H1.1 OPEN WATER

The open-water offshore habitat covers an area of Nova Scotia larger than the land mass, and includes salt water in inlets, bays and estuaries. The water and the organisms it supports are the primary means by which solar energy enters the marine ecosystem, similar to the layer of plants on land. The ocean waters are distinctive in having fostered the origins of life on the planet.

Plate H1.1.1: Right Whale, north of Brier Island (Unit 912). Photo: BIOS

FORMATION

Oceans are formed as part of major geological events. Nova Scotia's open-ocean habitats are part of the Atlantic Ocean, which opened during the Jurassic Period and has been in continuous existence ever since. The quality and depth of the water column have fluctuated in relation to post-glacial climatic conditions.

PHYSICAL ASPECTS

1. *Water conditions,* such as salinity, temperature, ice-formation, turbidity, light penetration, tides and currents, are extremely variable in the waters offshore.
2. *Air-water interaction,* surface-water turbulence determines the level of wave and gas exchange.
3. *Land-water interaction:* variable conditions in shallow waters along the coast are determined by enclosing land forms, freshwater runoff with products of erosion, turbidity and nutrient supply.
4. *Bottom-water interaction:* in deeper water, bottom turbidity currents maintain nutrient levels in the water column, while inshore tidal currents and wave action maintain nutrient levels.

ECOSYSTEM

Primary production is carried out by phytoplankton, utilizing light and dissolved nutrients from freshwater runoff or river input. The general pattern of production is markedly seasonal, with a conspicuous "bloom" in the spring. Lesser "blooms" occur throughout the summer on the southwestern coast of Nova Scotia, and there is a late summer "bloom" in most regions. The Minas Basin does not follow this pattern, and primary production by phytoplankton is significantly reduced, due to the high turbidity. Primary production supports diverse species of herbivorous crustaceans, particularly copepods, which in turn support a wide variety of carnivorous plankton organisms, pelagic animals, such as seals, whales, porpoises and dolphins, and numerous seabirds.

SUCCESSIONAL SEQUENCE

The normally understood process of ecological succession does not apply to open water. The characteristics of the water column will vary in response to environmental conditions.

PLANTS

The plants of the open ocean are almost entirely microscopic algae, collectively known as phytoplankton. Many different species occur, including representatives of the prochlorophytes (blue-green algae—evolutionary intermediates between bacteria and algae), diatoms, dinoflagellates, chrysomonads, cryptomonads, minute flagellates and unicellular reproductive stages of macroscopic algae. Phytoplankton are often grouped in size classes:

macroplankton: 200–2000 micrometres, includes larger diatoms.
microplankton: 20–200 micrometres, includes most diatoms.
nanoplankton: 2–20 micrometres, includes flagellates and dinoflagellates.
ultrananoplankton: below 2 micrometres.
picoplankton: < 1 micrometres, includes chiefly blue-green algae and bacteria.

Bacteria that live on particles and are in turn consumed by various organisms are grouped with plants. Floating seaweeds, including *Sargassum,* occasionally occur in Nova Scotia waters.

ANIMALS

There are two main groups of open-ocean animals:
1. *zooplankton,* which have limited powers of horizontal movement (though they migrate vertically on a daily basis) and are mainly carried by currents, e.g., copepods and jellyfish
2. *nekton,* which are active swimmers, are usually carnivorous, and commonly display vertical or horizontal migratory behaviour (e.g., squid, herring, mackerel, tuna, sharks and whales)

The zooplankton itself may be subdivided into two groups. The animals which spend their whole life in the plankton are collectively known as holoplankton and include immature and adult stages of coelenterates (medusae), ctenophores (Sea Gooseberries), rotifers, pteropods (Sea Butterflies), polychaete worms (e.g., *Tomopteris*), copepods (e.g., *Acartia* spp., *Calanus* spp. and *Oithona* spp.), mysids, amphipods, euphausoids ("krill"), arrow worms and salps.

