THE GULF OF MAINE IN CONTEXT

STATE OF THE GULF OF MAINE REPORT

Gulf of Maine Council on the Marine Environment

June 2010

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Fisheries and Oceans Canada / Pêches et Océans Canada

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The Gulf of Maine Council on the Marine Environment was established in 1989 by the Governments of Nova Scotia, New Brunswick, Maine, New Hampshire and Massachusetts to foster cooperative actions within the Gulf watershed. Its mission is to maintain and enhance environmental quality in the Gulf of Maine to allow for sustainable resource use by existing and future generations.

Cover map (background) courtesy of Census of Marine Life/Gulf of Maine Area Program

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1. Introduction

The Gulf of Maine Council on the Marine Environment was established in 1989 by the region's Premiers and Governors as a regional entity with the mission to "maintain and enhance environmental quality in the Gulf of Maine and to allow for sustainable resource use by existing and future generations" (GOMC 2007). The Gulf of Maine Council is a US/Canada public-private partnership that works to protect and conserve the Gulf's renewable and non-renewable resources for the use and benefit of all citizens, including future generations. The GOMC is made up of environmental planners and resource managers from the Provinces of Nova Scotia and New Brunswick and the States of Maine, Massachusetts and New Hampshire. Six Canadian and US federal agencies are also members of the Council as well as ten non-profit and for-profit representatives. The Council and its members have supported numerous initiatives, ranging from bi-national actions to local projects, to improve water quality, conserve land, restore coastal habitats, and enable citizens to be better stewards of the environment around them (see www.gulfofmaine.org).

Special emphasis should be placed on the transformation of existing information into forms more useful for decision-making and on targeting information at different user groups. Mechanisms should be strengthened or established for transforming scientific and socio-economic assessments into information suitable for both planning and public information.

Agenda 21, 1992

The Council has recognized the importance of state-of-the-environment reporting as a management tool. It has adopted the strategy for indicator development and state-of-the-environment reporting through the Gulf of Maine Ecosystem Indicator Partnership (ESIP), as outlined in the document *A Strategy for Gulf of Maine Ecosystem Indicators and State of the Environment Reporting* (Mills 2006). The *Gulf of Maine Council on the Marine Environment Action Plan 2007-2012* (GOMC 2007) recognises that the Council needs to "respond to managers' needs for state-of-the-environment reporting and ecosystem indicators" (GOMC 2007).

Over the years, participating members have individually taken steps to catalogue the collective understanding of the Gulf of Maine (e.g., Ecosystem Overview Report, Northwest Atlantic Bioregional Assessment, ESIP, etc.), and there are many fine examples of reports that address aspects of a state-of-the-environment report (e.g., Pesch and Wells 2004; ACZISC Secretariat and Dalhousie University 2006; New Hampshire Estuaries Project 2006; Wake et al. 2006; Taylor 2008). However, the State of the Gulf of Maine Report, of which this document is a part, is the first Gulf-wide synthesis of pressures on the environment, biophysical and socio-economic status and trends, and responses to identified issues.

The *State of the Gulf of Maine Report* is a modular, living document that consists of several parts, including this context document and a series of theme or issue papers. *The Gulf of Maine in Context* is intended to provide an introduction to the natural and socio-economic environment of the Gulf of Maine. The aim is to provide the information in a form that is easily accessible and readable, and that immerses the reader in the region. It is complementary to the theme papers, which provide a more in-depth look at important issues within the Gulf (Table 1), based on the six priority areas recognised by the Council under ESIP. The intention is that the theme papers will be developed incrementally and can be regularly updated at a time interval appropriate to each issue (see www.gulfofmaine.org/stateofthegulf).

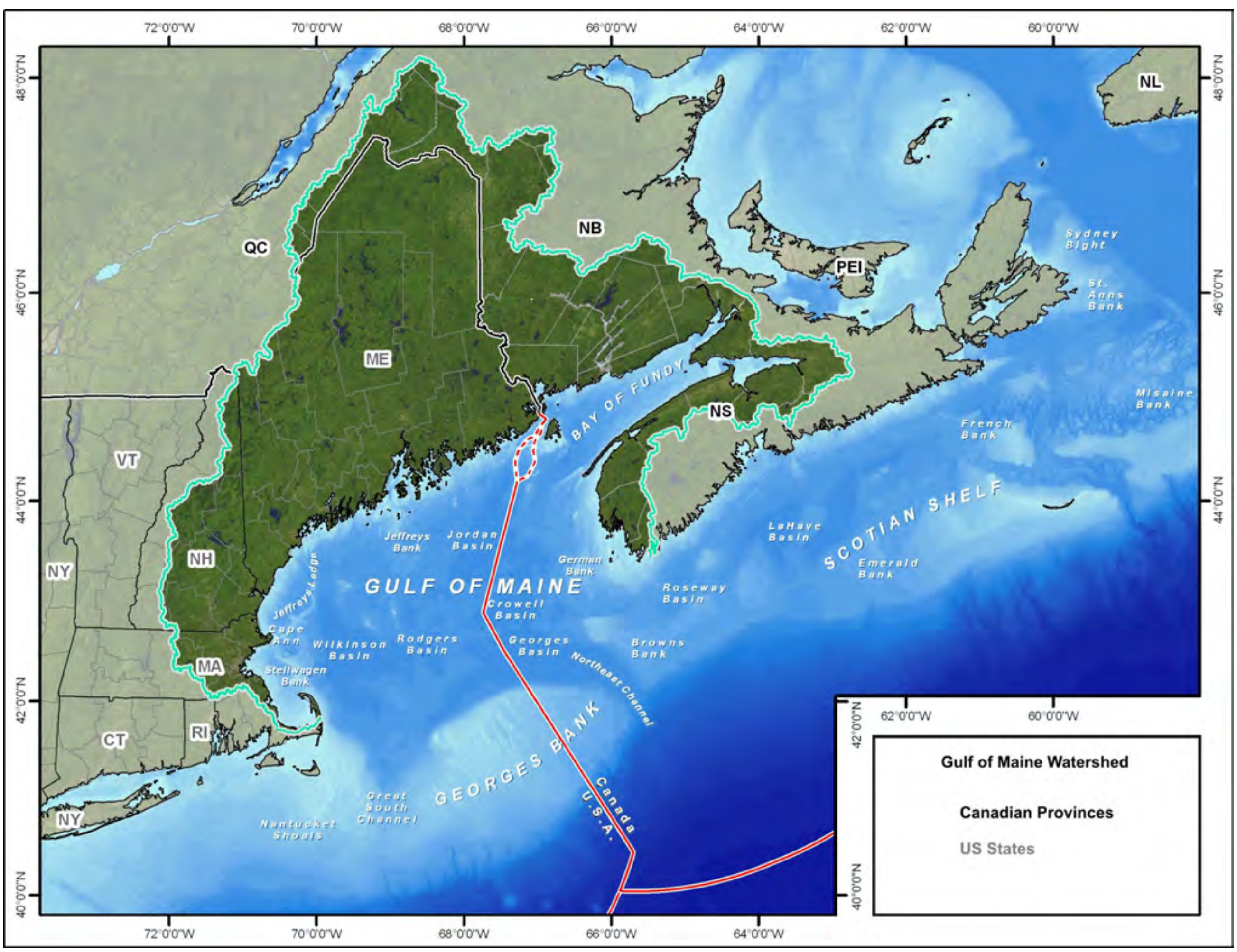
Table 1: Theme papers for the *State of the Gulf of Maine Report*

PRIORITY AREA	THEME PAPER
Climate Change	• Climate Change and its Effects on Humans • Climate Change and its Effects on Ecosystems, Habitats and Biota
Fisheries and Aquaculture	• Aquaculture in the Gulf of Maine • Commercial Fisheries and Fish Stock Status
Coastal Development	• Land Use and Coastal Development
Contaminants	• Toxic Contaminants • Microbial Pathogens and Toxins
Eutrophication	• Eutrophication
Aquatic Habitats	• Coastal Ecosystems and Habitats • Offshore Ecosystems and Habitats • Watershed Status
Other	• Invasive Species • Species at Risk • Emerging Issues

2. The Natural Conditions in the Gulf of Maine

The Gulf of Maine is a semi-enclosed sea, terrestrially bounded by the north-eastern American states of Maine, New Hampshire, Massachusetts and the Canadian provinces of Nova Scotia and New Brunswick. The watershed also includes a small portion of Quebec. The total land area of this watershed is 179,008 km^2 (69,115 square miles). Only one of the six jurisdictions, Quebec, does not have a Gulf of Maine shoreline and only Maine is located entirely in the watershed (Census of Marine Life 2009). Frequently described as a "sea within a sea", the Gulf of Maine area includes the Bay of Fundy, the Northeast Channel and Georges Bank. It is bounded to the northeast by the Scotian Shelf and is separated from the waters to the southwest (i.e., southern New England) by a boundary that extends to the tip of Cape Cod. The overall watershed may be sub-divided into 25 major watersheds (13 in the United States and 12 in Canada) and 11 minor coastal drainage areas. Major river drainages in the watershed include the Merrimack, Saco, Androscoggin, Kennebec, Penobscot, St Croix and Saint John rivers.

Figure 1: The Gulf of Maine and its watershed (dark green area).



The Gulf of Maine, Georges Bank and Bay of Fundy regions are among the most diverse, productive and complex marine temperate areas in the world (Sherman and Skjoldal 2002). The region's unique topography and oceanographic conditions combine to promote highly productive phytoplankton and zooplankton populations that support high fish populations. Piscivorous predators (carnivorous mammals and fish that consume primarily fish prey) and pelagic species which include marine mammals such as whales, porpoises and seals are resident and abundant (Waring et al. 2002).

Several political boundaries separate states, provinces and nations in the Gulf of Maine but the natural processes that occur in the region pay no heed to these boundaries. Several species of fish, marine mammals and birds regularly migrate across these political boundaries in their life cycles and the Gulf's currents ensure Gulf-wide dispersion of the young of many species. The Gulf of Maine is an important migratory staging area for millions of birds and is a significant summering and wintering region.

This section is a snapshot of the complex ecosystem of the Gulf of Maine and the reader is therefore, directed to a more comprehensive overview in the *Gulf of Maine Ecosystem Overview Report* (Parker 2009), as well as the reference section at the end of this document.

2.1 GEOLOGY, GEOMORPHOLOGY AND SEDIMENTOLOGY

Geology

The Gulf of Maine is a geologically complex coastal and ocean basin that gives rise to a great variety of habitats (Parker 2009). Coastal habitat diversity and complexity is greater here than it is in more southerly temperate coastal regions. The present-day morphology of the Gulf of Maine, including the numerous deep basins and the shallow banks, are believed to be the result of a complex sequence of marine deposition, subsequent river based deposition and erosion that was later altered by both glacial erosion and deposition (Backus and Bourne 1998).

The larger-scale geological features that add to the complexity of habitats include the basins, channels and banks of the Gulf of Maine. Basins are the deep areas of the Gulf, and typically range from 60-200 m deep (Parker 2009). Basins tend to hold a deep stratified layer of cold saline water, have little to no current movement, have virtually no light penetration to the sea floor, and have surface sediment of very fine-grained silt and mud particles. These characteristics support specific benthic communities, which are described in Section 2.1.3. Other large-scale habitats linked to the underlying geology are the deep channels within the Gulf of Maine. The most notable being the Northeast and Great South Channels, which bookend Georges Bank, and which serve as the primary inflow and outflow channels of marine waters to the Gulf. The Gulf of Maine banks, which include Georges Bank, Stillwater Bank and Jeffrey's Bank, are relatively shallow offshore areas and attract a unique variety of living organisms.

Much of the geological influence on marine habitats of the offshore Gulf of Maine has to do with sediment particle size. In contrast to the complex processes that have occurred, a large proportion of the offshore is overlain with sediments that form a relatively smooth, homogenous sea floor. The grain size of the sediments is perhaps the most influential geological parameter affecting the distribution of marine biota. This geological occurrence strongly influences the composition and distribution of benthic and demersal communities that live on, in, or near the sea floor (Conservation Law Foundation, WWF 2006).

Geomorphology

The southern and western Gulf of Maine is characterized by relatively gentle bathymetric relief that is covered by a thick layer of sediments and glacial deposits. In contrast, the northern and eastern Gulf has areas of exposed Paleozoic rocks (250+ million years old) that are formed into a series of irregular ridges, pinnacles, and channels. The geomorphology of the Gulf of Maine marine ecosystem further consists of: a 90,000 km^2 inner lowland area with an average depth of 150 m; the 28,000 km^2 Georges Bank, whose offshore crest is less than 40 m below the ocean surface; and the Bay of Fundy, a narrow funnel-shaped body of water with an average width of 56 km and a length of 190 km. On the seaward side of Georges Bank is the continental slope, deeply cut by numerous canyons. Two large channels, the Northeast and Great South Channels, lie east and west of Georges Bank, providing passageways from the Gulf of Maine to the open sea (Backus and Bourne 1987).

Erosion and sedimentation processes within the Gulf of Maine are complex. The area has likely been covered by ice several times, and has been both above and below sea level at different stages. Multiple glaciations over the past 2 million years probably smoothed the landscape and seafloor without altering the overall bedrock influence on major morphology (Kelley 1987). As the ice receded, tonnes of glacial till would have been left across what is now the Gulf of Maine. The most important influence of the last glaciation on the Gulf of Maine was to introduce significant quantities of sediment to the area. The sand, gravel, and other unconsolidated sediments that currently cover much of Maine, Nova Scotia, and the Gulf are largely the products of glaciation and continue to be eroded into the Gulf.

Smaller features such as canyons, pinnacles, and shoals add further complexity to the regions bathymetry. There are several deep basins within the Gulf of Maine that drop below the 200 m isobath. Georges Basin, Wilkinson Basin and Jordan Basin are the three most frequently noted basins. In total, basins make up about 30% of the floor area of the Gulf of Maine (Backus and Bourne 1987). There are also smaller offshore bathymetric features that contribute significantly to the Gulf of Maine ecosystem's habitat diversity.

Sedimentology

Much of the sediment that exists within the Gulf of Maine, and that continues to be eroded into the Gulf today, is the result a number of processes including land based erosion, marine deposition, and glacial erosion and deposition. Virtually the entire ocean floor of the offshore Gulf of Maine is covered by a blanket of sediment. Offshore bottom sediment mapping in the Gulf of Maine was conducted during the late 1980s by the Maine Geological Survey, the University of Maine, and the University of New Hampshire. The resulting reports defined broad-scale subdivisions within the Gulf based on terrain texture, rock type, geologic structure and history (Kelley and Belknap 1991). Three general classes of surficial materials are the most common in offshore areas of the Gulf of Maine: gravelly areas, sandy areas and muddy areas.

In summary, the geological processes of plate tectonics, faulting, sedimentation and glaciation that have formed the basement rocks and primary geomorphology of the Gulf of Maine have been very complex. These processes formed the basic bathymetric structures that today are visible as banks, basins and channels (Parker 2009). More modern marine sediments and land based erosion continue to add to the extensive blanket of mud, sand and gravel that covers the vast majority of the sea floor today. Tidal action, marine currents, and wave movement influence the sorting and distribution of the surface sediments, and create a complexity of other features that make up the bathymetry of the modern day Gulf of Maine.

2.2 OCEANOGRAPHIC CONDITIONS

Oceanography consists of the study of the physical and the chemical character of the ocean. Physical oceanography focuses on how the ocean moves through mechanisms such as tides, currents, upwelling or downwelling, waves, and stratification. Chemical oceanography examines the make-up of the water itself like temperature, salinity, and nutrients.

Physical Oceanography

There is large-scale coastal circulation influencing the Gulf of Maine that originates all the way from the Labrador Sea, north of the Province of Newfoundland, south to Cape Hatteras in the State of North Carolina. This means that the circulation and water properties within the Gulf may depend as much on influences originating over 1,000 km away as on local processes. Figure 2 shows the main currents circulating in the Gulf of Maine.

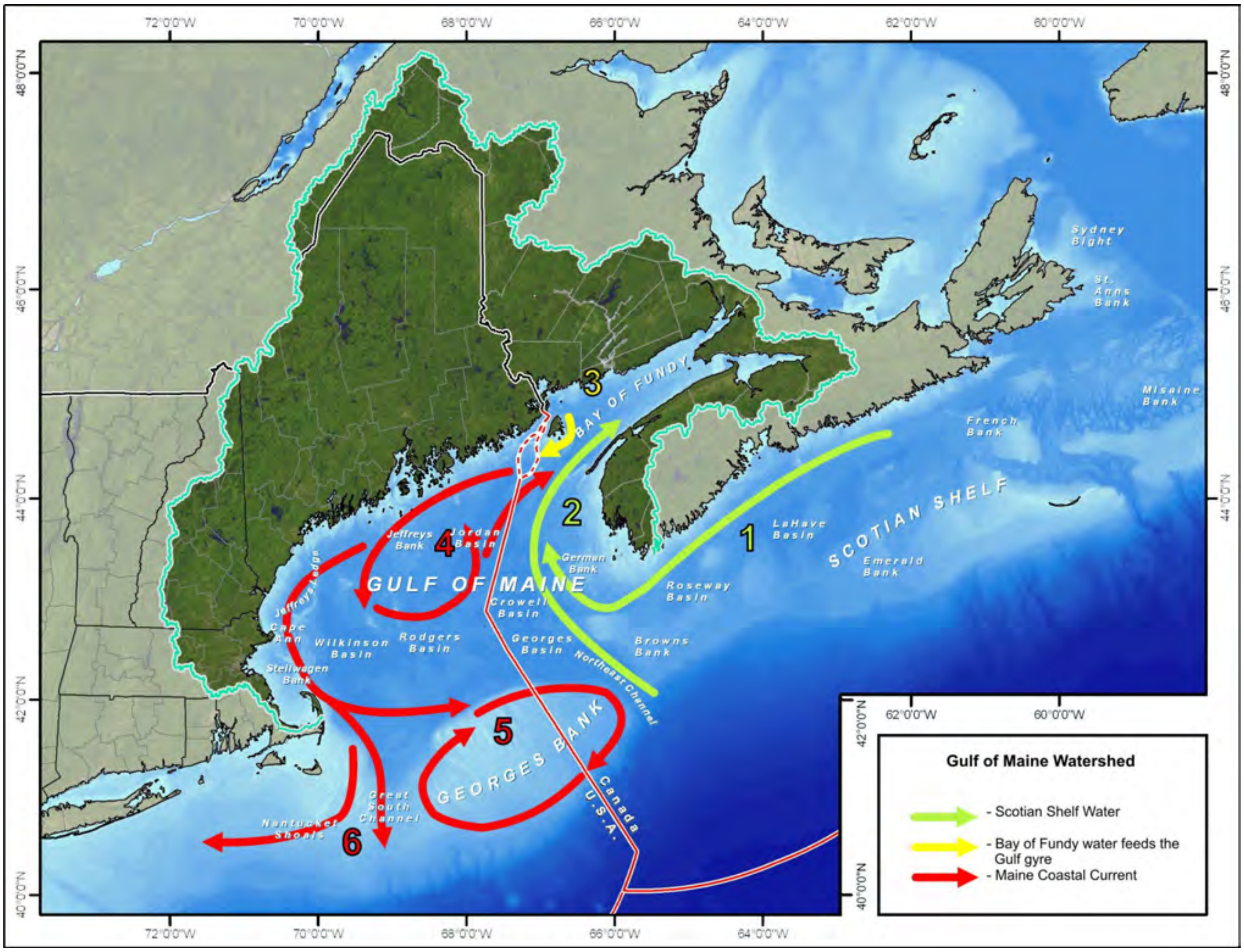


Figure 2: Currents in the Gulf of Maine. 1) Cold water enters the gulf over the Scotian Shelf, Browns Bank and through the Northeast Channel. 2) Once in the Gulf, water flows around Nova Scotia and into the Bay of Fundy. 3) The coast then deflects currents southwestward. 4) The Gulf of Maine Gyre is formed. 5) Tidal fluctuations and shallow water over Georges Bank form a secondary, clockwise-spinning gyre. 6) Water leaves the gulf through the Great South Channel and over the eastern portion of Georges Bank. Source: GoMOOS 2010.

