COASTAL ECOSYSTEMS AND HABITATS

STATE OF THE GULF OF MAINE REPORT

Gulf of Maine Council on the Marine Environment

September 2010

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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 photo by Peter Taylor/Waterview Consulting
Cover map (background) courtesy of Census of Marine Life/Gulf of Maine Area Program

The *State of the Gulf of Maine Report*, of which this document is a part, is available at: www.gulfofmaine.org/stateofthegulf.

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1. Issue in Brief

Coastal habitats can be characterised and classified several ways (McDougall et al. 2007; Taylor and Atkinson 2008; CBCL Limited 2009), but some of the most important in the Gulf of Maine include: salt marshes; mudflats; seagrass beds; kelp beds; shellfish beds; rocky and cobble shore; and sandy shore. Shorelines include both tidal/intertidal (between the high and low tide marks) and subtidal (below the low tide mark) components to depths of approximately 100 m. The ecosystems made up of these habitats support species that have both ecological and socio-economic importance. The issues faced by coastal ecosystems and habitats are diverse, and linked to the issues addressed by many of the other theme papers of the State of the Gulf of Maine Report. The structure and function of coastal ecosystems are currently threatened by several pressures that can have important impacts (Figure 1). Increasing population, economic growth and coastal development lead to increased physical habitat alteration and destruction, increased contamination and pollution and an increased need for renewable resource extraction. This, together with the pressures from a changing climate, can alter physical and chemical environments, change the distribution and extent of coastal habitats, affect the distribution and abundance of species within coastal ecosystems, and reduce the provision of critical ecosystem goods and services (e.g., supporting commercial fish production and protecting shorelines from erosion).

LINKAGES

This theme paper also links to the following theme papers:

- Climate Change and Its Effects on Ecosystems, Habitats, and Biota
- Aquaculture in the Gulf of Maine
- Commercial Fisheries and Fish Stock Status
- Land Use and Coastal Development
- Toxic Contaminants
- Microbial Pathogens and Toxins
- Eutrophication
- Offshore Ecosystems and Habitats
- Watershed Status
- Invasive Species
- Species at Risk

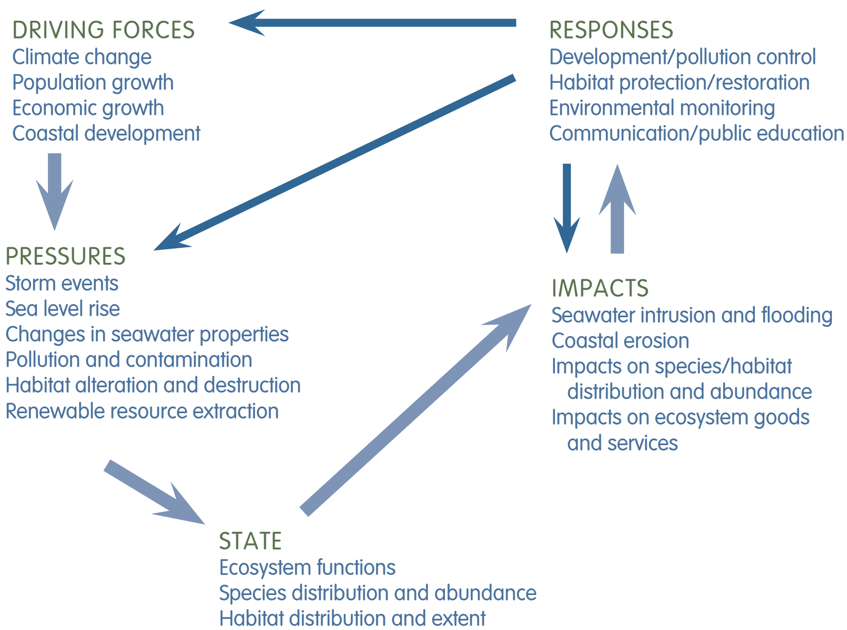

Figure 1: Driving forces, pressures, state, impacts and responses (DPSIR) to marine invasive species in the Gulf of Maine. The DPSIR framework provides an overview of the relation between the environment and humans. According to this reporting framework, social and economic developments and natural conditions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

2. Driving Forces and Pressures

The primary driving forces resulting in pressures on coastal ecosystems and habitats include climate change, population growth, economic growth and coastal development. The characteristics of these forces are dealt with in more detail in other theme papers and, thus, are not addressed further here (see also The Gulf of Maine in Context). The resulting pressures lead to the physical, chemical and biological alteration of habitat that, independently and cumulatively, can change both the structure and function of coastal ecosystems. Key biophysical changes of concern are: site energetics (wave and tidal action); nutrient loading; oxygen demand and availability; water turbidity (and availability of light); habitat fragmentation, and pollution and contamination with toxic chemicals.