Other animals, grouped as the meroplankton, include both herbivores and carnivores. These animals spend part of their lives either on the bottom (e.g., coelenterates, molluscs, polychaete worms, crustaceans, echinoderms and some chordates) or as nekton (e.g., herring, squid). Nekton includes the largest animals encountered in the open sea and many economically important species. Fish and squid that occur in deep water off the continental slope are also included in this group.

SPECIAL FEATURES

- Slope-water exchange brings warm, nutrient-rich water to the surface at the shelf edge, leading to elevated plant production and concentrations of phytoplankton, zooplankton and fish.
- Vertical migration of zooplankton and nekton occurs in open-ocean waters. Animals such as shrimp, squid and mesopelagic fish migrate to the surface at night to feed on the plankton. They migrate downwards at sunrise. Although distant from the shore of the Nova Scotia mainland, this process brings a food resource to the surface, where it is utilized by whales and ocean birds, e.g. petrels.
- Upwelling caused along the Atlantic coast by wind conditions and in other areas (Outer Bay of Fundy, Unit 912; Georges Bank, Unit 913) by tidal activity —leads to elevated plant production in coastal waters.
- The Gulf Stream transports organisms from more southerly regions and occasionally deposits them in Nova Scotia waters. The shores of southwestern Nova Scotia are frequently visited by larvae and adults of warm-water invertebrates and fish. Young American Eels from the hatching areas in the Sargasso Sea come into the area with the Gulf Stream, and disperse along the coast to freshwater streams.
- Paralytic shellfish poisoning is caused by toxins produced by species of dinoflagellates. In many areas of the world, the “bloom” of these species may become sufficiently concentrated to colour the sea, resulting in a phenomenon termed “red tide”. In Nova Scotia waters, the bloom of *Gonyaulax excavata* occurs only in the outer Bay of Fundy, where the high tidal range creates sufficient mixing to prevent development of the intense colour, though the bloom can still cause paralytic shellfish poisoning. *Gonyaulax* is consumed by shellfish, which accumulate the poison and become dangerous for human consumption. Shellfish beds are often closed in late summer and autumn as a precaution.
- Enclosed or semi-enclosed bodies of water on the coast, including bays, estuaries and barachois ponds, are strongly affected by runoff from the land, giving low salinities, high turbidity and often high nutrient levels. The shallow water may also be subject to wider seasonal temperature extremes than the open sea. There may be vertical stratification of the water and winter ice. These conditions strongly affect the planktonic and nektonic life, and many species are either totally or seasonally excluded. Extreme cases occur in barachois ponds and the upper reaches of estuaries. Because of access to nutrients, primary production may be greater in the summer than in the spring bloom.

DISTRIBUTION IN NOVA SCOTIA

Open marine waters occur all around the coast of Nova Scotia and in the Bras d’Or lakes. The main environments are

1. The Northumberland Strait (Unit 914) and southeastern Gulf of St. Lawrence exhibit high turbidity, warm summer surface temperatures, cold winter surface temperatures with ice development, and intermediate tidal range of 1.0 to 1.5 m. Salinities are in the range 30.0 to 31.0 parts per thousand. Jellyfish populations are often conspicuous during the summer.
2. Atlantic Ocean from Cape Breton to Yarmouth (Region 800 and Units 911, 915) exhibits low turbidity, surface temperature relatively low in summer (10°C), except in bays and where influenced by slope-water exchange. Surface temperatures are low in winter (0.5°C), and salinities range from 28.0 to 31.0 ppt, with lower values in bays and estuaries. There is relatively little ice development. Tidal range is intermediate (1.0 to 2.0 m) and productivity is elevated through wind-induced upwelling of nutrients along the coast. Migratory pelagic fish (herring, mackerel, tuna and sharks) and whales are present in the summer. Warm-water invertebrates and fish may be locally present in the late summer.
3. The Bay of Fundy (Units 912, 913) has high turbidity, especially in the upper reaches. It is generally a cold-water region, with surface temperature of 14.0°C in summer and 0.5°C in winter. These ranges are more extreme in the upper reaches. Salinity of 31.0 ppt for the Bay of Fundy is reduced to 25.0 ppt or less in parts of the Minas Basin. The tidal range is large, 4 m to 15.3 m. Phytoplankton productivity is low in the Minas Basin area, but abundant zooplankton populations are supported by quantities of

particulate organic matter, in a large part derived from decaying Cord Grass (*Spartina* spp.). The coast between Yarmouth and Cape St. Mary (District 820) is influenced by cold water upwelling and local nutrient enrichment.

