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Introduction



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Bordered by the northeastern United States and the Canadian Maritime Provinces, the Gulf of Maine is a semi-enclosed sea that is renowned as one of the world's richest marine ecosystems. Along the western and northern shores of the Gulf of Maine lie the cities, towns, and watersheds of coastal Massachusetts, New Hampshire, Maine, New Brunswick, and Nova Scotia, while the legendary fishing grounds of Georges Bank mark the southern and eastern boundary.

Salt marshes, seagrass beds, tidal mud flats, underwater rocky outcrops, kelp beds, and other marine and estuarine habitats are building blocks of the Gulf of Maine ecosystem. These habitats provide homes for the animals, plants, and microbes that inhabit the coastal and offshore waters, depending on each other and the environment for food, shelter, and the other necessities of life. Intact marine habitats in the Gulf of Maine support productive fisheries and serve a host of other functions such as cycling nutrients, filtering pollution, trap-

ping sediments, storing carbon, buffering upland areas from storm damage, and providing recreation opportunities.

The Gulf of Maine has supported a long tradition of fishing, marine transportation, coastal development, and recreation, and these human activities have affected habitat integrity. Effective management and regulation is imperative for the continued functioning of the ecosystem and economic prosperity of the region, particularly given the growing variety and intensity of human uses. Existing and proposed uses of Gulf of Maine habitats include aquaculture, wind farms, fishing, sand mining, pipelines, cables, docks, piers, sewage outfalls, and discharge of pollutants—all of which can alter the natural functions of habitats.

Consequently, managing the natural resources of the Gulf of Maine and its coastline—whether at a municipal, state, provincial, regional, or federal level—requires a broad understanding of habitat



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types, distributions, ecological functions, and the potential human effects on habitat. This document introduces information about the Gulf of Maine's coastal and offshore habitats for coastal decision-makers involved in reviewing projects, siting special management areas, developing regulations and resource management plans, and targeting habitat restoration efforts.

OVERVIEW OF HABITAT TYPES

Some of the Gulf of Maine's habitats are relatively well known, and scientific understanding of them has expanded in recent years. Other habitats such as cold-water corals have only recently been explored. In this primer, habitats are categorized based on **substrate type and sediment grain size, water depth**, and presence of structure-forming plants and animals that create **biogenic habitat**. Each of these characteristics occurs along a continuum: small to large sediment grain size, shallow to deep water, and sparse to abundant habitat-forming species. As a result, the variety of habitats is nearly infinite, and any categorization system for habitat types is somewhat arbitrary. This primer categorizes Gulf of Maine habitats into twenty types according to substrate, depth, and biogenic structure.

Substrate type and sediment grain size have a strong influence on the types of plants and animals that can inhabit a given place. Substrates and sediment sizes range from tiny mud particles to fine sand to coarse sand to pebbles to cobbles to boulders to solid rock outcrop. To live on a hard substrate, animals and plants attach themselves to surfaces or dwell in crevices. To inhabit soft sediments, many animals burrow into the seafloor. Geologic history and oceanographic conditions determine the type of substrate in a given place. For example, muddy tidal flats tend to occur in sheltered embayments with weak currents and little wave action. These conditions allow fine mud particles to settle from the water and accumulate on the bottom. In turn, muddy bottoms tend to be oxygen-poor because the small particle size limits water flow through the sediment, meaning that species must be capable of tolerating oxygen-poor conditions or pumping oxygenated water into burrows.