The Gulf of Maine near-surface circulation is generally characterized as a cyclonic (counter-clockwise) movement. The Northeast Channel and Great South Channel provide pathways for sub-surface flow into and out of the Gulf of Maine respectively. As offshore water sources enter the Gulf of Maine along the Northeast Channel, they appear to drive the eastern portion of the counter-clockwise Gulf of Maine gyre and initiate the overall counter-clockwise direction of flow around the Gulf of Maine. Some of the water enters the Bay of Fundy along the Nova Scotian coastline (Xue et al. 2000); another portion of this current turns west to feed the Maine Coastal Current.

The exception to this circulation is a clockwise pattern around Georges Bank (Van Dusen and Hayden 1989). The Georges Bank gyre picks up incoming slope circulation both directly from the Northeast Channel and from circulation of the Maine Coastal Current that gets pushed towards Georges Bank by the projection of the Cape Cod land mass. The shallower coastal shelf with its diverse morphology drives much of the detail we see regarding gyres and localized currents within the Bay of Fundy and along the Maine Coast. However, they may also be influenced by conditions outside of the Gulf of Maine. For instance, the North Atlantic Oscillation (NAO) (a climatic phenomenon in the North Atlantic Ocean of fluctuations in the difference of atmospheric pressure at sea-level between the Icelandic low and the Azores high) influences the relative location within the Atlantic Ocean of warm Gulf Stream waters that approach the Gulf of Maine from the south, and the colder Labrador Current waters that flow toward the area from the north. Small-scale changes in the North Atlantic can produce large-scale changes in the Gulf of Maine.

A seasonal variation in the Gulf-wide circulation exists, strongest and most coherent in the summer and lacking a recognizable pattern in the winter (Bumpus and Lauzier 1965, cited by Xue et al. 2000) Tidal currents, which in part drive the changing circulation patterns, are seasonally stronger in winter and spring (Desplanque and Mossman 1999). It has been suggested that the circulation in the Gulf is related to the evolving density structure of the water. Factors that influence the density distribution inside the Gulf of Maine include wind, winter cooling, river runoff, the periodic cooler and more fresh inflow from the Scotian Shelf, the deep warmer and more saline inflow of the slope water, and tidal mixing (Xue et al. 2000).

The Maine Coastal Current is commonly referred to as a tidally mixed plume that arises from the discharges of fresh spring meltwater that enters the Gulf through several land-based rivers (Xue et al. 2000). The primary freshwater input to the Gulf of Maine is from the river systems that enter the coastline from the southern tip of Nova Scotia around the Bay of Fundy and along the US coast to Cape Cod. These also play a role in circulation, mixing patterns and nutrient regimes of the Gulf. The combined discharge of the four largest rivers (St John, Penobscot, Kennebec and Merrimack) entering the Gulf of Maine has been estimated to be about 60 billion cubic metres of freshwater per year. This freshwater “plume” has a profound influence on water properties and dynamics not just in the estuaries, but also all along the Gulf of Maine coast (Xue et al. 2000).

The tides of the Bay of Fundy are the world’s largest, with a high tide that can exceed 16 m in the Minas Basin at the head of the bay. The tidal range in the whole Gulf of Maine-Bay of Fundy system is enhanced due to the natural period of oscillation (the time it takes for tidal water to flow into and then out of the Gulf). At peak flood tide the flow of water across the edge of the continental shelf into the Gulf of Maine is 25 million cubic meters, 2,000 times the average discharge of the St Lawrence River (Historica Dominion Institute 2010). There are other factors that also have an influence on the tidal range. Variations in atmospheric pressure and wind can create storm surges that result in changes in sea level. In addition, on a daily basis, the Coriolis force causes tides in the Bay of Fundy to move in a counter-clockwise direction. The strongest Bay of Fundy tides occur when four elements, scientifically known as perigee, spring tide, anomalistic and tropical monthly cycles, all peak simultaneously. The closest match occurs at intervals of 18.03 years, a time known as the Saros (Desplanque and Mossman 1999). With the approach of the 18-year Saros tidal cycle in 2012-2013, the risks of storm surge and coastal flooding will increase throughout the Gulf of Maine.

Chemical Oceanography

The temperature, salinity, density and nutrient content of the water across the Gulf of Maine vary enormously depending on the location, time of year and water depth. The water temperature of the North Atlantic ranges from -1.7 °C in the Labrador Current to 20 °C in the Gulf Stream (International Ice Patrol 2009). Both of these large-scale currents influence seasonal and interannual temperature, salinity, density, and nutrient characteristics in the Gulf of Maine.

There are two primary mechanisms that create water temperature variability in the Gulf of Maine. One is the exchange of heat between the water and the atmosphere; the second is the exchange of different temperature waters through currents and circulation. Ocean temperatures are measured within the upper 1 m of the water column, known as the sea surface temperature (SST). The mean annual SST in the Gulf of Maine, has mirrored global patterns, and are actually less than during the mid 20th-century warming period. However, there has been a recent increase in SST range. Mean annual SST range has increased on the continental shelf to the highest levels seen from 1875 to 2005. A change in temperature range can have significant implications on how quickly seasonal change occurs and seasonal changes have significant biological implications.

The primary source waters into the Gulf of Maine have great influence on salinity, just as they do on temperature. The continental slope water that enters through the Northeast Channel is warm and saline, whereas the water that comes off the Scotian Shelf is cool and relatively fresh. These waters mix with the existing Gulf of Maine water at various intensities and depths depending on location in the Gulf, and provide a range of salinities around the Gulf of Maine.

The same processes that bring variable salinities to different areas in the Gulf of Maine also tend to drive nutrients. In locations where mixing brings highly saline water to the surface, it also brings marine nutrients from deep within the water column. Where relatively fresh, low salinity occurs, fewer nutrients are generally observed. Freshening can impede nutrient exchange between surface and deep waters, which reduces the overall spring productivity throughout the region. The Maine Coastal Current system and its rich load of inorganic nutrients increase the biological productivity of the Gulf of Maine.

The Gulf of Maine has peculiar vulnerabilities to the world's changing climate well beyond rising sea levels. As physical characteristics in the Gulf change, so too will chemical and biological attributes. Oceanographic research and analysis of nutrients and hydrography over the past decades have shown that the principal source of nutrients to the Gulf of Maine, the deep, nutrient rich continental slope waters that enter through the Northeast Channel, may have become less important to the Gulf's nutrient load. Since the 1970s, the deeper waters in the interior Gulf of Maine (>100m) have become fresher and cooler, with lower nitrate but higher silicate concentrations. Prior to this decade, nitrate concentrations in the Gulf normally exceeded silicate, but now silicate and nitrate are nearly equal. Accelerated melting in the Arctic and freshening of the Labrador Sea in recent decades have likely increased the equatorward transport of the inner limb of the Labrador Current that flows over the broad continental shelf from the Grand Banks of Newfoundland to the Gulf of Maine. That current system now brings a greater fraction of colder and fresher deep shelf waters into the Gulf than warmer and saltier offshore slope waters which were previously thought to dominate the flux of nutrients. Those deep shelf waters reflect nitrate losses from sediment denitrification and silicate accumulations from rivers, which together are altering the nutrient regime and potentially the structure of the planktonic ecosystem of the Gulf of Maine (Townsend et al. 2010).

2.3 HABITATS, ECOSYSTEMS, FAUNA AND FLORA

Habitats

Habitats of the Gulf of Maine do not exist in isolation, a myriad of 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. 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. This overview of habitats in the Gulf of Maine is categorised based on substrate type and sediment grain size, the water column, and biogenic habitats.

Substrate Type and Sediment

Grain size has a strong influence on the types of plants and animals that can inhabit a given place. Substrates and sediment can be mud particles, fine sand, coarse sand, pebbles, cobbles, boulders or a 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 hydrographic conditions determine the type of substrate in a given place.

Rocky Habitats. The Gulf of Maine has more rocky intertidal habitats than other areas along the Atlantic coast (Roman et al. 2000). These habitats are most prevalent on the Gulf of Maine's northern shores, including Maine, New Brunswick and Nova Scotia. Rocky habitats provide food for many predatory birds (e.g., gulls, diving ducks and other birds). Lumpfish, rockfish, cunner, Acadian redfish, and sculpin are some of the predatory fish that feed in rocky intertidal and subtidal habitats. Mammal predation can be significant (Carlton and Hodder 2003); muskrats, mink, and other small mammals forage in the Gulf of Maine's rocky intertidal zone. The primary productivity of seaweed-dominated rocky shorelines is nearly ten times greater than that of the adjacent open ocean (Harvey et al. 1995) and helps fuel the marine ecosystem. Seaweeds sustain animals in other habitats, as fragments break off, drift away, and enter the food web. Both the physical structure provided by rock itself and the biogenic structure created by seaweeds, mussels and other attached species offer important habitat for many organisms. Spawning fish such as herring and capelin use the rocky habitats to shield their eggs from currents and predators. Rock crevices protect algae and small animals such as snails, crabs, isopods and amphipods from predators.

Sandy Habitats. Sandy environments tend to have comparatively low biological productivity and species diversity, but they have unique species assemblages. Some filter and deposit feeding invertebrates thrive in sandy habitats and fish hide among the ripples and ridges of subtidal sandy bottoms. Dunes provide nesting habitat for some imperilled birds, such as the roseate tern, northern harrier, piping plover, least tern and for the threatened diamondback terrapin.

Muddy Habitats. Muddy bottoms are areas of fine sediments that may be unvegetated or patchily covered with green algae and benthic diatoms. These habitats occur in calm, wave-sheltered, depositional environments in both the subtidal and intertidal zone, where they are commonly referred to as tidal flats. Mud habitats exist in many wave-protected areas along the Gulf of Maine coast, particularly at the heads of bays. The Bay of Fundy is well known for its highly productive tidal flats. In the subtidal zone, large areas of mud occur in deep waters off the coast of Massachusetts, including Cape Cod Bay and north of Georges Bank. Grain size can range from pure silt to mixtures containing clay and sand. The sediments of muddy habitats boast a higher proportion of nutrient-rich, organic-mineral aggregates (detritus) than the sediments in sandy habitats (Whitlatch 1982). The cohesive nature of muddy sediments facilitates burrow construction by many types of invertebrates. Watling (1998) estimates that a thousand species of macroinvertebrates live in muddy habitats of the Gulf of Maine. Mussels, clams and other filter feeders provide a vital link between water column and seabed habitats by feeding on plankton and other waterborne particles. These consumers, in turn, are prey for animals higher in the food web. Tidal flats are noteworthy for their value as shorebird feeding grounds. The high densities of crustacean and molluscan prey in tidal flats support vast numbers of shorebirds during migration.

The Water Column

The liquid realm between the seafloor and the sea surface is referred to generically as the water column. All of the estuarine and marine waters in the Gulf of Maine are part of the water column. The water column is a dynamic, three-dimensional environment with distinct layers, which can be considered habitats unto themselves. Water masses with different temperature, salinity and density exist within and among the depth zones. Organisms living in the water column are closely attuned to physical conditions and many migrate vertically or horizontally to stay in favourable conditions. Many factors influence the biological productivity of the water column. For example, the topography of underwater banks and ledges forces cold, nutrient-rich, deep currents toward the sea surface, fueling growth of phytoplankton. Water column habitats in the Gulf of Maine are highly productive. Upwelling areas are notable for having especially high primary productivity stimulated by the mixing of nutrients from the bottom waters. One by-product of the productivity is oxygen: Approximately 70% of oxygen in the atmosphere comes from photosynthesis of marine phytoplankton. The fronts that occur at boundaries of different water masses host abundant zooplankton that attracts dense aggregations of pelagic fish such as Atlantic sea herring and mackerel. In turn, larger fish, mammals, and birds such as storm petrels and shearwaters feed on the schools of fish. The water column serves as the nursery habitat for most bottom-dwelling species (ranging from seaweeds to barnacles to sea urchins) because they spend their early lives drifting and growing in the ocean currents. A variety of imperilled species live in the Gulf of Maine's water column habitats. The endangered northern right whale lingers in Cape Cod Bay during spring, feeding on copepods and then travels north to the Bay of Fundy in summer. The leatherback turtle, known for its unusual habit of eating jellies as a major part of its diet, inhabits the southern Gulf of Maine.

Biogenic Habitats

Certain plants and animals grow in such a manner that they provide a unique environment and physical structure for other organisms. Habitats created by plants or animals are called biogenic. Examples of biogenic habitats in the Gulf of Maine include seaweed beds, seagrass beds, salt marshes, mussel beds and cold-water coral thickets.

Salt marshes. These grass-dominated habitats extend from the low intertidal zone to the upper limits of the highest high tides. Meadow and fringing salt marshes are found in bays and tidal rivers along the Gulf of Maine coastline. Salt marshes are among the most biologically productive ecosystems in the world. In the Gulf of Maine, they help support rich coastal and estuarine food webs. Canada geese, snow geese, voles, insects, snails and crustaceans directly consume vegetation in the marsh and farmers historically grazed their livestock on salt marsh grasses. However, most of the plant matter that grows in salt marshes enters the food web after it dies, rather than being eaten while alive. Microbes and worms break down the decaying plant material, or detritus, producing food particles that are swept away by the tides, transporting nutrients to other habitats. The detritus is eaten by crabs and shellfish and several species of fish that feed, breed and find refuge in tidal channels or on the flooded marsh surface. Salt marshes provide critical resting and feeding grounds for migratory birds and serve as nurseries for some young fish, shellfish, crabs and shrimp because the physical structure of the grasses offers hiding places from predators. As they grow, salt marsh plants absorb atmospheric carbon dioxide, which is a major greenhouse gas. The carbon can be stored in the soil for thousands of years as the vegetation dies and is transformed into peat. The roots and stems of marsh plants improve water clarity by slowing water flow and trapping waterborne sediments, which block sunlight penetration, clog filter-feeding animals and fish gills, and may contain toxins or heavy metals. In addition, the grasses absorb excess nutrients that enter groundwater and surface water from fertilizers and sewage discharge. This reduces the risk of eutrophication and oxygen depletion in estuaries and nearby coastal waters.

Seagrass Beds. Seagrass is a general term for flowering plants that live in low intertidal and subtidal marine environments. Roots anchor seagrass to the sediment, but unlike terrestrial plants, seagrass also absorbs nutrients from the water along the entire length of its blades, which can reach ten feet. Two species of seagrass live along the Gulf of Maine coast. Eelgrass (*Zostera marina*) is the dominant seagrass throughout the region, while widgeon grass (*Ruppia maritima*) is limited to low-salinity waters. Seagrass usually lives in shallow (to a depth of 11 m), clear waters where it receives ample sunlight. The beds often lie next to salt marshes or in harbours and inlets where they are protected from storms. Seagrass is critical habitat in the Gulf of Maine. It improves water quality by filtering suspended sediment and excess nutrients; seagrass blades act as refuges for small animals and slow the water, providing inhabitants a respite from currents; seagrass produces oxygen through photosynthesis, which benefits the animals that inhabit the beds; they are also notable for their role as nurseries. Commercially valuable species such as bay scallop, cod, blue mussel and winter flounder use seagrass habitats as juveniles, although not exclusively. Many algal and invertebrate species attach themselves to seagrass blades, including encrusting and upright bryozoans, tunicates, hydroids, and red and green epiphytic algae. Atlantic silversides and other species spawn in eelgrass beds. Other species that occur commonly in seagrass beds are lobster, pipefish, tomcod, American brant, and European green crab.

Kelp Beds. While many different types of seaweed live on rocky substrates in the Gulf of Maine, kelps are noteworthy because they are large and create underwater forests with physical structure and layering similar to that of a terrestrial forest. Kelps are brown algae that use root-like holdfasts to attach to hard substrates. Although their general morphology resembles terrestrial plants, kelps are quite different. For example, nutrient absorption occurs throughout the whole organism, not just through the holdfast. Kelp beds resemble forests on land in that the kelp blades form a canopy layer, fleshy algae such as Irish moss form an understory layer, and the crustose red algae that live on rocks are comparable to a forest's herb layer. This complex structure creates homes for many different species. Invertebrates and fish, especially juvenile fish, find protection from predators and harsh environmental conditions, including ultraviolet radiation and strong currents, by inhabiting kelp beds. The holdfasts provide microhabitats for small invertebrates such as brittle stars, polychaete worms, snails, and juvenile mussels. Lobsters hide in kelp beds while moulting (Harvey et al. 1995). Some invertebrates such as sea slugs, snails, bryozoans and hydroids, as well as other algae, live attached to kelp blades and stems. Kelp is also significant because its rate of primary productivity is among the highest in the world. It contributes to nutrient cycling by absorbing inorganic nutrients and then entering the food web as dead tissue or detritus.