4. Bras d'Or Lake (District 560 and Unit 916) is a many-branched inland sea with moderate turbidity, warm summer surface temperature 15–20°C, and cold winter surface temperature with extensive ice cover. Surface salinity is between 20.0 and 25.0 ppt. There is no significant tide. Plankton species tend to be estuarine.

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Associated Topics

T6.1 Ocean Currents, T6.2 Oceanic Environments, T6.3 Coastal Aquatic Environments, T6.4 Estuaries, T7.2 Coastal Environments, T7.3 Coastal Landforms, T10.9 Algae, T11.7 Seabirds and Other Birds of Marine Habitats, T11.12 Marine Mammals, T11.14 Marine Fishes, T12.6 The Ocean and Resources

Associated Habitats

H1.2 Benthic, H2.1 Rocky Shore, H2.2 Boulder Cobble Shore, H2.3 Sandy Shore, H2.4 Mud Flat, H2.5 Tidal Marsh.

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H1.2 BENTHIC

The sea-bottom, or benthic, habitat is composed of a variety of sediment types and is exposed to a wide range of water conditions, leading to the development of diverse plant and animal communities. Benthic habitats dealt with in this section are restricted to those that occur subtidally, from extreme low water to the shelf break at 200 m depth. They are not exposed to air at low tide but are influenced by wave action and currents.

Plate H1.2.1: An extensive Eelgrass bed in Lingan Basin, Cape Breton County (Unit 531). This is a benthic habitat with sandy or mud bottom, commonly associated with mud flat (H2.4) and the lower levels of the salt marsh (H2.5). Photo: R. Merrick.

FORMATION

The formation of benthic habitats in Nova Scotia relates to the widening of the Atlantic Ocean during the Jurassic Period and the subsequent deposition of sediments and till. In deep areas, sediments have been in continuous formation. In nearshore areas, glacial deposits form the basis for most benthic habitats.

The structure of benthic communities is determined largely by bottom substrate, in combination with turbidity, depth, temperature, salinity and nutrient level. Offshore habitats may range from bedrock, to coarse sands and gravels, to silt and clay in specific locations (see Topic T3.5 and Region 900).

The subtidal habitat along the Atlantic Coast (Region 800) of Nova Scotia consists of bedrock with boulder fields and occasional cobble beds. The rock substratum usually extends to a water depth of about 15 m, where it is replaced by a sedimentary bottom, although rock ledges and bedrock exposures can occur up to 60 km offshore.

PHYSICAL ASPECTS

1. *Bottom-water interaction:* Nova Scotia's benthic habitats are largely influenced by cold water. In summer, shallow areas, such as the Upper Bay of Fundy (Unit 913) and Northumberland Strait (Unit 914), are subjected to warmer, lower-salinity water. Upwelling caused by tidal and wind action and slope-water exchange cause local decreases in temperature and/or increases in nutrient level.
2. *Bedrock and sediments:* distribution of bedrock and sediment types (gravel, sand and mud) relates to submerged glacial and glaciomarine features and contemporary erosion processes. Disturbance of the sediments by tides, bottom currents and wave action may be apparent. The seasonal, onshore/offshore movement of sediment in high-energy situations is important.
3. *Relief:* bottom relief, as indicated by water depth, is generally undulating. Basins can be up to 280 m below sea level, while the tops of banks can be as shallow as 50 m.

