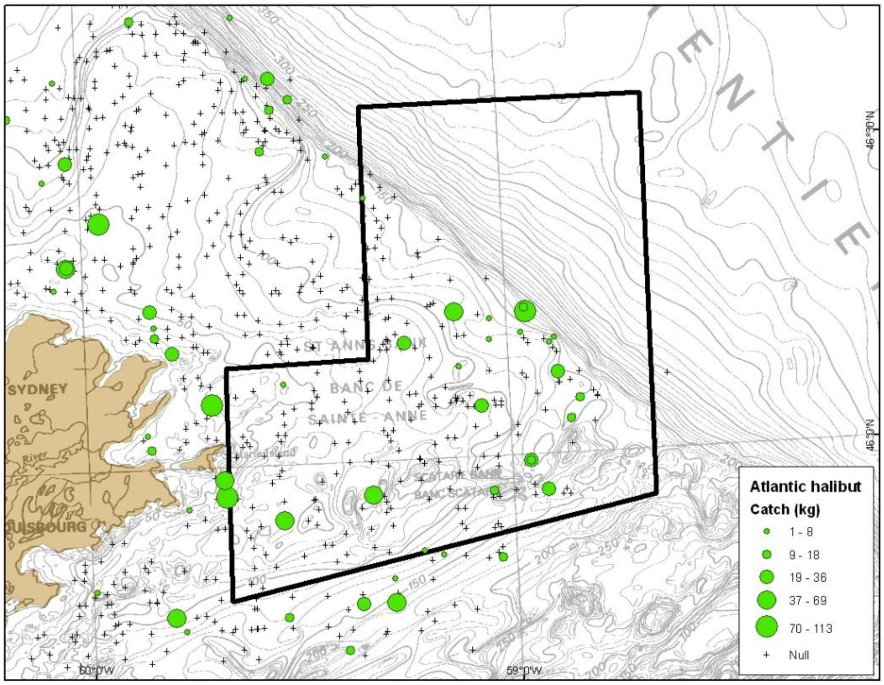


Figure 3.5.5-4. Halibut catches in the 4Vn sentinel survey (1994–2010; excludes commercial index and fixed stations), showing total weight caught (MT).

Biology

Productivity

Halibut are a long-lived species; the oldest observed was a 50-year-old male (Armsworthy and Campana 2010). Halibut are sexually dimorphic; females grow faster and larger than males. The most recent data collected on size at maturity is from the Gulf of St. Lawrence, where females reach 50% maturity at 130 cm (DFO 2009f), and males mature at 75 cm (DFO 2007a).

Although Atlantic halibut are believed to be annual, group-synchronous spawners, with peak spawning activity occurring in November–December (Neilson et al. 1993), no spawning aggregations have been documented and very few larvae have been found in the northwestern Atlantic. Based on the near absence of halibut larvae in the Northeast Fisheries Science Center (NEFSC) ichthyoplankton surveys (April 1977–1991) and the extensive monthly Scotian Shelf Ichthyoplankton Survey (1978–1982) surveys, Neilson et al. (1993) argue that spawning occurs in deep water off the continental shelf. Large halibut can have very high fecundity; a 90.7 kg female can produce over two million eggs (Lonning et al. 1982).

Natural Mortality

Based on life history, natural mortality was assumed to be 0.1 for the stock assessment model (DFO 2011e). The natural mortality estimated from an analysis of the tag recaptures was 0.26, which is thought to be high given that halibut are a long-lived species (DFO 2011e).

Ecosystem Interactions

On the Scotian Shelf, the stomach contents of 1335 halibut ranging in size between 18 and 204 cm have been analyzed. Small Atlantic halibut (< 30 cm) mainly consume invertebrates, those between 30 and 60 cm consume equal proportions of invertebrates and fish, and halibut greater than 60 cm consume predominantly fish. The prey fish of large halibut include Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), white (*Urophycis tenuis*), red (*Urophycis chuss*) and silver hake (*Merluccius bilinearis*), redfish (*Sebastes* spp.), wolffish (*Anarhichas denticulatus*), herring (*Clupea harengus*), and sand lance (*Ammodytes* spp.) whereas the medium-sized halibut consume predominantly silver hake and sand lance (Cook and Bundy 2010). Mature halibut are large, so likely have few predators, but they may be preyed on by seals (Kurtis Trzcinski, DFO Science, personal communication, February 2011).

<u>Fisheries and Other Human Activities</u>

Fisheries

Halibut are fished in 3NOPs4VWX5Zc mostly by longline using bottom hook and line gear. They are generally fished along the edges of the continental shelf. The fishery was unregulated until 1988, when a TAC was introduced (3200 t at the time; DFO 2011e). The average yearly landings from 1960–2009 were ~1800 t. In 2009, the TAC was set at 1700 t, and landings were 2081 t (DFO 2011e). The TAC has included landings from the halibut survey since 2006. Halibut are currently fished in St Anns Bank by hook and line gear fairly consistently. Fishing tends to occur in the southeastern corner of the site.

Other Vulnerabilities to Human Activities

Any other vulnerabilities to human activities (aside from fishing) are unknown.

<u>Status and Trends</u>

Stock Status

Catch rate analyses of the halibut survey show that the population of 3NOPs4VWX5Zc halibut has been increasing over the past five years, with a slight decrease in 2011 (DFO 2011e). Catch rates of halibut in the RV survey have increased since 2002, and the 2010 catch was the highest recorded in all 40 years of the RV survey (DFO 2011e). Overall, halibut biomass and recruitment have been increasing in the 2000s; the 3NOPs4VWX5Zc population is in a productive period due to high recruitment (DFO 2011e).

Species at Risk Considerations

A pre-COSEWIC assessment of halibut was completed by DFO (Trzcinski et al. 2011b), and there is a COSEWIC Status Report scheduled to be released in late 2011 or early 2012. The 3NOPs4VWX5Zc population of halibut is considered to be in a productive period due to high recruitment. The spawning stock biomass estimated by the stock assessment model is in the healthy zone (DFO 2011e).

Sources of Information
In addition to the halibut and RV surveys, a joint DFO/industry halibut tagging study was initiated in 2006, with the goals of estimating exploitation and relative abundance, and evaluating the distribution of halibut in 3NOPs4VWX5Zc (Trzcinski et al. 2009a).

Sources of Uncertainty
Halibut can move large distances, which creates uncertainty in their stock structure. In addition, halibut survey station coverage, which is of great importance in assessing the species, has become irregular (Trzcinski et al. 2009a).

3.5.6 Atlantic Wolffish

The Atlantic wolffish (*Anarhichas lupus*; also known as catfish) is a large demersal fish, named for its powerful jaws with canine-like teeth (Kulka et al. 2007)

Geographic Range and Habitat Preferences
Atlantic wolffish are distributed across the North Atlantic, from Labrador in the north to New Jersey in the south (Scott and Scott 1988). They are found across the Scotian Shelf, with concentrations near the Bay of Fundy, and Browns, Roseway, and LaHave banks in the west, and in the northeast part of the Scotian Shelf next to the Laurentian Channel, as well as off western Newfoundland (DFO 2002c). Distribution of Atlantic wolffish on the Scotian Shelf (based on the RV survey; see Section 3.5.2 above) is shown in Figure 3.5.6-1.

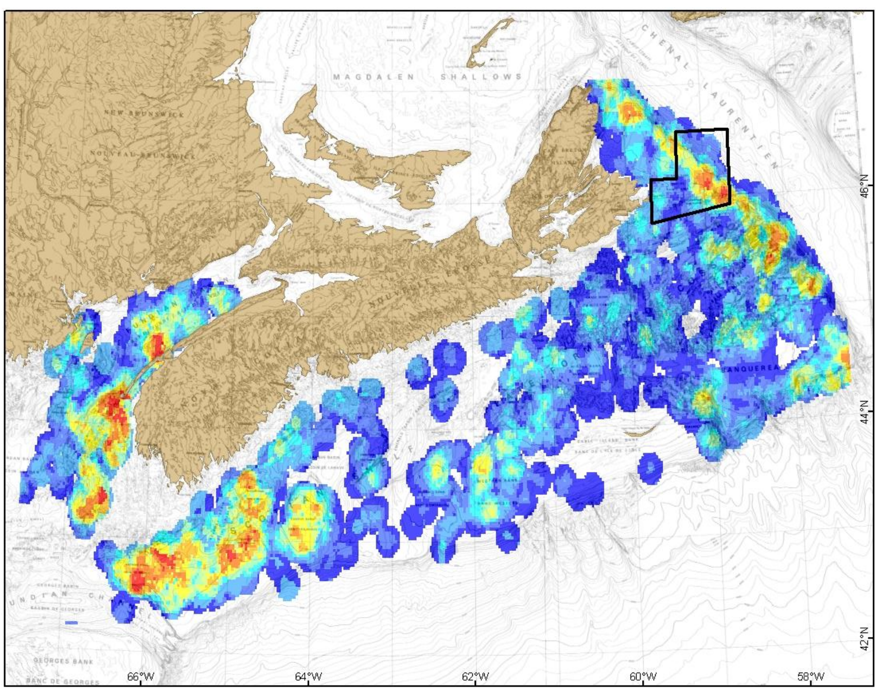


Figure 3.5.6-1. Distribution of Atlantic wolffish on the Scotian Shelf (Horsman and Shackell 2009). Preferred habitat is shown in red/orange. The St Anns Bank AOI boundaries are outlined in black.

Habitat Preferences

Atlantic wolffish are usually found in depths between 50 and 150 m, in temperatures from 0.4 to 6^oC (DFO 2002c). On the Scotian Shelf their preferred bottom conditions are depths of 73 to 126 m, temperatures of 3 to 6^oC, and salinity of 32 to 34 ppt (Albikovskaya 1982 in McRuer et al. 2000). They prefer hard substrate and are rarely found over mud bottoms (McRuer et al. 2000). Atlantic wolffish are largely sedentary; tagging studies have shown most individuals recaptured within eight kilometres of the original tagging location (Templeman 1984).

Populations or Stock Definitions

Nothing is known of the stock structure of Atlantic wolffish (McRuer et al. 2000), but the Scotian Shelf population is assessed as 4VWX.

<u>Atlantic Wolffish in St Anns Bank</u>

Within St Anns Bank, Atlantic wolffish are generally found along the slope of the Laurentian Channel in the RV survey (Figure 3.5.6-2).

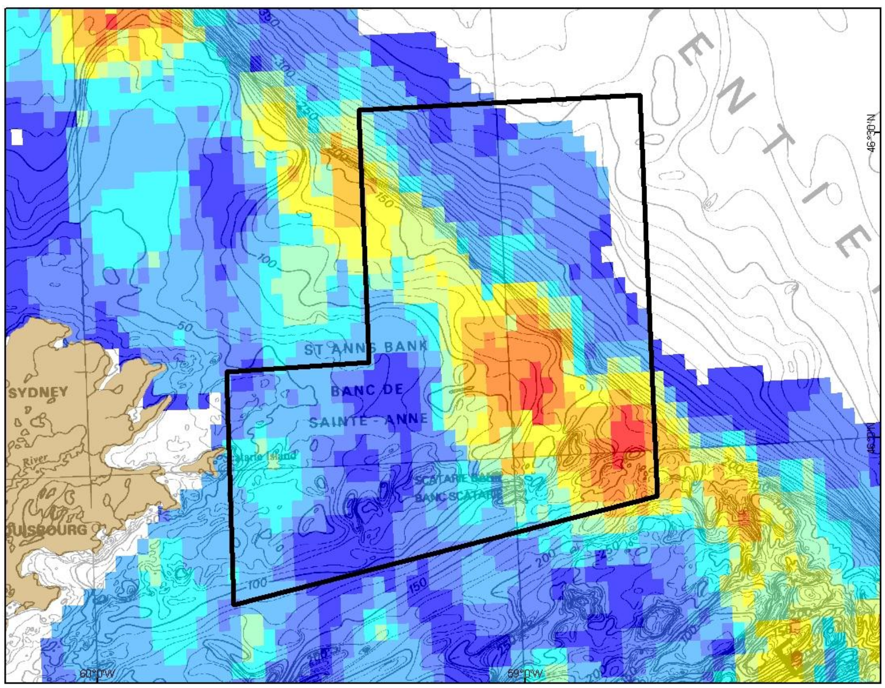


Figure 3.5.6-2. Distribution of Atlantic wolffish in the St Anns Bank area (Horsman and Shackell 2009). Preferred habitat is shown in red/orange. The St Anns Bank AOI boundaries are outlined in black.

Horsman and Shackell (2009) mapped preferred habitat for wolffish on the Scotian Shelf over four time periods using the RV survey (see Section 3.5.2 above). From 1978–1985, Atlantic wolffish were in high abundance and their most preferred habitat represented ~5% of the ESS. From 1994–2006, their most preferred habitat represented only 0.4% of the entire ESS, and ~50% of that occurred in St Anns Bank (Figure 3.5.6-3). For Atlantic wolffish, the St Anns Bank area represents one of the few remaining areas where they occupy their most preferred habitat. However, Simon et al. (2011a) report that the area of occupancy of Atlantic wolffish on the ESS has not shown any significant trend since the 1970s.

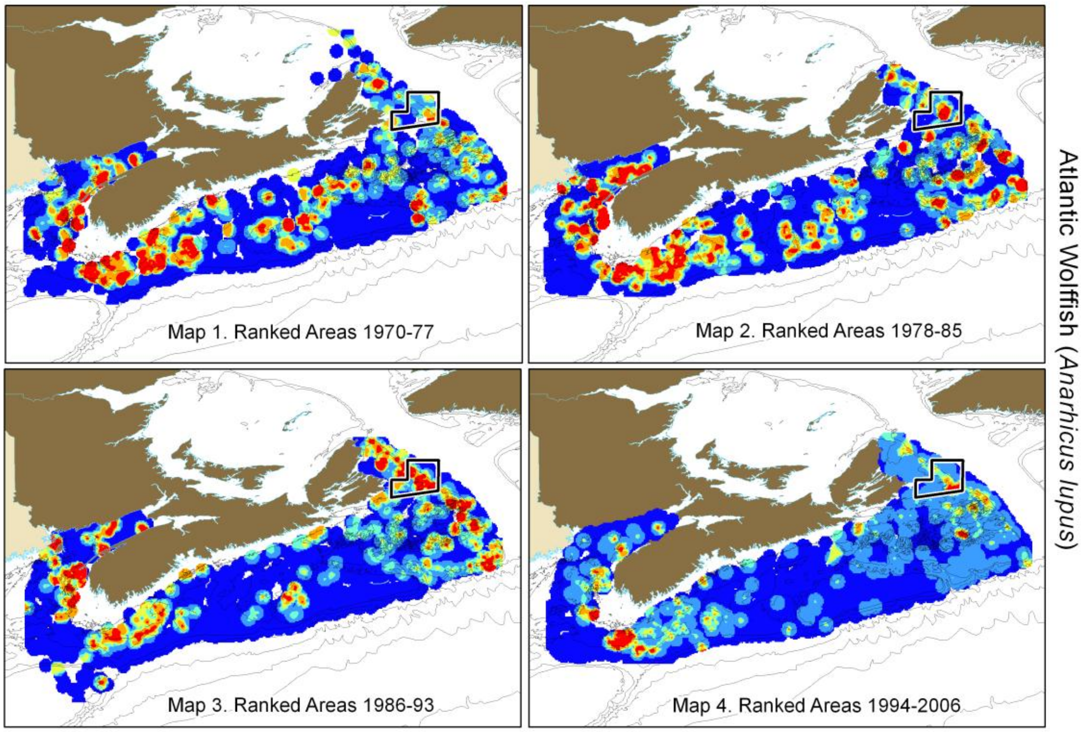


Figure 3.5.6-3. Atlantic wolffish distribution over four time periods from Horsman and Shackell (2009). Preferred habitat is shown in red/orange. The St Anns Bank AOI boundaries are outlined in black.

Atlantic wolffish have also been caught in the St Anns Bank area in the halibut industry survey (Figure 3.5.6-4), the 4Vn sentinel survey (Figure 3.5.6-5), and the snow crab survey (Figure 3.5.6-6) (the research surveys are described above in Section 3.1). The halibut survey shows concentrations of Atlantic wolffish closer to shore (~100 m depth) than the RV survey, on St Anns Bank itself, as does the 4Vn sentinel survey, while the snow crab survey shows wolffish caught both on the bank and near the slope into the Laurentian Channel.

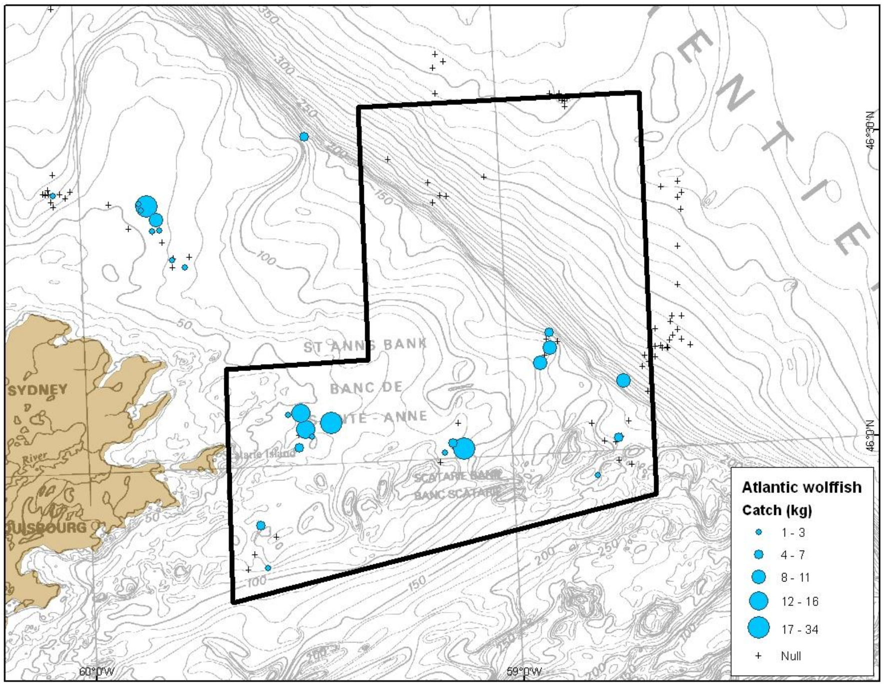


Figure 3.5.6-4. Distribution of Atlantic wolffish in the halibut industry survey (1998–2010; fixed stations only), showing total weight caught (kg).

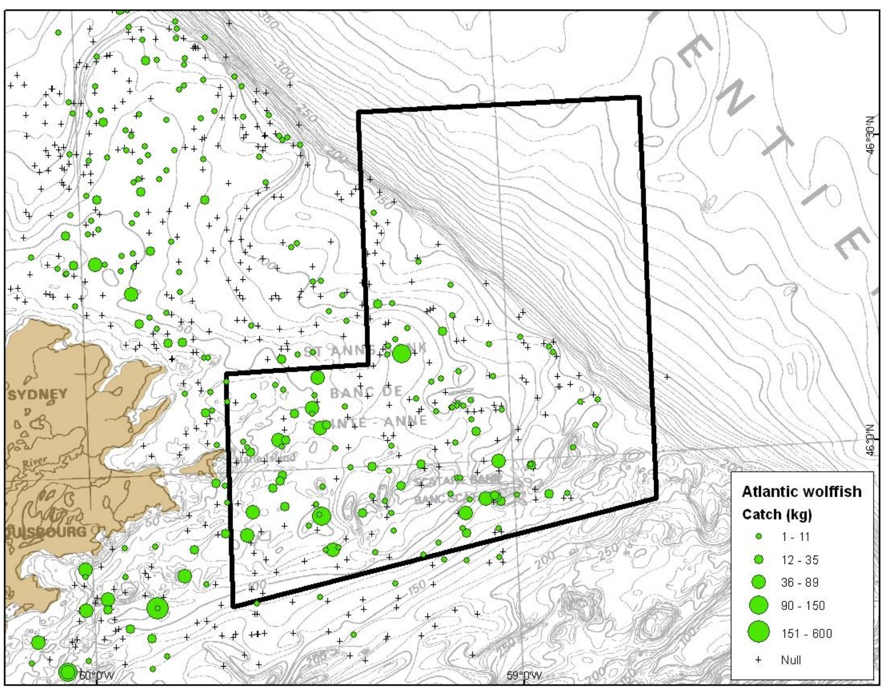


Figure 3.5.6-5. Distribution of Atlantic wolffish in the 4Vn sentinel survey (1994–2010; excludes commercial index and fixed stations), showing total weight caught (kg).

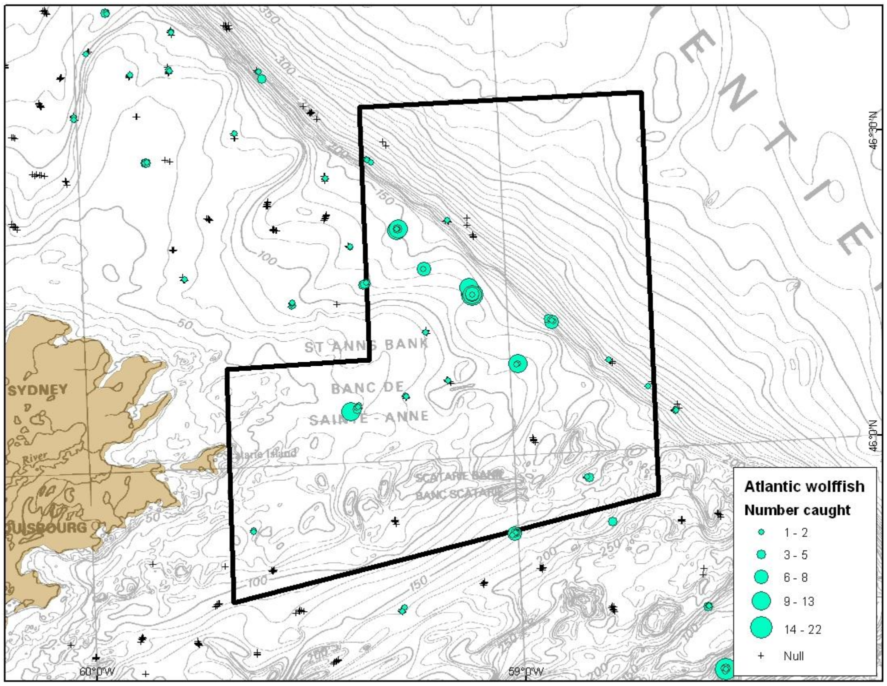


Figure 3.5.6-6. Distribution of Atlantic wolffish in the snow crab survey (2004–2010), showing the number of individuals caught (weight not available).

In summary, Atlantic wolffish have been found in the St Anns Bank area consistently in several surveys (RV, halibut, sentinel, snow crab). St Anns Bank contains a large portion of their preferred habitat (50% of preferred habitat on the ESS) for the years 1994–2006 (Horsman and Shackell 2009). It is not known how wolffish use the area, but they do appear to use it consistently.

Biology

Productivity
The largest Atlantic wolffish recorded in Canadian waters was 124 cm in length and weighted 19.5 kg (McRuer et al. 2000). Length at age for wolffish is not known, but maturity is assumed at ~55 cm (McRuer et al. 2000). Length at age estimates assume that 55 cm fish are approximately ten years old (McRuer et al. 2000).

Atlantic wolffish are not highly fecund, but the survival of their eggs is high (McRuer et al. 2000). Eggs are laid on rocks and gravel, and are guarded by an adult male until they hatch. Wolffish larvae generally do not move far from where they were hatched.

Natural Mortality
Little is known about the natural mortality of wolffish. It may have played a significant role in their decline, but natural mortality is still poorly understood (Kulka et al. 2007).

Ecosystem Interactions
Atlantic wolffish prey on invertebrates such as whelks, sea urchins, brittle stars, crabs, and scallops, and redfish (Templeman 1985). Cod may be predators of small wolffish (Saemundsson 1949 and Barsukov 1959 in McRuer et al. 2000), while seals may prey on adult wolffish (Hammill and Stenson 2000).

<u>Fisheries and Other Human Activities</u>

Fisheries
There is no directed fishery on the Scotian Shelf for wolffish, but Atlantic wolffish are caught as bycatch in groundfish fisheries (Kulka et al. 2007; Simon et al. 2011a). Landings of Atlantic wolffish in 4VW peaked in the 1970s at 700 t and have been close to zero since 1993 when directed fishing for cod and haddock ended. Wolffish may be directed for in specific sets to reach bycatch limits within a trip, but this generally occurs in the 4X area (Simon et al. 2011a).

Other Vulnerabilities to Human Activities
Kulka et al. (2007) suggest that other human threats to wolffish may include offshore oil, gas, and mining activities (seismic, exploration and production), ocean dumping, military activity, cables and pipelines, and marine and land-based pollution.

<u>Status and Trends</u>

Stock Status
In 4VW, the abundance of small (immature) Atlantic wolffish has been increasing since the 1970s (with high variability), and peaked in the early 2000s. The abundance of large (54+ cm, mature) fish in 4VW has been decreasing since the 1970s. Large/mature fish have declined 98.8% in 4VW since the 1970s, though if all fish (mature and immature) are considered, there is an increasing trend in catch rate (Simon et al. 2011a).

Species at Risk Considerations
Atlantic wolffish are listed by *SARA* and COSEWIC as Special Concern. The last COSEWIC assessment was done in 2000. A pre-COSEWIC review of wolffish in the Maritimes Region was completed in 2011 (Simon et al. 2011a).

<u>Sources of Information</u>
The main source of information for Atlantic wolffish on the Scotian Shelf is the summer RV survey conducted by DFO, but it is also caught in the sentinel, halibut, and snow crab surveys (see Section 3.1).

<u>Sources of Uncertainty</u>
There is still uncertainty regarding the biology/life history of Atlantic wolffish. Knowledge of reproduction, growth, and stock structure is lacking (McRuer et al. 2001).

3.5.7 Redfish
Redfish in the Cabot Strait include two species, *Sebastes mentella* and *S. fasciatus*. These species support commercial fisheries and are among the most abundant fish species along the Laurentian Channel slope, including the AOI.

Geographic Range and Habitat Preferences
The two redfish species are distributed according to a latitudinal gradient in the northwest Atlantic (DFO 2008a). The more northerly species, *S. mentella* or deep-water redfish, is dominant in Baffin Bay and Labrador waters, while the more southerly species, *S. fasciatus* or Acadian redfish, dominates in the Gulf of Maine and on the slopes and basins of the Scotian Shelf. The distribution of both species overlaps in the Gulf of St. Lawrence, the Laurentian Channel, the Grand Banks, southern Labrador Sea, and in the Flemish Cap area (Figure 3.5.7-1).

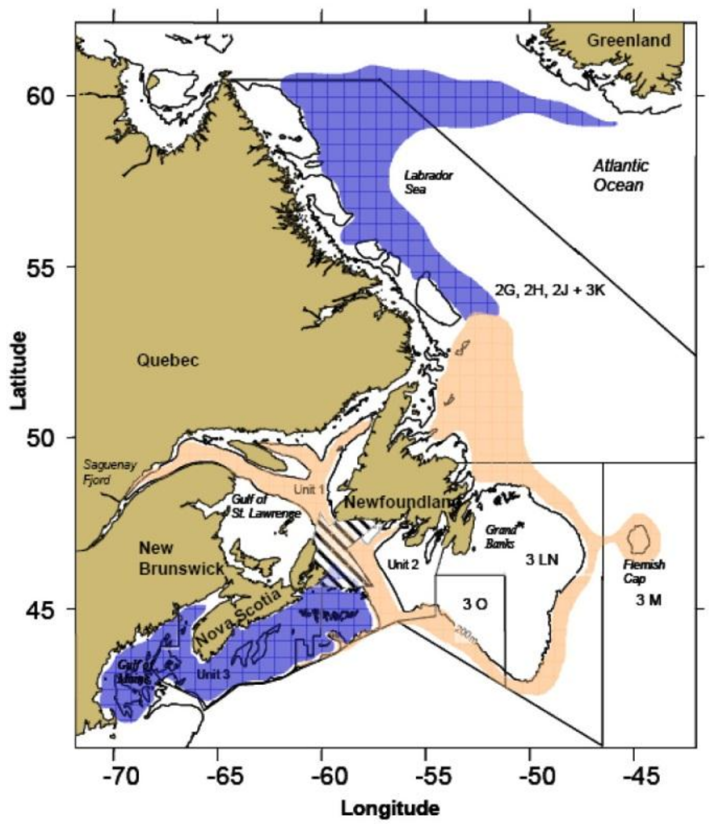


Figure 3.5.7-1. Distribution of *S. fasciatus* and S. *mentella*; areas where distribution of two species overlaps is represented by the peach colour; purple areas are those where only one of the two species is present; hatched area (NAFO Subdivisions 3Pn and 4Vn) indicates area of seasonal overlap (from DFO 2008a).

Fertilization in redfish is internal, and females bear live young. Mating takes place between September and December, and females carry the developing embryos until they are extruded as free-swimming larvae in the spring. Larval extrusion takes place from April to July depending on the area and species. Mating and larval extrusion do not necessarily occur in the same locations. This is consistent with the relatively widespread distribution of redfish larvae observed in ichthyoplankton surveys (O'Boyle et al. 1984), making it difficult to clearly identify mating sites. It appears that, historically, 4Vn is an area of significant larval concentrations (Figure 3.5.7-2).

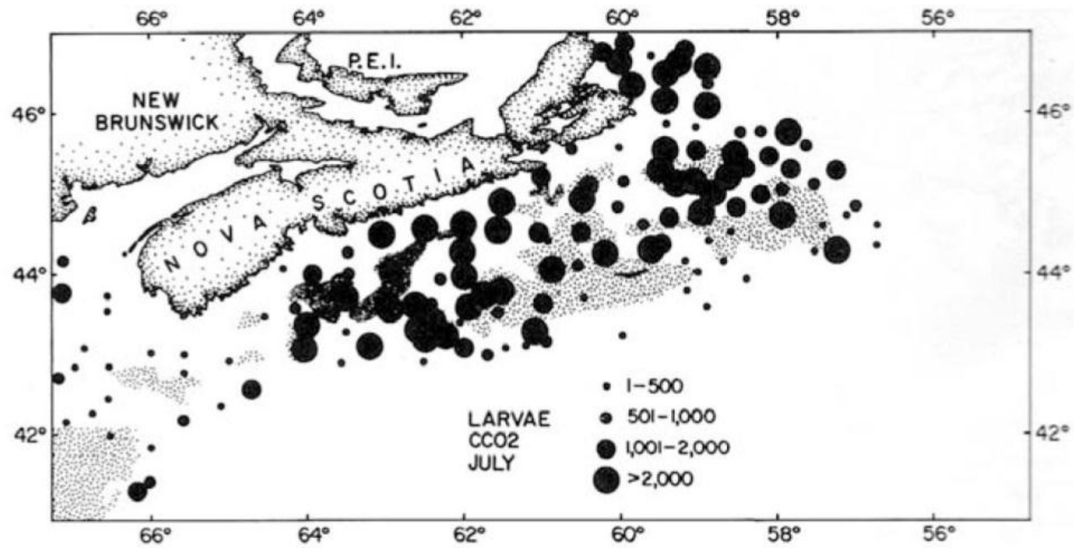


Figure 3.5.7-2. Distribution of redfish (*Sebastes* spp.) larvae on the Scotian Shelf in 1979 as determined by oblique bongo tows. All values in numbers per 100,000 m^3 of water strained (from O'Boyle et al. 1984).

As adults, redfish inhabit cool waters along the slopes of banks and deep channels in depths of 100–700 m. *S. fasciatus* typically occurs in shallower waters (150–300 m), whereas *S. mentella* is distributed at depths varying between 350 and 500 m. They are generally found near the bottom. However, studies have shown that these species undertake diel vertical migrations, moving off the bottom at night to follow the migration of their prey (Beamish 1966; Gauthier and Rose 2005).

Similar to other species that reside in the Gulf, redfish undergo overwintering migrations from 4T to 4Vn in November and return to the Gulf in May (Morin et al. 1994; Gascon 2003). During 1988–1992, there were also indications of increasing aggregations at the 4Vn/4Vs border (St Anns Bank area) during April, at about the same time as the northward movement into the Gulf. This aggregation persisted with high density until the end of June. It appears that a substantial portion of the stock biomass in 4T overwinters in the Cabot Strait (Gascon 2003). Campana et al. (2007a) examined this migration in some detail, corroborating earlier work. Unfortunately, their observations were only applicable to *S. mentella* due to sample size.

<u>Population or Stock Definitions</u>

Two populations are now recognized (DFO 2008a) for *S. mentella* in the northwest Atlantic:

- Gulf of St. Lawrence – Laurentian Channel (Units 1 + 2)

- Southern and northern Grand Banks and Labrador Sea (NAFO Divisions 3LN, 3O, 2GHJ-3K)

Three populations are now recognized for *S. fasciatus*:

- Units 1 + 2 (Gulf of St. Lawrence – Laurentian Channel)
- Northern group (slope of the Grand Banks (3LNO) to the southern margin of Unit 2, i.e., southern tip of St. Pierre Bank, with possible ramification on the slope of Scotian Shelf)
- Unit 3 (Southern group, Gulf of Maine, and Scotian Shelf)

However, redfish are not managed by individual species; they are managed by the units shown below in figure 3.5.7-3 that include differing proportions of both species.

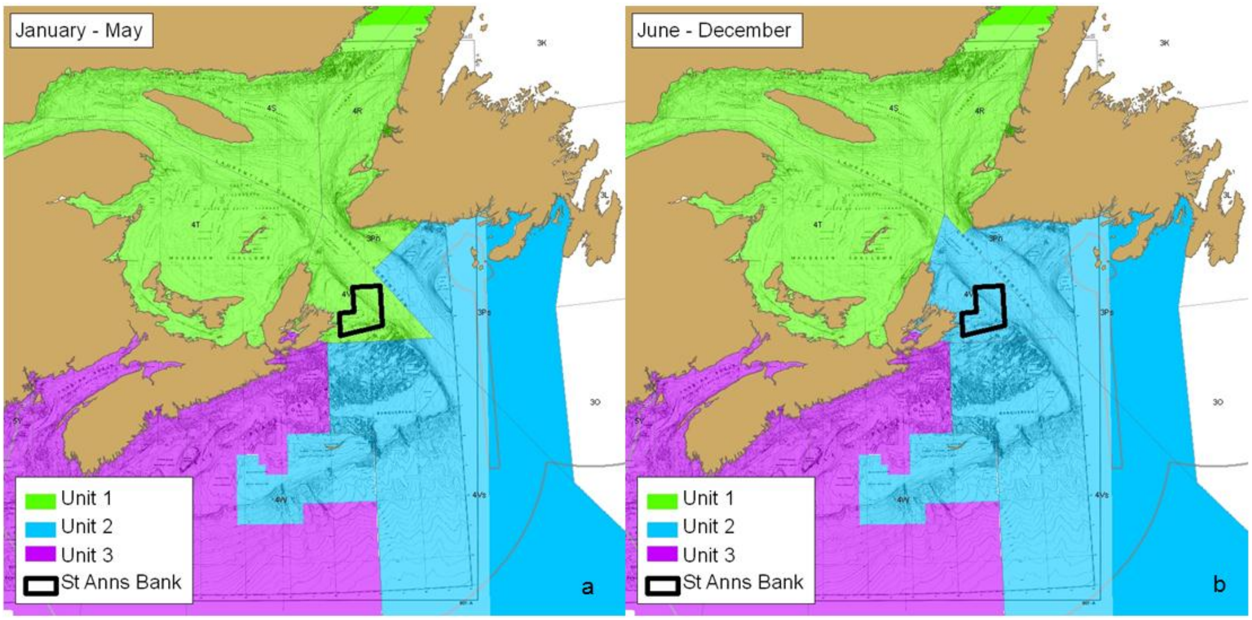


Figure 3.5.7-3. Redfish (*Sebastes* spp.) management units in the N-W Atlantic from a) January to May and b) June to December.

Redfish in St Anns Bank

Units 1 and 2 redfish can be found on St Anns Bank. Unit 1 redfish are found within the AOI during November–May and Unit 2 redfish are present during the rest of the year. It is uncertain as to what proportion of these units enters 4Vn, but it appears substantial for Unit 1 and less so for Unit 2.

Horsman and Shackell (2009) mapped preferred habitat for redfish on the Scotian Shelf over four time periods (see Section 3.5.2 above). It is clear from these maps that the Laurentian Channel slope is one of the most important areas for redfish, particularly on the ESS (Figures 3.5.7-4 and 3.5.7-5). The percentage of preferred habitat for redfish on the ESS, which is found in the AOI, increased from 8.7% in 1978–1985 to 11.2% in 1994–2006.

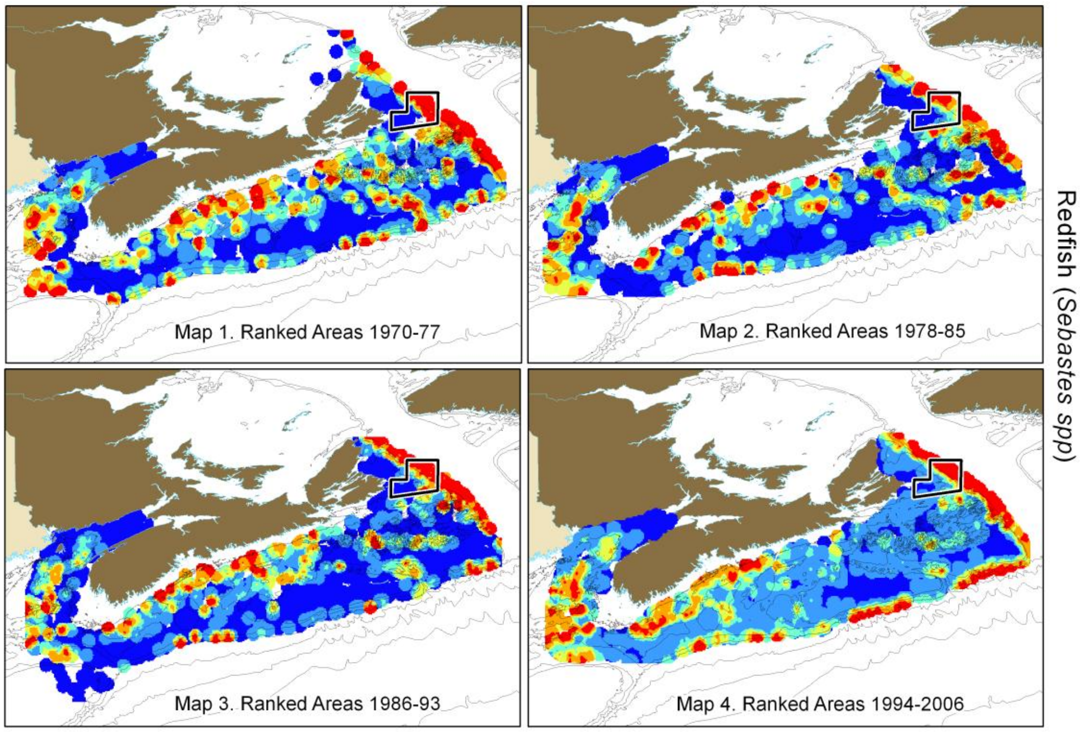


Figure 3.5.7-4. Distribution of redfish on the Scotian Shelf for the years 1970–1977, 1978–1985, 1986–1993, and 1994–2006 (Horsman and Shackell 2009). Preferred habitat is shown in red/orange. The St Anns Bank AOI boundaries are outlined in black.

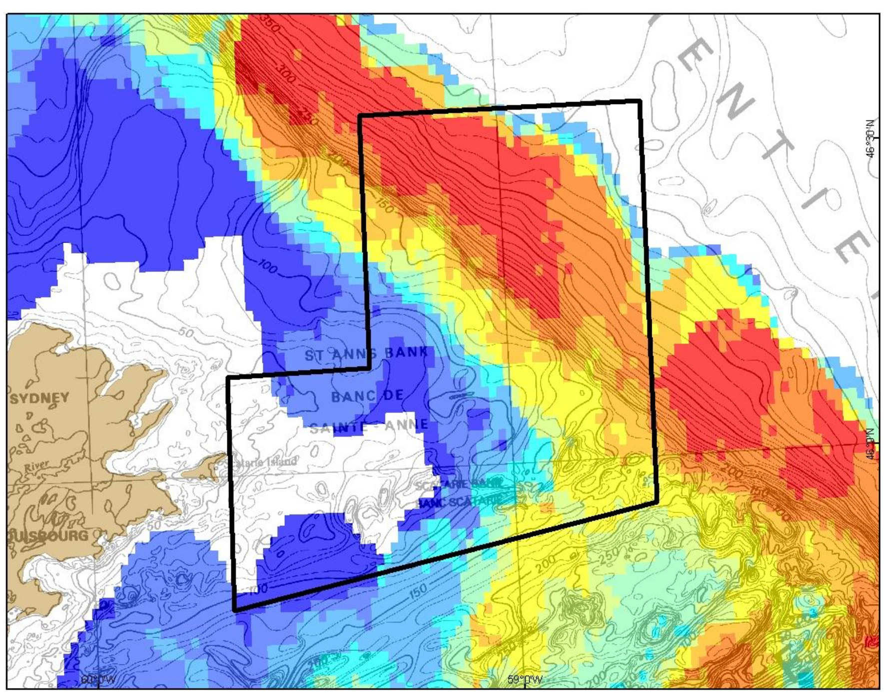


Figure 3.5.7-5. Distribution of redfish in the St Anns Bank area (Horsman and Shackell 2009). Preferred habitat is shown in red/orange. The St Anns Bank AOI boundaries are outlined in black.

Redfish had the highest abundance of any fish recorded in the RV survey in the AOI, and the fourth highest frequency of catch. Though their abundance is highest on the slope, they were found widely in the site (Figure 3.5.7-5) in all snow crab survey stations except one and in most sets of the RV survey.

<u>Biology</u>

Productivity
Redfish are a slow growing and long-lived species, living to at least 75 years of age (Gascon 2003). They mature at a relatively old age (8.03–10.5 years on the Scotian Shelf and Gulf of St. Lawrence) but at relatively small sizes (24–25 cm) (McAllister and Duplisea 2011a). Fecundity is 3,300–107,000 eggs for a mature female.

Natural Mortality
There are no estimates of natural mortality (M) for Units 1 and 2 redfish. The most recent assessment assumed M of 0.1 yr^{-1} for *S. mentella* and 0.125 yr^{-1} for *S. fasciatus* (McAllister and Duplisea 2011a).

Ecosystem Interactions
Bundy (2004; 2005) discuss the role of redfish in the Scotian Shelf ecosystem. Their prey consists primarily of small demersal feeders (e.g., large zooplankton) and shrimp. COSEWIC (2010a) indicates that deep-water and Acadian redfish appear to have a similar diet. Their main predators are large gadoids (cod, pollock, haddock) and grey seals. Redfish are noted by COSEWIC (2010a) as being a significant part of grey seal diet and thus an important contributor to redfish natural mortality

<u>Fisheries and Other Human Activities</u>
For Unit 1, the directed trawl fishery was closed in 1995 as a result of low stock abundance and the absence of significant recruitment (DFO 2010e), and has remained closed since then. However, a small index fishery established in 1998 has continued with an annual allocation of 2000 t (1000 t in 1998). During 2004–2008, the average annual landings of the index fishery and bycatch in Unit 1 reached 626 t for a TAC of 2000 t. For 2009, preliminary data indicate landings of 600 t against an allocation of 2000 t.

For Unit 2, landings by the trawl fishery averaged 10,500 t during 1995–2003. From 2004 to 2008, landings averaged 5250 t compared to a mean annual TAC of 8333 t. Industry reported that market conditions were the major reason why catches fell short of the TAC. In 2009, preliminary data indicated landings of 5132 t against a TAC of 8500 t.

<u>Status and Trends</u>
Regional assessment updates were last published in 2004 for both Units 1 and 2. A summary of the most recent zonal review (DFO 2011a) can be found below.

In the northwest Atlantic, redfish are characterized by extensive variability in recruitment with strong pulses generally occurring at 5–12 year intervals. However, recruitment has been low in both Units 1 and 2 in the last 20 years. Some year-classes that appeared strong at young ages in research surveys, particularly in Unit 1, subsequently declined within a few years without contributing to either the adult populations or the fishery. The factors responsible for the disappearance of these year-classes remain unknown, but the species composition of a given year-class may be a key factor in the recruitment dynamics.

Based upon genetic studies, it appears that 30 years ago, Units 1 and 2 produced the last strong *S. mentella* year-class that greatly contributed to the fishery; all the recent strong year-classes are by *S. fasciatus* (1974, 1985, 1988, and 2003). These *S. fasciatus* year-classes disappeared well before recruiting to the Unit 1 fishery but contributed to Unit 2 fisheries, with the exception of the 2003 year-class which is still largely pre-recruit.

The survey index of spawning stock biomass of *S. fasciatus* was estimated at 146,400 t in 2009. Since 2000, the average percentage of spawning biomass estimated in Unit 1 and Unit 2 is 18% and 82%, respectively. The survey index of spawning stock biomass of *S. mentella* was estimated at 115,400 t in 2009. Since 2000, the average percentage of spawning biomass estimated in Unit 1 and Unit 2 is 27% and 73%, respectively. In both cases, Unit 2 is a much larger portion of the overall Unit 1 + 2 spawning biomass.

During 2000–2009, the unified *S. fasciatus* survey biomass index appeared stable (Figure 3.5.7-6) whereas that of *S. mentella* declined continuously (Figure 3.5.7-7). From 2000–2005, *S. fasciatus* and *S. mentella* biomasses were comparable, but in recent years, *S. mentella* biomass has been smaller than *S. fasciatus*. The same trends are observed for the mature biomass (DFO 2010e). DFO (2010e) noted that given the relatively low level of biomass observed and the prospect of only typical low recruitment, the exploitation rate should remain low for both species.

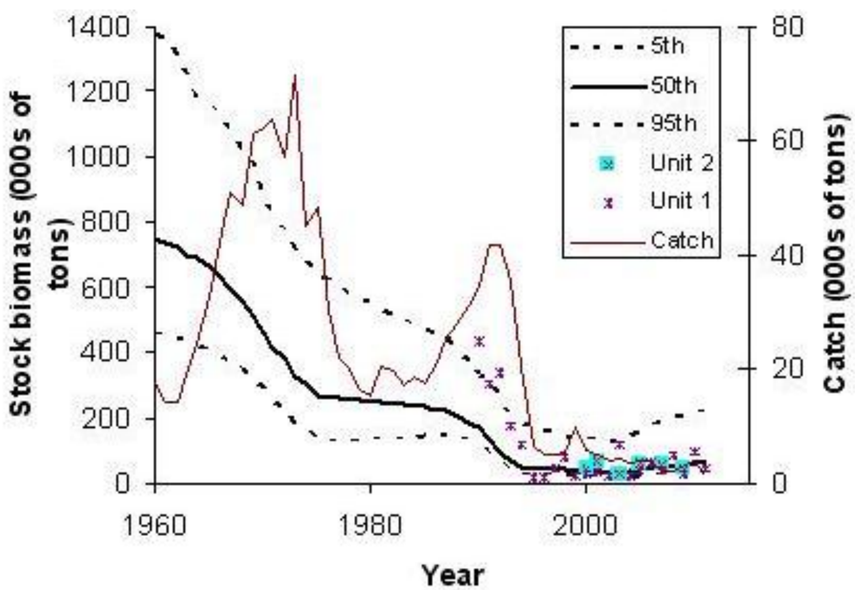


Figure 3.5.7-6. Plots of catch biomass (kt), and 5th, median, and 95% percentiles for mature stock biomass of S. *fasciatus* in Units 1 and 2. The survey biomass indices divided by the median estimates of q are also shown (McAllister and Duplisea 2011b).

The relatively low level of current biomass combined with the prospect of only low recruitment plus the biology of two slow-growing species implies that the stock conditions will remain similar into the near future. This outlook is consistent with the conclusions of COSEWIC (2010a).