Water depth also influences the types of species that inhabit a particular location. For example, animals and plants that live in the intertidal zone must endure exposure during low tide. Shallow waters tend to have more sunlight than deeper waters because of the attenuation of sunlight with depth. Seaweed and seagrass require sunlight for photosynthesis and can grow only in relatively clear, shallow water, not on

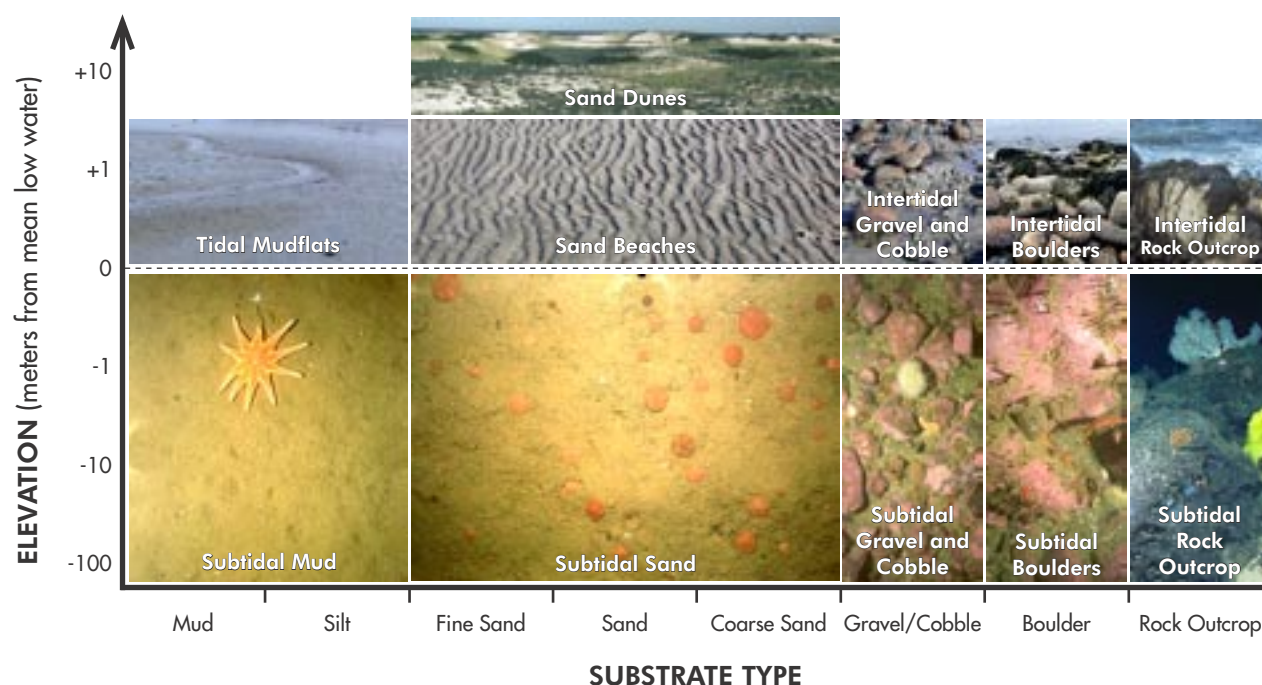


Figure 1. The distribution of physically defined habitats according to substrate type and elevation from mean low water. Sand dunes are formed primarily by wind and therefore extend above the intertidal zone into the supralittoral zone.

Figure concept: David Burdick, University of New Hampshire. Design: Ethan Nedeau.