The pressures of most concern are dependent on the type of coastal ecosystem and habitat, but many threats are pervasive. Overall, coastal ecosystems are particularly susceptible to: effluent from wastewater treatment and outfalls; runoff and sedimentation from coastal development, forestry and agricultural activities; contamination from aquaculture facilities, and direct destruction of habitat through infilling and other activities that remove habitat from production. Contamination by pathogens (bacterial and viral) and heavy metals is a persistent threat, particularly as it restricts the use of coastal waters and the harvest of species such as blue mussels, clams and oysters by humans (GOMC 2005). Habitat degradation due to fishing (dredging, trawling), the commercial and recreational overfishing of species, the introduction of invasive species, shoreline armouring, coastal infilling and waterfront development threaten several different habitats across the region (GOMC 2005). Key pressures to coastal habitats are summarized in Table 1.

Photo: Woodley Wonderworks

For salt marshes, coastal development and habitat alteration, resulting in tidal restrictions, dykes, draining and infilling, can have a substantial effect on hydrology and, thus, the viability of the habitat (GOMC 2004; Taylor 2008; CBCL Limited 2009). The alteration of habitat by tidal restrictions is of particular concern because of the effects on site energetics and water flows. Marsh-building processes may not be able to keep pace with accelerated rates of sea level rise, resulting in degraded salt marsh ecosystems and a loss of function (Titus and Richman 2001); the migration of salt marshes inland in response to sea level rise may also be hindered by coastal development, leading to a loss of habitat due to a lack of available space (Bozek and Burdick 2003).

Mudflats are particularly susceptible to pollution and contamination from coastal development (sewage and stormwater discharge), agriculture and industrial activity because they are depositional environments where organic pollutants and metals can accumulate. Dredging of mudflats and overharvesting of clams and worms from mudflats are known to have a substantial effect on the physical habitat (GOMC 2005).

Table 1: Pressures of most concern by habitat type.

HABITAT TYPE	KEY PRESSURES
Salt Marshes	• Habitat alteration and destruction (e.g., from coastal development) • Sea level rise • Pollution and contamination
Mudflats	• Navigational dredging • Pollution and contamination • Renewable resource extraction (clam and worm harvesting) • Dredging activities causing habitat alteration and destruction
Seagrass Beds	• Changes in seawater properties (sedimentation, turbidity) • Pollution (nutrient loading)
Kelp Beds	• Storm events • Changes in seawater properties (temperature) • Renewable resource harvesting
Shellfish Beds	• Renewable resource harvesting • Pollution and contamination (persistent organic pollutants, metals, bacteriological and viral) • Changes in seawater properties (temperature, acidification) • Navigational dredging
Rocky/Cobble Shore	• Changes in seawater properties (sedimentation, turbidity, temperature) • Renewable resource harvesting
Sandy Shore	• Habitat alteration and destruction (removal and physical alteration of habitat) • Storm events • Beach nourishment

The primary threat to seagrass habitat is water quality degradation associated with watershed development, including increased nutrient loading, sedimentation, algal growth and turbidity (GOMC 2005), all of which alter its productivity. Within kelp bed habitat, heavy harvesting of groundfish, sea urchins, kelp and rockweed has the potential to substantially shift ecosystem structure and function (GOMC 2005). An increase in storm events, and the corresponding increase in wave energy, can denude areas of kelp by physically dislodging the species from the bottom. The warming of coastal waters can also threaten the kelp beds, which require cooler water temperatures.

With respect to sub-tidal shellfish beds, the harvesting of oysters, mussels and scallops has an immediate effect on the habitat primarily due to the impact of fishing gear on the bottom and the resulting change in shellfish size and structure (GOMC 2005). Other pressures of concern are

TIDAL RESTRICTIONS

Information has been collected on the location of tidal restrictions in Maine, New Hampshire, New Brunswick, and Nova Scotia. Data are not currently available for Massachusetts. A total of 21 road culvert restrictions of concern have been identified in coastal areas of Maine, 107 tidal restriction structures have been identified in New Brunswick, and 216 have been described in Nova Scotia. These structures include culverts, bridges, causeways, dams and aboiteaux (water control structures installed in dykes). The data are incomplete, particularly for the US states, and the information that has been collected to date awaits more detailed analysis.