ECOSYSTEM

Sunlight, the main source of energy, drives primary production by phytoplankton in the water column. In shallow water, primary production by benthic algae is also important and directly supports populations of herbivorous animals. In addition, energy enters the system through particulate organic matter derived from the land and intertidal areas or recycled from the bottom. Animals that filter particles from the water or sort particles from the sediment are of considerable importance and support several levels of carnivores, including bottom-feeding fish, such as cod.

The ecosystem of the rocky subtidal habitat along the Atlantic Coast (Region 800, Unit 911) appears to cycle between two alternative states. This relates to large-scale fluctuations in the abundance of herb-

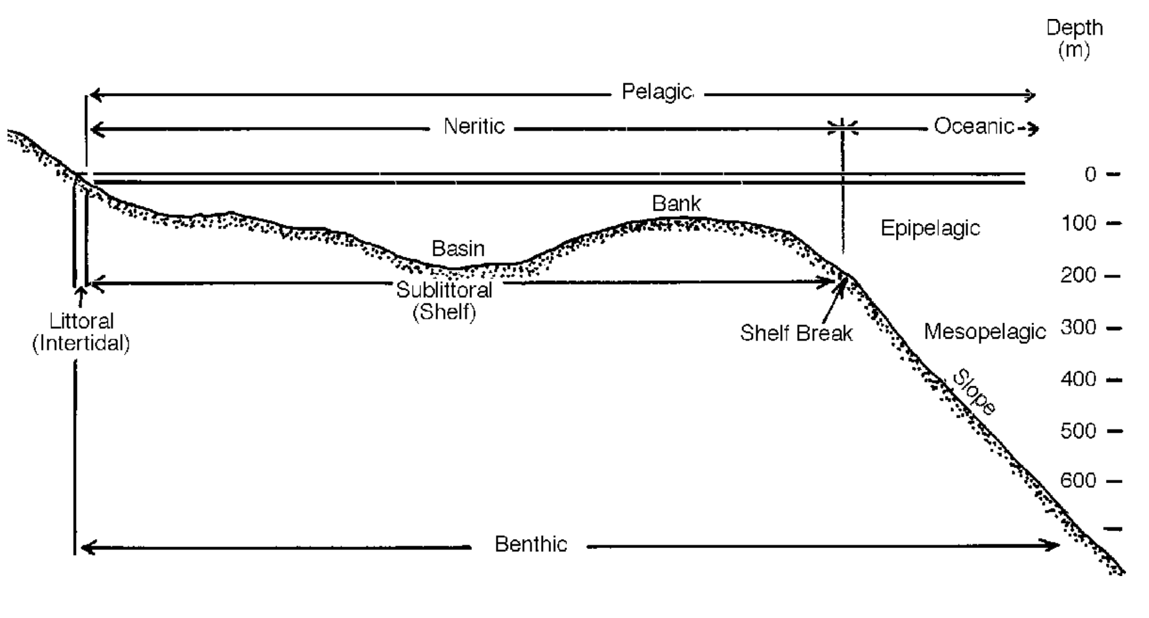

Figure H1.2.1: Terminology used for marine environments on the continental shelf off Nova Scotia ivorous sea urchins *Strongylocentrotus droebachiensis*. When sea urchins are rare, luxuriant and highly productive kelp beds cover the rock substratum; when abundant, they form large, moving aggregations, or “grazing fronts”, that consume the seaweeds and leave “barren grounds” where only the encrusting algae remain. Sea urchins persist in these areas, grazing upon films of microscopic algae and newly recruited seaweeds, and thereby prevent the re-establishment of kelp beds.

SUCCESSIONAL SEQUENCE

Successional changes in benthic habitats occur in response to major disturbances of the substrate. These include natural conditions, such as reworking of sediments and till, turbidity flow and ice-scouring, and cultural factors, such as industrial pollution, dredging and deposition of muds.

Benthic plants and animals will respond by recolonizing the substrate. Submerged structures, such as shipwrecks, also provide substrate for the colonization of species.