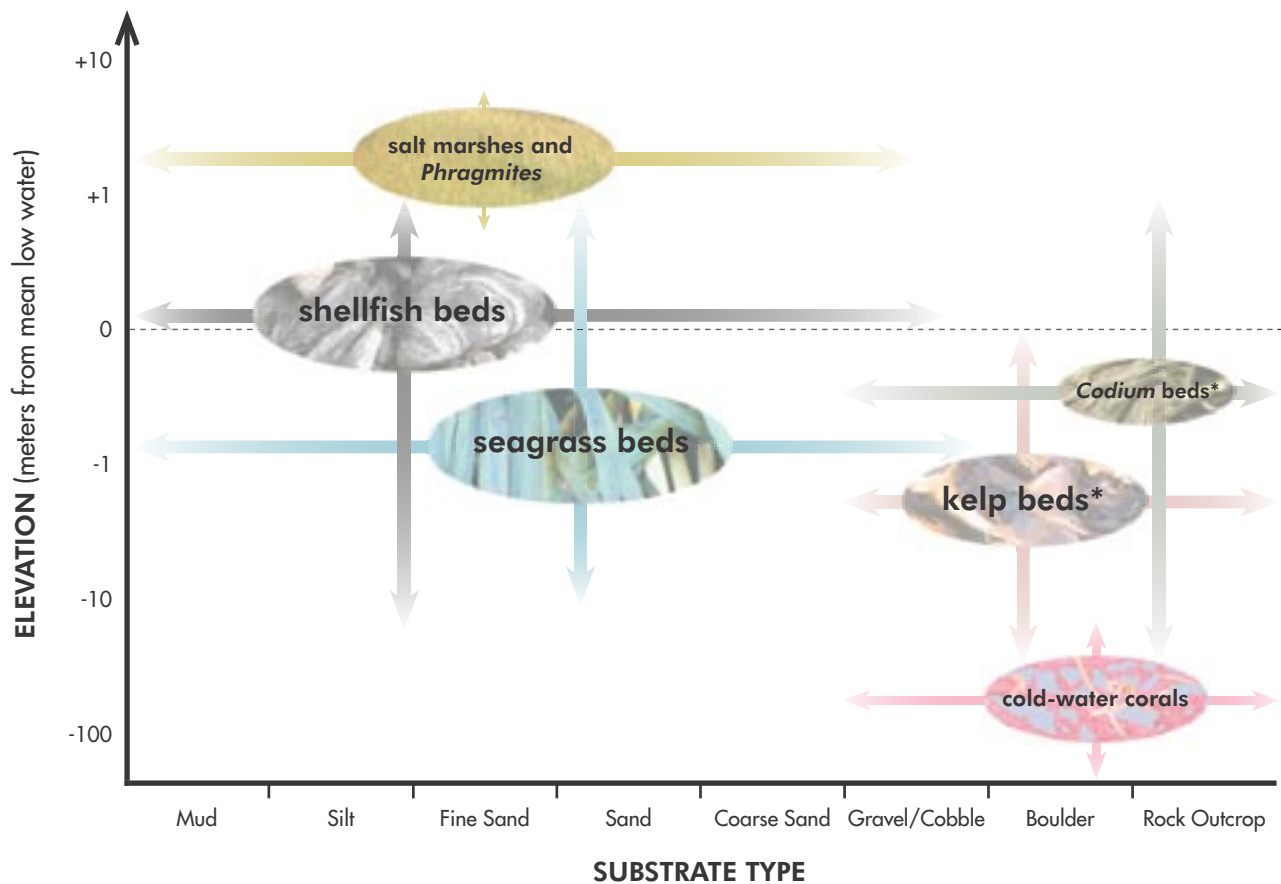


Figure 2. The distribution of biogenic habitats according to substrate type and elevation from mean low water. Depth distributions, particularly for lower depth limits, are approximate. **Codium* and kelp can attach to a wide variety of substrates, including shellfish that occur in soft sediments, but neither algal species forms beds in soft sediments.

Figure concept: David Burdick, University of New Hampshire. Design: Ethan Nedeau.

the deep seafloor. Because seaweed beds serve as habitat for many animals and plants, it can be useful from an ecological perspective to define the lower limit of seaweed presence as the transition between shallow and deep habitats.

Biogenic habitats such as seaweed beds, seagrass beds, salt marshes, mussel beds, and cold-water coral thickets are distinguished by high densities of structure-forming species that substantially modify the physical environment and consequently host a distinct ecological community. Kelp beds, for example, are like undersea forests formed by the long blades of kelp that provide shelter and food for fish, lobsters, and other organisms. Typically, a structure-forming species must occur in great abundance to modify the environment enough to qualify as a distinct biogenic habitat. For example, a large, dense oyster reef provides hiding places for fish and invertebrates and slows the currents, which promotes the deposition of sediments. However, sparse oysters do not provide useful hiding places or substantially slow the currents, so they do not function

as biogenic habitat. For similar reasons, small, isolated clumps of seagrass do not provide the same biogenic habitat value as dense, extensive seagrass beds. In some cases, the plants and animals of a biogenic habitat help to maintain the habitat type, such as when salt marshes accumulate sediment to match the rate of sea-level rise.