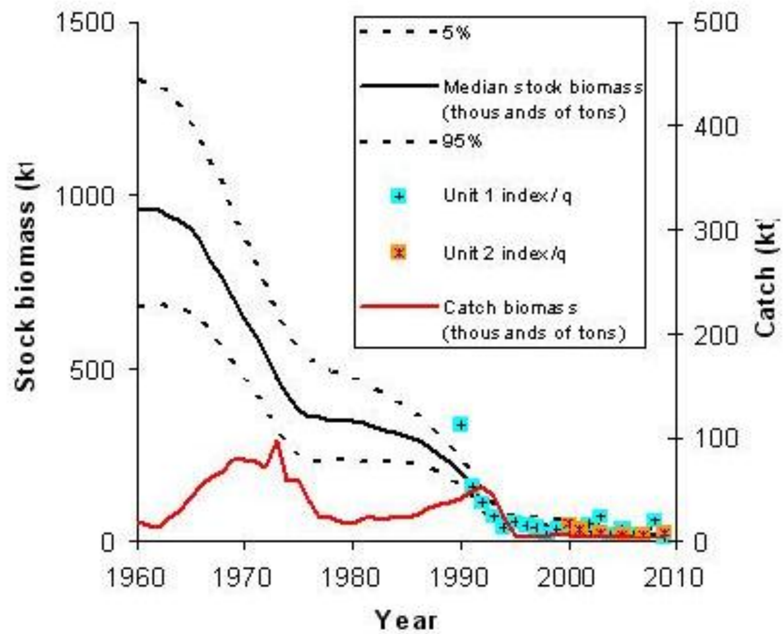


Figure 3.5.7-7. Plots of catch biomass (kt), and 5th, median, and 95% percentiles for mature stock biomass of S. *mentella* in Units 1 and 2. The survey biomass indices divided by the median estimates of q are also shown (McAllister and Duplisea 2011a).

Species at Risk Considerations

COSEWIC (2010a) has different designatable units than DFO, their assessed status being:

- *S. mentella*
  - Gulf of St. Lawrence – Laurentian Channel: Endangered
  - Northern: Threatened
- *S. fasciatus*
  - Atlantic: Threatened (DU comprised of three stocks of DFO)
  - Bonne Bay: Special Concern (this DU is split off compared to that of DFO)

<u>Sources of Information</u>

Stock status is monitored using data from Unit 1 and Unit 2 fisheries (commercial landings and catch at length) and catch per unit of effort (CPUE) from a commercial (index) fleet for Unit 1 only. Indices of abundance derived from DFO and industry surveys are also available for both Units 1 and 2.

In Unit 1, the July otter trawl sentinel survey (1995–2009) and the DFO RV survey (1990–present) are examined. For Unit 2, the industry September GEAC survey (1997–present, partially funded by DFO since 2007) is analyzed. In the most recent assessment (DFO 2010e), a unified Units 1 and 2 index of abundance for each species was derived using the Unit 1 annual DFO survey and the Unit 2 GEAC industry survey through comparative fishing trials that allowed a conversion of each series into Campelen trawl equivalent estimates.

Sources of Uncertainty

While much has been clarified on species and stock identification, much remains to be done to elucidate the processes responsible for the recruitment and biomass trends in the populations. Recruitment mechanisms for redfish species are not well understood. More research needs to be focused on the current low annual recruitment to determine its species composition and to identify its origin.

It appears that both Units 1 and 2 redfish are found in the St Anns Bank AOI. Unit 1 is present during the November–May overwintering period and Unit 2 during the remainder of the year. While a significant portion of these units enters 4Vn, it is uncertain what portion would enter the area in and around the AOI.

Lastly, a significant source of uncertainty is the relatively short time period for the monitoring series available given the long generation times.

3.5.8 Smooth Skate

The smooth skate (*Malacoraja senta*, formerly *Raja senta*) is a small species of skate found only in the northwest Atlantic. Published information regarding this species is currently limited.

Geographic Range and Habitat Preferences

Smooth skate are found on the continental shelf off the east coast of North America, from the Carolinas to Labrador (Kulka et al. 2006). On the Scotian Shelf, there are concentrations in the Bay of Fundy, north of Browns Bank, on the eastern banks and slopes, and in 4Vn (Kulka et al. 2006). Smooth skate is the third most common skate species throughout most of its range; it is caught in 9% of Canadian trawl survey sets (Kulka et al. 2006).

Distribution of smooth skate on the Scotian Shelf, based on the RV survey, is shown in Figure 3.5.8-1 (see Section 3.5.2 above). However, the RV survey is poor at catching the smallest sizes (< 25 cm) of smooth skate (Kulka et al. 2006), so this distribution map may not show the full size range of this species.

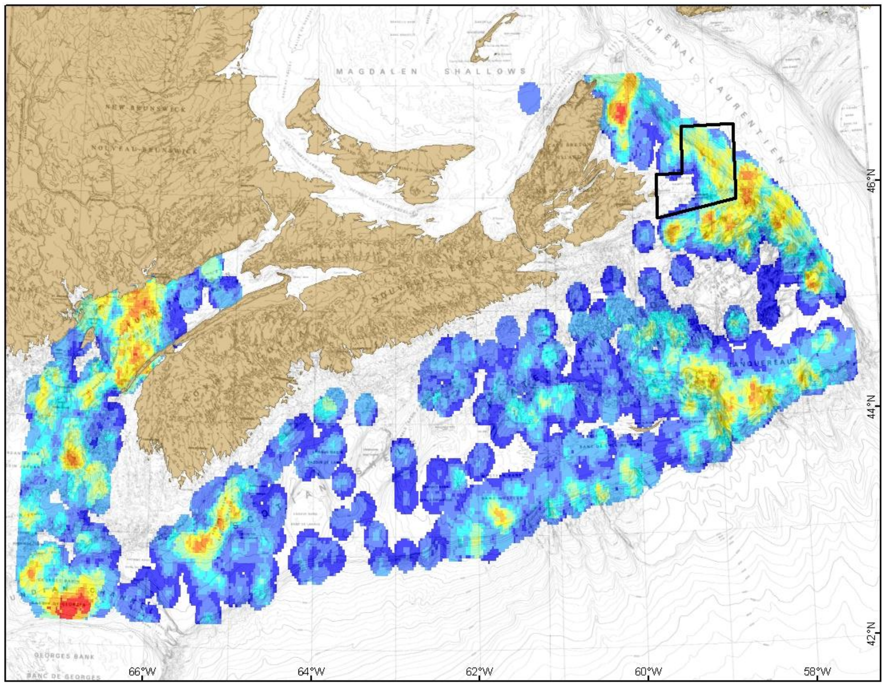


Figure 3.5.8-1. Distribution of smooth skate on the Scotian Shelf based on the RV survey (1970–2006; Horsman and Shackell 2009). Preferred habitat is shown in red/orange. The St Anns Bank AOI boundaries are outlined in black.

Habitat Preferences

Smooth skate live on soft mud and clay bottoms in deep troughs and basins (Scott and Scott 1988). Kulka et al. (2006) report smooth skate found over a range of depths in scientific surveys on the east coast of Canada. Before 1995, the densest concentrations were found between 150 and 450 m; after 1995, the densest concentrations were between 150 and 550 m. They tend to be found in shallower waters at the southern end of their distribution (Kulka et al. 2006). Smooth skate are found over a narrow range of temperatures. Kulka et al. (2006) report the densest concentrations in the above-mentioned surveys were where bottom temperature was between 2.7 and 10^{o}C.

Populations or Stock Definitions

The population structure of smooth skate is currently unknown. Kulka et al. (2006) defined five DUs where they found distinct concentrations of smooth skate: Hopedale Channel, Funk Island, Flemish Cap, Laurentian, and Gulf of Maine. The Laurentian DU was the largest, encompassing the southwest slope of the Grand Bank, the Laurentian Channel, the Gulf of St. Lawrence, and the Eastern Scotian Shelf (north and east of Sable Island Bank), and representing ~48% of the global range of smooth skate (Kulka et al. 2006). However, there is still uncertainty surrounding whether or not the Laurentian DU is appropriately partitioned (Kulka et al. 2006).

<u>Smooth Skate in St Anns Bank</u>

Smooth skate found in St Anns Bank would be considered part of the Laurentian DU as defined by Kulka et al. (2006). Figure 3.5.8-2 shows concentrations of smooth skate in

St Anns Bank along the slope into the Laurentian Channel. However, these concentrations are not preferred habitat as defined by Horsman and Shackell (2009; see Section 3.5.2 above). There are no reported catches of smooth skate in St Anns Bank in the 4Vn sentinel survey.

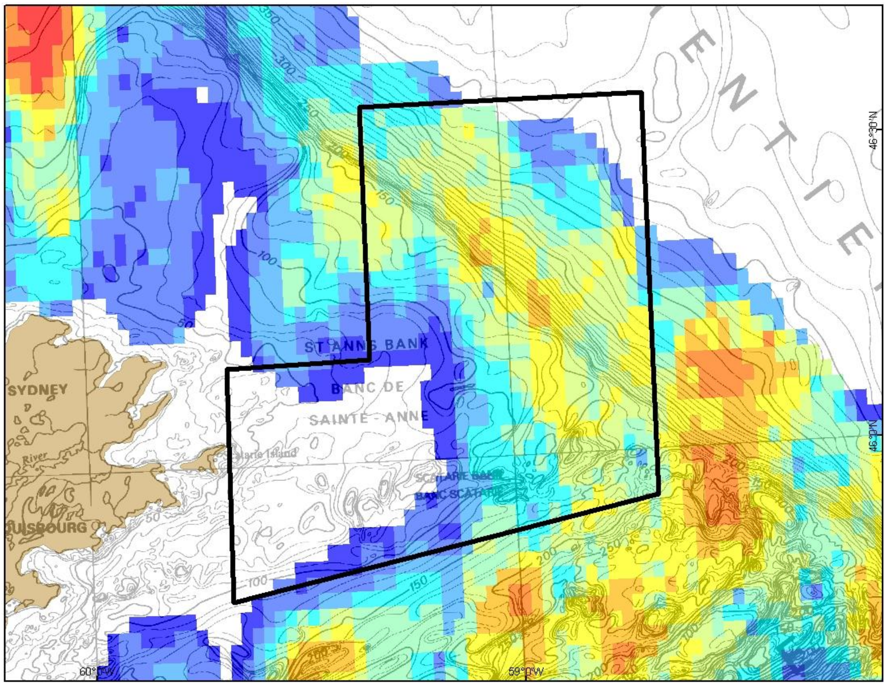


Figure 3.5.8-2. Distribution of smooth skate in the St Anns Bank area (Horsman and Shackell 2009). Preferred habitat is shown in red/orange. The St Anns Bank AOI boundaries are outlined in black.

Smooth skate have been consistently caught in St Anns Bank in the RV survey over the 40-year time series. However, the area does not appear to be of particular importance to the species, at least for the size of skate caught by the RV survey. There have also been high numbers of skate purses caught in the snow crab survey in the St Anns Bank area, as described in further detail at the end of this section.

<u>Biology</u>

Productivity

Kulka et al. (2006) reported average length at 50% maturity was 49.8 cm for males and 47.2 cm for females in the Maritimes Region (based on survey data). They reported a minimum age at maturity of eight years and a generation time of thirteen years. Little is known about the life history of smooth skate. They produce egg capsules containing single embryos. They are considered a “k selected” (Winemiller and Rose 1992) species, with slow growth, late sexual maturation, low fecundity, and long reproductive cycles (Kulka et al. 2006)

Ecosystem Interactions
Simon et al. (2011b) report the diet of smooth skate in 4VWX is made up of mostly shrimp, arthropods, oregoniids, euphausiids, and crustaceans. Larger skates also feed on small fish (Garrison and Link 2000). Little is known about the predators of smooth skate; Simon et al. (2011b) did not observe smooth skate in the stomach contents of any predator fish in their database. Other skates may eat them when they are embryos in egg capsules (McEachran 2002 in Packer et al. 2003).

Fisheries and Other Human Activities

Fisheries
There is no directed fishery for smooth skate. There was a skate fishery on the Eastern Scotian Shelf from 1994–2005, but it directed for winter and thorny skate (> 60 cm; Kulka et al. 2006). Smooth skate may also be caught as bycatch, but Kulka et al. (2006) report that it is "relatively insignificant" in 4VW fisheries (< 50 t). This species is thought to have low resilience to fishing mortality due to slow growth and low fecundity (Musick et al. 2000; Musick 2004 in Kulka et al. 2006).

Other Vulnerabilities to Human Activities
Swain et al. (2006) suggest that skate purses may be vulnerable to trawling, dredging, and other bottom disturbances due to their long residency on the bottom (one year or more).

Status and Trends

Stock Status
The area occupied by smooth skate in 4VW has been decreasing since the 1970s, with the lowest level found in 2005. The mean catch per tow in 4VW has generally been less than one fish per tow since 1980 (Kulka et al. 2006). Within 4Vn, Kulka et al. (2006) report a decline rate since 1970 of 76.5% for all fish and 93.9% for mature fish.

Species at Risk Considerations
Smooth skate has not been listed by *SARA*, but is listed by COSEWIC as Special Concern as of May 2012.

Sources of Information
The main source of information for smooth skate in the Maritimes Region is the RV survey (see Section 3.1 above). It is also caught by the 4VsW and 4Vn sentinel surveys.

Sources of uncertainty
There is still very little known about smooth skate; population structure is unknown and there is little information on population dynamics or biology. There are also uncertainties regarding gear selectivity and/or catchability; larger juveniles appear to be under-sampled by most survey gears (Kulka et al. 2006).

Skate Purses in St Anns Bank

In the snow crab survey, unidentified skate purses are found in many locations, but the highest numbers of skate purses found have been in the St Anns Bank AOI, particularly the southeast corner (Figure 3.5.8-3). The only catches of skate purses greater than 50 purses in one set are in this area. In the southeast corner of the site, catches of skate purses include 322 purses in one set in 2005, and 243 purses in one set in 2005 just south of the AOI boundary. These are by far the largest catches in the survey data examined (2004–2007, Figure 3.5.8-3), with the vast majority of catches (90%) being of less than ten purses. However, this is also at the edge of the surveyed area, so whether adjacent sites in deeper water would have similar concentrations of skate purses is not known.

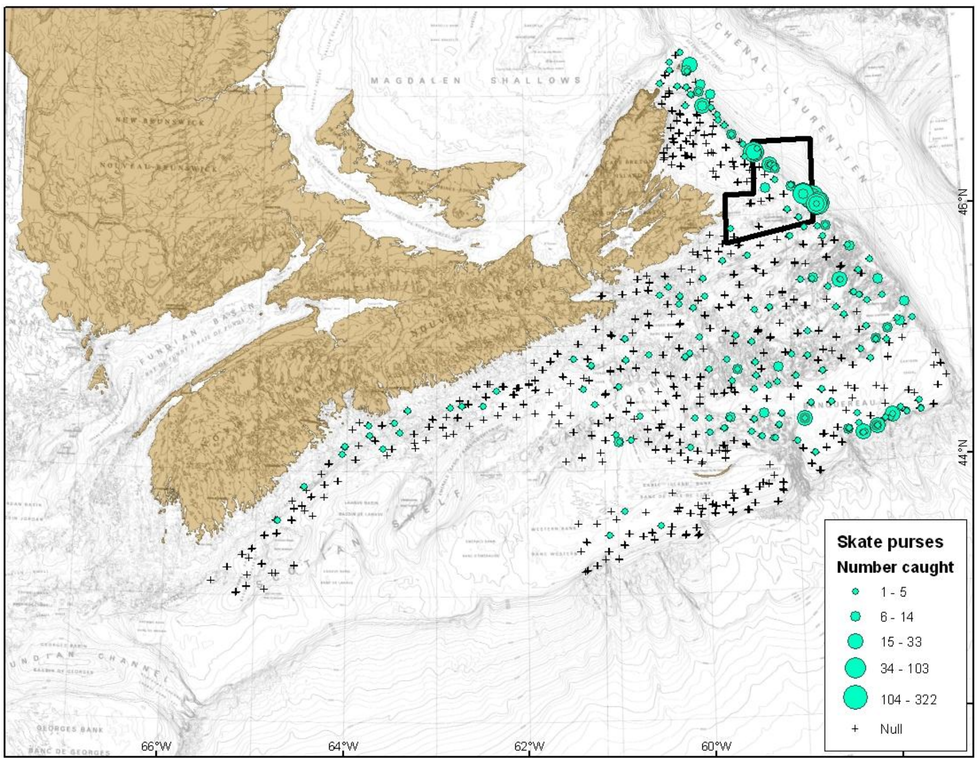


Figure 3.5.8-3. Skate purse catches in the snow crab survey (2004–2007).

Skate purses have also been recorded in the RV surveys since 2005 (Figure 3.5.8-4). These catches indicate that skate purses are common along the Laurentian Channel slope, and that the most likely species being found in the St Anns Bank area are thorny or smooth skate. The number of skate purses recorded in a tow in the snow crab survey in this area is much higher, likely because the smaller, Nephrops trawl used in the snow crab survey is a more efficient sampling tool for skate purses than the larger, Western IIA bottom trawl used in the RV surveys.

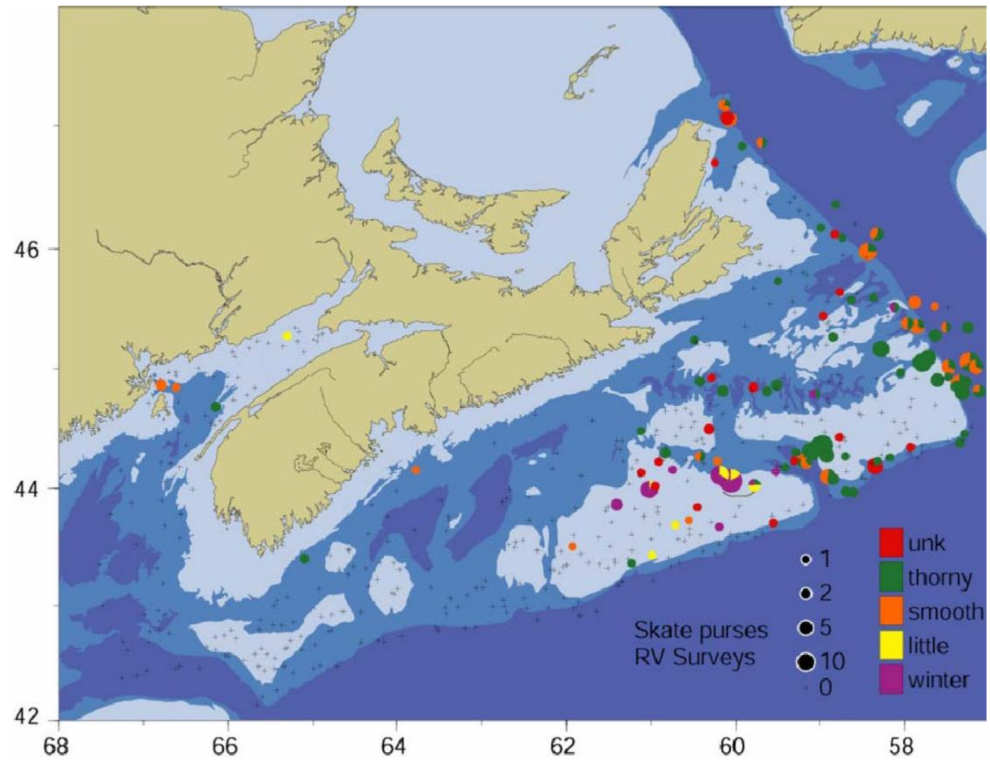


Figure 3.5.8-4. Skate purse catches in the RV surveys (2006–2007; Simon et al. 2011b).

3.5.9 White Hake

White hake (*Urophycis tenuis*) is a demersal fish found in the western North Atlantic in areas with mud bottoms. It lives at various depths throughout its life history.

Geographic Range and Habitat Preferences

White hake are found in the North Atlantic, from Iceland in the north to North Carolina in the south. Scott and Scott (1988) report concentrations in the Laurentian and Fundian channels, and on the continental slope off Nova Scotia. White hake distribution on the Scotian Shelf (based on the summer RV survey) is shown in Figure 3.5.9-1 (Horsman and Shackell 2009; see Section 3.5.2 above).

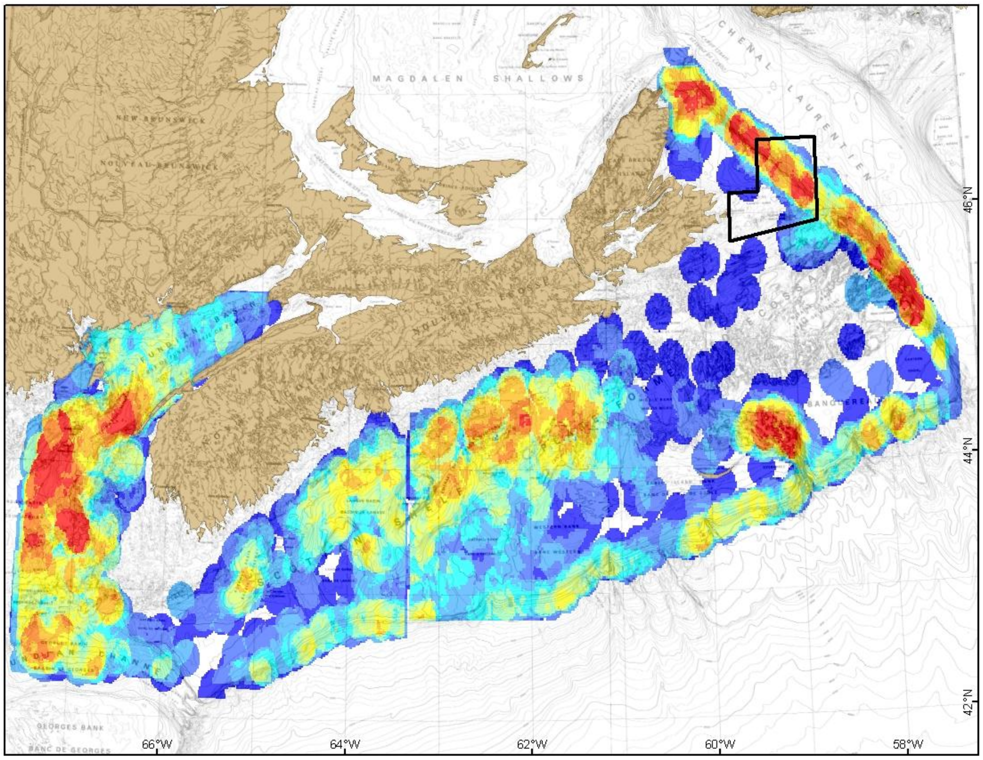


Figure 3.5.9-1. Distribution of white hake on the Scotian Shelf (Horsman and Shackell 2009). Preferred habitat is shown in red/orange. The St Anns Bank AOI boundaries are outlined in black.

White hake are pelagic spawners, with what appear to be two spawning components. The eggs and larvae drift in the upper 50 meters for about a month in the late spring/early summer or late summer/early fall. The larvae metamorphose into juveniles in the pelagic zone and subsequently migrate into the shallow coastal zone; at an age of about two months, the small pelagic juveniles (approximately 4 cm) move to the bottom in shallow water. They appear to stay in shallow water for a year and then migrate to the offshore adult distributional area at some time during their second year (Bundy and Simon 2005).

Hare et al. (2001) hypothesized that white hake larvae actively cross the shelf/slope front to reach nearshore estuarine juvenile habitats, as small larvae were not caught on the shelf. A similar mechanism may occur for the spring/early summer offshore spawning of white hake on the Scotian Shelf (Bundy and Simon 2005). Data from the Scotian Shelf Icthyoplankton Surveys (SSIP) (1977–1982) support the studies above. Juveniles occurred from May to November, with June to September being the peak months. Major concentrations occur around the northeast edge of Georges Bank from June through August, and just north of the shelf edge near Emerald Bank from August to October (Figure 3.5.9-2). A northerly trend in the timing of spawning as waters warm up might be inferred.

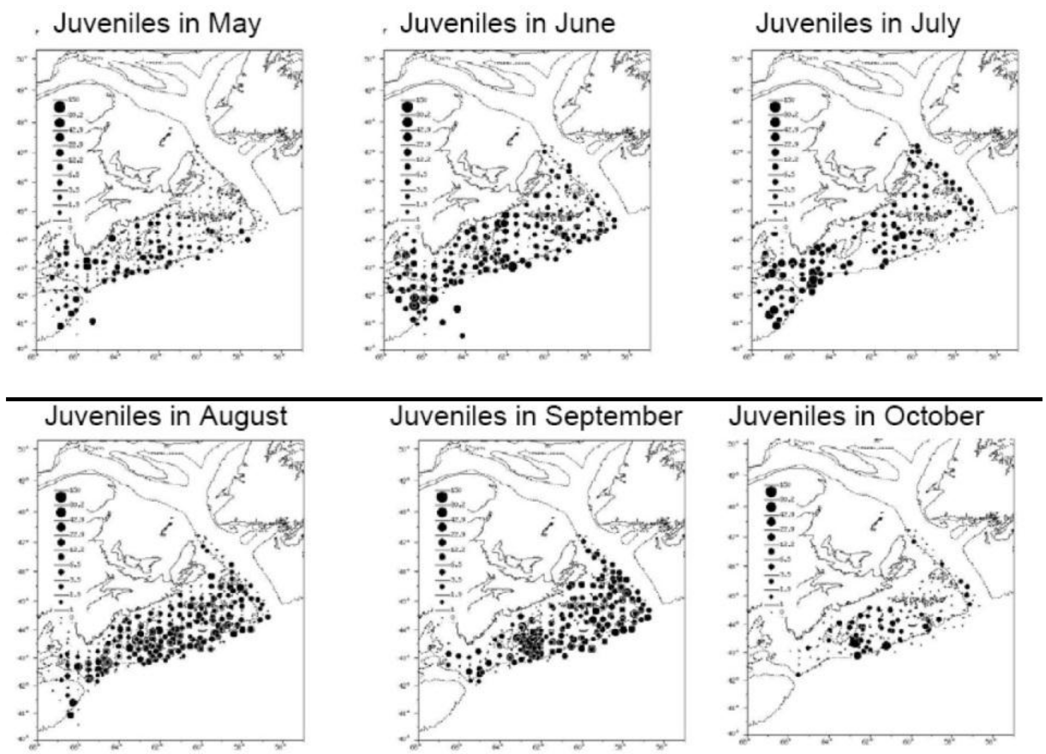


Figure 3.5.9-2. Distribution of juvenile white hake from the SSIP (1977–1982) (from Bundy and Simon 2005).

<u>Habitat Preferences</u>

As adults, white hake are bottom dwelling fish found in areas with a mud bottom. Their depth range varies with life history stage, with age two and older fish occurring predominantly at depths between 50 and 200 m. They favour temperatures between 6° and 10 °C.

<u>Populations or Stock Definitions</u>

White hake in the St Anns Bank area are members of resident populations in the southern Gulf of St. Lawrence (4T) as well as on the Scotian Shelf (4VW). Regarding 4T, while white hake is considered one management unit, the biological stock structure has been a long-standing issue (DFO 2005b). Hurlbut and Clay (1998) considered that there were at least two stock components in the southern Gulf, one occupying shallow inshore areas during summer, principally the Northumberland Strait area (the Strait component) and another occupying deep water along the Laurentian Channel during summer (the Channel component). The extent of mixing between these two stock components was and still is unknown. Their analysis indicated that the distribution of Channel white hake extends outside of 4T in winter (see Section 4.1 below on migration) although some historical tagging (Kohler 1971) suggests limited mixing between 4T and 4Vn white hake.

The stock structure of white hake on the Scotian Shelf is complex with several self-sustaining populations (DFO 2005c). As noted above, white hake in 4Vn Laurentian

Channel slope waters are contiguous with 4T, while those in the Bay of Fundy and its approaches are contiguous with 5Z and 5Y (i.e., the Gulf of Maine area). The central Scotian Shelf (parts of 4X and 4W) may be separate from those to the east and west.

Recent genetic work by Roy et al. (2011) suggests three genetically distinguishable populations with two (southern Newfoundland and Scotian Shelf) straddling management divisions and two (southern Gulf of St. Lawrence and Scotian Shelf) overlapping in their range and coexisting within a single region. However, stock definitions are still unclear and more research is needed before they can be properly defined (DFO 2012).

White Hake in St Anns Bank

Figure 3.5.9-3 shows the distribution of white hake in St Anns Bank based on the RV survey (Horsman and Shackell 2009). Within the AOI boundaries, white hake appears to be concentrated on and near the slope into the Laurentian Channel.

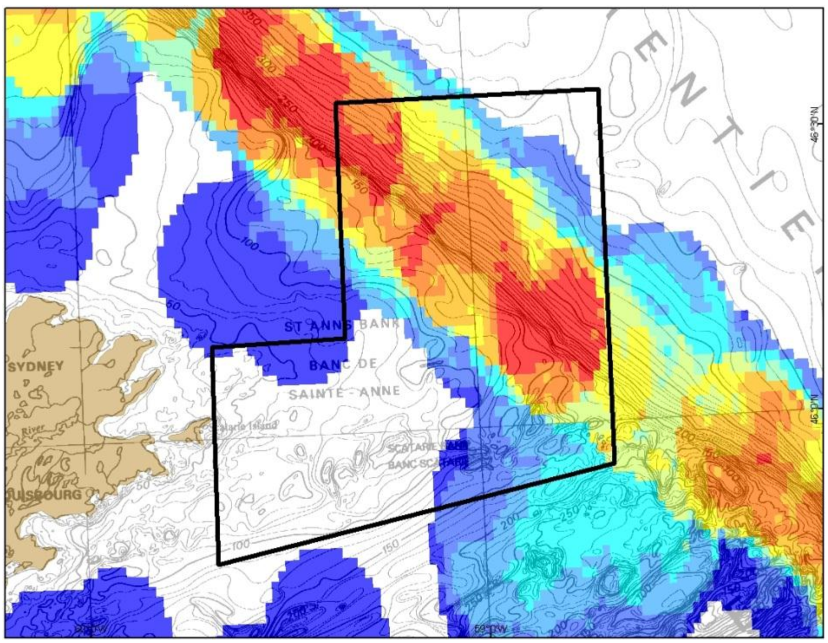


Figure 3.5.9-3. Distribution of white hake in the St Anns Bank area (Horsman and Shackell 2009). Preferred habitat is shown in red/orange. The St Anns Bank AOI boundaries are outlined in black.

Horsman and Shackell (2009) mapped preferred habitat for white hake on the Scotian Shelf over four time periods (see Section 3.5.2 above). Over the years 1978–1985, ~8% of the Eastern Scotian Shelf was considered preferred habitat, of which ~6% was in St Anns Bank. Over the years 1994–2006, only ~5% of the Eastern Scotian Shelf was preferred habitat, and ~9% of this was in St Anns Bank (Figure 3.5.9-4).

White hake is also caught in St Anns Bank in the halibut and 4Vn sentinel surveys, as shown in Figures 3.5.9-5 and 3.5.9-6.

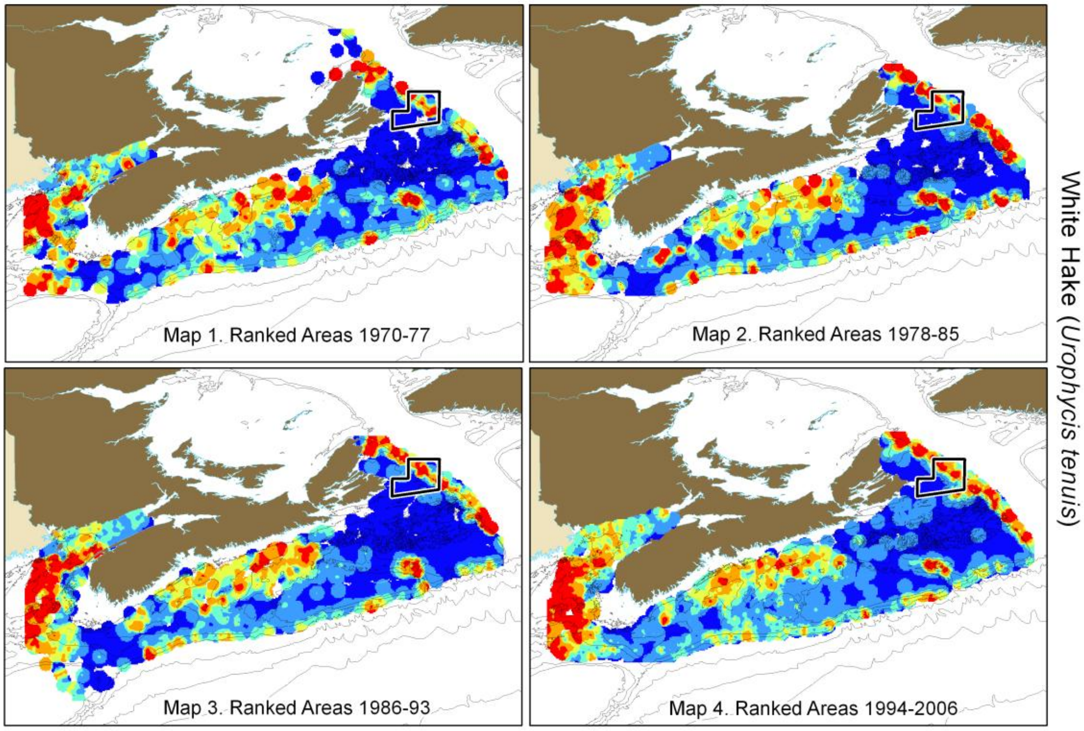


Figure 3.5.9-4. Distribution of white hake on the Scotian Shelf for years 1970–1977, 1978–1985, 1986–1993, and 1994–2006 (Horsman and Shackell 2009). Preferred habitat is shown in red/orange. The St Anns Bank AOI boundaries are outlined in black.

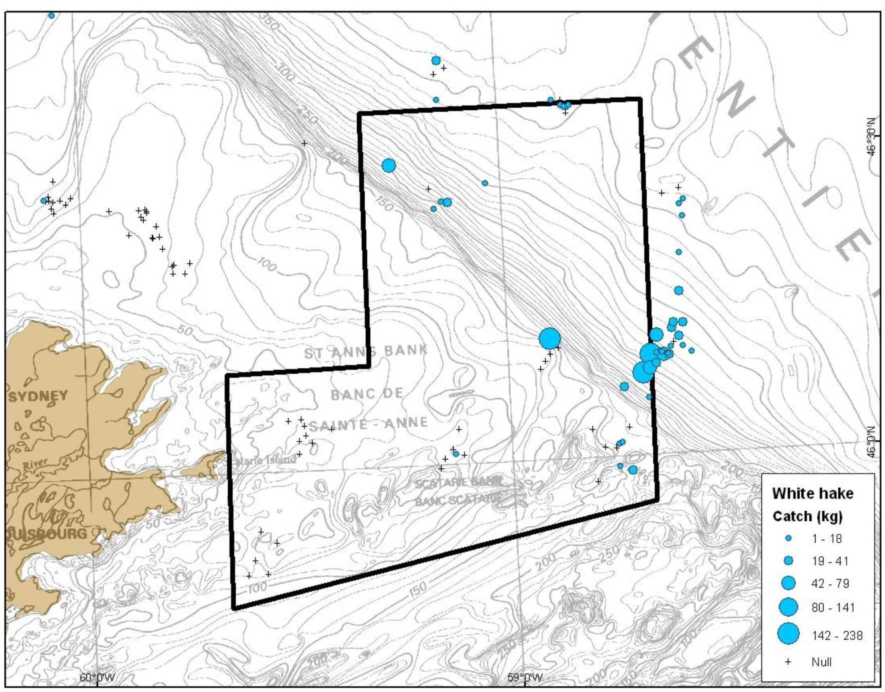


Figure 3.5.9-5. Distribution of white hake in the halibut industry survey (1998–2010; fixed stations only), showing total weight caught (kg).

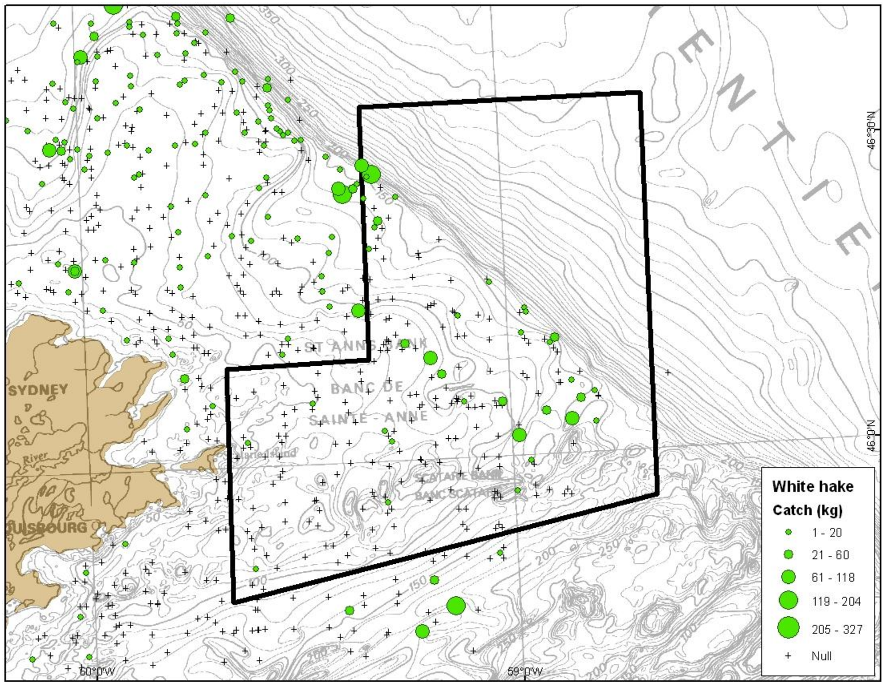


Figure 3.5.9-6. Distribution of white hake in the 4Vn sentinel survey (1994–2010; excludes commercial index and fixed stations), showing total weight caught (kg).

There is also some evidence of juvenile white hake in coastal areas of Cape Breton. An FSRS study observed white hake less than seven centimetres in length in inshore areas off Cape Breton and the southern shore of Nova Scotia (Bundy and Simon 2005). There are anecdotal reports that the Bras d’Or Lakes in Cape Breton are a nursery area (Tim Lambert, DFO Science, personal communication, March 2011).

<u>Biology</u>

Productivity

Bundy and Simon (2005) provide the growth characteristics of white hake, indicating that the average size at maturation is about 45 cm or about age 3.5. Total mortality in the 2000s, during which fishing was reduced, was high, averaging 1.0 (see below), which implies high natural mortality, perhaps in the order of 0.8. This implies a relatively short generation time of 4.8 years. White hake are highly fecund demersal egg layers, having several million eggs per female.

Natural Mortality

As noted above, natural mortality (M) is observed to have been high in the 2000s, the causes of which are unknown. However, white hake can be a significant component of a grey seal’s diet in 4T (Hammill et al. 2007a), a species that has been hypothesized as the source of high natural mortality in 4T cod (Chouinard et al. 2005).

Ecosystem Interactions
Bundy (2004; 2005) discuss the role of white hake in the Scotian Shelf ecosystem, classifying it as a large (> 40 cm) demersal piscivore. On the Scotian Shelf, their diet includes herring, silver hake, shrimp, krill, gadoids, shortfin squid, cod, haddock, redfish, and a wide variety of other prey species. Their main predators are large gadoids and grey seals.

<u>Fisheries and Other Human Activities</u>
White hake are caught in groundfish fisheries in 4VWX/5 targeting halibut, redfish, cod, and pollock with longline, gillnet, and otter trawl (< 65 ft vessels) gear. Prior to 1996, there were no restrictions on fishing white hake in 4VWX; in 1999 it was recommended that white hake be caught as bycatch only, and a quota cap was put in place. Since 2003, landings in 4VWX/5 have been below 2000 t, and as of 2005, landings were 1532 t, of which 90% is taken from 4X/5. Both the fixed gear and otter trawl fleets have reported difficulty staying within white hake catch restrictions while fishing other species (DFO 2005c). White hake are consistently caught in the St Anns Bank AOI, mostly by longline and otter trawl along the slope into the Laurentian Channel.

<u>Status and Trends</u>

Stock Status
It is useful to report abundance trends of 4Vn white hake in the context of that elsewhere on the Scotian Shelf (Bundy and Simon 2005). In the 1970's, the mean number and weight of white hake per tow were low, and then increased in the mid 1980's. There was a decline again between the mid 1980's and the early 1990's, and since then have been variable, but low. Mean abundance since the 1990s is at a comparable level to mean abundance during the 1970s. There was a peak increase in 2001, which was due to several large catches of fish between 30 and 45 cm in length, which may be due to white hake from 4T. Abundance in 4Vs was low in the 1970s, peaked in the mid-1980s, peaked in 1997, but has otherwise been low since 1987. Similarly in 4W, abundance was low in the 1970s, peaked throughout the 1980s, and has been low since 1992. The mean weight per tow and mean numbers per tow in 2002, 2003, and 2005 are all-time lows. There has been a declining trend of peaks since the early 1980s, and it is likely that the 2005 point is one more in this series. These trends have continued to 2009 with 4VW survey biomass during the mid-2000s being the lowest since 1970.

In 4Vn, 4Vs, and 4W, there has been a decrease in the proportion of large fish in the population from the 1970s to the mid-1990s; since then, the proportion has remained below the long-term mean. This indicates that in 4VW, there has been a sustained loss of large fish in the population to a point where they constitute only 20–30% of the population.
In general, the survey indicates low abundance during the 1970s, increased abundance during the 1980s, and low abundance in the 1990s and 2000s. This pattern is especially pronounced in 4VW. Since 1990, mean abundance in 4Vn and 4WX has been comparable (4Vn) or lower (4WX) than the average abundance during the 1970s.

Overall, there are very few large white hake on the Scotian Shelf (4VW) now compared to the 1980s, despite reduced catches in all areas and indications of good recruitment. The area occupied by large fish has decreased, total mortality is high, and fishing mortality has decreased in recent years. The status of white hake in 4Vn and 4VsW is poor. Until the high natural mortality returns to historical averages, stock rebuilding will be very slow.

Species at Risk Considerations
The most recent assessment of white hake in the area of the St Anns AOI is by Bundy and Simon (2005) while the most recent summer survey trends are provided by Clark et al. (2010). COSEWIC initiated an assessment of white hake in 2005 but this was not completed. It is planning to release a status report on white hake in November 2013. As yet, DFO has no plans to undertake a Recovery Potential Assessment (RPA).

<u>Sources of Information</u>
The main source of information for white hake is the summer RV survey. White hake are also caught by the halibut, sentinel, and snow crab industry surveys (see Section 3.1 above).

<u>Sources of Uncertainty</u>
A key uncertainty of white hake is stock structure and how the various populations might intermingle in 4Vn. Two stocks are hypothesized as resident in the southern Gulf (Strait and Channel) and approximately three on the Scotian Shelf, none of which strictly correspond to the management units. It is likely that the Channel stock mixes with 4Vn white hake, but the extent of intrusions from 4Vs is unknown.

Another key uncertainty for white hake in the area of the St Anns AOI is the source of current high natural mortality. While grey seals may be the cause, their role in high cod mortality is contentious (DFO 2010d). The high level of natural mortality makes interpretation of the potential mitigative effects of the St Anns Bank AOI and associated zonation very difficult, if not impossible.

The last source of uncertainty is the lack of an assessment of the white hake stocks. This may be resolved as a consequence of the November 2012 COSEWIC initiative to assess white hake status in relation to *SARA*.

<u>3.5.10 Witch Flounder</u>
Witch flounder (*Glyptocephalus cygnoglossus*; also known as greysole) is a moderately sized flatfish that is found throughout the North Atlantic.

<u>Geographic Range and Habitat Preferences</u>
Witch flounder are distributed in the western North Atlantic from Labrador in the north to North Carolina in the south (Scott and Scott 1988). Witch flounder distribution on the

Scotian Shelf (based on the summer RV survey) is shown in Figure 3.5.10-1 (Horsman and Shackell 2009; see Section 3.5.2 above).

Spawning occurs over a prolonged period, occurring during May–October, peaking in July–August. In the Gulf of St. Lawrence, spawners aggregate in Channel waters during January–February with spawning occurring in these waters during late spring–early summer (DFO 2007b). Adults undertake seasonal migrations, moving into deep water in the winter and shallower water in the summer. SSIP surveys during 1978–1982 observed witch flounder larvae widely distributed on the Eastern Scotian Shelf as a consequence of spawning during the preceding summer months (Figure 3.5.10-1), but few were observed near St Anns Bank.

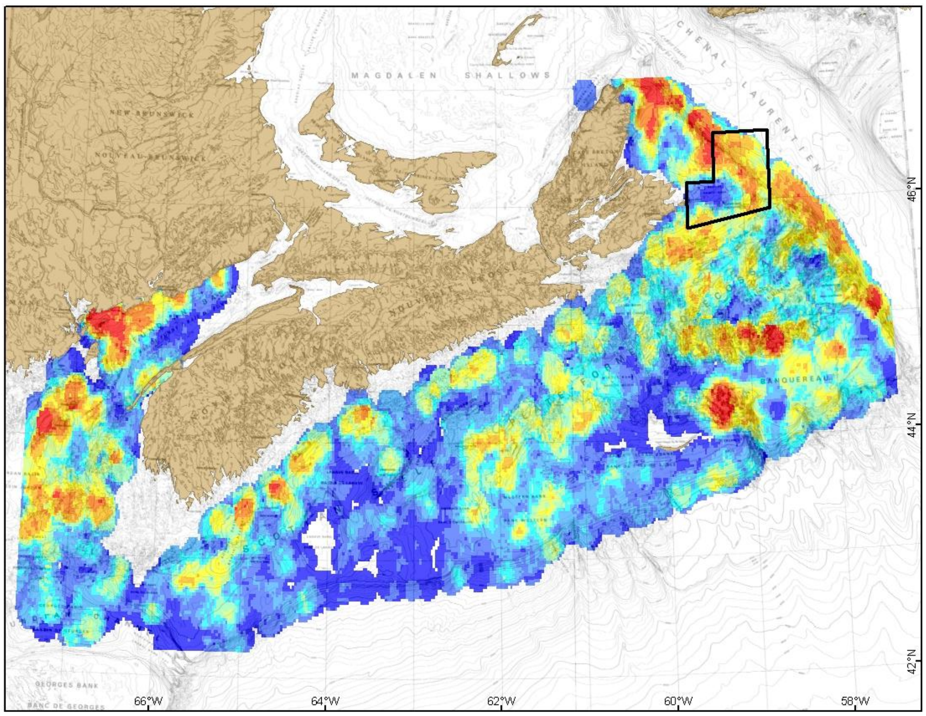


Figure 3.5.10-1. Distribution of witch flounder on the Scotian Shelf (Horsman and Shackell 2009). Preferred habitat is shown in red/orange. The St Anns Bank AOI boundaries are outlined in black.

Habitat Preferences

Witch flounder are often associated with deep holes and channels between banks, preferring mud and mud-sand bottoms at depths of 185–366 m (Scott and Scott 1988). Juveniles tend to occupy deeper water than adults, especially during the summer (Swain and Morin 2006). They settle to the bottom in these areas, where they then grow to adults.

Populations or Stock Definitions

In the Gulf of St. Lawrence, which is managed within the 4RST management unit; on the Scotian Shelf it is managed in two management units, 4VW and 4X5, the former being relevant to the St Anns Bank AOI. Issues with the stock structure of witch in both areas have been recognized for some time. A proposal was made to redefine the 4RST management unit as 4Twest + 4R + 4S and create a new management unit composed of 4Teast and 4VW (O'Boyle 2001). Tagging studies (Stobo and Fowler 2006) have confirmed that 4VW witch flounder migrate into 4Vn and 4T and presumably the reverse also occurs. This proposal formally recognized this interaction (see Section 4.1 below). Due to data deficiencies, it was concluded that a change in the 4RST management unit could not be made at this time with further research recommended. Since then, there has been little progress on this stock definition issue (Doug Swain, DFO Science, personal communication, March 2011).

Notwithstanding the above, it is likely that witch flounder in the Cabot Strait are a mixture of 4Teast, 4Vn resident, and 4VW fish. For the purposes of the St Anns Bank AOI, both witch flounder in 4Teast and 4VW will be considered. This requires consideration of information from both 4T and 4VW in the assessment of the AOI.

<u>Witch Flounder in St Anns Bank</u>
The previous sections provide a general indication of witch distributional trends by life stage. In the area of the St Anns Bank AOI, it is likely that witch from both 4Teast and 4V spawn in the deep water of the Strait during the spring and summer. Given the annual overwintering migration of many Gulf species, it is speculated that 4T witch flounder spawners in the Strait are part of this overwintering migration. After spawning, these witch flounder would move into the shallow water, either back in 4T or in 4VW. At this time, this part of the life history in unclear. The source of the larvae on the Scotian Shelf (Figure 3.5.10-2) further adds to this uncertainty.