Shellfish Beds. Some bivalve mollusks form large, dense aggregations called shellfish beds that function as distinct biogenic habitats. Small animals find refuge in the crevices among the shellfish, while others attach to the shells. Each species that forms shellfish beds has different environmental requirements and, therefore, shellfish beds can be found in the intertidal and subtidal zone and from estuaries to far offshore. The Gulf of Maine has three types of shellfish beds that are especially noteworthy as biogenic habitats. Mussels secrete strong, flexible threads that bind individuals together in clumps. Oysters settle onto the seabed in clusters and as they grow, their shells attach permanently to the substrate, leading to formation of a calcareous reef. Scallops do not attach to each other or the substrate, but their dense aggregations are nevertheless referred to as shellfish beds. Shellfish are filter feeders that improve water quality by removing suspended material and particulate pollutants (Gili and Coma 1998). Shellfish also provide an important function in the food web by transferring food from the water column to benthic habitats. These filter feeders convert water column productivity in the form of phytoplankton and zooplankton into their tissues, which then becomes available as food to animals higher in the food web, such as the birds, crabs and fish that eat filter feeders.

Cold-Water Corals. Cold-water corals can form a unique habitat that hosts a great diversity of species. Suspension-feeding invertebrates such as crinoids, basket stars and anemones live on the corals, which improves their exposure to currents carrying food particles, protects them from some predators and helps them avoid sedimentation. Fish, shrimp and crabs swim or crawl among the corals and some fish, sea stars, sea slugs, snails and other invertebrates eat the soft tissues of corals.

Fauna and Flora

About 3,317 species of flora and fauna can be found in the Gulf of Maine (Valigra 2006); approximately 2,350 of those are found in the Bay of Fundy (Census of Marine Life 2009). There have been 120 species of marine fish found in the Bay of Fundy, of which nearly 54% fall within one of the four orders of Gadiformes (cods, burbot, hake and rocklings), Perciformes (perches, bass and mackerel), Scorpaeniformes (sculpins and ling cod) and Pleuronectiformes (flatfish such as flounder, halibut, plaice and sole). However, more than 652 species of fish have been documented living in, or migrating through, the Gulf of Maine. It is estimated that of these 87 (13%) species of fish are resident (live their whole lives) within the Gulf of Maine. This section gives a broad overview of some of the key species and communities found within the Gulf of Maine (see also *Gulf of Maine Ecosystem Overview Report*, Parker 2009).

Planktonic Communities

Phytoplankton consist of microscopic plants that form the base of the marine food chain. Though they are small, the energy they capture from the sun through photosynthesis helps to sustain almost all life in the ocean. A phytoplankton bloom has been defined as a "high concentration of phytoplankton in an area, caused by increased reproduction; which often produces discoloration of the water" (Garrison 2005). Blooms occur when sunlight and nutrients are readily available to the plants, and they grow and reproduce to a point where they are so dense that their presence changes the colour of the water in which they live. Blooms can be quick events that begin and end within a few days or they may last several weeks. They can occur on a relatively small scale or cover hundreds of square kilometres of the ocean's surface. In the Gulf of Maine, spring and fall blooms occur on an annual basis. Other planktonic community members include the ichthyoplankton (developing fish with limited mobility) and bacterioplankton (bacterial component of plankton important in fixing carbon dioxide and nitrogen).

Benthic Communities

Macrobenthos, excluding groundfish, dominates the intermediate trophic-level biomass, production and consumption in the Gulf of Maine. It is the macrobenthos such as sea grasses, star fish and shellfish that transfer the greatest proportion of energy through the ecosystem. Human activities, including overfishing and species introductions, have had a dramatic impact on benthic communities in the Gulf of Maine within the past two decades. In addition to changes in relative abundance, many of these introduced species have greatly expanded their distribution and habitat selection. The habitats and roles of introduced and established species and the interactions between species within communities are changing in unpredictable ways in the Gulf of Maine. The factors that will determine the future direction of shallow water benthic community development are not well known. The present observations indicate that the changes underway are increasing in magnitude and spreading to affect other communities (Harris and Tyrrell 2001).

Macrophytes. There have been 271 species of macrophytes (marine algae large enough to be seen with the naked eye) identified in the Gulf of Maine. Important coastal species include eelgrasses, brown algae and the commercially important Irish moss. Kelps (brown algae) are also found in the Gulf of Maine. The most common species in this region are sugar kelp, oarweed, edible kelp and shotgun kelp.

Invertebrates: Infaunal communities. There are about 1,410 species of invertebrates making up approximately 60% of the known marine species of plants and animals within the Gulf of Maine. Infauna comprises those species that live within the bottom substrates of the Gulf. Relatively common infaunal invertebrate

bivalves include the American cupped oyster (*Crassostrea virginica*), American sea scallop (*Placopecten magellanicus*), Atlantic razor clam (*Ensis directus*), Atlantic bay scallop (*Argopecten irradians*), Atlantic surf clam (*Spisula solidissima*), blue mussel (*Mytilus edulis*), European flat oyster (*Ostrea edulis*), Iceland scallop (*Chlamys islandica*), northern quahog (*Mercenaria mercenaria*), Ocean quahog (*Arctica islandica*), sand gaper (*Mya arenaria*) and Stimpson's surf clam (*Spisula polynyma*) (Heymans 2001).

Invertebrates: Key Commercial Species. Large crustaceans within the Gulf of Maine include the American lobster (*Homarus americanus*) and large crabs such as the Atlantic rock crab (*Cancer irroratus*), green crab (*Carcinus maenas*), horseshoe crab (*Limulus polyphemus*), Jonah crab (*Cancer borealis*) and red crab (*Geryon quinquedens*). The American lobster, the rock crab and sea scallop are among the most common and abundant macroinvertebrates in coastal zones of the Gulf of Maine as well as being the most significant commercial species.

Invertebrates: Non-commercial epifaunal communities. Epifauna are those organisms living on the sea floor. Significant species diversity, abundance, and biomass have been found on Georges Bank, with 76% representing organisms living on the surface of the sea floor. Molluscs, crustaceans, annelids, and echinoderms were the most common with bivalves ranking first in abundance (55%) and biomass (86%). Another invertebrate living on the surface of the sea floor is coral. Deep-water corals represent a variety of habitats for other organisms and 114 invertebrate species have recently been found associated with corals.

Groundfish. There are 652 species of fish that have been listed in the Gulf of Maine Register of Marine Species. Benthic fish communities that live on or near the bottom of the ocean are typically referred to as groundfish if they are commercially harvested or (generically) as demersal fish. These fish fall primarily under three taxonomic orders in the Gulf of Maine. Two of those, the Gadiformes (cods, burbot, hake, pollock and rocklings) and Pleuronectiformes (flatfish such as flounder, halibut, plaice and sole), constitute the majority of commercially valuable groundfish. Table 2 gives an overview of some well-studied groundfish species found within the Gulf of Maine.

Pelagic Communities

Pelagic communities are those flora and fauna that live in the water column (as opposed to those close to the sea floor). Because of the trophic interactions between the benthic fish communities and the pelagic communities, changes observed in one group of fishes are often tied to the other. Significant numbers of commercial benthic fish have exhibited recent abundance declines but several key pelagic species have increased over their historic means.

Pelagic Invertebrates. The largest invertebrates found within the Gulf of Maine include the northern (pink) shrimp (*Pandalus borealis*) and two species of squid

Table 2: Deepwater and shelf/slope fish assemblages found in the Gulf of Maine.

DEPTH CLASS	DEMERSAL FISH ASSEMBLAGE	BOUNDARY RELEVANCE TO THE GULF OF MAINE	PRIMARY ASSEMBLAGE SPECIES	
> 200 m	Temperate deepwater	From the Gulf of Maine northwards; the Gulf of Maine is approximately southern in extent.	Marlin – spike Black dogfish Atlantic argentine	Longfin hake Barracudinas Roughnose grenadier
> 200 m	Southern deepwater	From the Gulf of Maine southwards; the Gulf of Maine is approximately northern in extent.	Blackbelly rosefish Offshore hake Shortnose greeneye Shortfin squid	Buckler dory Beardfish Slatjaw cutthroat eel Armoured searobin
< 200 m	North-temperate bank/slope	From Georges Bank northward; the Gulf of Maine is approximately southern in extent.	Northern wolffish Spotted wolffish Atlantic sea poacher Arctic cod Greenland halibut Polar sculpin	Greenland cod Fourline snake blenny Threebeard rockling Atlantic spiny lumpsucker Atlantic hookear sculpin
< 200 m	South-temperate bank/slope	Extends to both north and south of the Gulf of Maine.	Red hake Goosefish (angler) Spiny dogfish Silver hake White hake Pollock Cusk Yellowtail flounder Winter flounder Ocean pout	Longhorn sculpin Winter skate Northern sand lance Atlantic hagfish Fourbeard rockling Haddock Atlantic soft pout Wrymouth Threespine stickleback Sea raven
< 200 m	Southern bank/ slope	From the Gulf of Maine southwards; the Gulf of Maine is approximately northern in extent.	Fourspot flounder Butterfish Spotted hake Fawn cusk-eel Gulf Stream flounder Summer flounder Scup Black sea bass Northern (common) searobin	Smooth dogfish Windowpane flounder Little skate Bigeye scad Rough scad Round scad Plainhead filefish Smallmouth flounder

—the longfin inshore squid (*Loligo paeleii*) and the highly migratory northern shortfin squid (*Illex illecebrosus*). A number of other pelagic invertebrates are found within the Gulf of Maine, and several are important as prey items to fish communities. Echinoderm (star fish and sea urchins), barnacle larvae, and krill are observed during spring and summer in the Bay of Fundy. Jellyfish commonly encountered include ctenophores (comb jellies), medusae, salps (tunicate), and Chaetognatha (predatory worm). Leatherback turtles feed almost exclusively on jellyfish while in the Gulf of Maine.

Marine Turtles. Three sea turtles, loggerhead (*Caretta caretta*), Kemp's ridley (*Lepidochelys kempii*) and leatherback (*Dermochelys coriacea*) are documented as regularly occurring in the Gulf of Maine (Census of Marine Life 2009). The green sea turtle (*Chelonia mydas*) have also been reported around Cape Cod, MA. All sea turtles in the Gulf of Maine are considered migrants, coming to forage in northerly areas on or along the shelf (Shoop 1987).

Pelagic Fish. Perciformes (perch, bass, mackerel and tuna) are the most abundant pelagic fish found in the Gulf of Maine, with 132 having been documented (Census of Marine Life 2009). The species have great significance as prey items, as a commercially targeted resource, or as an apex consumer within the Gulf of Maine ecosystem. Pelagic species in the Gulf of Maine include:

- Seven different species of tuna. Albacore, bigeye and yellowfin tunas are at the northern edge of their range in Canada, and they are found along the edge of the Gulf Stream and Georges Bank throughout the year.
- Atlantic herring (*Clupea harengus*) is found on both sides of the North Atlantic, and is a very important prey species within the Gulf of Maine. Herring is considered a keystone prey species in the Gulf of Maine ecosystem (Overholtz and Link 2006).
- Atlantic mackerel (*Scomber scombrus* L.) is widely distributed in the waters of the North Atlantic. In spring and summer, mackerel is found in inshore waters; but from late autumn into winter, it is found in warmer, deeper waters at the edge of the continental shelf.
- The blue shark (*Prionace glauca*), porbeagle shark (*Lamna nasus*), mako shark (*Isurus oxyrinchus*) and the spiny dogfish (*Squalus acanthias*) are four shark species that are commonly found in the Gulf of Maine.
- Atlantic salmon (*Salmo salar*) is another pelagic species found and is perhaps more familiar to the general public than any other, primarily due to its excursions up the coastal rivers that feed into the Gulf. Since the late 1980s and 1990s, Gulf of Maine salmon populations have diminished at an unprecedented magnitude. Migration routes, distribution and abundance for specific stocks are completely unknown.

Marine Mammals

More than 32 species of marine mammals have been observed in the Gulf of Maine (Valigra 2006). There are three general communities: the medium-large cetacean (whales), the small cetaceans (dolphins and porpoises) and the seals.

Medium to Large Cetaceans. In the Gulf of Maine, large cetaceans are dominated by baleen whales. In fact, the Gulf of Maine has high baleen whale biomass (0.5-0.6 t/km^2) when compared to other ecosystems around the world (Gaichas et al. 2009). This group includes the commonly seen, globally endangered, North Atlantic right whale (*Eubalaena glacialis*), humpback whale (*Megaptera novaeangliae*), fin whale (*Balaenoptera physalus*), sei whale (*Balaenoptera borealis*) and minke whale (*Balaenoptera acutorostrata*). The fin whale dominates the large cetacean mass within the Gulf of Maine at all locations in virtually all seasons. Several species are listed under Canada's Species at Risk Act and the US Endangered Species Act, due to their low abundance. These include right, blue and the northern bottlenose whale (*Hyperoondon ampullatus*) (endangered under SARA) and the fin, humpback and Sowerby's beaked whale (*Mesoplodon bidens*) (special concern under SARA).

Small Cetaceans. Related to the whales, this group includes species of dolphin and porpoise. In the Gulf of Maine, the main species sighted (in descending order) are harbour porpoise (*Phocoena phocoena*), white-sided dolphin (*Lageno-rhynchus acutus*), and two species of pilot whales (long-finned - *Globicephala melas*; and short-finned - *Globicephala macrorhynchus*) and the common dolphin (*Delphinus delphinus*). Two other dolphin species, Atlantic bottlenose dolphin (*Tursiops truncates*) and white-beaked dolphin (*Lagenorhynchus albirostris*) are occasionally seen. Significant numbers of (~40,000) of both white-sided dolphin and harbour porpoise reside in the US Gulf of Maine year round, with virtually 100% of the northeast shelf population being located in the Gulf. The Gulf of Maine-Bay of Fundy population of harbour porpoise is one of four in the western North Atlantic (NOAA 2006). Harbour porpoise is listed as threatened under the US Endangered Species Act and under the Canadian Species at Risk Act, and is the only member of this group of small cetaceans that is currently a federally listed species.

Seals. Harbour, harp, hooded and grey seals are listed on the Gulf of Maine species census. In general, there is evidence that the seal populations in the Gulf of Maine have increased over the last 20 years (Parker 2009).

Seabirds

The Gulf of Maine is rich in avian diversity and abundance. There are more than 184 species of Marine birds that have been documented within the Gulf of Maine. The Gulf of Maine has several attractive features for pelagic birds, including ice-free winters and areas of high marine productivity that ultimately produce food supplies at the top of the food chain. The Gulf of Maine ecosystem components support breeding, migrating/staging and non-breeding populations of waterfowl, seabirds and shorebirds (Table 3).

Table 3: Important marine areas within the Gulf of Maine for select seabirds.

SPECIES	STATUS OF BIRD	TIME OF YEAR/LOCATION	ENVIRONMENTAL CHARACTERISTICS
Northern Gannet	Immature	Winter: Cape Cod Breeding: Grand Manan Post-breeding: Grand Manan and Cape Cod	Shallow and mixing regime Strong tidal currents Strong tidal currents
Greater Shearwater	Moulting	June: Georges Bank	Shallow waters
Black Legged Kittiwake	Immature	Post-breeding: Grand Manan Small breeding colony in Bay of Fundy	Shallow and mixing regime
Herring Gull	Immature	Winter: Cape Cod Breeding: Cape Cod Post-breeding: Cape Cod, Grand Manan and Georges Bank	Mixing regime Strong tidal currents Strong tidal currents and shallow waters
Great Black-backed Gull	Immature	Winter: Cape Cod and Georges Bank Breeding: Cape Cod Post Breeding: Georges Bank	Shallow and mixing regime Currents and shallow waters Shallow waters

3. Socio-Economic Overview

The socio-economic environment refers to a wide range of interrelated and economic factors that influence the well-being and prosperity of human society (Intergovernmental Oceanographic Commission 2006). These include demographic and economic considerations, public health and safety, culture, and aesthetic factors. Humans have been an integral part of the Gulf of Maine since the earliest native settlers in the region. To understand the human impact to the marine ecosystem, we must consider the historic and current patterns of human activity within the Gulf of Maine.

3.1 A HISTORICAL PERSPECTIVE

The initial influx of people to the Gulf of Maine began approximately 12,000 years ago. It is only in the last 500 years, however, that the region has witnessed extensive coastal settlement and development, and exploitation of its fisheries and other resources.

European settlers were first drawn to the Gulf's shores in search of fortune, religious freedom or a new life and the bounty of the Gulf served these people well. Settlements grew up near natural salt and fresh water marshes and, in the upper reaches of the Bay of Fundy, a vast network of dikes was constructed to convert tidal salt marshes into farmland. Cod was plentiful and well-suited to salt curing, which was essential for the long shelf-life necessary for export. Salt, hay and cod were the first steps in a maritime enterprise that would bring the region two centuries of prosperity. By the 1730s, shipbuilding in the Gulf grew up to support the salt cod trade with Europe. Cod and surplus products from thousand of farms were shipped from the handful of seaports on harbours and major rivers that today remain the major cities of the Gulf. The products were exchanged for letters of credit and molasses, which along with cod, were then traded with Great Britain, Ireland, and southern Europe for salt, iron, glass, molasses, spices, and imported fabrics the settlers could not produce themselves. These products, later supplemented with granite, lime, and ice, further fuelled New England's shipbuilding industry, which in turn, promoted economic growth and industrialization of the region (Boeri and Gibson 1976).

Spurred on by the Industrial Revolution that was taking hold in Great Britain, entrepreneurs in the Gulf began to develop an industrial base of their own in the late 1790s. Fuelled first by water power and later by steam, the economy of the Gulf was changing and with it, its environment. Shoe-making, precision engineering, clothing, wool, and cotton textile, and later paper manufacture became an important part of the region's economy. New England inventors and entrepreneurs transformed old mercantile cities into manufacturing centers (Pesch and Wells 2004).