Habitat Complexity and Species Diversity

In general, habitats with more structural complexity, such as seagrass beds or cobble bottoms, support a greater diversity of species than relatively simple habitats, such as muddy or sandy bottoms. Each habitat has a different assemblage of species, so animals and plants found in a seagrass bed may not survive if that bed is transformed into a mudflat. Even habitats characterized by soft sediments can vary in their complexity. Waves and currents, for example, can shape the topography of a sandy bottom into ripples and ridges where fish hide to ambush prey. Similarly, some amphipods and other animals build tubes of sediment on the seafloor, creating structures among which other animals find shelter.



Glaciers up to one mile thick covered the Gulf of Maine region thousands of years ago, not unlike those seen today in Greenland, Alaska, and northern Canada.

NOAA Photo Library

Habitats Are Interconnected

Habitats of the Gulf of Maine do not exist in isolation. Myriad ecological relationships and oceanographic processes link them, and each habitat functions as part of the larger Gulf of Maine landscape. The movement of water plays a major role in the interconnection of habitats by transporting nutrients, food, larvae, sediments, and pollutants among them. Many marine species rely on different habitats in different parts of their life cycle. For example, lobsters begin life as larvae that drift in the water before settling onto the seafloor. Larval habitat is the top few meters of the water column, but juvenile habitat is a pebble or cobble seabed, where they can hide from predators. As adults, lobsters move into open habitats, such as sandy bottom or rocky outcrop, because large adults are less vulnerable to predators. The ecological linkages among marine habitats are unlike terrestrial habitats, and present a special challenge for resource managers and policy makers who must consider the Gulf of Maine ecosystem as a regional, interconnected system.

REGIONAL SETTING: THE GULF OF MAINE

Geologic History

The Gulf of Maine is within the cold-temperate Acadian biogeographic province. Although this province has relatively low species diversity, many of its species occur nowhere else. Glaciers scoured the Gulf of Maine 10,000 to 20,000 years ago, helping shape the wide variety of marine and estuarine habitats. During the last ice age, glaciers extended as far south as Cape Cod. Along the way, the ice sheets

sculpted the bedrock and created the indented, rocky coast that characterizes much of the Gulf of Maine. The glaciers deposited huge quantities of sediment at Cape Cod to form extensive dunes, beaches, and sandy bottoms.