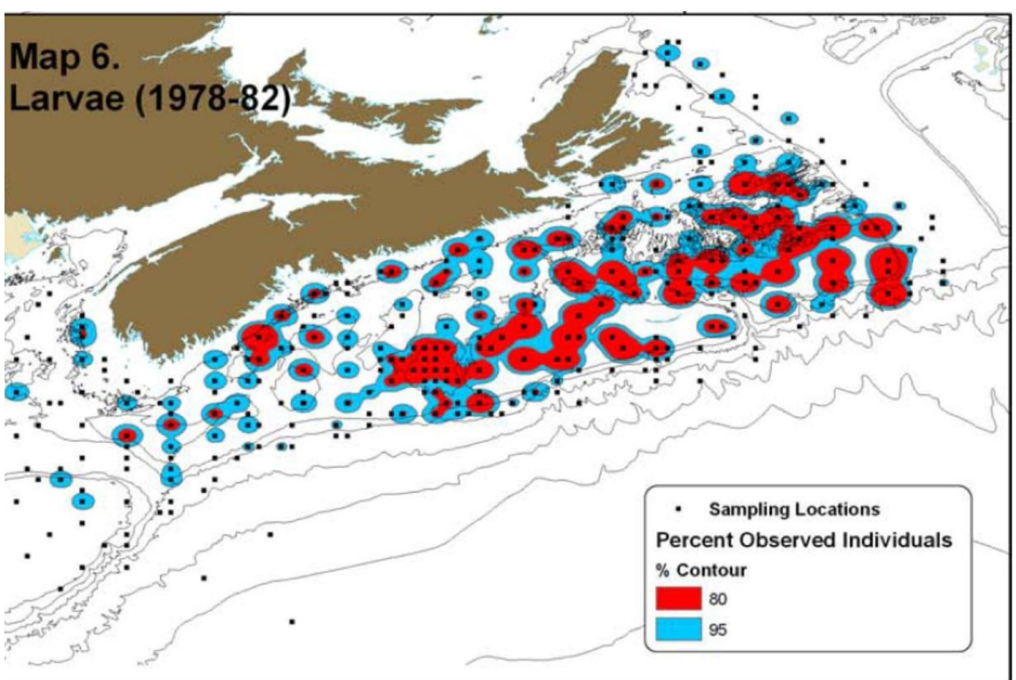


Figure 3.5.10-2. Distribution of witch flounder larvae on the Scotian Shelf as observed by SSIP surveys during 1978–1982 (from Horsman and Shackell 2009).

Figure 3.5.10-3 shows the distribution of witch flounder in St Anns Bank based on the summer RV survey (Horsman and Shackell 2009). Within the AOI boundaries, witch flounder appear to be concentrated on and near the slope into the Laurentian Channel.

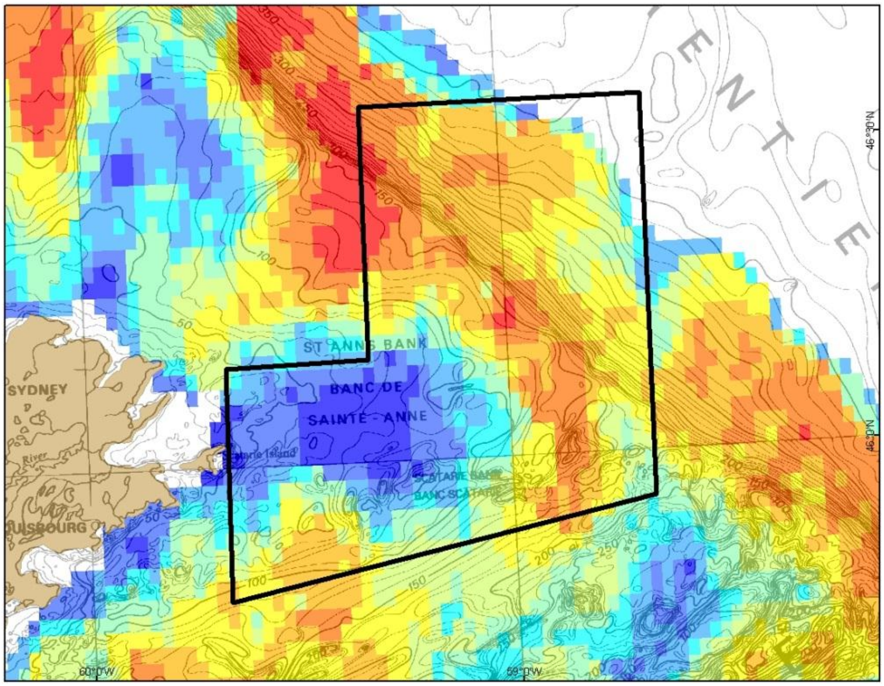


Figure 3.5.10-3. Distribution of witch flounder in the St Anns Bank area (modified from Horsman and Shackell 2009). Preferred habitat is shown in red/orange. The St Anns Bank AOI boundaries are outlined in black.

Horsman and Shackell (2009) mapped preferred habitat for witch flounder on the Eastern Scotian Shelf over four time periods (see Section 3.5.2 above). Over the years 1978–1985, ~10% of the Eastern Scotian Shelf was considered preferred habitat, of which ~11% was in St Anns Bank. Over the years 1994–2006, ~8% of the Eastern Scotian Shelf was preferred habitat, and ~4% of this was in St Anns Bank (Figure 3.5.10-4).

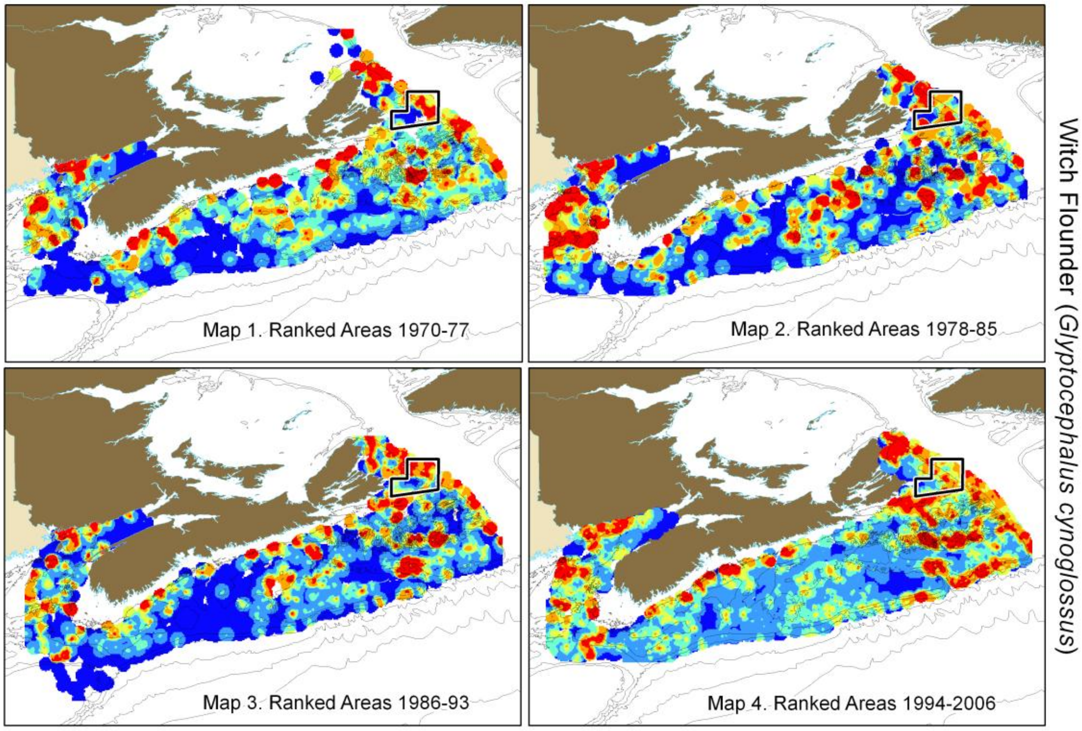


Figure 3.5.10-4. Distribution of witch flounder on the Scotian Shelf for years 1970–1977, 1978–1985, 1986–1993, and 1994–2006 (Horsman and Shackell 2009). Preferred habitat is shown in red/orange. The St Anns Bank AOI boundaries are outlined in black.

Biology

Productivity

Relative to other flounder, witch are slow-growing and long-lived. In the late 1970s and early 1980s, 50% of females reached maturity at lengths of 40–45 cm (9–14 years of age) and 50% of males matured at lengths of 30–34 cm (5–8 years of age) (DFO 2007b). This relatively low productivity is characterized by the low values of R_{MAX} (0.05–0.35) that Swain and Morin (2006) used in a surplus production model of 4RST witch flounder. The latter also attempted a stage-structured (juvenile and adult) population model which, while unsuccessful in fitting the observations conclusively, indicated high levels (0.33–0.62) of adult natural mortality. Assuming natural mortality (M) is 0.48 implies a generation time of 13.6 years. Females are relatively highly fecund demersal egg layers, releasing as many as 500,000 eggs in a single spawn (DFO 2007b).

Natural Mortality

As noted above, natural mortality (M) of 4RST witch flounder is observed to have been high (0.4–0.6) in the 2000s, the causes of which are unknown although flatfish, including witch, can be a significant component of a grey seal's diet in 4T (Hammill et al. 2007a).

Ecosystem Interactions
Scott and Scott (1988) report the principal food items of witch flounder include polychaete worms, amphipods, small fish, and molluscs such as small bivalves and snails, with only minor differences in this diet with an increase in size.

Fisheries and Other Human Activities
There are still directed fisheries for flatfish on the Scotian Shelf. In 4VW three species of flatfish (plaice, witch flounder, and yellowtail flounder) are managed as a multispecies stock, which is assessed in the context of the most vulnerable species. The TAC is 1000 t in 4VW. Witch flounder landings in 4VW have been below 500 t since the mid-1970s.

Status and Trends

Stock Status
The last assessment of 4RST witch flounder was by DFO (2007b) while that on the Scotian Shelf was by DFO (2002d) although the most recent resource trends are provided by Clark et al. (2010).

DFO (2007b) provides a biomass index for commercial sizes (30+ cm) of witch flounder in 4RST for 1987–2006 by combining data from annual RV surveys conducted in the southern Gulf each September and in the northern Gulf each August. A sharp decline in biomass throughout 4RST occurred from 1990 to 1993, remained low during 1993–1998, increased to an intermediate level by 2000, and has subsequently declined (Figure 3.5.10-5). The increase in biomass in the late 1990s and early 2000s was primarily due to increased abundance of fish under 40 cm in length. Biomass of fish 40 cm and longer has remained relatively low.

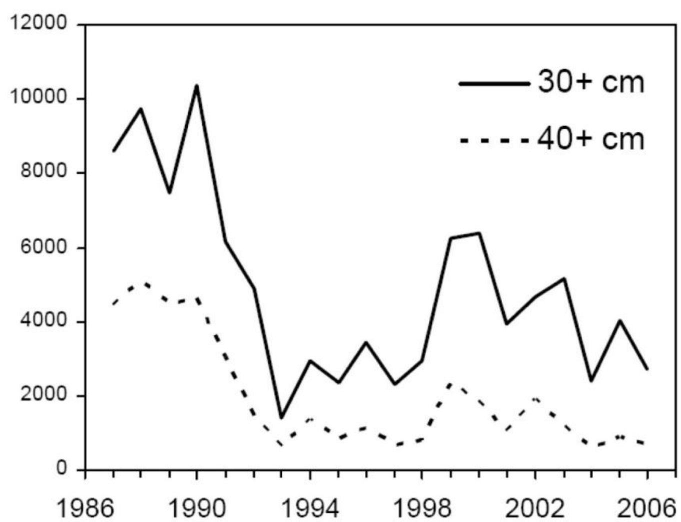


Figure 3.5.10-5. Biomass index for commercial sizes of witch flounder throughout 4RST (from DFO 2007b).

Changes in biomass have not occurred uniformly throughout 4RST (Figure 3.5.10-6). The biomass decline during the early 1990s was large in 4R, 4S, and western 4T, but not in eastern 4T. Biomass has remained low in 4S and western 4T. In the late 1990s and early 2000s, biomass was relatively high in eastern 4T, though it has declined in recent years.

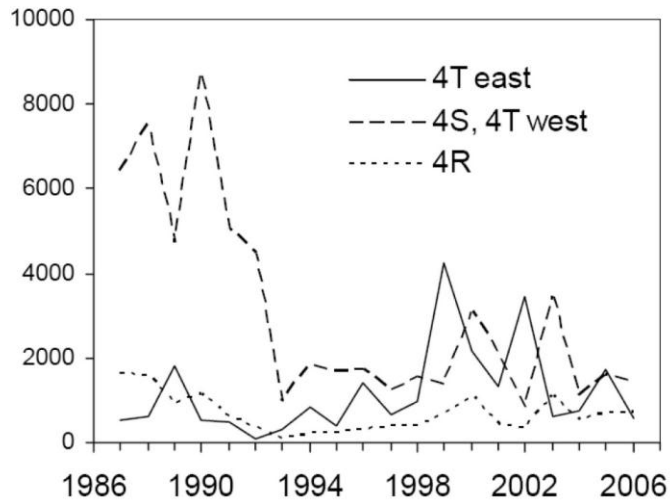


Figure 3.5.10-6. Biomass index for witch flounder in three regions of the Gulf of St. Lawrence (from DFO 2007b).

The geographic distribution of catches in the RV surveys in 2006 was typical of the pattern seen in recent years, with catches highest in the Cape Breton Trough off northwestern Cape Breton (Figure 3.5.10-7). Relatively high catches also occurred in the St. Lawrence Estuary and along the southern slope of the Laurentian Channel. Catches on the shelf off western Newfoundland were lower than in recent years. This highlights the importance of the Laurentian Channel, particularly the eastern part, in the life history of witch flounder.

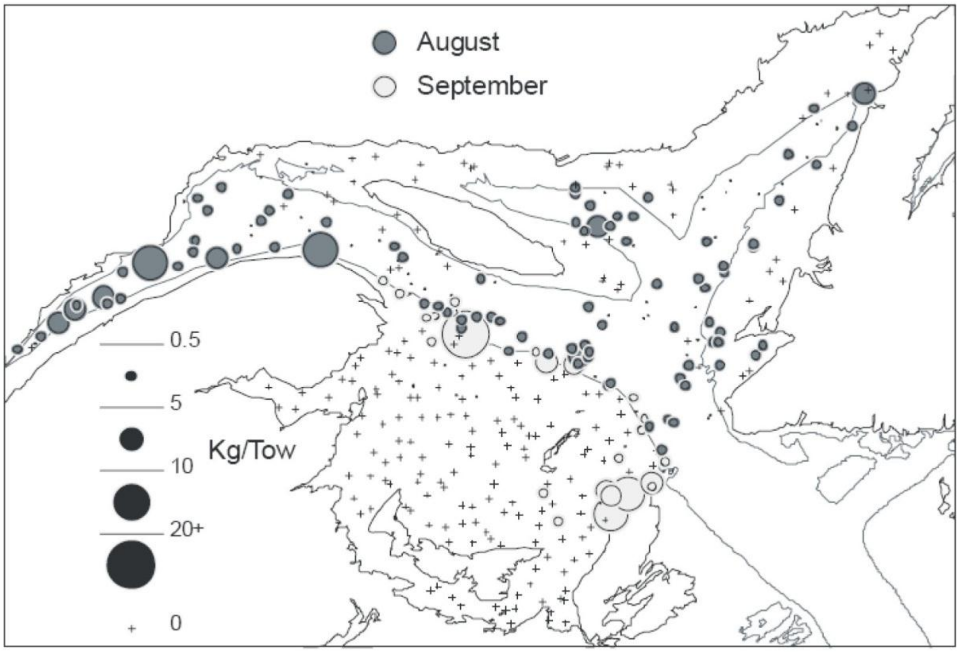


Figure 3.5.10-7. Geographic distribution of witch flounder in the summer RV surveys of the Gulf of St. Lawrence (from DFO 2007b).

The status of 4RST witch flounder has not changed significantly since 2007. Swain (DFO Science, personal communication, March 2011) considers that the Gulf resource remains depressed due to high total mortality likely due to high natural mortality of unknown origin. The only recent information on 4VW witch is provided by Clark et al. (2010). Biomass in 4VW has followed an increasing trend since the early 1990s and was the second highest in the series in 2009, although the 2009 value is very dependent on one large catch. Abundance in 4VW was well above average for most lengths below 40 cm in 2009 and about average in 2008.

Species at Risk Considerations
Witch flounder is not listed by COSEWIC or *SARA*. There are as yet no plans for COSEWIC to assess this species.

Sources of Information
The main source of information for witch flounder is the summer RV survey (see Section 3.1 above).

Sources of Uncertainty
A key uncertainty of witch flounder is stock structure and how the various populations might intermingle in 4Vn. It is evident that witch flounder from 4T migrate into the Channel each year. It is unclear whether or not this is part of or a separate population from that in 4V.

Another key uncertainty for witch flounder in the area of the St Anns Bank AOI is the source of current high natural mortality. While grey seals may be the cause, their role in high cod mortality is contentious (DFO 2010d). The high level of natural mortality makes interpretation of the potential mitigative effects of the St Anns Bank AOI and associated zonation very difficult, if not impossible.

3.5.11 Capelin

Capelin is an important forage species off Newfoundland and in the Gulf of St. Lawrence. They are not always found on the Eastern Scotian Shelf, and their abundance in this area, including St Anns Bank, changes considerably over time depending on water temperatures (Frank et al. 1996). When they are present, and abundant, they are a food source for many species.

Geographic Range and Habitat Preferences

In the RV survey, capelin were found over a wide range of depths but narrow range of temperatures (< 4 ºC) (DFO 1996b). Capelin were very sparsely distributed in the region over 1970–1985, but since that time they have been quite widespread in Division 4V in the summer months (Figure 3.5.11-1; Horsman and Shackell 2009). In the late 1990s, capelin were the second most common fish species found in RV survey trawls in Sydney Bight (Schaefer et al. 2004). This is believed to be a result of lower water temperatures in the Eastern Scotian Shelf over this time period (Frank et al. 1996).

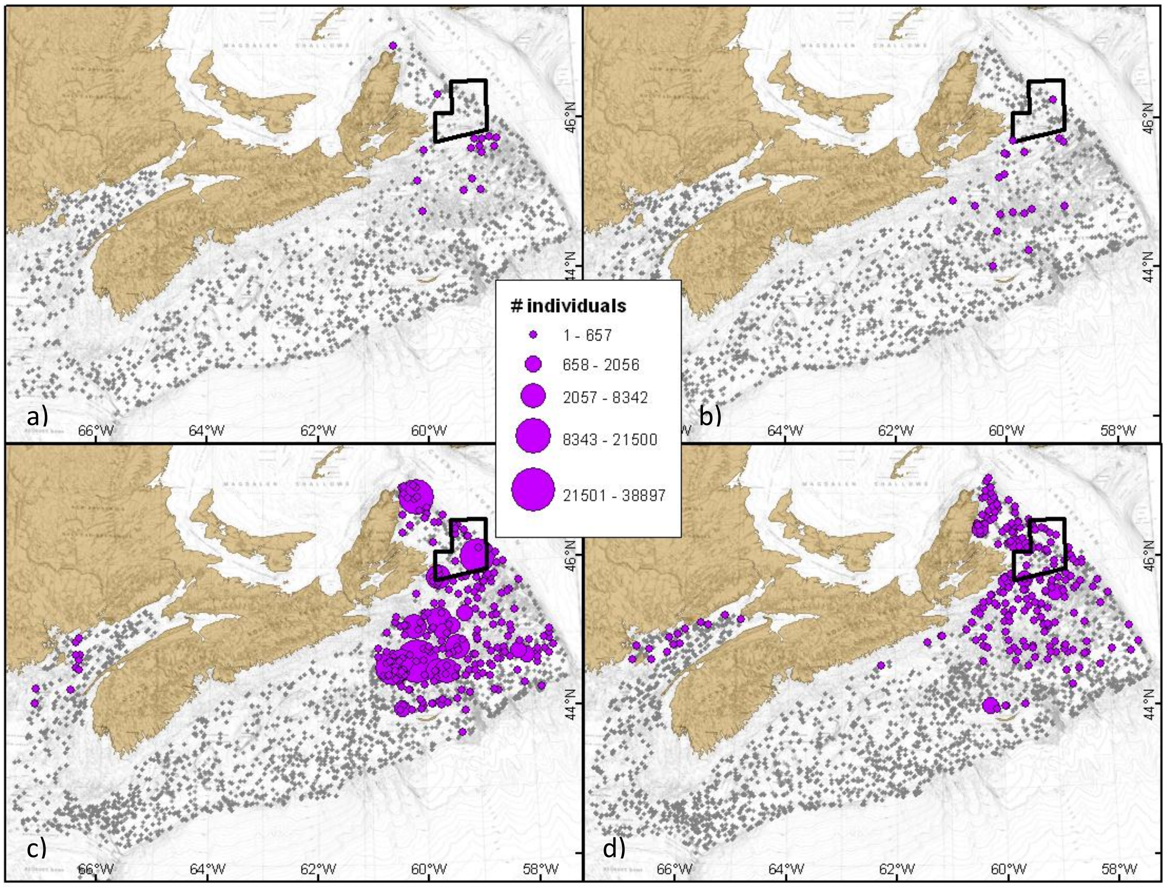


Figure 3.5.11-1. Catch of capelin in the summer RV survey over four decades (a)1970–1979, b) 1980–1989, c) 1990–1999, d) 2000–2010). St Anns Bank is outlined in black.

Populations or Stock Definitions

Not much is known about the population structure of capelin on the Eastern Scotian Shelf, although polymodality in the size-frequency distributions of the capelin caught in the RV survey is considered to be a strong indicator of local recruitment (spawning) on the Scotian Shelf (Frank et al. 1996).

There is no scientific information about where capelin might spawn on the Eastern Scotian Shelf was found, but there is traditional ecological knowledge indicating capelin spawning areas in coastal areas of Sydney Bight, with the most southerly area identified near Glace Bay (Schaefer et al. 2004). Fishermen have also reported capelin spawning on beaches in Aspy Bay (François Grégoire, DFO Science, personal communication, July 2011). Capelin can also spawn in deep water, and do so in the northern Gulf of St. Lawrence and on the Grand Banks (Francois Gregoire, DFO Science, personal communication, July 2011).

Capelin in St Anns Bank

During the years that capelin were widespread on the Eastern Scotian Shelf, they were also found in the St Anns Bank AOI (Figure 3.5.11-2). There are 33 records of capelin being caught in St Anns Bank in the RV survey from 1970 to 2010, though most of those catches are of less than ten individuals. In summary, St Anns Bank is not an area of consistently high densities of capelin in the summer months, though they are known to use the area when their abundance on the ESS is high.

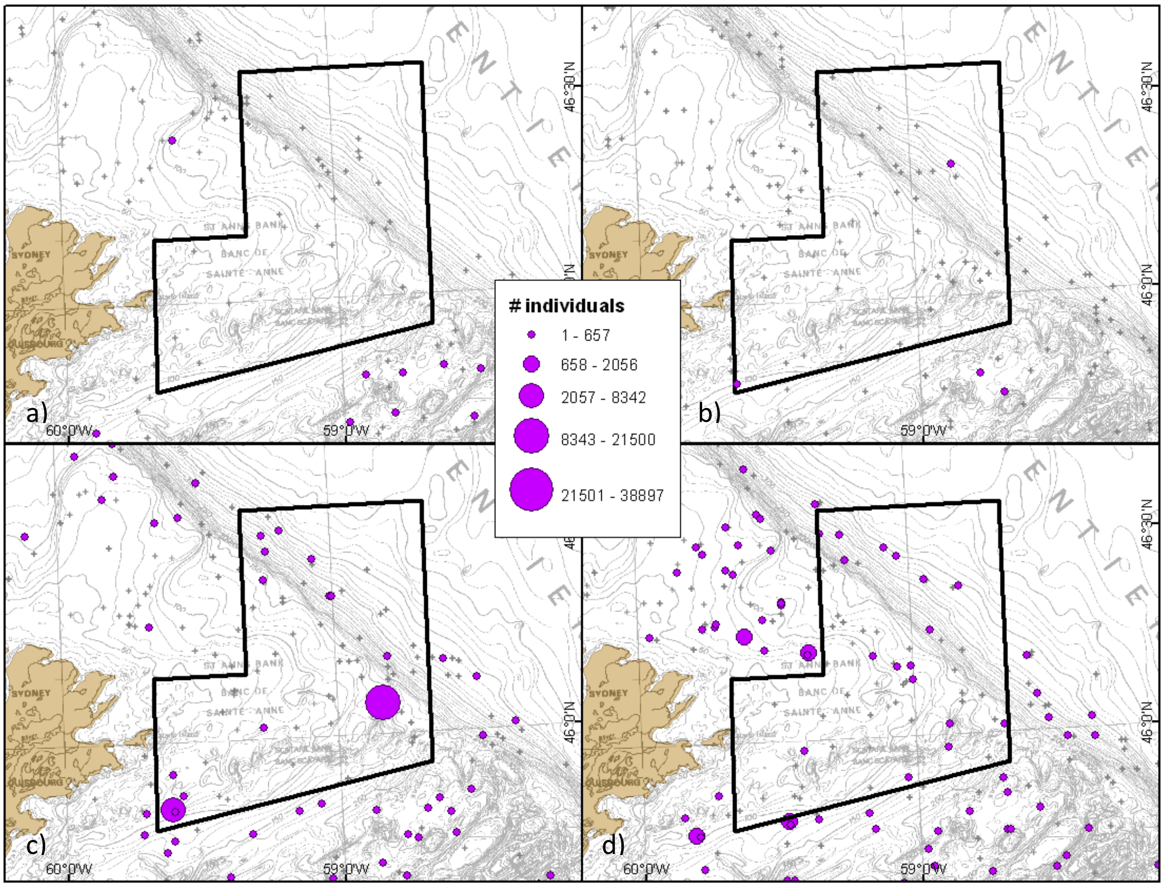


Figure 3.5.11-2. Catch of capelin in the summer RV survey in the St Anns Bank (black polygon) area over four decades (a)1970–1979, b) 1980–1989, c) 1990–1999, d) 2000–2010).

Biology

Ecosystem Interactions

Capelin sampled on the Eastern Scotian Shelf in the RV Survey from 1995 to 2008 mainly ate euphasiids, unidentified arthropods and decapods, with some unidentified fish (Cook and Bundy 2010).

Capelin are an important forage item for many species of groundfish, seabirds, and whales (DFO 1996b). The role of capelin on the Eastern Scotian Shelf is poorly understood, but in Newfoundland, where capelin are more abundant and their presence is more consistent, they are considered to be a critical forage species that allowed Atlantic cod to achieve large abundances in earlier decades (Rose 2007). They are also a key prey species for many species of seabirds in Newfoundland, some of whose breeding success has been shown to depend on access to capelin (Carscadden et al. 2002). In the Gulf of St. Lawrence, the main predators for capelin in the mid-1980s were Atlantic cod (*Gadus morhua*) and redfish (*Sebastes* spp.). These species were replaced in the mid-1990s and early 2000s by cetaceans, harp seals (*Phoca groenlandica*), and Greenland halibut (*Reinhardtius hippoglossoides*), and finally by redfish in the mid-2000s (Grégoire et al. 2008). Also, fin whales and minke whales are observed to closely follow capelin distributions in the Gulf of St. Lawrence (Simard et al. 2002).

Fisheries and Other human Activities
There has never been a directed fishery for capelin on the Scotian Shelf and only occasionally have capelin been reported as bycatch in commercial fisheries operating in Division 4VWX (DFO 1996b). No records of capelin catch from St Anns Bank were found in DFO's commercial fisheries databases (ZIF [Zonal Interchange Format] and MARFIS [Maritime Fishery Information System]) over the years 1991–2010.

Status and Trends
Because capelin are a schooling fish that spend considerable time in the water column, RV survey catch rates are considered to be indicative of general trends in abundance but not adequate to make absolute biomass estimates (DFO 1996b). An analysis of catch trends from the RV survey data for this report show regular capelin catches in 4VW in recent years, but much lower volumes than were caught in the area in the 1990s (Figure3.5.11-1). Capelin are caught in the St Anns Bank area in the RV survey on a regular basis.

Sources of Information
There is limited monitoring of capelin on the Eastern Scotian Shelf, primarily through the summer RV survey.

3.5.12 Atlantic Herring

Geographic Range and Habitat Preferences
Atlantic herring are widely distributed in the region. Once they mature, they follow a predictable migration to spawn, overwinter, and feed in the summer, with spawning groups often mixing (Power et al. 2010).

Populations or Stock Definitions
Herring that use the St Anns Bank AOI come from several populations. Herring from the southern Gulf of St. Lawrence (4T) migrate into 4Vn by the end of October and return to the Gulf of St. Lawrence to spawn between April (for spring spawners) and June or July (for fall spawners) (LeBlanc et al. 2001), so they spend upwards of half the year in 4Vn. In the past this population supported a winter fishery in the northern part of Sydney Bight (LeBlanc et al. 2001).

The Atlantic coastal spawning population of herring is referred to as coastal spawners in 4VWX for stock assessment purposes, and there are multiple small spawning groups within this unit (Power et al. 2010).

From 1977 to 1980, herring tagged in Sydney Bight in the winter fishery in 4Vn were recovered off the coast of Newfoundland, throughout the Gulf of St. Lawrence, in Sydney Bight, in the Bras d'Or Lakes, along the Nova Scotia coast, and into the Bay of Fundy (Figure 3.5.12-1; Stobo and Simon 1982). In addition to what may be a resident 4Vn/Sydney Bight population, there is some mixing within this area, especially during the fall and winter.

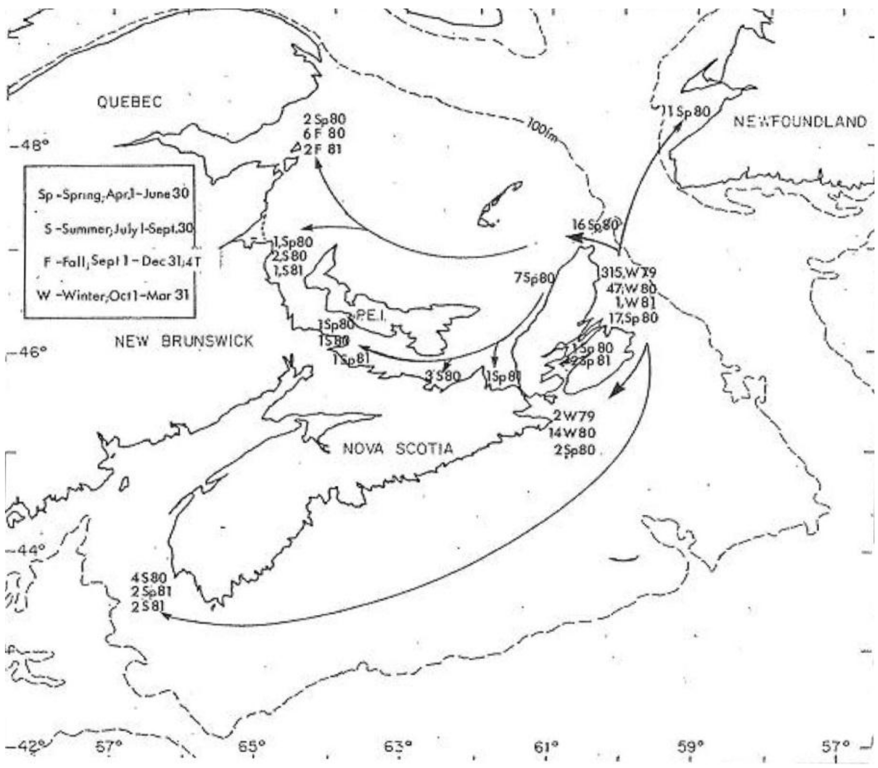


Figure 3.5.12-1. Recoveries from 11,101 herring tagged 10 December 1979 to 7 January 1980 in the Ingonish–Bird Island area of Sydney Bight (from Stobo and Simon 1982).

Herring in St Anns Bank

Herring spawn along the coast of Cape Breton in Red Grounds, Glace Bay, and the Big Shoal (Power et al. 2010). The Big Shoal spawning area is in the upper western corner of the AOI, where water depths are less than 50 m (Figure 3.5.12-2).

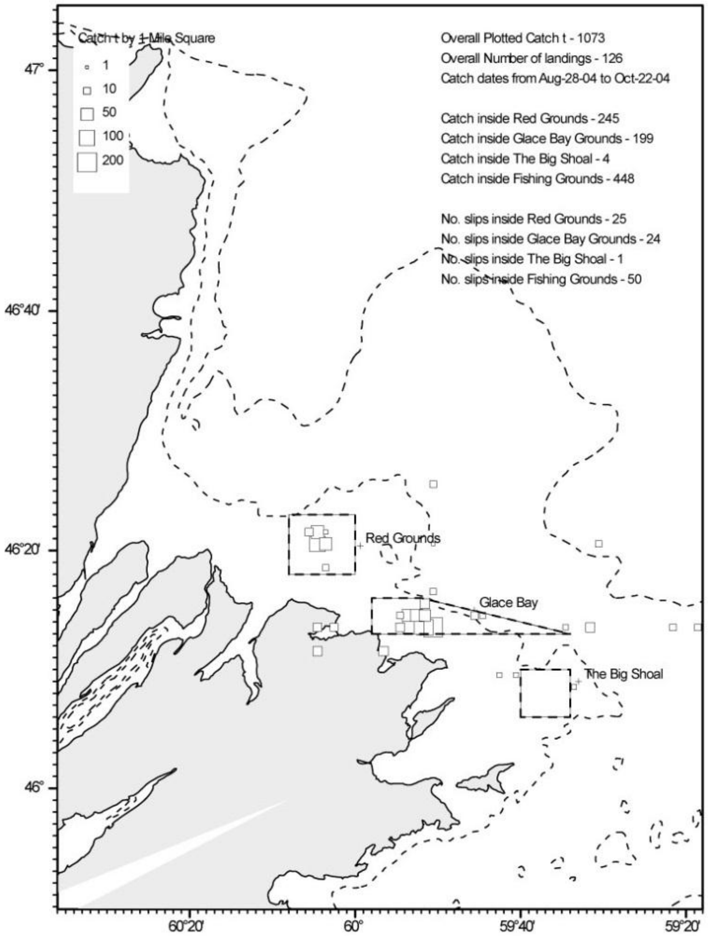


Figure 3.5.12-2. Herring gillnet catches in the fall spawning period (Michael Power, personal communication).

In the January bottom trawl groundfish survey that took place in 4Vn between 1994 and 1997, Atlantic herring were mainly found around and below 200 m in the Laurentian Channel. The largest concentrations surrounded St. Paul's Island (Figure 3.5.12-3), but in 1996 in particular there were significant concentrations in the slope and channel parts of St Anns Bank.

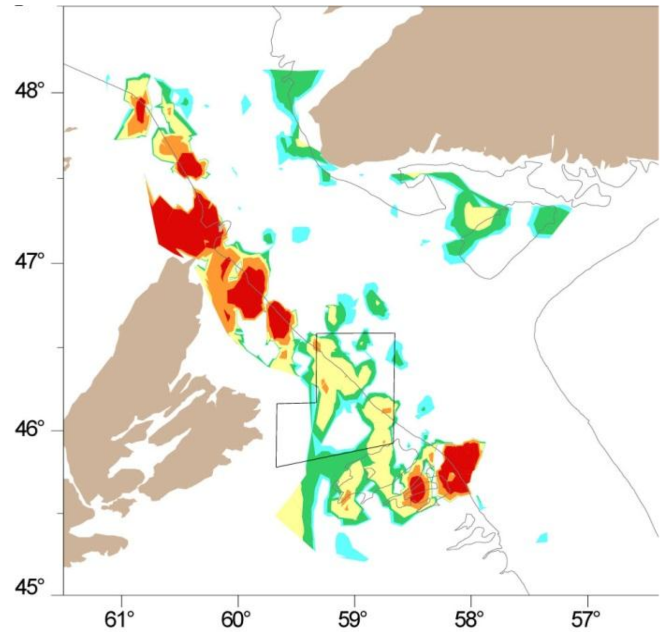


Figure 3.5.12-3. Total catch of herring in surveys in the Cabot Strait in January from 1994–1997 (Doug Swain, DFO Science, personal communication, September 2011).

St Anns Bank is not an area of particular concentration for herring in the summer RV survey, but herring have been found in the area since the late 1970s, particularly in recent years (Figure 3.5.12-4; Horsman and Shackel 2009; Power et al. 2010). Given the time of year, this is more indicative of the resident 4Vn population.

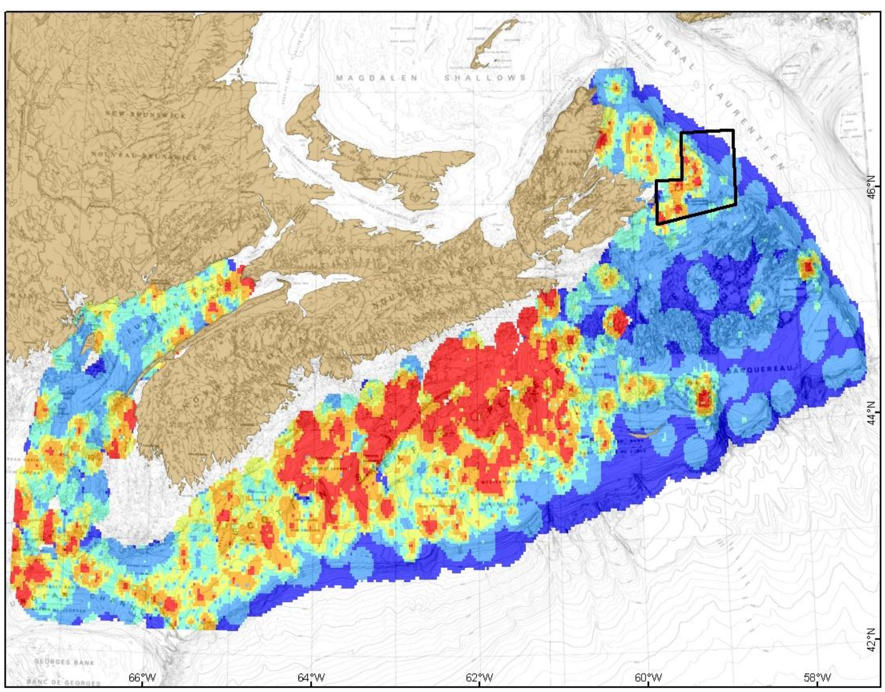


Figure 3.5.12-4. Herring distribution over 1994–2006 based on the RV survey (Horsman and Shackell 2009).

Biology

Productivity

Herring are a highly productive pelagic fish that can reach large abundances in North Atlantic ecosystems. In the Gulf of St. Lawrence, average age at maturity is four years and average fork length at maturity is 23.5 cm (LeBlanc et al. 2010); large females are believed to produce up to 360,000 eggs (Messieh 1988). In 4VWX, herring were reported to mature at three to four years of age and 23 to 28 cm, having very similar biology to the Gulf of St. Lawrence population (Power et al. 2010).

Natural Mortality

Natural mortality is assumed to be 0.2 in stock assessments (LeBlanc et al. 2010). However, recent work suggests that higher values for natural mortality on the order of 0.3 to 0.4, depending on size and age, may be more appropriate (Guénette and Stephenson 2010).

Ecosystem Interactions

Herring are an important prey item in North Atlantic coastal ecosystems, and are eaten by other fish, marine mammals, and seabirds (Scott and Scott 1998). As a group, small pelagic fish play a key role in transforming zooplankton biomass into fish biomass where it is available to higher level predators (McQuinn 2009). Because of their significant biomass, it has been hypothesized that herring may also exert top-down control on their prey species, including Atlantic cod through their consumption of cod eggs (Bundy and Fanning 2005; Frank et al. 2005).

Herring are visual predators that mainly consume plankton. Young herring eat small plankton, including copepod nauplia and invertebrate eggs, switching to larger plankton, especially euphasiids, as they grow (Savenkoff et al. 2006). On the Scotian Shelf, sampling from the RV survey between 1995 and 2008 showed their diets were dominated by euphausiids and decapods, followed by unidentified arthropods, amphipods, and fish eggs, as well as unidentified larval fish (Cook and Bundy 2010).

On the Scotian Shelf, herring have been identified as a significant prey item of porbeagle, blue, and mako sharks (Zwanenburg et al. 2006); grey (Beck et al. 2007), harp (Tucker et al. 2009), and harbour seals (Zwanenburg et al. 2006); humpback (Stevick et al. 2006) and fin (Woodley et al. 1996) whales; and Atlantic cod, silver hake, and white hake (Cook and Bundy 2010). They were the most common prey species found in Atlantic cod stomachs in summer RV survey sampling from 1995 to 2008 (Cook and Bundy 2010).

In the Gulf of St. Lawrence, herring was among the three main prey items consumed by all groups of predators over three time periods from the mid-1980s to the early 2000s (Savenkoff et al. 2006). Savenkoff et al. (2006) considered predation from cetaceans, seals, and seabirds to be among the main sources of mortality for herring in the early 2000s, while redfish and large cod predation were among the highest sources of mortality early in the time series.

Fisheries and Other Human Activities

In the Gulf of St. Lawrence, herring are harvested by an inshore gillnet fishery and a purse seine fishery, which has also taken place in northern 4Vn in some years (LeBlanc et al. 2010). Purse seiners from the Gulf are permitted to fish as far south as Cape Smokey, while Nova Scotia purse seiners can fish as far northeast as Scatarie Island (Figure 3.5.12-5). This means that much of St Anns Bank is closed to herring seining (DFO 2003b).

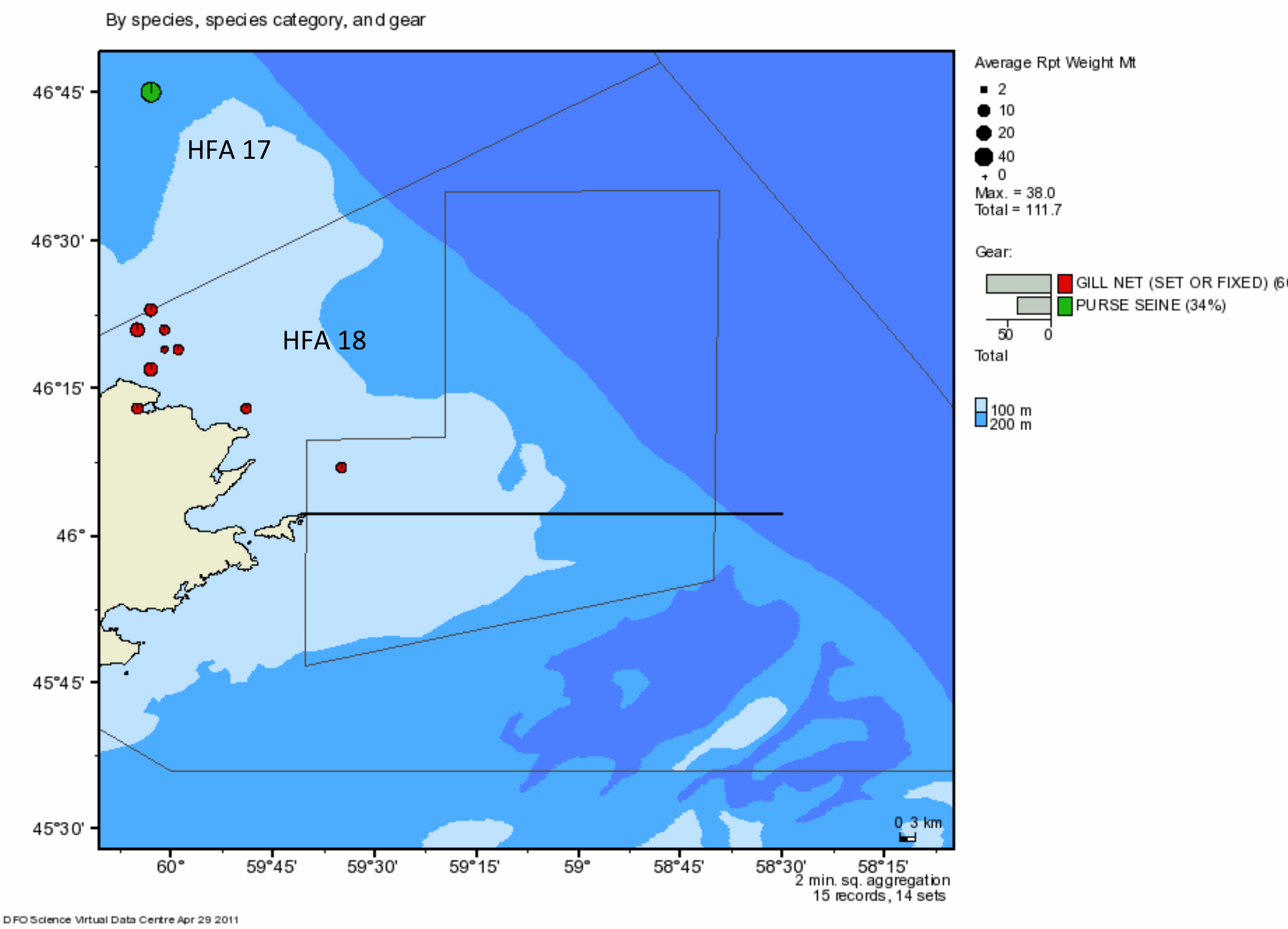


Figure 3.5.12-5. Herring fishing in and around St Anns Bank since 2006. Purse seining is not allowed south of the diagonal line dividing Herring Fishing Areas 17 and 18, or north of Scatarie Island (horizontal line).

There is an inshore gillnet roe fishery in Glace Bay, however, catches have dropped from a high of over 3000 t in 2002 to only 12 t in 2008 (Power et al. 2010), with a very small amount of catch in St Anns Bank in recent years (Figure 3.5.12-5). In addition, many fishermen have bait licences to catch herring with gillnets, and do not have to report these landings. This is an unknown potential source of mortality in the area that is being addressed with the implementation of new management measures for reporting in 2011. The total bait catch is assumed to be relatively small (on the order of < 100 t). In the ZIF/MARFIS databases there are records of herring caught with gillnets in St Anns

Bank for 1997–2004 (maximum 115 t in 1998). The resident 4Vn herring are considered vulnerable to fishing because of the small size of the populations and their proximity to shore (Power et al. 2010).

Status and Trends

Spring spawning herring in 4T have been declining since 1985. They have been at a consistently low level from 2002 through 2008, with a slight increase in 2009. The estimate of spawning stock biomass (28,200 t) is above the limit reference point (22,000 t) but below the upper stock reference (54,000 t). The fall spawning component is at a high level of abundance (about 307,400 t) relative to the late1970s and early 1980s, and is above the upper stock reference point (172,000 t) (LeBlanc et al. 2010).

Coastal 4Vn spawning populations are monitored with acoustic surveys (Power et al. 2010). The closest spawning population that is monitored is the Glace Bay population, where biomass was estimated through acoustic surveys to be 240 t in 2007 and less than 500 t in 2008 (Power et al. 2010). These estimates are considered quite low relative to estimates from 1999–2003, and the gillnet fishery in the area has been very limited in recent years, though partly due to market conditions. Relative to southwest Nova Scotia, this component and the associated fishery are very small, and therefore much less in known about their abundance and trends.

Sources of Information

There are stock assessments for both 4T and 4VWX herring from 2010. In 4T, stock assessment is mainly based on a gillnet opinion survey and acoustic surveys. The RV survey is a source of some information; 4VWX herring is at low levels of abundance in the survey after 10 years of higher values, but this is not representative of their overall abundance (Power et al. 2010). Acoustic surveys on the spawning grounds are considered more important in the 4VWX assessment.

For the inshore fisheries (like the gillnet roe fishery in Glace Bay), the approach has been to acoustically survey the spawning grounds on a bi-weekly basis during the spawning period, assess the resource available, then allow fishing based on a 10% yield of surveyed spawning biomass. In recent years there has been limited survey effort, and the recent estimates are considered to underestimate the true spawning population for the area.

Sources of Uncertainty

Population structure for coastal Nova Scotia spawners, abundance and status of these populations, including Bras d’Or Lakes spawners, and the importance of the area for overwintering from other populations are all key areas of uncertainty.

3.5.13 Mackerel

Geographic Range and Habitat Preferences

Overall, mackerel are found throughout much of the Maritimes Region, inshore in spring and summer, and deeper in warmer waters at the edge of the shelf in fall and winter

(DFO 2008b). The southern Gulf of St. Lawrence is the major nursery area for this stock. The Cabot Strait is part of the annual migration of mackerel in and out of the Gulf of St. Lawrence. The population migrates relatively rapidly through the area, from late May to early July in the spring/summer, out-migrating mainly in October/November, as inferred from landings (Grégoire et al. 2009).

Mackerel prefer warm water, and water temperature strongly influences their distribution along the coast (Grégoire 2001) and in the water column (Grégoire 2006; Bruneau and Grégoire 2011).

<u>Population or Stock Definitions</u>
Atlantic mackerel off Nova Scotia are part of the “northern contingent” of Atlantic mackerel. They migrate annually from the edge of the continental shelf and Georges Bank in early spring to spawning areas and feeding grounds in the Gulf of St. Lawrence and off the east coast of Newfoundland (Grégoire et al. 2009).

<u>Mackerel in St Anns Bank</u>
Mackerel seem to migrate through the St Anns Bank area fairly rapidly. There are no records of catch in St Anns Bank since 2002, but the ZIF database shows 23 t over the period 1997–2001, which was taken mostly with handlines.

