MARINE HABITATS AND COMMUNITIES

State of the Scotian Shelf Report

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The material in this document is co-published as:
MacLean M, Breeze H, Walmsley J and Corkum J (eds). 2013.
State of the Scotian Shelf Report. Can. Tech. Rep. Fish. Aquat. Sci. 3074.

First published November 2011

ISBN: 978-0-9869437-5-1

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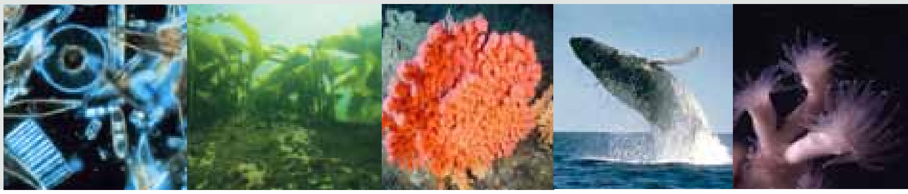
ISSUE IN BRIEF

'Habitat' is loosely defined as any area that provides the conditions and resources that organisms need to survive. The offshore marine habitats of the Scotian Shelf fall into two broad categories: the water column and benthic habitats. Within these habitats live groups of organisms known as 'communities' that interact with each other while sharing a similar environment. The structure and function of these communities have evolved in response to the natural conditions on the Scotian Shelf (e.g. temperature, salinity, light regime and depth), which in turn are influenced by the broader oceanography, geology, circulation and climate. The driving forces influencing marine habitats and communities of the Scotian Shelf include changes in the economic, human and natural environments (**Figure 1**). Anthropogenic pressures on marine habitats and communities include those from ocean activities such as commercial fisheries, offshore oil and gas activity, marine shipping and vessel traffic, and the laying of submarine cables. These activities can disturb and alter habitat, contaminate the marine environment, and change the structure (i.e. species diversity, productivity and food-web structure) of communities. Variability in the natural environment also places pressure on the habitats and communities of the Scotian Shelf by altering dominant oceanographic conditions and the physical and chemical properties of seawater. These changes can affect the distribution and extent of habitat and the distribution and structure of biological communities (see *Climate Change and its Effects on Ecosystems, Habitats and Biota*). As a result of the combined effects of

LINKAGES

This theme paper also links to the following theme papers:

- Climate Change and its Effects on Ecosystems, Habitats and Biota
- Fish Stock Status and Commercial Fisheries
- Incidental Mortality
- Ocean Acidification
- Ocean Noise
- Species at Risk
- Water and Sediment Quality



human activities and changing environmental conditions, the Scotian Shelf ecosystem has undergone a major structural shift since the 1970s which has impacted all trophic levels and altered the structure of marine communities (Bundy 2005; DFO 2010a; see *Trophic Structure)*. A variety of management actions have been implemented to protect the offshore habitats and communities of the Scotian Shelf including a variety of legislation and policies, and scientific research and monitoring programs.

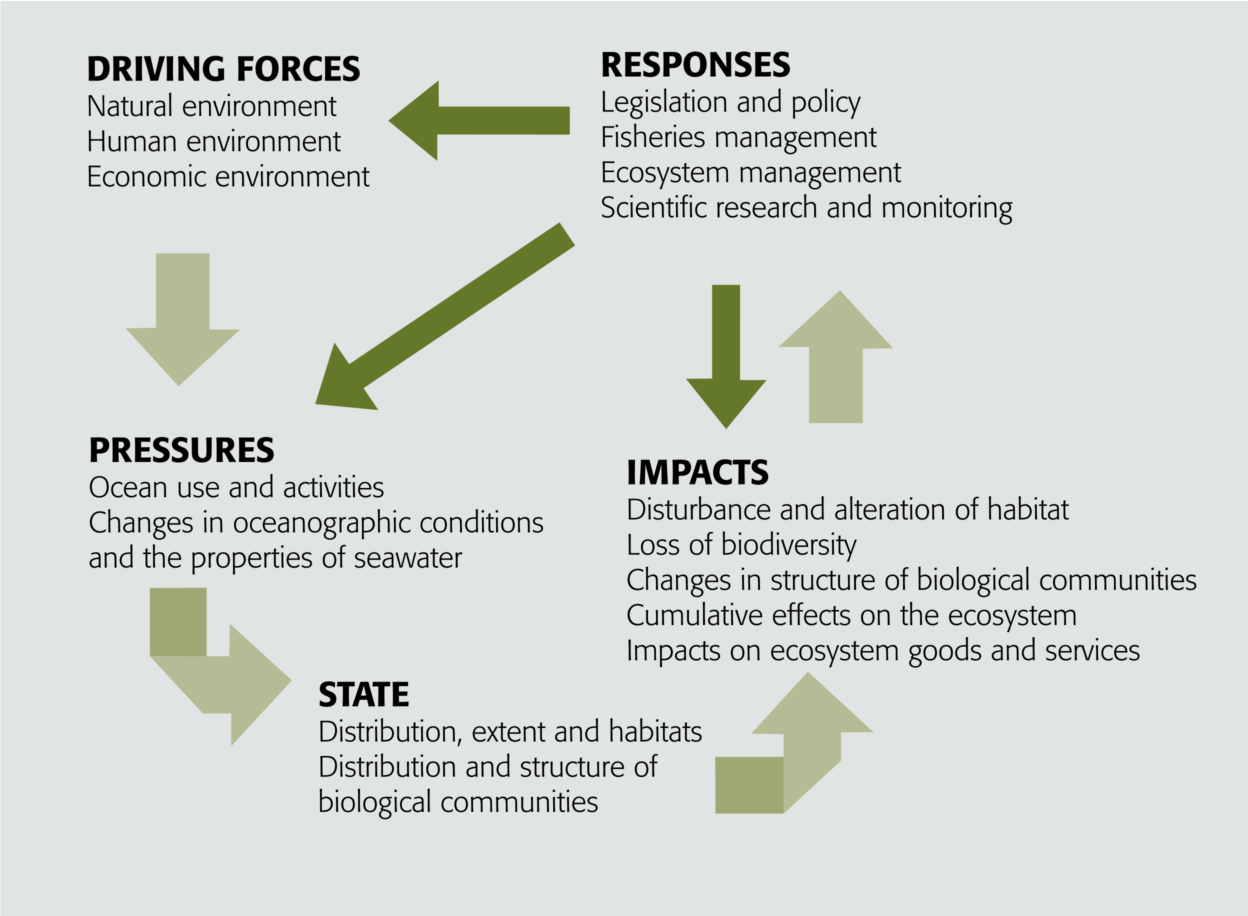


Figure 1: Driving forces, pressures, state, impacts and responses (DPSIR) for marine habitats and communities on the Scotian Shelf. The DPSIR framework provides an overview of the relation between the environment and humans. According to this reporting framework, social and economic developments and natural conditions (driving forces) exert pressures on the environment and, as a consequence, the state of the environment changes. This leads to impacts on human health, ecosystems and materials, which may elicit a societal or government response that feeds back on all the other elements.

2 DRIVING FORCES AND PRESSURES

Changes in the human and economic environment influence demand for ocean resources, such as seafood and offshore energy, and may lead to increased human activity on the Scotian Shelf. These ocean uses and activities are important pressures on marine habitats and communities. The natural conditions of the Scotian Shelf, such as variations in the physical and chemical properties of seawater, are another important driving force influencing marine habitats and communities (see *The Scotian Shelf in Context* and *Climate Change and its Effects on Ecosystems, Habitats and Biota*.)

2.1 NATURAL CONDITIONS

Natural conditions refer to the geomorphology, geology, climate and oceanographic conditions of the Scotian Shelf. These natural conditions are described in detail in *The Scotian Shelf in Context*. Physical features, such as the sediment and topography of the seabed, strongly influence habitat type and the distribution and abundance of marine organisms. Temperature, salinity and water circulation are also important factors influencing habitat quality and the distribution, growth and survival of marine organisms. Temperature and salinity are important because each organism has a particular range of temperature and salinity that is optimal for its success. Ocean currents are important because they transport food and oxygen, remove wastes and transport less active organisms from place to place.

Oceanographic conditions on the Scotian Shelf such as water temperature and salinity vary over time and space. Changes in oceanographic conditions over the past 30 years have been associated with expansion of range by some fish and invertebrate species, the occurrence of new species in the area, and decreases in the average size and condition of fish within some groundfish populations (Worcester and Parker 2010). For example, the cooling of waters in the Scotian Shelf in the late 1980s has been associated with the appearance and subsequent increases in abundance of capelin (a species of cold-water, pelagic fish) in the northeastern Scotian Shelf (Worcester and Parker 2010). Some recent studies have suggested that long-term changes in ocean temperature and circulation could affect marine organisms by changing species abundance and distribution (with respect to both latitude and depth) and the structure and dynamics of plankton and fish communities (Cheung et al. 2010; Engelhard et al. 2010; Lehodey et al. 2006; MacNeil et al. 2010; Rijnsdorp et al. 2009).

2.2 OCEAN USES AND ACTIVITIES

Numerous ocean-related industries and activities occur on the Scotian Shelf including commercial fisheries, offshore oil and gas, marine shipping, ocean tourism, and submarine cables (see *The Scotian Shelf in Context*). Combined with the effects of changing natural conditions, these activities can impact marine habitats and communities in a variety of different ways.

Commercial fishing is a major source of income and employment in Nova Scotia and is widespread on the Scotian Shelf. A diverse range of species is targeted in commercial fisheries on the Scotian Shelf including groundfish (e.g. cod, haddock, pollock, flatfishes), small pelagic fishes (e.g. herring, mackerel), large pelagic fishes (e.g. tuna, sharks, swordfish) and invertebrates (e.g. lobster, crab, shrimp, scallop) (Coffen-Smout et al. 2001). Different types of gears are used in fisheries on the Scotian Shelf including otter trawl, seine, longline, gillnet, handline, dredge, weir, traps and pots, and harpoon (DFO 2005a). **Figure 2** shows the total groundfish landings from 1999 to 2003 in the Scotia-Fundy Region and the proportion of landings by gear type. There are also many different types and sizes of fishing vessels, from small vessels used in coastal lobster fisheries to very large vessels used in offshore scallop and groundfish fisheries (DFO 2005a).