PLANTS

Benthic plants are dependent upon sunlight and therefore occur only in shallow water, where sufficient light penetrates. The depth of light penetration is reduced with increased turbidity, as in muddy bays and estuaries. The plant species are almost exclusively algae, including the conspicuous macrophytes commonly grouped as seaweeds. The algae have no roots, but are attached to a firm substrate by a stocky, thickened portion known as a holdfast. The distribution of these plants is therefore also limited by the availability of rock or other firm substrate. There are also benthic microalgae that grow attached to surfaces of submerged sand, mud and gravels.

Eelgrass (*Zostera marina*) is a specially adapted vascular plant which is abundant in sheltered bays with soft sediment bottoms. On the Atlantic and Fundy coasts (Units 911, 912, 913, 915), in relatively clear water, there are commonly extensive growths of brown and red seaweeds, extending from the extreme-low-water mark to a depth of 25 m. These include Irish Moss, Dulse and the conspicuous brown kelps, such as *Laminaria* spp., *Alaria esculenta* in shallow, subtidal areas, and *Agarum cribrosum* in deeper water. Other brown and red filamentous and foliose algae, and branching coralline red algae make up the understory. Encrusting coralline red algae *Lithothamnion glaciale, Phymatolithon rugulosum*, *P. laevigatum* and *Clathromorphum circumscriptum* cover most of the rock surface, forming the secondary substratum upon which the seaweeds grow.

In the Northumberland Strait (Unit 914), there are more extreme seasonal temperatures, more turbid waters and erosion by ice in winter, and extensive kelp beds do not develop. Subtidal rock ledges are extensively colonized by Serrated Wrack (*Fucus serratus*), Irish Moss (*Chondrus crispus*) and

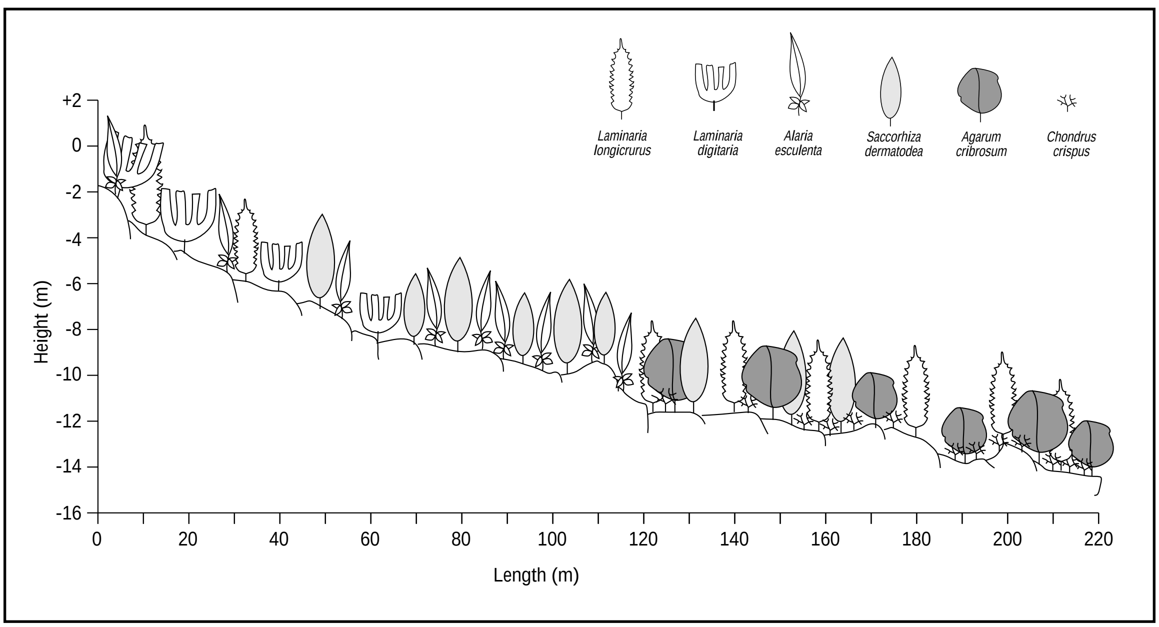

Figure H1.2.2: Zonation of benthic seaweeds on an exposed rocky bottom at West Ironbound Island, Lunenburg County. (Unit 911).