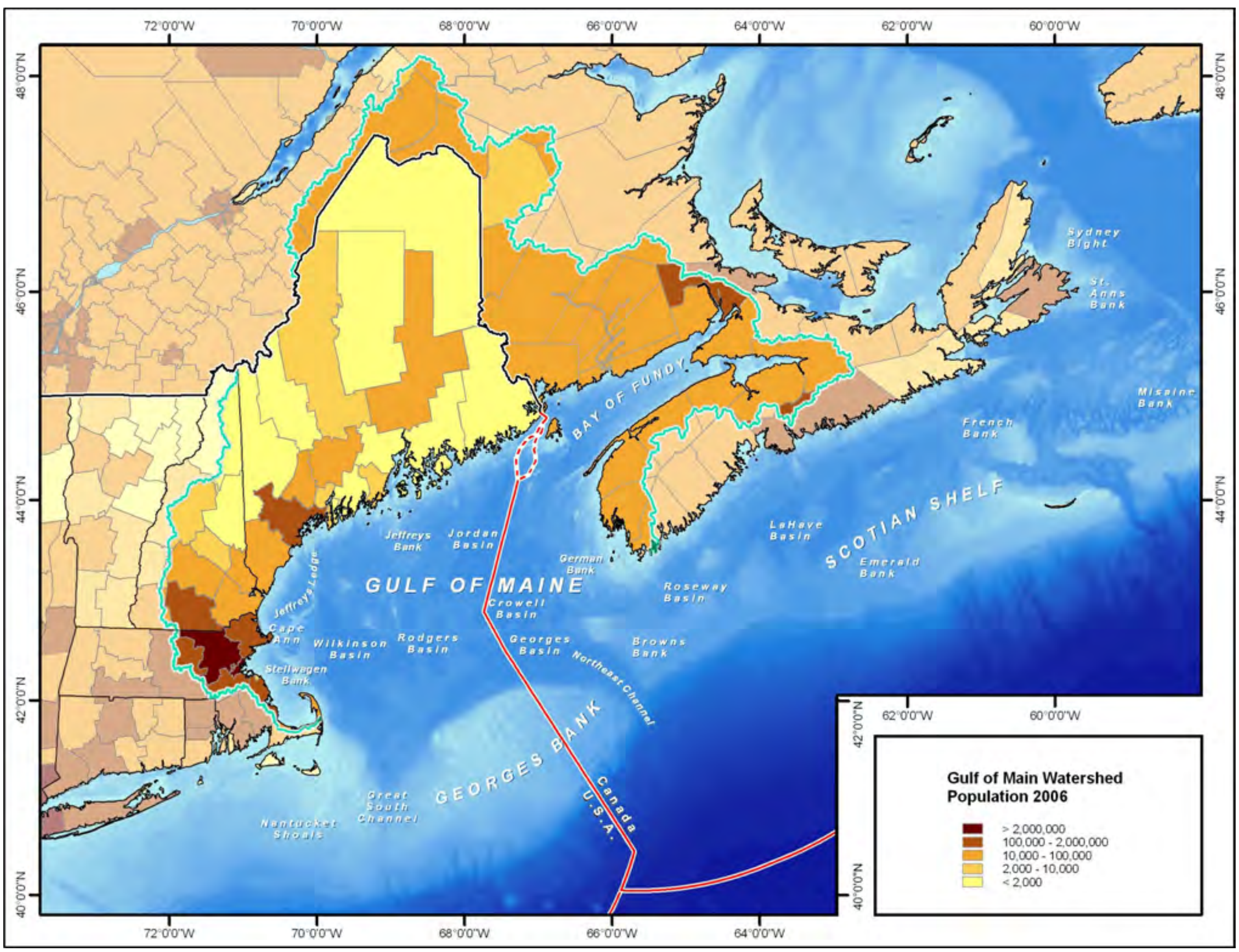
After 1880, farms declined in size and number and urban areas expanded. Electrification brought more dams, many of which still remain today. By 1920, there was still approximately 2 million acres (0.8 million hectares) of "virgin" forest in New England, but harvesting was occurring 3.5 times faster than replacement. By the 1940s, 38% of the forests were less than 20 years old and many states were forced to import wood. In Canada, much of the abandoned farm and forest land reverted to the Crown (McInnis Leek 2004) and over-harvesting was limited to areas near water transportation.

The population grew moderately in the 20th century. By 1940, two-thirds of the population lived in coastal counties of the Gulf in a limited number of centres, fuelled by industrialization of its shores. Population continued to migrate from rural to urban areas, following employment opportunities and services. Settlement patterns began to change after World War II, spurred by federal housing policies and construction of the US Interstate and Trans-Canada highways. Housing rates increased dramatically and changes in household size and structure prompted demand for new housing types. Increased prosperity led to construction of vacation and retirement homes in settings near recreational amenities. Dispersal of development into rural lands, commonly known as "sprawl," is now a defining feature of the Gulf's landscape (Pesch and Wells 2004).

3.2 DEMOGRAPHY

As of 2007, nearly 10.8 million people live within the Gulf of Maine region, which includes: New Brunswick (NB, 0.75 million), Nova Scotia (NS, 0.94 million), and in the US, the New England states of Massachusetts (MA, 6.45 million), Maine (ME, 1.32 million) and New Hampshire (NH, 1.32 million) (US Census Bureau 2007, Statistics Canada 2007). Distribution of population by county is shown in Figure 3. The current population growth in the region is just over 1%, as compared to the US and Canadian averages of less than 1%. This population trend and the migration of human settlement toward the coast will continue to impact the Gulf of Maine ecosystem for decades to come. By 2025, the population of the Gulf is expected to increase by approximately 0.6 million people. While growth trends in the Canadian provinces are mixed (population is projected to decrease in Nova Scotia), the US states are growing and likely to continue to do so. Most of that growth (95%) is residential. The fastest growing towns within expanding metropolitan areas are the low density new suburbs, 16 to 40 kilometres (10 to 25 miles) distant from traditional metropolitan centers. Two major trends for the Gulf of Maine region are out-migration from rural to metropolitan centres and ageing population. Growth projections for the coast of Maine categorise nearly all of it as "suburban" by year 2050. Nova Scotia has the highest median age in the region at 41.8, followed by New Brunswick at 41.5. Both provinces are higher than Canada's median age of 39.5. Maine has the highest median age (41.2) of any state in the US (36.4) and the proportion of elderly residents is projected to almost double by 2030. New Hampshire and Massachsuetts are experiencing similar trends with median population ahead of the national curve at 39.3 and 36.5 respectively. As the region's older population increases, its younger population is also simultaneously decreasing. Coastal areas, with prime recreational opportunities and waterfront lands, are becoming increasingly popular settings for retired and seasonal residences. Seasonal dwellings along the coast now represent almost one third of the housing stock in areas like Hancock County, Maine and Barnstable County (Cape Cod) and Massachusetts (US Census Bureau 2009).

Figure 3: Population by county of the Gulf of Maine watershed. Sources: US Census Bureau 2009; Statistics Canada 2009.



3.3 ECONOMIC OVERVIEW

The Gulf of Maine economy had a gross domestic product (GDP) of over US$500 billion[1] in 2008, which comprised: Massachusetts $365 billion, New Hampshire $60 billion, Maine 49.7 billion, Nova Scotia $32 billion and New Brunswick $ 25.6 billion (Bureau of Economic Analysis 2009; Statistics Canada 2009). Between 2004 and 2008 the region's economy grew by approximately 17%. The economy is largely serviced-based, with 80% of its GDP generated by service industries and only a small 2.5% arising from natural resource based industries, i.e., agriculture, forestry, fishing, hunting, mining, and oil and gas extraction (Figure 4).

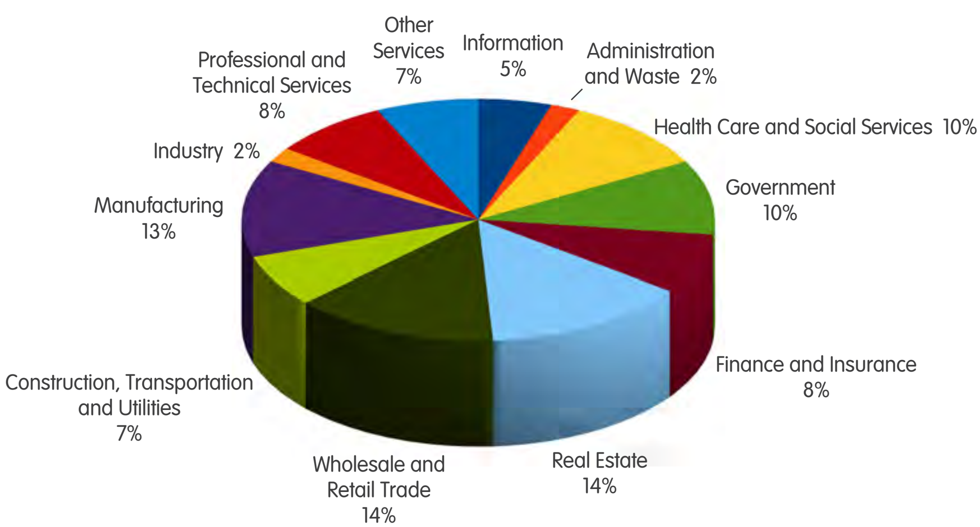


Figure 4: Relative contribution to GDP by major industry sectors in the Gulf of Maine region for 2007. Sources: Bureau of Economic Analysis 2009; Statistics Canada 2009.

The Gulf of Maine Marine Economy

The marine economy of a region comprises commercial activities related to and/or having inputs from the sea. The marine economy in the Gulf of Maine region is constantly evolving as it adapts to changing demands for products and services and supply of natural resources. Over two-thirds of the population in the region lives along the coastline and this serves as a driver that is exerting pressure on coastal and ocean ecosystem health. An economic valuation of the marine environment is based on the marine services it provides. Marine ecosystem services refer to benefits that people obtain from marine ecosystems, including the open ocean, coastal seas and estuaries (Daly 1997). Ecosystem services are critical to the functioning of coastal systems and contribute significantly to human well-

[1] All currency quoted in US dollars unless specified in Canadian dollars (C$). Canadian dollar conversions are based on market rates and yearly exchange averages.

The loss of natural capital and ecological goods and services can result in:

- Poorer water quality and increased water treatment costs
- Increased health care costs associated with decreased human health
- Increased insurance costs (flooding, crop failure)
- Loss of land suitable for agriculture
- Decreased property values due to the loss of natural land and the associated aesthetic appeal
- Irrigation water shortage
- Water hauling and deeper wells
- Decreased fish stocks
- Tourism losses

Source: Ducks Unlimited Canada 2004

being, representing a significant portion of the total economic value of the marine environment.

The marine economy is categorised into specific sectors of marine activity which include commercial fisheries, coastal tourism and recreation, marine transportation, aquaculture, marine science and technology and marine/coastal construction and infrastructure.

The coastal tourism and recreation sector is by far the largest of the marine economy in the Gulf of Maine region in terms of both the number of establishments and the number of employees. The economic impacts of tourism in general are particularly difficult to calculate. Additionally, differentiating between general tourism and marine-related tourism is also frequently difficult. While any tourism that occurs in a small, coastal town may be assumed to be almost entirely marine-related, the same is not true in larger counties that offer a wider range of attractions. It is, therefore, extremely difficult to determine what fraction of the economic impact of tourists can be directly attributed to marine-related tourism. To assume that all tourism is marine-related would greatly overestimate the economic impacts of marine and coastal tourism on the region.

In addition to goods and services that are traded in the marketplace such as seafood and marine transportation, the Gulf of Maine's coastal and marine ecosystems generate goods and services that are not easily quantified: processes that influence climate and biodiversity; wetlands and dunes that protect lands during storms; nutrient cycling; control of diseases and pests; carbon sequestration; waste recycling and storage; recreation, educational opportunities, spiritual enrichment and aesthetic experiences. Table 4 provides a summary of the impact of the marine economy within the Gulf of Maine, by province/state.

3.4 RESOURCE USE AND ENVIRONMENTAL PRESSURE

Commercial Fisheries

Fishing plays a vital role in the cultural and economic fabric of the Gulf of Maine region with the identity and current-day economy of many of its coastal communities deeply tied to fishing and to iconic species such as cod and lobster. As one of the oldest European settlements in North America, the region's fisheries have been very important historically.

The cod fisheries helped feed Europe's industrial revolution and were an important part of the 17th through early 19th century's trade routes between Africa, the Caribbean, North America and Europe. Due to the galleons, shallops, sloops, and

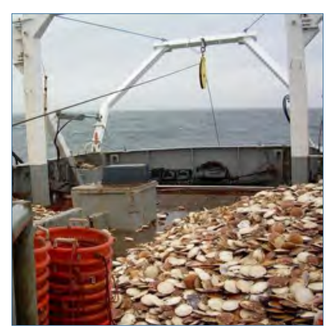
Table 4: Some key economic statistics for the marine economic sector in the Gulf of Maine.

NOVA SCOTIA	Major marine sectors:	Military defense, offshore oil & gas, fishing
	Percentage of GDP:	15.5%
	Percentage of household income:	10.2%
	Employment:	>30,000 direct full-time jobs
	Annual output:	C$2.6 billion
NEW BRUNSWICK	Major marine sectors:	Fish processing, ship/boat building, transportation & ports
	Percentage of GDP:	4.3%
	Percentage of household income:	4.1%
	Total direct impact (1995–97):	C$610 million
MAINE	Major marine sectors:	Tourism/recreation, ship/boat building
	Employment:	45,685
	Annual wages:	$1.2 billion
NEW HAMPSHIRE	Major marine sectors:	Tourism/recreation, transportation
	Employment:	14,005
MASSACHUSETTS	Major marine sectors:	Commercial seafood, transportation, tourism/ recreation, science/technology, construction/ infrastructure
	Estimated total marine payroll:	$4.3 billion
	Annual output:	$14 billion

Data were compiled from different sources that varied in their methods and the years analyzed.

Sources: Gardner et al. 2009; Mandale et al. 2000; Colgan 2004; University of Massachusetts/Donahue Institute 2006.

schooners that plied its waters, and the resulting maritime culture that developed on its shores, the Gulf of Maine has inherited one of the greatest maritime histories. Multiple factors, however, have led to reduced commercial fishing in this region over the past 20 years including stock depletion and changes in fishing regulation.



All of these factors are changing the face and nature of fishing communities within the Gulf of Maine. Ground fish stocks in the Gulf of Maine have become severely depleted (although several fish stocks are recovering and their status is improving, e.g., monkfish and haddock) and traditional maritime-oriented ways of life are in decline, changing the structure of many coastal communities. In particular, established fishing communities are forced to adapt to new social, economic, and environmental conditions in part because of a lack of marine resources from over-fishing and increased fishery management regulations. These communities are also being supplemented with new technology-based industries and tourism and gentrification are factors in some communities (e.g., Chatham, Marblehead and Scituate, MA and Vinalhaven, ME). Many processors and fish

FISHING COMMUNITIES FAST FACTS

- Gloucester, MA has been a fishing community continuously since its founding in 1623.
- Boston's Fish Pier, which opened in 1914, is the oldest continuously operating fish pier in the US.
- The "Man at the Wheel" statue of the Gloucester Fishermen's Memorial is one of the most famous fishing monuments in the US.
- Marblehead, MA is known as the "Yachting Capital of America."
- There are a number of active fishermen's and fishermen's wives associations in the region. One of the oldest (founded in 1954) and largest (1,200 members in 2006) is the Maine Lobstermen's Association.
- A large number of the region's fishing communities host seafood festivals and fishing related festivals such as blessings of the fleet in the warmer months including the communities of Gloucester, Provincetown, Scituate (MA); Hampton, Seabrook and Portsmouth (NH); Winter Harbour, Bar Harbor, Portland and Rockland (ME).
- The Fishermen's Memorial (1867-1967) in Digby, NS is dedicated to fisherman who lost their lives at sea.
- Digby County is also known as the "Scallop Capital" of the World. Each year in August, in observation of Digby's historic dependence on the sea, it celebrates a festival fittingly known as "Scallop Days."

houses have ceased operating in the last decade and many rely on imported rather than local product. Fluctuations in fish stocks, resulting from natural and anthropogenic environmental changes, threaten the strength of the regions commercial fishing industry. In regions such as Downeast Maine, in which the average income from fishing is higher than the state average and the median household income is lower than it is in other parts of the state, the commercial fishing industry provides a vital source of income. Some of the most pressing economic variables for the industry include decreases in market demand, declines in seafood prices, and increased operating costs.

Economic Impact of Commercial Fishing

In 2007, the ex-vessel value of combined landings for the Gulf of Maine region was approximately $900 million (Table 5; Figure 5). Shellfish landings were dominated by lobster and sea scallop with approximately $600 million in dockside revenue from lobsters alone in 2007. Table 5 provides information on fish landings revenue for the four regions within the Gulf of Maine. The Scotia-Fundy region covers a large area that stretches along the entire Atlantic Coast of Nova Scotia and around the Bay of Fundy to southwest New Brunswick. Massachusetts landing calculations are based on the landings from the key fishing ports within the Gulf of Maine region which includes New Bedford, Gloucester, Boston and Provincetown.

Table 5: Total landings revenue per Gulf of Maine region (millions of US dollars). Nominal quotations based on market rates and yearly averages in terms of US dollars. Conversions from $C based on market rates and yearly exchange averages.

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Maine	225,185	217,011	265,208	269,086	241,380	290,312	287,047	367,094	391,906	361,847	348,336
New Hampshire	12,570	11,183	12,539	16,198	17,865	16,692	15,122	17,211	22,116	18,842	19,366
Massachusetts	147	143	178	216	220	234	237	274	359	360	347
Scotia/Fundy	359,306	360,145	416,769	454,222	490,535	496,957	576,654	536,291	583,304	566,005	535,700
Total	597,208	588,482	694,694	739,722	750,000	804,195	879,060	920,870	997,685	947,054	903,749

Sources: National Oceanic and Atmospheric Administration (NOAA) 2009; Fisheries and Oceans Canada (DFO) 2009.