Fishing has direct and indirect effects on habitat and on the diversity, structure and productivity of benthic communities, and it is the main activity affecting marine habitats and communities in the region (Fuller et al. 2008; Jennings and Kaiser 1998). Some fishing gear types, such as trawls, dredges and other mobile, bottom-contacting gears can disturb and alter benthic habitat and communities (DFO 2006a; Fuller et al. 2008). They impact the physical features of the seafloor by damaging or reducing structural biota and complexity, altering the seafloor structure and large habitat features, and temporarily increasing sedimentation rates (DFO 2006a). These types of gear can also impact benthic communities by changing the relative abundance of species in a community, decreasing the abundance of some long-lived species, increasing the abundance of some short-lived species, increasing the abundance of scavenger species, and changing the rates of nutrient cycling within a community (DFO 2006a). Other types of fishing gear, such as demersal longlines and gillnets, pots and traps can also disturb and damage bottom habitat and have been found to cause entanglement and breakage of bottom features such as corals (Baer et al. 2010; Donaldson et al. 2010). Overexploitation of commercial species and/or the incidental capture of non-target species may alter biological communities by changing the productivity, species diversity and size structure of the community (DFO 2010b; Jennings and Kaiser 1998; see *Fish Stock Status and Commercial Fisheries* and *Incidental Mortality)*.

Oil and gas activity is one of the main non-fishing industrial activities taking place on the continental shelf and slope (Worcester and Parker 2010). As of 2004, over 300,000 km of seismic survey tracks had been recorded and 194 wells had been drilled, with the majority of wells concentrated on the eastern shelf near Sable Island (Coffen-Smout et al. 2001: Zwanenburg et al. 2006). To date, two petroleum production projects have operated on the Scotian Shelf near Sable Island including the Cohasset-Panuke Project (1992 - 1999) and the Sable Offshore Energy Project (1999 – present) (CNSOPB 2011). A third project, the Deep Panuke Offshore Gas Development Project is currently under development and is expected to start production in 2012 (CNSOPB 2011). Oil and gas activity can affect marine habitats and communities by generating noise, pollution and contamination, and disturbing the seabed (CNSOPB 2005; Hurley and Ellis 2004; Thomson et al. 2000; see *Ocean Noise* and *Water and Sediment Quality*).

The strategic location of Nova Scotia on the Great Circle Route (i.e. shortest distance over the earth's surface) between eastern

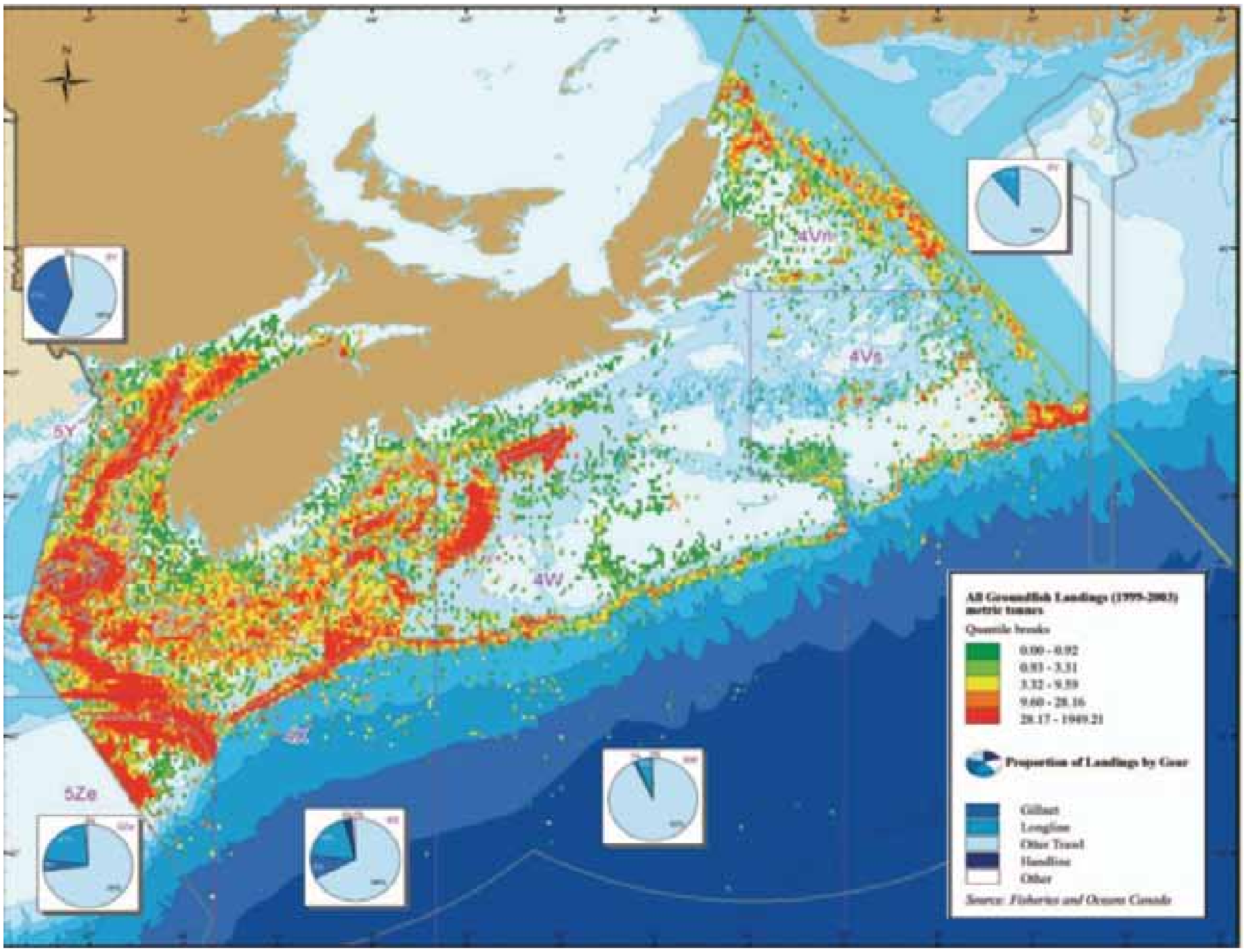
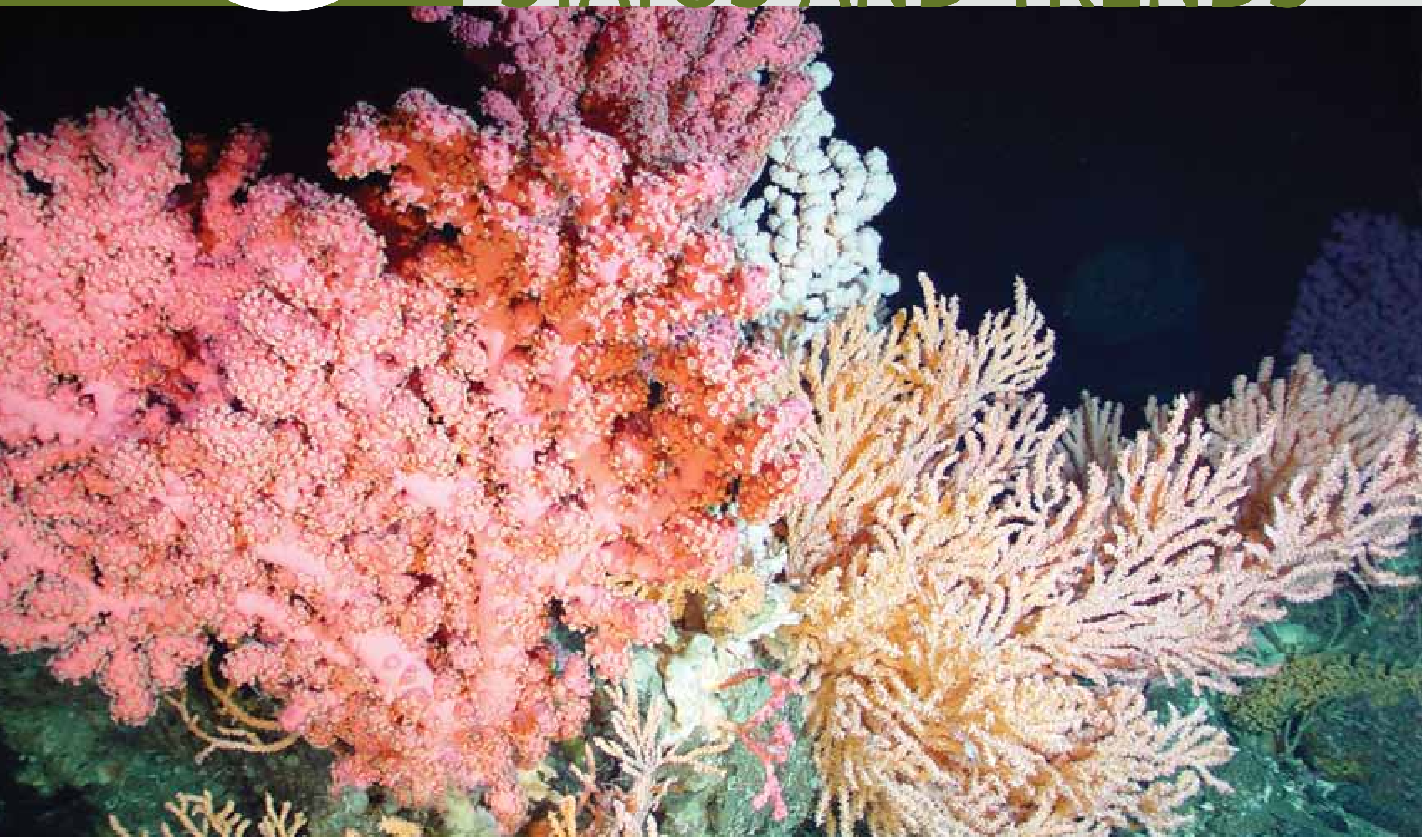


Figure 2: Total groundfish landings (1999-2003) in the Scotia-Fundy Region and the proportion of landings by gill-net, longline, otter trawl, handline and other gear types. Source: DFO 2005a.

North America and Europe makes it important for international shipping (Coffen-Smout et al. 2001). Commercial shipping in this area is generally in the form of tankers, general bulk and containerized cargo carriers (Coffen-Smout et al. 2001). The area is also transited locally by a range of fishing vessels, cruise ships and various government vessels (Coffen-Smout et al. 2001). The primary commodities being moved in the region include crude oil and gas, minerals and chemicals, paper and forest products, coal and coke and various containerized goods (Coffen-Smout et al. 2001). Pressures on marine habitats and communities resulting from the high volume of shipping activity and vessel traffic in the Scotian Shelf include ship-source pollution, shipboard wastes, noise and collisions between vessels and marine life (see *Incidental Mortality*; Ocean Noise; and *Water and Sediment Quality*).