Source: Aquatic Habitats Subcommittee, Ecosystem Indicator Partnership, Gulf of Maine Council on the Marine Environment. http://www.gulfofmaine.org/esip/.


Photo: Bodhisoma

persistent organic pollutants and metals, which may affect shellfish health and marketability; changes in water temperature and hydrographic regimes due to climate change will result in changes to the distribution of shellfish communities and may increase the prevalence of disease causing organisms and phytotoxins (GOMC 2005).

Overharvesting of intertidal seaweeds on the rocky shore can have a negative effect on these diverse ecosystems. Turbidity and sedimentation can smother sessile filer-feeding species. With respect to sandy shore, major threats include sand extraction, the installation of marine infrastructure (seawalls and jetties), inappropriate placement of buildings and roads, and human use (beach vehicles, trampling) (GOMC 2004; CBCL Limited 2009).

3. Status and Trends

The Gulf of Maine has about 12,000 km (7,500 miles) of coastline (Horton and McKenzie 2009). Coastal habitats are typically distinguished based on substrate type, water depth, physical properties of the water (e.g., salinity, temperature, current regime), and the specific structure-forming plants and animals that are present (Tyrrell 2005). The status of these habitats can be described by their distribution and geographical extent across the Gulf of Maine. A more comprehensive assessment of the health of coastal ecosystems, including species composition, trophic relationships and ecosystem functioning (e.g., productivity), is not possible within the constraints of this paper, but the status and trends of certain key species can be used as indicators of coastal ecosystem health.

3.1 SALT MARSHES

Salt marshes are grass-dominated habitats that can extend across the intertidal zone (Taylor 2008; Tyrrell 2005). They are influenced by gradients associated with the duration of tidal flooding and the extent of freshwater influx. Different species become dominant along different parts of these gradients. There is a gradient from fringing marshes to salt marsh meadows along the Gulf of Maine coast (Taylor 2008). Fringing marshes form narrow bands along the shoreline, and are dominated by tall forms of salt marsh cordgrass. Salt marsh meadows form in well-protected areas and have a greater diversity of communities, including high-marsh plants, border plants, marsh pannes and pools, low-marsh plants, and intertidal and subtidal creeks with muddy bottoms (Tyrrell 2005). Key salt marsh plant species include: salt marsh cordgrass (*Spartina alterniflora*); tall cordgrass (Spartina pectinata); saltmeadow hay (*Spartina patens*); black grass (*Juncus gerardii*); sea lavender (*Limonium nashii*); spike grass (*Distichlis spicata*); marsh elder

(*Iva frutescens*); seaside goldernrod (*Solidago sempervirens*); and switch grass (*Panicum virgatum*). Salt marshes provide habitat for numerous species, provide nurseries for juvenile fish, and are important feeding and breeding habitats for waterfowl.

Salt marshes tend to be largest and most common in Nova Scotia, New Brunswick and Massachusetts (Taylor 2008). Data on the spatial extent and distribution of salt marsh habitats have been collected for all three states and two provinces by the Ecosystem Indicator Partnership (ESIP, Gulf of Maine Council on the Marine Environment) and are available at http://www2.gulfofmaine.org/esip/reporting/. Salt marsh habitat has been documented to be in decline within the Gulf of Maine (e.g., Natural Resources Canada 2006; CBCL Limited 2009). Within New Brunswick and Nova Scotia, approximately 65% of salt marsh area has been lost since European settlement (Wiken et al. 2003). Approximately 50% of salt marsh area has been lost in Massachusetts and New Hampshire, and 25-50% lost in Maine (Dionnne et al. 1998). Coastal wetlands continue to be degraded and lost.

Photo: Waterview Consulting

3.2 MUDFLATS

Mudflats are typically non-vegetated, intertidal environments (with the exception of algae and benthic diatoms) of silt and clay, with some sand, that occur in relatively calm, sheltered depositional areas (Tyrrell 2005) such as bays, lagoons, and estuaries. Mudflats may be viewed geologically as exposed layers of bay mud, resulting from deposition of estuarine silts, clays and marine animal detritus. The habitat supports numerous burrowing invertebrates, including clams, worms, and amphipods. Related subtidal mud bottoms also support anemones, brittle stars, lobster, and a variety of fish and crab species (Tyrrell 2005; see also Offshore Ecosystems and Habitats). The infauna can consist of a large diversity of micro- and macro-invertebrate species, most notably clams and worms (GOMC 2005).