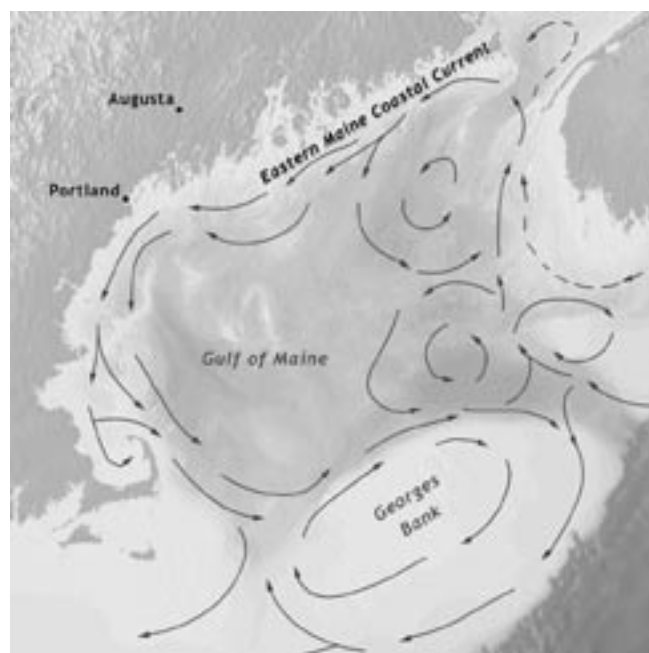
Physical Oceanography

Water in the Gulf of Maine generally flows counterclockwise with coastal currents sweeping from northeast to southwest from New Brunswick to Massachusetts. The deep Labrador Current dominates the oceanography of the Gulf of Maine and helps to drive the counterclockwise circulation. Its frigid waters enter the Gulf of Maine through the Northeast Channel to the south of Nova Scotia, after flowing southward along Nova Scotia's Atlantic Coast. The water exits the Gulf approximately three months later at the Great South Channel near Cape Cod. Warmer waters from the Gulf Stream sometimes enter the Gulf of Maine when eddies called warm-core rings spin off from that major current, carrying subtropical fish and other animals.

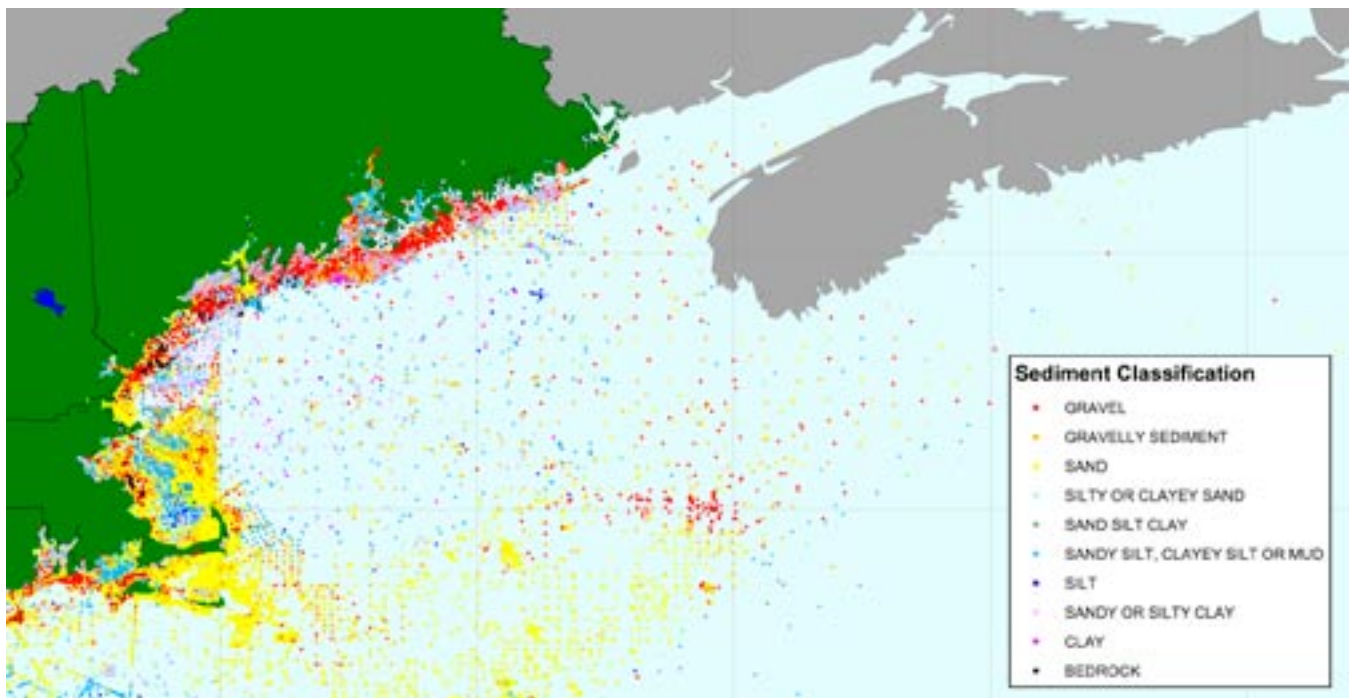
The Gulf of Maine's tidal range is relatively large. Strong tidal currents keep waters well mixed, increasing the availability of nutrients and fueling the ecosystem's biological productivity. In the northern reaches of the Gulf of Maine, the Bay of Fundy experiences the world's biggest tides.