There are numerous active and inactive submarine cables on the Scotian Shelf and Slope, some of which are more than 100 years old (DFO 2005a). At present, no high voltage DC power cables cross the Scotian Shelf, although some have been proposed (DFO 2005a). Several active submarine telecommunications cables make landfall in Nova Scotia and cross the Scotian Shelf (DFO 2005a). Submarine cables are either installed on the surface of the seabed or buried in the seabed, and therefore have the potential to disturb and alter benthic habitats and communities in the vicinity (Carter et al. 2009; Worzyk 2009). A new telecommunications cable running from England to Halifax is proposed by Hibernia Atlantic for 2012.

3 STATUS AND TRENDS



3.1 MARINE HABITATS

The focus of this paper is on offshore marine habitats and communities of the Scotian Shelf, particularly the water column, which is home to pelagic species, and benthic habitats, which are home to bottom-dwelling organisms. For information on the status and trends associated with coastal and nearshore habitats in the region, the reader is directed to the *2009 State of Nova Scotia's Coast Report* (CBCL Limited 2009; http://www.gov.ns.ca/coast/state-of-the-coast.htm).

3.1.1 The Water Column

The area between the seafloor and the sea surface, including all marine and estuarine waters, is referred to generically as the water column and represents the most widespread habitat in the Scotian Shelf. It is a dynamic environment consisting of distinct layers and water masses (see *Scotian Shelf in Context*). The physical and chemical properties of water masses (i.e. temperature, salinity, acidity) greatly influence their suitability as habitat for organisms (Davis and Browne 1996; Todd and Kostylev 2010; Zwanenburg et al. 2006), and variations in these properties affect the distribution and abundance of marine organisms.

- Between 1961 and 2003, global ocean temperature increased by 0.10°C from the surface to a depth of 700 m, with lesser temperature increases observed to a depth of 3,000 m (IPCC 2007). Regional trends in water temperature are less clear as water temperatures on the Scotian Shelf are among the most variable in the North Atlantic, with noticeable warm (1979-1986; 1999-2000) and cool cycles (1987-1993; 2003-2004) (Worcester and Parker 2010). The greatest temperature anomaly in the 38-year time series for the Scotian Shelf was recorded in 2006 and it appears that variability in water temperature has been increasing over the past decade (Worcester and Parker 2010).
- Over several decades, changing patterns of precipitation, evaporation, river run-off and ice melt have led to changes in ocean salinity on gyre and basin scales, with a global trend towards freshening in subpolar latitudes (IPCC 2007). Salinity in the Scotian Shelf region is variable, decreasing from the mid-1970s to the mid-1990s, then increasing to 2002 before decreasing again (Worcester and Parker 2010).
- The pH of seawater on the Scotian Shelf decreased by 0.002 pH units per year over the period 1927 to 2009 (DFO 2009a; Worcester and Parker 2010).

3.1.2 Benthic Habitats

The physical attributes of the seabed are known to be important factors influencing habitat and the distribution of benthic organisms, including: topography (macro relief), roughness (micro relief), sediment type and distribution, grain size and shape, patchiness, rock composition and sediment thickness (Davis and Browne 1996; Fader et al. 1998; Todd and Kostylev 2010). Oceanographic factors such as oxygen saturation, temperature variability, water stratification and chlorophyll-a concentration are also important for structuring benthic habitat and communities and are strongly related to water depth (Todd and Kostylev 2010).

The Scotian Shelf is host to a diverse range of benthic habitats due to its geological and topographical complexity (Davis and Browne 1996; Todd and Kostylev 2010). Substrate type and sediment grain size have a particularly strong influence on the benthic fauna that inhabit a particular area (Davis and Browne 1996; Kostylev et al. 2001; Todd and Kostylev 2010). Some areas of the Scotian Shelf are homogenous, with similar substrate type and grain size, but many areas are characterized by a variety of surface sediments, and tend to support greater biological diversity (Breeze et al. 2002; Todd and Kostylev 2010). The main characteristics of the various substrate types and sediment grain sizes found on the Scotian Shelf include:

- **Clay and Silt:** Areas of the Scotian Shelf with muddy bottoms include the mouth of the Laurentian Channel, the Gully Fan, the Scotian Rise and the basins of the Middle Scotian Shelf (Breeze et al. 2002; WWF 2009). Muddy bottoms are usually comprised of varying proportions of silt and clay and provide habitat for a variety of infauna (i.e. organisms that live in sediment), epifauna (i.e. organisms that live on or above sediment) and bottom-feeding fish (Davis and Browne 1996). Some common species of infauna found in areas with muddy bottoms include sea anemones, sea pens, polychaete worms, bivalve molluscs, tusk shells, gastropods, sea cucumbers, brittlestars and starfish (Davis and Browne 1996; Kostylev et al. 2001). Common species of epifauna found on muddy bottoms include bryozoans, ascidians, crabs, shrimp, sea spiders, skates and groundfish (Davis and Browne 1996; Kostylev et al. 2001).

- **Sand and Gravel:** Sand and gravel bottoms are widespread on the Scotian Shelf and are found throughout the Inner Shelf, on the tops of banks, the flanks of basins and channels, and on the floors of submarine canyons (Breeze et al. 2002; WWF 2009). Quahogs, sea scallops, and surf clams commonly occur on the sandy/gravelly bottoms of the Inner Shelf and on offshore banks (Davis and Browne 1996; WWF 2009). The sand dollar, *Echinarachnius parma*, is strongly associated with fine sandy sediments and is commonly found in areas of the Scotian Shelf with fine and medium-grained sands (Breeze et al. 2002). Species typically occurring on sandy substrate include sand dollars, cumaceans, amphipods, polychaete worms, tanaidaceans, and sand lance (Davis and Browne 1996; WWF 2009). Horse mussels, brittle stars, lobsters and crabs are common in gravelly areas of the Shelf (WWF 2009). Structurally complex gravel habitats found on banks have been associated with a diverse range of fauna and abundant epifauna including sponges, brachiopods, tunicates, polychaetes and sea cucumbers (Kostylev et al. 2001). Gravel sediments on the Laurentian Fan are home to unique 'cold seep' communities of clams, snails, crabs and feathery polychaete worms that derive energy from the available carbon and hydrogen sulphide seeping out of the sediment (WWF 2009).

- **Boulders and Bedrock:** Rocky bottoms can be found on the banks of the Outer Scotian Shelf, the basins of the Middle Scotian Shelf, and in parts of the Northeast Channel (WWF 2009). Areas of the sea-bottom with bedrock and boulders are ideal for epifauna, but provide little habitat for infauna, except where sediment has accumulated in cracks and under rocks and boulders (Davis and Browne 1996). Horse mussels, brittle stars, starfish, lobsters, crabs, polychaete worms, sea urchins, sea cucumbers, corals, sponges, hydroid polyps, bryozoans and tunicates inhabit areas with rocky bottoms (Davis and Browne 1996; WWF 2009). Rocky bottoms also serve as important habitat for a range of fish species including sculpin, cunner, lumpfish, wolffish and pollock (Davis and Browne 1996). Most species of deep-sea corals and sponges found on the Scotian Shelf need the hard surfaces of boulders and bedrock on which to settle (Breeze et al. 2002). Sampling equipment is usually not suitable for representative sampling of hard rocky bottoms and fewer samples have been taken from these environments than others on the Shelf (Breeze et al. 2002).

- **Biogenic Habitats:** Certain structure-forming animals that live on the seabed including ascidians, bryozoans, corals, hydroids, and sponges can create, modify and maintain habitat for other species by producing complex structures on top of sediments (Breeze et al. 2002; Fuller 2011). These habitats, known as biogenic habitats, may offer space for attachment, increased food supply, hiding places from predators, and shelter from harsh environmental conditions (see *Scotian Shelf in Context*). The distribution and extent of biogenic habitats can influence species richness and community structure in the surrounding ecosystem (Fuller 2011), and may be a limiting factor for populations of certain species (Breeze et al. 2002). On the Scotian Shelf, deep-sea corals and sponges are common in certain areas and form complex structures that support increased biodiversity compared to most other benthic habitats (DFO 2010c). Corals provide shelter for numerous species and influence, both directly and indirectly, the local occurrence or abundance of fish and invertebrate species (DFO 2010c). They provide habitats at key life stages of many marine species as well as a food source for other invertebrates (DFO 2010c). Sponge reefs provide habitat for fish and high-complexity reefs are associated with higher species richness and abundance (DFO 2010c). Additional information on the status of coral and sponge communities on the Scotian Shelf is provided in Section 3.2 below.

3.2 MARINE COMMUNITIES

The term 'community' describes a group of interacting organisms living near, on, or within one another and found in similar environments (Breeze et al. 2002). The structure (i.e. species diversity, productivity and trophic structure) of biological communities depends on a range of factors such as climate, competition, predator-prey relationships, disturbance, nutrient availability, and habitat type (Greenstreet 2003; Emery 1978). Traditionally, research on marine organisms of the Scotian Shelf has focused on population level studies of species targeted by commercial fisheries (DFO 2007a). As a result, there is a lack of information on the structure, distribution and dynamics of marine communities, making the identification of ecologically significant species and community properties difficult (DFO 2006b).

TYPES OF FISHES

Fishes of the Scotian Shelf can be grouped into three categories: demersal fishes that spend most of their life near the ocean bottom (e.g. groundfish such as haddock and cod); pelagic fishes that live in the water column (e.g. herring, mackerel, tuna); and diadromous fish that spend part of their lives in freshwater and part in salt or brackish water (e.g. Atlantic salmon) (Breeze et al. 2002).

Furthermore, reliable indicators for assessing the status of biological communities are not yet available (ICES 2005; Rochet and Trenkel 2003). In some cases, studies have been conducted on 'assemblages'. Assemblages are subsets of species or taxonomic groupings (e.g. finfish assemblages) found in similar environments (Fauth et al. 1996). Usually, the ecological relationships among species in an assemblage are not well understood. Information about the individual populations and/or assemblages which comprise a biological community can help assess the status of the community when there is insufficient data or information at the community level (Rochet and Trenkel 2003).

The Scotian Shelf ecosystem has undergone a major structural shift since the 1970s, which has impacted all trophic levels and many biological communities (Bundy 2005; DFO 2010a; Frank et al. 2005; see *Trophic Structure)*. This shift involved concurrent increases in seals, small pelagic fish, benthic macroinvertebrates, and phytoplankton; and decreases in groundfish and zooplankton (Bundy 2005; DFO 2010a; Frank et al. 2005; see *Trophic Structure)*. However, in 2006 the ecosystem began showing signs of recovery towards its previous structure, including a declining abundance of forage fish and an increasing abundance of zooplankton and groundfish such as cod and haddock (Frank et al. 2011). The status of some of the main communities and assemblages found on the Scotian Shelf is summarized below.