<u>Biology</u>

Productivity
Fishbase[9] characterizes mackerel as having a medium level of maximum productivity (Rmax = 0.33–0.56), but high fecundity (up to 200,000 eggs/year). In the Gulf of St. Lawrence, the average size at maturity is about 25 cm (Grégoire et al. 2009). Less than 40% of mackerel are mature at one year, and all are mature at four years (Grégoire et al. 2009).

Ecosystem Interactions
In the Gulf of St. Lawrence, mackerel are a significant forage species, and the ichthyoplankton of the Gulf is dominated by mackerel in summer (Dufour and Ouelette 2007). In the Gulf, mackerel are preyed upon by cetaceans, cod, large pelagics, redfish, harp seals, grey seals, and seabirds (DFO 2005d). Modelling found that cetacean predation was an important source of mortality from the mid-1980s to the early 2000s, while large cod and other large demersal predators were important in the mid-1980s (DFO 2005d). No similar work has been done to describe predation on mackerel while on the Scotian Shelf or in the Cabot Strait. Small and large zooplankton are the main components of their diet, though some capelin, shrimp, and molluscs have also been found to be eaten by mackerel (DFO 2005d).

[9] http://www.fishbase.org

Fisheries and Other Human Activities
The main gear for fishing mackerel in the Gulf of St. Lawrence is purse seine, but mackerel are also taken with gillnets, traps, and handlines, and less often can be taken with “jiggers, trawls, other types of seines, weirs and lastly longlines” (Grégoire et al. 2009). There is mackerel fishing along the east coast of Cape Breton in spring and fall, mainly using traps in spring and hand lines in fall (Grégoire et al. 2009). The average catch in 4Vn was as high as 1468 t between 1985 and 1999 (Grégoire 2001), falling to 553t/year between 1995 and 2006 (Grégoire et al. 2009). However, landings from only one index trap fisherman were almost as high (and even higher in 2004) than the official DFO landings for all the fishermen from this subdivision, indicating a significant data collection issue (Grégoire et al. 2009).

In Cape Breton, the most mackerel have been caught in Dingwall/Aspy Bay, but Glace Bay and Port Morien also harvest significant amounts (Grégoire 2001). St Anns Bank is in Mackerel Fishing Area 7; in this area, catch has been reported mainly in September and October using handlines and some gillnets (Grégoire 2001). Reported landings in this Mackerel Fishing Area have been very low in recent years (as low as 4 t in 2007), down from 370 t in 1995 (Grégoire et al. 2009). It is important to note that bait fishing catches and locations are not reported, so there may be additional mackerel catch in the St Anns Bank area that is not included here.

Status and Trends
The most recently estimated spawning biomass, 76,532 t, is one of the lowest in the time series that begins in 1983. The peak biomass was in 1986 at about 1,750,000 t, but the stock has been estimated to be below 500,000 t since 1994 (DFO 2008b).

Sources of Information
Mackerel are only monitored regularly in the Gulf of St. Lawrence, using a survey of egg abundance. In 2009, an egg survey of the Scotian Shelf was completed, but very low egg densities were found (TRAC 2010).

3.5.14 Sharks
While sharks can play an important role in marine systems as apex predators, most are wide-ranging and low in abundance relative to the other fish species being considered in detail in this report. Porbeagle sharks are being considered in more detail than other shark species due to their abundance and commercial importance, and because St Anns Bank is located at the entrance to the Gulf of St. Lawrence, which is part of the mating grounds for this species. Other common shark species in the region are described briefly below.

Additional information on Canadian shark species and shark research in the Maritimes is available on the Web site for the Shark Research Laboratory[10].

[10] http://www.marinebiodiversity.ca/shark

Porbeagle Shark
Porbeagle shark are a large pelagic shark, reaching lengths of over three metres, and are distributed widely in the Maritimes Region, including in the St Anns Bank AOI.

Geographic Range and Habitat Preferences
Porbeagle in the North Atlantic range from the northern tip of Newfoundland to New Jersey. The entrance to the Gulf of St. Lawrence (including St Anns Bank) and the area of the Grand Banks off southern Newfoundland are believed to be mating grounds for this species (Campana et al. 2003). Porbeagle are found at all depths but prefer temperatures between 5 and 10 ºC (Campana et al. 2003).

Populations or Stock Definitions
Porbeagle in the northwest Atlantic are believed to be a single population.

Porbeagle in St Anns Bank
Information on porbeagle in the St Anns Bank area comes from the fishery and from the shark survey. A small number of porbeagle were caught in the shark survey in St Anns Bank in both years that it was undertaken (Figure 3.5.14-1; Steve Campana, DFO Science, personal communication, June 2011). There are a small number of records of porbeagle caught in the directed fishery in the St Anns Bank area (7 records were found in the MARFIS database from 2003 to 2008, and 11 records in the ZIF database from 1991 to 2003).

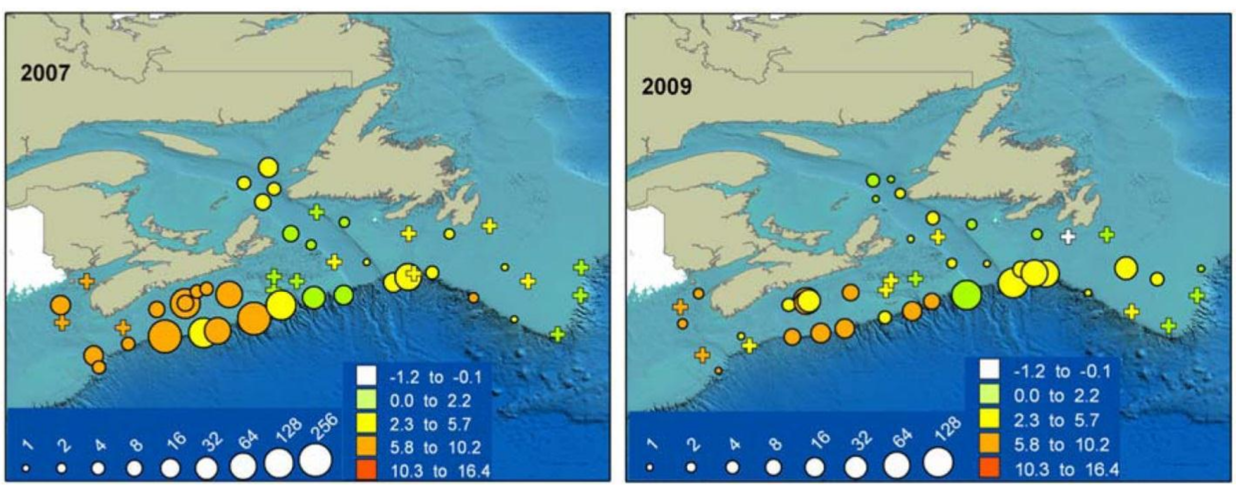


Figure 3.5.14-1. Catch of porbeagle sharks in the shark survey in 2007 and 2009. Crosses represent null sets (for porbeagle); color coding represents temperature in ºC (Steve Campana, DFO Science, personal communication, June 2011).

Biology

Productivity
The porbeagle has a low fecundity, late age at sexual maturation, and low natural mortality, even relative to other sharks (COSEWIC 2004). Male porbeagle mature at

about eight years and 175 cm and females at about thirteen years and 216 cm (Jensen et al. 2002). Females appear to have a one-year reproductive cycle, giving birth to an average of four young in the spring (Jensen et al. 2002), with pupping occurring in the Sargasso Sea (Campana et al. 2010a).

Ecosystem Interactions
Porbeagle are a large predator, and a study in the Maritimes Region documented that the majority of their diet was teleost fish (especially lancetfish, flounders, lumpfish, and Atlantic cod), with cephalopods being found in a much smaller number of stomachs (Joyce et al. 2002).

Fisheries and Other Human Activities
There is a directed fishery for porbeagle on the Scotian Shelf using pelagic longlines, and the majority of the catch is along the shelf break. The species is considered to be highly vulnerable to overexploitation because of very low productivity and because population abundance and recruitment are strongly coupled (COSEWIC 2004). Currently, the TAC for porbeagle in the Maritimes region is 250 t. They are also caught as bycatch in the pelagic longline fishery for offshore tunas, and in smaller numbers in various other fisheries (Campana and Gibson 2005). Since 2001, directed fishing for sharks has been prohibited in NAFO Divisions 4Vn (including St Anns Bank) and 3LNOP from September to January to protect mature (pregnant) females.

Status and Trends

Stock Status
The porbeagle population in the northwest Atlantic is considered to be depleted, but has not decreased since around 2001 (Campana et al. 2012b). It is considered to be currently recovering, and expected to continue recovering if current low fishing rates are continued (Campana et al. 2010b). Historically, intensive fisheries have depleted porbeagle stocks quickly and recovery times have been slow (COSEWIC 2004; Campana and Gibson 2005).

Species at Risk Considerations
COSEWIC lists the population as Endangered, but it is not listed under *SARA*.

Sources of Information
Porbeagle populations are monitored with a shark-directed scientific survey that uses catch rates with commercial gear to estimate population abundance and trends. Porbeagle stock assessments have been undertaken regularly in recent years, with the most recent assessment published in 2010 (Campana et al. 2010b).

Other Sharks
In addition to the porbeagle shark, other sharks that may be relatively common in the St Anns Bank area are blue sharks, basking sharks, shortfin mako, and spiny dogfish (Zwanenberg et al. 2006).

Blue sharks are listed as Special Concern by COSEWIC. They are the most abundant shark in Canadian waters and are distributed across the Atlantic Ocean (COSEWIC 2006a). There does not appear to be any special significance of the St Anns Bank area to this species; no mature females are found in Canadian waters, and no reproduction occurs in this area (COSEWIC 2006a). Blue sharks are caught as bycatch in the directed porbeagle fishery, pelagic longline fisheries for tuna and swordfish, and occasionally in other fisheries (Campana et al. 2004). Of the fisheries occuring in St Anns Bank, only the porbeagle fishery, which occurs occasionally, would catch blue sharks with any frequency (one record in MARFIS).

Basking sharks are large, long-lived sharks that feed on plankton near the ocean surface. They were designated as Special Concern by COSEWIC in 2009. Basking sharks follow areas of zooplankton concentration, and may pass through the St Anns Bank area when migrating in and out of the Gulf of St. Lawrence (Zwanenberg et al. 2006). There is no indication that they exist in higher than usual concentrations in the St Anns Bank area, but there were basking sharks sited in this vicinity in the 2007 TNASS (Trans North Atlantic Sightings Survey) aerial surveys for marine megafauna (Figure 3.5.14-2), and there have been basking sharks reported in this region by observers (Campana et al. 2008). Basking sharks can be caught in fishing gear including groundfish trawls and groundfish longlines, both of which are actively used in the St Anns Bank area (Campana et al. 2008).

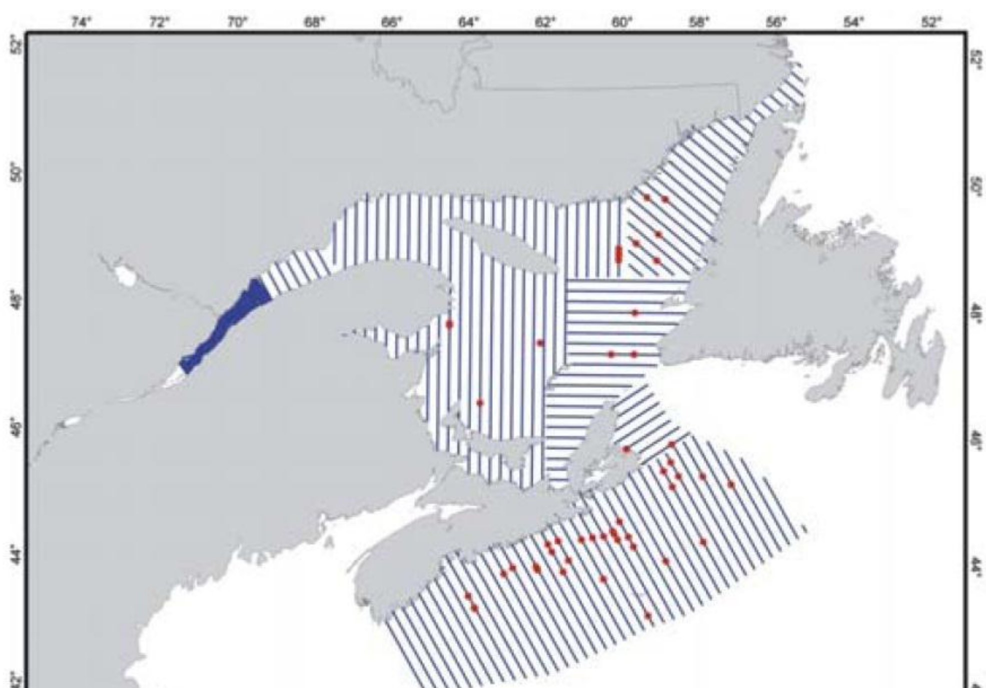


Figure 3.5.14-2. Sightings of basking sharks on the Scotian Shelf and in the Gulf of St. Lawrence during DFO’s 2007 TNASS aerial surveys for marine megafauna (Campana et al. 2008).Blue lines indicate survey lines and the red dots are basking shark sightings.

Shortfin mako are a relatively abundant shark that are mainly found offshore in warmer Gulf Stream waters, but have been recorded on the Scotian Shelf and in the Gulf of St. Lawrence (Campana et al. 2006). There are records of shortfin mako in fisheries in the St Anns Bank area (MARFIS database), though fairly infrequently (6 in the AOI from 2002-2012). Shortfin mako have been designated as Threatened by COSEWIC. The main threats to this species appear to be fisheries outside of Canadian waters as this area is on the edge of their distribution (Campana et al. 2006). There is no indication that the St Anns Bank area is of particular importance to any life history stage of shortfin mako, though it is likely a migration route into the Gulf of St. Lawrence.

Spiny dogfish is a small shark that is an abundant predator in the Western Scotian Shelf and Gulf of Maine. The St Anns Bank area does not appear to be preferred habitat for spiny dogfish (Campana et al. 2007b; Horsman and Shackell 2009), but they are present in the St Anns Bank area. Spiny dogfish are often subject to high levels of bycatch and discard in groundfish fisheries (Campana et al. 2007b). It is unknown whether there would be any reproduction of this species in the St Anns Bank area, but mating and pupping seems to occur in deeper waters on the continental slope, which could include the area of the slope in St Anns Bank and to the south of St Anns Bank (Campana et al. 2007b). Spiny dogfish were found on the slope in the St Anns Bank area in January (1994–1997) (Campana et al. 2007b). The relatively slow growth, late maturation, and low fecundity of this species make it vulnerable to overexploitation. The species is not fished commercially in the St Anns Bank AOI and it does not seem to experience heavy bycatch in the area, but there are records from fisheries observers of spiny dogfish caught and discarded in fisheries in this area (Campana et al. 2007b).

<u>Sources of Information</u>

In 2007 and 2009 a shark survey was completed covering the Canadian side of the Gulf of Maine, the Scotian Shelf, the entrance to the Gulf of St. Lawrence, and the Grand Banks, and it is expected that the same survey will be undertaken periodically. The primary objective of the survey is to provide a fishery-independent index for monitoring the status of the porbeagle population. A secondary objective is to monitor the population abundance and size composition of other sharks in the region. There was one survey set in the St Anns Bank AOI in each year, and a small number of porbeagle sharks were caught (Steve Campana, DFO Science, personal communication, June 2011).

3.6 MARINE MAMMALS

<u>3.6.1 Cetaceans</u>

<u>Introduction</u>

At least twenty species of cetaceans, including various species of baleen whales, toothed whales, dolphins and porpoises, have been observed in waters of the northwest Atlantic off Nova Scotia. Many of these species are commonly observed off southeastern Nova Scotia during at least part of the year.

To date, there are no comprehensive studies that describe the presence or abundance of cetaceans in the St Anns Bank area. There has been very little cetacean research or observational effort in the area and most of the sightings data available are biased towards the late spring, summer, and early fall. Very few cetacean sightings have been reported within the AOI boundaries, and no cetacean abundance estimates exist specifically for St Anns Bank. Because of the lack of available data, only species likely to occur on St Anns Bank based on knowledge of general distribution and migration patterns in the Scotian Shelf area combined with limited sightings data are described in this section.

As discussed in the sections below, St Anns Bank AOI likely encompasses an important migration route for baleen whales traveling through the Cabot Strait to and from the Gulf of St. Lawrence, and potentially to and from other regions further north (such as north of Newfoundland and Labrador). Most cetaceans likely occur in the area seasonally or as transients. It is not known if there are resident populations of cetaceans that occur in the St Anns Bank area, but some species may use the area throughout the year.

<u>Sources of Data</u>

Although there are no comprehensive studies that describe the presence or abundance of cetaceans in the St Anns Bank area specifically, there are sources of data available that can be used to help describe the distribution of cetacean species in the region. The following sources of sightings data and distribution and abundance information were used to identify cetacean species likely to occur in St Anns Bank.

Fisheries and Oceans Maritimes Region Cetacean Sightings Database

The DFO Maritimes Region Cetacean Sightings Database contains data on whale sightings within the region dating back to the 1960s. These data were collected from researchers, fisheries observers, industry, and others on a variety of platforms. The majority of the data comprise opportunistic sightings, with few data from systematic cetacean surveys. It is important to note that the number of observations are skewed to particular areas where there has been research effort. Area coverage is not complete and varies over time, thus an absence of sightings within an area does not necessarily mean that whales were not present, but rather is more likely to reflect the lack of search effort within the area. Table 3.6.1-1 summarizes all cetacean sightings on the Scotian Shelf and off eastern Cape Breton currently in this database, and Figures 3.6.1-1a–d show where these reported sightings occurred for each species.

Table 3.6.1-1. Summary of cetacean sighting events recorded in the DFO Maritimes Region Cetacean Sightings Database. Horizontal lines indicate no sightings reported in the database for a particular species or group. See Figures 3.6.1-1A–B for a depiction of the boundaries used for the three different areas.

Type of cetacean	Area		
	Scotian Shelf and east of Cape Breton	**St. Ann's Bank and surrounding area to 50 nm**	**St. Ann's Bank AOI**
Baleen whales			
Blue whale (*Balaenoptera musculus)*	195	----------	----------
Fin whale (*Balaenoptera physalus*)	1305	9	----------
Sei whale (*Balaenoptera borealis*)	598	----------	----------
Minke whale (*Balaenoptera acutorostrata*)	181	8	----------
Humpback whale (*Megaptera novaeangliae*)	345	17	1
Right whale (*Eubalaena glacialis*)	73	2	----------
Large odontocetes			
Sperm whale (*Physeter macrocephalus*)	326	----------	----------
Northern bottlenose whale (*Hyperoodon ampullatus*)	1427	----------	----------
Other beaked whales	41	----------	----------
Beluga whale (*Delphinapterus leucas*)	3	1	----------
Killer whale (*Ocinus orca*)	12	2	----------
Long-finned pilot whale (*Globicephala melas*)	1214	8	----------
Small odontocetes			
Harbour porpoise (*Phocoena phocoena*)	30	3	----------
Atlantic white-sided dolphin (*Lagenorhynchus acutus*)	591	9	----------
Short beaked common dolphin (*Delphinus delphis)*	435	5	----------
White-beaked dolphin (*Lagenorhynchus albiorstris*)	3	----------	----------
Striped dolphin (*Stenella coeruleoalba*)	78	----------	----------
Atlantic bottlenose dolphin (*Tursiops truncatus)*	71	----------	----------
Risso's dolphin (Grampus griseus)	5	----------	----------
Unknown Dolphin Species	774	17	----------
Unidentified cetaceans			
Unknown Whale Species	445	26	3

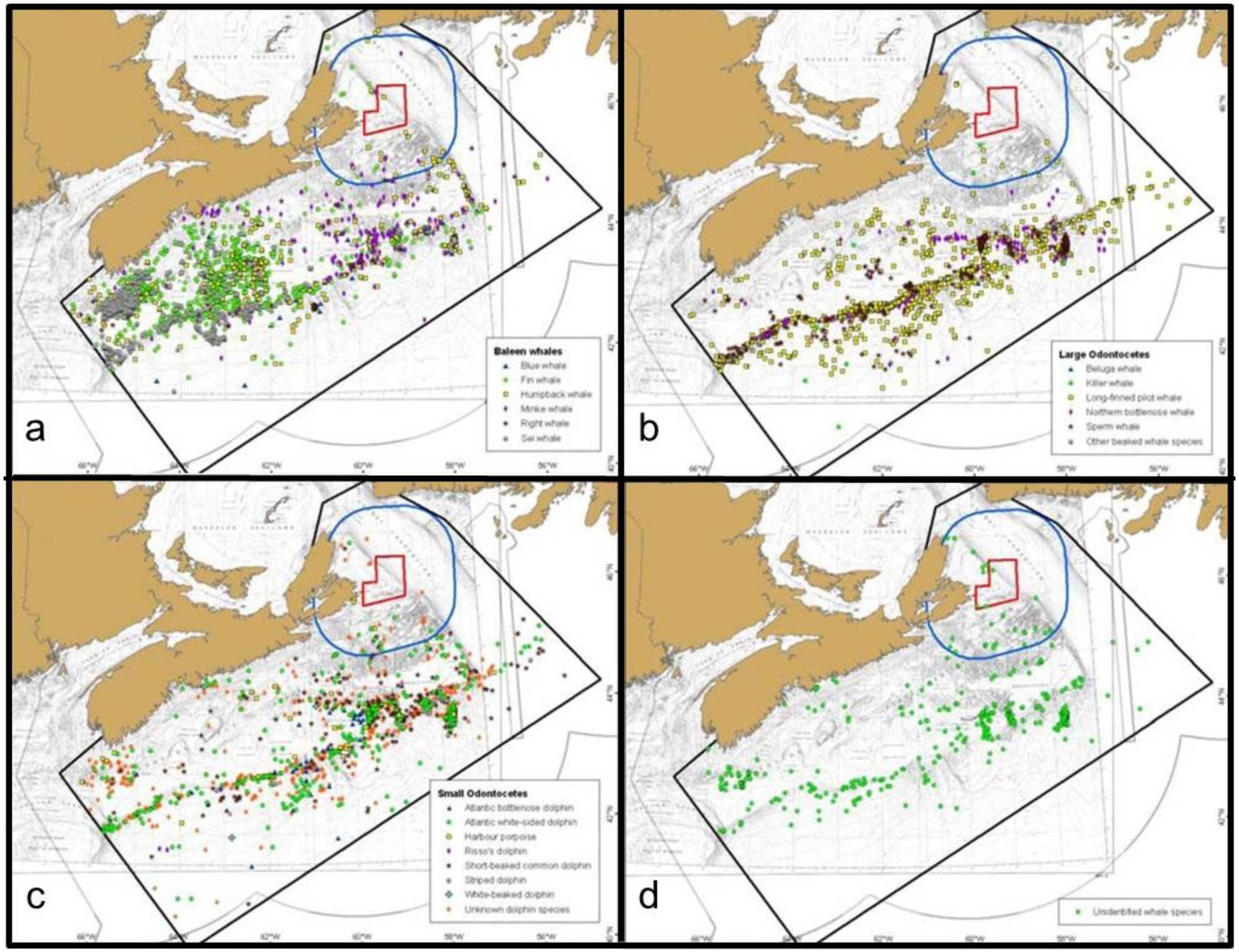


Figure 3.6.1-1a–d. Whale sightings from the DFO Maritimes Region Cetacean Sightings Database within the Scotian Shelf and eastern Nova Scotia (black boundary), within approximately a 50 nautical radius of and including St. Anns Bank (blue boundary), and within St Ann's Bank AOI (red boundary). Records represent a) baleen whales, b) large odontocetes, c) small odontocetes, and d) unidentified cetaceans.

Trans North Atlantic Sightings Survey
An aerial survey of marine megafauna in the northwest Atlantic, including St Anns Bank, was conducted in 2007 as a part of the multinational TNASS. The Canadian portion of this survey covered the area from the Scotian Shelf to northern Labrador, with surveys on the Scotian Shelf and off Cape Breton occurring during July and August 2007. Table 3.6.1-2 summarizes all cetacean sightings that occurred on the Scotian Shelf and off eastern Cape Breton during this survey. Lawson and Gosselin (2009) used the sightings from this survey to estimate the abundance of cetacean species in eastern Canadian waters (Table 3.6.1-2), although abundance estimates for just the Scotian Shelf and Cape Breton areas were not calculated.

Table 3.6.1-2. Cetacean sighting events for the Scotian Shelf and Cape Breton from TNASS survey areas, and estimated total abundance for Eastern Canada and 95% confidence intervals for cetacean species with more than 20 sightings during the full Canadian TNASS survey (horizontal lines indicate insufficient data for abundance estimates). Data obtained from Lawson and Gosselin (2009).

Type of cetacean	Area		Total Abundance	95% Confidence Interval
	Scotian Shelf	East of Cape Breton		
Blue whale	4	1	----------	----------
Fin whale	44	0	1,352	821 - 2,226
Sei whale	2	0	----------	----------
Minke whale	86	1	3,242	2,051 - 4,845
Humpback whale	51	0	2,080	1,337 - 3,172
Right whale	0	0	----------	----------
Sperm whale	11	0	----------	----------
Northern bottlenose whale	3	0	----------	----------
Other beaked whales	13	0	----------	----------
Beluga whale	0	0	907	509 - 1,583
Killer whale	7	0	----------	----------
Long-finned pilot whale	36	2	6,134	2,774 - 10,573
Harbour porpoise	4	0	4,862	2,204 - 8,801
Atlantic white-sided dolphin	15	0	----------	----------
Common dolphin	198	2	53,625	35,179 - 81,773
White-beaked dolphin	0	0	1,842	1,188 - 2,854
Striped dolphin	0	0	----------	----------
Atlantic bottlenose dolphin	8	0	----------	----------
Risso's dolphin	5	1	----------	----------
Unknown Dolphin Species	192	13	34,462	20,560 - 57,862
Unknown Whale Species	80	0	----------	----------

Cetacean Species Most Likely to Occur in the St Anns Bank AOI

It is generally accepted that prey availability greatly influences cetacean distribution. Consequently, cetacean distribution and abundance is indirectly related to environmental variables and oceanographic features that affect the distribution and abundance of their prey (Gaskin 1982; Bowen and Siniff 1999; Stevick et al. 2002). Physical features that enhance primary productivity and convert it to prey biomass over short temporal and spatial scales, that concentrate prey through physical mechanisms, or make prey more assessable at the surface are likely to be important habitat for cetaceans (Baumgartner et al. 2001).

Baleen whales feed primarily on copepods, euphasiids, and amphipods, as well as small schooling fish such as herring and capelin (Breeze et al. 2002), while toothed whales typically feed on fish and cephalopods (Gaskin 1982; Bowen and Siniff 1999). Areas of high primary and secondary productivity are thus likely to attract baleen whales, while areas known for high concentrations of fish and squid are likely to be more important for toothed whales.

As discussed in Section 2.2, the Gulf of St. Lawrence is one of the primary sources of nutrients for the Scotian Shelf (Breeze et al. 2002). Relatively high levels of chlorophyll typically occur over the western portion of the Laurentian Channel throughout most of the year. St Anns Bank is a region where some copepod species important to cetaceans are especially abundant (see Section 3.2), and Sameoto and Cochrane (1996) note the Laurentian Channel as an area where relatively high concentrations of some species of krill occur, such as *Meganyctiphanes norvegica*.

There are some reports of large groups of cetaceans along the western wall of the Laurentian Channel, most notably in an area near the mouth of the Channel known as the Stone Fence, and many sightings along the western wall have been reported in the DFO Cetacean Sightings Database (Figures 3.6.1-1a and b). The Laurentian Channel is a known migration corridor for cetaceans moving into or out of the Gulf of St. Lawrence (Breeze et al. 2002; Templemen et al. 2010), but may also provide feeding opportunities. Given that the northeastern portion of the St Anns Bank AOI extends out into the Laurentian Channel and encompasses part of the western wall of the Channel, it is likely that cetacean species may occur in this area to feed, or pass through this area on their way to other regions. Given the observation that most cetaceans in the Gulf of St. Lawrence are expected to migrate from the Scotian Shelf or Newfoundland Shelf, the lack of cetacean sightings in the area seems likely to result from lack of effort rather than lack of use by migrating whales.

Based on the available sightings data (Tables 3.6.1-1 and 3.6.1-2; Figures 3.6.1-1a–d) and distribution maps produced by Breeze et al. (2002), the cetacean species most likely to occur on St Anns Bank include fin whales, minke whales, humpback whales, pilot whales, Atlantic white-sided dolphins, and common dolphins. Species that are less likely to be found in the area but may occasionally occur there include blue whales, sei whales, northern right whales, killer whales, and harbour porpoise. A more detailed overview of these species and their possible connections to the St Anns Bank AOI are described in the sections below.

Blue Whales (*Balaenoptera musculus*) – Northwest Atlantic Population
In the North Atlantic, blue whales undergo annual migrations; they travel to productive feeding areas of temperate to sub-Arctic latitudes in summer and move south to equatorial latitudes for the winter (Beauchamp et al. 2009). During the summer, whales of the northwest Atlantic population range from the Scotian Shelf to the Davis Strait. They are likely distributed throughout the southern half of the North Atlantic in the winter, though little is known about their winter distribution (Reilly et al. 2008a). Most recent blue whale sightings off eastern Canada have occurred in the Gulf of St. Lawrence, off the southern and southwestern coasts of Newfoundland, and on the Scotian Shelf (Beauchamp et al. 2009). Blue whales are most often seen in these areas in the spring, summer, and fall; most sightings are reported from May to December and peak sighting rates occur between June and August (Beauchamp et al. 2009). There is evidence that some individuals remain in waters of the Gulf of St. Lawrence and off eastern Nova Scotia throughout the winter (Beauchamp et al. 2009; Templeman et al. 2010).

Blue whales are not known to regularly occur in the St Anns Bank area. Areas of known and probable regular occurrence on the Scotian Shelf identified by Breeze et al. (2002) are located southwest of St Anns Bank in waters off southwestern Nova Scotia. As well, all blue whale sightings in the DFO Cetacean Sightings Database were more than 50 nautical miles south or southwest of the AOI (Figure 3.6.1-1A). However, sightings of blue whales have been reported in the Laurentian Channel (Beauchamp et al. 2009), which is thought to be a migratory corridor for whales traveling to the Gulf of St. Lawrence and other regions north (Breeze et al. 2002; Templeman et al. 2010). Blue whales thus may occasionally pass through the portion of St Anns Bank AOI that extends out into the Laurentian Channel, most likely during summer months, although they may also pass through during other times of the year.

Estimates of the global blue whale population range between 5000 and 12,000 individuals; however, the accuracy of these estimates is uncertain (Beauchamp et al. 2009). The number of blue whales in the northwest Atlantic population is not known, but it is unlikely that the population consists of more than 250 sexually mature individuals (Sears and Calambokidis 2002). This population is listed as Endangered by both COSEWIC and *SARA* (COSEWIC 2002; Canada Gazette 2004).

Fin Whales (*Balaenoptera physalus)* – North Atlantic Population
Fin whales are widely distributed across continental shelves and offshore areas throughout the world, and are found throughout the northwest Atlantic in both coastal and offshore waters (Breeze et al. 2002). Similar to blue whales, fin whales of the North Atlantic are a migratory species that travel to northern feeding grounds off Atlantic Canada each summer and migrate south each winter (although some whales remain in the Laurentian Channel and other locations around Newfoundland and Labrador throughout the winter; Templeman et al. 2010). Within Canadian waters, fin whales are

usually associated with low surface temperatures and oceanic fronts, and concentrations of fin whales are often found in the Gulf of St. Lawrence, off Newfoundland, on the Scotian Shelf, and in the Bay of Fundy (COSEWIC 2005).

Breeze et al. (2002) indicate probable regular occurrence of fin whales around the St Anns Bank area, and several fin whale sightings have been reported near the AOI in the DFO Cetacean Sightings Database (Table 3.6.1-1, Figure 3.6.1-1A). This species is most likely to occur in the AOI throughout the spring, summer and fall months, though it is possible that they use the area throughout the year.

Mitchell (1974) estimated a population size of 10,800 fin whales off eastern Canada in the 1970s, while more recent estimates include 2814 whales (CV = 0.21) between Georges Bank and the Gulf of St. Lawrence in 1999 (COSEWIC 2005) and 1352 whales (95% CI: 821 – 2,226) in waters off eastern Canada in 2007 (Table 3.6.1-2; Lawson and Gosselin 2009). Fin whales are the most commonly recorded species on the Scotian Shelf in the DFO Cetacean Sightings Database (Table 3.6.1-1). This population is designated as Special Concern by both COSEWIC and *SARA* (COSEWIC 2005; Canada Gazette 2006).

Sei Whales (*Balaenoptera borealis*) – Atlantic Population
Sei whales are broadly distributed globally, mainly in offshore regions. Like most other large baleen whales, sei whales are a migratory species, moving from tropical and subtropical regions in winter to temperate and subpolar regions in summer (Reilly et al. 2008b). In the northwestern Atlantic, sei whales occur anywhere from Nova Scotia to the Davis Strait (Reilly et al. 2008b), and sighting records on the Scotian Shelf show a preference for the shelf edge and the edges of banks (Figure 3.6.1-1A; Breeze et al. 2002). Little is known about the movements of the whales in the northwest Atlantic, though they are probably more common in the region in the summer months.

Areas of known and probable distribution on the Scotian Shelf do not overlap the St Anns Bank area (Breeze et al. 2002), and no sei whales have been reported within or near the St Anns Bank AOI in the DFO Cetacean Sightings Database (Table 3.6.1-1, Figure 3.6.2-1A). However, Breeze et al. (2002) do note that sei whales likely move between the Scotian Shelf and other regions by way of the Laurentian Channel. Given their affinity for banks, it is possible that sei whales could occasionally occur in the AOI, most likely during summer months.

The global population size of sei whales is not known, and there are no recent estimates for the North Atlantic population (Reilly et al. 2008b). Sei whales were the second most commonly recorded species on the Scotian Shelf in the DFO Cetacean Sightings Database (Table 3.6.1-1), but were not commonly seen during the TNASS survey (Table 3.6.1-2; Lawson and Gosselin 2009). This population was assessed as Data Deficient by COSEWIC (2003a) and is not listed under *SARA*.

Minke Whales (*Balaenoptera acutorostrata acutorostrata*) – Canadian East Coast Population

Minke whales have a cosmopolitan distribution, occurring in all oceans at all latitudes. They are widely distributed throughout the North Atlantic, and the Canadian east coast population ranges from Baffin Bay to as far south as 40^{o}N (Reilly et al. 2008c). Breeze et al. (2002) indicate that minke whales are probably distributed across the entire Scotian Shelf from coastal waters to the shelf edge. It is known that while some whales remain in waters off Nova Scotia throughout the year, others migrate south during winter months (Breeze et al. 2002).

The probable distribution of minke whales includes the area around St Anns Bank (Breeze et al. 2002) and sightings of minke whales have been reported near the AOI (Table 3.6.1-1; Figure 3.6.1-1A). Minke whales may occur in the AOI throughout the year, though they are probably more likely to use the area in spring and summer.

While there are no global population estimates, there are an estimated 182,000 minke whales in the North Atlantic and about 4000 whales in the Canadian east coast population. This includes approximately 3000 individuals in the Gulf of St. Lawrence and 1000 individuals off the Gulf of Maine (Reilly et al. 2008c). Minke whales were the most abundant baleen whale species observed on the Scotian Shelf during the TNASS surveys, with an estimated abundance of 3242 individuals (95% CI: 2051 – 4845, Table 3.6.1-2; Lawson and Gosselin 2009). The Canadian east coast population of minke whales is listed as Not at Risk by COSEWIC (2006b), and is not listed under *SARA*.

Humpback Whales (*Megaptera novaeangliae*) – Western North Atlantic Population

Humpback whales are a cosmopolitan species found in all major ocean basins (Reilly et al. 2008d), though they are generally characterized as a coastal species (Baird 2003). Whales of the western North Atlantic population are commonly observed off eastern North America from the Gulf of Maine to southeast Labrador (Baird 2003), although their range does extend up to the Davis Strait (Reilly et al. 2008d). The western North Atlantic population arrives in Canadian waters in the spring where the whales remain to feed throughout the summer, and then migrate back to southern breeding grounds in the winter (Reilly et al. 2008d). Not all individuals migrate south during the winter; some individuals remain in waters around Newfoundland and Labrador year-round (Templeman et al. 2010), and humpback whales have been reported on the Scotian Shelf in the winter (Breeze et al. 2002). There are three feeding aggregations recognized off eastern Canada: the Gulf of Maine stock (which includes animals from the Bay of Fundy and Scotian Shelf), the Gulf of St. Lawrence stock, and the Newfoundland and Labrador stock (Baird 2003).

The areas of known and probable occurrence of humpback whales on the Scotian Shelf identified by Breeze et al. (2002) do not encompass St Anns Bank; however, numerous humpback whale sightings around the AOI have been reported in the DFO Cetacean Sightings Database. The only sighting of an identified cetacean species within the AOI boundaries in the DFO Cetacean Sightings Database is a humpback whale sighting

(Table 3.6.1-1; Figure 3.6.1-1a). Humpback whales are most likely to be found in St Anns Bank in spring, summer, and fall, but may be found in the area year-round.

There is no current global population estimate for humpback whales (Reilly et al. 2008d). An estimate of 11,570 individuals was obtained for the northwest Atlantic population in 1992/1993, but there have been no reliable estimates for the three Canadian feeding aggregations (Baird 2003). The TNASS survey estimates an abundance of 2080 individuals in Canadian waters (95% CI: 1337 – 3172, Table 3.6.1-2; Lawson and Gosselin 2009). The western North Atlantic population of humpback whales is listed as Not at Risk by COSEWIC (2003b) and as Special Concern by *SARA* (Canada Gazette 2005a).

Right Whales (*Eubalaena glacialis*) – North Atlantic Population
The range of north Atlantic right whales extends from Florida off the southeastern United States to Labrador off eastern Canada. These whales are a migratory species, traveling each year from winter breeding and calving grounds off Georgia and Florida to summer feeding grounds off the northeastern United States and eastern Canada. Within Canadian waters, right whales are most often sighted from June to December in the Bay of Fundy and off southwestern Nova Scotia, and Grand Manan and Roseway basins have been identified as critical habitat areas (Brown et al. 2009). Areas of known and probable distribution on the Scotian Shelf include the southwestern portion of the Shelf (Breeze et al. 2002), and right whales have been sighted on numerous occasions in the Gulf of St. Lawrence (Brown et al. 2009).

Although St Anns Bank was not included in the area identified as having a probable regular occurrence of right whales (Breeze et al. 2002), sightings have occurred in the Laurentian Channel and two right whale sightings were reported near the St Anns Bank AOI in the DFO Cetacean Sightings Database (Table 3.6.1-1; Figure 3.6.1-1A). Right whales likely transit to the Gulf of St. Lawrence by way of the Laurentian Channel, and therefore may occasionally occur in the portion of the AOI extending out into the Channel. Right whales are most likely to occur in the AOI during spring, summer, and fall.

Northern Atlantic right whales are one of the most endangered species in Canadian waters. Both COSEWIC and *SARA* list the north Atlantic right whale as Endangered (COSEWIC 2003c; Canada Gazette 2005a).

Long-finned Pilot Whales (*Globicephala melas*)
Long-finned pilot whales occur in temperate and subpolar regions of the North Atlantic Ocean, from the eastern United States to northern Labrador in the northwest Atlantic (Taylor et al. 2008a). They are found in waters of the Scotian Shelf throughout the year. Most pilot whale sightings occur along the shelf edge during the spring and summer, though they also occur on the Shelf. They are frequently sighted in nearshore waters off Cape Breton during the summer and appear to move further offshore during winter (Breeze et al. 2002). Pilot whales are considered year-round residents of the Laurentian Channel (Templemen et al. 2010).

The probable regular occurrence of pilot whales on the Scotian Shelf includes the whole Scotian Shelf including the St Anns Bank AOI (Breeze et al. 2002). Lawson and Gosselin (2009) report pilot whale sightings along the outer Scotian Shelf, the Laurentian Channel, and in the Cape Breton Trough off NW Cape Breton, and numerous pilot whale sightings on the Scotian Shelf and within the vicinity of St Anns Bank exist in the DFO Cetacean Sightings Database (Table 3.6.1-1; Figure 3.6.1-1b). It is likely that pilot whales regularly occur in the AOI throughout the year.

There is no information on global trends in long-finned pilot whale abundance. An estimated 31,000 pilot whales (CV = 0.27) occur in the western North Atlantic, although some of these are short-finned pilot whales (Taylor et al. 2008a). During the TNASS survey, pilot whales were the second most frequently sighted species on the Scotian Shelf, and an abundance estimate of 6134 individuals for eastern Canada was obtained (95% CI: 2774 – 10,573, Table 3.6.1-2; Lawson and Gosselin 2009). Long-finned pilot whales were assessed as Not at Risk by COSEWIC in 1994, and are not listed by *SARA*.

Killer Whales (*Orcinus orca*) – Northwest Atlantic/Eastern Arctic Population
Killer whales are the most widely distributed of all marine mammals, occurring in all oceans and at all latitudes (Taylor et al. 2008b). They are most common in coastal waters of temperate regions (Breeze et al. 2002). Their distribution in the northwestern Atlantic and eastern Arctic is not well documented, but sightings are widespread and most commonly reported in coastal waters off Newfoundland (COSEWIC 2008).

Killer whales are not considered to be a common species of the Scotian Shelf (Breeze et al. 2002), although occasional sightings have occurred on the Shelf. Two sightings have been reported near St Anns Bank (Table 3.6.1-2; Figure 3.6.1-1B), and thus it is possible that these whales may occasionally occur in the AOI.

It is estimated that there are at least 50,000 killer whales worldwide (Taylor et al. 2008b), relatively few of which occur in the western North Atlantic. There are less than 1000 killer whales in the northwest Atlantic population, and likely fewer than 250 whales (COSEWIC 2008). The population is designated as Special Concern by COSEWIC (2008) and is not listed by *SARA*.

Short-beaked Common Dolphins (*Delphinus delphis*)
Short-beaked common dolphins are widely distributed through subtropical and temperate waters of the Atlantic and Pacific oceans, occurring both nearshore and offshore (Hammond et al. 2008a). Distribution of common dolphins is closely associated with warmer water temperatures and thus varies seasonally off eastern Canada. They have been observed on the Grand Banks, the Scotian Shelf, and further offshore. Most sightings on the Scotian Shelf occur in the summer and fall when common dolphins migrate to these areas as ocean temperatures rise above 11^{o}C (Gowans and Whitehead 1995). Common dolphins appear to prefer areas of the continental slope between 100 and 200 m with steep topographical features (Selzer and Payne 1988; Whitehead et al. 1998).

The areas of probable regular occurrence of common dolphins identified by Breeze et al. (2002) encompass the entire Scotian Shelf, including the St Anns Bank area. Common dolphins were the most frequently sighted cetacean on the Scotian Shelf during the TNASS survey (Table 3.6.1-2; Lawson and Gosselin 2009), and there are a few common dolphin sightings reported within the vicinity of the AOI in the DFO Cetacean Sightings Database (Table 3.6.1-1; Figure 3.6.1-1c). Common dolphins thus probably regularly occur in the AOI, most likely in the summer, although they may occur there throughout the year.

Common dolphins are a very abundant species, although there are no current global population estimates (Hammond et al. 2008a). Common dolphins were the most abundant species sighted on the Scotian Shelf during the TNASS surveys, with estimates of 53,625 individuals in Canadian waters (95% CI: 35,179 – 81,773, Table 3.6.1-2; Lawson and Gosselin 2009). Short-beaked common dolphins were listed as Not at Risk by COSEWIC in 1991, and are not listed by *SARA*.

Atlantic White-sided Dolphins (*Lagenorhynchus acutus*)
Atlantic white-sided dolphins are found in temperate and sub-Arctic waters of the North Atlantic Ocean, from about 38^{o}N to southern Greenland in the northwest Atlantic (Hammond et al. 2008b). They occur in both shallow and deep waters of the continental shelf and slope (Reeves et al. 1999), as well as oceanic waters across the Atlantic (Hammond et al. 2008b). This species appears to associate with steep topography of continental shelves (Hammond et al. 2008b). Atlantic white-sided dolphins exhibit seasonal movements, occurring in more northern latitudes and inshore in the summer, and moving to more southern latitudes and offshore in the winter (Templeman et al. 2010). They are most commonly observed on the Eastern Scotian Shelf in summer and early fall (Reeves et al. 1999). It has been suggested, however, that they remain in some parts of the Scotian Shelf year-round, such as in the Gully canyon (Gowans and Whitehead 1995).

The entire Scotian Shelf is identified as an area of probable regular occurrence of Atlantic white-sided dolphins, including the St Anns Bank area (Breeze et al. 2002). There are numerous sightings of this species reported across the Scotian Shelf in the DFO Cetacean Sightings Database, with several in the vicinity of St Anns Bank AOI (Table 3.6.1-1; Figure 3.6.1-1c). These dolphins probably regularly occur in the AOI, most likely in the summer, although they may occur there throughout the year.

Atlantic white-sided dolphins are widespread and abundant. Little evidence exists for separate populations, and total population estimates exceed 100,000 animals (Hammond et al. 2008b). Waring et al. (2006) estimate 51,640 animals (CV = 0.38) off of eastern North America, while Lawson and Gosselin (2009) estimate 5796 individuals (95% CI: 2681 – 3088) in Canadian waters (Table 3.6.1-2). The Atlantic white-sided dolphin was assessed as Not at Risk by COSEWIC in 1991 and is not listed by *SARA*.

Harbour Porpoise (*Phocoena phocoena*) – Northwest Atlantic Population
Harbour porpoise are found throughout temperate and subpolar continental shelf waters of the Northern Hemisphere (Hammond et al. 2008c), preferring water temperatures from 5 to 16^{o}C (Breeze et al. 2002). In the North Atlantic, they are found from the southeastern United States to southern Baffin Island (Hammond et al. 2008c). The Scotian Shelf is an important part of their range in Canadian waters, with sightings generally occurring in waters less than 125 meters deep (Breeze et al. 2002). Harbour porpoise do display some seasonal movement patterns, inhabiting nearshore and coastal regions from spring–fall and moving further offshore during winter (Breeze et al. 2002).

Several harbour porpoise sightings have been reported across the Scotian Shelf in the DFO Cetacean Sightings Database, including in the vicinity of St Anns Bank (Table 3.6.1-1; Figure 3.6.1-1c). Though they are probably more likely to occur in the AOI in summer months, they may occur there year-round.

Globally, there is an estimated 700,000 harbour porpoises, which are divided into fourteen proposed populations (Hammond et al. 2008c). The Bay of Fundy–Gulf of Maine population includes porpoise of the Scotian Shelf and is estimated to contain 75,438 individuals (CV = 0.42), while there are an estimated 27,000 individuals in the Gulf of St. Lawrence (Hammond et al. 2008c). The abundance estimate for harbour porpoise in Canadian waters from the 2007 TNASS survey was 4862 (95% CI: 2204 – 8801, Table 3.6.1-2; Lawson and Gosselin 2009). Harbour porpoise are designated as Special Concern by COSEWIC (2006c) and listed as Threatened by *SARA* (Canada Gazette 2005b).

3.6.2 Seals
Six pinniped species are found in the Canadian northwest Atlantic: the harp (*Pagophilus groenlandica*), hooded (*Cystophora cristata*), grey (*Halichoerus grypus*), harbour (*Phoca vitulina*), ringed (*Pusa hispida*), and bearded (*Erignathus barbatus*) seals. Of these, the grey, harp, and harbour seals are the only species that are likely to be found in the St Anns Bank AOI.

Hooded, Ringed and Bearded Seals
The hooded seal is a migratory species with breeding sites found off the northeast coast of Newfoundland, in the Gulf of St. Lawrence, and in Davis Strait (Bowen et al. 1987). After the breeding season in March, seals from all breeding sites migrate to southeast Greenland and remain there until after the moult in July, after which they disperse to west Greenland and north to Baffin Bay. In the fall they begin their migration back toward the breeding sites, moving to the Labrador and northeast Newfoundland coasts with some animals entering the Gulf of St. Lawrence. Ringed and bearded seals are mostly found in the Arctic and sub-Arctic, inhabiting the waters around Labrador, northern Newfoundland, and the northern Gulf of. St. Lawrence (Smith and Stirling 1975; Smith and Hammill 1981; Lunn et al. 1997). The distributions of these three species suggest it unlikely that they use the AOI.