Information is not readily available on the distribution and spatial extent of mudflats, or changes over time, throughout the Gulf of Maine.

3.3 SEAGRASS BEDS

Eelgrass (*Zostera marina*), the dominant seagrass species throughout the region, is found on coarse sand to mud bottoms in low intertidal and subtidal environments, typically inlets and bays. Widgeon grass (*Ruppia maritima*) occurs sporadically, mainly in low salinity waters. The lower extent of seagrass habitat is predominantly determined by the light penetration; areas will not support the development of eelgrass beds if there is insufficient water clarity, despite having a suitable substrate. Eelgrass has been identified as an ecologically significant species in that it creates habitat used preferentially by other species, provides protection for associated communities, and has substantial influence over the ecology of the habitat (Fisheries and Oceans Canada 2009).

The total area of seagrass bed habitat along coastal areas is currently estimated to be approximately 12,000 ha in Maine, 1,040 ha in New Hampshire, and 12,610 ha in Massachusetts.[1] In the Bay of Fundy within Canada, the distribution of eelgrass is very limited, occurring only along the outer portions of the bay (Fisheries and Oceans Canada 2009). Data on the spatial extent and distribution of eelgrass beds in the US have been collected by ESIP and are available at www2.gulfofmaine.org/esip/reporting/. Seagrass habitat throughout the Gulf of Maine is believed to be in significant decline. Green and Short (2003) estimated overall eelgrass loss in the region to be approximately 20% since European settlement, although much greater localized declines have been documented (Neckles et al. 2009).

3.4 KELP BEDS

Photo: Adrienne Pappal

Kelps attach to hard substrates in the subtidal zone and can form tall "forests" extending upward in the water column, with the dominant species varying according to water depth and wave exposure regime. Kelp requires relatively clear water and a suitably firm substrate for attachment (Tyrrell 2005). The most common species include: sugar kelp (*Laminaria saccharina*), oarweed (*Laminaria digitata*), edible kelp (*Alaria esculenta*), and shotgun kelp (*Agarum clathratum*) (Tyrrell 2005; East Coast Aquatics 2009). For the Gulf of Maine as a whole, information is not readily available on the distribution and spatial extent of kelp beds or changes over time, although there are site-specific studies. The "deforestation" of kelp beds is a general concern, but a comprehensive habitat inventory has yet to be completed. An initial baseline study is required before changes in status and trends can be established over time.

3.5 SHELLFISH BEDS

Bivalves can form large, dense aggregations, which in turn provide a refuge for smaller species and a surface for attachment for certain sessile organisms (GOMC 2005; Tyrrell 2005). Shellfish beds are found in intertidal and subtidal zones, although the species composition varies according to biological requirements. Within the Gulf of Maine, the main shellfish-bed forming species are mussel, oyster and scallop (GOMC 2005; Tyrrell 2005). Blue mussels and oysters occur in the intertidal to shallow subtidal; scallops and horse mussels occur in the deep subtidal (Tyrrell 2005). Shellfish beds are often associated with rocky bottoms, which provide a substrate for attachment; however, scallops neither attach to each other nor the bottom, but nonetheless occur in dense aggregations.

Shellfish beds are widely found throughout the Gulf of Maine, mussels and oysters less so in the reaches of the Bay of Fundy where suitable rocky shore habitat is not as predominant. Information is not readily available on the distribution and spatial extent of shellfish beds throughout the Gulf of Maine.

[1] Data obtained by the Aquatic Habitats Subcommittee, Ecosystem Indicator Partnership (ESIP), Gulf of Maine Council on the Marine Environment (http://www.gulfofmaine.org/esip/).

3.6 ROCKY AND COBBLE SHORE

Rocky and cobble shores are some of the most variable coastal habitats, with their character dependent on the prevailing rock type and geomorphology. Rocky shores form as a result of marine erosion, in areas where there is low sediment supply (Nova Scotia Museum of Natural History 1996). They are physically complex, with changes of slope and the presence of rockpools, gullies, crevices, and boulders increasing the range of habitats. Boulder or cobble shores form where there is erosion of glacial till on headlands and islands, often forming cobble beaches. The variable physical conditions, including light availability, degree of exposure, changes in temperature and salinity, substrate type and biotic features lead to the development of a characteristic zonation of species and habitats. Zones include the splash zone (above spring high tide), the intertidal zone (between high tide and low tide) and the subtidal zone (below low tide).