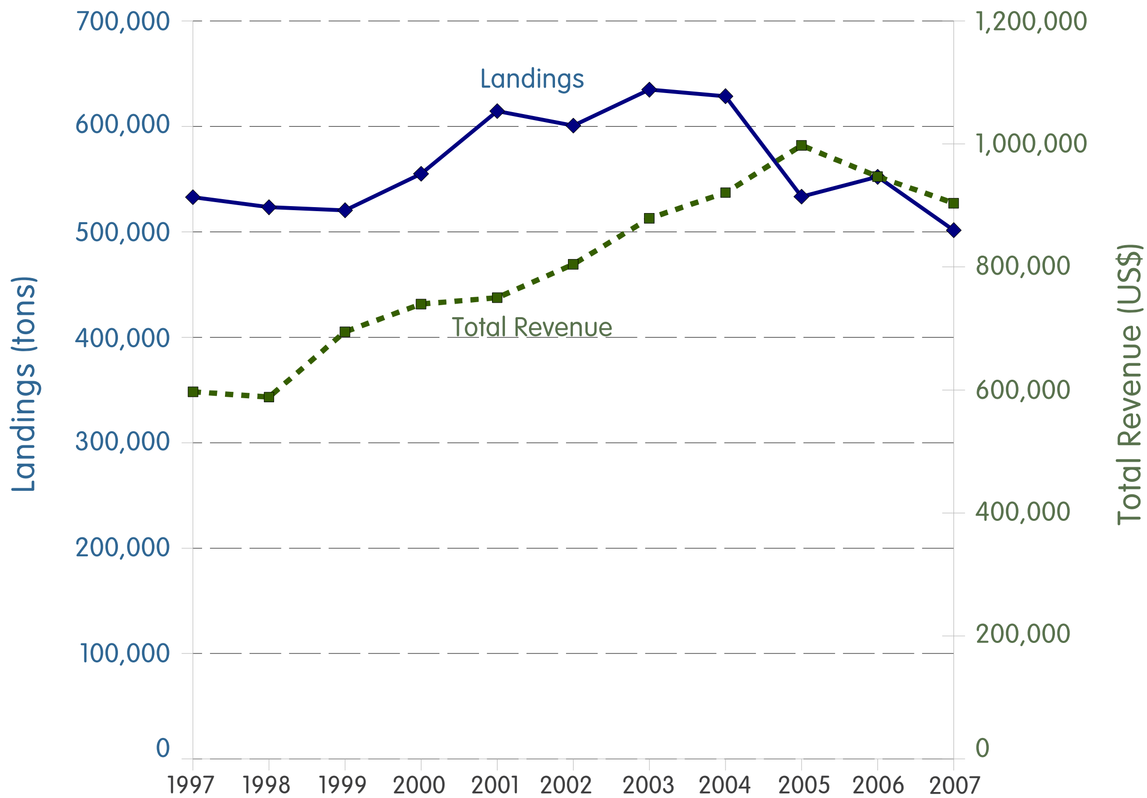


Figure 5: Fisheries landings, by revenue and weight (tons) 1997-2007.
Sources: NOAA 2009; DFO 2009.

Figure 5 shows fish landing by revenue and weight for all four regions combined. Over the period 1997-2007, total landings averaged 563 million tons, ranging from a high of 635 million tons in (2003) to a low of 502 million tons in 2007. Overall Massachusetts had the largest increase in landings (136%), with Gloucester and New Bedford having the highest landed value from commercial fishing among all ports in the entire US from 2000-2006. This was largely due to an increase in Atlantic mackerel landings. Shellfish landings for 2007 were 175 million tons.

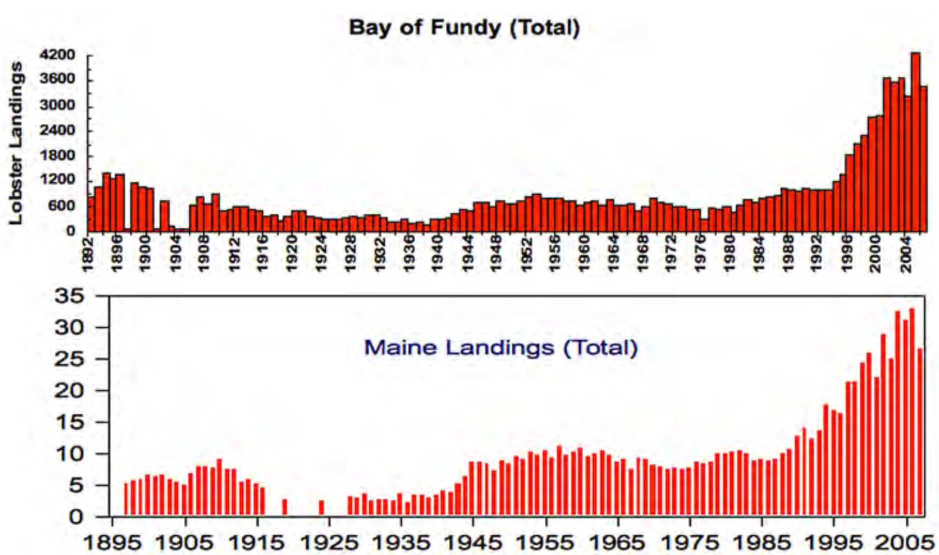
Overall, revenue increased 54% from 1997 to 2007, largely due to the increase in revenue from shellfish (76% in real terms). Revenues from finfish and other fishery products declined 9%. Massachusetts and New Hampshire experienced the largest growth in ex-vessel revenue during this period, increasing 136% and 57% respectively.

The ten key species represented on average 84% of the ex-vessel value in the Gulf of Maine, with American lobster accounting for 42% of total landings revenue. American lobster and sea scallops accounted for 71% of the average annual

Lobster Landings

Commercial lobster fishing began during the mid 1800s and annual lobster landings in the Gulf of Maine were first recorded in 1892 (Williamson 1992). Lobster landings in the State of Maine averaged 5,000 tons during the period 1897-1945 and 9,110 tons during 1946-1986. Over the following two decades, Maine lobster landings tripled. In the Bay of Fundy, landings remained relatively constant, averaging ~680 tons seasonally for the 40 years from 1946-1986. However, during the 1980s the wide-scale increase observed in Maine and over most of the range of lobsters in the western Atlantic was also observed in the Bay of Fundy. A recent peak in landings during the 2006-2007 Bay of Fundy seasons reached 3,997 tons. During the last five years, landings have levelled off at a historical high plateau, averaging 3,701 tons seasonally. Recent landings have been well above historic means.

While lobster landings have been increasing, other Gulf of Maine fisheries have been declining. The relative health of the lobster resource has allowed the industry to absorb an influx of harvesters displaced from other fisheries that have experienced declining stocks. Meanwhile, access to other fisheries in the region has become tightly controlled. It is believed that many fishermen who previously targeted lobsters only part-time or not at all are now exclusively dependent on the lobster resource. Many rural coastal towns now depend almost entirely on lobstering to support the local economy, which puts many coastal communities at risk. Any number of factors could reduce lobster landings: disease, overfishing, an oil spill or other man-made disaster, or environmental factors such as warming water temperatures.



Yearly lobster landings in tons for the Bay of Fundy and the State of Maine document the observed increase that occurred over much of the western Atlantic since the 1980s (Robichaud 2009).

revenue for all key species combined. Scallops in particular, have allowed the port of New Bedford to prosper in comparison to other Massachusetts ports. The largest annual increase during the period 1997-2007 was 764% for Atlantic mackerel (2001-2002). This species also had the largest annual decrease in revenue, declining 69% from 2004-2005.

Despite being a lower value species ($0.11 per pound in 2007), Atlantic herring contributes more to the harvest tonnage than any other species or group. The landings in 2007 contributed 162 million tons, approximately 32% of total landings for the region. The Scotia/Fundy region's contribution to the Atlantic herring harvest is the highest in the region, at 92,704 tons. Scallop landings from Georges Bank are currently at an historic high while those from the Gulf of Maine are among the lowest on record.

Coastal Tourism and Recreation

Tourism and recreation are an important aspect of the coastal economy in the Gulf of Maine region. Tourism offers communities both economic promise and environmental concern. In Maine, the tourism industry and its affiliated support services employ more than fishing, farming, forestry, and aquaculture combined. The region's fame as a coastal destination generated over $40 billion in tourism revenue in 2006 and created over 300,000 jobs. The term "coastal tourism and recreation" embraces the full range of tourism, leisure, and recreational activities that take place in the coastal zone and the offshore coastal waters. These include coastal tourism development (hotels, resorts, restaurants, food industry, vacation homes, second homes, etc.), and the infrastructure supporting tourism development (retail businesses, marinas, fishing tackle stores, dive shops, fishing piers, recreational boating harbours, beaches and recreational fishing facilities). Also included is ecotourism and recreational activities such as recreational boating, cruises, swimming, recreational fishing, snorkelling, and diving.

Of all the activities taking place in coastal zones and the near-shore coastal ocean within the Gulf of Maine, none is increasing in both volume and diversity more than coastal tourism and recreation. Virtually all coastal and ocean issue areas affect coastal tourism and recreation either directly or indirectly. Clean water, healthy coastal habitats, and a safe, secure, and enjoyable environment are clearly fundamental to successful coastal tourism. Similarly, healthy living marine resources (fish, shellfish, wetlands, coral reefs, etc.) are important to most recreational experiences. Security from risks associated with natural coastal hazards such as storms, hurricanes, flooding, and the like is a requisite for coastal tourism to be sustainable over the long term.

It is not within the scope of this document to address all aspects of tourism and recreation, but merely to provide an overview of general tourism by province/state (not only marine tourism) as well as some of the activities occurring in the region. It is important to note that different methodologies were used by the different jurisdictions and that comprehensive tourism data are not systematically compiled for the region. The figures below provide a good approximation of the economic impact of general tourism.

Table 6: An economic overview of tourism in the Gulf of Maine for 2006.

	NEW BRUNSWICK	NOVA SCOTIA	MAINE	NEW HAMPSHIRE	MASSACHUSETTS
Tourism Impact	C$ 1.2 billion	C$ 1.3 billion	$ 10 billion	$ 10.7 billion	$ 22.6 billion
% Contribution to GDP	3.2%	NA	20.3%	7.6%	NA
Employment	31,000	32,800	140,000	65,000	126,000

Sources: Maine Office of Tourism 2006; New Brunswick Parks and Tourism 2006; Massachusetts Office of Travel and Tourism 2007; New Hampshire Tourism 2007; Tourism Industry Association of Nova Scotia 2009.

Maine. Branded as 'Vacationland', tourism has become the most important industry in Maine. Visitors to Maine in 2006, directly and indirectly generated $10 billion in sales, employed 139,700 people, and contributed 20.3% to the state GDP (Maine Office of Tourism 2006), exceeding the combined contributions of agriculture, marine fisheries and aquaculture (Vail 2003). Currently, three of the most popular reasons people visit Maine are to visit a small town, the beach, or the ocean; to eat lobster and other local foods; and to shop for gifts and souvenirs (Longwoods International 2004).

New Hampshire. In 2006, spending in New Hampshire by travelers and tourists increased by 5.8%, with direct spending over $4.19 billion. The total impact on the state's economy (direct, indirect and induced impacts) of traveler spending was over $10.7 billion and contributed 7.6% of state GDP (The Institute for New Hampshire Studies 2006).

Massachusetts. Total domestic and international traveler spending in Massachusetts, including direct and indirect spending, was nearly $22.6 billion in 2006, up 8.9% from 2005. Suffolk County, which includes the city of Boston, received close to $6.0 billion in domestic travel expenditures to lead all Massachusetts counties during 2006. Travel expenditures directly generated 125,800 jobs within Massachusetts in 2006, up 0.5% from 2005. Travel-generated jobs in Massachusetts comprised 3.9% of the total non-farm employment in the state during 2006 (Massvacation 2009).

New Brunswick. The Government of New Brunswick, Department of Tourism and Parks, estimated that in 2006, the province received 1.74 million visitors who spent C$1.2 billion. The New Brunswick tourism industry also employed 31,000 people full-time and in seasonal positions (New Brunswick Parks and Tourism 2006).

Nova Scotia. In 'Canada's Ocean Playground', tourism contributed C$1.31 billion in 2006 to the province's economy. Tourism revenues increased 1% from 2005 generating 510.5 million in tax dollars and 32,800 direct and indirect jobs (Tourism Industry Association of Nova Scotia 2009).

Coastal Activities

Whale Watching. The Gulf of Maine region supports a very active whale watching industry. Approximately 1.5 million people took part in whale watching cruises throughout the region in 2007, generating approximately $30 million in direct ticket revenue, with another $30 million in indirect expenditures. The season generally begins in April, peaks in August and ends in October. Whale-watching companies are based in many ports in the Gulf of Maine, ranging from Provincetown MA to Digby NS. Currently there are eight operators in New Brunswick (St Andrews, Grand Manan Island), seven in Nova Scotia (Digby, Brier Island); six in Maine (Bar Harbor), three in New Hampshire and fourteen in Massachusetts (Gloucester 4; Boston 5; Plymouth 1; Barnstable 1; Provincetown 4). In Nova Scotia and New Brunswick whale watching is concentrated in the Bay of Fundy. In addition to the commercial boats, a large fleet of smaller private craft, dubbed by operators "the mosquito fleet," follow commercial whale-watching boats, or otherwise seek out whales independently.

Birding. Sustainable tourism niche markets, such as birding, have been increasing in the region over the last few years. Several birding festivals take place each year like the Down East Spring Birding Festival, headquartered in Whiting, ME, and the Warblers and Wildflowers Festival in Bar Harbor, ME. There are also several state and federal wildlife preserves. Acadia National Park, the Grand Lake Stream area, Northeastern Coastal Maine, the waters around Machias Seal Island (Puffin Breeding Colony) as well as Cape Sable Island, NS, have all been recognised as Globally Important Bird Areas by the American Bird Conservancy.

Recreational Fishing. Recreational salt-water fishing directly contributes over $1 billion to the Gulf of Maine economy, and involves as many as 1.9 million residents and visitors. Anglers took approximately 6 million recreational trips in 2006 in one of three fishing modes: party/

SUSTAINABLE TOURISM

With tourism generating such large revenues, employment numbers, and visitor statistics, it is important that the tourism industry preserves and improves the natural and cultural resources that draw people to the Gulf of Maine region. The Gulf of Maine Council's 2001-2006 Action Plan sets out a goal of developing "a nature-based tourism strategy that sustains the environment and the wellbeing of local people" and several studies and proposals have pointed to the need for university based extension in the area of sustainable tourism development.

The University of Maine has heeded this call by creating a new Center for Tourism Research and Outreach and the state recently unveiled its new nature-based tourism initiative. The premise of many of these proposals is that, if carefully planned and managed, tourism can contribute to the economic development of the regions rural and urban areas. State agencies and the University of Maine co-sponsored a Symposium on Nature-based Tourism in April 2002. In 2003, the Governor's Conference on Tourism highlighted sustainability challenges and the synergies between agriculture and tourism. The Bureau of Parks and Lands and the Maine Island Trail Association are framing a ten-year management plan for public islands. The Downeast Resource and Conservation District's Vacationland Resources Committee is one of eight regional bodies working on a sustainable tourism strategy. The Maine Tourism Commission has created a Natural Resources Committee to investigate problems and opportunities in managing Maine's natural attractions. Operators and stakeholders in the Nova Scotia tourism industry created the Nova Scotia Strategy for Sustainable Coastal Tourism Development in 2007 and released a comprehensive inventory of success stories on Nova Scotia sustainable tourism.

Natural resources will continue to be the region's primary tourism draw. Research indicates that the 140 million Americans interested in nature tourism and/or historical/cultural travel spend twice the average amount tourists typically spend (Fermata 2005). It is this class of visitor who most appreciates and will pay extra for sustainable tourism.

charter fishing boat; privately owned or rented fishing boat, or from shore. More fishing trips were taken in Massachusetts than in any other state or province with 1.26 million registered anglers in 2006 (Massachusetts Division of Marine Fisheries 2009). The second highest number of anglers was from Maine, with 489,000 followed by New Hampshire (187,000), New Brunswick (60,524) and Nova Scotia (50,807). The key recreational species are striped bass, Atlantic mackerel, bluefish, scup, summer flounder, Atlantic cod, tautog, winter flounder, little tunny and bluefin tuna.

Marinas and Boating. In 2007 there were 358,575 recreational motor boats registered in the US (Massachusetts, Maine, New Hampshire) including sail boats, canoes, kayaks and rowboats (US Coast Guard 2007). Massachusetts had the highest number of motor boats registered in 2007 with 145,496, down from 148,640 in 2006. This information is not readily available in New Brunswick and Nova Scotia. One aspect of recreational boat ownership that is of major economic importance in the region is the marine industry associated with recreational boating. These enterprises include: boatyards, boat manufacturing and sales, boat trade shows, boat transportation, canvas makers, charters and excursions, dock management, harbourmasters, manufacturer representatives, marine surveyors, and yacht brokers.

Ports and Shipping

The marine transportation sector is a large component of the Gulf of Maine coastal economy. It is made up of predominantly cargo vessels that make use of the large ports at Portland ME, Boston MA Portsmouth NH, and Saint John NB. This sector also includes cruise ships, ferries and support services including marine towing, ship chartering, cargo handling, harbour and port operations, pilotage and shipping agencies.

About 80 million tons of maritime cargo move through the main ports in the Gulf of Maine each year Table 7). More than 80% of this is oil and petroleum prod-

Table 7: Cargo tonnage handled (volumes in millions of tons).