Harbour Seal

The harbour seal is a coastal species inhabiting the waters along the Newfoundland and Labrador coasts, the Gulf of St. Lawrence, and around Nova Scotia (Boulva and McLaren 1979). There is a slight sexual dimorphism with females weighing on average 85 kg compared with 108 kg for males (Bowen et al. 1994; Coltman et al. 1998). Adult females have their first young between the ages of four and six years (Boulva and McLaren 1979; Bowen et al. 2001). In eastern Canada, females give birth to a single pup between May and June and nurse the pup for 24 days (Muelbert and Bowen 1993). Currently, there is no population estimate for this species and very little is known of their movement and breeding distribution in eastern Canada. However, severe declines have been recorded on Sable Island, Nova Scotia (Lucas and Stobo 2000; Bowen et al. 2003a). Studies on the diet and movement of the harbour seal in various parts of its range suggest it is likely they use the AOI for foraging and/or travel. Sand lance (*Ammodytes dubious*) are known to be an important component of the harbour seal diet (Walker and Bowen 1993; Tollit and Thompson 1996) and given the nature of the habitat are likely to occur on St Anns Bank (DFO 1996a). Although several studies have suggested that the movement of harbour seals tends to be limited to coastal areas (Thompson et al. 1996; Thompson et al. 1998), more recent studies suggest they are capable of longer distance movements (Lesage et al. 2004).

Harp Seal

The harp seal is the most abundant pinniped of the northwest Atlantic with a pup production estimate in 2009 of 1,113,900 (Hammill and Stenson 2009). They are a migratory species, spending their summer in the Canadian Arctic, breeding during late February and March in the Gulf of St. Lawrence and northern Newfoundland, and moulting in April and May in northeastern Newfoundland and the northern Gulf of St. Lawrence (Ronald and Dougan 1982; DFO 2009g). The male and female harp seal is of a similar size, reaching on average 1.6 m in length and 130 kg in weight. Mean age of sexual maturity for females is four to six years (Sergeant 1966), and they give birth to a single pup which they nurse for about twelve days, after which they mate and then disperse (Kovacs and Lavigne 1985). The pup remains on the ice until it moults its white coat, approximately three weeks of age.

Given variation in the extent of ice cover from one year to the next in the southern Gulf of St. Lawrence (Johnston et al. 2005; DFO 2009g; Figure 3.6.2-1), it is possible that during heavy ice years harp seals may use the AOI as a breeding site or drift with the ice out of the Gulf and into the AOI. On average over the last 30 years, at least some part of the AOI is covered with sea ice on a regular basis (ranging from one year out of ten to eight or nine years out of ten (see Figure 2.1-6). Harp seals are harvested commercially in Atlantic Canada for oil, meat and fur, as well as for subsistence purposes in Arctic Canada and Greenland (DFO 2008c; Hammill and Stenson 2010). Sealing Area 27 encompasses the AOI (DFO 2011f). Thus if harp seals of an appropriate age were in this area they would be accessible to the annual harp seal hunt, which operates from late March to mid-April (DFO 2011f). Hunting for harp seals has occurred close to or in the AOI in some recent years, including 2008 (A. Newbould, DFO Resource Management, personal communication, October 2011). Recently observed change in climatic conditions has led to a reduction in ice cover in the Gulf of St. Lawrence such that it has become a concern for the future viability of the harp seal population in the Gulf of St. Lawrence (Johnston et al. 2005; DFO 2011f). If these trends continue, harp seal breeding in the AOI would occur much less frequently, if at all.

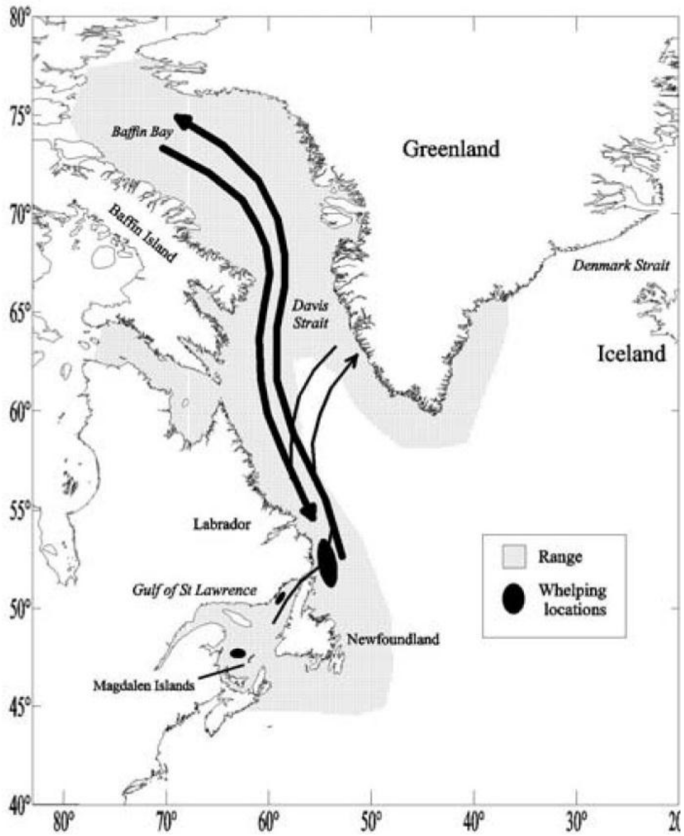


Figure 3.6.2-1. Migration routes, range and breeding locations of harp seals in eastern Canada (from DFO 2009g).

Grey Seal

Given the known distribution, movement patterns and habitat preferences of grey seals, of the six pinniped species in eastern Canadian waters, the grey seal is the most likely species to utilize the AOI for both foraging and travelling.

Geographic Ranges and Habitat Preferences

The grey seal is an abundant pinniped in Canadian Atlantic waters, and is found from the Gulf of St. Lawrence, Newfoundland, and south to Georges Bank. Breeding populations occur in the southern Gulf, on pack ice and coastal islands, Sable Island, and on small coastal islands along the Eastern Shore, with the largest population being found on Hay Island (Figure 3.6.2-2).

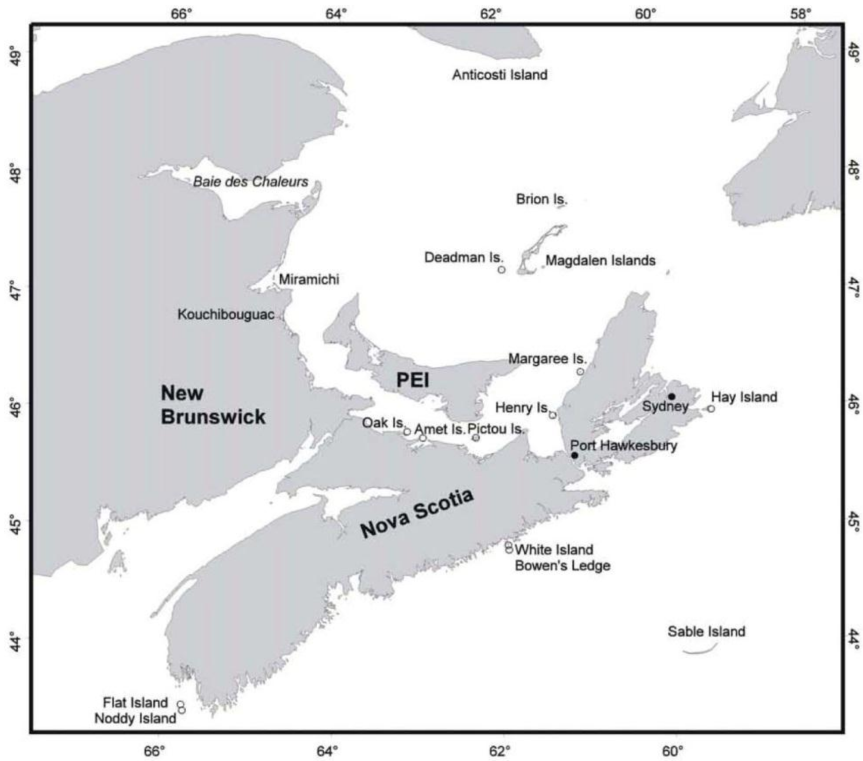


Figure 3.6.2-2. Distribution of grey seal breeding sites in the Canadian northwest Atlantic (from Hammill et al. 2007b).

Populations or Stock Definitions
Although grey seals in the northwest Atlantic are considered to be from a single stock (Boskovic et al. 1996), for the purposes of management, the breeding population is divided into three components: Gulf of St. Lawrence, Sable Island, and the Eastern Shore (Thomas et al. 2007). The 2010 estimate of pup production for the western Atlantic grey seal population was 84,200 (S.E. 3000), with a total population size of 402,700 (S.E. 7,700) (Hammill and Stenson 2011).

<u>Grey Seals in St Anns Bank</u>

Gulf of St. Lawrence Population
The movements of grey seals tagged in the Gulf of St. Lawrence (n = 49) suggest it is likely that they use the AOI. In general, grey seals show a strong preference for habitats with depths less than 50 m, and the majority of dives are to depths of less than 40 m (Harvey et al. 2008). Home ranges of grey seals are focused in the Gulf are ten times larger in the winter compared with the summer (Harvey et al. 2008), and likely include the AOI. During the winter, seals spend more time in habitats deeper than 50 m, which is likely due to their prey inhabiting deeper waters.

Sable Island Population
Similar to the Gulf of St. Lawrence, beyond the breeding season, grey seals exhibit a wider distribution that varies by age, sex, and season and likely includes the AOI

(Figures 3.6.2-3 a & b). Satellite telemetry data from Sable Island suggest that favoured foraging areas are heterogeneously distributed across the Eastern Scotian Shelf and occur over shallow banks, with large, deeper, unfavourable areas in between (Breed et al. 2009). During the winter, foraging locations are more scattered and tend to be deeper whilst during the summer individuals show a tendency to stay close to haul-out sites, have shorter foraging trips, and spend more of their time ashore. Compared with females, males show a tendency to travel further, have fewer foraging locations, and appear more likely to use the AOI (Figure 3.6.2-3B).

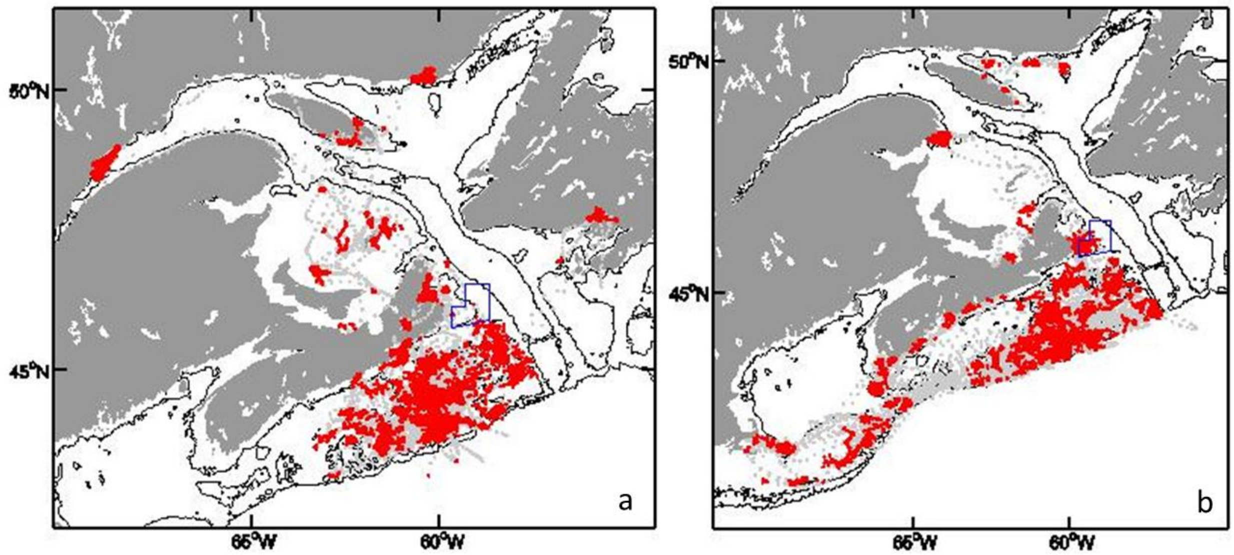


Figure 3.6.2-3. Annual distribution of (a) female (n = 43) and (b) male (n = 41) grey seals tagged with satellite transmitters on Sable Island. Red dots are inferred foraging locations while open dots are inferred travel. Blue polygon indicates approximate location of AOI (Source: Greg Breed, personal communication).

Eastern Shore Population

Colonies along the Eastern Shore represent the smallest of the stocks, with the majority of seals breeding on Hay Island (Hammill et al. 2007c). To date, nothing is known of the foraging distribution or movements of grey seals that use the Eastern Shore. However, the proximity of Hay Island to St Anns Bank and the habitat preference of grey seals for shallow banks for foraging suggest that it is likely that seals from Hay Island use St Anns Bank.

In summary, a review by DFO (2010d) indicated that Gulf pups and juveniles inhabit 4Vn during the first two quarters of the year, more so than their Sable counterparts (Table 3.6.2-1).

Table 3.6.2-1. Proportion of time being spent in different NAFO Divisions by seals from Sable Island and the southern Gulf of St Lawrence, by season (quarter), and population component.

		Pups & Juveniles				Males				Females			
		Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4
Sable	4T	0.056	0.048	0.082	0.059	0.024	0.000	0.048	0.014	0.031	0.067	0.131	0.061
	4VN	0.020	0.008	0.020	0.017	0.007	0.002	0.061	0.020	0.046	0.038	0.032	0.004
	4VSW	0.846	0.873	0.833	0.852	0.642	0.851	0.792	0.869	0.894	0.833	0.688	0.888
Gulf	4T	0.112	0.490	0.733	0.655	0.369	0.530	0.851	0.801	0.514	0.444	0.700	0.736
	4VN	0.262	0.134	0.000	0.061	0.185	0.104	0.005	0.107	0.060	0.000	0.000	0.051
	4VSW	0.499	0.237	0.000	0.096	0.237	0.217	0.023	0.067	0.403	0.429	0.000	0.046

Biology

Productivity

The grey seal is a moderately sexually dimorphic pinniped with males approximately 1.5 times heavier than females (Mohn and Bowen 1996). In December and through to February, adults congregate at traditional breeding grounds to give birth to a single young and mate. They are a capital breeder and thus accumulate energy stores prior to the breeding season and fast or greatly reduce their food intake during this time (Beck et al. 2003; Lidgard et al. 2005).

In the Gulf of St. Lawrence, the mean age of females at first birth is 5.5 years while the mean age of males at sexual maturity is 5.6 years (Hammill and Gosselin 1995). On Sable Island, approximately 60% of females have their first young between the ages of four and seven years and may continue to breed until their late 30s to early 40s (Bowen et al. 2006; Bowen et al. 2007a). Males may not reach physical maturity until age ten years and may continue to breed into their early to mid-30s (Godsell 1991). After the breeding season both sexes alternate foraging trips with periods of haul-out until the annual moult in May and June (Beck et al. 2003). After this time, individuals continue the cycle of alternate foraging trips and periods of haul-out until the start of the next breeding season.

Ecosystem Interactions

The grey seal is a top marine predator and primarily piscivorous throughout its range (Benoit and Bowen 1990a, b; Bowen et al. 1993; Hammill 2010). The majority of the grey seal diet is comprised of high-energy species such as capelin (*Mallotus villosus*), sand lance (*Ammodytes sp.*), herring (*Clupeus harengus*), mackerel (*Scomber scombrus*), gadoids (e.g., cod, *Gadus morhua*), and flatfish (e.g., winter flounder). The size of prey falls between 15 and 30 cm in length.

Fisheries and Other Human Activities

Although the harp seal is the main commercial species for the Canadian seal fishery, grey seals are also harvested with a TAC set for the Gulf of St. Lawrence and the Scotian Shelf (DFO 2011f). Total numbers of grey seals taken in a year varies, but has never been greater than 5000; no grey seals were taken in 2010 (DFO 2011f). The timing of the harvest is set out by Variation Orders pursuant to the Marine Mammal Regulations and based upon consultations with participants of the harvest and scientific advice (DFO 2011f). One of the main areas for the commercial grey seal hunt on the Scotian Shelf is Hay Island, which lies adjacent to the AOI.

Personal use licences for harvesting grey seals are not available (DFO 2011f). However, subject to the National Nuisance Seal Licence Policy and Procedures, full-time fishers may be awarded a nuisance seal licence to kill grey seals if they can demonstrate that their fishing operations are being detrimentally impacted by grey seal predation (DFO 2011f).

Status and Trends

Gulf of St. Lawrence

Estimates of pup production are quite variable due to culling and scientific collection (Stobo and Zwanenburg 1990; Hammill et al. 1998), and mortality associated with breeding on an unstable substrate (Hammill et al. 2007c; Thomas et al. 2007). In 1984 pup production was at a low (5436, Standard Error [S.E.] = 672) but increased to 10,700 (S.E. = 1300) by 1996, and in more recent years has varied between 5300 (S.E. = 900; in 2000) and 14,200 (S.E. = 1200; in 2004) (Hammill et al. 2007c). Pup production in 2010 was 11,228 (S.E. = 6442) (Hammill and Stenson 2011). The population of grey seals in the Gulf of St. Lawrence is believed to be increasing.

Sable Island

From the 1960s to the early 2000s, pup production of grey seals on Sable Island increased exponentially at a rate of approximately 13% (Bowen et al. 2003b). Since the early 2000s it has shown signs of reduced growth (i.e., levelling off). The 2010 pup production estimate was 65,200 (S.E. = 2800; Hammill and Stenson 2011).

Eastern Shore

In 2010 the total pup production for the Eastern Shore was 4200 (S.E. = 300; Hammill and Stenson 2011). These populations are believed to be increasing in abundance and distribution overall.

Sources of Information

Pup production in the Gulf of St. Lawrence has been measured over a relatively short time frame. During the 1980s and 1990s, pup production was estimated every four years using mark and recapture methods (Hammill et al. 1998), whereas it is now estimated using aerial photography (Hammill and Gosselin 2005). Pup production on Sable Island has been monitored since the 1960s by tagging all pups (Stobo and Zwanenburg 1990) and more recently using aerial photography (Bowen et al. 2007b). Pup production in this area is monitored intermittently using direct counts or year-class tagging (Hammill et al. 2007c). Pup production on the Eastern Shore (especially Hay Island) is currently monitored annually using aerial photography.

As described above, movement of grey seals in the region is currently being studied using satellite tagging (Harvey et al. 2008; Breed et al. 2009).

3.7 SEA TURTLES

3.7.1 Leatherback Turtle

The leatherback turtle (*Dermochelys coriacea*) is the largest marine turtle, attaining a curved carapace length of up to 172 cm and weighing up to 640 kg (James et al. 2007). Leatherbacks can dive up to 1280 m (Doyle et al. 2008) and may remain submerged for as long as 86.5 minutes (Lopez-Mendilaharsu et al. 2009). The morphology of the leatherback diverges from that of other sea turtles too—the entire body (including the shell) is covered in skin and the carapace is spade-shaped, terminating in a blunt point. The leatherback is also the most widely distributed reptile in the world (COSEWIC, 2001).

Geographic Range and Habitat Preferences

Natal origins of leatherbacks found in Canadian waters include tropical and subtropical beaches of the western Atlantic (James et al. 2007). Peak nesting in these areas occurs between April and June, with mature male and females turtles aggregating adjacent to nesting beaches to breed before and during this period (James et al. 2005a). After the nesting season, large sub-adult and adult leatherbacks migrate to temperate waters at high latitudes to forage on gelatinous zooplankton (James et al. 2005b). In the northwest Atlantic, leatherbacks are distributed throughout shelf and slope waters of the northeastern United States and eastern Canada (Shoop and Kenney 1992). Relatively high densities of leatherbacks occur in waters off Atlantic Canada indicating that this area provides important seasonal foraging habitat (James et al. 2006a). While the distribution of leatherbacks is thought to reflect the distribution of their jellyfish prey, the oceanographic context for leatherback foraging is not well understood. Various data sources (satellite, telemetry, fisheries observers) suggest that leatherbacks are normally present in Canadian waters from May through to November, with some turtles remaining in warmer offshore waters until December (James et al. 2005b, 2006a). The proportion of the Atlantic leatherback population that uses Canadian waters is not known. Leatherbacks are capable of tolerating a wide range of water temperatures (James and Mrosovsky 2004) and routinely venture into cold, nearshore waters when foraging at high latitudes (James et al. 2006b).

Populations or Stock Definitions

The leatherback turtle has the widest geographic range of any reptile and is found throughout the Atlantic, Pacific, and Indian oceans. Only one species, *Dermochelys coriacea*, is recognized.

Leatherback Turtles in St Anns Bank

Patterns of leatherback distribution in Canadian waters show both annual and seasonal variability, but several key foraging areas appear to be used each year. James et al. (2005c) used satellite tagging to identify several high use areas for leatherbacks. Their results showed high use of an area off the east coast of Cape Breton (including both Sydney Bight and St Anns Bank), as well as the southern Gulf of St. Lawrence and the Northeast Channel.

St Anns Bank (as well as the other high use areas identified by James et al. 2005c) appears to be an important foraging area for leatherback turtles, perhaps due to association with higher-than-average prey densities (Kareiva and Odell 1987). Leatherbacks would be expected in the area from July through October (James et al. 2006a).

Biology

Productivity
Skeletochronological analysis of scleral ossicless suggest that median age at maturation for leatherbacks in the western North Atlantic ranges from 24.5 to 29 years (Avens et al. 2009). The life expectancy of leatherback turtles is not known. However, Hughes (1996) reports a nesting history for one turtle spanning 18 years.

Females nest in the tropics on beaches with open access, lay 50–166 eggs (Ernst et al. 1994), and then return to sea. In the Atlantic, they lay an average of six clutches per season (Van Buskirk and Crowder 1994), and normally nest every 2–3 years, although annual nesting has been occasionally observed on some beaches (Stewart et al. 2011). The incubation time of the eggs is 60–65 days (Ernst et al. 1994). There is high predation during incubation and emergence (COSEWIC 2001).

Natural Mortality
Natural mortality is very high for eggs and hatchlings. Leatherback hatchlings and small juveniles have many predators, including crabs, dogs, vultures, skunks, lizards, seabirds, large fish, and sharks, but adults have few—only sharks and killer whales (Caldwell and Caldwell 1969; Pitman and Dutton 2004).

Ecosystem Interactions
Leatherbacks feed mostly on jellyfish and other soft pelagic invertebrates (Lazell 1980; Lutcavage and Lutz 1986; Grant et al. 1996). These prey are relatively energy poor (Doyle et al. 2007), however, research in leatherback foraging areas off Atlantic Canada has revealed that such prey are consumed in large numbers (Heaslip et al. 2012). Reliance on this diet requires effective location of dense patches of prey.

Fisheries and Other Human Activities

Fisheries
Leatherback turtles are caught as bycatch in a variety of fishing gears. At high latitudes of the northwest Atlantic, the leading cause of fisheries-related injury and mortality involves interaction with vertical horizontal lines associated with fixed fishing gear (James et al. 2005c). Leatherbacks appear to be vulnerable to entanglement in pelagic longlines, lines for pots and gillnets, buoy anchor lines, and other ropes and cables. Entanglement in lines associated with fixed fishing gear is a leading cause of injury and/or mortality for leatherbacks in Canadian waters (James et al. 2005c).

Other Vulnerabilities to Human Activities
Leatherback turtles may also be vulnerable to other human activities. There are a number of human threats to the species in nesting areas, including poaching of adult females, coastal construction, artificial light, and climate change. Human activities that may affect leatherbacks in Canadian waters include collisions, marine pollution, and acoustic disturbances (NMFS 1992; Mrosovsky et al. 2009; O'Hara and Wilcox 1990; Moein et al. 1994).

- Collisions – Leatherbacks may be vulnerable to collisions with ships. Collisions are known to have occurred in U.S. waters, but it is unclear whether or not those collisions result in mortality (NMFS 1992).
- Marine pollution – Leatherbacks are known to ingest marine debris, which is concentrated in convergence zones where leatherback turtles feed (Shoop and Kenney 1992; Lutcavage et al. 1997). A recent study of necropsy findings from across the globe revealed presence of plastics in the gastrointestinal tracts of 33% of leatherbacks that were examined (Mrosovsky et al. 2009).
- Acoustic disturbances – There is some concern that acoustic disturbances may displace leatherbacks from foraging areas (O'Hara and Wilcox 1990; Moein et al. 1994). Leatherbacks detect low frequency sounds, and studies have shown that exposure to such sounds may cause displacement and increased surfacing (O'Hara and Wilcox 1990). There are several anthropogenic noise sources in Atlantic Canada including oil and gas exploration and production, shipping, fishing, and military detonation.

<u>Status and Trends</u>

Stock Status
Population estimates of leatherback turtles are normally based on surveys of females on nesting beaches. Pritchard (1982) estimated the global population of leatherbacks at 115,000 nesting females in 1980, while Spotila et al. (1996) estimated the population at 34,000 nesting females in 1995, including 18,000 nesting females in the western Atlantic.

More recently, an expert working group comprised of leatherback biologists and population modelers considered data from key leatherback nesting areas and derived a population estimate of 34,000–94,000 adult leatherbacks in the North Atlantic (TEWG 2007). A corresponding estimate of the number or origin of leatherbacks in specific foraging zones of the North Atlantic has not been proposed.

Species at Risk Considerations
Both *SARA* and COSEWIC list the leatherback turtle as Endangered, due to severe global decline and vulnerability to even small increases in rates or mortality. The leatherback turtle is also listed as Endangered by the World Conservation Union (IUCN), the U.S. *Endangered Species Act*, and is globally protected under the Convention on International Trade in Endangered Species (CITES).

Sources of Information

The Canadian Sea Turtle Network[11] (CSTN) maintains a sightings database that includes records of free-swimming, entangled, and stranded turtles in Atlantic Canada, as well as detailed information on all turtles live-captured and released during CSTN field research studies off Nova Scotia (1999–present). Other regional sea turtle sightings databases are maintained by regional DFO Science staff in Newfoundland and Quebec.

Sources of Uncertainty

Habitat requirements and preferences are poorly understood. In addition, it is not known what proportion of the population spends time in Canadian waters and in the St Anns Bank area itself.

3.7.2 Loggerhead Turtle

The loggerhead sea turtle (*Caretta caretta*) is found throughout the Atlantic, Pacific, and Indian oceans. Within Canadian waters, they are most often sighted on the Scotian Shelf and Slope, Georges Bank, and the Grand Banks off Newfoundland (McAlpine et al. 2007). Research suggests that while loggerheads in temperate northwest Atlantic waters may occupy waters between 13.3 and 28 °C (Coles and Musick 2000), they generally prefer water temperatures greater than 22 °C (Hawkes et al. 2007). Inshore water temperatures in Atlantic Canada are generally cooler than this, and therefore provide only occasional habitat for the species. However, offshore waters more proximate to the influence of the Gulf Stream appear to be used regularly by the species, as evidenced by incidental capture data associated with pelagic longline fisheries (Brazner and McMillan 2008). Given the current, limited understanding of loggerhead distribution in Canadian waters, it seems unlikely that this species is regularly present in the St Anns Bank area. Therefore, they will not be considered for this assessment.

3.8 SEABIRDS

Summary

Seabird species observed during surveys and occurring in high densities within and in the vicinity of the St Anns Bank AOI include storm-petrels, great black-backed and herring gulls, northern fulmars, great shearwaters, sooty shearwaters, and northern gannets. For most of these species, concentrations are believed to be of migrating individuals, though gulls and storm-petrels present may include nesting birds foraging in the area. Scatarie Island, just outside the AOI, is a Nova Scotia Provincial Wilderness Area for the protection of natural landscapes, native biodiversity, and outstanding natural features. Species nesting on and near Scatarie Island include coastally-associated common eider, double-crested and great cormorants, black guillemot, common and Arctic terns, as well as the typically more pelagic leach's storm-petrel and black-legged kittiwake.

[11] www.seaturtle.ca

Introduction

Offshore waters of the northwest Atlantic host seabirds belonging predominantly to three bird Orders: Procellariiformes (e.g., fulmars, shearwaters, storm-petrels), Charadriiformes (e.g., alcids, gulls, terns, phalaropes), and Pelecaniformes (e.g., gannets and cormorants). Coastal areas of the northwest Atlantic host marine bird species not generally considered seabirds. These include Gaviiformes (e.g., loons), Podicipediformes (e.g., grebes), Anseriformes (e.g., waterfowl), and Ciconiiformes (e.g., herons). Although species from many other bird orders, including landbirds, are known to pass over large ocean expanses during the course of normal spring and fall migratory movements, their relative contribution to marine ecosystems is assumed to be negligible.

Distribution and abundance data assessed include all observations within but not limited to AOI boundaries (Figure 3.8-1) (Note: Figures 3.8-1–3.8.8 are located below at "Sources of Uncertainity"). Mention is made of colony sites where such colonies might contribute significantly to distribution and abundance patterns.

Geographic Range and Habitat Preferences

Seabird populations are composed of mature breeders as well as non-breeding adults, sub-adults, and juveniles. Spatial distribution and timing of migratory movements have been shown to vary dramatically as a function of breeding status in several species (Bogdanova et al. 2011). Once they have reached breeding age, seabirds are reliant on availability of four fundamental marine habitat components to meet essential life history requirements:

1. Colonies/breeding sites: Seabirds mostly rely on predator/disturbance-free islands, and/or cliffs and escarpments, on which to breed. From the seabird perspective, these sites effectively constitute terrestrial extensions of the marine ecosystems to which they belong.
2. Seaward extensions of breeding colonies: During breeding, adults are effectively 'tethered' to their breeding sites, thus are active within a restricted foraging range. At this time, they must balance trade-offs between self-maintenance requirements, needs of their mates (where applicable), and needs of developing young.
3. Migration corridors: During the course of large-scale migratory movements, seabirds often are constrained to pass through narrow passages, skirting prominent headlands and landscape features that otherwise limit transit or access to prey resources.
4. Staging and wintering areas: No longer constrained by the requirements of breeding, seabirds can move more freely over broad areas in response to prey distribution, generally congregating at sites characterized by predictably high prey abundance, and availability.

Seabirds in St Anns Bank

Phalaropes

Red Phalarope (*Phalaropus fulicaria*)
Red-necked Phalarope (*Phalaropus lobatus*)

Arctic-nesting phalaropes occur only as migrants within the St Anns Bank AOI limits and area. Ship-based surveys reveal that low densities (< 75th percentile) occur in the western half of the AOI area. Moderate to high densities (75th to 95th percentiles) of phalaropes have been detected within 60 km of the AOI, to the southwest. If not an important staging area, the western portion of the AOI likely constitutes an important migratory corridor for individuals entering and exiting the Gulf of St. Lawrence during migratory movements.

Storm-petrels

Leach's Storm-petrel (*Oceanodroma leucorhoa*)
Wilson's Storm-petrel (*Oceanites oceanicus*)

The nearest known large (> 10,000 individuals) Leach's Storm-petrel colony on the Scotian Shelf is located at Country Island (NS), approximately 200 km away. This species also nests on closer St. Paul Island, but surveys of breeding storm-petrels have not been undertaken at that site. However, ship-based surveys reveal that only low densities (< 75th percentile) occur in the western half of the AOI. Higher densities (75th to 95th percentile) have been observed just along the southeast edge of the AOI, more so to the northwest of the site, and throughout the outer Cabot Strait (Figure 3.8-2). A significant proportion of storm-petrels observed during surveys in the area are Wilson's Storm-petrels, a southern hemispheric breeding species present in our waters during the austral winter.

Large Gulls

Great Black-backed Gull (*Larus marinus*)
Herring Gull (*Larus argentatus*)
Glaucous Gull (*Larus hyperboreus*)
Iceland Gull (*Larus glaucoides*)

Several large Great Black-backed and Herring Gull colonies are situated within 100 km of the AOI, and if totalled, may nearly reach 10,000 individuals. The largest are located on Hay Island (NS), adjacent to Scatarie Island, and the Bird Islands (NS). Other large colonies are located along the southeast coast of Cape Breton Island. Though ship-based surveys reveal low densities (< 75th percentile) in the western half of the AOI, higher densities (75th to 95th percentile) have been observed just outside the AOI to the southeast, southwest, and northwest (Figure 3.8-3).

Black-legged Kittiwake (*Rissa trydactyla*)

Black-legged Kittiwakes have a relatively restricted foraging range (≤ 30 km). A few small breeding colonies of Black-legged Kittiwakes (totalling ≤ 300 individuals) are located within 30 km of the AOI. Though birds originating at much larger colonies located in the Gulf of St. Lawrence may pass through the Cabot Strait during spring and fall migration periods, evidence suggests higher concentrations pass through the northern portion of the Cabot Strait. Densities do not exceed the 75th percentile within the AOI. Evidence of occurrence of higher densities exists immediately southeast of the AOI. Kittiwakes are known to forage on copepods (e.g., *Calanus* spp.), which are found in high abundance in this area of the Cabot Strait in the fall (Gjerdrum et al. 2008).

Skuas and Jaegers

Parasitic Jaeger (*Stercorarius parasiticus*)
Pomarine Jaeger (*Stercorarius pomarinus*)
Long-tailed Jaeger (*Stercorarius longicaudus*)
Great Skua (*Stercorarius skua*)
Southpolar Skua (*Stercorarius maccormicki*)

Though distribution and abundance of these species appears limited within the Gulf of St. Lawrence, patterns suggest that the western portion of the AOI may constitute part of a migratory corridor for Arctic-nesting jaegers as they pass through the Cabot Strait. Skuas do not breed in North America. High concentrations of jaegers and rarer skuas have been detected immediately south and southeast of the AOI boundary.

Northern Fulmar (*Fulmarus glacialis*)

Nesting by this northern circumpolar species does not occur in the vicinity of the AOI. However, evidence of high densities exists along the southern margin of the outer Laurentian Channel, intersecting the AOI from the northwest to the southeast (Figure 3.8-4), suggesting that the area is valuable as a migratory corridor, but also as a foraging area for a more limited number of wintering individuals. Congregations also have been detected to the northwest, also along the southern edge of the Channel. None of these sites are situated within the foraging range of colonies of this species during the breeding season.

Great Shearwater (*Puffinus gravis*)

The western portion of the AOI incorporates an area that likely constitutes a migratory corridor for individuals entering and exiting the Gulf or foraging along the northern and southern margins of the outer Laurentian Channel (Figure 3.8-5). Important densities have also been observed to the northwest and immediately south of the AOI. The species only breeds on isolated islands in the South Atlantic.

Sooty Shearwater (*Puffinus griseus*)

The eastern portion of the AOI incorporates areas constituting a migratory corridor for individuals entering and exiting the Gulf or foraging along the northern and southern margins of the outer Laurentian Channel (Figure 3.8-6). Important densities also have been observed to the northwest and immediately south of the AOI. The species breeds only at colonies in the Southern Hemisphere.

Northern Gannet (*Morus bassanus*)
Although none of the six North American colonies of this species are located within 200 km of the AOI, its western portion most likely constitutes a migratory corridor for individuals entering and exiting the Gulf, including those associated with the three Gulf of St. Lawrence colonies (~75% of the North American population). Important densities observed northwest and southwest of the AOI support this assumption (Figure 3.8-7).

Dovekie (*Alle alle*)
Evidence suggests that this species does not occur in high concentrations within the AOI, though higher densities have been detected to the east and southeast. Densities lower than the 75th percentile have occurred along the southern margin of the AOI. This species, which nests in only very small numbers in North America, and abundantly elsewhere in the Arctic, is commonly observed in waters over northwest Atlantic continental shelves during winter.

Large Alcids

Thick-billed Murre (*Uria lomvia*)
Common Murre (*Uria aalge*)
Razorbill (*Alca torda*)
Atlantic Puffin (*Fratercula arctica*)

No large colonies are located in the AOI area, which lies outside the foraging range of individuals breeding at the nearest known colonies hosting these species. Still, densities approaching the 75th percentile have been detected in the eastern portion of the AOI. Higher densities have been detected immediately south and southeast of the AOI limits, toward Misaine Bank. The immediate AOI area likely is used by individuals, including those associated with large Gulf of St. Lawrence colonies, entering and exiting the Gulf along the coastal margins of the Newfoundland and Scotian Shelf.

Murres

Thick-billed Murre (*Uria lomvia*)
Common Murre (*Uria aalge*)

No large colonies are located in this area and the area lies outside the foraging range of individuals breeding at the nearest known colonies. Still, densities reaching the 75th percentile have been detected in the eastern portion of the AOI. Higher densities have been detected immediately south and southeast of the AOI limits, toward Misaine Bank. The immediate AOI area likely is used by individuals passing in and out of the Gulf of St. Lawrence along the coastal margins of the Newfoundland and Scotian Shelf.

Sea Ducks
High numbers of sea ducks (mostly Common Eiders) have been observed foraging near Scatarie Island in winter, to the east of the AOI (Figure 3.8-8). This area is also known to host nesting Common Eiders during the breeding season.

Biology

Ecosystem Interactions

Seabirds are considered top predators although their own eggs and young can be vulnerable to mammalian and avian predators. Seabird diet is extremely variable across species and includes phytoplankton, small zooplankton, small crustaceans (e.g., mysid shrimp, euphausiids, copepods), molluscs (e.g., bivalves, squid), and small fish (e.g., capelin, herring, Arctic cod, mackerel, sand lance, larval fish), as well as carrion.

Fisheries and Other Human Activities

Fisheries

At sea, bycatch resulting from interaction between seabirds and fishing gear has been identified as a significant threat to populations of several seabird species globally, particularly diving species and pursuit divers (Tasker et al. 2000). More pronounced interactions and subsequent bycatch can be expected at biological hot spots created by temporal and spatial aggregations of forage fish, especially when these are commercially valuable species (DFO 2007c). Of the fishing gear types presently used in Atlantic Canada, pelagic longlines are the most likely to catch seabirds, followed by bottom gillnets and bottom longlines (Fuller et al. 2008b). Gillnets have been known to catch large numbers of seabirds when placed near seabird colonies (Benjamins et al. 2008) and within migration corridors and wintering areas.

Other Vulnerabilities

Seabirds are long-lived and have low annual reproductive output. As such, they are most sensitive to factors that affect adult survival. Direct anthropogenic threats to seabirds include hunting, illegal shooting, oil spills, mortality via drowning in fishing gear (Benjamins et al. 2008), marine industrial activities and structures (Fraser et al. 2006; Montevecchi 2006; Wiese et al. 2001), ingestion of plastics and floating man-made debris (Provencher et al. 2010), and direct exposure to heavy metals and contaminants from agricultural and atmospheric sources (Michelutti et al. 2010). Indirect threats to seabirds include habitat destruction and degradation (e.g., coastal development, industrial fishing, and physical resource extraction), displacement by competitors at colony sites, contamination of prey resources, and climate change (e.g., sea level rise, increased storm frequency, changing distribution and abundance of prey, incorrect timing of life history activities, temporal mismatch with prey, and increased disease prevalence) (Crick 2004). These threats can be expected to be more pronounced at coastal sites used for breeding, colony islands, and within seaward extensions of seabird colonies where populations are concentrated and reliant on abundant locally available prey.

Status and Trends

Three seabird species known to occur predictably in the northwest Atlantic have been designated as Species at Risk by COSEWIC (COSEWIC 2011). Contrasts in conservation status of these and other species with the IUCN program (BirdLife International 2011) are presented in Table 3.8-1. Of the six species listed in the table, one is extinct, but historically is likely to have frequented the St Anns Bank AOI although to an unknown degree. Occurrence of two more species (Ivory Gull, Roseate Tern) has not been documented in the area, but is possible. Rare Bermuda and Black-capped Petrels are largely undocumented in Canadian waters, perhaps due to small population sizes and inadequate targeted survey effort. Though largely hypothetical, occurrence remains plausible. The Sooty Shearwater has not been assessed by COSEWIC, but concerns are mounting internationally due to declines in breeding populations of this historically abundant species. High densities have been found in the AOI and to the northwest and south of the AOI (Figure 3.8-6).

Species belonging to other bird orders that are known to use sites in the vicinity of the AOI also are listed by COSEWIC. However, they are not treated here as data on their use of this particular site is lacking. Enhanced monitoring (i.e., greater survey frequency, targeted surveys, use of geospatial tracking instruments, etc.) could provide additional evidence on the relative value of these and other sites to species listed in Table 3.8-1, and other species.

Table 3.8-1. All seabirds occurring in the Northwest Atlantic designated as extinct or in some danger of disappearance (Procellariiformes, Charadriiformes, and Pelecaniformes only).

Common Name	**Scientific Name**	**Committee on the Status of Endangered Wildlife in Canada (COSEWIC)**	**International Union for Conservation of Nature (IUCN)**
Great Auk	*Pinguinus impennis*	Extinct (QC, NB, NS, NL)	Extinct
Ivory Gull	*Pagophila eburnea*	Endangered (NT, NU, NL)	Near Threatened
Roseate Tern	*Sterna dougallii*	Endangered (QC, NB, NS)	Least Concern
Bermuda Petrel	*Pterodroma cahow*	Not listed	Endangered
Black-capped Petrel	*Pterodroma hasitata*	Not listed	Endangered
Sooty Shearwater	*Puffinus griseus*	Not listed	Near Threatened

<u>Sources of Information</u>

Since 1966, Environment Canada’s Canadian Wildlife Service has undertaken monitoring via seabird surveys using ships of opportunity (Table 3.8-2). These surveys were undertaken initially (1966 to 1992) as the Programme intégré de recherches sur les oiseaux pélagiques (PIROP). More recently, the Environment Canada Seabirds at Sea (ECSAS) program (2005 to present; ongoing) has refined survey protocols and incorporated technical advancements to data collection methods and subsequent analysis techniques. Data span eastern Canadian waters, including portions of Nunavut and the northeastern United States.

Table 3.8-2. Large monitoring datasets used to assess habitat qualities of key areas identified, origins and descriptions, as well as contact information of dataset manager.

Dataset Category	Dataset 'Name'	Description	Temporal Coverage Assessed	Geographic Coverage
Pelagic data	*'Eastern Canada Seabirds at Sea' ('ECSAS')*	Ship-of-opportunity surveys; seabird focused	2005 – present Annual; ongoing; year-round	Opportunistic; Atlantic Canada, Gulf of St. Lawrence
Pelagic data	*'Programme intégré des recherches sur les oiseaux pélagiques' ('PIROP')*	Ship-of-opportunity surveys; seabird focused	1966 – 1992 Annual; ended; year-round	Opportunistic; Atlantic Canada, Gulf of St. Lawrence
Colony data	*'Atlantic Region Waterbird Colony Database' ('ARWCD')*	Colony surveys; migratory birds	1960 (1534) – present Annual; ongoing; spring and summer	Systematic; Atlantic Canada
Colony data	*'Banque informatisée des oiseaux de mer au Québec' ('BIOMQ')*	Colony surveys; migratory birds	1960 (1833) – present Annual; ongoing; spring and summer	Systematic; Gulf of St. Lawrence

The Canadian Wildlife Service also has conducted waterbird colony surveys (1960 to present; ongoing) throughout eastern Canada's Atlantic coast. In Atlantic Canada, data are held within the Atlantic Canada Waterbird Colony Database. In Quebec, data are held within the Base informatisée des oiseaux migrateurs du Québec. All data on seabird colonies are held by Environment Canada, Canadian Wildlife Service, and also include information on France's St. Pierre et Miquelon seabird colonies.

Sources of Uncertainty

Before examining the maps presented in this section (Figures 3.8-1–3.8-8), it is critical to understand the objectives of the mapping exercise through which these were derived. These maps strive to illustrate, using all available data, the demonstrated relative capacity of a given location to host large numbers of individuals of a given species. The result is a summary of all available data (years and seasons confounded) using a 5 km X 5 km square grid. No attempts were made to calculate areal densities of birds (i.e., birds per square kilometre) from the raw data. Instead, linear densities were used that made it possible to combine historical with modern survey data. As emphasis also was placed on location of spatial data gaps, data was not interpolated to create an uninterrupted density surface. A kernel density estimation was performed with adaptive bandwidth to calculate relative abundance values for each square in which at least one observation of the species of interest had occurred, incorporating information from ten neighbouring surveys nearest to the square's centroid point. Squares in which surveys had been conducted, but no observations of the species of interest made, received a relative abundance value of zero.

Hence, these maps make no attempt to illustrate present-day patterns of abundance and distribution, or account for their seasonal fluctuation. It is hoped that this approach will introduce a measure of buffering to account for potential large-scale shifts and oscillation in species distribution over time. To display resulting patterns, the results were scaled into the following quantiles (excluding records of zero individuals observed), 0<x<75%, 75≤x<80%, 80≤x<85%, 85≤x<90%, 90≤x<95%, 95≤x≤100% (top 5% of values). In the maps, the colour white indicates that surveys occurred in a square, but no birds were observed (0), while deep red indicates squares with calculated densities in the top 5% of all values for a given species (or species grouping), etc.

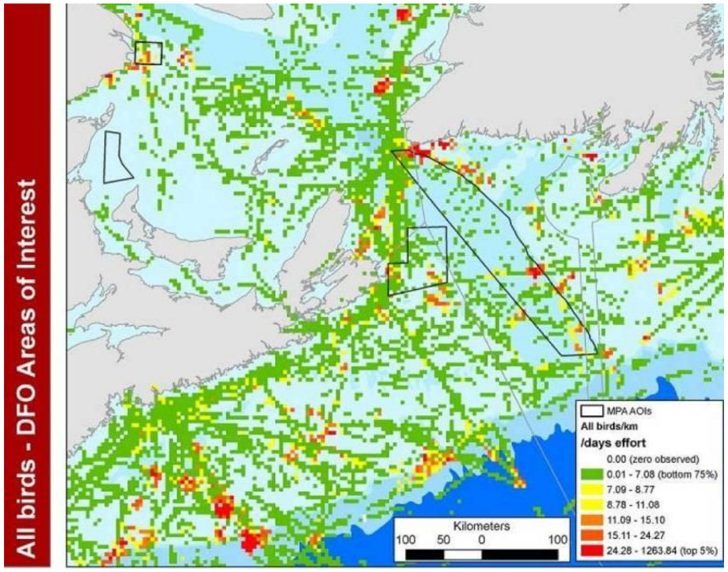


Figure 3.8-1. Density of all birds on the ESS and GSL based on surveys. The St Anns AOI is shown just east of Cape Breton. Other polygons overlaid are other AOIs.

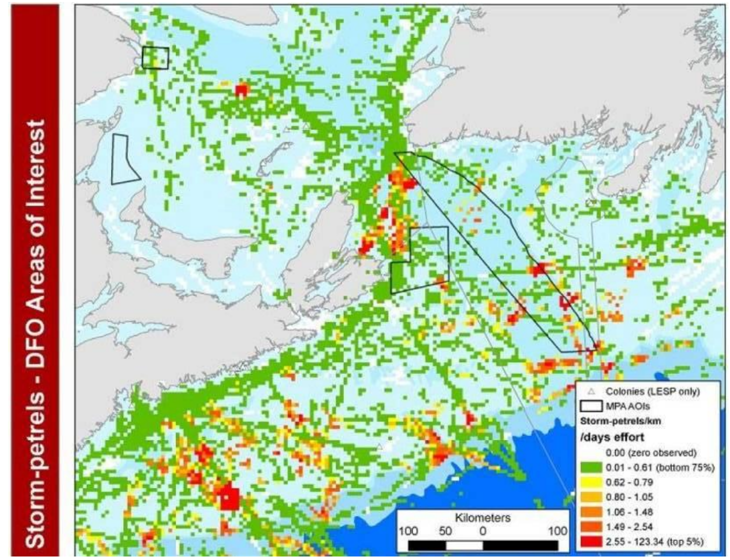


Figure 3.8-2. Density of storm-petrels on the ESS and GSL.

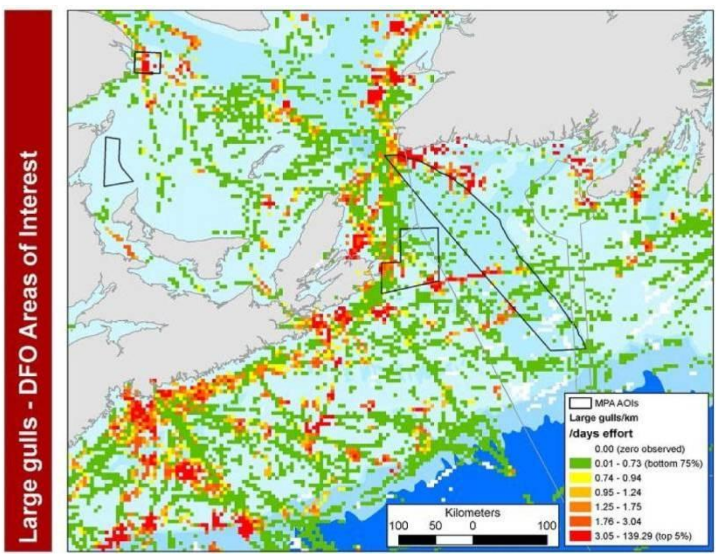


Figure 3.8-3. Density of large gulls on the ESS and GSL.