Conditions on rocky shores are harsh; organisms have to be able to survive rapidly to changing environmental conditions and to be capable of rapid recolonisation. The type of species inhabiting rocky and cobble shores is predominantly determined by water depth, wave and air exposure, and stability of the substrate (Bertness 1999; Tyrrell 2005). Species predominant on stable rock areas include rockweed, anemones, barnacles and mussels; species predominant on more unstable, exposed cobble areas include smaller amphipods and isopods (Tyrrell 2005). Higher species diversity is typically found on rocky, as opposed to cobble, coastal habitats because of greater habitat stability. Rocky intertidal areas are dominated by brown seaweeds (knotted wrack *Ascophyllum nodosum*; bladder wrack *Fucus vesiculosus*; spiral wrack *Fucus spiralis*), as well as many species of crab, snail, whelk, mussel and barnacle (Tyrrell 2005; CBCL Limited 2009). Irish moss (*Chrondrus crispus*) is also a prominent species in the lower intertidal zone. Rocky subtidal habitats are home to a diversity of animal species including lobster, crabs, starfish, sea urchins and fish (Tyrrell 2005). In addition to seaweeds, soft corals, brachiopods, mussels, tunicates, sponges, hydroids, and anemones can predominate (Tyrrell 2005).

Photo: Peter Taylor

Information is not readily available on the distribution and spatial extent of rocky and cobble shore, or changes over time, throughout the Gulf of Maine. In general, these habitats are ubiquitous and not seen as severely under threat, and thus are not a priority for inventory work (CBCL Limited 2009).

3.7 SANDY SHORE

The sandy shore includes beaches, dunes and the sandy subtidal habitat. Grain size and the wave regime of the environment influence the type and diversity of species. Beaches are relatively exposed, harsh environments that support few species, mainly isopods and amphipods. The surf zone is inhabited by clams and certain crab species that are, in turn, preyed upon by shorebirds (GOMC 2005; Tyrrell 2005). In the subtidal, infauna (burrowing animals) abundance is dominated by annelids and arthropods, while molluscs become more dominant in the softer (sand-silt and silt clay) bottoms (East Coast Aquatics 2009). Common subtidal epifauna species, living on the surface of the sand, include moon snails, welks, sand dollar, and American sand lance (Tyrrell 2005).

Photo: Joshua Bousel

Information of the spatial distribution and extent of sandy shore within the Gulf of Maine is not readily available. There are prominent and extensive beach areas along the shorelines of the Bay of Fundy (CBCL Limited 2009). It is unknown how these habitats are changing, specifically as measured by beach erosion and deposition rates. But sandy shore habitat has been documented to be in decline (e.g., Natural Resources Canada 2006). In a study of five locations in southeastern New Brunswick between 1944 and 2001, beach and dune habitat was reduced in area from between ~8% and ~40% (O'Carroll et al. 2010).

3.8 INDICATOR SPECIES

The distribution and spatial extent of coastal habitats, and patterns of change in the distribution of those habitats resulting from alteration and destruction, provides a measure of their status; however, a deeper understanding of the health of coastal ecosystems can be obtained by looking at the status of key indicator species (Rapport et al. 1998), which reflect the condition of an ecosystem. For the purposes of this report, shorebirds are examined as indicators for the broad range of coastal ecosystems on which they depend.

The coastal areas of the Gulf of Maine provide important habitat for migrating and breeding shorebirds. The upper Bay of Fundy is particularly important as a stopover area. Although migrating birds are negatively affected by habitat changes throughout their range and there are potentially other limiting factors outside of the Gulf of Maine, they have undoubtedly been adversely affected by impacts on local coastal habitats. A comparison of changes in the populations of 16 different species of migrating shorebirds from the 1970s through the 1990s in the Maritimes showed a strong and significant negative trend in most species (Morrison and Hicklin 2001). This overall negative trend in abundance has continuing through the 2000s.

4. Impacts

The relationship between the various driving forces, pressures and resulting impacts on coastal ecosystems is complex. Actual biophysical and socio-economic impacts depend on the ecosystem in question, site-specific biophysical conditions, and local landscape-level processes. In sum, the impacts can best be described in terms of the functions performed by each habitat type – impacts occur when those functions are substantially affected by the pressure on them. Table 2 summarizes the key biophysical and socio-economic functions by habitat type.