- **Planktonic communities:** On the Scotian Shelf, phytoplankton biomass is dominated by diatoms and dinoflagellates (Zwanenberg et al. 2006). Zooplankton include a range of organisms which feed on phytoplankton and other zooplankton including single-celled protozoa, copepods, euphausiids (krill), cheatognaths (arrow worms), salps and jellyfish (Zwanenberg et al. 2006). The patterns of abundance of phytoplankton are largely determined by variations in the physical oceanographic features of the ocean environment, and the complex nature of these features on the Scotian Shelf makes high spatial and temporal variability in phytoplankton biomass a common feature of the region (Zwanenberg et al. 2006). There is also a distinctive seasonal cycle of growth characterized by a conspicuous and widespread spring biomass peak (the spring "bloom") and a more diffuse fall bloom (Zwanenberg et al. 2006).

The composition of the phytoplankton community on the Scotian Shelf has remained relatively constant over time, with diatoms dominating in the winter/spring, and flagellates and dinoflagellates dominating the rest of the year (DFO 2009b). Compared with historical data records dating back to 1961, recent phytoplankton abundances on the Scotian Shelf have been at or above the long term average while zooplankton abundances have been at or below the norm (DFO 2009b). These changes in abundance have been linked to the increased abundance of forage fish on the Scotian Shelf (Bundy 2005; Frank et al. 2005; see *Trophic Structure*). In 2007, the magnitude of the spring phytoplankton bloom reached a record high, but was followed by a decrease to an average or below average level in 2008 (DFO 2009b). Chlorophyll levels outside of the spring bloom period have been declining since observations began in 1999 (DFO 2009b).

- **Finfish assemblages:** There are 538 species of finfish known to occur in the Canadian Atlantic (Worcester and Parker 2010). The abundance and distribution of marine fishes on the Scotian Shelf is continually changing as a result of fishing and environmental factors (Shackell and Frank 2003). The distribution patterns of fish are linked to environmental factors such as water temperature and salinity, bottom type, and availability of food, and these patterns often differ at different life stages (Breeze et al. 2002). Horsman and Shackell (2009) identified areas of important habitat for a variety of ecologically significant fish species on the Scotian Shelf including forage species, influential predators, depleted and rare species, and other dominant species. The distribution maps are presented on a species-by-species basis and no analysis was performed at the assemblage or community level. Certain areas on the Scotian Shelf have been identified as having a high degree of finfish diversity including the Eastern Gully, the slopes, Western Bank and the northeastern shelf (Shackell and Frank 2003).

  Studies of fish assemblages on the Scotian Shelf have focused on demersal species, as pelagic species are highly migratory and may not have strong associations with other fishes (Worcester and Parker 2010). Membership in the demersal fish assemblages is relatively constant, but also adaptable to different environmental conditions (Breeze et al. 2002; Mahon and Smith 1989). They may vary in location over time, and do not conform to accepted biogeographical boundaries (Breeze et al. 2002; Mahon and Smith 1989).

  Overall, the composition of marine finfish on the Scotian Shelf has remained relatively constant, but the dominance structure has changed dramatically over the past 30 years (Shackell and Frank 2003; Worcester and Parker 2010). Notable changes include decreases in the abundance and distribution of groundfish, increases in the abundance of small pelagic fish, and the geographic expansion of species that are known to be important prey items of groundfish such as herring, sand lance and snake blenny (Shackell and Frank 2003; Worcester and Parker 2010). The collapse of benthic/demersal fish communities in the 1990s was a primary factor in the structural changes that have occurred in the Scotian Shelf ecosystem (Frank et al. 2005). Since 2006, the abundance of small pelagic fish has declined and the abundance of groundfish has increased, with Atlantic cod and redfish reaching levels of abundance not seen since the early 1990s and haddock reaching a unprecedented high (Frank et al. 2011). Changes in oceanographic conditions such as water temperature have been associated with the expansion of range by some fish species and the occurrence of new species to the Scotian Shelf (Shackell and Frank 2003; Worcester and Parker 2010). For more detailed information on the status of fish stocks and trophic structure see *Fish Stock Status and Commercial Fisheries* and *Trophic Structure*).

- **Benthic invertebrate communities:** There is a lack of information on the abundance and distribution of non-commercial benthic fauna on the Scotian Shelf, and community trends over time are largely unknown (Hargrave et al. 2004; Worcester and Parker 2010). Currently, there is no comprehensive listing of marine invertebrates on the Scotian Shelf. However, there has been an increase in directed research on benthic habitats and communities in recent years, especially on coral and sponge communities (see following section for more detail). General descriptions of the distribution of common bottom invertebrate species found on the Scotian Shelf are presented in Breeze et al. (2002), Davis and Browne (1996), Mobil Oil (1983); and Steele et al. (1979). Much more is known about the distribution and abundance of commercial invertebrate species.

Benthic habitats and species assemblages have been relatively well defined for some areas of the Scotian Shelf, but data tend to be both spatially and temporally limited (Breeze et al. 2002; Worcester and Parker 2010). For the purposes of mapping, benthic habitats were defined as areas where physical, chemical and biological characteristics combine to form recognizable ecological units (Kostylev et al. 2001; Todd and Kostylev 2010). Kostylev et al. (2001) identified six benthic habitat types and corresponding species associations for Browns Bank (**Figure 3** and **Table 1**). Habitat types were distinguished by sediment type, water depth, geomorphology, habitat complexity, and relative current strength (Kostylev et al. 2001). In general, the distribution of benthic mega-invertebrates showed a predominance of suspension-feeders (e.g. *Placopecten*, *Cucumaria*, Sabellidae) on the western, shallower part of the bank and an increase in abundance of deposit-feeders (e.g. Nothriidae) with increasing depth towards the east (Kostylev et al. 2001). Structurally complex gravel habitats on the central and eastern parts of the bank had the greatest species diversity and the greatest abundance of sessile epifauna including sponges, brachiopods and tunicates (Kostylev et al. 2001). No megafauna were observed on large sand formations (Kostylev et al. 2001).

Table 1: Benthic habitat types and corresponding species of megafauna on Browns Bank, Scotian Shelf. Compiled from Kostylev et al. (2001).

HABITAT TYPE	DESCRIPTION	COMMON SPECIES
1. Shallow water	Sand, high energy	Gilded wedgeclams (*Mesodesma deauratum*), possibly surf clams (*Spisula solidissima*) and soft-shelled clams (*Mya truncata*)
2. Deep water	Sand, low energy	Gilded wedgeclams, sand dollars, Stimpson's surf clams (*Spisula polynyma*), barnacles, sea snails (*Neptunea sp.*), Iceland scallops (*Chlamys islandica*), solitary hydroids (*Corymorpha sp.*)
3. Soft coral and sea cucumber	Gravel, sand, high energy	Soft corals (*Alcyonium digitatum* and *Duva multiflora*), sea cucumbers (Cucumaria frondosa)
4. Scallop	Gravel, sand, high energy, low diversity	Sea scallops (*Placopecten magellanicus*), hydroidea especially *Sertularella* sp., whelks, hermit crabs
5. Terebratulina	a. Gravel, boulders, sand, high diversity and abundance b. Tunicates and sponges predominate	a. Brachiopods (*Terebratulina septentrionalis*), Ascidians, serpulid polychaetes (commonly *Filograna implexa*, *Spirorbis* sp., and less often *Serpula vermicularis*), sea stars (*Henricia* sp.), bivalves (*Astarte* sp., *Macoma calcarea*, and *Clinocardium ciliatum*) b. dominated by tunicates and sponges
6. Deposit-feeder	Gravel, silt, low energy	Polychaetes (possibly *Nothriidae* and *Terebellidae*), occasionally anemones, brachiopods and sponges, abundant infauna

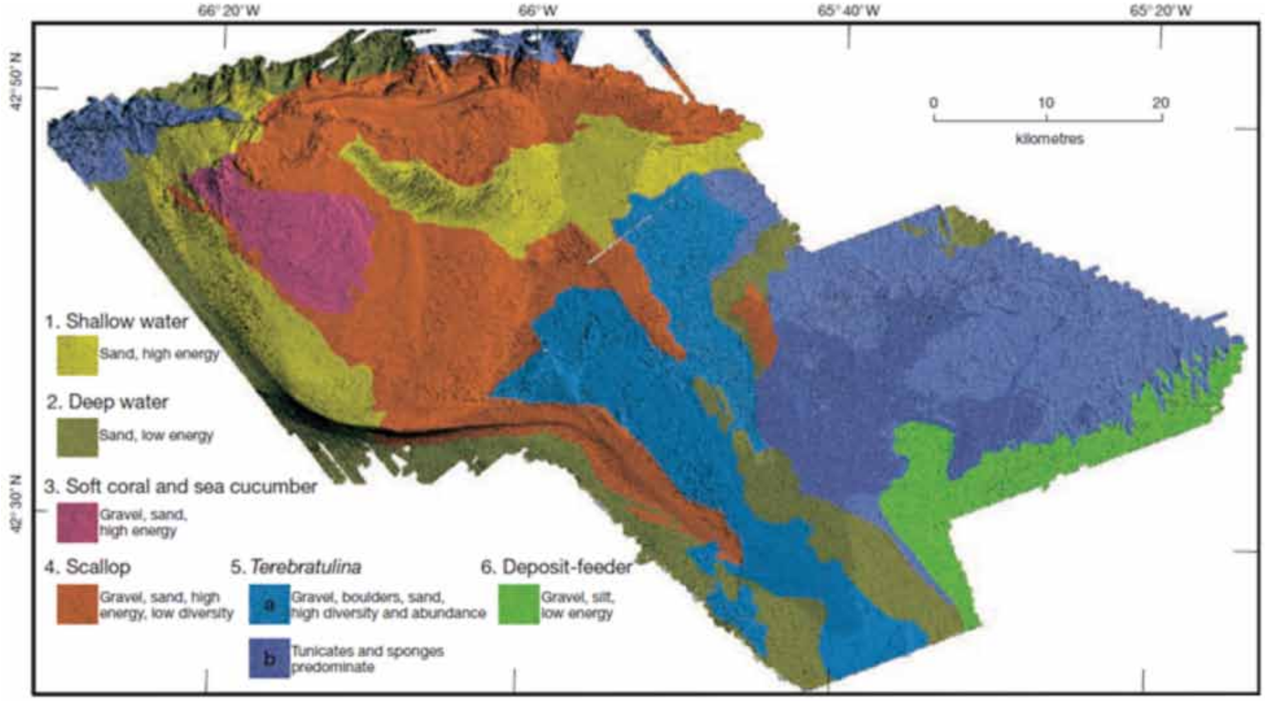


Figure 3: Benthic habitat map of Browns Bank showing six colour-coded benthic habitats. Source: Kostylev et al. (2001).