	2003	2004	2005	2006	2007
Boston, MA	24,832	25,796	25,796	21,852	22,370
Portland, ME	29,160	29,709	29,709	25,242	24,253
Saint John, NB	26,090	26,300	26,300	24,870	27,030
Portsmouth, NH	4,971	4,794	4,794	4,823	4,026
Searsport, ME	1,264	1,832	1,832	2,039	1,782
Total	86,317	88,431	86,420	78,826	79,461

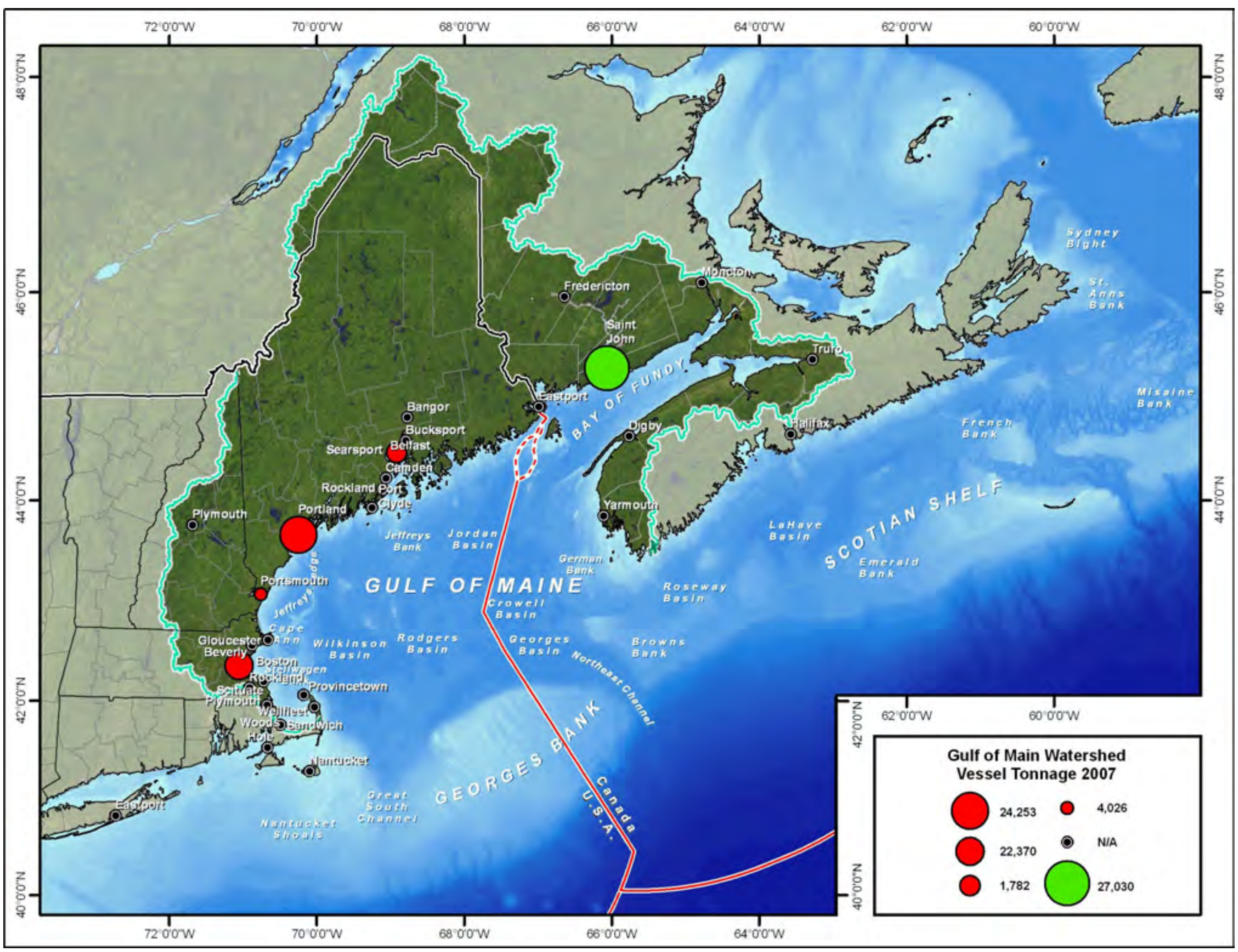
Sources: US Army Corps of Engineers 2009; St John Port Authority 2009.

ucts. This cargo is associated with some 2,000 port calls by self-propelled vessels (mostly foreign flag) and 1,500 barges (mostly domestic) per year and represents about 4% of total US oceangoing cargoes (US Army Corps of Engineers 2009).

The largest port, based on cargo tonnage in the Gulf of Maine region, is the Port of Portland ME, with an average of 27.5 million tons for the past five years (see Figure 6). It also ranked as: the largest foreign inbound tonnage transit port in the US; the largest tonnage port in New England; the 25th largest port in the United States, and the largest oil port on the US East Coast. Ships destined for the Portland-Montreal Pipe Line, a crude oil pipeline that stretches from South Portland to Montreal, was a major contributing factor in these rankings.

The second largest US port in the region is Boston, MA with an average of 23.4 million metric tons and 478 vessels making use of the port in 2007. The Port of Boston handles more than 1.3 million tons of general cargo, 1.5 million tons of

Figure 6: Cargo ports in the Gulf of Maine. Sources: US Army Corps of Engineers/Navigation Data Center 2007; St John Port Authority 2009.



non-fuels bulk cargo and 12.8 million tons of bulk fuel cargo yearly (Massachusetts Port Authority 2009). The Port of Saint John, is the largest seaport in New Brunswick and the largest Canadian port in the Gulf of Maine region. The port handles 26.3 million metric tonnes of cargo per year (St John Port Authority 2009).

Cruise Ships

Cruise ships provide a large economic impact to many of the coastal communities within the Gulf of Maine. Cruising Maine has long been a popular summer and autumn vacation option for passengers on scenic port of call stops from Boston, MA, to Bar Harbor, ME, and then onto Nova Scotia and New Brunswick in Canada. Spending by cruise ship passengers and crew provide a stimulus to the economies of ports of embarkation (i.e., where cruises originate, for example Boston) and ports of call (i.e., where ships visit, for example Bar Harbor, ME). Cruise ships and their passengers had a $500 million impact on the region's economy during 2008. Cruise industry spending generated approximately 7,500 jobs and over $400 million in wages and salaries (Cruise Lines International 2007).

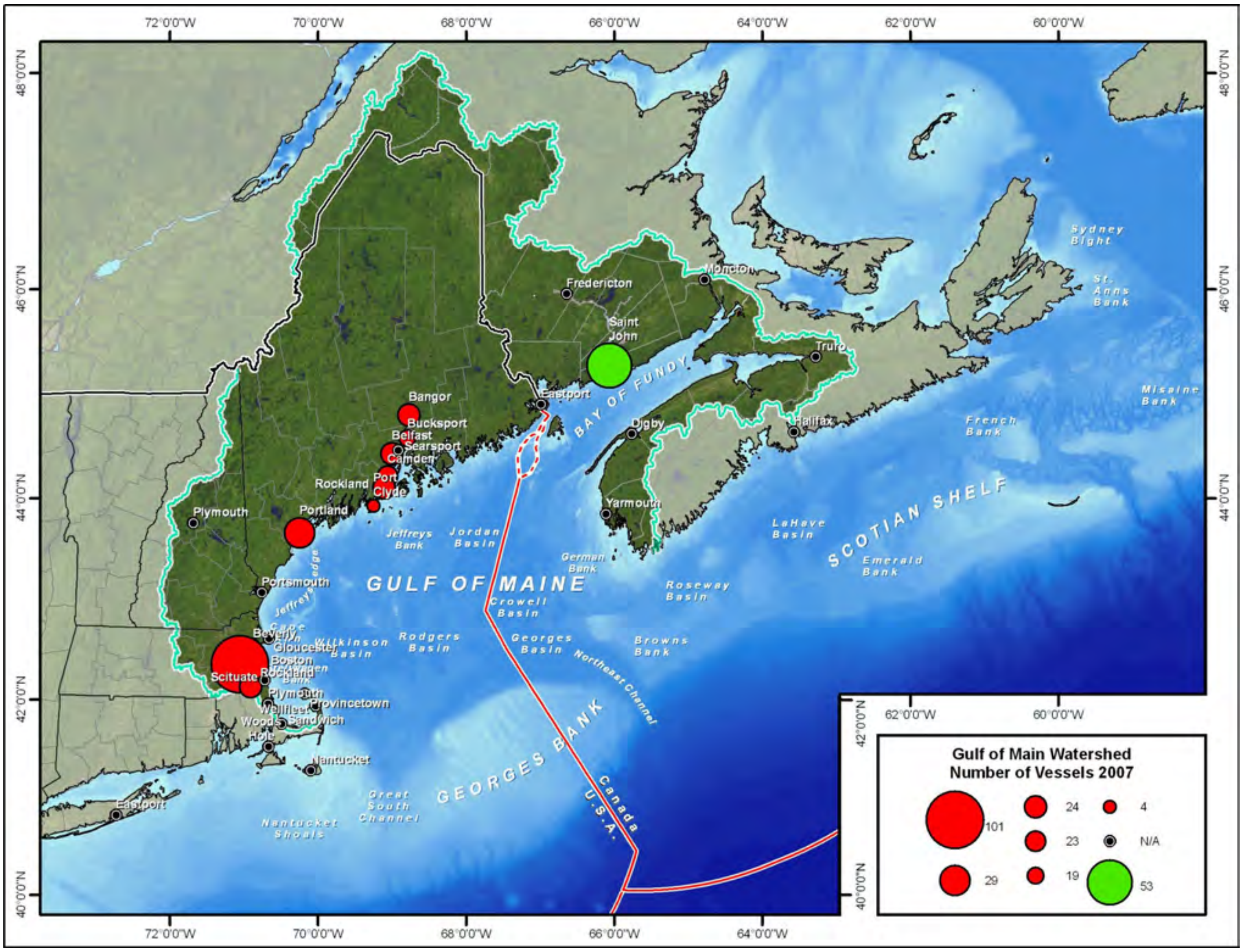
In 2008, the Port of Boston set a record with the most scheduled cruise ships ever to visit Cruiseport, Boston. There were 113 ship calls, an increase of 12% over 2007, and passenger counts were up by 15%, setting a new record of 270,000 (Massachusetts Port Authority 2009; Table 8). In 2007, the industry contributed $407 million to the Massachusetts economy, a 5% increase over 2006 (Cruise Lines International Association 2007). In 2008, Massachusetts accounted for more than $434 million in cruise industry direct spending, a 6.5% increase over

Table 8: Number of cruise ship vessels docking in Gulf of Maine ports.

PORT	2003	2004	2005	2006	2007	2008
St John, NB	38	60	35	39	53	80
Boston, MA	NA	NA	NA	NA	101	113
Portland, ME	23	30	29	27	29	31
Bangor, ME	7	9	9	15	24	18
Bar Harbor, ME	78	87	76	73	91	97
Belfast, ME	8	9	15	20	24	26
Bucksport, ME	8	9	11	17	19	18
Camden, ME	10	10	10	4	23	24
Port Clyde, ME	0	0	4	5	4	4
Rockland, ME	8	11	15	19	24	26

Sources: St John's Port Authority 2009; Maine Port Authority 2009; Massachusetts Port Authority 2009.

Figure 7: Cruise ship ports and number of vessels docking in the Gulf of Maine in 2008.
Sources: US Army Corps of Engineers/Navigation Data Center 2007; St John Port Authority 2009.



2007. The state ranks eleventh nationally for economic impact from the cruise industry in North America.

In 2008, Maine accounted for more than $29 million in cruise industry direct spending, a 20% increase over 2007 (Maine Port Authority 2009). Maine cruise ship traffic is heaviest in Bar Harbor ME, which experienced 91 ship calls in 2007 and 97 in 2008 (see Table 8 and Figure 7), carrying more than 200,000 passengers. Given its rural charm and close proximity to the Acadia National Park, it has emerged as one of the most popular ports of call along the Maine coast. The port of Portland has seen the most growth in cruise ship passengers. The city hosted an estimated 47,841 cruise ship passengers in 2008, a 45% increase above passengers who visited in 2003 (Gabe and McConnon 2009). Bangor, Belfast, Boothbay Harbor, Bucksport, Camden, and Rockland received a total of 144 ships calls combined.

Ferry Services

Ferry services run between Saint John, NB, and Digby, NS, using the vessel *M/V Princess of Acadia*. Passenger traffic on the Digby–Saint John service has been in steady decline, decreasing by 21% from 180,000 passengers in 2000 to 140,000 passengers in 2005. Tourism traffic entering at Digby dropped by 27%, from 41,700 person-trips in 2000 to 30,500 person-trips in 2005. In August 2009, federal and provincial authorities approved over C$15 million in subsidies to rescue the year-round ferry service.

The ferry services across the Gulf of Maine from Yarmouth, NS, to Bar Harbor, ME, and from Yarmouth, NS, to Portland, ME, using a high-speed catamaran ferry service under the marketing name "The Cat" was discontinued in 2010.

Casco Bay Lines provides a year-round ferry service, carrying passengers, vehicles and freight between Portland and Peaks Island, Little Diamond Island, Great Diamond Island, Long Island, Chebeague Island, and Cliff Island. The Maine State Ferry Service services a number of island communities, primarily in the Penobscot Bay region. Continuing the area's maritime tradition, the Quoddy Loop's centre is connected by a series of ferries (all Canadian operations). These vessels transport travellers and vehicles among the five principal islands (Campobello Island, Deer Island, Grand Manan Island, White Head Island, and Moose Island and the mainland of New Brunswick.

MAINE MARINE VESSEL EMISSIONS

Although international shipping only produces about 7% of the world's nitrogen oxide (NO) emissions, the impact of these pollutants on local air quality can be significant. Produced primarily by the burning of fossil fuels, NO and volatile organic compounds (VOCs) react in sunlight and stagnant air to form ground-level ozone, one of the primary components of smog. NO and VOCs are not the only air pollutants released from the smokestacks of ocean-going vessels. Particulate matter (PM), sulphur dioxide (SO_2), carbon dioxide (CO_2) and carbon monoxide (CO) also make up part of the blend. In an effort to reduce airborne pollution from ships, the International Maritime Organization (IMO) has negotiated NO standards for marine vessels and is seeking similar controls for particulate matter. The NO standards are currently pending acceptance by all members of the IMO, including Canada and the US.

The Maine coastline (3,480 miles) has six cargo ports and 12 cruise ship ports. While freight traffic has remained steady or decreased slightly at many of Maine's ports, it has more than doubled over the last decade at the state's largest port, Portland Harbor. Commercial marine vessels (cargo ships entering and leaving Maine ports) contribute approximately 166 tons of VOC's, 1134 tons of NO, 374 tons of CO, 124 tons of SO_2 and 91 tons of particulate matter (PM10) per year.

The commercial marine emissions inventory only takes into account cargo ships entering and leaving Maine ports. At this point, Maine Department of Environmental Protection's inventory resources do not allow for a more detailed marine vessel emissions inventory, one that would also include the fishing fleet, ferries, cruise ships and tug boats, and assess land-side port emissions such as cargo-handling equipment and trucks. In addition, a single engine on a cruise or cargo ship is large enough that, if it were based on land, would be considered a major source and require mandatory emission controls (Maine Department of Environmental Protection 2005).

Energy

From tidal power turbines in Nova Scotia and New Brunswick to proposed offshore wind farms from Maine to Massachusetts, the energy-producing possibilities from the Gulf of Maine have become the focus of state and provincial interest. Three forms of energy have been highlighted in recent years within the Gulf of Maine area. Two of these forms, tidal and wind are renewable and there is great interest in further development. A third, liquefied natural gas, is a traditional use that has the potential for considerable expansion.

Liquified Natural Gas (LNG)

LNG is the liquid form of natural gas, a clear, colourless, non-toxic, liquid composed mainly of methane with small quantities of ethane, propane, and heavier hydrocarbons. Taken out of the ground as natural gas, it is turned into a liquid by being chilled to -162 °C and can be kept at normal atmospheric pressures in specially designed tanks that work on principles similar to a thermos container.

Natural gas is contributing an ever larger share of the energy mix to Gulf of Maine communities for heating homes and generating electricity. There are currently two LNG terminal facilities operating in the region and three have been proposed in the Passamaquoddy Bay area.

Irving Oil and Repsol YPF, SA, an integrated international energy company based in Spain, received approval from the Canadian government in 2006 to jointly construct a terminal in Saint John. Canaport LNG will eventually have a send-out capacity of 30-million cubic metres (one billion cubic feet) of regasified natural gas per day (Canaport 2009). The C$1-billion terminal is the first to be built on the East Coast of North America in 30 years. The first phase of the terminal is operational, and is estimated it will attract double-hull tankers varying in size from 70,000 to 140,000 m3 and vessel traffic into the port will increase by approximately 100 vessels per year (Williams 2007).

Distrigas of Massachusetts LLC owns and operates the only other LNG import and regasification facility in the region, located along the Mystic River in Everett MA (the Everett Marine Terminal). This terminal has been operating longer than any other LNG import terminal in the United States. Between 1971 and 2003, it received approximately half of the LNG imported into the United States. Currently, the Everett Marine Terminal meets approximately 20% of New England's annual gas demand. Also in MA, the Northeast Gateway LNG project is operational and the Neptune LNG project has been constructed and will have received shipments by the time this document is published.

Washington DC-based Downeast LNG plans to develop a terminal in Robbinston, ME. Robbinston residents voted 227 to 83 in favour of the project (Downeast LNG 2009). The proposed terminal is currently going through environmental assessments and anticipates approvals to be secured soon and construction to be completed by 2010.

Ecological preservation and international management organizations charged with protecting the St Croix River and adjacent water bodies will be following the development of both Downeast's and Quoddy LNG projects. The area contains several conservation areas and historical sites that cross US and Canadian borders, including the National Park Service and Parks Canada's St Croix Island International Historical Site.

Elsewhere in the Gulf of Maine, other energy companies are vying for approval to build terminals, for example: Excelerate Energy plans to develop a facility near Gloucester, MA. Algonquin Gas Transmission LLC, a unit of Duke Energy, filed an application with The Federal Regulation and Oversight of Energy to build a 16 mile pipeline that would connect the terminal to Algonquin's existing pipeline system.

Wind Energy

The Gulf of Maine is estimated to be able to generate 149 GW of energy per year, or about 40 nuclear power plants' worth and is equivalent to approximately 10% of the US energy needs for a year (Dagher 2008; see Elston and Landon 2009).