Table 2: Key biophysical and socio-economic functions by habitat type.

HABITAT TYPE	KEY PRESSURES
Salt Marshes	• Refuge, feeding, migratory and nursery areas for fish and shellfish • Resting, feeding and breeding areas for migratory birds • Removal of contaminant, nutrients and suspended sediments • Export of nutrients and energy to support coastal fisheries • Coastal storm surge and infrastructure protection, flood protection and erosion control • Recreation (bird watching, hunting) and education
Mudflats	• Feeding areas for shorebirds and coastal mammals • Spawning areas for crabs • Habitat for commercially fished or harvested species (clams, worms, crabs)
Seagrass Beds	• Removal of nutrients and suspended sediment from seawater • Refuge, spawning, feeding and nursery areas for many species of shellfish and fish, including commercially important species • Protection from coastal erosion • Nursery areas for commercially important species • Recreation (bird watching, hunting)
Kelp Beds	• Habitat complexity to support biodiversity • Habitat and refuge areas for fish and shellfish species, including commercially important species • Food source for invertebrates • Habitat for commercially fished or harvested species
Shellfish Beds	• Habitat complexity to support biodiversity • Removal of suspended sediment from seawater • Refuge and habitat space for a number of species • Food source for higher trophic levels • Habitat for commercially fished or harvested species (mussels, oysters, scallops)
Rocky/Cobble Shore	• Habitat complexity to support biodiversity (feeding, spawning and refuge areas) • Feeding areas for shorebirds and coastal mammals • Habitat for commercially harvested species (seaweed) • Protection from coastal erosion • Recreation (wildlife viewing)
Sandy Shore	• Nesting grounds for shorebirds (e.g. sand piper) • Protection from coastal erosion • Recreation (beach use)

Pressures on the functions listed in Table 2 result in biophysical and socio-economic impacts. The main biophysical impacts include: seawater intrusion and flooding; coastal erosion; impacts on species distribution and abundance; and impacts on habitat distribution and extent. Socio-economic impacts occur indirectly as a result of the occurrence of biophysical impacts on coastal ecosystems and habitats. The most notably affected include outdoor recreation values, production of species fished or harvested, and protection of coastal properties from erosion, among other ecosystem goods and services. These are described below as they vary by habitat type.

4.1 SALT MARSHES

Photo: Ashleigh Bennett

Historically, salt marshes have been drained and dyked for agriculture, filled for development, transected by roads and rail lines, and drained or dredged for the perceived benefit of controlling mosquito numbers (Tyrrell 2005; Taylor 2008). Although some of these practices have been halted, or greatly curtailed, climate change and coastal development-related pressures continue to affect these habitats. Upland development serves as a barrier to the natural migration of salt marshes in response to sea level rise (Bozek and Burdick 2003). Coastal infrastructure (ports, seawalls, etc.) may displace habitat, alter water flows, and increase sedimentation. These pressures result in negative impacts on the ability of salt marshes to provide refuge and nursery areas for fish and shellfish species, food for a number of animal (e.g., rodents, snails, crustaceans), bird and insect species, as well as resting, feeding and breeding areas for migratory birds. Salt marshes are also important in removing contaminants, nutrients and sediments as water enters the marine environment from upland activities (Taylor 2008). A reduction in the amount and quality of fish rearing grounds has a negative impact on commercial and recreational fisheries. Protection of coastal properties from erosion, recreational values (bird watching, hunting), and education values may also be affected.

4.2 MUDFLATS

The filter-feeding organisms (e.g., clams, worms) and other invertebrates found in mudflats, provide an important trophic link between primary coastal productivity and higher tropic levels in the marine food chain. The pressures on mudflats also hinder their ability to provide important shorebird feeding areas. Coastal foraging mammals also feed on mudflats, including racoon and mink, and they provide important spawning habitat for spider crabs and horseshoe crabs (Tyrrell 2005). Mudflats support important commercial fisheries for softshell clams, quahogs, bloodworms and sandworms (Roman et al. 2000). The deposition and accumulation of contaminants in mudflats has an impact on harvests of these species. Inputs of nutrients from agricultural and sewage sources can lead to massive growth of bottom algae, and the subsequent biological oxygen demand (use of oxygen to decompose organic materials) can further stress the infaunal community and have a negative impact on harvested species (Tyrrell 2005).