Furcellaria lumbricalis. The latter two species are harvested commercially. Seaweed growth becomes sparse below a depth of 10 m.

In the Bras d'Or lakes (Unit 916), seaweeds do not grow below 3–4 m depth, presumably due to increased turbidity of the water column. In sheltered bays of the Northumberland Strait and in the Bras d'Or Lake, the seaweed *Gracilaria* grows in association with Eel Grass. Eel Grass beds have an associated fauna of warm-water algae and animals.

Where seaweed beds have not developed or have been reduced by grazing herbivores and other factors, calcareous red algae, including *Lithothamnium*, are found encrusting rocks, boulders and other hard surfaces. These species can grow in low light intensities and can occur to a depth of 100 m in clear water.

ANIMALS

Benthic animals include a wide variety of invertebrate species and fish. Most may be conveniently placed in two groups: epifauna that live attached to (sessile) or roving over (vagrant) the surface of the substrate; or infauna that burrow into the substrate. The relative importance of each group at a particular site therefore depends largely upon the nature of the substrate. Several types of invertebrates (for example, cumaceans, isopods, mysids and some amphipods) and some fish species (known as hyperbenthos) live in close association with the sea bed but leave it to feed.

RELATION TO SEDIMENTS

Bedrock and Boulders

These hard surfaces are ideal for epifauna and plants, but provide little habitat for infauna, except where sediment has accumulated in cracks and under rocks and boulders. Species of encrusting sponges, hydroid polyps, bryozoans and tunicates inhabit rock surfaces. Colonial species of sufficient size provide habitat for small polychaete worms, crustaceans, various snails (including sea slugs), as well as attached limpets and chitons. In certain locations in the outer Bay of Fundy, the brachiopod *Terebratulina septemtrionalis* is common on rock surfaces.

Common species include gastropods (the limpet *Notoacmaea testudinalis;* periwinkle *Littorina littorea;* chitons *Tonicella* spp. and *Ischnochiton rubra;* slipper shells *Crepidula fornicata* and *C. plana*); bivalves (*Hiatella arctica, Mytilus edulis*, and *Modiolus modiolus*); and barnacles (*Balanus crenatus* and *B. improvisus*). Vagrant species include decapod crustaceans (hermit crabs, *Pagurus* spp; and other crabs, *Cancer* spp. and *Hyas* spp.; and lobsters *Homarus americanus*); whelks (*Buccinum undatum*, *Colus stimpsoni* and *Neptunea lyrata*

Plate H1.2.2: Marine organisms in a benthic habitat. The sea bed is formed of densely packed cobbles and boulders from the Sable Island Sand and Gravel Formation (see T3.5) in Unit 911. Colonizing species include encrusting organisms, such as anemones, sponges, tunicates and coralline algae. Photo: BIO.