Hargrave et al. (2004) identified seven benthic assemblages in The Gully that were associated with specific habitat types characterized by depth, substrate type, seasonal temperature variance and average annual salinity (**Table 2**). Eight visible epifauna and megafauna phyla (Echinodermata, Coelenterata, Annelida, Chordata, Mollusca, Porifera, Brachiopoda and Arthropoda in order of decreasing abundance) and 175 taxa were identified from photo and video observations (Hargrave et al. 2004). Their analysis showed that epifauna communities in The Gully are associated with different substrates and that the highest species richness occurred on hard glacial substrates, where there was a predominance of suspension-feeding species (Hargrave et al. 2004). Epifauna biomass was found to be highest where gravel cover was greater than 50% (Hargrave et al. 2004).

Todd and Kostylev (2010) studied the seabed geology and benthic habitats on German Bank. They used statistical analysis of biological data and oceanographic and geological variables to identify eight benthic habitat types and associated fauna on the Bank (**Figure 4** and **Table 3**). Their analysis showed the distribution of benthic assemblages are scattered in a mosaic fashion and are associated with topographic or geological features.

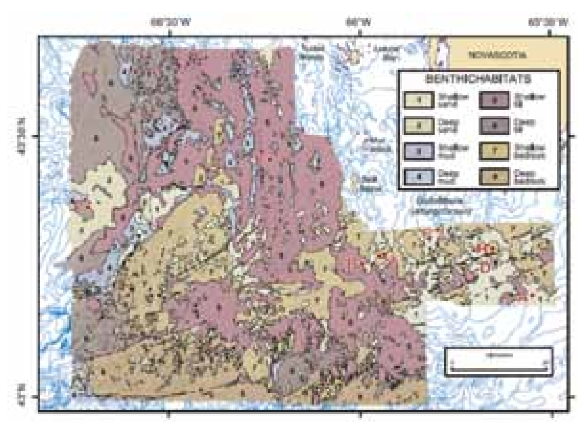


Figure 4: Benthic habitat map of German Bank showing eight colour-coded benthic habitat types. Source: Todd and Kostylev (2010).

- **Corals and Sponges:** Corals are mainly found below about 200 m along the edge of the continental slope, in canyons or in channels between fishing banks, but sponges and some soft corals are common in shallower waters on the continental shelf (Kenchington et al. 2010; Mortensen et al. 2006). The distribution of deep-water corals is patchy and largely influenced by substrate type, but temperature, salin-

Table 2: Epifauna assemblages identified by cluster analysis in areas within The Gully, Scotian Shelf, with common habitat characteristics for each group (Hargrave et al. 2004).

BENTHIC ASSEMBLAGE	MAJOR TAXA	PREDOMINANT HABITAT TYPE
Cluster 1	Brittlestars (*Ophiomusium* sp.), banded corals (*Keratoisis ornate*), sea whips (likely *Balticina* sp.), hydroids, soft alcyonacean corals (*Anthomastus* sp.)	Deep-water, mouth of The Gully, on canyon walls, >600 m depth, ridges dominated by suspension feeders, depositional valleys dominated by deposit-feeders
Cluster 2	Infaunal brittlestars (*Ophiopholis* sp.), daisy-top anemones (*Stomphia* sp.), sponges, chitons, and crinoids	Deep-water, gravelly substrate, 250–650 m, relatively constant temperature and high salinity along edge of canyon
Cluster 3	Cerianthid anemones (*Cerianthus borealis*), shrimp (*Pandalidae, Crangonidae spp*.), burrowing anemones, polychaetes, krill, (*Meganyctiphanes norvegica*), deposit- feeding brittlestars (*Ophiura* sp.), sea urchins (*Strongylocentrotus pallidus*)	Upper Gully, 130–410 m, glaciomarine deposits, microhabitats in bedrock, outcrops in tributary channels, moderate salinity and varying temperature
Cluster 4	Sand dollars (*Echinarachnius parma*), brittlestars (*Ophiura sarsi*), tube-dwelling polychaetes (*Northriidae*), hermit crabs (*Pagurus* sp.) and spider crabs (*Hyas araneus*), burrowing anemones (*Edwardsia* sp.), gastropods (*Trochidae*), polar sea stars (*Leptasterias* sp.)	Shallow depth (50–300 m), sand (bank tops) with highly variable oceanographic conditions
Cluster 5	Protozoan (*Bathysyphon* sp.), burrowing brittlestar (*Amphioplus* sp.), anemones, sponges (*Polymastia* sp.), soft corals (Alcyonacea spp.), sea feathers (*Pennatula* sp.)	Variable sediments (in tributary canyons), 200–600 m in areas with steep slopes, substrates range from silty sand to till, soft sediment between cobbles and boulders
Cluster 6	Sponges (*Halichondria* sp., *Scypha ciliata*, and *Crella guernei*), encrusting and solitary tunicates (*Molgulidae* spp.), bryozoans (*anascan* and *ascophoran*), stalked hydrozoans (*Sertullaria* sp.), gastropods (*Buccinum* sp.), and terebellids	Winnowed gravel 100–500 m in areas affected by shelf water with lower salinity and moderately variable temperature
Cluster 7	Many taxa similar to Cluster 6 brachiopods (*Terebratulina septentrionalis*), white encrusting sponges, anemones (*Fragesia* sp.), serpullid worms (*Filograna implexa*), and (*Protula tubularia*), tube-building polychaetes (*Nothriidae*)	Poorly sorted gravel (glacial till), 100–500 m on top of deep banks with average salinity, moderately variable temperatures and strong currents

ity, currents, and topographic relief are important environmental factors as well (Bryan and Metaxas 2006; Mortensen et al. 2006; Watanabe et al. 2009). There are only two known concentrations of the stony, reef-building coral *Lophelia pertusa* in Atlantic Canada (Cogswell et al. 2009). One concentration is located in The Gully, and the other on southeast Banquereau Bank, and was heavily damaged by fishing prior to its discovery (Cogswell et al. 2009; Kenchington et al. 2010). The known distribution of corals on the Scotian Shelf is shown in **Figure 5**.

Table 3: Seafloor habitats and species associations on German Bank, Scotian Shelf. Compiled from Todd and Kostylev (2010).

SEAFLOOR/HABITAT DESCRIPTION	SPECIES ASSOCIATIONS
• 100-140 m depth • Flat sea bed • Sediment varies from gravely sand to mud	• Amphipods and polychaete tubes, anemones (*Cerianthus borealis*), shrimp (*Pandalus* sp.), hake (*Urophycis* sp.), monkfish, flatfish, Jonah crabs (*Cancer* sp.), hermit crabs (*Pagurus* sp.) • Scarce benthic epifauna
• 50-100 m depth • Topographically complex and heterogeneous seabed • Seabed varies from exposed bedrock through cobbles and boulders to sandy gravel and shell hash beds	• **Hard substrates:** Sponges, sea stars (*Asterias* sp., *Crossaster papposus, Solaster endeca, Hippasteria phrygiana*), tunicates *(Boltenia ovifera*), brachiopods (*Terebratulina* sp.), soft corals (*Gersemia* sp.), mats of hydrozoans and bryozoans • **Complex rock habitat:** fish • **Poorly sorted sediments:** Polychaete tubes, sponges • **Sandy gravel, gravely sand, and shell beds:** Sea stars (*Asterias* sp., *Crossaster* sp., *Hippasteria* sp.) • **Sand and sandy mud patches among till and bedrock:** scarce fauna, infrequent occurrence of flatfish, Great spider crabs *(Hyas aranaeus*), sea urchins (*Strongylocentrotus* sp.) • Shell beds containing populations of horse mussels (*Modiolus modiolus*)
• 50-100 m depth • Dominated by moraines • Seabed varies from gravelly mud to complex cobble and boulder bottom	• **Hard substrates:** Abundant epifauna with low diversity • **Gravely sand in troughs between drumlins:** Groundfish, Jonah crabs (*Cancer* sp.), scallops (*Placopecten magellanicus*) • **Drumlins:** Anemones, sea stars (*Asterias* sp.), sponges (*Halichondria panicea*)
• 30-70 m depth • Sand deposits	• **Deep waters (70 m):** Brittlestars (*Ophiura sarsi*), sea urchins (*Strongylocentrotus* sp.), rigid cushion stars (*Hippasteria phygiana*), hermit crabs (*Pagurus* sp.), whelk (*Colus* sp.; *Buccinum* sp.), gastropods (*Neptunea* sp.), hydrozoans, bryozoans, anemones • **Shallow waters (30-40 m):** Scarce fauna including scallops (*P. magellanicus*), horse mussels (*M. modiolus*), anemones, sponges (*Polymastia sp.*)
• 20-40 m depth • Seabed dominated by bedrock and boulders with a few patches of sand	• Coralline algae (*Lithothamnium* sp.) on boulders • Frilled anemones (*Metridium senile*) and stalked tunicates (*B. ovifera*) are very abundant • Horse mussels (*M. modiolus*), sponges (*Haliclona oculata*), mound-shaped sponges, echioderms (*Asterias* sp., *Henricia* sp., *Strongylocentrotus* sp.)

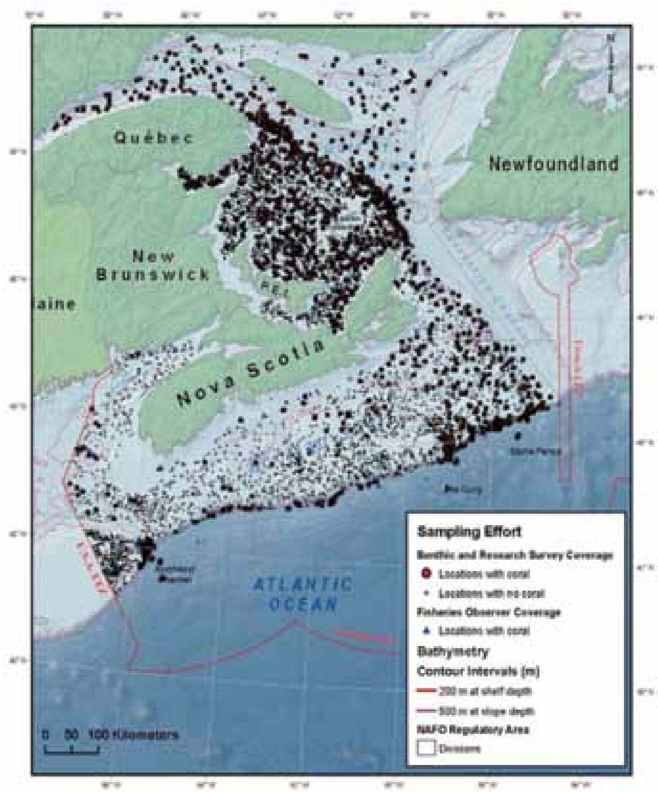


Figure 5: Distribution of cold-water corals on the Scotian Shelf and the Gulf of St. Lawrence. Source: Campbell and Simms (2009).