Substrates: Rock, Sand, Mud

The Gulf of Maine has a wide variety of substrate types. Mud and sand accumulate in depositional areas such as



Direction of ocean currents in the Gulf of Maine.
Map by Chris Brehme. Redrawn from map by Neal R. Pettigrew.



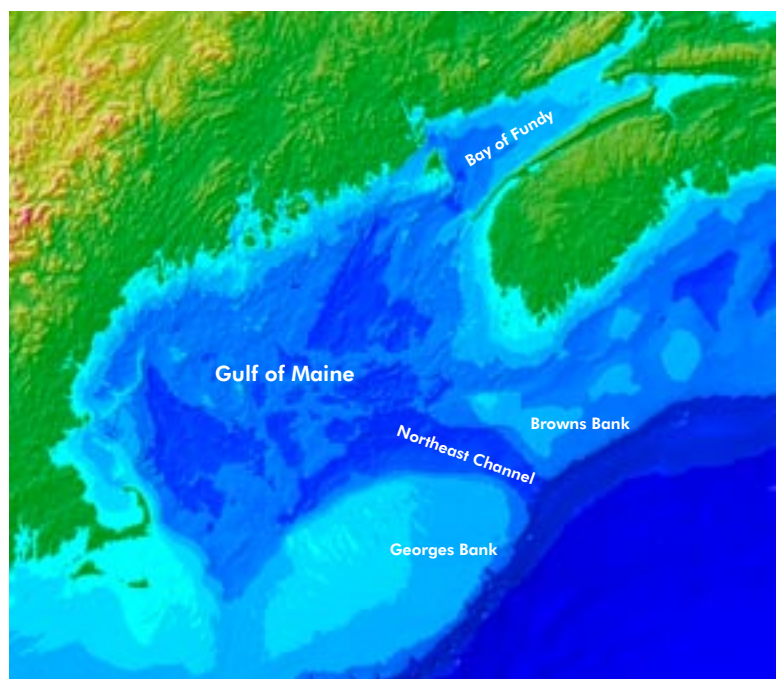
Distribution of sediments and bedrock in the Gulf of Maine. Source: U.S. Geological Survey

sheltered bays and deep offshore basins, which are common along subsiding coastlines such as North America's east coast. Solid rock outcrops, boulder fields, and cobble and pebble bottoms occur in places where fast currents or strong waves erode the finer sediments. The geographic pattern of substrate types in the Gulf of Maine ranges from soft sandstones and mud flats at the head of the Bay of Fundy to hard granite and basalt on the western shores of the Bay of Fundy into Maine, New Hampshire, and Massachusetts. At the southern edge of the Gulf of Maine, Cape Cod has glacial deposits of sand and gravel, and no bedrock. Within this broad geographic pattern, however, lies a mosaic of other substrate types, such as sandy pocket beaches along Maine's rocky coast.

Geographic Features

When glaciers scoured the region, they carved basins, channels, and banks. Banks, such as Georges Bank, are relatively shallow areas with a foundation of rock that resisted erosion. Basins are deep, depositional environments usually with muddy or sandy bottoms. Stellwagen Bank National Marine Sanctuary in Massachusetts Bay features a great variety of habitat types on top of banks, along their steeply sloped sides, and in basins. Similarly, the West Isles area between Maine and New Brunswick in the Bay of Fundy has steep

zones, boulders, and ledges among areas of soft sediment. Complex topography, large tides, and tidal streams around the small islands result in high diversity of habitat types. Channels between banks allow deep, nutrient-rich water to circulate among basins. The Northeast Channel that separates Brown Bank and Georges Bank allows deep ocean water to move into the Gulf of Maine.