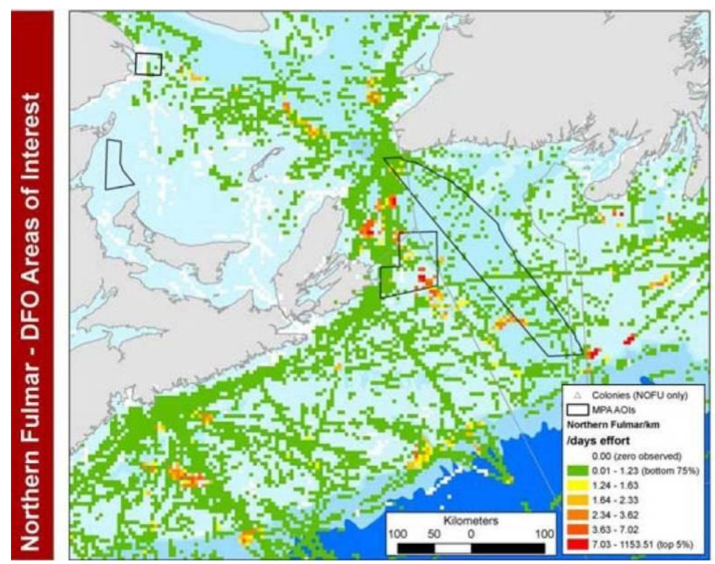


Figure 3.8-4. Density of Northern Fulmars on the ESS and GSL.

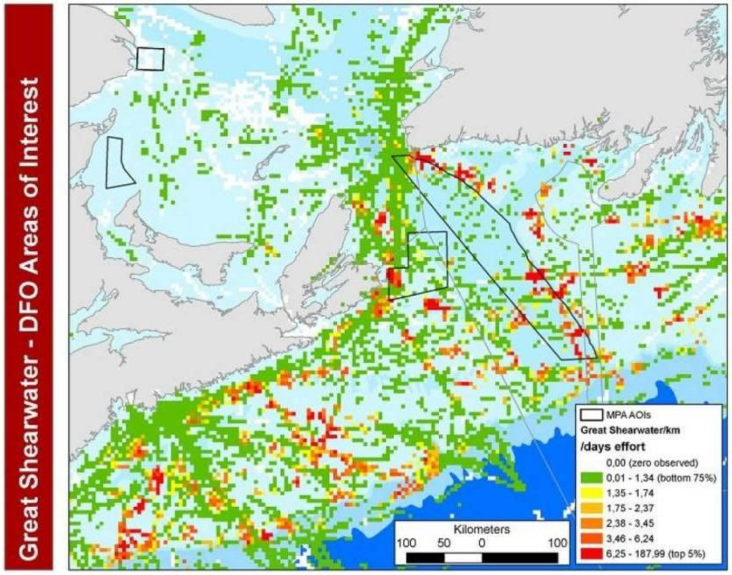


Figure 3.8-5. Density of Greater Shearwaters on the ESS and GSL.

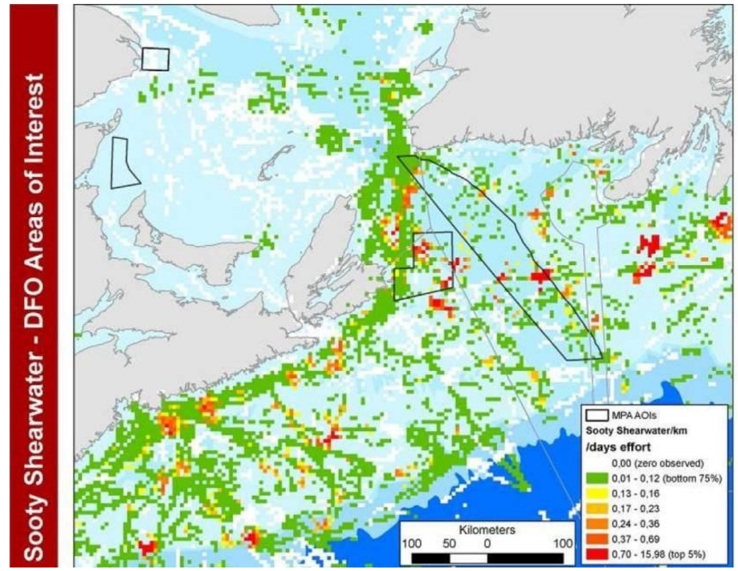


Figure 3.8-6. Density of Sooty Shearwaters on the ESS and GSL.

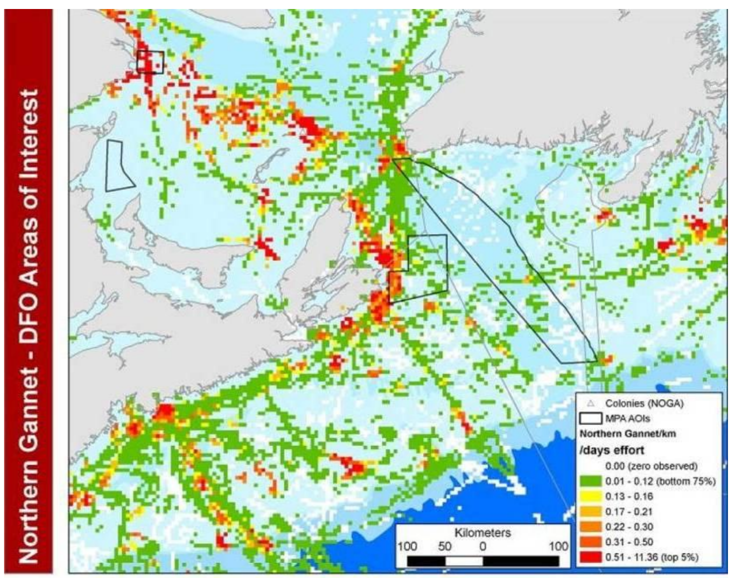


Figure 3.8-7. Density of Northern Gannets on the ESS and GSL.

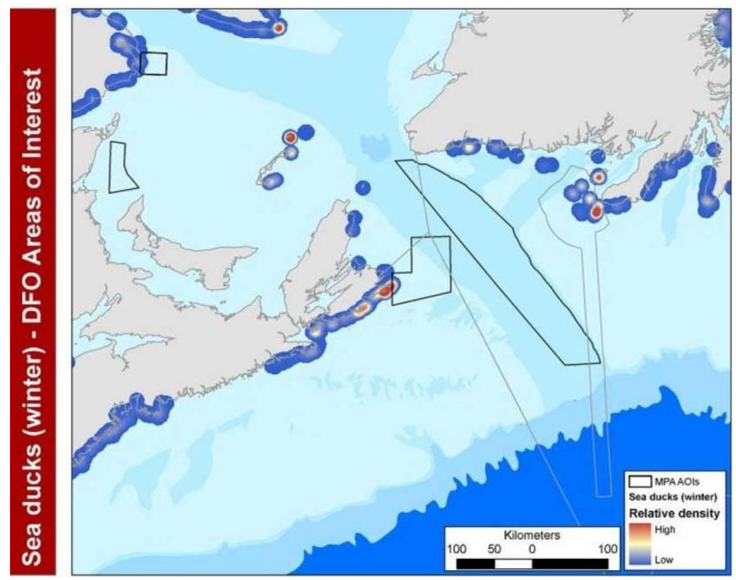


Figure 3.8-8. Density of sea ducks on the ESS and GSL.

4. TROPHIC LEVELS AND ECOSYSTEMS

The trophic levels and ecosystem of the St Anns Bank area, and more generally, the Eastern Scotian Shelf, are described in this section. St Anns Bank is part of a migration route for a number of species, described below in section 4.1. Long-term ecosystem changes are described in section 4.2. Data gaps and sources of uncertainty are noted in section 4.3, and finally, key ecosystem components of St Anns Bank are listed in section 4.4.

4.1 MIGRATION IN ST ANNS BANK

4.1.1 Overview

During November of every year, a wide array of fish species undertakes a migration out of the Gulf of St. Lawrence to overwinter in the Cabot Strait area at the mouth of the Gulf, to return again in April. Given the proximity of the Cabot Strait area to St Anns Bank, there is a possibility that species may also migrate into the St Anns bank area to overwinter. The extent of this migration varies by species, some (e.g., redfish) migrate quite far while others stay closer to the entrance of the Gulf. For some species (e.g., cod), the migration occurs on both sides of the Cabot Strait with those on the north-eastern side originating predominantly from the northern Gulf and those on the south-western side of the Strait from the southern Gulf, with little apparent mixing between the two (Chouinard 2001).

It is unclear what cues (mating, food, density-dependent population process, avoidance of predators, etc.) trigger the migration, though they may vary by species. The seasonal physical oceanographic changes in the Gulf, including the very low temperatures in winter, are well documented (Galbraith et al. 2010) and are likely involved. Notwithstanding this, many species undertake these overwintering migrations, which represent a sizeable annual contribution of nutrients and biomass to 4Vn and 3P. It is useful to consider the potential size of this migration by species and in aggregate. Stock assessments and related reports were used to provide estimates of recent biomass and where these were not available, length and species q-corrected biomass estimates from the fall 2005–2009 4T bottom trawl survey (Benoît and Swain 2008) were used. Assumptions were made on the percentage of the population that may migrate. There are reports for some species (e.g., redfish) that a significant proportion of the stock undertakes the winter migration. This is interpreted as being greater than 50%. However, for the analyses below, the more conservative estimate of at most 50% of the populations overwintering was generally used. As well, as the migrations are being considered in relation to the St Anns Bank AOI, only the southern Gulf migrations were considered. As noted above, equivalent northern Gulf migrations also occur but are not considered here.

4.1.2 Groundfish

Several groundfish species are known to participate in the annual overwintering migration. The main species for which there is some evidence of this (cod, redfish, white hake, plaice, witch flounder, turbot, skates, and spiny dogfish) are considered here.

These are a subset of all the possible species that could be migrating and thus represent a conservative estimate.

Cod from 4TVn migrate out of the Gulf in November and return in April (Campana et al. 1995; 1999; Comeau et al. 2002b). Details of this migration are provided in the species overview. DFO (2009e) assessed 2009 total biomass as being 27,598 t. If 50% of this biomass migrates, about 14,000 t of cod biomass could be overwintering outside the Gulf.

The Unit 1 redfish migrations are well documented and are also discussed at length in the species overview (Campana et al. 2007a; Gascon 2003; Morin et al. 1994). Based on the most recent assessment (DFO 2010e), of the 146,000 t of the 2009 total biomass of *S. fasciatus*, 18% (26,452 t) is from Unit 1; of the 115,400 t of the 2009 *S. mentella* total biomass, 27% (31,158 t) is from Unit 1. Thus, the total redfish in Unit 1 is 57,670 t, which, assuming 50% migrates, implies 28,835 t overwinters outside 4T.

Meristic and genetic markers discriminate white hake in the Northumberland Strait from those in Laurentian Channel (Hurlbut and Clay 1998; Roy et al. 2011). It is felt that those in the Channel are the ones most likely to migrate. Estimates of assessed biomass are currently not available. If it is assumed that 50% of the population in the Gulf resides in the Laurentian Channel, this portion of the 2005–2009 average fall 4T survey biomass (3244 t) could be migrating out of the Gulf each fall.

Busby et al. (2007) discuss the annual overwintering migration of plaice, noting that the Gulf population migrates along the Laurentian Channel into Division 4V on the Scotian Shelf during the winter, where it mixes with the eastern portion of the Scotian Shelf population. As with white hake, no assessed biomass estimates are available, although current biomass is estimated to be low. The average 2005–2009 4T fall survey estimate of 150,931 t thus appears to be high. Assuming 25% of this overwinters outside the Gulf, 37,733 t could be engaged in the migration through the western Cabot Strait.

The current fisheries management unit of witch flounder is 4RST. Genetic work on this species is limited, although a proposal to change the stock structure into two units, 1) 4T west, 4R, and 4S, and 2) 4T east and 4VW, was reviewed by O'Boyle (2001). There was no consensus on the origin of witch flounder in the Cape Breton Trough, which were considered a mixture of 4T east, 4Vn resident, and 4VW fish. Therefore, the proposal did not proceed; unfortunately, further work on stock structure has been limited (Doug Swain, DFO Science, personal communication, March 2011). Tagging studies (Stobo and Fowler 2006) confirm that 4VW witch flounder migrate into 4Vn and 4T and presumably the reverse also occurs. The 4T fall survey observed an estimated annual average 3407 t of witch in 4T during 2005–2009. Assuming 50% of this biomass overwinters outside of the Gulf implies that 1703 t are involved in the migration.

Turbot and yellowtail flounder are potential migrators which together represent 31,936 t of the 2005–2009 4T fall survey biomass. If 50% overwinters outside of the Gulf, then 15,968 t overwinters outside the Gulf.

Skates (smooth, thorny and winter), of which the fall 4T survey estimated 1475 t, could undergo the overwintering migration. Assuming 50% of this migrates, 737 t overwinters outside of the Gulf.

4.1.3 Pelagics

Herring used to undertake an annual migration out of the Gulf in the fall to overwinter on the south coast of Newfoundland (Winters and Beckett 1978), however this has not been observed in recent years. While juvenile herring in the southern Gulf frequently overwinter in shallow coastal areas of the Gulf, adult herring were not found in the southern Gulf in December or January in a survey undertaken in 1986/1987 (LeBlanc et al. 2001). Based on this observation, and surveys of the Cabot Strait in January of 1996 and 1997, herring are believed to mainly overwinter in the deep areas of the Cabot Strait, particularly the northern Cabot Strait around St. Paul's Island, with a smaller number moving down into the St Anns Bank area (LeBlanc et al. 2001). LeBlanc et al. (2010) assessed the 2009 spring spawner and fall spawner biomass at 27,227 t and 307,393 t respectively. If 50% of this overwinters outside the Gulf, 167,310 t could be involved in the seasonal migration, though the percentage may be much higher.

Regarding mackerel, the northwest Atlantic stock is composed of a northern contingent and a southern contingent (Deroba et al. 2010). The two contingents overwinter primarily along the continental shelf between the mid-Atlantic and Nova Scotia, although it has been suggested that overwintering occurs as far north as Newfoundland. With the advent of warming shelf water in the spring, the two contingents begin migration, with the northern contingent moving along the coast of Newfoundland and historically into the Gulf of St. Lawrence for spawning from the end of May to mid-August. The southern contingent spawns in the mid-Atlantic and Gulf of Maine from mid-April to June, then moves north to the Gulf of Maine and Nova Scotia. In late fall, migration turns south and fish return to the overwintering grounds. If one assumes that half the stock is composed of the northern contingent and that 50% of this migrates in and out of the Gulf, then 96,968 t of the 2008 assessed biomass (Deroba et al. 2010) could be migrating through the western Cabot Strait.

While capelin are currently managed as 4RST (DFO 2008d), four stocks were estimated by O'Boyle and Lett (1977) to reside in 4T, one of which resides in eastern 4T. During 2005–2009, an annual average of 381,822 t total biomass was observed in the fall Gulf survey. If only the fish close to the Cabot Strait are involved in the overwintering migration (assumed to be 25% of the total) and of this if 50% migrates, then 47,728 t total biomass would be involved.

The northwest Atlantic population of bluefina tuna was assessed (ICCAT 2010a) at 10,942 t total biomass in 2009. Various fishing groups in the Gulf are given 54% of the overall Canadian TAC for bluefin tuna, 250 t in 2009 (DFO 2009h). In recent years, fishers in the Gulf of St. Lawrence have caught their quota for bluefin tuna quite easily, indicating that a larger biomass than 250 t is migrating into the Gulf annually.

The North Atlantic population of swordfish was assessed (ICCAT 2010b) at 64,840 t total biomass in 2009, of which a small fraction (assumed 1% or 648 t) would likely migrate to and from the Gulf.

The status of the northwest Atlantic porbeagle resource was assessed by Gibson and Campana (2005), which estimated vulnerable biomass in the order of 4,500 t in 2005. Only a very small fraction of this would be expected to migrate to and from the Gulf, and thus this estimate is not included here.

Other pelagic species are not considered here, but many anadromous species, including Atlantic salmon and eels, also migrate through the Cabot Strait from the Gulf of St. Lawrence.

4.1.4 Commercially Harvested Invertebrates

There is little information on the movement of invertebrates such as lobster, snow crab, and shrimp in the vicinity of the Cabot Strait. Some movement is to be expected, but given the paucity of data, estimates of biomass migrating are not included here.

4.1.5 Marine Mammals

The annual migrations of the Gulf and Sable grey seal herds were considered at a DFO meeting on the interaction between cod and seals (DFO 2010d). Both herds use the 4Vn area during the first two quarters of each year, although the Gulf herd does this to a much greater extent than the Sable herd (see Section 3.5.4, Atlantic cod overview). Based upon this distributional information, 3700 t of grey seal migrants from both herds are estimated to seasonally move to and from the Gulf.

Several whale species also inhabit the Gulf and move between it and the Scotian Shelf. Dufour and Ouellet (2007) note that the "Cabot Strait, off Cape Breton, is also an important migratory corridor for marine mammals moving in and out of the Gulf of St. Lawrence." The large cetaceans found in the Gulf of St. Lawrence, including finback whales, minke whales, blue whales, humpback whales, northern right whales, and long-finned pilot whales, are all believed to migrate to the Atlantic or into the Laurentian Channel on a seasonal basis (see Section 3.6.1 above for details).

4.1.6 Summary

Conditional on the assumptions on the proportion of populations undertaking an overwintering migration, an estimated 479,137 t of fish biomass could potentially be migrating from the Gulf in the fall and back into the Gulf in the spring of each year. The total biomass estimates by species, while uncertain, are based upon a combination of recent stock assessments and q-corrected biomass from the Gulf fall survey; these estimates are considered reasonably accurate. The migration rates, on the other hand, are educated guesses and open to interpretation. They could be high. However, many species were not included in the analysis, which would bias the estimates down. On balance, the analysis suggests that almost half a million tons of fish biomass are involved in the seasonal overwintering migration, with perhaps a similar amount engaged in the migrations on the northern side of the Cabot Strait. However, this estimate does not include the cetaceans (right, blue, fin whales, etc.) that likely migrate through the area and would represent a substantial biomass. Therefore this is very likely an underestimate of the total migrating biomass.

4.2 LONG-TERM CHANGES

Decadal scale changes of the Scotian Shelf ecosystem are described throughout this report. This section will address the degree to which the processes responsible for the observed changes are understood. There are multiple interpretations of the relative importance of diverse ecological and oceanographic processes on the changes that have been observed in this area during the past four decades; some of the interpretations are mutually exclusive. It is likely that the trends described here are evident in the St Anns Bank area.

The Scotian Shelf ecosystem is situated in a region of considerable oceanographic and biogeographic complexity. Longhurst (1998) states that this geographic area, along with that off Japan, is characterized by the largest spatial gradients in oceanographic properties in the global oceans. Mahon et al. (1998) conclude that the Eastern Scotian Shelf is a transition area between temperate and sub-Arctic fish communities. This spatial complexity in the oceanographic setting and the biogeographic transition would be expected to complicate interpretation of the observed temporal changes in ecosystem structure. Part of the observed changes may be due to spatial shifts in the distribution and relative abundance of species due to climate variability, and other parts of the observed shifts may be due to internal changes in the functioning of the ecosystem itself. Teasing apart the relative importance of the two categories of processes is a difficult challenge.

Halliday and Pinhorn (2009) provide an overview of the relative importance of fishing and environmental change on groundfish populations for the northwest Atlantic. This broader context is a useful starting point. They conclude that increases in natural mortality of cod began in the late 1980s, contiguous with the collapses of the several cod stocks off Atlantic Canada, and that this phenomenon was widespread. They also suggest that environmental conditions, at the scale of the northwest Atlantic, influenced the productivity of demersal fish species on decadal time scales. Their analysis concludes that a combination of overfishing and climate variability has been responsible for the observed fluctuations in demersal fish populations. They do not, however, specify the ecological processes involved in the changes in productivity.

On a smaller scale, Zwanenberg et al. (2002) provide a comprehensive summary of the decadal changes in the diverse fisheries, as well as the ecological and oceanographic properties, of the Scotian Self from the 1960s to about 2000. They focus on the marked differences in trends observed in the eastern and western portions of the Shelf. The synthesis concludes that the rudimentary understanding of the connections between trophic levels constrains interpretation of the causes of observed trends and fluctuations. In essence they argue that the relative importance of the ecological processes is not well understood. That said, the role of overfishing is highlighted as a major driver of change.

Fisher et al. (2008) provide an elegant summary of the temporal shifts in the distribution of fish species off Atlantic Canada, with an emphasis on species diversity in relation to the North Atlantic Oscillation (NAO). Although the expected bottom temperature response to the anomalies is estimated to be minimal at the latitudes of the Scotian Shelf, there has been about a 5 to 10% difference in diversity during the three decades in response to NAO fluctuations. The southern Gulf of St. Lawrence analysis by Benoît and Swain (2008) indicate that there has been relatively rapid response in the spatial distribution of fish species to changes in bottom temperature with, for example, the abundance of cooler-water species peaking following the period of coldest water temperatures. It would appear that there has not been as significant a change in species composition due to climate variability on the Scotian Shelf as compared to that observed in the southern Gulf.

Bundy (2004, 2005) and Bundy and Fanning (2005) use a trophic dynamic modelling approach (Ecopath) to tease out the relative importance of processes that have prevented the lack of recovery of cod on the Eastern Scotian Shelf. They conclude that fishing down the food chain (i.e., systematic removal of larger fish) has resulted, through trophic cascade dynamics, in an increase of abundance of species at the middle trophic levels. These species, through enhanced predation on cod, are interpreted to have generated a higher level of natural mortality for small cod, as well as a reduction in condition (due to competition). However, the estimated high level of mortality of larger cod since the early 1990s is not easily interpreted in this modelling approach. In a broader sense it is interpreted that the ecosystem has changed fundamentally from a demersal-feeder-dominated system to a pelagic-feeder-dominate system. The authors conclude that the changes in ecological processes are consistent with the cultivation-depensation hypothesis of Walters and Kitchell (2001), and that cod are somewhat trapped in this alternate state of low productivity.

Bundy et al. (2009) use a similar modelling approach to compare four geographic areas off Atlantic Canada, including the Eastern Scotian Shelf. The conclusions are similar to the earlier studies, but a variant of the cultivation-depensation hypothesis is suggested. As well as interpreting that the forage species out-compete small cod for small zooplankton, they suggest that these competitors also prey on larval cod (thus generating lower levels of recruitment success). These aggregate Ecopath studies conclude that grey seals have not had a major influence on the changing dynamics of Scotian Shelf cod stocks.

Many researchers have a rich set of papers that address the processes responsible for the dramatic change in properties of the Scotian Shelf ecosystem (Choi et al. 2004; Choi et al. 2005; Frank et al. 2005; Frank et al. 2006; Frank et al. 2007; Shackell et al. 2010).

Choi et al. (2004) invoke a somewhat similar transition in the structural features of the Eastern Scotian Shelf fish community as the Ecopath studies summarized above, but use an empirical rather than a modelling approach. They describe community-level reductions in the body size, biomass, and physiological condition in demersal fish species and conclude that there has been a reduction in the energy flow through the benthic system. Also it is interpreted that there has been a decoupling of the benthic and pelagic systems. They interpret the decoupling as being due to a complex set of factors that were triggered by the cumulative removal of biomass of demersal species and exacerbated by decadal scale variability in bottom temperature and water column stratification. Due to this “hysteresis ... in the Scotian Shelf ecosystem” (Choi et al., 2004), they also conclude that predictions on future states of the ecological community are not really possible.

The methodology for undertaking an integrated assessment of marine ecosystems is discussed in detail in Choi et al. (2005). Frank et al. (2005) use the integrated assessment approach to interpret that the trophic level changes on the Eastern Scotian Shelf are due to the cascading impacts of the removal of large fish (in particular the larger cod). In essence the release of predation on mid-trophic level fish caused by overfishing is interpreted to have led to increases in the relative abundance of small pelagic species (such as herring) and of benthic invertebrates (such as snow crab). This in turn is interpreted to have caused decreases in zooplankton abundance and lower predation on phytoplankton (resulting in higher biomass at the base of the food chain). This interest has been in part due to the relative lack of evidence for top-down trophic cascades in the oceans (with most of the previous interpretations of this phenomena coming from studies of lakes). Also, as there is considerable global interest in the collapse and lack of recovery of cod off Atlantic Canada, this clear and comprehensive interpretation resonated with the broader scientific community. Shackell et al. (2010) interpret the somewhat different features of the Western Scotian Shelf temporal dynamics as also showing evidence of trophic cascades in response to the reduction in abundance of larger fish. In this case, the biomass of the top predators has not declined during the past several decades, but their average size has. They infer that the change in the size composition of the predators has led to an increase in the biomass of prey, with subsequent knock-on effects at lower trophic levels. It is also suggested that temporal changes in stratification have contributed to the structural shifts.

It is to be noted that Frank et al. (2005) do not interpret the continued high natural mortality of cod subsequent to the fisheries moratorium, and they do not consider marine mammal population increases to be important in the trophic cascade. McQuinn (2009) has questioned the evidence for the trophic cascade interpretation of Frank et al. (2005). He concludes that the trawl survey time series showing a pelagic outburst on the Scotian Shelf during the 1990s is an artefact of changes in the depth distribution of herring that made them more available to the groundfish trawl survey.

Frank et al. (2011) have updated the integrated assessment of the Eastern Scotian Shelf to include recent observations. The aggregate data suggest that the overall state of the ecosystem may be returning to that observed during the 1980s (e.g., less pelagic fish, somewhat higher abundance levels of groundfish). There is great interest in following the new data each year, but several years are probably needed prior to drawing conclusions on the degree to which a transition back to a demersal-feeder dominated system is underway.

Frank et al. (2007), taking a meta-analysis approach to the North Atlantic observations on trophic level fluctuations, concluded that top-down impacts due to overfishing are more prevalent in ecosystems with lower species diversity and at lower temperatures. This generalization of the Scotian Shelf analysis to other shelf seas areas has also generated considerable interest.

Choi (unpublished) subsequently came to a somewhat different conclusion on the causes of the lack of recovery of cod despite the moratorium on fishing for this species. He addresses a combination of parameters at the demersal fish community level (high natural mortality, poor condition, declines in size at maturity, and size structure for the aggregate species), and concludes that a parsimonious explanation of the observations is "intense inter-specific competition of small size classes and a consequent runaway Darwinian selection for individuals able to grow, mature and reproduce rapidly – classical r-selection." (Choi, unpublished). He also argues that this change in fish community structure has led to changes in the efficiency of the energy cycle causing enhanced oxygen depletion at depth (an additional change in the Scotian Shelf ecosystem that has been difficult to interpret).

Although there are differences in the details of the diverse interpretations of the dramatic decadal scale changes in the ecosystem properties summarized above, there is considerable agreement on several aspects. Overfishing on demersal species is interpreted as generating a fundamental change in the functioning of the ecosystem. Top-down effects, due to removal of the larger fish in the ecosystem by fishing, are interpreted to have generated a transition to an alternate state favouring small fish and with less energy reaching the benthos. Fisher et al. (2010), through an elegant global analysis, conclude that "fish body size may act as a factor of considerable importance in mediating the relationship between marine fish species richness and ecosystem functioning." They also state that "ecosystems characterized by low diversity fish assemblages that also contain higher proportions of large-bodied species are likely to be more vulnerable to the destabilizing effects of size-selective harvesting" (Fisher et al. 2010). These conclusions are consistent with the Scotian Shelf observations.

For the southern Gulf of St. Lawrence ecosystem there is a relatively broad consensus that a combination of overfishing and grey seal predation (in combination with climate variability) has led to the observed dramatic changes in ecosystem structure that have been described during the past several decades (Chouinard et al. 2005; Bundy et al. 2009; Benoît and Swain 2008). Furthermore, there is evidence that there have been some evolutionary consequences on the fish populations that are difficult to reverse on the time scales of fisheries management.

For the Scotian Shelf, there is less of a consensus on the relative importance of the processes that have caused the dramatic changes in ecological properties of this shelf area. Most studies conclude that top-down effects (essentially the removal of the larger demersal fish due to fishing) have changed the functioning of the ecosystem. Also it is generally concluded that reversal to the previous state, even with low fishing effort, is not ensured. Prediction of future conditions is difficult. Most of the ecosystem level studies do not account for the exceedingly high natural mortality of larger cod since the late 1980s. Also the role of grey seals remains controversial. Some studies conclude that seals have had an insignificant role in the lack of recovery of cod since the moratorium in 1993 (Mohn and Bowen 1996; Fu et al. 2001; Trzinski et al. 2009b). Other studies conclude that the exponential growth of this species during the past four decades has been one of or the major process inhibiting the lack of recovery of cod (Trzinski et al. 2006), as well as the cause of the temporal patterns in natural mortality (O'Boyle and Sinclair 2011). However, other potential contributing factors include changes in habitat due to fishing or other activities, changes to when fishing can occur, etc. It is perhaps appropriate to state that, in spite of the extensive monitoring of the Scotian Shelf and considerable research efforts, there is still uncertainty on the relative importance of the ecological processes that have generated the decadal scale changes.

4.3 DATA GAPS AND SOURCES OF UNCERTAINTY

A number of interesting ecosystem components that require more work for their significance to be understood have been identified in the preceding sections (Table 4.3-1).

More generally, there are several data gaps that make it more difficult to understand the ecosystem of St Anns Bank. To date, there has been little directed sampling for plankton in the AOI. As a result, our understanding of these communities comes largely from adjacent parts of the Laurentian Channel and the Scotian Shelf. Benthic sampling has also been limited mainly to the research surveys, especially in the northern half of the AOI. These surveys do not sample the full range of habitats in the site (neither the very deep nor very shallow), and they do not sample smaller benthic invertebrates, or identify all invertebrates to species. Winter sampling is another general gap. While there were some trawl surveys done in the winter in the mid-1990s, they were limited to a few years and directed towards understanding the winter distribution of a fairly limited number of commercial species.

The population structure of several of the most abundant groundfish species in the AOI—white hake, American plaice, and witch flounder—is debated (DFO 2005b, Fowler and Stobo 2000, O'Boyle 2001), despite these being species with long histories of commercial exploitation. In some respects, however, these debates are actually a result of having more information about these species than other less common species, whose population structure is largely unstudied.

A paucity of cetacean sightings effort, particularly systematic effort, was noted in Section 3.6.1. Given the observation that most cetaceans in the Gulf of St. Lawrence are expected to migrate from the Scotian Shelf or Newfoundland Shelf, the lack of cetacean sightings in the area seems likely to result from lack of effort rather than lack of use by migrating whales.

Table 4.3-1. Ecosystem components requiring more research

	Report section	**Ecosystem component**	**Interesting because**	**Identified by**
3.1.2	Zooplankton	Potential high concentration of krill in channel	Important forage resource	AZMP; Sameoto and Cochrane 1996
3.3	Benthic Habitats and Communities	Bank/shelf/slope communities	Fuller characterization of benthic habitats and communities would be helpful	Photo surveys by CCGS *Hudson* (2009) and CCGS *Matthew* (2010)
3.4.2	Corals and Sponges	Area of high sponge concentrations	Some sponges are highly vulnerable to disturbance, recovery is species dependent and also dependent on levels of natural disturbance, life history and depth, so would be good to have a better idea of species in the area	Kenchington et al., 2010
3.3.4	Whelk	High whelk concentrations	Only commercially viable density of whelks identified in this area to date	Test fishing near Scatarie Island
3.4.7	Smooth skate	Area of high catches of skate purses in snow crab survey	Area of high catches of skate purses – among the highest seen in region	Snow crab survey
3.5.1	Cetaceans	Pilot whales; cetaceans in general	Pilot whales may be resident to Cabot Strait; other cetaceans likely in the area but not recorded due to lack of effort	Templemen et al. 2010

4.4 KEY ECOSYSTEM COMPONENTS

Throughout the previous sections, a large number of components and attributes of the St Anns Bank ecosystem have been identified. In this section, some of the important ecosystem components identified in previous sections are summarized. These ecosystem components generally meet the definition of important ecosystem components from DFO (2005e):

> Ecosystem components (properties and relationships) are considered important if, when perturbed, they are likely to cause many higher-order follow-on consequences. Ecosystem components may also be considered important if they are perturbed readily, and when perturbed are slow to recover after the pressure causing the perturbation is removed.

Components are considered to cause many higher-order follow-on consequences when perturbed if they are trophically important, including both influential predators and important forage species (Horsman and Shackell 2009). Trophically important species and functional groups on the Eastern Scotian Shelf and in the southern Gulf of St. Lawrence have been identified (Bundy 2005; Bundy et al. 2009), and include both species that shape the ecosystem through their high biomass and/or abundance (very common species) and keystone species, which have an impact on the ecosystem that is disproportionate to their abundance (Bundy 2005). Components are considered to be “perturbed readily, and when perturbed, slow to recover”, if they are fragile and therefore highly vulnerable to disturbance (such as sponges and sea pens), or if they are considered to be depleted species (i.e., COSEWIC or *SARA*-listed).

Unique or regionally unique features of St Anns Bank are also identified. In a few cases, ecosystem components are considered to be important because of their relevance to MPA network planning goals, for example, including representation of different habitats and communities, and areas of high biodiversity.

Table 4.4-1 does not indicate conservation priorities or conservation objectives for a future MPA in St Anns Bank. The list of priority components for which conservation objectives will be written will likely be a subset of the components identified here.

Table 4.4-1. Important ecosystem components identified.

	Report Section	Important ecosystem component	Rationale for identification as an important component	Role of AOI for this component
3.2	Plankton	**Deep-water aggregation of *Calanus* sp.**	Important forage species	Part of LC overwintering area
3.3.2	Benthic communities of St Anns Bank	**Bank communities**	Diversity of habitat and species represented	
		Shelf communities		
		Slope communities		
3.4.1	Invertebrates - Diversity	**Invertebrate diversity hotspot**	Area of high biodiversity	
3.4.2	Corals and sponges	**Area of high sponge concentrations**	Highly vulnerable to disturbance	Area of regionally high concentration
		Area of high seapens concentrations	Highly vulnerable to disturbance	Area of regionally high concentration
3.4.3	Lobster	**LFA 27 lobster**	Very common species	Winter lobster habitat
3.4.4	Snowcrab	**N-ENS snowcrab**	Very common species	Habitat for females and juveniles
		S-ENS snowcrab	Very common species	Habitat for females and juveniles
3.5.1	Fish diversity	**Area of high fish diversity (slope)**	Area of high biodiversity	
3.5.3	American plaice	**Resident 4Vn American plaice**	Influential predator	Preferred habitat
3.5.4	Atlantic cod	**4TVn cod (southern Gulf)**	Influential predator / Depleted species	Part of overwintering area
		4Vn cod	Influential predator / Depleted species	Preferred habitat
		4VsW cod	Influential predator / Depleted species	
3.5.5	Atlantic halibut	**Atlantic halibut**	Influential predator	Regular occurrence in AOI
3.5.6	Atlantic wolffish	**4VWX Atlantic wolffish**	Depleted species	High proportion of preferred

Continued Table 4.4-1. Important ecosystem components identified

	Report Section	Important ecosystem component	Rationale for identification as an important component	Role of AOI for this component
				habitat
3.5.7	Redfish	**Redfish sp. (2 sp.) in Units 1 +2**	Influential predator/ Depleted species	Preferred habitat
3.5.8	Smooth skate	**Smooth skate**	Influential predator	
3.5.9	White hake	**Resident 4Vn white hake**	Influential predator	Preferred habitat
3.5.10	Witch flounder	**4T east + 4VW witch flounder**	Influential predator	Preferred habitat
3.5.11	Capelin	**ESS capelin**	Periodically important forage species	
3.5.12	Herring	**4T herring**	Important forage species	Part of Laurentian Channel overwintering area
		Coastal 4VWX spawning herring	Important forage species	Spawning area
3.5.13	Mackerel	**Mackerel**	Important forage species	Seasonal migratory route
3.5.14	Sharks	**Sharks**	Many species depleted	
		Porbeagle	Depleted species	Part of breeding area
3.6.1	Cetaceans	**Migration route for cetaceans migrating to and from the Gulf of St Lawrence**		Migration route
3.6.2	Seals	**Harp seals**		Part of breeding area
		Grey seals, esp. Hay Island grey seals	Influential predator	Feeding area
3.7	Sea turtles	**High use areas for leatherback turtles**	Depleted species	Feeding area
3.8	Seabirds	**Seabirds, esp. storm-petrels, Northern Fulmars, Great Shearwaters, Sooty Shearwaters, and Northern Gannets**	Influential predator	Migration area for most, feeding for gulls and storm-petrels nesting nearby

5. SUMMARY

The St Anns Bank area is home to a number of different species and interesting features that have been identified in this report. We have classified the AOI into three broad benthic habitat/community types: the shallow inshore bank, the mid-depth shelf, and the deeper slope and Laurentian Channel areas. The components that we have identified as being important or potentially unique to the AOI are identified in table 4.4.-1. Important fish species in the area include American plaice, Atlantic cod, Atlantic halibut, Atlantic wolffish, redfish, smooth skate, white hake, witch flounder, capelin, herring, and mackerel. Important invertebrate species include lobster, snow crab, sponges, and corals (particularly sea pens). Other species and groups of interest may include porbeagle and other sharks, leatherback sea turtles, cetaceans, seals, and sea birds. Other interesting components include areas of high fish and invertebrate diversity along the slope of the AOI, and deep water aggregations of plankton (*Calanus* sp.). The St Anns Bank area is also part of an important migration corridor for a number of species migrating in and out of the Gulf of St Lawrence, with at least ~0.5 million t of biomass passing through the area each year.

6. REFERENCES

Albikovskaya, L.K. 1982. Distribution and abundance of Atlantic wolffish, spotted wolffish and northern wolffish in the Newfoundland Region. NAFO Sci. Coun. Studies 3: 29–32.

Armsworthy, S.L., and Campana, S.E. 2010. Age determination, bomb-radiocarbon validation and growth of Atlantic halibut (*Hippoglossus hippoglossus*) from the northwest Atlantic. Environ. Biol. Fishes 89: 279–295.

Avens, L., Taylor, J.C., Goshe, L.R., Jones, T.T., and Hastings, M. 2009. Age estimation for leatherback sea turtles (*Dermochelys coriacea*) using skeletochronological analysis. Endangered Species Research 8: 165–177.

Baird, R.W. 2003. Update COSEWIC status report on the humpback whale *Megaptera novaeangliae* in Canada. *In* COSEWIC assessment and update status report on the humpback whale *Megaptera novaeangliae* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. 25 p.

Bakken, E. 1987. Growth, biomass, and production of a small unexploited plaice stock in St. Margaret's Bay, Nova Scotia. Can. Tech. Rep. Fish. Aquat. Sci. 1555: vii + 51 p.

Barsukov, V.V. 1959. The wolffish (*Anarhichadidae*). Zool. Inst. Akad. Nauk. USSR Fauna: Fishes 5(5), 173 p. [Translated for Smithsonian Institution and National Science Foundation, Washington, D.C., by Indian National Scientific Documentation, New Delhi, 1972.]

Baumgartner, M.F., Mullin, K.D., Nelson May, L., and Leming, T.D. 2001. Cetacean habitats in the northern Gulf of Mexico. Fisheries Bulletin 99: 219–239.

Beacham, T.D. 1983. Variability in size and age at sexual maturity of American plaice and yellowtail flounder in the Canadian Maritimes region of the northwest Atlantic Ocean. Can. Tech. Rep. Fish. Aquat. Sci. 1196: 75 p.

Beamish, F.W.H. 1966. Vertical migration by demersal fish in the northwest Atlantic. J. Fish. Res. Board Can. 23: 109–139.

Beauchamp, J., Bouchard, H., de Margerie, P., Otis, N., and Savaria, J.-Y. 2009. Recovery strategy for the blue whale (*Balaenoptera musculus*), northwest Atlantic population, in Canada [Final]. Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. 62 p.

Beck, C.A., Bowen, W.D., and Iverson, S.J. 2003. Sex differences in the seasonal patterns of energy storage and expenditure in a phocid seal. J. Anim. Ecol. 72: 280–291.

Beck, C.A., Iverson, S.J., Bowen, W.D., and Blanchard, W. 2007. Sex differences in grey seal diet reflect seasonal variation in foraging behaviour and reproductive expenditure: evidence from quantitative fatty acid signature analysis. J. Anim. Ecol. 76(3): 490–502.

Benjamins, S., Kulka, D., and Lawson, J. 2008. Incidental catch of seabirds in Newfoundland and Labrador gillnet fisheries, 2001–2003. Endangered Species Research 5: 149–160.

Benoit, D., and Bowen, W.D. 1990a. Summer diet of grey seals (*Halichoerus grypus*) at Anticosti Island, Gulf of St. Lawrence, Canada. Can. Bull. J. Fish. Aquat. Sci. 222: 227–242.

Benoit, D., and Bowen, W.D. 1990b. Seasonal and geographic variation in the diet of grey seals (*Halichoerus grypus*) in eastern Canada. Can. Bull. J. Fish. Aquat. Sci. 222: 215–226.

Benoît, H.P., and Swain, D.P. 2008. Impacts of environmental change and direct and indirect harvesting effects on the dynamics of a marine fish community. Can. J. Fish. Aquat. Sci. 65: 2088–2104.

Bergquist, P.R. 1978. Sponges. Hutchinson and Company, London.

Bigelow, H.R., and Schroeder, W.C. 1953. Fishes of the Gulf of Maine. U.S. Fish Wildl. Serv. Fish. Bull. 53: 577 p.

BirdLife International. 2011. IUCN Red List for birds. http://www.birdlife.org (accessed 4 February 2011).

Bogdanova, M.I., Daunt, F., Newell, M., Phillips, R.A., Harris, M.P., and Wanless, S. 2011. Seasonal interactions in the black-legged kittiwake, *Rissa tridactyla*: links between breeding performance and winter distribution. P. Roy. Soc. B-Biol. Sci. 278(1717): 2412–2418.

Boskovic, R., Kovacs, K.M., Hammill, M.O., and White, B.N. 1996. Geographic distribution of mitochondrial DNA haplotypes in grey seals (*Halichoerus grypus*). Can. J. Zoolog. 74: 1787–1796.

Boudreau, S.A., and Worm, B. 2010. Top-down control of lobster in the Gulf of Maine: insights from local ecological knowledge and research surveys. Mar. Ecol-Prog. Ser. 403: 181–191.

Boudreau, S.A., Anderson, S.C., and Worm, B. 2011. Top-down interactions and temperature control of snow crab abundance in the northwest Atlantic Ocean. Mar. Ecol-Prog. Ser. 429: 169–183.

Boulva, J., and McLaren, I.A. 1979. Biology of the harbour seal, *Phoca vitulina*, in eastern Canada. B. Fish. Res. Board Can. 200: 1–24.

Bowen, W.D., and Siniff, D.B. 1999. Distribution, population biology, and feeding ecology of marine mammals. *In* Biology of marine mammals. Edited by J.E. Reynolds and S.J. Rommel. Smithsonian Institution, Washington, DC. pp. 423–484.

Bowen, W.D., Myers, R.A., and Hay, K. 1987. Abundance estimation of a dispersed, dynamic population: hooded seals (*Cystophora cristata*) in the northwest Atlantic. Can. J. Fish. Aquat. Sci. 44: 282–295.

Bowen, W.D., Lawson, J.W., and Beck, B. 1993 Seasonal and geographic variation in the species composition and size of prey consumed by grey seals (*Halichoerus grypus*) on the Scotian Shelf. Can. J. Fish. Aquat. Sci. 50: 1768–1778.

Bowen, W.D., Oftedal, O.T., Boness, D.J., and Iverson, S.J. 1994. The effect of maternal age and other factors on birth mass in the harbour seal. Can. J. Zoolog. 72: 8–14.

Bowen, W.D., Ellis, S.L., Iverson, S.J., and Boness, D.J. 2001. Maternal effects on offspring growth rate and weaning mass in harbour seals. Can. J. Zoolog. 79: 1088–1101.

Bowen, W.D., Ellis, S.L., Iverson, S.J., and Boness, D.J. 2003a. Maternal and newborn life-history traits during periods of contrasting population trends: implications for explaining the decline of harbour seals, *Phoca vitulina*, on Sable Island. J. Zool. London 261: 155–163.

Bowen, W.D., McMillan, J., and Mohn, R. 2003b. Sustained exponential population growth of grey seals at Sable Island, Nova Scotia. ICES J. Mar. Sci. 60: 1265–1274.

Bowen, W.D., Iverson, S.J., McMillan, J.I., and Boness, D.J. 2006. Reproductive performance in grey seals: age-related improvement and senescence in a capital breeder. J. Anim. Ecol. 75: 1340–1351.

Bowen, W.D., McMillan, J.I., and Blanchard, W. 2007a. Reduced population growth of grey seals at Sable Island: evidence from pup production and age of primiparity. Mar. Mammal Sci. 23: 48–64.

Bowen, W.D., McMillan, J.I., Lidgard, D., and Blanchard, W. 2007b. Continued reduction in population growth rate of grey seals at Sable Island. DFO Can. Sci. Advis. Sec. Res. Doc. 2007/087: 20 p.

Bowering, W.R., and Brodie, W.B. 1991. Distribution of commercial flatfishes in the Newfoundland-Labrador region of the Canadian northwest Atlantic and changes in certain biological parameters since exploitation. Neth. J. Sea Res. 27: 407–422.

Bowlby, H.D., Hanson, J.M., and Hutchings, J.A. 2008. Stock structure and seasonal distribution patterns of American lobster, *Homarus americanus*, inferred through movement analyses. Fish. Res. 90(1–3): 279–288.

Brazner, J.C., and McMillan, J. 2008. Loggerhead turtle (Caretta caretta) bycatch in Canadian pelagic longline fisheries: Relative importance in the western North Atlantic and opportunities for mitigation. Fish. Res. 91(2–3): 310–324.

Breed, G.A., Jonsen, I.D., Myers, R.A., Bowen, W.D., and Leonard, M.L. 2009. Sex-specific, seasonal foraging tactics of adult grey seals (*Halichoerus grypus*) revealed by state–space analysis. Ecology 90: 3209–3221.

Breeze, H., and Horsman, T. 2005. The Scotian Shelf: an atlas of human activities. Department of Fisheries and Oceans, Maritimes Region, Dartmouth, NS, Canada.

Breeze H., Davis, D.S., Butler, M., and Kostlyev, V. 1997. Distribution and status of deep sea corals off Nova Scotia. Marine Issues Committee Special Publication 1, Ecology Action Centre, Halifax.

Breeze, H., Fenton, D., Rutherford, R. and Silva, M. 2002. The Scotian Shelf: an ecological overview for ocean planning. Can Tech. Rep. Fish. Aquat. Sci. 2393: x + 259 p.

Brickman, D., and Drozdowski, A. 2012. Development and Validation of a Regional Shelf Model for Maritime Canada based on the NEMO-OPA Circulation Model. Can. Tech. Rep. Hydrogr. Ocean Sci. 278: vii + 57 pp.

Brown, M.W., Fenton, D., Smedbol, K., Merriman, C., Robichaud-Leblanc, K., and Conway, J.D. 2009. Recovery strategy for the north Atlantic right whale (*Eubalaena glacialis*) in Atlantic Canadian Waters [Final]. Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. vi + 66 p.

Bruneau, B., and Grégoire, F. 2011. Spatial distribution study of Atlantic mackerel (*Scomber scombrus*) and capelin (*Mallotus villosus*) abundance data from winter groundfish surveys in NAFO Divisions 4VW using generalized additive models. Can. Tech. Rep. Fish. Aquat. Sci. 2930: vi + 21 pp.

Buhl-Mortensen, L., and Mortensen, P.B. 2005. Distribution and diversity of species associated with deep-sea gorgonian corals off Atlantic Canada. *In* Cold-water Corals and Ecosystems. Edited by A. Freiwald and J.M. Roberts. Springer-Verlag, New York. pp. 849–879

Bundy, A. 2004. Mass balance models of the eastern Scotian Shelf before and after the cod collapse and other ecosystem changes. Can. Tech. Rep. Fish. Aquat. Sci. 2520: xii + 193 p.

Bundy, A. 2005. Structure and functioning of the eastern Scotian Shelf ecosystem before and after the collapse of groundfish stocks in the early 1990s. Can. J. Fish. Aquat. Sci. 62: 1453–1473.

Bundy, A., and Fanning, L.P. 2005. Can Atlantic cod (*Gadus morhua*) recover? Exploring trophic explanations for the non-recovery of the cod stock on the eastern Scotian Shelf. Canada. Can. J. Fish. Aquat. Sci. 62: 1474–1489.

Bundy, A., and Simon, J. 2005. Assessment of white hake (*Urophycis tenuis*) in NAFO Divisions 4VWX and 5. DFO Can. Sci. Advis. Sec. Res. Doc. 2005/081: iv + 46 p.