The Scotian Shelf hosts different sponge assemblages, but the overall biomass is relatively low (Kenchington et al. 2010). Typically, sponge grounds are composed of one or two species of large structure-forming sponges and many other smaller but abundant associated sponge species (Kenchington et al. 2010). Unique populations of the large, barrel-shaped glass sponge *Vazella pourtalesi* (also known as "Russian Hats") exist in the vicinity of Emerald Basin and Sambro Bank as well as areas of the Northeast Channel (Fuller 2011; Kenchington et al. 2010; Metaxas and Davis 2005; WWF 2009). More detailed information on the distribution and abundance of corals and sponges on the Scotian Shelf can be found in Cogswell et al. (2009); Kenchington et al. (2010) and Mortensen et al. (2006).

CORALS OF THE SCOTIAN SHELFS

Five major orders of coral are known to occur on the Scotian shelf including: *Alcyonacea* (soft corals), *Antipatharia* (black/thorny corals), *Gorgonacea* (branching corals), *Pennatulacea* (sea pens), and *Scleractinia* (stony corals, cup corals) (Cogswell et al. 2009).

Corals and sponges form complex structures that serve as important deep-sea habitat (see Section 3.1.2 above). Therefore, a variety of fish and invertebrate species are often associated with coral and sponge communities on the Scotian Shelf. Studies of benthic habitats and species assemblages on Browns Bank (Kostylev et al. 2001), in The Gully (Hargrave et al. 2004), and on German Bank (Todd and Kostylev 2010) describe some organisms commonly associated with coral and sponge communities in these areas (see Tables 2-4 above). Buhl-Mortensen and Mortensen (2005) studied the associated fauna of the most abundant large gorgonian corals (*Primnoa resedaeformis* and *Paragorgia arborea*) on the continental shelf and slope off Atlantic Canada. They identified 114 associated species and 3,915 specimens. Crustaceans were the most abundant fauna associated with the corals, contributing 46% to the total number of individuals and 26% to the total number of species (Todd and Kostylev 2010.; see **Figure 6**). Mortensen and Buhl-Mortensen (2005) examined the diversity of benthic megafauna in The Gully. A total of 95 megafauna taxa were observed, with the most species rich groups being fish (Teleostei, 19 taxa) and octocorals (18 taxa). The most common fish species observed were redfish (*Sebastes* sp.) followed by long-finned hake (*Urophycis chesteri*). Metaxas and

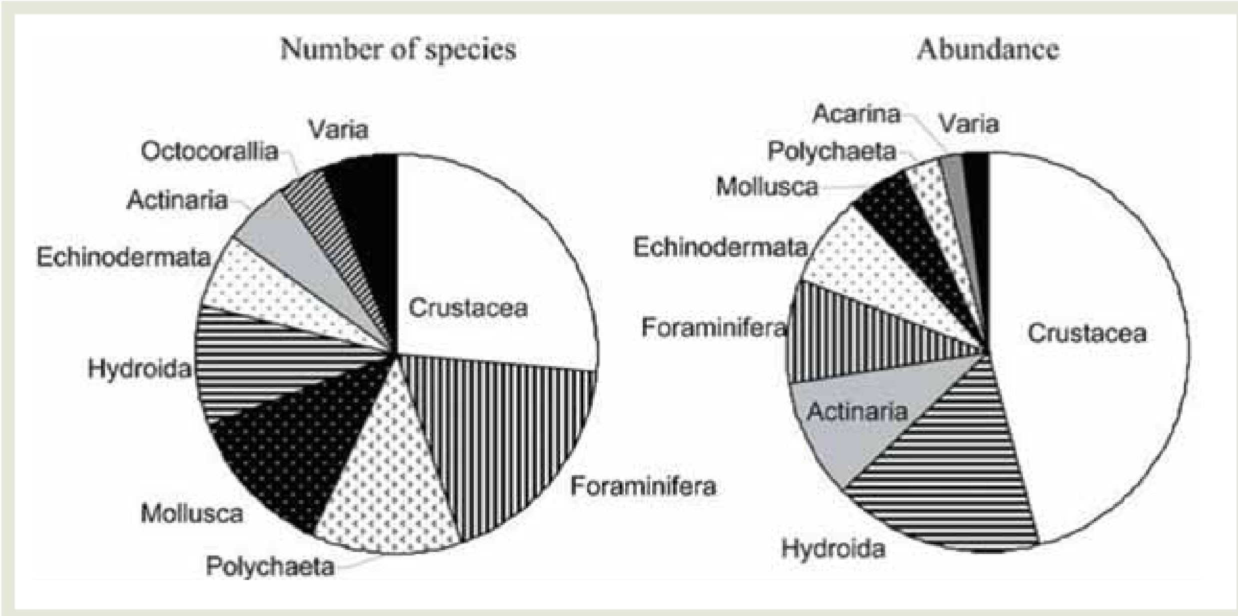


Figure 6: The relative species richness and abundance of different taxonomic groups associated with Primnoa resedaeformis and Paragorgia arborea from off Atlantic Canada. Source: Buhl-Mortensen and Mortensen (2005).

Davis (2005) studied the distribution and abundance of benthic megafauna in areas of Northeast Channel associated with known gorgonian coral assemblages using a remotely operated vehicle (ROV). The most abundant epibenthic taxa they observed included gorgonian corals (*Primnoa resedaeformis* and *Paragorgia arborea*), suspension feeders (*Actinauge verrilli* and *Bolocera tudiae*), an unidentified anemone, encrusting sponges (*Ophiacantha abyssicola*), and basket stars (*Gorgonocephalus arcticus*). In the canyons of Georges Bank, shrimp are commonly associated with the large gorgonian corals *P. arborea*, *P. resedaeformis*, and *Paramuricea grandis* and the alcynocean coral *Eunepthya florida* (Breeze et al. 2002). In the same area, the brittle star *Asteronyx loveni* is associated with colonies of *P. grandis* (Breeze et al. 2002).

Organisms commonly associated with sponges and sponge grounds in Atlantic Canada include species of marine worms, bryozoans, fish, crabs, shrimp, prawns, and other euphausids (Campbell and Simms 2009; DFO 2010c). Fuller (2011) describes benthic megafauna associated with *V. pourtalesi* sponges in Emerald Basin. The ocean pout (*Zoarces americanus*) was the most frequently observed fish species, followed by redfish (*Sebastes* spp.), hake (*Merluccius merluccius*), flatfishes and gadoids. Shrimp (*Pandalus borealis*) were the most frequently observed invertebrates associated with *V. pourtalesi*. Other invertebrate species observed included various other sponges, rock crabs (*Cancer borealis*), cerianthid anemones and sea stars (*Henricia* sp.).

Corals and sponges are vulnerable to anthropogenic disturbance because of their slow growth and sensitivity to physical and chemical changes (Fuller 2011; Watanabe et al. 2009). Evidence of fishing impacts to corals such as broken live corals, tilted corals, scattered skeletons, tracks made by fishing gear and lost longlines entangled in corals have been observed in a variety of locations on the Scotian Shelf, including the Northeast Channel and the Stone Fence (Cogswell et al. 2009; Mortensen et al. 2006).

4 IMPACTS

Pressures from changing environmental conditions and ocean activities such as commercial fisheries, offshore oil and gas activity, marine shipping and vessel traffic, and the laying of submarine cables result in a number of important biophysical and socio-economic impacts **Table 4**.

Table 4: Potential biophysical and socio-economic impacts of pressures on marine habitats and communities of the Scotian Shelf.

ELEMENT	POTENTIAL IMPACTS
BIOPHYSICAL	
Habitat	• Physical disturbance or alteration of the seabed from bottom-contacting fishing gear (DFO 2006a; Fuller et al. 2008; Fuller 2011; Jennings and Kaiser 1998), oil and gas activity (Hurley and Ellis 2004; Thomson et al. 2000), and submarine cables (Carter et al. 2009; Worzyk 2009) may affect the distribution and extent of benthic habitats as well as the distribution and structure of associated biological communities.
Community Structure	• Short-term and long-term changes in seawater properties (i.e. temperature, salinity, acidity) and oceanographic conditions may affect the distribution and extent of some marine habitats (see *Climate Change and its Effects on Ecosystems, Habitats and Biota* and *Ocean Acidification*).
Ecosystem Structure and Function	• Changes in the distribution and extent of marine habitats resulting from ocean activities and changing natural conditions may affect the distribution and structure of associated biological communities and biodiversity in the Scotian Shelf region (Cheung et al. 2009; DFO 2006a; Fuller 2011; Fuller et al. 2008; Jennings and Kaiser 1998; Rijnsdorp et al. 2009). • Pollution and noise from marine shipping, vessel traffic, and oil and gas activity may affect the quality of marine habitats (see *Water and Sediment Quality* and *Ocean Noise*). • Removal of organisms from the ecosystem through fishing and incidental mortality may affect the distribution and structure of biological communities (Baer et al. 2010; Bundy 2005; DFO 2006a; Donaldson et al. 2010; see *Incidental Mortality*). • Changes in the structure of biological communities resulting from ocean activities and changing natural conditions may affect the Scotian Shelf ecosystem by altering trophic structure and biodiversity (Bundy 2005; Frank et al. 2005; see also Trophic Structure).
SOCIO-ECONOMIC	
Ecosystem Goods and Services	• Loss of benefits and services to humans derived from ecosystem functioning (e.g. disturbance regulation, biological control and the regulation of populations, food production, genetic resources, etc.) (Costanza et al. 1997).
Economy and Livelihoods	• Changes in the distribution and extent of marine habitats and the distribution and structure of biological communities could impact commercial fisheries (Bundy 2005; Charles et al. 2009; Frank et al. 2005; Gien 2000; see also Trophic Structure).