Maine. In response to the Obama administration setting a national goal of 20% wind energy by the year 2030, Governor Baldacci of Maine established the Ocean Energy Task Force in November 2008. The primary mission of the Task Force was to recommend strategies to meet or exceed the goals established in the Maine Wind Energy Act, to install at least 2,000 MW of wind capacity by 2015 and at least 3,000 MW by 2020, 300 MW of which could be located in coastal waters. The state selected five test sites for offshore, deep-water wind turbines in December, 2009. Currently the state has several wind farms on land, installed or in the construction stages, including Mars Hill (28 turbines generating 42 MW of electricity), Kibby Mountain (44 turbines potentially generating 130 MW) and Stetson Ridge (potentially generating 57 MW). The University of Maine is receiving federal funds for construction of a new offshore wind energy research and testing facility with capabilities for designing, prototyping, and testing components for industry.

Nova Scotia. There are currently 41 land based wind turbines in Nova Scotia, with an installed capacity of 60 MW. In May 2008, The Nova Scotia Wind Integration Study reported on the potential impacts of integrating wind power projects to the province's electric grid in two phases: by 2010 and by 2013. The Nova Scotia Department of Energy set those ambitious time-frames in 2007 when it announced the renewable energy standard. That standard requires that 20% of the provinces electricity be generated through renewable energy by 2013. Wind energy currently accounts for around 1% of electricity produced in Nova Scotia.

New Brunswick. The province of New Brunswick has committed to increasing its generation capacity from renewable resources and as such has required, under the Electricity from Renewable Resources regulation, that NB Power purchase 10% of its sales from new renewable sources by 2016. The provincial government has accelerated this time frame by asking NB Power to move immediately with the addition of an extra 300 MW of wind power in New Brunswick, which would bring the wind power generation capacity to over 400 MW once all projects are completed. There are currently no marine wind farms.

Massachusetts. Energy Management Inc., a Boston-based company, announced its plans in 2001 to construct a wind farm called Cape Wind comprised of 130 turbines located between four and 11 miles off the Cape Cod coast in federal waters. The towers will be 78.6 metres from the water surface to the center of the blades. The blades will reach 146.6 metres above the water. The company says the proposed wind farm would produce an average of 170 MW of electricity. The power would be transported through 12.8 kilometres of transmission cable coming ashore at West Yarmouth, MA. The Cape Wind project was approved by the US Department of the Interior in 2010.

Tidal Power

During the past two decades, tidal energy devices have advanced considerably in design and efficiency. The technology of the moment uses tidal stream generators (in-stream turbines), which do not require damming of rivers or inlets. The moving tide rotates a series of blades, which then spin a generator to produce electricity. Tidal turbines can be arrayed underwater in rows, similar to turbines in a terrestrial wind farm. The key requirement, however, is a strong coastal current running at least four knots.

Maine, New Brunswick, and Nova Scotia all border the Bay of Fundy, through which more than 115 billion tons of water flows each day. The Bay of Fundy tidal range can reach 15.2 m at its eastern edge since the bay is generally U-shaped and tapers significantly near its northern terminus. The incoming tide gains greater strength at it moves inward, resulting in a renowned tidal bore found in the Minas Basin. This is viewed as a perfect source of clean, reusable, alternative energy.

Nova Scotia. The province has committed to draw nearly 20% of its electricity supply from renewable sources by 2013. In 1984, Nova Scotia opened a small plant that took

THE OCEAN ENERGY INSTITUTE

The Ocean Energy Institute, founded by Matthew Simmons, is advocating developing wind power in the Gulf of Maine. Simmons and his partner, physicist George Hart, are proposing a 5 GW wind farm, with five 64 nmi² (220 km²) sections, each containing 200 5-MW turbines. That would generate sufficient power in winter to replace the state of Maine's consumption of home heating oil. According to Simmons, a proponent of peak oil, "If we don't do this, we're going to have to evacuate most of Maine."

As proposed, the turbines would be built on floating platforms, anchored in waters 100–200 m deep - something that has never been done in the US. It will take several years to test the feasibility of such buoyed turbines. (The Hywind wind turbine became the world's first operating large-capacity (2.3 MW) floating wind turbine in the summer of 2009, operating in the North Sea off Norway.) Angus King, a former governor of Maine, is supportive of the idea, "I see this as a huge economic development opportunity for Maine. This thing could create 20,000 to 30,000 jobs." However, others have challenged the project's projected cost, which could reach $25 billion.

advantage of the massive Fundy tide, building a barrage that funnels the surge through turbines to generate power. This Annapolis plant continues to produce about 20 MW a day, enough to power about 4,000 homes. In 2008, Clean Current, Nova Scotia Power and Minas Basin Power and Pulp Company began working jointly on a project to demonstrate tidal devices in the Bay of Fundy. Funds for the project come from a C$4.7 million grant from the Nova Scotian Ecotrust for Clean Air and Climate Change program, a C$3 million loan from EnCana Corporation's Environmental Innovation Fund and contributions from each of the successful developers. Nova Scotia's Department of the Environment is also providing C$300,000 for environmental and permitting work.

Nova Scotia Power Inc., the first of three companies to test their power-generating turbine, deployed the 10 m turbine in the Minas Passage of the Bay of Fundy in the fall of 2009. Testing will last up to two years and operational data will be collected and shared by Nova Scotia Power to determine the environmental performance and future feasibility of tidal power in the Bay of Fundy. The testing will focus on the robustness of the turbine in the harsh environment of the Bay of Fundy, close monitoring of any environmental impacts of the turbine, and the energy production capabilities of the technology.

Minas Pulp and Power Company Ltd., who are also the builders of the facility that will connect the turbines to the electricity grid, and another company, Clean Current, will be testing their turbines in 2010.

New Brunswick. In May of 2008, New Brunswick offered leases on eleven submerged land sites in the Bay of Fundy to businesses and organizations that would conduct up to two years of research on the sites' tidal energy potential. The leases included Head Harbour Passage and Western Passage in Passamaquoddy Bay, an area near Chignecto Bay and one off Cape Spencer near Saint John. Irving Oil, in partnership with the Huntsman Marine Science Center, won the rights to the sites. Currently the public-private partnership is testing the strength of the daily tidal currents through an array of floating sampling devices.

Maine and New Hampshire. Several private companies have announced their intentions to locate tidal turbines in Maine and New Hampshire tidal waters. Maine Tidal Energy Company, a subsidiary of Oceana Energy of Washington DC, received a preliminary permit from FERC in 2007 to study developing a tidal power project in the Kennebec River just north of Bath.

The New Hampshire Tidal Energy Company, also owned by Oceana Energy, received its preliminary permit from FERC in 2007 to study the potential for tidal power in the Piscataqua River, shared by Maine and New Hampshire. A rival company, the Underwater Electric Kite Corporation, plans to do the same. Each company predicts that their respective turbines placed appropriately in the Piscataqua River could generate between 40 to 100 MW of power.

Ocean Renewable Power Company, a Miami, Florida firm, worked with students from the Washington County (Maine) Community College Marine Technology Center, and created a turbine generator unit that hangs 300 feet down into the water column from a stationary barge. The $1.2 million device, which can generate 32 KW in a 6-knot tidal current, was completed and installed in December, 2007. It began producing limited electrical power in 2008 and the company predicts the turbines eventually will send 250 KW into the local power grid.

Aquaculture

Aquaculture continues to be the fastest growing sector of the world's fishery. The Food and Agriculture Organization of the United Nations, reports that global marine-based aquaculture production now represents almost 50% of world fisheries production (FAO 2006). Aquaculture production in Canada and the US has dramatically increased in conjunction with global production. Total US aquaculture production is about $1 billion annually, relatively small when compared to world aquaculture production of about $70 billion. About 20% of US aquaculture production is marine species. The largest single sector of the US marine aquaculture industry is molluscan shellfish culture (oysters, clams, mussels), which accounts for about two-thirds of total US marine aquaculture production, followed by salmon (about 25%) and shrimp (about 10%) (NOAA 2009). In Canada, the industry is dominated by the production of finfish, primarily salmon off the coasts of British Columbia and New Brunswick. Gross output by aquaculture producers in Canada for 2007 was approximately 170 thousand metric tonnes valued at C$845.4 million (DFO 2009).

Aquaculture as has been practiced in the Gulf of Maine region for over a century including both finfish and shellfish culture (Brennan 1991). Marine aquaculture as an industry however, is relatively new and dates to the early 1970s. Within the Gulf of Maine, aquaculture was worth $454.9 million in 2007 up from $72.3 million in 1990. These figures do not include New Hampshire, which has had only minimal marine-based aquaculture production. New Brunswick's had the greatest production in the region in 2007 at 48.7 metric tons and a value of C$295.9 million (NB Fisheries and Aquaculture 2007). This was followed by Maine (13.5 million metric tons; $100 million; Maine DMR 2009), Nova Scotia (10.1 million tons; C$53 million; Government of Nova Scotia 2009), and Massachusetts ($6.2 million).

New Brunswick. Since its initiation in the early 1940s for oysters and late 1970s for Atlantic salmon and mussels, aquaculture in New Brunswick has grown dramatically. In 2008 there were two shellfish aquaculture sites (blue mussels, scallop, soft shell clam) and 96 finfish sites. The total aquaculture development area is 1,780.8 ha (0.025% of the Bay of Fundy). Atlantic salmon is still the dominant species raised, accounting for approximately 89% in terms of volume of annual production in 2007, followed by oysters (8.9%) and mussels (1.3%). New Brunswick also has an interest in continuing to develop Atlantic halibut, Atlantic cod, Atlantic and shortnose sturgeon, bay scallop, the giant scallop, and kelp.

Nova Scotia. Oysters were cultivated in Nova Scotia more than 100 years ago and the first attempt to rear Atlantic salmon as a commercial product in a land-based saltwater facility took place here in the late 1960s (Brennan 1991). In 2007 the industry generated 10.1 million metric tons, worth C$53 million. The principal species raised in Nova Scotia are salmon and rainbow trout, which account for 67.6% in volume followed by blue mussels and American oysters. There are currently 351 licensed sites in the province and in 2007 the industry employed 741 people. In October 2009, Fisheries and Aquaculture Minister, Sterling Belliveau, announced C$793,499 in funding for Nova Scotia aquaculture operators (44 are located within the Gulf of Maine) and projects to boost capabilities. The investment is part of C$2.5 million in aquaculture funding from the Community Development Trust Fund (NS Fisheries and Aquaculture 2009).

Maine. Aquaculture has been present within the coastal waters of Maine since the 1800s. In fact, laws governing fish and shellfish culture date back to 1905 (Chapter 88 of the Seventy-Second Legislature of the State of Maine). The leasing of Maine waters for the private culture of marine fish, shellfish and plants, however, has a much more recent history. Following the development of advanced pen-rearing techniques in New Brunswick, the first Atlantic salmon operation was established in Maine in 1982 (Brennan 1991). There are aquaculture sites located from Kittery to Eastport and as of August 2009, there were 77 shellfish leases (including experimental leases), totalling 667 acres, and 28 finfish leases, totalling 650 acres, located in marine and estuarine waters along the Maine coast. While Atlantic salmon is by far the dominant species produced, other species of importance include trout, mussels, oysters, and nori, a red algae used in sushi.

New Hampshire. The value of aquaculture in 2007 was approximately $334,000, with eight sites occupying 44.6 acres. The University of New Hampshire's Atlantic Marine Aquaculture Centre is experimenting with an offshore aquaculture site.

Massachusetts. The Massachusetts aquaculture industry within the Gulf of Maine region, generated approximately $4.5 million in 2007 (71% of the total state value). In 2007 there were 248 aquaculture sites (66% of the total number of sites in the state) and they were located on 489.5 acres (52.4% of total state acreage of aquaculture). 80% of aquaculture takes place on Cape Cod, with the South and North Shores experiencing the greatest increase since 2000. The reported (landing) value of aquaculture shellfish in Massachusetts is difficult to calculate. The Division of Marine Fisheries (DMF) and municipalities collects annual landing data from aquaculture producers as a part of their reporting requirements under Section 35 of Massachusetts General Law Chapter 130. Precise reporting to DMF is not required of aquaculturists and the information received and summarized by

DMF reflects only the producers who self-reported.

Industrial Development

Beginning in the late 1700s, the rivers, estuaries and marine waters of this area were used to transport logs, harvest fish and power sawmills. As the population of the region increased and other industries developed, they were used as waste dumps for a wide range of activities including logging operations, sawmills, fish processing plants, private septic systems, municipal sewage plants, pulp mills, agricultural drainage and more recently, aquaculture operations.

Growth in coastal populations around the Gulf of Maine, increased development, and changes in land use have all contributed towards increased contaminant levels in coastal waters in the region. A contaminant is defined as any foreign, undesirable physical, chemical, or biological substance into the environment (Environment Canada 1991) and could include anything from sawdust to nutrients, suspended solids, pesticides, and industrial chemicals. It has been estimated that 100-500 thousand chemicals are now in regular industrial use and most have the potential to enter the marine environment through a variety of sources (Parrett 1998).

Contaminants enter the Gulf of Maine from point sources such as wastewater treatment plants (WWTP) and industries and from non-point sources such as atmospheric deposition (power plants, incinerators and vehicle emissions) and storm water runoff from urban and agricultural areas. Oil refineries, pulp mills, port activities and manufacturing plants release a complex cocktail of heavy metals, chlorinated hydrocarbons, petroleum products and many other chemicals into the Gulf of Maine/Bay of Fundy waters.

FAST FACTS

- There are 2,024 active point source facilities in the region, 273 are major facilities.
- Major point source dischargers are wastewater treatment plants and paper mills.
- There are 378 wastewater treatment plants.
- There are 93 power plants.
- 40% of facilities are located in 2 watersheds in the US – Massachusetts Bay and Merrimack River.
- The Deer Island wasterwater treatment plant is the largest overall discharger in the Gulf of Maine.

TOP TEN POINT SOURCE DISCHARGERS IN THE GULF OF MAINE

Rank	State	Facility
1	MA	Deer Island WWTP
2	ME	Great Northern Paper, Inc.
3	MA	Greater Lawrence WWTP
4	ME	SAPPI Fine Paper North America
5	MA	South Essex WWTP
6	ME	Mead Oxford Paper
7	NH	Manchester WWTP
8	MA	Lowell WWTP
9	ME	Fraser Paper Limited
10	MA	Lynn Regional WWTP

Source: Hameedi et al. 2002

Generally, five major types of sediment contaminants are recognized. Directly or indirectly they cause a wide range of adverse biological effects in plants, animals, and people, through direct chemical toxicity, genotoxicity, physiological dysfunction, behavioural abnormalities and habitat disruption and destruction. Contaminants include:

- Bulk organics, including organic wastes from sewage treatment plants, oil and grease, other deoxygenating substances, and humic materials.

- Halogenated hydrocarbons or persistent organic contaminants, such as dichlorodiphenyltrichloroethanes (DDTs) and polychlorinated biophenyls (PCBs) that have accumulated in the environment long after discontinuation of their use.
- Polycyclic aromatic hydrocarbons (PAHs), contaminants associated with crude oil and distillate products, burning of fossil fuels, municipal and industrial effluents, and natural sources.
- Metals, such as copper, iron, zinc, lead and mercury, and metalloids such as arsenic and selenium.
- Nutrients, through unwanted algal growth, oxygen depletion in overlying waters, and altered food chains or species succession (Hameedi et al. 2002).

The major point source dischargers in the Gulf of Maine are wastewater treatment plants (WWTPs) and paper mills. Boston Harbor, for example, has consistently shown some of the highest levels of PAHs and PCBs in the region and Salem Harbor is generally very high in levels of pesticides such as hexachlorobenzene, heptachlor, chlordane and aldrin. The largest discharger of treated waster-water in the region is Deer Island WWTP complex in Boston MA. This facility discharges approximately 390 million gallons of secondary treated water per day to Massachusetts Bay through a 9.5 mile outfall tunnel. A number of other facilities discharge to Massachusetts Bay or to rivers such as the Merrimack, Penobscot, Androscoggin and Saint John which empty into the Gulf of Maine (Hameedi et al. 2002).

INDUSTRY IN THE BAY OF FUNDY

- Irving Pulp and Paper Mill
- Irving Oil Refinery
- Coleson Cove Generating Station.
- Coutney Bay Generating Station
- Point Lepreau Nuclear Facility
- Canaport Liquefied Natural Gas Terminal

The Gulf of Maine Council on the Marine Environment has identified sewage, nutrients and mercury as the three contaminant problems of the greatest concern for the Gulf of Maine region (Pesch and Wells 2004).

Sewage

Land based activities are recognized as a significant contributor to many of the environmental problems in the Gulf of Maine. Of these, management of sewage (or more accurately, the lack of management of sewage) has been identified as an area of concern. The impacts of sewage on the aquatic environment fall into three major categories: 1) bacteriological contamination, 2) nutrient loading, and 3) chemicals, such as endocrine disrupting substances, persistent organics, and metals. Three hundred and seventy eight facilities around the Gulf of Maine discharged approximately 305 billion gallons of wastewater treatment effluent into the Gulf. Nearly half of that volume (130 billion gallons) entered Boston Harbour from Massachusetts Water Resources Authority (Hinch 2002).

In New Brunswick, 60% are on communal sewage systems, while the remaining 40% have on-site systems. There are 130 municipal wastewater treatment facilities.

In the largest urban area, Saint John, only 58% of the population's sewage is treated; the remainder is discharged raw. Smaller communities including St Stephen, St George, Blacks Harbour, and Alma have systems in need of upgrading.

In Nova Scotia, Parrsboro and Amherst are discharging untreated sewage. In rural areas, people utilize on-site septic systems that, if inadequately maintained or poorly designed, also contribute to coastal contamination. The result is that as the density of coastal development increases, there is an increase of contamination in many bays and estuaries that impact shellfish growing areas and opportunities for recreation (Hinch 2002).

Seven hundred square kilometres of the Canadian portion of the Gulf of Maine are closed to shellfish harvesting due to bacteriological contamination. This includes some of the most productive shellfish areas in the region.

New Hampshire has a small Gulf of Maine coastline, however about two-thirds of the state is a watershed that drains into the Gulf of Maine. Discharges of untreated sewage from a straight pipe or municipal outfall are not permitted. All communities have secondary treatment except for Portsmouth, which has a waiver allowing a super primary treatment plant. Fifteen percent of the population is on municipal systems and most treatment plants are government owned. The largest city is Manchester, with just over 100,000 people has a 34 million gal/day treatment plant. There are about 110 small municipal treatment systems (Hinch 2002).