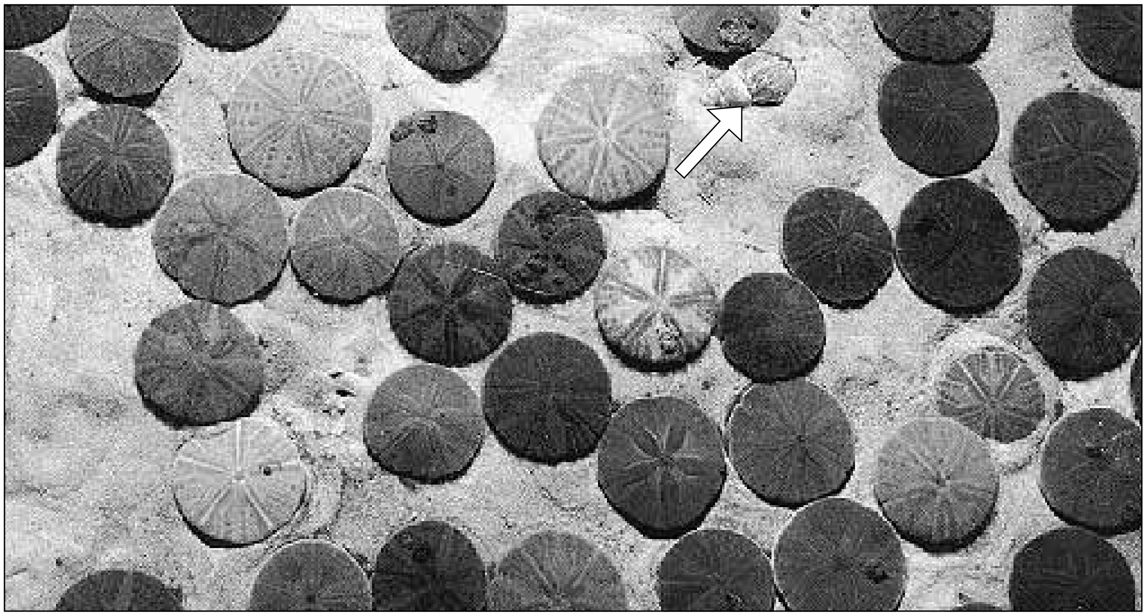

Plate H1.2.3: A benthic habitat with a sandy bottom, showing a spindle shell *(arrow)*, and a dense concentration of sand dollars. On central Banquereau (District 930), 60 m depth. Photo: BIO

decemcostata); sea urchins, starfish (*Asterias* spp. and *Henricia sanguinolenta*), the Sea Cucumber (*Psolus fabricii*) and the Brittle Star (*Ophiopholis aculeata*). The Basket Star (*Gorgonocephalus arcticus*) occurs in association with sponges and coelenterates. Fish such as Sculpin, Cunner, Lumpfish, Wolffish and Pollock commonly occur.

In shallow water, the surfaces of seaweeds may become colonized by epifaunal species, such as the polychaete worms (*Spirorbis* spp.), and various snails that graze the surfaces of the fronds. The branching holdfasts of kelp provide shelter for bivalve molluscs, brittle starfish, small crustaceans and polychaete worms. Sea urchins that graze on the seaweeds are a significant factor in the dynamics of kelp beds (see above). Various types of fish, including the Cunner, prey on small animals in the seaweed beds.

Sand and Gravel Bottoms

Sand is usually a mobile bottom and generally provides a smooth (though frequently undulating) and rippled terrain. In areas of intense currents, a sand bottom can form a hard pavement, with small animal populations. Gravel and sand waves can have different animals in the crests and in the troughs, owing to the different grades of sediment found in each place. The small particles do not provide a habitat for attached epifauna, although small stones and shells of dead molluscs may be colonized by forms typical of the rock and boulder bottom. On sand bottoms, the infauna is important, but many species of hyperbenthos (living at the surface or in the lower water column) commonly occur here.

Species typically occurring on subtidal sandy substrate include cumaceans (*Diastylis quadrispinosa* and *D. sculpta*); amphipods (*Unciola irrorata, Ampelisca macrocephala, Psammonyx nobilis*); small polychaete worms living between sand grains and tube-building species, as well as the sand dollar *Echinarachnius parma* and tanaidaceans. *Ampelisca* spp. build tubes in the sandy bottom.

Ocean Quahogs (*Arctica islandica*), sea scallops (*Placopecten magellanicus*), and Stimpson's Surf Clam (*Mactromeris polynyma*) commonly occur on sandy/gravelly bottom on the Inner Shelf (District 910) and on offshore banks, and the surf clam *Spisula solidissima* occurs on sand bars and banks in shallow water.