Bundy, A., Heymans, J., Morissette, L., and Savenkoff, C. 2009. Seals, cod and forage fish: a comparative exploration of variations in the theme of stock collapse and ecosystem change in four Northwest Atlantic ecosystems. Prog. Oceanogr. 81: 188–206.

Busby, C.D., Morgan, M.J., Dwyer, K.S., Fowler, G.M., Morin, R., Treble, M., Maddock Parsons, D., and Archambault, D. 2007. Review of the structure, the abundance and distribution of American plaice (*Hippoglossoides platessoides*) in Atlantic Canada in a species-at-risk context. DFO Can. Sci. Advis. Sec. Res. Doc. 2007/069: 90 p.

Caldwell, D.K., and Caldwell, M.C. 1969. Addition of the leatherback sea turtle to the known prey of the killer whale *Orcinus-Orca*. J. Mammal. 50(3): 636.

Campana, S., Fanning, P., Fowler, G.M., Frank, K., Halliday, R.G., Lambert, T.C., Mohn, R.K., Wilson, S., Stobo, W.T., Hanson, J.M., and Sinclair, A.F. 1995. Report of the 4Vn Cod Working Group on the scientific value of a 4Vn cod (May–Oct) stock assessment. DFO Atl. Fish. Res. Doc. 95/16: 110

Campana, S.E., Chouinard, G.A., Hanson, J.M., and Frechet, A. 1999. Mixing and migration of overwintering Atlantic cod (*Gadus morhua*) stocks near the mouth of the Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci. 56: 1873–1881.

Campana, S., Joyce, W., and Marks, L. 2003. Status of the porbeagle shark (*Lamna nasus*) population in the northwest Atlantic in the context of species at risk. DFO Can. Sci. Advis. Sec. Res. Doc. 2003/007: iii + 27 p.

Campana, S., Marks, L., Joyce, W., and Kohler, N. 2004. Influence of recreational and commercial fishing on the blue shark (*Prionace glauca*) population in Atlantic Canadian waters. DFO Can. Sci. Advis. Sec. Res. Doc. 2004/069: 72 p.

Campana, S.E., and Gibson, A.J.F. 2005. Status and recovery potential of porbeagle shark in the northwest Atlantic. DFO Can. Sci. Advis. Sec. Res. Doc. 2005/053: 79 p.

Campana, S., Brazner, J., and Marks, L. 2006. Assessment of the recovery potential of shortfin mako sharks in Atlantic Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/091: 24 p.

Campana, S.E., Valentin, A., Sevigny, J-M., and Power, D. 2007a. Tracking seasonal migrations of redfish (*Sebastes* spp.) in and around the Gulf of St. Lawrence using otolith elemental fingerprints. Can. J. Fish. Aquat. Sci. 64: 6–18.

Campana, S.E., Gibson, J.A., Marks, L., Joyce, W., Rulifson, R., and Dadswell, M. 2007b. Stock structure, life history, fishery and abundance indices for spiny dogfish (*Squalus acanthias*) in Atlantic Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2007/089: 136 p.

Campana, S.E., Gibson, J., Brazner, J., Marks, L., Joyce, W., Gosselin, J-F., Kenney, R.D., Shelton, P., Simpson, M., and Lawson, J. 2008. Status of basking sharks in Atlantic Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/004: 67 p.

Campana, S.E., Gibson, A.J.F., Fowler, M., Dorey, A., and Joyce, W. 2010a. Population dynamics of porbeagle in the northwest Atlantic, with an assessment of status to 2009 and projections for recovery. Collect. Vol. Sci. Pap. ICCAT 65(6): 2109–2182.

Campana, S.E., Joyce, W., and Fowler, M. 2010b. Subtropical pupping ground for a cold-water shark. Can. J. Fish. Aquat. Sci. 67(5): 769–773.

Canada Gazette. 2004. Order Amending Schedules 1 to 3 to the Species at Risk Act. Canada Gazette Part 1. 138(43). October 23, 2004.

Canada Gazette. 2005a. Order Amending Schedules 1 to 3 to the Species at Risk Act. Canada Gazette Part 1.139(2). January 26, 2005

Canada Gazette. 2005b. Order Amending Schedules 1 to 3 to the Species at Risk Act. Canada Gazette Part 1.139(50). December 10, 2005

Canada Gazette. 2006. Order Amending Schedules 1 to 3 to the Species at Risk Act. Canada Gazette Part 1.140(23). June 10, 2006.

Canadian Ice Service. 2010. http://ice-glaces.ec.gc.ca/WsvPageDsp.cfm?ID=10432 (accessed 15 February 2010).

Carscadden, J.E., Montevecchi, W.A., Davoren, G.K., and Nakashima, B.S. 2002. Trophic relationships among capelin (*Mallotus villosus*) and seabirds in a changing ecosystem. ICES Mar. Sci. 59(5): 1027–1033.

Chadwick, E.M.P., Brodie, W., Colbourne, E., Clark, D., Gascon, D., and Hurlbut, T. 2007. History of annual multi-species trawl surveys on the Atlantic coast of Canada. AZMP Bull. 6: 25–42.

Chassé, J. 2001. Physical oceanography of southern Gulf of Saint Lawrence and Sydney Bight areas of coastal Cape Breton. DFO Can. Sci. Advis. Sec. Res. Doc. 2001/113: 21 p.

Chassé, J., and Miller, R.J. 2010. Lobster larval transport in the southern Gulf of St. Lawrence. Fish. Oceanogr. 19(5): 319–338.

Choi, J.S. Unpublished. Can a competitive bottleneck explain the lack of recovery of Atlantic cod and the hysteresis of a Canadian shelf ecosystem?

Choi, J.S., and Zisserson, B.M. 2011. Assessment of Scotian Shelf snow crab in 2009. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/005: 96 p.

Choi, J.S., Frank, K.T., Leggett, W.C., and Drinkwater, K. 2004. Transition to an alternate state in a continental shelf ecosystem. Can. J. Fish. Aquat. Sci. 61: 505–510.

Choi, J.S., Frank, K.T., and Leggett, W.C. 2005. Integrated assessment of a large marine ecosystem: a case study of the devolution of the eastern Scotian Shelf, Canada. Oceanogr. Mar. Biol. Annu. Rev. 43: 47–67.

Chouinard, G.A. 2001. Report of the Cod Mixing Workshop, 16–17 October 2000. DFO Can. Sci. Advis. Sec. Proc. Ser. 2000/027: 19 p.

Chouinard, G.A., Swain, D.P., Hammill, M.O., and Poirier, G.A. 2005. Covariation between grey seal (*Halichoerus grypus*) abundance and natural mortality of cod (*Gadus morhua*) in the southern Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci. 62: 1991–2000.

Clark, D., Emberley, C., Clark, C., and Peppard, B. 2010. Update of the 2009 summer Scotian Shelf and Bay of Fundy research vessel survey. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/008: 78 p.

Cogswell, A.T., Kenchington, E.L.R., Lirette, C.G., MacIsaac, K., Best, M.M., Beazley, L.I., and Vickers, J. 2009. The current state of knowledge concerning the distribution of coral in the Maritime provinces. Can. Tech. Rep. Fish. Aquat. Sci. 2855: v + 66 p.

Coles, W.C., and Musick, J.A. 2000. Satellite sea surface temperature analysis and correlation with sea turtle distribution off North Carolina. Copeia 2000 (2): 551–554.

Coltman, D.W., Bowen, W.D., Iverson, S.J., and Boness, D.J. 1998. The energetics of male reproduction in an aquatically mating pinniped, the harbour seal. Physiol. Zool. 71: 387–399.

Comeau, L.A., Campana, S.E., and Castonguay, M. 2002a. Automated monitoring of a large-scale cod (*Gadus morhua*) migration in the open sea. Can. J. Fish. Aquat. Sci. 59: 1845–1850.

Comeau, L.A., Campana, S.E., and Chouinard, G.A. 2002b. Timing of Atlantic cod (*Gadus morhua* L.) seasonal migrations in the southern Gulf of St Lawrence: interannual variability and proximate control. ICES J. Mar. Sci. 59: 333–351.

Conover, R.J. 1988. Comparative life histories in the genus *Calanus* and *Neocalanus* in high latitudes of the northern hemisphere. Hydrobiologia 167/168: 127–142.

Cook, A.M., and Bundy, A. 2010. The Food Habits Database: an update, determination of sampling adequacy and estimation of diet for key species. Can. Tech. Rep. Fish. Aquat. Sci. 2884: iv + 140 p.

COSEWIC 2001. COSEWIC assessment and update status report on the leatherback turtle *Dermochelys coriacea* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. vii + 25 p.

COSEWIC. 2002. COSEWIC assessment and update status report on the blue whale *Balaenoptera musculus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. vi + 32 p.

COSEWIC. 2003a. Annual report to the Canadian Endangered Species Conservation Council (CESCC) by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) May 2003. Committee on the Status of Endangered Wildlife in Canada, Ottawa. 56 p.

COSEWIC. 2003b. COSEWIC assessment and update status report on the humpback whale *Megaptera novaeangliae* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. viii + 25 p.

COSEWIC. 2003c. COSEWIC assessment and update status report on the north Atlantic right whale *Eubalaena glacialis* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. vii + 28 p.

COSEWIC. 2004. COSEWIC assessment and status report on the porbeagle shark *Lamna nasus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. viii + 43 p.

COSEWIC. 2005. COSEWIC assessment and update status report on the fin whale *Balaenoptera physalus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. ix + 37 p.

COSEWIC. 2006a. COSEWIC assessment and status report on the blue shark *Prionace glauca* (Atlantic and Pacific populations) in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. vii + 46 p.

COSEWIC. 2006b. Annual report to the Minister of the Environment and the Canadian Endangered Species Conservation Council (CESCC) by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) August 2006. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 74 p.

COSEWIC. 2006c. COSEWIC assessment and update status report on the harbour porpoise *Phocoena phocoena* (northwest Atlantic population) in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. vii + 32 p.

COSEWIC. 2008. COSEWIC assessment and update status report on the killer whale *Orcinus orca*, southern resident population, northern resident population, west coast transient population, offshore population and northwest Atlantic / eastern Arctic population, in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. viii + 65 p.

COSEWIC. 2009. COSEWIC assessment and status report on the American plaice *Hippoglossoides platessoides*, Maritime population, Newfoundland and Labrador population and Arctic population, in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. x + 74 p.

COSEWIC. 2010a. COSEWIC assessment and status report on the deepwater redfish / Acadian redfish (*Sebastes mentella* and *Sebastes fasciatus*) in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. x + 80 pp.

COSEWIC. 2010b. COSEWIC assessment and update status report on the Atlantic Cod *Gadus morhua* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. xi + 76 p.

COSEWIC. 2011. Committee on the Status of Endangered Wildlife in Canada. http://www.cosewic.gc.ca/; Wildlife Species Search (accessed 15 January 2011).

Crick, H.Q.P. 2004. The impact of climate change on birds. Ibis 146: 48–56.

Daly, M., Brugler, M.R., Cartwright, P., Collins, A.G., Dawson, M.N., Fautin, D.G., France, S.C., McFadden, C.S., Opresko, D.M., Rodriguez, E., Romano, S.L., and Stake, J.L. 2007. The phylum Cnidaria: a review of phylogenetic patterns and diversity 300 years after Linnaeus. Zootaxa 1668: 127–182.

Davis, D., and Brown, S. (eds). 1996. The natural history of Nova Scotia: volume two, theme regions. Revised Edition. Nimbus Publishing, Halifax. 304 p.

den Heyer, C.E., Bundy, A., and MacDonald, C. 2010. At-sea catch analysis of inshore Scotian Shelf lobster fishery and 4VsW commercial index groundfish sentinel fishery. Can. Tech. Rep. Fish. Aquat. Sci. 2890: viii + 39 p.

Deroba, J.J., Shepherd, G., Grégoire, F., Nieland, J., and Link, J. 2010. Stock assessment of Atlantic mackerel in the northwest Atlantic – 2009. TRAC Ref. Doc. 2010/01: 59 p.

DFO. 1996a. Scotian Shelf sand lance. DFO Atl. Fish. Stock Status Rep. 96/77E: 2 p.

DFO. 1996b. Scotian Shelf capelin. DFO Atl. Fish. Stock Status Rep. 96/35E: 3 p.

DFO. 2002a. Cod in Sydney Bight (Div. 4Vn May–October). DFO Sci. Stock Status Rep. A3-02: 10 p.

DFO. 2002b. American plaice and yellowtail flounder on the eastern Scotian Shelf (Div. 4VW). DFO Sci. Stock Status Report A3-34 (2002): 11 p.

DFO. 2002c. Wolffish on the Scotian Shelf, Georges Bank and in the Bay of Fundy (Div. 4VWX and Div. 5YZe). DFO Sci. Stock Status Rep. A3-31(2002): 7 p.

DFO. 2002d. Updates on selected Scotian Shelf groundfish stocks in 2002. DFO Sci. Stock Status Rep. A3-35 (2002): 27 p.

DFO. 2003a. State of the eastern Scotian Shelf ecosystem. DFO Can. Sci. Advis. Sec. Ecosystem Status Rep. 2003/004: 25 p.

DFO. 2003b. 2003–2006 Scotia-Fundy fisheries integrated herring management plan NAFO sub-divisions 4WX, 4Vn and 5Z. Fisheries and Oceans Canada.

DFO. 2005a. The Gulf of St. Lawrence: A unique ecosystem. The stage for the Gulf of St. Lawrence Integrated Management (GOSLIM). Fisheries and Oceans Canada, Ottawa. 30 p.

DFO. 2005b. White hake in the Southern Gulf of St. Lawrence (Div. 4T). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2005/009: 6 p.

DFO. 2005c. White hake in 4VWX and 5. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2005/058: 8 p.

DFO. 2005d. Atlantic mackerel of the Northwest Atlantic in 2004. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2005/014: 9 p.

DFO. 2005e. Guidelines on evaluating ecosystem overviews and assessments: necessary documentation. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2005/026: 10 p.

DFO. 2006. Identification of ecologically significant species and community properties. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2006/041: 24 p.

DFO. 2007a. Stock assessment of Atlantic halibut of the Gulf of St. Lawrence (NAFO Divisions 4RST) in 2006. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2007/007: 13 p.

DFO. 2007b. Stock assessment of witch flounder in the Gulf of St. Lawrence (NAFO Div. 4RST). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2007/004: 10 p.

DFO. 2007c. National Plan of Action for Reducing the Incidental Catch of Seabirds in Longline Fisheries. Fisheries and Oceans Canada, Ottawa. Cat. No. Fs23-504/2007. ISBN 978-0-662-49883-4: 29 p.

DFO. 2008a. Advice on the stock definition of redfish (*Sebastes fasciatus* and *S. mentella*) in Units 1 and 2. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/026: 12 p.

DFO. 2008b. Assessment of the Atlantic mackerel stock for the northwest (4RST) Atlantic (Subareas 3 and 4) in 2007. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/041: 15 p.

DFO. 2008c. Overview of the Atlantic seal hunt 2003–2005. http://www.dfo-mpo.gc.ca/fm-gp/seal-phoque/reports-rapports/mgtplan-plangest2003/mgtplan-plangest2003-eng.htm (accessed 8 December 2011).

DFO. 2008d. Assessment of the estuary and Gulf of St. Lawrence (Divisions 4RST) capelin stock in 2007. DFO Can. Sci. Advis. Sec., Sci. Advis. Rep. 2008/037: 12 p.

DFO. 2009a. Science advice on potential impacts of Sydney Harbour access channel deepening and the proposed Sydport container terminal. DFO Can. Sci. Advis. Sec. Sci. Rep. 2009/005: 10 p.

DFO. 2009b. Underwater World: North American lobster. http://www.dfo-mpo.gc.ca/Science/publications/uww-msm/articles/americanlobster-homarddamerique-eng.html (accessed August 2011).

DFO. 2009c. Underwater World: Snow crab. http://www.dfo-mpo.gc.ca/Science/publications/uww-msm/articles/snowcrab-crabedesneiges-eng.html (accessed August 2011).

DFO. 2009d. Proceedings of a Workshop on Canadian Science and Management Strategies for Whelk, 3–4 June 2008. DFO Can. Sci. Advis. Sec. Proc. Ser. 2009/024: 27 p.

DFO. 2009e. Assessment of cod in the southern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/007: 15 p.

DFO. 2009f. Stock assessment of Atlantic halibut of the Gulf of St. Lawrence (Divisions 4RST) in 2008. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/023: 14 p.

DFO. 2009g. Current status of northwest Atlantic harp seals, *Pagophilus groenlandicus*. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/074: 15 p.

DFO. 2009h. Fisheries management decisions: past decisions – 2009. Bluefin tuna–Atlantic Canada. http://www.dfo-mpo.gc.ca/decisions/fm-2009-gp/bluefin-thonrouge-0714-01-eng.htm (accessed September 2011, last updated July 2009).

DFO. 2010a. Occurrence, susceptibility to fishing, and ecological function of corals, sponges, and hydrothermal vents in Canadian waters. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2010/041: 54p

DFO. 2010b. Inshore lobster Integrated Fishery Management Plan: Lobster Fishing Areas 27–38. Scotia-Fundy Sector, Maritimes Region (2010–2014).

DFO. 2010c. Assessment of Nova Scotia (4VWX) snow crab. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2010/040: 24 p.

DFO. 2010d. Impacts of grey seals on fish populations in eastern Canada. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2010/071: 48 p.

DFO. 2010e. Assessment of redfish stocks (*Sebastes fasciatus* and *S. mentella*) in Units 1 and 2 in 2009. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2010/037: 20 p.

DFO. 2011a. News Release. Government of Canada announces progress on marine protection: Minister Ashfield announces three new areas of interest. 8 June 2011. NR-HQ-11-10E. http://www.dfo-mpo.gc.ca/media/npress-communique/2011/hq-ac10-eng.htm (accessed 8 December 2011).

DFO. 2011b. Zonal science advisory process on the 13th annual meeting of the Atlantic Zone Monitoring Program (AZMP), March 22–24, 2011. DFO Can. Sci. Advis. Sec. Proc. Ser. 2011/036: 48 p.

DFO. 2011c. Assessment of lobster off the Atlantic coast of Nova Scotia (LFAs 27-33). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/064: 25 p.

DFO. 2011d. Recovery potential assessment for the Laurentian South designatable unit of Atlantic cod (*Gadus morhua*). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/028: 39 p.

DFO. 2011e. Assessment of Atlantic halibut on the Scotian Shelf and southern Grand Banks (NAFO Divisions 3NOPs4VWX5Zc). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/001: 11 p.

DFO. 2011f. 2011–2015 Integrated fisheries management plan for Atlantic seals. http://www.dfo-mpo.gc.ca/fm-gp/seal-phoque/reports-rapports/mgtplan-planges20112015/mgtplan-planges20112015-eng.htm (accessed 8 December 2011).

DFO. 2012. Zonal advisory process pre-COSEWIC peer review meeting of white hake (*Urophycis tenuis*); November 1 and 2, 2011. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2012/037.

Doyle, T.K., Houghton, J.D.R., McDevitt, R., Davenport, J., and Hays, G.C. 2007. The energy density of jellyfish: estimates from bomb-calorimetry and proximate-composition. J. Exp. Mar. Biol. Ecol. 343: 239–252

Doyle, T., Houghton, J., O Súilleabháin, P., Hobson, V., Marnell, F., Davenport, J., and Hays, G. (2008). Leatherback turtles satellite-tagged in European waters Endangered Species Research, 4, 23-31

Drinkwater, K., and Pettipas, R. 1996. Near-bottom temperatures on Sydney Bight and the northeastern Scotian Shelf during 1995. DFO Atl. Fish. Res. Doc. 96/136: 14 p.

Drinkwater, K., Pettipas, R., Petrie, L., and Swain, D. 1997. Temperature conditions in the Gulf of St Lawrence and on the Scotian Shelf during 1996 relevant to snow crab. DFO Can. Stock Assess. Sec. Res. Doc. 97/02: 18 p.

Drinkwater, K., Lochman, S., Taggart, C., Thompson, K., and Frank, K. 2000. Entrainment of redfish (*Sebastes* spp.) larvae off the Scotian Shelf. ICES J. Mar. Sci. 57: 372–382.

Dufour, R., and Ouellet, P. 2007. Estuary and Gulf of St. Lawrence marine ecosystem overview and assessment report. Can. Tech. Rep. Fish. Aquat. Sci. 2744E: 112 p.

Dumont, C.P., Roy, J.S., and Himmelman, J.H. 2008. Predation by the sea urchin *Strongylocentrotus droebachiensis* on capsular egg masses of the whelk *Buccinum undatum*. J. Mar. Biol. Assoc. UK 88(5): 1025–1031.

Elner, R.W., and Campbell, A. 1987. Natural diets of lobster *Homarus americanus* from barren ground and macroalgal habitats off Southwestern Nova Scotia, Canada. Mar. Ecol-Prog. Ser. 37(2–3): 131–140.

Ernst, C.H., Barbour, R.W., and Lovich, J. 1994. Turtles of the United States and Canada. Smithsonian Institution, Inc., Washington, DC.

ESSIM Planning Office. 2006. Coral Conservation Plan. Maritimes Region (2006–2010). Oceans and Coastal Management Division, Fisheries and Oceans Canada, Maritimes Region, Dartmouth, NS. Oceans and Coastal Management Report 2006-01: 59 p.

Fisher, J.A.D., Frank, K.T., Petrie, B., Leggett, W.C., and Shackell, N.L. 2008 Temporal dynamics within a contemporary latitudinal diversity gradient. Ecol. Lett. 11: 883–897.

Fisher, J.A.D., Frank, K.T., and Leggett, W.C. 2010. Global variation in marine fish body size and its role in biodiversity-ecosystem functioning. Mar. Ecol-Prog. Ser. 405:1–13.

Fisheries Diversification Program. 2001. Gear and by-catch concerns: Interactions in the turbot, crab, and shrimp fisheries in 2J3KL. Project summary: EACT-4.2001.DFO (FDP 334). Newfoundland and Labrador Department of Fisheries and Aquaculture. http://www.fishaq.gov.nl.ca/research_development/fdp/fdp_334.pdf (accessed 8 December 2011).

Fowler, G.M., and Stobo, W.T. 2000. Status of 4VW American plaice and yellowtail flounder. DFO Can. Stock Ass. Sec. Res. Doc. 2000/144: 87 p.

Frank, K.T., Drinkwater, K.F., and Page, F.H. 1994. Possible causes of recent trends and fluctuations in Scotian Shelf/Gulf of Maine cod stocks. ICES Mar. Sci. Symp. 198: 110–120.

Frank, K.T., Carscadden, J.E., and Simon, J.E. 1996. Recent excursions of capelin (*Mallotus villosus*) to the Scotian shelf and Flemish Cap during anomalous hydrographic conditions. Can. J. Fish. Aquat. Sci. 53(7): 1473–1486.

Frank, K.T., Petrie, B., Choi, J.S., and Leggett, W.C. 2005. Trophic cascades in a formerly cod-dominated ecosystem. Science 308: 1621–1623.

Frank, K.T., Petrie, B., Shackell, N.L., and Choi, J.C. 2006. Reconciling differences in trophic control in mid-latitude marine ecosystems. Ecol. Lett. 9: 1096–1105.

Frank, K.T., Petrie, B., and Shackell, N.L. 2007. The ups and downs of trophic control in continental shelf ecosystems. Trends Ecol. Evol. 22: 236–242.

Frank, K.T., Petrie, B., Fisher, J.A.D., and Leggett, W.C. 2011. Transient dynamics of an altered large marine ecosystem. Nature 477: 86–89.

Fraser, G.S., Russell, J., and Von Zharen, W.M. 2006. Produced water from offshore oil and gas installations on the Grand Banks, Newfoundland: are the potential effects to seabirds sufficiently known? Mar. Ornithol. 34: 147–156.

Friewald, A., Fosså, J.H., Grehan, A., Koslow, T., and Roberts, J.M. 2004. Cold-water coral reefs. United Nations Environment Programe – World Conservation Monitoring Centre, Cambridge, UK. 84 p.

FSRS. 2011. Fishermen & Scientists Research Society – Lobster recruitment project. http://www.fsrs.ns.ca/projects/Lobster/index.html (accessed August 2011).

Fu, C., Mohn, R., and Fanning, L.P. 2001. Why the Atlantic cod (*Gadus morhua*) stock off eastern Nova Scotia has not recovered. Can. J. Fish. Aquat. Sci. 58: 1613–1623.

Fuller, S.D. 2011. Diversity of marine sponges in the northwest Atlantic. Thesis (Ph.D.), Dalhousie University, Halifax, Canada. 215 p.

Fuller, S.D., Murillo Perez, F.J., Wareham, V., and Kenchington, E. 2008a. Vulnerable marine ecosystems dominated by deep-water corals and sponges in the NAFO Convention Area. NAFO Sci. Coun. Res. Doc. 08/22: 24 p.

Fuller, S.D., Picco, C., Ford, J., Tsao, C.-F., Morgan, L.E., Hangaard, D., and Chuenpagdee, R. 2008b. How we fish matters: addressing the ecological impacts of Canadian fishing gear. Ecology Action Centre, Living Oceans Society, and Marine Conservation Biology Institute. http://www.howwefish.ca/images/downloads/How_We_Fish_Report.pdf (accessed 8 December 2011).

Galbraith, P.S., Pettipas, R.G., Chassé, J., Gilbert, D., Larouche, P., Pettigrew, B., Gosselin, A., Devine, L., and Lafleur, C. 2010. Physical oceanographic conditions in the Gulf of St. Lawrence in 2009. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/035: 77 p.

Garrison, L.P., and Link, J.S. 2000. Dietary guild structure of the fish community in the northeast United States continental shelf ecosystem. Mar. Ecol-Prog. Ser. 202: 231–240.

Gascon, D. 2003. Redfish Multidisciplinary Research Zonal Program (1995–1998): final report. Can. Tech. Rep. Fish. Aquat. Sci. No. 2462: xiii + 139 p.

Gaskin, D.E. 1982. The ecology of whales and dolphins. Heinemann Educational Books Inc., London, UK. 459 p.

Gass, S.E. 2002. An assessment of the distribution and status of deep sea corals in Atlantic Canada by using both scientific and local forms of knowledge. Thesis (M.E.S.), Dalhousie University, Halifax, Canada. 186 p.

Gass, S.E., and Willison, J.H.M. 2005. An assessment of the distribution of deep-sea corals in Atlantic Canada by using both scientific and local forms of knowledge. *In* Cold-water corals and ecosystems. Edited by A. Freiwald and J.M. Roberts. Springer-Verlag, New York. pp. 223–245.

Gass, S.E., and Roberts, J.M. 2006. The occurrence of the cold-water coral *Lophelia pertusa* (Scleractinia) on oil and gas platforms in the North Sea: colony growth, recruitment and environmental controls on distribution. Mar. Pollut. Bull. 52: 549–559.

Gauthier, S., and Rose, G.A. 2005. Diel vertical migration and shoaling heterogeneity in Atlantic redfish: effects on acoustic and bottom-trawl surveys. ICES J. Mar. Sci. 62: 75–85.

Gibson, A.J.F., and Campana, S.E. 2005. Status and recovery potential of porbeagle shark in the Northwest Atlantic. DFO Can. Sci. Advis. Sec. Res. Doc. 2005/053: 79 p.

Gilbert, D., Sundby, B., Gobeil, C., Mucci, A., and Tremblay, G.-H. 2005. A seventy-two-year record of diminishing deep-water oxygen in the St. Lawrence estuary: the northwest Atlantic connection. Limnol. Oceanogr. 50: 1654–1666.

Gjerdrum, C., Head, E.J.H., and Fifield, D.A. 2008. Monitoring seabirds at sea in eastern Canada. AZMP Bull. 7: 52–58.

Godsell, J. 1991. The relative influence of age and weight on the reproductive behaviour of male grey seals *Halichoerus grypus*. J. Zool. London 224: 537–551.

Gordon, D.C., Jr, and Kenchington, E.L. 2007. Deep water corals in Atlantic Canada: A review of DFO research (2001–2003). Proceedings of the Nova Scotia Institute of Science 44: 27–50.

Gotelli, N.J., and Colwell, R.K. 2001. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. Ecol. Lett. 4: 379–391.

Government of Canada. 2011. National Framework for Canada’s Network of Marine Protected Areas. Fisheries and Oceans Canada, Ottawa. 31 p.

Gowans, S., and Whitehead, H. 1995. Distribution and habitat partitioning by small odontocetes in the Gully, a submarine canyon on the Scotian Shelf. Can. J. Zoolog. 73: 1599–1608.

Grant, G.S., Malpass, H., and Beasley, J. 1996. Correlation of leatherback turtle and jellyfish occurrence. Herpetol. Rev. 27(3): 123–125.

Grégoire, F. 2001. Oil and gas exploration off Cape Breton Island: Information concerning the biology and fishery of the Atlantic mackerel (*Scomber scombrus* L.) present in this area. DFO Can. Sci. Advis. Sec. Res. Doc. 2001/114: 52 p.

Grégoire, F. 2006. Vertical distribution of the midwater trawl catches of Atlantic mackerel (*Scomber scombrus* L.) in relation with water temperature. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/097: iii + 44 p.

Grégoire, F., Gauthier, J., Savenkoff, C., Lévesque, C., Beaulieu, J.-L., and Gendron, M.-H. 2008. Commercial fishery, by-catches and biology of capelin (*Mallotus villosus*) in the estuary and Gulf of St. Lawrence (NAFO Divisions 4RST) for the 1960–2007 period. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/084: 95 p.

Grégoire, F., Lévesque, C., Beaulieu, J.-L., and Gendron, M.-H. 2009. Commercial fishery and biology of the Atlantic mackerel (*Scomber scombrus* L.) in NAFO Subareas 3 and 4 in 2007. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/025: vi + 161 p.

Guénette, S., and Stephenson, R. 2010. Accounting for predators in ecosystem-based management of herring fisheries. Unpublished paper presented at Ecosystems 2010: Global Progress on Ecosystem-Based Fisheries Management, Fairbanks, Alaska, 8–11 November 2010.

Halliday, R.G., and Pinhorn, A.T. 2009. The roles of fishing and environmental change in the decline of northwest Atlantic groundfish populations in the early 1990s. Fish. Res. 97: 163–182.

Hammill, M.O. 2010. Feeding of grey seals in southern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/130: 31 p.

Hammill, M.O., and Gosselin, J.F. 1995. Grey seal (*Halichoerus grypus*) from the northwest Atlantic: female reproductive rates, age at first birth, and age of maturity in males. Can. J. Fish. Aquat. Sci. 52: 2757–2761.

Hammill, M.O., and Gosselin, J.-F. 2005. Pup production of non-Sable Island grey seals in 2004. DFO Can. Sci. Advis. Sec. Res. Doc. 2005/033: 24 p.

Hammill, M.O., and Stenson, G.B. 2000. Estimated prey consumption by harp seals (*Phoca groenlandica*), hooded seals (*Cystophora cristata*), grey seals (*Halichoerus grypus*) and harbour seals (*Phoca vitulina*) in Atlantic Canada. J. Northw. Atl. Fish. Sci. 26: 1–23.

Hammill, M.O., and Stenson, G.B. 2009. Abundance of northwest Atlantic harp seals (1952–2010). DFO Can. Sci. Advis. Sec. Res. Doc. 2009/114: 16 p.

Hammill, M.O., and Stenson, G.B. 2010. A preliminary evaluation of the performance of the Canadian management approach for harp seals using simulation studies. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/093: iv + 47 p.

Hammill, M.O., and Stenson, G.B. 2011. Modelling grey seal abundance in Canadian waters. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/014: 31 p.

Hammill, M.O., Stenson, G.B., Myers, R.A., and Stobo, W.T. 1998. Pup production and population trends of the grey seal (*Halichoerus grypus*) in the Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci. 55: 423–430.

Hammill, M. O., Stenson, G.B., Proust, F., Carter, P., and McKinnon, D. 2007a. Feeding by grey seals in the Gulf of St. Lawrence and around Newfoundland. NAMMCO Sci. Publ. 6: 135B152.

Hammill, M.O., Lawson, J.W., Stenson, G.B., and Lidgard, D. 2007b. Pup production of northwest Atlantic grey seals in the Gulf of St. Lawrence and along the Nova Scotia Eastern Shore. DFO Can. Sci. Advis. Sec. Res. Doc. 2007/084: 29 p.

Hammill, M.O., Gosselin, J.-F., and Stenson, G.B. 2007c. Abundance of northwest Atlantic grey seals in Canadian waters. *In* Grey seals in the North Atlantic and the Baltic. Edited by T. Haug, M. Hammill, and D. Olafsdottir. NAMMCO Sci. Publ. 6: 99–115.

Hammond, P.S., Bearzi, G., Bjørge, A., Forney, K., Karczmarski, L., Kasuya, T., Perrin, W.F., Scott, M.D., Wang, J.Y., Wells, R.S., and Wilson, B. 2008a. *Delphinus delphis*. *In* IUCN 2011. IUCN Red List of Threatened Species. Version 2011.1. http://www.iucnredlist.org (accessed 31 October 2011).

Hammond, P.S., Bearzi, G., Bjørge, A., Forney, K., Karczmarski, L., Kasuya, T., Perrin, W.F., Scott, M.D., Wang, J.Y., Wells, R.S., and Wilson, B. 2008b. *Lagenorhynchus acutus*. *In* IUCN 2011. IUCN Red List of Threatened Species. Version 2011.1. http://www.iucnredlist.org (accessed 31 October 2011).

Hammond, P.S., Bearzi, G., Bjørge, A., Forney, K., Karczmarski, L., Kasuya, T., Perrin, W.F., Scott, M.D., Wang, J.Y., Wells, R.S., and Wilson, B. 2008c. *Phocoena phocoena*. *In* IUCN 2011. IUCN Red List of Threatened Species. Version 2011.1. http://www.iucnredlist.org (accessed 31 October 2011).

Hanson, J.M. 2009. Predator-prey interactions of American lobster (*Homarus americanus*) in the southern Gulf of St. Lawrence, Canada. New Zeal. J. Mar. Fresh. 43(1): 69–88.

Hare, J.A., Fahay, M.P., and Cowen, R.K. 2001 Springtime icthyoplankton of the slope region off the north-eastern United States of America: larval assemblages, relation to hydrography and implications for larval transport. Fish. Oceanogr. 10: 164–192.

Harvey, V., Côté, S.D., and Hammill, M.O. 2008. The ecology of 3-D space use in a sexually dimorphic mammal. Ecography 31: 371–380.

Hawkes, L.A., Broderick, A.C., Coyne, M.S., Godfrey, M.H., and Godley, B.J. 2007. Only some like it hot–quantifying the environmental niche of the loggerhead sea turtle. Divers. Distrib. 13: 447–457.

Head, E., and Harris, L. 2004. Estimating zooplankton biomass from dry weights of groups of individual organisms. DFO Can. Sci. Advis. Sec. Res. Doc. 2004/045: ii + 22 p.

Head, E., and Pepin, P. 2007. Variations in overwintering depth distributions of *Calanus finmarchicus* in the slope waters of the NW Atlantic continental shelf and the Labrador Sea. J. Northw. Atl. Fish. Sci. 39: 49–69.

Head, E.J.H., and Pepin, P. 2008. Seasonal cycles of *Calanus finmarchicus* abundance at fixed time series stations on the Scotian and Newfoundland shelves. AZMP Bulletin No. 7, 17–20.

Head, E., and Pepin, P. 2009. Long-term variability in phytoplankton and zooplankton abundance in the Northwest Atlantic in continuous plankton recorder (CPR) samples. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/063: vi + 29 p.

Head, E., Pepin, P., and Runge, J. 2001. Proceedings of the Workshop on the Northwest Atlantic Ecosystem – A Basin Scale Approach, 21–21 June 2001, Halifax, Canada. DFO Can. Sci. Advis. Sec. Proc. Ser. 2001/23: 113 p.

Heaslip, S.G., Iverson, S.J., Bowen, W.D., and James, M.C. 2012. Jellyfish Support High Energy Intake of Leatherback Sea Turtles (*Dermochelys coriacea*): Video Evidence from Animal-Borne Cameras. PLoS ONE 7(3): e33259.

Horsman, T.L., and Shackell, N.L. 2009. Atlas of important habitat for key fish species of the Scotian Shelf, Canada. Can. Tech. Rep. Fish. Aquat. Sci. 2835: viii + 82 p.

Horsman, T.L., Serdynska, A., Zwanenburg, K.C.T., and Shackell, N.L. 2011. Report on marine protected area network analsysis for the Maritimes Region of Canada. Can. Tech. Rep. Fish. Aquat. Sci. 2917: xi + 188 p.

Houghton, R., and Fairbanks, R. 2001. Water sources for Georges Bank. Deep-Sea Res. (2 Top. Stud. Oceanogr.) 48(1–3): 95–114.

Hughes, G.R. 1996. Nesting of the leatherback turtle (*Dermochelys coriacea*) in Tongaland, KwaZulu-Natal, South Africa, 1963–1995. Chelonian Conserv. Bi. 2(2): 153–158.

Hurlbut, T., and Clay, D. 1998. Morphometric and meristic differences between shallow- and deep-water populations of white hake (*Urophycis tenuis*) in the southern Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci. 55: 2274–2282.

ICCAT. 2010a. Report of the 2010 Atlantic bluefin tuna stock assessment session. ICCAT report.

ICCAT. 2010b. Report of the 2009 Atlantic swordfish stock assessment session. Collect. Vol. Sci. Pap. ICCAT 65: 1–123.

ICES. 2009. Report of the ICES-NAFO Working Group on Deep-water Ecology (WGDEC), 9–13 March 2009. ICES CM 2009\ACOM:23: 94 p.

James, M.C., and Mrosovsky, N. 2004. Body temperatures of leatherback turtles (*Dermochelys coriacea*) in temperate waters off Nova Scotia, Canada. Can. J. Zoolog. 82: 1302–1306.

James, M.C., Eckert, S.A., and Myers, R.A. 2005a. Migratory and reproductive movements of male leatherback turtles (*Dermochelys coriacea*). Mar. Biol. 147: 845–853.

James, M.C., Myers, R.A., and Ottensmeyer, C.A. 2005b. Behaviour of leatherback sea turtles, *Dermochelys coriacea*, during the migratory cycle. P. Roy. Soc. Lond. – Bio 272: 1547–1555.

James, M.C., Ottensmeyer, C.A., and Myers, R.A. 2005c. Identification of high-use habitat and threats to leatherback sea turtles in northern waters: new directions for conservation. Ecol. Lett. 8: 195–201.

James, M.C., Sherrill-Mix, S.A., Martin, K., and Myers, R.A. 2006a. Canadian waters provide critical foraging habitat for leatherback turtles. Biol. Conserv. 133: 347–357.

James, M.C., Davenport, J., and Hays, G.C. 2006b. Expanded thermal niche for a diving vertebrate: a leatherback turtle diving into near-freezing water. J. Exp. Mar. Biol. Ecol. 335: 221–226.

James, M.C., Sherrill-Mix, S.A., and R.A. Myers. 2007. Population size structure, sex ratios, and seasonal migrations of leatherback sea turtles at high latitudes. Mar. Ecol-Prog. Ser. 337: 245–254.

Jensen, C.F., Natanson, L.J., Pratt, H.L., Kohler, N.E., and Campana, S.E. 2002. The reproductive biology of the porbeagle shark (*Lamna nasus*) in the western North Atlantic Ocean. Fish. B-NOAA 100(4): 727–738.

Johnson, D.L. 2004. American plaice, *Hippoglossoides platessoides*, life history and habitat characteristics. U.S. Department of Commerce, NOAA Tech. Mem. NMFS-NE-187: v + 72 p.

Johnson, C., Harrison, G., Head, E., Spry, J., Pauley, K., Maass, H., Kennedy, M., Porter, C., Yashayaeva, I., and Casault, B. 2011 in prep. Optical, chemical, and biological oceanographic conditions in the Maritimes Region in 2010. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/xxx. vi + xx

Johnston, D.W., Friedlaender, A.S., Torres, L.G., and Lavigne, D.M. 2005. Variation in sea ice cover on the east coast of Canada from 1969 to 2002: climate variability and implications for harp and hooded seals. Climate Res. 29: 209–222.

Joyce, W.N., Campana, S.E., Natanson, L.J., Kohler, N.E., Pratt, H.L., and Jensen, C.F. 2002. Analysis of stomach contents of the porbeagle shark (*Lamna nasus* Bonnaterre) in the northwest Atlantic. ICES J. Mar. Sci. 59(6): 1263–1269.

Kareiva, P.M., and Odell, G. 1987. Swarms of predators exhibit “preytaxis” if individual predators use area-restricted search. Am. Nat. 130(2):233–270.

Keizer, P.D., and Boudreau, P.R. 2002. Proceedings of the Regional Advisory Process (RAP) workshop on the possible environmental impacts of petroleum exploration activities in the southern Gulf of St. Lawrence and Sydney Bight ecosystems, 21–23 November 2001, Antigonish, NS. DFO Can. Sci. Advis. Sec. Proc. Ser. 2001/032: 75 p.

Kenchington, E., and Glass, A. 1998. Local adaptation and sexual dimorphism in the waved whelk (*Buccinum undatum*) in Atlantic Nova Scotia with applications to fisheries management. Can. Tech. Rep. Fish. Aquat. Sci. No. 2237: iv + 43 p.

Kenchington, E., and Lundy, M.J. 1996. A summary of a whelk (*Buccinum undatum*) test fishery in the Tusket Island Area of southwest Nova Scotia with a review of biological characteristics relevant to the development of this resource. DFO Atl. Fish. Res. Doc. 96/12: 17 p.

Kenchington, E., Lirette, C., Cogswell, A., Archambault, D., Archambault, P., Benoit, H., Bernier, D., Brodie, B., Fuller, S., Gilkinson, K., Lévesque, M., Power, D., Siferd, T., Treble, M., and Wareham, V. 2010. Delineating coral and sponge concentrations in the biogeographic regions of the east coast of Canada using spatial analyses. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/041: 208 p.

Kenchington, E., Kenchington, T.J., Henry, L., Fuller, S., and Gonzalez, P. 2007. Multi-decadal changes in the megabenthos of the Bay of Fundy: The effects of fishing. J. Sea Res. 58(3): 220-240.

Koeller, P., Covey, M., and King, M. 2009. An assessment of the eastern Scotian Shelf shrimp stock and fishery in 2008 with an outlook for 2009. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/030: 52 p.

Kohler, A.C. 1971. Tagging of white hake, *Urophycis tenuis* Mitchill, in the southern Gulf of St. Lawrence. Int. Comm. Northw. Atl. Fish. Res. Bull. 8: 21B25.

Kostylev, V.E., and Hannah, C.G. 2007. Process-driven characterization and mapping of sea bed habitats. *In* Mapping the seafloor for habitat characterization. Edited by B.J. Todd and H.G. Greene. Geological Association of Canada, Special Paper 47. pp. 171–184.

Kovacs, K.M., and Lavigne, D.M. 1985. Neonatal growth and organ allometry of northwest Atlantic harp seals (*Phoca groenlandica*). Can. J. Zoolog. 63: 2793–2799.

Kuhn, P.S., and Choi, J.S. 2011. Influence of temperature on embryo developmental cycles and mortality of female *Chionoecetes opilio* (snow crab) on the Scotian Shelf, Canada. Fish. Res. 107(1–3): 245–252.

Kulka, D.W., Swain, D., Simpson, M.R., Miri, C.M., Simon, J., Gauthier, J., McPhie, R., Sulikowski, J., and Hamilton, L. 2006. Distribution, abundance, and life history of *Malacoraja senta* (smooth skate) in Canadian Atlantic waters with reference to its global distribution. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/093: vi + 112 p.

Kulka, D., Hood, C., and Huntington, J. 2007. Recovery strategy for northern wolffish (*Anarhichas denticulatus*) and spotted wolffish (*Anarhichas minor*), and management plan for Atlantic wolffish (*Anarhichas lupus*) in Canada. Fisheries and Oceans Canada: Newfoundland and Labrador Region. St. John’s, NL. x + 103 pp.

Lambert, T.C. 1995. The first report of the 4Vn sentinel survey: Autumn 1994: a government/industry cooperative venture. DFO Atl. Fish. Res. Doc. 1995/107: 52 p.

Lawson, J.W., and Gosselin, J.-F. 2009. Distribution and preliminary abundance estimates for cetaceans seen during Canada’s marine megafauna survey – a component of the 2007 TNASS. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/031: vi + 28 p.

Lazell, J.D., Jr. 1980. New England waters: critical habitat for marine turtles. Copeia 2: 290–295.

LeBlanc, C.H., Chouinard, G.A., Hurlbut, T., Poirier, G.A., Benoit, H., and Swain, D.P. 2001. Summary of information on Atlantic herring in the NAFO 4Tfg area of the southern Gulf of St. Lawrence and NAFO 4Vn area of Cape Breton. DFO Can. Sci. Advis. Sec. Res. Doc. 2001/119: 50 p.

LeBlanc, C.H., Swain, D., MacDougall, C., and Bourque, C. 2010. Assessment of the NAFO Division 4T southern Gulf of St. Lawrence herring stocks in 2009. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/059: 153 p.

Lesage, V., Hammill, M.O., and Kovacs, K.M. 2004. Long-distance movements of harbour seals (*Phoca vitulina*) from a seasonally ice-covered area, the St. Lawrence River estuary, Canada. Can. J. Zoolog. 82: 1070–1081.

Li, W.K.W., Andersen, R.A., Gifford, D.J., Incze, L.S., Martin, J.L., Pilskaln, C.H., Rooney-Varga, J.N., Sieracki, M.E., Wilson, W.H., and Wolff, N.H. 2011. Planktonic microbes in the Gulf of Maine area. PloS ONE 6(6): e20981. doi:10.1371/journal.pone.0020981.

Lidgard, D.C., Boness, D.J., Bowen, W.D., and McMillan, J.I. 2005. State-dependent male mating tactics in the grey seal: the importance of body size. Behav. Ecol. 16: 541–549.

Longhurst, A. 1998. Ecological geography of the sea. Academic Press, San Diego. xiv + 398 p.

Lonning, S.E., Kjorsuik, E., Haug, T., and Gilliksen, B. 1982. The early development of halibut (*Hippoglossus hippoglossus* (L.)) compared with other marine teleosts. Sarsia 67: 85–91.

López-Mendilaharsu, M., Rocha, C.F.D., Domingo, A., Wallace, B.P., and Miller, P. 2009. Prolonged, deep dives by the leatherback turtle *Dermochelys coriacea*: pushing their aerobic dive limits. J. Mar. Biol. Assoc. UK Biodiversity Records 1–3.

Lucas, Z., and Stobo, W.T. 2000. Shark-inflicted mortality on a population of harbour seals (*Phoca vitulina*) at Sable Island, Nova Scotia. J. Zool. London 252: 405–414.

Lunn, N.J., Stirling, I., and Nowicki, S.N. 1997. Distribution and abundance of ringed (*Phoca hispida*) and bearded seals (*Erignathus barbatus*) in western Hudson Bay. Can. J. Fish. Aquat. Sci. 54: 914–921.

Lutcavage, M., and Lutz, P.L. 1986. Metabolic rate and food energy requirements of the leatherback sea turtle, *Dermochelys coriacea*. Copeia 3: 796–798.

Lutcavage, M.E., Plotkin, P., Witherington, B., and Lutz, P.L. 1997. Human impacts on sea turtles survival. *In* The biology of sea turtles. Edited by P.L. Lutz and J.A. Musick. CRC Press, Boca Raton, FL. pp. 387–409.

MacIsaac, K., Bourbonnais, C., Kenchington, E., Gordon, D., and Gass, S. 2001. Observations on the occurrence and habitat preference of corals in Atlantic Canada. *In* Proceedings of the First International Symposium on Deep-sea Corals. Edited by J.H.M. Willison, J. Hall, S.E. Gass, E.L.R. Kenchington, M. Butler, and P. Doherty. Ecology Action Centre and Nova Scotia Museum, Halifax, Nova Scotia. pp. 58–75.

Mahon, R., and Smith, R. 1989. Fish assemblages on the Scotian Shelf, northwest Atlantic: spatial distribution and persistance. Can. J. Fish. Aquat. Sci. 46: 134–152.

Mahon, R., Brown, S.K, Zwanenberg, K.C.T., Atkinson, D.B., Buja, K.R., Claflin, L., Howell, G.D., Monaco, M.E., O'Boyle, R.N., and Sinclair, M. 1998. Assemblages and biogeography of demersal fishes of the east coast of North America. Can. J. Fish. Aquat. Sci. 55: 1704–1738.

Martel, A., Larrivee, D.H., and Himmelman, J.H. 1986. Behavior and timing of copulation and egg-laying in the neogastropod *Buccinum undatum* L. J. Exp. Mar. Biol. Ecol. 96(1): 27–42.

McAllister, M., and Duplisea, D.E. 2011a. Production model fitting and projection for Atlantic redfish (*Sebastes fasciatus* and *Sebastes mentella*) to assess recovery potential and allowable harm. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/057: vi + 75 p.