4.1 BIOPHYSICAL IMPACTS

Ocean uses and activities have the potential to impact marine habitats and communities in variety of ways (**Table 4**). The overexploitation of commercial species and/or the incidental capture of non-target species in fisheries can alter biological communities by changing the productivity, species diversity and size structure of the community (DFO 2010b; Jennings and Kaiser 1998; see also *Fish Stock Status and Commercial Fisheries* and *Incidental Mortality*). Marine pollution and ocean noise from commercial shipping, vessel traffic and oil and gas activity can reduce the quality of marine habitat [DFO 2004a; Hurley and Ellis 2004; Southall 2005; Thomson et al. 2000; see also *Water and Sediment Quality* and *Ocean Noise*.The greatest impact of ocean activities on benthic habitats and communities is physical disturbance and alteration of the seabed, especially from mobile, bottom-contacting fishing gear (DFO 2006a; Fuller et al. 2008). DFO has recently reviewed a framework for the classification and characterization of benthic habitats in the Scotian Shelf and Bay of Fundy which helps to identify benthic habitats that are sensitive to physical disturbance from human activities (DFO 2005b; Kostylev and Hannah 2007). This framework classifies benthic habitats as a function of *disturbance* and *scope for growth*. Disturbance is defined as a natural, mechanical force determined by the action of currents and waves on the seabed (DFO 2005b). Scope for growth is related to the energy available for organisms to spend on reproduction and growth after meeting basic metabolic needs and can be described by some combination of food availability to the benthos, annual bottom temperature, seasonal and interannual temperature variability, and oxygen saturation (DFO 2005b). Using these parameters, the framework characterizes the potential sensitivity and predicted response of benthic communities to physical disturbances resulting from human activities (**Figure 7**). In this model, *sensitivity* is defined as a function of the recoverability and the vulnerability of some biological component, such as a community, species, or population. *Vulnerability* is the likelihood that a biological component will be exposed to some impacting factor and *recoverability* is the rate at which the component is able to return to some previous state after being impacted. Therefore, the most sensitive benthic communities are those with high vulnerability and low recovery rate such as deep-sea coral communities. At the other end of the spectrum, the least sensitive benthic communities are those with a low vulnerability and high recovery rate, such as communities dominated by scavengers and mobile species.

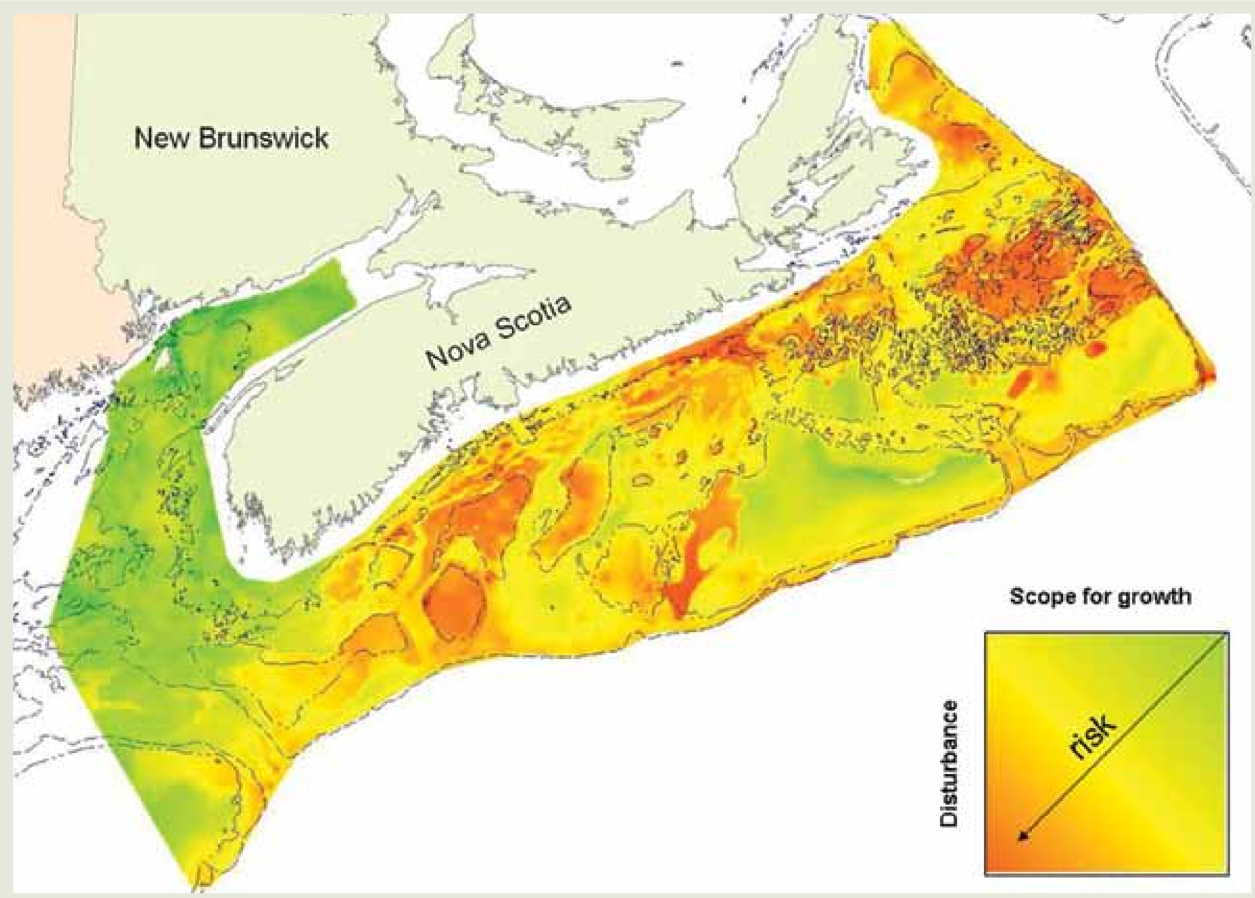


Figure 7: Potential sensitivity and predicted response of benthic communities to physical disturbances resulting from human activities. Source: DFO 2006d

4.2 SOCIOECONOMIC IMPACTS

The marine habitats and communities of the Scotian Shelf are associated with a number of important economic, social, and cultural values. Nova Scotia's fishing industry is a major source of direct and indirect employment and income and is the province's leading source of export earnings (see *Scotian Shelf in Context*). The productivity and health of commercially valuable fish and invertebrate populations is strongly influenced by the status of their habitat and the community and ecosystem that they are a part of. Therefore, biophysical impacts on marine habitats and communities can affect the status of commercial fish and invertebrate populations and result in socioeconomic impacts on those who rely on the fishery. Marine habitats and communities also provide many important functions and services that contribute both directly and indirectly to human welfare such as climate regulation, disturbance regulation, biological control and the regulation of populations, food production, genetic resources, and opportunities for recreation and other non-commercial uses (Costanza et al. 1997). Changes in marine habitats and communities can alter these functions and services, having a range of potential socioeconomic impacts.

5 ACTIONS AND RESPONSES

Management actions and responses to impacts on marine habitats and communities include legislation and policy, and scientific research and monitoring.

5.1 LEGISLATION AND POLICY

There are various pieces of legislation that contribute to the conservation and protection of marine habitats and communities. Key legislation includes Canada's *Oceans Act, Fisheries Act* and *Species at Risk Act.*

Fisheries Management

DFO regulates the use of fishery resources and restricts certain fishing activities to protect and conserve fishery resources and to limit as much as possible, the destruction of sensitive marine habitat and species (DFO 2009c). The most common fisheries management measures used are area or time closures, gear restrictions, and requirements for gear modification (DFO 2009c). Although fisheries closures may not be put in place to protect marine habitats and communities, many spatial/time closures provide indirect protection. Under the Fisheries Renewal Initiative (http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/fish-ren-peche/index-eng.htm), DFO has committed to implementing an ecosystem approach to fisheries. DFO is currently developing an Ecosystem Approach to Management (EAM) Framework (DFO 2010e). The ecosystem approach requires that fisheries management decisions consider the impact of the fishery not only on the target species, but also on non-target species, seafloor habitats, and the ecosystems of which these species are a part (DFO 2009d).

The EAM framework for fisheries is currently being implemented through Integrated Fisheries Management Plans (IFMPs) for fisheries that occur on the Scotian Shelf. In 2010, DFO released the *Sustainable Fisheries Framework*. The Framework comprises two main elements: (1) conservation and sustainable use policies, and (2) planning and monitoring tools (DFO 2009e; see http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/fish-ren-peche/sff-cpd/overview-cadre-eng.htm). The Framework includes a new *Policy for Managing Impacts of Fishing on Sensitive Benthic Areas.*

In addition to fisheries management regulations, the fishing industry has also implemented voluntary conservation measures. Atlantic Canada's offshore groundfish fishing companies recently announced a voluntarily fishing closure in a 332 km^2 area of the Emerald Basin to protect a concentration of the rare glass sponge *Vazella pourtalesi* (The Sou'Wester 2010).

Ecosystem Management

DFO's framework for the classification and characterization of benthic habitats on the Scotian Shelf will facilitate improved ocean planning and management by identifying benthic habitats that are sensitive to physical disturbance from human activities (DFO 2005b). DFO has established criteria for identifying Ecologically and Biologically Significant Areas (EBSAs) and Ecologically Significant Species and Community Properties. The identification of EBSAs and Ecologically Significant Species and Community Properties is a tool for facilitating a greater degree of risk aversion in the management of human activities that may affect such areas, species or community properties (DFO 2006b; DFO 2004b). EBSAs of the Scotian Shelf have been identified in Doherty and Horsman (2007). Scotian Shelf EBSAs have been considered during oil and gas planning and conservation planning.

Several major spatial conservation measures including Marine Protected Areas (MPAs) and coral conservation areas have been established on the Scotian Shelf to protect habitat, ecologically significant species and species at risk (**Table 5**). Three federal departments and agencies including DFO, Environment Canada, and Parks Canada Agency have specific mandates to establish and manage MPAs. Canada's *Federal Marine Protected Areas Strategy* aims to establish and manage a network of MPAs that contributes to the health of Canada's oceans and marine environment (Government of Canada 2005). More recently, a *National Framework for Canada's Network of Marine Protected Areas* was created to provide guidance for the planning and implementation of MPA networks within 13 bioregions across Canada (DFO 2010f). The Scotian Shelf (along with the Bay of Fundy) is one of these bioregions and DFO will be leading an MPA network planning process for this bioregion in the coming years. The federal MPA network is comprised of three core programs: *Oceans Act* MPAs; National Wildlife Areas (NWAs); and National Marine Conservation Areas (NMCAs). Currently, there is one *Oceans Act* MPA on the Scotian Shelf (The Gully, see **Table 5**). In 2010, DFO completed consultations to identify an Area of Interest (AOI) for designation as the next *Oceans Act* MPA in the eastern Scotian Shelf region (DFO 2009f). DFO has also implemented conservation measures to protect cold-water corals including the establishment of the Northeast Channel Coral Conservation Area and the Lophelia Coral Conservation Area which restrict bottom fishing year-round (Campbell and Simms 2009; Cogswell et al. 2009; DFO 2002; see

Table 5). DFO has also developed a *Coral Conservation Plan* which aims to document what has been done to conserve corals, put forward a more comprehensive approach on coral conservation, identify issues where more work is needed, and build collaboration among a variety of groups to address coral conservation (DFO 2006c).