Massachusetts has about 60 major wastewater treatment facilities that are permitted for surface water discharges. Minor discharges are designated more on flow than on impact. Groundwater discharge permits are handled under state authority. Any discharge in excess of 15,000 gal/day requires a permit, whereas anything below 15,000 gal/day can be handled under State Sanitary Code Title 5 Septic System Regulations (Hinch 2002).

Nutrients

Nutrients are substances that organisms require from their environment because they cannot make the substances themselves. Nutrients can become pollutants when they are too abundant. Over-enrichment of water with nutrients, that otherwise limit plant growth, can cause too much plant growth and have deleterious effects on the environment. The nutrients of most

GULF OF MAINE CONTAMINANT MONITORING PROGRAMS

Gulf of Maine-wide programs

- Gulfwatch, Mercury Deposition Network
- Gulf of Maine Ocean Observing System

Canadian programs

- Canadian Shellfish Sanitation Program (CSSP)/Maritime SSP
- Atlantic Coastal Action Program
- Dredged Material Ocean Disposal Site
- Biotoxin Monitoring Program
- Moosehead Maritimes Beach Sweep and Litter Survey
- Toxic Chemicals in Canadian Seabirds

US programs

- National SSP/state SSPs, National Estuary Program
- National Estuarine Research Reserves-System Monitoring
- Disposal Area Monitoring System
- National Marine Debris Monitoring
- NOAA National Benthic Surveillance
- Bioeffects Studies & Mussel Watch projects
- EPA Environmental Monitoring and Assessment Program
- National Coastal Assessment Program, Ambient Air & National Atmospheric Deposition Program
- National Water Quality Assessment Program
- Toxic Contaminants in Tissue of Seals in the Gulf of Maine

Source: RARGOM Symposium 2003

concern in the Gulf of Maine are nitrogen, phosphorus, and carbon. An inventory of the coastal point sources estimated that 91% of that nitrogen input came from WWTPs, and 9% from industries (half of that from pulp and paper operations). Eighty percent of all the point sources lie within four watersheds: Massachusetts Bay and Sheepscot Bay, ME, and the Saint John and Merrimack rivers. According to this model of nitrogen-loading in the Gulf, Massachusetts accounted for 58% of the total load, Maine 22%, New Hampshire 9%, New Brunswick 8% and Nova Scotia 3% (Pesch and Wells 2004).

Mercury

In recent years, mercury has become the heavy metal of greatest concern due to its prevalence in Gulf ecosystems, its tendency to bioaccumulate in organisms and also biomagnify (occurring in greater concentrations in organisms higher up the food chain), and its high toxicity. While industrial and municipal sources (such as chlor-alkali industries, paint-containing mercury additives and pharmaceuticals) were once the dominant source of mercury entering the Gulf, the primary pathway today is through atmospheric deposition (from municipal and medical waste combustion, utility and non-utility fuel combustion, and manufacturing) (Pesch and Wells 2004). In the Gulf of Maine, blue mussels, common loons, common eider, Leach's storm-petrel, double-crested cormorant and black guillemot have all been shown to be effective bioindicators (organisms that are useful in environmental monitoring) of mercury in the environment. Each species has a different foraging strategy and participates in a different food web, making it of particular interest for monitoring programs.

All the jurisdictions surrounding the Gulf of Maine have taken action to reduce mercury use and decrease environmental releases, especially since the adoption of the Mercury Action Plan in 1998 by the Conference of the New England Governors and Eastern Canadian Premiers (see Section 4). Although efforts to reduce atmospheric, terrestrial, and aquatic disposal of mercury are ongoing, the amount of mercury currently available to marine organisms is high.

4. Environmental Management in the Gulf of Maine

This section focuses on the work of the Gulf of Maine Council as well as highlighting some important transboundary initiatives between Canada and the US. A detailed overview of the governance of the area can be found in *Overview of Current Governance in the Bay of Fundy/Gulf of Maine: Transboundary Collaborative Arrangements and Initiatives* (DFO 2006).

4.1 THE GULF OF MAINE COUNCIL ON THE MARINE ENVIRONMENT

By the late 1980s, growing evidence of declining water quality, resource degradation, and user conflicts in the Gulf of Maine emphasised the need for a more cooperative, management approach to address these issues. In December 1989, after the region's Premiers and Governors formed the Gulf of Maine Council on the Marine Environment, planners and resource managers from the region formed the Gulf of Maine Working Group. The Working Group was convened for two primary purposes, to facilitate and improve communication among the jurisdictions on Gulf topics and to compile a set of recommendations for the sustainable management of the Gulf ecosystem.

Gulf of Maine Council on the Marine Environment

In 1989 representatives from numerous provincial, state and federal agencies, along with members from academia, the scientific community, and the public, met to discuss suggestions for an action plan for the Gulf of Maine, which resulted in the region's Premiers and Governors signing an Agreement on the Conservation of the Marine Environment of the Gulf of Maine. Under the terms of the Agreement, the parties pledged to establish the Gulf of Maine Council on the Marine Environment. Among the topics to be addressed by the Council were ecosystem protection, pollution, sustainable resource use and the development of cooperative management programmes. The Council was also tasked with the preparation of an Action Plan, which would set out environmental trends and conditions and provide specific recommendations.

The Gulf of Maine Council functions as a regional forum for exchanging information and engaging in long-term planning. The Gulf of Maine council was established by the Premiers of Nova Scotia, New Brunswick and the Governors of Maine, New Hampshire, and Massachusetts. The Council's mission statement is "to maintain and enhance environmental quality in the Gulf of Maine to allow for sustainable resource use by existing and future generations". Councilors meet twice a year to set objectives, convene partnerships, and marshal the resources necessary to implement the Action Plan. To achieve these goals, the Council partners with government agencies, environmental organisations, researchers, businesses and the public to sponsor research, implementation, and education initiatives throughout the Gulf of Maine. Currently, each Governor or Premier appoints two senior level government representatives and two non-profit or business sector representatives to serve on the Council. Since 1992, Canadian and US federal agencies have also served on the Council. Space is also reserved on the Council for two senior members of the scientific community from each country. The Secretariat, which rotates annually through the five Gulf of Maine jurisdictions, is responsible for all of the Council's administrative, organisational, and reporting needs. The Council's core functions are funded from annual contributions from the five participating States and Provinces and federal agencies.

The Council relies on the Working Group to conduct strategic planning, prepare policy options, and develop annual work programs and budgets for Council activities. The Working Group includes one representative for each state, provincial, and federal Council member, as well as the Canadian and US co-chairs from each of the Council's Committees. The Working Group meets quarterly, and its functions include: developing annual work programs and budgets for Council activities; overseeing Committee operations and approving work plans; conducting strategic planning; and preparing policy options for the Council's consideration.

The Gulf of Maine Agreement set out a requirement for the Council to prepare action plans to guide its management and research initiatives in the Gulf of Maine. The current plan describes the goals and outcomes that the Council will pursue through its committees and partnerships from 2007-2012. The Plan focuses on three bold and ambitious goals identified by the people living and working around the Gulf of Maine, including protecting and restoring habitats; fostering environmental and human health; and supporting vibrant communities.

The Council's Committees take responsibility for implementing the goals of the Council's Action Plans. They operate under work plans reviewed and approved by the Working Group, report to the Working Group quarterly, and meet as needed in the interim. Action Plan projects and tasks are supported by several contract staff members based around the Gulf of Maine. In 2006 the Council structured the following Committees to coincide with the 2007-2012 Action Plan: 1. Habitat Committee (with subcommittees that included Conservation, Monitoring, and Restoration); 2. Contaminants Committee (includes the Gulfwatch Contaminants Monitoring Subcommittee); 3. Sustainable Industries and Communities Committee; and cross-cutting areas by the 4. Ecosystem Indicator Partnership (ESIP), and 5. Climate Change Committee.

4.2 BILATERAL INITIATIVES

Cooperation between Canada and the US on transboundary issues affecting the Gulf of Maine and the Bay of Fundy have involved both direct bilateral cooperation and indirect multi-lateral initiatives through regional management organizations. Some cooperative arrangements pre-date the establishment of the Gulf of Maine Council, while other co-operative efforts post-date the Council. This discussion gives a brief overview of the co-operative bilateral initiatives currently in place.

Climate Change Program

The Climate Change Committee was one of three regional air initiatives developed by the New England Governors and Eastern Canadian Premiers (NEG/ECP). An action plan was drafted in 2001 that recognised the human influence on climate change and the benefits of reducing emissions. A steering committee was established to oversee the implementation of the plan which identified short, medium and long-term goals for the reduction of GHG emissions in the region:

- Short-term goal: Reduce regional GHG emissions to 1990 emissions by 2010.
- Medium-term goal: Reduce GHG emission by at least 10% below 1990 emissions by 2020.
- Long-term goal: Reduce regional emissions sufficiently to eliminate any dangerous threat to the climate (estimated to require reductions of 75-85% below current levels).

Specific actions were then identified in four general categories to help achieve these goals. Actions identified included standardised emissions inventories and a regional emissions registry; the need to anticipate and avoid negative social, economic and environmental impacts of climate change; education and outreach; and regional plans for reducing green house gas (GHG) emissions and conserving energy. States and provinces have committed to taking measures to reduce GHG emissions. Within the electricity sector, the parties have agreed to reduce CO2 emissions per unit of power by 20% by 2025. In addition, there is a general commitment to reduce energy demand by the year 2025 by 20% through efficiency and conservation.

Fisheries Management

In 1970 Canada and the US extended their respective offshore jurisdictions to 200 nautical miles and the Gulf of Maine became the exclusive domain of Canadian and US fisheries. Problems emerged in the region of Georges Bank when the two countries' claims overlapped. The disputed area was home to several transboundary commercial species such as cod, haddock, and scallops. In 1984 the International Court of Justice established the Hague Line as the international boundary between the two countries in the Gulf of Maine. Following the court's decision, fishing by the two countries was confined to their respective jurisdictions. However, the problem of managing transboundary fisheries resources in the region remained and co-operative management was virtually non-existent. Increased fishing efforts led to the overexploitation of the transboundary groundfish stocks that migrated back and forth between the countries.

In 1984, The Gulf of Maine Advisory Committee (GOMAC) was established by Fisheries and Oceans Canada (DFO) to serve as a government-industry forum for discussing the management of fish stocks in the Gulf of Maine. GOMAC provides

DFO with advice on transboundary fisheries issues in the Gulf of Maine. The committee is also responsible for liaising with the Transboundary Management Guidance Committee (TMGC) and recommending total allowable catch levels for Gulf of Maine groundfish stocks to the Minister of Fisheries and Oceans. In the US a Regional Fishery Management Council process is used to bring forward this advice. Further, both DFO and NMFS have an established history of communicating on marine fishery analysis on fish stock assessments of population status.

In 1994 a joint effort was made to reduce fishing levels and rebuild stocks in the region of Georges Bank. The success of this effort increased communication and cooperation on management issues and led to the formation of the Bilateral Steering Committee in 1995. The Committee functions as an overseeing body in guiding transboundary management issues in the Gulf of Maine. It is an informal committee co-chaired by the Director General of the Maritime Region DFO and the Northeast Regional Administrator of NOAA's National Marine Fisheries Service (NMFS). The Committee was instrumental in the development of the Transboundary Resource Assessment Committee (TRAC) and Transboundary Management Guidance Committee (TMGC).

Contaminants

Population and urbanization of the watershed has created a tremendous, ongoing impact on its ecosystem. Approximately 80% of all pollutants entering the Gulf's waters come from urbanized, land-based, point and non-point sources. Impacts of this pollution are felt in closed shellfish beds and beaches, and changes in fish stocks, distribution, and migration patterns. Based on discussions with scientists, policy-makers and citizens around the Gulf, the GOMC identified sewage, nutrients and mercury as the three contaminant problems of greatest concern to the Gulf.

Mercury Program

Regional efforts on mercury were initiated in 1997, which charged the Environment Committee to develop a Mercury Action Plan. The Plan called for the establishment of a Mercury Task Force to coordinate the implementation of a reduction in mercury emissions from all sources. The Mercury Task Force is now working toward a target of 75% regional reduction in emissions by 2010.

Shellfish Sanitation

Due to an outbreak of typhoid fever, traced to the consumption of raw oysters, in the early 20th Century, shellfish sanitation became a public health concern in the US. Because of the relationship Canada and the US share in importing and exporting shellfish, a formal bilateral agreement was signed in 1948 to deal with the sanitary practices of each country. Currently, the US Food and Drug Administration is the designated agency in the US, and the responsibility in Canada is shared among DFO, the Canadian Food Inspection Agency, and Environment Canada. The Canada-US Shellfish Agreement of 1948 remains the foundation for the respective shellfish sanitation programs of the two countries.

The Gulf of Maine Council on the Marine Environment administers Gulfwatch, a chemical contaminants monitoring program. Scientists from agencies and universities around the Gulf of Maine analyze tissue from *Mytilus edulis* (blue mussels) to measure the type and concentration of contaminants in the coastal marine environment. Both Canadian and US authorities have used Gulfwatch data in making sanitary survey reports to determine whether it is safe to harvest shellfish from an area. A similar nationwide initiative is the US NOAA's National Status and Trends Mussel Watch program, the longest chemical contaminant monitoring program in US coastal waters.

Species At Risk

Endangered species habitats overlap the Canadian and US borders, which creates several transboundary issues such as commercial fisheries and environmental contamination that may affect species' recoveries. Collaboration, therefore, between Canada and the US in research and recovery is important in order to conserve the species and their habitat. A Species at Risk Working Group was formed in 2003 to address interactions between fisheries and the North Atlantic right whale. In 2006 its mandate was expanded to discuss broader transboundary species at risk issues.

- **The Leatherback Turtle** - is listed as "endangered" by the Species at Risk Act (SARA/Canada) the Endangered Species Act (ESA/US). A number of transboundary issues face turtles, including environmental degradation, contamination, accidental capture and entanglement from fishery operations. Canada and the US work co-operatively to identify and address these threats and both participate in the Annual Symposia on Sea Turtle Conservation and Biology hosted by the National Marine Fisheries Service.
- **The North Atlantic Right Whale** – is listed as "endangered" under SARA and ESA. The Bay of Fundy and Gulf of Maine represent the primary foraging ground for the whales. All threats are, therefore, transboundary issues, and include, collisions with commercial vessels, entanglements with fishing gear, disturbance from human activity, and habitat degradation. The North Atlantic Right Whale is an organization made up of governmental, NGO's and individuals from both countries who work to study and conserve North Atlantic Right Whales.
- **Atlantic Salmon** – is listed as endangered under SARA and ESA. Common marine habitat in Canadian and US waters creates similar concerns over threats to Atlantic salmon survival. Canada and the US are contracting parties to the Convention for the Conservation of Salmon in

the North Atlantic Ocean, and members of the North Atlantic Salmon Conservation Organization. Agencies from both Canada and the US cooperate in management activities along the St Croix and Aroostook Rivers. With regard to fish health relating to aquaculture, the Maine Department of Marine Resources, the NB Department of Agriculture, Fisheries and Aquaculture and the US Department of Agriculture have a strong consultative relationship.

North American Waterfowl and Migratory Birds Cooperation

The Gulf of Maine and Bay of Fundy play a critical role for resident and migratory bird populations, providing critical habitat, food resources and breeding areas. The sea bird populations face many threats in the Gulf of Maine region including: oil and chemical spills; persistent contaminants, plastics, and pollutants; harmful algal blooms; entanglement in fishing gear and other debris; disease; lead shot and illegal hunting; habitat loss and degradation; and wind energy development.

Across the region, population surveys suggest that many species have been or are in decline. As a result, several transboundary conservation and management initiatives have been put in place. Several of these conservation initiatives including the North American Waterfowl Management Plan, the North American Bird Conservation Initiative, Western Hemisphere Shorebird Reserve Network, the National Shorebird Conservation Plan in Canada and the United States, and the Waterbird Conservation for the Americas initiative. Several collaborative research and monitoring initiatives in the Gulf of Maine region also take place.

Collaborative Scientific Research and Monitoring

Scientists from across the region have longstanding collaborative research programs and initiatives in the Gulf of Maine. Current collaborative scientific initiatives include research on distribution and numbers of shorebirds in the Bay of Fundy and Gulf of Maine; shorebird surveys (e.g., The Program for Regional and International Shorebird Monitoring), and ecological assessments (e.g., The Seabird Ecological Assessment Network). Increasingly, governments are reluctant to fund foreign scientists' participation in research programs, but collaboration is common on specific projects.

In support of its mission of maintaining and enhancing environmental quality in the Gulf of Maine and ensuring sustainable resource use, the Council supports directly and indirectly programs and activities that are science-based. These programs and activities include:

- **Ecosystem Indicator Partnership (ESIP)** is a science-based initiative to leverage existing monitoring datasets into a comprehensive reporting system for regional decision-makers.

- **Gulf of Maine Science Translation Project** facilitates the transfer of scientific findings and techniques.
- **Gulfwatch Monitoring Program**, a bi-national program that assesses the fate and impacts of toxic contaminants in the Gulf of Maine by measuring contaminant concentrations in blue mussels

Scientists from across the region have longstanding collaborative research programs and initiatives in the Gulf of Maine in support of conservation for migratory and resident aquatic birds. Current collaborative scientific initiatives include research on distribution and numbers of phalaropes in the Bay of Fundy and Gulf of Maine with support from the Canadian Wildlife Service (CWS) and US Fish and Wildlife Service (FWS). Collaborative scientific programs on foraging ecology of shorebirds and monitoring of shorebird migrations are also conducted through CWS and FWS and the Manomet Center for Conservation Studies. Other initiatives include the Regional Association for Research in the Gulf of Maine and the Northeast Coastal and Ocean Data Partnership. These collaborative programs throughout the migratory and foraging range of aquatic bird species allow scientists to quantify why certain areas and habitats are important for species and facilitate designation of specific sites for conservation purposes.

5. In Conclusion

The Gulf of Maine in Context gives a brief overview of the region by providing some baseline knowledge of the biophysical, social and economic environment in the Gulf and its watershed. It is intended as a useful resource for a broad-based audience, as well as a providing context for the more in-depth discussion in the theme papers. Readers interested in finding out more about the issues facing us in the Gulf of Maine are encouraged to read the theme papers at: www.gulfofmaine.org/stateofthegulf.

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