McAllister, M., and Duplisea, D.E. 2011b in prep. Production model fitting and projection for Acadian redfish (*Sebastes fasciatus*) in Units 1 and 2. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/xxx.

McAlpine, D.F., James, M.C., Lien, J., and Orchard, S.A. 2007. Status and conservation of marine turtles in Canadian waters. *In* Ecology, Conservation and Status of Reptiles in Canada. Herpetological Conservation 2: 85–112. Edited by C.N.L. Seburn and C.A. Bishop.

McEachran, J.D. 2002. Skates. Family Rajidae. *In* Bigelow and Schroeder's fishes of the Gulf of Maine. 3rd Edition. Edited by B.B. Collette and G. Klein-MacPhee. Smithsonian Institution Press, Washington, DC. pp. 60–75.

McQuinn, I.H. 2009. Pelagic fish outburst or suprabenthic habitat occupation: legacy of the Atlantic cod (*Gadus morhua*) collapse in eastern Canada. Can. J. Fish. Aquat. Sci. 66: 2256–2262.

McRuer, J., Hurlbut, T., and Morin, B. 2000. Status of wolffish (*Anarhichas lupus*) in the Maritimes (NAFO SubArea 4 and Division 5Ze). DFO Can. Stock Assess. Sec. Res. Doc. 2000/138: 55 p.

Messieh, S.N. 1988. Spawning of Atlantic herring in the Gulf of St. Lawrence. Am. Fish. S. S. 5: 31–48.

Michelutti, N., Brash, J., Thienpont, J., Blais, J.M., Kimpe, L., Mallory, M.L., Douglas, M.S.V., and Smol, J.P. 2010. Trophic position influences the efficacy of seabirds as contaminant biovectors. Proc. Nat. Acad. Sci. 107: 10543–10548.

Mitchell, E. 1974. Present status of northwest Atlantic fin and other whale stocks. *In* The whale problem: a status report. Edited by W.E. Schevill. Harvard University Press, Cambridge, MA. pp. 109–169.

Moein, S.E., Musick, J.A., Keinath, J.A., Barnard, D.E., Lenhardt, M., and George, R. 1994. Evaluation of seismic sources for repelling sea turtles from hopper dredges: final report submitted to the U.S. Army Corps of Engineers waterways experiment station. 33. Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, VA. 33 p.

Mohn, R., and Bowen, W.D. 1996. Grey seal predation on the eastern Scotian Shelf: modelling the impact on Atlantic cod. Can. J. Fish. Aquat. Sci. 53: 2722–2738.

Montevecchi, W.A. 2006. Influences of artifical light on marine birds. *In* Ecological consequences of artificial night lighting. Edited by C. Rich and T. Longcore. Island Press, Washington, DC. pp. 94–113.

Morin, B., Power, D., and Gagnon, P. 1994. Distribution of redfish (*Sebestaes* spp.) in the Gulf of St. Lawrence and in the Laurentian Channel based on RV surveys and commercial fishery catch rates. DFO Atl. Fish. Res. Doc. 94/91.

Morissette, L., Despatie, S.-P., Savenkoff, C., Hammill, M.O., Bourdages, H., and Chabot, D. 2003. Data gathering and input parameters to construct ecosystem models for the northern Gulf of St. Lawrence (mid-1980s). Can. Tech. Rep. Fish. Aquat. Sci. 2497: vi + 94 p.

Mortensen, P.B., and Buhl-Mortensen, L. 2005. Deep-water corals and their habitats in The Gully, a submarine canyon off Atlantic Canada. *In* Cold-water corals and ecosystems. Edited by A. Freiwald and J.M. Roberts. Springer-Verlag, New York. pp. 247–277.

Mortensen, P.B., Buhl-Mortensen, L., and Gordon, D.C., Jr. 2006. Distribution of deep-water corals in Atlantic Canada. *In* Proceedings of the 10th International Coral Reef Symposium, 28 June – 3 July 2004. Edited by Y. Suzuki, T. Nakamori, M. Hidaka, H. Kayanne, B. E. Casareto, K. Nadaoka, H. Yamano, and M. Tsuchiya. Japanese Coral Reef Society, Okinawa, Japan. pp. 1832–1848.

Mrosovsky, N., Ryan, G.D., and James, M.C. 2009. Leatherback turtles: the menace of plastic. Mar. Poll. Bull. 58: 287–289.

Muelbert, M.M.C., and Bowen, W.D. 1993. Duration of lactation and postweaning changes in mass and body composition of harbour seal, *Phoca vitulina*, pups. Can. J. Zoolog. 71: 1405–1414.

Mullowney, D.R., Dawe, E.G., Morado, J.F., and Cawthorn, R.J. 2011. Sources of variability in prevalence and distribution of bitter crab disease in snow crab (*Chionoecetes opilio*) along the northeast coast of Newfoundland. ICES J. Mar. Sci. 68(3): 463–471.

Musick, J.A. 2004. Introduction: management of sharks and their relatives (Elasmobranchii). *In* Elasmobranch Fisheries Management Techniques. Edited by J.A. Musick and R. Bonfil. Asia Pacific Economic Cooperation Publication APEC#203-FS-03.2. pp. 1–6.

Musick, J.A., Burgess, G., Cailliet, G., Camhi, M., and Fordham, S. 2000. Management of sharks and their relatives (Elasmobranchii). Fisheries 25: 9–13.

Myers, R.A., Mertz, G., and Fowlow, P.S. 1997. Maximum population growth rates and recovery times for Atlantic cod, *Gadus morhua*. Fish. B-NOAA 95: 762–772.

Nagler, J.J., Adams, B.A., and Cyr, D.G. 1999. Egg production, fertility, and hatch success of American plaice held in captivity. Trans. Amer. Fish. Soc. 128: 727–736.

Neilson, J.D., Kearney, J.F., Perley, P., and Sampson, H. 1993. Reproductive biology of Atlantic halibut (*Hippoglossus hippoglossus*) in Canadian waters. Can. J. Fish. Aquat. Sci. 50: 551–563

Nesis, K.N. 1962. Soviet investigations of the benthos of the Newfoundland-Labrador fishing area. Israel Program of Scientific Translations for the U.S. Department of the Interior and National Science Foundation, Jerusalem.

Nevinsky, M.M., and Serebryakov, V.P. 1973. American plaice, *Hippoglossoides platessoides* Fabr., spawning in the northwest Atlantic area. ICNAF Res. Bull. 10: 23–36.

NMFS (National Marine Fisheries Service) and U.S. Fish and Wildlife Service. 1992. Recovery plan for leatherback turtles (*Dermochelys coriacea*) in the U.S. Caribbean, Atlantic and Gulf of Mexico. National Marine Fisheries Service, Washington, DC. 65 p.

O’Boyle, R.N. 2001. Proceedings of a meeting on Subarea 4 witch stock structure, Regional Advisory Process, Maritimes Region, Miramichi, NB, 18–19 January 2001. DFO Can. Sci. Advis. Sec. Proc. Ser. 2001/06: 16 p.

O’Boyle, R.N., and Lett, P.F. 1977. Status of capelin (*Mallotus villosus*) stocks in the Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Res. Doc. 77/004: 18 p.

O’Boyle, R.N., Sinclair, M., Conover, R.J., Mann, K.H., and Kohler, A.C. 1984. Temporal and spatial distribution of ichthyoplankton communities of the Scotian Shelf in relation to biological hydrological and physiographic features. Rapp. P.-V. Reun. Cons. Int. Explor. Mer. 183: 27–40.

O’Boyle, R.N. and Sinclair, M. 2011. Seal-cod interactions on the Eastern Scotian Shelf: reconsideration of modelling assumptions. Fish. Res. 116: 1–13.

O’Hara, J., and Wilcox, J.R. 1990. Avoidance responses of loggerhead turtles, *Caretta caretta*, to low frequency sound. Copeia 2: 564–567.

OTN. 2011. Ocean Tracking Network Newsletter 1(1). http://oceantrackingnetwork.org/newslettervol1iss1.pdf (accessed 9 December 2011).

Packer, D.B., Zetlin, C.A., and Vitaliano, J.J. 2003. Smooth skate, *Malacoraja senta*, life history and habitat characteristics. U.S. Department of Commerce, NOAA Tech. Mem. NMFS-NE-177: 26 p.

Petrie, B., and Yeats, P. 2000. Annual and interannual variability of nutrients and their estimated fluxes in the Scotian Shelf–Gulf of Maine region. Can. J. Fish. Aquat. Sci. 57: 2536–2546.

Petrie, B., Drinkwater, K., Gregory, D., Pettipas, R., and Sandstrom, A. 1996. Temperature and salinity atlas for the Scotian Shelf and the Gulf of Maine. Can Tech. Rep. Hydrogr. Ocean. Sci. 171: v + 398 p.

Petrie, B., Pettipas, R., and Petrie, W. 2005. An overview of meteorological, sea ice and sea-surface temperature conditions off eastern Canada during 2004. DFO Can. Sci. Advis. Sec. Res. Doc. 2005/020: 37 p.

Petrie, B., Pettipas, R., Petrie, W., and Soukhovtsev, V. 2009. Physical oceanographic conditions on the Scotian Shelf and in the Gulf of Maine during 2008. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/039: iv + 13 p.

Pitman, R.L., and Dutton, P.H. 2004. Killer whale predation on a leatherback turtle in the northeast Pacific. Pac. Sci. 58: 497–498.

Pocklington, R., Leonard, J.D., and Crewe, N.F. 1991. Sources of organic matter to surficial sediments from the Scotian Shelf and Slope. Cont. Shelf Res. 11: 1069–1082.

Power, M.J., Fife, F.J., Knox, D., and Melvin, G.D. 2010. 2009 evaluation of 4VWX herring. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/111: vi + 89 p.

Powles, P.M. 1965. Life history and ecology of American plaice (*Hippoglossoides platessoides* F.) in the Magdalen shallows. J. Fish. Res. Bd. Can. 22: 565–598.

Pritchard, P.C.H. 1982. Nesting of the leatherback turtle, *Dermochelys coriacea*, in Pacific Mexico, with a new estimate of the world population status. Copeia 4: 741–747.

Prouse, N.J., and Ellis, D.V. 1997. A baseline survey of dogwhelk (*Nucella lapillus*) imposex in eastern Canada and interpretation in terms of Tributyltin (TBT) contamination. Environ. Technol. 18 (12): 1255–1264.

Provencher, J.F., Gaston, A.J., Mallory, M.L., O'Hara, P.D., and Gilchrist, H.G. 2010. Ingested plastic in a diving seabird, the thick-billed murre (*Uria lomvia*), in the eastern Canadian Arctic. Mar. Poll. Bull. 60(9): 1406–1411.

Rawlings, T., McVarish, C., and Hatcher, B. 2009. Experimental fishing trials for waved whelk (*Buccinum undatum*) in eastern Nova Scotia: Autumn, 2008. New Fisheries Centre Research Publication No. 2009-1, Bras d'Or Institute for Ecosystem Research, Cape Breton University, Sydney, NS. 22 p.

Reeves, A., Choi, J., and Tremblay, J. 2011. Lobster size at maturity estimates in eastern Cape Breton, Nova Scotia. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/079: vi + 18 p.

Reeves, R.R., Smeenk, C., Brownell Jr., R. L. and Kinze, C.C. 1999. Atlantic white-sided dolphin *Lagenorhynchus acutus* (Gray, 1828). *In* Handbook of marine mammals, Vol. 6: The second book of dolphins and the porpoises. Edited by S. H. Ridgway and R. Harrison. Academic Press, London. pp. 31–56.

Reilly, S.B., Bannister, J.L., Best, P.B., Brown, M., Brownell Jr., R.L., Butterworth, D.S., Clapham, P.J., Cooke, J., Donovan, G.P., Urbán, J., and Zerbini, A.N. 2008a. *Balaenoptera musculus*. *In* IUCN Red List of Threatened Species [online Version 2011.1]. http://www.iucnredlist.org (downloaded 31 October 2011).

Reilly, S.B., Bannister, J.L., Best, P.B., Brown, M., Brownell Jr., R.L., Butterworth, D.S., Clapham, P.J., Cooke, J., Donovan, G.P., Urbán, J., and Zerbini, A.N. 2008b. *Balaenoptera borealis*. *In* IUCN Red List of Threatened Species [online Version 2011.1]. http://www.iucnredlist.org (downloaded 26 October 2011).

Reilly, S.B., Bannister, J.L., Best, P.B., Brown, M., Brownell Jr., R.L., Butterworth, D.S., Clapham, P.J., Cooke, J., Donovan, G.P., Urbán, J., and Zerbini, A.N. 2008c. *Balaenoptera acutorostrata*. *In* IUCN Red List of Threatened Species [online Version 2011.1]. http://www.iucnredlist.org (downloaded 26 October 2011).

Reilly, S.B., Bannister, J.L., Best, P.B., Brown, M., Brownell Jr., R.L., Butterworth, D.S., Clapham, P.J., Cooke, J., Donovan, G.P., Urbán, J., and Zerbini, A.N. 2008d.

Megaptera novaeangliae. *In* IUCN Red List of Threatened Species [online Version 2011.1]. http://www.iucnredlist.org (downloaded 28 October 2011).

Roff, J.C., Taylor, M.E., and Laughren, J. 2003. Geophysical approaches to the classification, delineation and monitoring of marine habitats and their communities. Aquat. Conserv. 13(1): 77–90.

Ronald, K., and Dougan, J.L. 1982. The ice lover: biology of the harp seal (*Phoca groenlandica*). Science 215: 928–933.

Rose, G.A. 2007. Cod: the ecological history of the North Atlantic fisheries. Breakwater, St. John's, NL.

Roy, D., Hurlbut, T.R., and Ruzzante, D.E. 2011. Biocomplexity in a demersal exploited fish, white hake (*Urophycis tenuis*): depth related structure and inadequacy of current management approaches. Proc. Royal Soc. B. (in review).

Saemundsson, B. 1949. Marine pisces. *In* The zoology of Iceland, 4(72). Edited by A. Frioriksson and S.L. Tuxen. Ejnar Munksgaard, Copenhagen. pp. 72–124.

Sainte-Marie, B. 1993. Reproductive cycle and fecundity of primiparous and multiparous female snow crab, *Chionoecetes opilio*, in the northwest Gulf of Saint Lawrence. Can. J. Fish. Aquat. Sci. 50(10): 2147–2156.

Sameoto, D.D., and Herman, A.W. 1992. Effect of the outflow from the Gulf of St. Lawrence on Nova Scotian shelf zooplankton. Can. J. Fish. Aquat. Sci. 49: 857–869.

Sameoto, D.D., and Cochrane, N. 1996. Euphasiids on the eastern continental shelf. DFO Atl. Fish. Res. Doc. 96/119.

Savenkoff, C., Grégoire, F., Castonguay, M., Hanson, J.M., Chabot, D., and Swain, D.P. 2006. Main prey and predators of Atlantic herring (*Clupea harengus* L.) in the Gulf of St. Lawrence during the mid-1980s, mid-1990s, and early 2000s. Can. Tech. Rep. Fish. Aquat. Sci. 2643: vi + 28 p.

Schaefer, H.L., McCullough, D.M., Johnson, S.K., and Duggan, D.R. 2004. Significant habitats: Atlantic Coast Initiative (SHACI): Sydney Bight, Unit 11. Can. Manuscr. Rep. Fish. Aquat. Sci. 2650: x + 213 p.

Scott, J.S. 1982. Selection of bottom type by ground fishes of the Scotian Shelf. Can. J. Fish. and Aquat. Sci. 39: 943–947.

Scott, W.B., and Scott, M.G. 1988. Atlantic fishes of Canada. University of Toronto Press, Toronto. Can. B. Fish. Aquat. Sci. 219. 731 p.

Sears, R., and Calambokidis, J. 2002. Status of the blue whale, *Balaenoptera musculus*, in Canada. Report to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), Ottawa. 38 p.

Selzer, L.A., and Payne, P.M. 1988. The distribution of white-sided (*Lagenorhynchus acutus*) and common dolphins (*Delphinus delphis*) vs. environmental features of the continental shelf of the northeastern United States. Mar. Mammal Sci. 4(2): 141–153.

Sergeant, D.E. 1966. Reproductive rates of harp seals, *Pagophilus groenlandicus* (Erxleben). J. Fish. Res. Board Can. 23: 757–766.

Shackell, N., Frank, K.T., Fisher, J.A.D., Petrie, B., and Leggett, W.C. 2010. Decline in top predator body size and changing climate alter trophic structure in an oceanic ecosystem. Proc. R. Soc. B 277: 1353–1360.

Shoop, C.R., and Kenney, R.D. 1992. Seasonal distributions and abundances of loggerhead and leatherback sea turtles in waters of the northeastern United States. Herpetol. Monogr. 6: 43B67.

Simard, Y., Lavoie, D., and Saucier, F.J. 2002. Channel head dynamics: capelin (*Mallotus villosus*) aggregation in the tidally driven upwelling system of the Saguenay St. Lawrence Marine Park's whale feeding ground. Can. J. Fish. Aquat. Sci. 59(2): 197–210.

Simon, J.E., Rowe, S., and Cook, A. 2011a. Pre-COSEWIC review of Atlantic, northern, and spotted wolffish in the Maritimes Region. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/088: vi + 73 p.

Simon, J.E., Rowe, S., and Cook, A. 2011b. Status of smooth skate (*Malacoraja senta*) and thorny skate (*Amblyraja radiata*) in the Maritimes Region. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/080: viii + 102 p.

Sinclair, A., 1992. Fish distribution and partial recruitment: the case of eastern Scotian Shelf cod. J. Northw. Atl. Fish. Sci. 13: 15–24.

Smith, T.G., and Hammill, M.O. 1981. Ecology of the ringed seal, *Phoca hispida*, in its fast ice breeding habitat. Can. J. Zoolog. 59: 966–981.

Smith, T.G., and Stirling, I. 1975. The breeding habitat of the ringed seal (*Phoca hispida*). The birth lair and associated structures. Can. J. Zoolog. 53: 1297–1305.

Song, H., Rubao, J., Stock, C., Kearney, K., and Wang, Z. 2011. Interannual variability in phytoplankton blooms and plankton productivity over the Nova Scotian Shelf and in the Gulf of Maine. Mar. Ecol. Prog. Ser. 426: 105–118.

Sourisseau, M., Simard, Y., and Saucier, F.J. 2006. Krill aggregation in the St. Lawrence system, and supply of krill to the whale feeding grounds in the estuary from the gulf. Mar. Ecol. Prog. Ser. 314: 257–270.

Spotila, J.R., Dunham, A.E., Leslie, A.J., Steyermark, A.C., Plotkiin, P.T., and Paladino, F.V. 1996. Worldwide population decline of *Dermochelys coriacea*: are leatherback turtles going extinct? Chelonian Conserv. Bi. 2(2): 209–222.

Steele, D.H., Green, J.M., and Carter, J. 1979. A biological and oceanographic study of the Atlantic southeast coast marine region. A report submitted to Parks Canada, Department of Indian and Northern Affairs. 236 p.

Stevick, P.T., McConnell, B.J., and Hammond, P.S. 2002. Patterns of movement. *In* Marine mammal biology: an evolutionary approach. Edited by A.R. Hoelzel. Blackwell Science, Malden, MA. pp. 185–216.

Stevick, P.T., Allen, J., Clapham, P.J., Katona, S.K., Larsen, F., Lien, J., Mattila, D.K., Palsboll, P.J., Sears, R., Sigurjonsson, J., Smith, T.D., Vikingsson, G., Oien, N., and Hammond, P.S. 2006. Population spatial structuring on the feeding grounds in North Atlantic humpback whales (*Megaptera novaeangliae*). J. Zool. 270(2): 244–255.

Stewart, K., Sims, M., Meylan, A., Witherington, B., Brost, B., and Crowder, L.B. 2011. Leatherback nests increasing significantly in Florida, USA: trends assessed over 30 years using multilevel modeling. Ecol. Appl. 21:263–273.

Stobo, W.T., and Fowler, G.M. 2006. Canadian tagging of commercial groundfish and small pelagic fish in the vicinity of the Scotian Shelf and Gulf of St. Lawrence, 1953–1985. Can. Tech. Report. Fish. Aquat. Sci. No. 2669. xii + 137 p.

Stobo, W.T., and Simon, J. 1982. Biological update for 4Vn herring, 1981–82. DFO Can. Atl. Fish. Sci. Advis. Cmte Res. Doc. 82/039.

Stobo, W.T., and Zwanenburg, K.C.T. 1990. Grey seal (*Halichoerus grypus*) pup production on Sable Island and estimates of recent production in the Northwest Atlantic. Can. Bull. Fish. Aquat. Sci. 222: 171–184.

Stobo, W., Neilson, J.D., and Simpson, P. 1988. Movements of Atlantic halibut (*Hippoglossus hippoglossus*) in the Canadian North Atlantic: inference regarding life history. Can. J. Fish. Aquat. Sci. 45: 484–491.

Swain, D.P. 1993. Age- and density-dependent bathymetric pattern of Atlantic cod (*Gadus morhua*) in the southern Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci. 50: 1255–1264.

Swain, D.P. 2011. Life-history evolution and elevated natural mortality in a population of Atlantic cod (*Gadus morhua*). Evol. Apps. 4(1): 18–29.

Swain, D.P., and Chouinard, G.A. 2008. Viability of the southern Gulf of St. Lawrence cod population. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/018: iv + 10 p.

Swain, D.P., and Morin, R.B. 2006. Status of witch flounder in NAFO divisions 4RST, February 2006. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/005: iv + 50 p.

Swain, D.P., Frank, K.T., and Maillet, G. 2001. Delineating stocks of Atlantic cod (*Gadus morhua*) in the Gulf of St Lawrence and Cabot Strait areas using vertebral number. ICES J. Mar. Sci. 58(1): 253–269.

Swain, D.P., Simon, J.E., Harris, L.E., and Benoît, H.P. 2006. Recovery potential assessment of 4T and 4VW winter skate (*Leucoraja ocellata*): biology, current status and threats. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/03: 69 p.

Tasker, M.L., Camphuysen, C.J., Cooper, J., Garthe, S., Montevecchi, W.A., and Blaber, S.J.M. 2000. The impacts of fishing on marine birds. ICES J. Mar. Sci. 57: 531–547.

Taylor, B.L., Baird, R., Barlow, J., Dawson, S.M., Ford, J., Mead, J.G., Notarbartolo di Sciara, G., Wade, P., and Pitman, R.L. 2008a. *Globicephala melas*. *In* IUCN Red List of Threatened Species [online Version 2011.1]. http://www.iucnredlist.org (downloaded 28 October 2011).

Taylor, B.L., Baird, R., Barlow, J., Dawson, S.M., Ford, J., Mead, J.G., Notarbartolo di Sciara, G., Wade, P., and Pitman, R.L. 2008b. *Orcinus orca*. *In* IUCN Red List of Threatened Species [online Version 2011.1]. http://www.iucnredlist.org (downloaded 28 October 2011).

Templeman, W. 1984. Migrations of wolffishes, *Anarhichas* sp., from tagging in the Newfoundland area. J. Northw. Atl. Fish. Sci. 5: 93–97.

Templeman, W. 1985. Stomach contents of Atlantic wolffish (*Anarhichas lupus*) from the Northwest Atlantic. NAFO Sci. Coun. Studies 8: 49–51.

Templeman, N.D., Brattey, J., Campana, S., Colbourne, E., Han, G., Kulka, D.W., Lawson, J., Maillet, G., Miri, C.M., Roy, A., Shea, N., Ollerhead, L.M.N., Pepin, P., Power, D., Simpson, M.R., and Wareham, V. 2010. Biophysical overview of the Laurentian Channel study area in support of marine protected area development. DFO DFO Can. Sci. Advis. Sec. Res. Doc. 2010/XXX. vv + XX pp. In press.

TEWG (Turtle Expert Working Group). 2007. An assessment of the leatherback turtle population in the Atlantic Ocean. U.S. Dept. of Commerce, NOAA Tech. Mem. NMFS-SEFSC-555: 116 p.

Thomas, L., Hammill, M.O., and Bowen, W.D. 2007. Estimated size of the northwest Atlantic grey seal population 1977–2007. DFO Can. Sci. Advis. Sec. Res. Doc. 2007/082: 31 p.

Thompson, P.M., McConnell, B.J., Tollit, D.J., MacKay, A., Hunter, C., and Racey, P.A. 1996. Comparative distribution, movements and diet of harbour and grey seals from the Moray Firth, NE Scotland. J. Appl. Ecol. 33: 1572–1584.

Thompson, P.M., MacKay, A., Tollit, D.J., Enderby, S., and Hammond, P.S. 1998. The influence of body size and sex on the characteristics of harbour seal foraging trips. Can. J. Zoolog. 76: 1044–1053.

Todd, B.J., and Kostylev, V.E. 2011. Surficial geology and benthic habitat of the German Bank seabed, Scotian Shelf, Canada. Cont. Shelf Res. 31(2): S54–S68.

Todd, B.J., Kostylev, V.E., and Shaw, J. 2006. Benthic habitat and sun-illuminated seafloor topography, Browns Bank, Scotian Shelf, offshore Nova Scotia. Geological Survey of Canada, Ottawa.

Tollit, D.J., and Thompson, P.M. 1996. Seasonal and between-year variations in the diet of harbour seals in the Moray Firth, Scotland. Can. J. Zoolog. 74: 1110–1121.

TRAC (Transboundary Resources Assessment Committee). 2010. Proceedings of the Transboundary Resources Assessment Committee (TRAC) mackerel benchmark assessment: report of meetings held 22–23 October 2009 and 1–4 March 2010. TRAC Proceedings 2010/003.

Tremblay, M.J., Black, G.A.P., and Branton, R.M. 2007. The distribution of common decapod crustaceans and other invertebrates recorded in annual ecosystem surveys of the Scotian Shelf 1999–2006. Can. Tech. Rep. Fish. Aquat. Sci. 2762. iii + 74 p.

Tremblay, M.J., Smith, S.J., Todd, B.J., Clement, P.M., and McKeown, D.L. 2009. Associations of lobsters (*Homarus americanus*) off southwestern Nova Scotia with bottom type from images and geophysical maps. ICES J. Mar. Sci. 66(9): 2060–2067.

Tremblay, J., Pezzack, D., Denton, C., Reeves, A., Smith, S., Silva, A., and Allard, J. 2011. Framework for assessing lobster off the coast of eastern Cape Breton and the eastern and south shores of Nova Scotia (LFAs 27–33). DFO Can. Sci. Advis. Sec. Res. Doc. 2011/058: viii + 180 p.

Trzcinski, M.K., Mohn, R., and Bowen, W.D. 2006. Continued decline of an Atlantic cod population: how important is gray seal predation? Ecol. Apps. 16: 2276–2292.

Trzcinski, M.K., Armsworthy, S.L., Wilson, S., Mohn, R.K., Fowler, M., and Campana, S.E. 2009a. Atlantic halibut on the Scotian Shelf and southern Grand Banks (NAFO Divisions 3NOPs4VWX5Zc) – Industry/DFO longline survey and tagging results to 2008. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/026: vi + 43 p.

Trzcinski, M.K., Mohn, R., and Bowen, W.D. 2009b. Estimating the impact of grey seals on the eastern Scotian Shelf and western Scotian Shelf cod populations. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/052. viii + 19 p.

Trzcinski, M.K., Armsworthy, S.L., Wilson, S., Mohn, R.K., and Campana, S.E. 2011a. A framework for the assessment of the Scotian Shelf and southern Grand Banks Atlantic halibut stock. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/002: vi + 112 p.

Trzcinski, M.K., den Heyer, C., Armsworthy, S., Whoriskey, S., Archambault, D., Treble, M., Simpson, M., and Mossman, J. 2011b. Pre-COSEWIC review of Atlantic halibut (*Hippoglossus hippoglossus*) on the Scotian Shelf and Southern Grand Banks (Divs. 3NOPs4VWX5Zc), Gulf of St. Lawrence (Divs. 4RST), Newfoundland and Labrador, and Central and Arctic. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/030: vi + 77 p.

Tucker, S., Bowen, W.D., Iverson, S.J., Blanchard, W., and Stenson, G.B. 2009. Sources of variation in diets of harp and hooded seals estimated from quantitative fatty acid signature analysis (QFASA). Mar. Ecol-Prog. Ser. 384: 287–302.

Van Buskirk, J., and Crowder, L.B. 1994. Life-history variation in marine turtles. Copeia (1): 66–81.

Wade, E., Surette, T., Apaloo, J., and Moriyasu, M. 2003. Estimation of mean annual natural mortality for adult male snow crab *Chionoecetes opilio* in the southern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Res. Doc. 2003/017: 29 p.

Walker, B.G., and Bowen, W.D. 1993. Changes in body mass and feeding behaviour in male harbour seals, *Phoca vitulina*, in relation to female reproductive status. J. Zool. London 231: 423–436.

Walters, C., and Kitchell, J.F. 2001. Cultivation/depensation effects on juvenile survival and recruitment: implications for the theory of fishing. Can. J. Fish. Aquat. Sci. 58: 1–12.

Waring, G.T., Josephson, E., Fairfield, C.P., and Maze-Foley, K. 2006. U.S. Atlantic and Gulf of Mexico marine mammal stock assessments – 2005. U.S. Department of Commerce, NOAA Tech. Mem. NMFS-NE-194: 346 p.

Whitehead, H., Bowen, W.D., Hooker, S.K., and Gowans, S. 1998. Marine mammals. *In* The Gully: a scientific review of its environment and ecosystem. Edited by W.G. Harrison and D.G. Fenton. Department of Fisheries and Oceans, Ottawa. DFO Can. Stock Ass. Sec. Res. Doc. 98/83: 186–221.

Wiese, F.K, Montevecchi, W.A., Davoren, G.K., Huettmann, F., Diamond, A.W., and Linke, J. 2001. Seabirds at risk around offshore oil platforms in the North-west Atlantic. Mar. Poll. Bull. 42: 1285–1290.

Wilson, J.B. 1979. 'Patch' development of the deep-water coral *Lophelia pertusa* (L.) on Rockall Bank. J. Mar. Biol. Assoc. UK 59: 165–177.

Winemiller, K.O., and Rose, K.A. 1992. Patterns of life history diversification in North American fishes: implication for population regulation. Can. J. Fish. Aquat. Sci. 49: 2196–2218.

Winters, G.H., and Beckett, J.S. 1978. Migrations, biomass and stock interrelationships of southwest Newfoundl and southern Gulf herring from mark-recapture experiments. Int. Comm. Northw. Atl. Fish. Res. Bull. No. 13: 68–79.

Woodley, T.H., and Gaskin, D.E. 1996. Environmental characteristics of north Atlantic right and fin whale habitat in the lower Bay of Fundy, Canada. Can. J. Zoolog. 74(1): 75–84.

Worcester, T., Brattey, J., Chouinard, G.A., Clark, D., Clark, K.J., Deault, J., Fowler, M., Fréchet, A., Gauthier, J., Healey, B., Lambert, Y., Parsons, D.M., Mohn, R., Morgan, M.J., Murphy, E.F., Power, D., Powles, H., Schwab, P., Swain, D.P., and Treble, M. 2009. Status of Atlantic cod (*Gadus morhua*) in 2008. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/027: vi + 167 p.

WWF-Canada. 2009. An ocean of diversity: the seabeds of the Canadian Scotian Shelf and Bay of Fundy. WWF-Canada, Halifax, Canada. 24 p.

Yeats, P., Hellou, J., King, T., and Law, B. 2009. Measurements of chemical contaminants and toxicological effects in the Gully. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/066: iv + 21 p.

Yeats, P., Ryan, S., and Harrison, G. 2010. Temporal trends in nutrient and oxygen concentrations in the Labrador Sea and on the Scotian Shelf. AZMP Bull. 9: 23–27.

Zamarro, J. 1992. Determination of fecundity in American plaice and its variation from 1987 to 1989 on the tail of the Grand Bank. Neth. J. Sea Res. 29: 205–209.

Zeller, D., and Pauly, D. 2000. How life history patterns and depth zone analysis can help fisheries policy. *In* Methods for evaluating the impacts of fisheries on North Atlantic ecosystems. Edited by D. Pauly and T.J. Pitcher. Fisheries Centre Research Reports 8(2). pp. 40–53.

Zwanenburg, K.C.T., and Wilson, S. 2000. Scotian Shelf and southern Grand Banks Atlantic halibut (*Hippoglossus hippoglossus*) survey – collaboration between the fishing and fisheries science communities. 88th Statutory Meeting, Annual Science Conference 2000, Bruges, Belgium, theme session on Cooperative Research with the Fishing Industry: Lessons Learned. ICES CM 2000/W:20. ICES, Copenhagen.

Zwanenburg, K.C.T., Bowen, D., Bundy, A., Drinkwater, K., Frank, K., O'Boyle, R., Sameoto, D., and Sinclair, M. 2002. Decadal changes in the Scotian Shelf large marine ecosystem. *In* Large marine ecosystems of the North Atlantic. Changing states and sustainability. Edited by K. Sherman and H.R. Skoldal. Elsevier Press, Amsterdam. pp. 105–150.

Zwanenburg, K., Bundy, A., Strain, P., Bowen, W., Breeze, H., Campana, S., Hannah, C., Head, E., and Gordon, D. 2006. Implications of ecosystem dynamics for the integrated management of the eastern Scotian Shelf. Can. Tech. Rep. Fish. Aquat. Sci. 2652: xiii + 91 p.

7. APPENDICES

A. ABBREVIATIONS

AOI	Area of Interest
AZMP	Atlantic Zone Monitoring Program
CBD	Convention on Biological Diversity
CCGS	Canadian Coast Guard Ship
CIL	Cold Intermediate Layer
CITES	Convention on International Trade in Endangered Species
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPR	Continuous Plankton Recorder
CPUE	catch per unit of effort
CSAS	Canadian Science Advisory Secretariat
CSL	Cabot Strait Line
CSTN	Canadian Sea Turtle Network
DFO	Fisheries and Oceans Canada
DU	designatable unit
DWAO	Design-Weighted Area Occupied
ECSAS	Environment Canada Seabirds at Sea
ESA	*Endangered Species Act*
ESS	Eastern Scotian Shelf
FSRS	Fishermen & Scientists Research Society
GEAC	Groundfish Enterprise Allocation Council
GOSLIM	Gulf of St. Lawrence Integrated Management
GSL	Gulf of St. Lawrence
HOTO	Health of the Oceans
ICES	International Council for the Exploration of the Sea
ICNAF	International Commission for the Northwest Atlantic Fisheries
IUCN	International Union for the Conservation of Nature
LEK	local ecological knowledge
LFA	lobster fishing area
LL	Louisburg Line
LOMA	large ocean management area
LRP	limit reference point
MARFIS	Maritime Fishery Information System
MPA	marine protected area
MT	metric tonnes
NAFO	Northwest Atlantic Fishing Organization
NAMMCO	North Atlantic Marine Mammal Commission
NAO	North Atlantic Oscillation
NEFSC	Northeast Fisheries Science Center
NL	Newfoundland and Labrador
NOAA	National Oceanic and Atmospheric Administration (United States)
NS	Nova Scotia
OBIS	Ocean Biogeographic Informationa System

PCI	phytoplankton colour index
PIROP	Programme intégré de recherches sur les oiseaux pélagiques
PSU	practical salinity unit
RMS	root mean square
RPA	Recovery Potential Assessment
RV	research vessel
SAB	St Anns Bank
SARA	*Species at Risk Act*
SSB	spawning stock biomass
SSIP	Scotian Shelf Icthyoplankton Survey
TAC	total allowable catch
TNASS	Trans North Atlantic Sightings Survey
WSS	Western Scotian Shelf
WWF	World Wildlife Fund
ZIF	Zonal Interchange Format

B. ALL DATA APPENDICES

PART 1 - COMMON SPECIES IN PHOTOS AND VIDEO SAMPLING ON SAB

Hudson 2009

Table 1. The ten most common taxa identified in Stations 09-66 and 09-67.

Station 66		Station 67	
Taxa	**Average Count Per Photo**	**Taxa**	**Average Count Per Photo**
Sponges	135.04*	Sponges	139.31*
Coralline algae	64.50*	Coralline algae	89.92*
Serpulid tube worm	29.73	Skeletal fragments	29.94
Hydrozoa	20.19*	Serpulid tube worm	28.90
Tunicate	18.35	Hydrozoa	16.83
Spirorbis tube worm	9.69	Brittle star	9.38*
Ectoprocta	9.12	Shell hash	6.06
Skeletal fragments	6.62	Ectoprocta	6.04
Gersemia soft coral	6.19	*Gersemia* soft coral	3.15
Shell hash	3.23	Chiton	3.10

* These taxa are also sometimes described as having “even distribution” across the square instead of being counted.

***Matthew* 2010**

Table 2. These tables (overleaf) show the ten taxa with the highest average percent cover per photo or average count per photo in each station. Taxa with less than 0.10 percent cover/photo or 0.10 organixms/photo are omitted. These images are not standardized for area, so this gives a general idea about what is dominant in each station and the relative abundance of different taxa, but density of taxa/area is not available.

Station 10-01

Common Name	**Latin Name**	**Average Count Per Photo**	**Average % Cover**
Bryozoa/hydrozoa	Bryozoa/hydrozoa		6.02
Coralline algae	e.g., *Lithothamnion* sp.		5.22
Tunicate or sponge		3.78	
Encrusting sponge/algae?			1.86
Encrusting sponge	Demospongiae (class)		
Sponge	Demospongiae (class)		
Soft coral	*Gersemia*	1.00	
Protosuberites	*Hymedesmia* sp.		0.96
Bryozoan	Bryozoa, Cyclostomata	0.80	
Sea grape (tunicate)	*Molgula* sp.	0.41	

Station 10-02

Common Name	**Latin Name**	**Average Count Per Photo**	**Average % Cover**
Burrows		1.32	
Brittle star	*Ophiura* sp.	1.03	
Toad crab	*Hyas* sp.	0.16	
Soft coral	*Gersemia rubiformis*	0.14	

Station 10-03

Common Name	**Latin Name**	**Average Count Per Photo**	**Average % Cover**
Red algae			51.49
Coralline algae	e.g., *Lithothamnion* sp.		31.76
Kelp	*Agarum nodosum*	4.29	
Encrusting sponge	Demospongiae (class)		0.82
Frilled anemone	*Metridium senile*	0.20	

Station 10-04

Common Name	Latin Name	Average Count Per Photo	Average % Cover
Burrows		27.88	
Nordic krill	*Meganyctiphanes norvegica*	1.94	

Station 10-05

Common Name	Latin Name	Average Count Per Photo	Average % Cover
Feather star/sea lily	Comatulid crinoids (Trichometra or Hathrometra)	46.59	
Tunicate or sponge	Tunicate or sponge	13.32	
Anemone	*Urticina felina*	8.11	
Coralline algae	e.g., *Lithothamnion* sp.		6.18
Bryozoa/hydrozoa	Bryozoa/hydrozoa		3.52
Anemone	Actinaria	2.67	
Sponge	Demospongiae (class)	2.12	
Sea grape (tunicate)	*Molgula* sp	1.33	
Encrusting sponge	Demospongiae (class)		0.37

Station 10-06

Common Name	Latin Name	Average Count Per Photo	Average % Cover
Maldanid worms, sabellid worms and tube-building amphipods	Sabellidae, Aoridae and Ericthonius		32.83
Tunicate or sponge		10.05	
	Bathysiphon sp.	9.95	
Northern Lamp shell (brachiopod)	*Terebratulina septentrionalis*	8.20	
Anemone	Anthozoa (class)	1.67	
Encrusting sponge	Demospongiae (class)		1.45
Polymastia	*Polymastia* spp.	1.33	
Polychaete tube worm	*Thelepus cincinnatus*	0.97	
Anemone	Cerianthidae (family)	0.92	
Suberites	Suberitidae (class)	0.90	

Station 10-07

Common Name	Latin Name	Average Count Per Photo	Average % Cover
Maldanid worms, sabellid worms and tube-building amphipods	Sabellidae, Aoridae and Ericthonius		42.80
Burrows		17.54	
	Bathysiphon sp.	11.49	
Anemone	Cerianthidae (family)	8.51	
Tunicate or sponge		1.60	
Northern Lamp shell (brachiopod)	*Terebratulina septentrionalis*	0.46	
Encrusting sponge	Demospongiae (class)		0.46
Anemone	Anthozoa (class)	0.34	

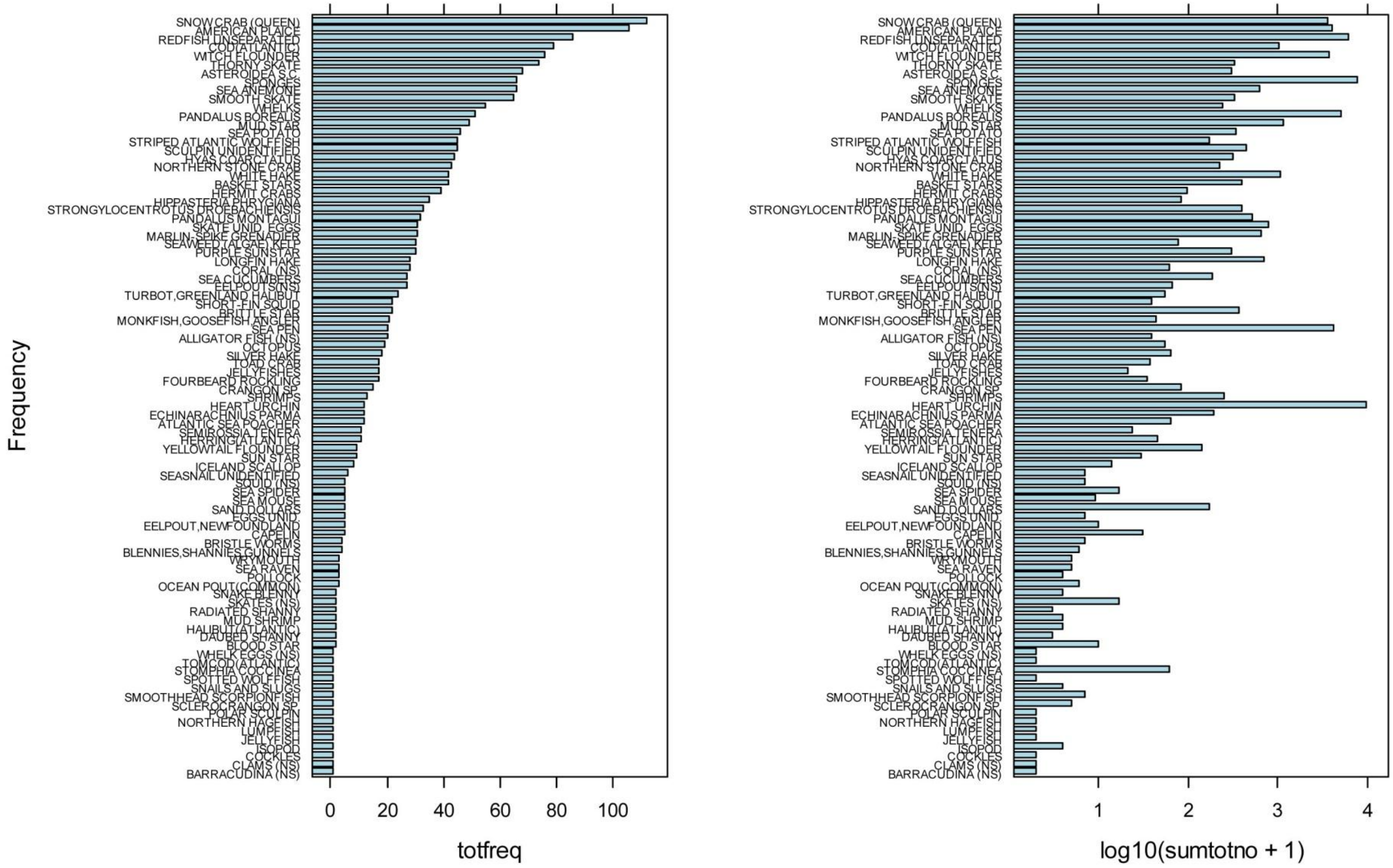
Station 10-08

Common Name	Latin Name	Average Count Per Photo	Average % Cover
Burrows		13.51	
Maldanid worms, sabellid worms and tube-building amphipods	Sabellidae, Aoridae and Ericthonius		9.25
	Bathysiphon sp.	4.27	
Northern Lamp shell (brachiopod)	*Terebratulina septentrionalis*	0.92	
Anemone	Anthozoa (class)	0.45	
Polychaete tube worm	*Thelepus cincinnatus*	0.35	
Anemone	Cerianthidae (family)	0.29	
Stalked sponge	*Stylocordyla* sp.	0.27	
Tunicate or sponge		0.22	
Encrusting sponge	Demospongiae (class)		0.2
Bryozoa/hydrozoa	Bryozoa/hydrozoa		0.18

Station 10-09

Common Name	Latin Name	Average Count Per Photo	Average % Cover
Burrows		18.42	
Nordic krill	*Meganyctiphanes norvegica*	1.58	
	Bathysiphon sp.	0.68	

PART 2 - FREQUENCY AND ABUNDANCE OF ALL TAXA RECORDED IN SNOW CRAB SURVEY IN ST ANNS BANK, 2004–2010



PART 3 - SNOW CRAB SURVEY STATIONS IN ST ANNS BANK

Seabed Feature	Station No.	Mean Depth (m)	Total No. Taxa	Years Sampled	Top Five Taxa by Count	Description and Notable Features
Slope	2	287	24	2	Northern shrimp Sea pens Redfish Heart urchin Mud star	Species associated w deeper muddy environments. Sea pens: 212 total. Deepest station in SAB.
	4	211	41	5	Redfish Northern shrimp Witch flounder Snow crab Marlin-spike grenadier	Species associated w deeper muddy environments. This station has the most Marlin-spike grenadier. Skate eggs: 102 total.
	8	223	38	5	Northern shrimp Witch flounder Snow crab Sea pens Redfish	Species associated w deeper muddy environments. Sea pens: 277 total
	9	240	32	5	Sea pens Northern shrimp Heart urchin White hake Snow crab	Species associated w deeper muddy environments. Most sea pens in SAB: 2910 total
	15	213	34	7	Redfish Northern shrimp Witch flounder White hake Longfin hake	Species associated w deeper muddy environments. Most hake in SAB (both spp).
	20	254	36	5	Heart urchin Redfish Sea pens Northern shrimp Skate eggs	Species associated w deeper muddy environments. Heart urchins 1 giant catch (8820 in 2006). 700 sea pens total. 263 skate eggs, caught in all 5 years.
	21	254	27	2	Skate eggs Northern shrimp Redfish White hake Sea anemone	Skate eggs 318 total, largest amount in SAB, 243 in 1 year is largest catch of skate eggs per tow SAB. Largest catch of skate eggs in snow crab survey is nearby, station 22 (outside boundary).

	7	152	34	7	Witch flounder American plaice Redfish Snow crab Atlantic cod	Catch dominated by fish. 24 Atlantic wolffish is second highest in SAB, caught in 5 of 7 years. Shelf sites in this area have highest cod (95 total for this station).
	11	111	38	7	American plaice Sponges Snow crab Witch flounder Atlantic cod	
	12	143	37	3	Witch flounder Sponges Striped shrimp American plaice Mud star	Some sea pens – 37
Shelf	13	126	36	7	Sponges Redfish Atlantic cod Shrimps unsp. Witch flounder	By far the highest catches of Atlantic wolffish are at this site – 70 total, caught in all years, 2–21 per tow. Also by far the highest catch of cod is here, 222 total, caught in all years, 3–147 per tow.
	19	117	34	6	Sponges American plaice Purple sunstar Witch flounder Atlantic cod	Large number of sponges (1186 total) but may represent pieces of animals and not individuals.
	23	147	35	7	Snow crab Redfish American plaice Witch flounder Northern shrimp	Highest catch of snow crab in SAB is here, 1177 total, catch 39–397 per tow.
	26	153	40	7	Witch flounder Mud star American plaice Redfish Snow crab	

	14	87	35	7	American plaice Brittle stars Sponges Green sea urchin Atlantic cod	High cod catches – 91 total.
	16	64	39	7	Sponges Striped shrimp Basket stars Atlantic cod Lyre crab	Stations 16 and 24 are the shallowest stations sampled in SAB.
	17	77	32	7	American plaice Striped shrimp Sea potato Sponges Basket stars	Similar group as 16 – sponges, striped shrimp, basket stars, lyre crab, etc.
Bank	18	99	28	6	American plaice Sponges Snow crab Atlantic cod Witch flounder	Also similar group to 16, 17
	24	64	24	2	Sculpin Sea potato Atlantic cod Crustacean unk. Lyre crab	
	25	74	38	7	American plaice Yellowtail flounder Green sea urchin Snow crab Atlantic cod	Yellowtail flounder catches in all years.
	28	89	33	5	Northern shrimp American plaice Snow crab Sand dollars Basket stars	