Canada's *Species at Risk Act* (SARA) provides for the legal protection of wildlife species at risk and contains prohibitions against the damage or destruction of their residences (Government of Canada 2009). Once an area is identified as Critical Habitat in a Recovery Strategy or Action Plan, provisions of SARA prevent activities that would destroy

Table 5. Major spatial conservation measures protecting marine habitats on the Scotian Shelf.

LOCATION	RESTRICTED ACTIVITIES	CLOSURE PERIOD	REASON FOR PROTECTION	SOURCES
***OCEANS ACT* MPAS**				
The Gully: a 2,364 km2 area near Sable Island	General prohibitions against disturbance, damage, destruction or removal of any living marine organism or any part of its habitat within the MPA apply to the entire water column and include the seabed to a depth of 15 m Coral Conservation Areas	Closed year-round since 2004	Protects a rich diversity of marine habitats and species; Endangered northern bottlenose whales; and deep-sea corals including one of only two known areas in Atlantic Canada with the reef-building *Lophelia pertusa*	DFO (2004b)
CORAL CONSERVATION AREAS				
Northeast Channel Coral Conservation Area: a 424 km2 portion of the Northeast Channel	90% of the area is restricted to all bottom fisheries;10% is open only to longline fishing gear	Closed year-round since 2002	Protects high densities of intact octocorals, mainly bubblegum (*Paragorgia arborea*) and seacorn coral (*Primnoa resedaeformis*)	Campbell and Simms (2009); DFO (2002)
Lophelia Coral Conservation Area: a 15 km2 zone located at the mouth of the Laurentian Channel	All bottom fishing activities	Closed year-round since 2004	Protects one of only two areas of the reef-building *Lophelia pertusa* in Atlantic Canada	Campbell and Simms (2009); Cogswell et al. (2009)
VOLUNTARY CLOSURES				
Emerald Basin Closure: a 332 km2 portion of Emerald Basin	Voluntary closure of all groundfish fisheries	Closed year-round since 2010	Protects a concentration of the rare glass sponge *Vazella pourtalesi*	The Sou'Wester 2010

any part of the species' Critical Habitat, including issuance of a Protection Statement or a Protection Order (DFO 2007b). For more information on SARA, see *At Risk Species*.

Habitat Management Program and Environmental Assessments

Subsection 35(1) of the *Fisheries Act* prohibits the harmful alteration, disruption or destruction (HADD) of fish habitat without an authorization from the Minister or by regulation. This applies to works or undertakings in the offshore which could result in a HADD (e.g. exploratory wells, pipelines), but it does not apply to commercial fishing activities. Development proposals in the offshore are subject to the regulations outlined in the *Canadian Environmental Assessment Act* (CEAA) and generally require an environmental assessment. The CNSOPB is responsible for conducting environmental assessments on all proposed oil and gas activities in the offshore, while DFO's Habitat Management Program is responsible for assessing all other proposed activities which could result in a HADD. For oil and gas activities that occur on the Scotian Shelf, environmental assessments have been conducted and take into account habitats and communities that DFO identifies as vulnerable to the activity, particularly MPAs, conservation areas and EBSAs.

Pollution and Ocean Noise

Canada has many laws, regulations, policies and guidelines related to the management of marine pollution and ocean noise. For a detailed description of the actions and responses to the impacts of pollution and noise on the Scotian Shelf ecosystem, the reader is directed to *Water and Sediment Quality* and *Ocean Noise*.

5.2 SCIENTIFIC RESEARCH AND MONITORING

The data and information generated from research and monitoring programs improves our understanding of the Scotian Shelf ecosystem and is used to develop more effective strategies for managing ocean activities and protecting marine habitats and communities. A wide range of government agencies, universities and research institutions are involved in research and monitoring of the Scotian Shelf ecosystem. Some of the main research organizations and institutions in the region include DFO's Science Branch (DFO-Science), Natural Resources Canada (NRCan), Environment Canada, the Canadian Hydrographic Service (CHS), Dalhousie University, the Huntsman Marine Science Centre and the Bedford Institute of Oceanography (BIO). As the primary ocean research agency of the federal government, DFO-Science conducts research on a broad range of ocean issues including the sustainable use of ocean resources, conservation and environmental protection, and integrated oceans management. DFO-Science has recently committed to an ecosystem science approach and has developed *A New Ecosystem Science Framework in Support of Integrated Management* in order to implement this approach (DFO 2007a). An ecosystem science approach supports integrated oceans management and science-based decision-making by improving our understanding about how human activities interact with one another and how they affect marine ecosystems (DFO 2007a).

Some of the key ongoing research and monitoring activities and programs related to marine habitat and communities that are carried out on the Scotian Shelf include:

- ***Atlantic Zone Monitoring Program (AZMP):*** The AZMP collects and analyzes biological, chemical, and physical field data on Atlantic Canada`s marine environment. There are several sampling transects on the Scotian Shelf: the Cabot Strait line across the Cabot Strait, the Louisbourg line across Misaine and Banquereau banks, the Halifax line across Emerald Basin and Emerald Bank, and the Browns Bank line across Browns Bank (DFO 2005a). For more information visit: http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/azmp-pmza/index-eng.html.

- ***Continuous Plankton Recorder (CPR) Survey:*** The CPR Survey program is run by the Sir Alister Hardy Foundation for Ocean Science (SAHFOS) in the United Kingdom. SAHFOS has been using vessels of opportunity to collect plankton samples from the northwest Atlantic since 1959, including a limited number of samples from the Scotian Shelf (DFO 2005a). For more information visit: http://www.sahfos.ac.uk/about-us/cpr-survey/the-cpr-survey.aspx.

- ***DFO's Coral Research Program:*** In 1998, DFO began collaborating with university, NGO and industry partners to collect information on corals in the Scotian Shelf region. DFO initiated a full coral research program in 2000 (DFO 2011). The DFO coral research program conducted four dedicated research surveys in several areas of the Scotian Shelf and Slope between 2000 and 2003 in order to document the distribution, abundance and condition of corals as well as their preferred habitats and associated species (DFO 2011). For more information visit: http://www.mar.dfo-mpo.gc.ca/e0010591.

- ***Geoscience for Oceans Management (GOM) Program and the Geology of the Eastern Scotian Shelf Project:*** The GOM program is based on a systematic approach to seafloor mapping for integrated ocean management, including the development of maps of the bathymetry, geology, and distribution of benthic habitat and organisms of Canada's offshore areas (NRCan 2008). For more information visit: http://ess.nrcan.gc.ca/2002_2006/gom/index_e.php.

- ***Marine Fish Research and Monitoring:*** Researchers at DFO have conducted annual bottom trawl surveys on the Scotian Shelf since 1970. These surveys are one of the most important sources of information on marine fish and invertebrate populations (DFO 2005a). Other research surveys conducted on the Scotian Shelf include cooperative surveys with industry, such as the sentinel surveys for groundfish, the skate survey, the Scotian Shelf and Grand Banks halibut survey, and surveys for invertebrates such as shrimp, scallops and snow crab (DFO 2005a).

- ***University Research Programs:*** A number of universities in the region are collaborating with other research institutions to study the marine habitats and communities of the Scotian Shelf. For example, researchers at Dalhousie University in Halifax have studied the distribution and ecology of benthic invertebrates and associated communities on the Scotian Shelf (e.g. Fuller 2011; Metaxas and Davis 2005; Watanabe et al. 2009). Some studies have used fishermen's knowledge to help determine the distribution and ecosystem function of cold-water corals and sponges on the Scotian Shelf (Breeze 1997; Fuller 2011; Gass and Willison 2005).

INDICATOR SUMMARY

INDICATOR	POLICY ISSUE	DPSIR	ASSESSMENT	TREND
Sea Surface Temperature	Temperature influences habitat quality and the distribution, growth and survival of marine organisms	Pressure	Good	/
Average salinity	Salinity influences habitat quality and the distribution, growth and survival of marine organisms	Pressure	Fair	-
Disturbance from human activities (fishing, oil and gas, cables)	Direct and indirect effects on benthic habitat communities by disturbing and altering the seabed	Pressure	Fair	/
Abundance and distribution of structure-forming organisms (e.g. corals and sponges)	Structure-forming organisms create, modify and maintain habitat for other species by producing complex structures on top of sediments	State	Good	/
Community structure	Changes in species diversity, the abundance of ecologically significant species, trophic balance, size-based properties, and productivity within a community can affect its structure and function	State	?	?
Total area of habitat protected by conservation and management measures (e.g. MPAs, fisheries closures, gear restrictions, etc.)	Conservation and management measures can protect marine habitat from harmful human activities	Response	Fair	+
Total number of ecologically significant species protected by conservation and management measures (e.g. catch limits, size restrictions, gear modifications, etc.)	Conservation and management measures can protect ecologically significant species and the communities they are a part of from harmful human activities	Response	?	?

Data Confidence:

- Water temperature, salinity and pH are monitored regularly
- Recent advances in benthic mapping and research have improved the state of knowledge regarding the abundance and distribution of structure-forming organisms and associated communities
- Species diversity is monitored infrequently and information is available for only a small number of species assemblages (e.g. finfish; plankton; site-specific benthic assemblages)
- Changes in the trophic structure of the Scotian Shelf ecosystem have been studied
- Fishing effort of vessels using bottom-contact fishing gear is monitored regularly
- Data on the location and quantity of drilling wells and submarine cables is available
- Data on the total area of habitat protected by conservation measures is available

Data Gaps:

- Data on benthic and pelagic community trends
- Overall ecological footprint of human activities on the Scotian Shelf
- High degree of uncertainty regarding the ecological significance of many species

Key:
Negative trend: -
Unclear or neutral trend: /
Positive trend: +
No assessment due to lack of data: ?

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