4.3 SEAGRASS BEDS

It has been estimated that 50% of the seagrass beds in the North Atlantic have disappeared over the last century (Short, as cited in GOMC 2004). The specific reasons cited for the decline include the pressures associated with nutrient overloading (leading to light depravation and smothering by algae growth) and damage from boats, dredging activities, and drag fisheries (GOMC 2004). In the Gulf of Maine, resulting impacts are believed to be greater in southern Gulf and in the upper reaches of estuaries (GOMC 2005).

The most important environmental factor for the growth and survival of seagrass is light limitation (GOMC 2005). High nutrient levels, such as would occur due to runoff from agricultural fields and urban areas, promote the growth of phytoplankton and macroalgae over seagrass (Roman et al. 2000). Harbour dredging typically focuses on the same areas that support seagrass, resulting in removal and smothering of adjacent areas with sediment (Tyrrell 2005). Impacts on seagrass beds are largely non-site specific (GOMC 2005).

These impacts lead to a reduction in the ecological functions provided by seagrass habitat. This includes the ability of seagrass beds to: trap suspended sediment and reduce the load entering the marine environment from land; absorb dissolved nutrients; provide refuge, spawning, feeding and nursery areas for many species of shellfish and fish (e.g., cod and winter flounder juveniles are found in eelgrass habitats; Tyrrell 2005; GOMC 2005); serve as a source of vegetative detritus for marine filter-feeding organisms; and provide habitat space for a number of coastal species, including scallop and American brant (GOMC 2005). The socio-economic impacts include: a reduction in the extent to which coastlines are protected from erosion; decreased nursery areas for commercially important species (e.g. cod and flounder); and a decrease in recreational opportunities (e.g., for bird watching and hunting; Tyrrell 2005).

4.4 KELP BEDS

Kelp beds provide habitat for numerous marine species. Bryozoans (moss animals) and hydrozoans (related to corals) live attached to kelp blades; under the canopy, fish and shellfish species find protection from predators, and microhabitats around the holdfasts (roots) provide habitat for starfish, brittle stars, polychaetes, and snails (Tyrrell 2005). Kelp is an important food source for sea urchins, molluscs and crustaceans and is a key provider of primary production to the ocean waters (Tyrrell 2005).

With the deterioration or destruction of kelp beds, these ecological functions are adversely impacted. Socio-economic impacts include negative effects on commercial fisheries (e.g., sea urchin, which is dependent on kelp as a food) and reduced protection of shoreline from erosion because of the ability of kelp to absorb wave and tidal energy.

4.5 SHELLFISH BEDS

Fishing has a direct impact on the size, community structure and habitat structure of shellfish beds. This is particularly evident with the use of more destructive fishing gear, such as dredges (GOMC 2005). The installation of coastal infrastructure, such as wharfs and marinas, also results in the direct removal and alteration of shellfish bed habitat. Persistent organic pollution and metal contamination are also a particular concern with respect to shellfish, which as filter feeders concentrate these pollutants within their flesh (GOMC 2005; Tyrrell 2005). A number of ecological functions are adversely impacted. Shellfish beds provide habitat for many species (e.g., fish, molluscs, polychaete worms and various crustaceans; Tyrrell 2005). Broadly, the habitat provides support for biodiversity and as a direct source of food for fish, lobster, predatory snails, and seabirds. Shellfish also play an important role as filter feeders in the food chain. With respect to socio-economic impacts, oyster and mussel reefs offer protection to shorelines from erosion. Shellfish have substantial value directly as a fishery, as well as indirectly supporting the biological production of other fished species.

Photo: Jessica Langlois

Monitoring of concentrations of metal and organic contaminants in the blue mussel (*Mytilus edulis*) is conducted by the GulfWatch Program for the Gulf of Maine Council (LeBlanc et al. 2009). Many of these contaminants have been shown to bioaccumulate and biomagnify throughout the food web, and can adversely affect the growth, reproduction, and survival of marine organisms; thus, contaminant levels in marine organisms serves as a useful indicator of ecosystem health. LeBlanc et al. (2009) concluded that the status of contaminants in near shore areas around the Gulf of Maine suggests that the more heavily developed areas have higher contaminant levels compared to locations with smaller communities and less industrial activity. They further note that lead and mercury levels in 2008 exceeded the 85th percentile of the NOAA national dataset at several sites. Overall, organic contaminants were highest in Massachusetts and Maine (LeBlanc et al. 2009). Further information of contaminants in the blue mussel around the Gulf of Maine is available through the GulfWatch Program (www.gulfofmaine.org/gulfwatch/data/files.php) and ESIP (www2.gulfofmaine.org/esip/reporting/).