Geographic features, including basins (deep blue) and shallow banks (light blue), of the Gulf of Maine seafloor. USGS-Woods Hole Field Center

HABITAT CONSERVATION IS UNDERWAY

Many marine habitat conservation efforts have been implemented around the Gulf of Maine to address management concerns, as the following examples indicate. To facilitate a coordinated, regional approach, the Gulf of Maine Council on the Marine Environment is working with organizations to develop a habitat conservation strategy. One product is an inventory of habitat conservation tools and efforts.

To download the complete inventory and obtain more information about developing the strategy, visit:
www.gulfofmaine.org/habitatconservation

Examples of Habitat Conservation Efforts

Atlantic Reference Centre

Sponsored by the Huntsman Marine Science Center in St. Andrews, New Brunswick, and the Canadian Department of Fisheries and Oceans, the Atlantic Reference Centre has an extensive collection of marine life; conducts research in marine taxonomy, biodiversity, and ecology; and provides information for the Gulf of Maine Biogeographic Information System.
 Web site: www.huntsmanmarine.ca/arc

Bay Area Management and Aquaculture Leases

New Brunswick has an aquaculture site allocation policy to ensure that aquaculture development is conducted in an environmentally-sustainable manner. A task force in Maine is investigating how to balance the range of potential uses of state waters and accommodate the growth of marine aquaculture, while considering scientific data, constraints, and opportunities.
 Web site: www.state.me.us/dmr/aquaculture/aqtaskforce/aqtfhomepage.htm

Bay of Fundy Ecosystem Partnership

The Bay of Fundy Ecosystem Partnership, a virtual institute, is an inclusive, flexible, and multidimensional organization for encouraging communication and cooperation among all individuals and groups interested in the Bay of Fundy. It achieves on-the-ground progress through various working groups, focusing on topics such as *Corophium* as a keystone species, Minas Basin integrated management, salt marshes and restricted tidal systems, sublittoral ecology and habitat conservation,

and communications.

Web site: www.bofep.org

Conservation Law Foundation (CLF) and WWF Canada Marine Conservation Project

A habitat-mapping project for the Gulf of Maine and Scotian Shelf is being conducted by the Conservation Law Foundation and World Wildlife Fund Canada. The project is using physical and biological data to determine priority areas for conservation.

Web site: www.wildsea.org

Cooperative Research Partners Initiative (CRPI)

The National Marine Fisheries Service is partnering with the New England Fisheries Management Council to produce better scientific information for fishery management decisions and to facilitate communication and collaboration among New England's commercial fishermen, marine scientists, and fishery managers.

Web site: <http://coopresearch.nero.noaa.gov>

Gulf of Maine Census of Marine Life (CoML)

CoML is a global network of researchers in more than 45 nations engaged in a ten-year initiative to assess and explain the diversity, distribution, and abundance of marine life. Synthesis of this knowledge is intended to inform management decisions and improve predictions of change in species numbers and abundance over time.

Web site: www.usm.maine.edu/gulfofmaine-census

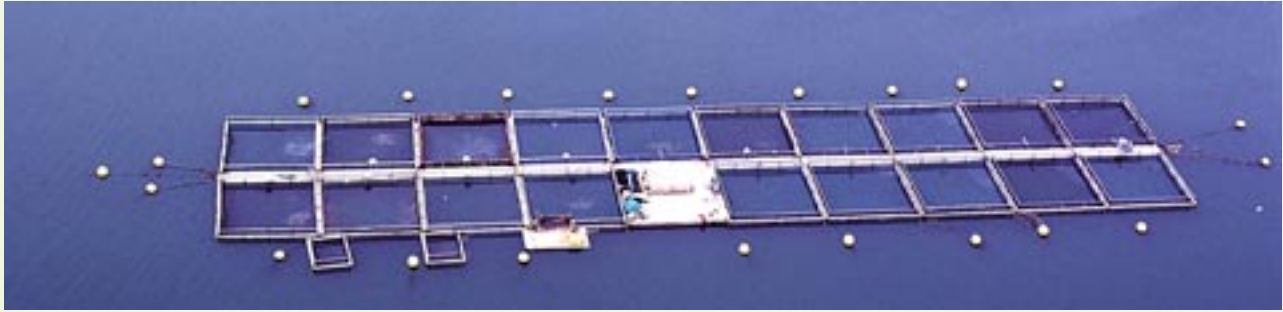
Gulf of Maine Council Habitat Restoration Strategy