Mud Bottoms

A mud bottom usually contains varying proportions of silt and clay, as well as other constituents. Clay is finer and accumulates in relatively still conditions in basins and smaller depressions, and provides a flat terrain. Subtidal areas near river mouths, and particularly on the New Brunswick side of the Outer Bay of Fundy (Unit 912), typically have high proportions of silt. Infaunal species are most important on silt/clay bottoms, and the majority feed on particulate organic matter sorted from the sediment or filtered from the water. These in turn support a variety of epifaunal carnivores and bottom-feeding fish. Species diversity and abundance are generally reduced as the sediment grades into fine, compacted clay deposits. Occasional stones and shells are colonized by an epifauna similar to that associated with rock and boulder bottoms.

The mud-bottom infauna includes burrowing sea anemones; sea pens (in deeper water); polychaete worms; bivalve molluscs, including *Yoldia* spp. and *Nucula* spp.; Tusk Shells, *Dentalium* spp.; the gastropod *Aporrhais occidentalis;* Sea Cucumbers; brittlestars and starfish. The burrowing shrimp *Axius serratus* has been found building burrows several metres into the muddy bottom of Chedabucto Bay (Unit 911). Epifauna consists of hermit crabs, crabs, shrimps, sea spiders and bottom-feeding fish.

The diversity and abundance of polychaete worms, crustaceans, molluscs and echinoderms often increases as the proportion of mud in the sediment increases, due to the mechanical and nutritional advantages of a sandy/mud habitat. The burrowing fauna includes sea anemones (*Cerianthus* spp.); polychaetes (*Onuphis conchylega, Pectinaria* spp., tube-building maldanid polychaetes); echinoderms, including Brittle Stars (*Ophiura sarsi*) and particularly the mud star (*Ctenodiscus crispatus*); polychaete worms, including the seamouse (*Aphrodite* spp.) and scaleworm (*Laetmonice filicornis*); bivalve molluscs (*Cyclocardia borealis, Astarte* spp.); and the large predatory Moon Snail (*Lunatia heros*).

Several kinds of starfish (Asteroidea), brittlestars (Ophiuroidea), sea urchins, and sand dollars (Echinoidea) occur on sandy/muddy bottom. The distinctive Heart-urchin (*Schizaster fragilis*) occurs on sandy mud in basins of the continental shelf. Snow Crab and Northern Pink Shrimp prefer muddy bottoms, and the deep-sea red crab (*Geryon quinquedens*) occurs on muddy bottom along the edge of the continental shelf. The edges of offshore banks frequently have a sandy to muddy bottom, where groundfish, particularly flatfish species, are common and are fished. Other typical species include skate; American Plaice; Atlantic Haddock and Atlantic Cod. In some mud-bottom areas nearshore, lobster have been known to excavate caves for shelter.

Eel Grass beds on muddy bottom in shallow water provide habitat for benthic animals, which typically require warm summer temperatures for reproduction and growth, such as American Oyster (*Crassostrea virginica*); snails (*Acteocina canaliculata, Bittium alternatum, Mitrella lunata,* and *Turbonilla interrupta*); the bivalves *Macoma balthica, Gemma gemma* and *Mysella planulata*; the crab *Neopanopeus sayi*; the amphipods *Corophium insidiosum, Gammarus mucronatus, Ampithoe longimana;* the isopods *Jaera marina, Idotea balthica and I. phosphorea;* the polychaetes *Capitella capitata and Scoloplos armiger;* and the oyster borer *Polydora cornuta*. Typical fish of Eel Grass beds include Northern Pipefish, Atlantic Silversides and American Eels. Warm-water species introduced through slope-water exchange during the summer as planktonic larvae (e.g., Blue Crab and Striped Mullet) are able to grow in the Eel Grass beds but do not normally establish breeding populations.

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Associated Topics

T3.5 Offshore Bottom Characteristics, T6.1 Ocean Currents, T6.2 Oceanic Environments, T10.9 Algae, T11.14 Marine Fishes, T11.17 Marine Invertebrates, T12.11 Animals and Resources

Associated Habitats

H1.1 Open Water, H2.1 Rocky Shore, H2.2 Boulder/ Cobble Shore, H2.3 Sandy Shore, H2.4 Mud Flat, H2.5 Tidal Marsh

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