The Council's Habitat Restoration Subcommittee developed a strategy that identifies important coastal habitat types in the Gulf, makes recommendations for enhancing restoration, provides background information on restoration techniques, and identifies regionally significant projects in states and provinces around the Gulf.

Web site: www.gulfofmaine.org/habitatrestoration

Gulf of Maine Mapping Initiative (GOMMI)

The Gulf of Maine Mapping Initiative is a multi-year project to map the entire sea floor of the Gulf of Maine. The maps will inform and improve decision-making



Aquaculture pens in New Brunswick Gilles Daigle

for management of ocean resources.

Web site: www.gulfofmaine.org/gommi

Gulf of Maine Ocean Observing System (GoMOOS)

GoMOOS is a national pilot program that conducts routine monitoring on weather and oceanographic conditions in the Gulf of Maine through a system of buoys and monitoring stations. The data function as a baseline for ocean parameters from which human-induced impacts and natural changes in the marine environment can be gauged.

Web site: www.gomoos.org

Gulfwatch

Gulfwatch is a chemical-contaminants monitoring program administered by the Gulf of Maine Council on the Marine Environment. Conducted and coordinated by scientists and managers from universities and agencies around the Gulf of Maine, the program uses blue mussels as indicators of habitat exposure to pollutants in coastal waters.

Web site: www.gulfofmaine.org/gulfwatch

Northeast Aquatic Nuisance Species Task Force

NEANS was established in 2001 by the Federal Aquatic Nuisance Species Task Force as one of six regional panels. Its mission is to “protect the marine and freshwater resources of the Northeast from invasive aquatic nuisance species through committed and coordinated action.”

Web site: www.northeastans.org

Northeast Channel Coral Conservation Area

The Canadian Department of Fisheries and Oceans and the fishing industry are working to address the potential impacts of fisheries on deep-sea corals. Management measures, including restrictions

on bottom-fishing gear, were implemented in 2002 to protect deep-sea corals in an area centered on Romey’s Peak in the Northeast Channel. Web site: www.mar.dfo-mpo.gc.ca

Regional Marine Research Program

The Gulf of Maine was the subject of one of the nine Regional Marine Research (RMR) Programs overseen by NOAA and the EPA. The goal of the Gulf of Maine Regional Marine Research Program was to produce models that collectively simulated how the Gulf of Maine ecosystem functions naturally and under stress.

Web site: <http://woodshole.er.usgs.gov/project-pages/oracle/gomaine/regional.htm>

Stellwagen Bank National Marine Sanctuary Mapping and Habitat Characterization

A partnership between the U.S. Geological Survey and the National Marine Sanctuary Program developed seabed maps to support management, research, monitoring, education, outreach, and enforcement in the National Marine Sanctuaries.

Web site: <http://woodshole.er.usgs.gov/project-pages/stellwagen>

Taunton and Great Salt Bay Closures

In Maine, a moratorium on dragging gear in Taunton Bay was established in response to public concern about habitat alteration and overfishing. Similarly, the Great Salt Bay marine shellfish preserve legislation, enacted in 2001, prohibits any harvesting activities resulting in bottom disturbance. The Taunton Bay legislation required the Department of Marine Resources to study the impacts of dragging and provide recommendations on whether to maintain the ban on dragging.

Web sites:

<http://janus.state.me.us/legis/statutes/12/title12sec6961.html>
<http://janus.state.me.us/legis/statutes/12/title12ch627.pdf>