4.6 ROCKY AND COBBLE SHORE

Biophysical impacts on rocky and cobble shore habitat include reduced habitat complexity for the protection and development of a number of species (e.g., fish, molluscs, polychaetes, crustaceans), and reduced food for animals that occur along the shore, including many birds and mammals (e.g., foraging rats and mink). Bivalves living on rocky and cobble shore play an important role in the trophic food web, as a link between phytoplankton and zooplankton productivity to fish, shellfish and birds. Subtidal areas are key spawning habitat for fish species that include herring and capelin, as well as providing substrate for kelp forests. These important ecological functions are affected by resource harvesting and increases in sedimentation, water turbidity and temperature.

Socio-economic impacts include negative effects on the value of species harvested from rocky shore, including rockweed, Irish moss and dulce (with commercial harvests in Maine, New Brunswick and Nova Scotia; CBCL limited 2009). Damage to habitat from tourism and recreational use is also a concern (CBCL Limited 2009). For subtidal areas, impacted commercially fished species including lobster, crab and sea urchin; recreational values associated with beachcombing and recreational diving are also negatively affected.

4.7 SANDY SHORE

Intertidal and subtidal sandy shores have relatively low biodiversity and productivity, although some subtidal areas can be highly productive. Sandy shore and higher dune areas are important nesting grounds for some species (e.g., sandpiper); this ecological function may be affected by disturbance from humans and development of foreshore areas. Beaches are sought after for recreation, and erosion of these areas due to an increase in storm events, or due to a change in local physical oceanographic conditions associated with marine infrastructure (e.g., wharfs, seawalls, jetties), can have a substantial impact.

Photo: Joshua Bousel

Table 3 provides a summary description of the important biophysical and socio-economic impacts on some key roles that coastal ecosystems and habitats play in the Gulf of Maine.

Table 3: Summary of key biophysical and socio-economic impacts on coastal ecosystems and habitats in the Gulf of Maine.

VALUE	IMPACT
Biophysical	
Amelioration of seawater intrusion and flooding	Salt marshes, in particular, have a reduced ability to ameliorate effects of sea level rise and storm events; natural migration of salt marshes upland in response to sea level rise is inhibited with upland development and habitat fragmentation and alteration.
Mitigation of coastal erosion	The effectiveness of salt marsh, seagrass bed, kelp bed, and shellfish bed habitat to ameliorate the effects of waves and tidal action on the shoreline is reduced.
Biodiversity	Due to the identified pressures, all coastal ecosystems and habitats experience a change in species distribution and abundance.
Habitat diversity and extent	Due to the identified pressures, all coastal ecosystems and habitats experience a reduction in distribution and abundance.
Socio-Economic	
Recreation	Biophysical impacts reduce the recreation values provided by salt marshes, seagrass beds, rocky and cobble shore, and sandy shore.
Fisheries production	Biophysical impacts reduce the biological support for fisheries production, particularly with respect to salt marsh, mudflat, seagrass bed, kelp bed, shellfish bed, and rocky and cobbles shore habitats.
Coastal protection	Biophysical impacts reduce the coastal protection function provided by salt marshes, seagrass beds, kelp beds, and shellfish beds.
Education	Biophysical impacts reduce the education values provided by all habitats

5. Actions and Responses

Actions and responses to impacts on coastal ecosystems and habitats include: regulatory control of development, pollution and direct habitat disturbance; habitat protection and the creation of conservation areas; habitat restoration initiatives; and environmental mapping and monitoring to inform adaptive management. These responses all provide different avenues to conserve coastal areas, in order to maintain or enhance ecological function and ensure the provision of ecosystem goods and services.

5.1 CONTROL OF DEVELOPMENT, POLLUTION AND HABITAT DISTURBANCE

Photo: Dale Calder

The regulation of development is primarily addressed at the municipal, county and, to a lesser extent, state and provincial levels. Provisions of land use plans and municipal development plans can reduce or mitigate impacts on coastal habitats by regulating development practices. Regulatory approaches and levels of control vary substantially across jurisdictions. Pollution discharge and habitat disturbance associated with human activity is also directly controlled by federal and provincial/state legislation, policies and guidelines. For example, Section 404 of the Clean Water Act in the United States regulates discharge of dredge or fill in wetlands and unvegetated and vegetated shallows in the general waters of the US, while in Canada the Fisheries Act prohibits the harmful alteration, disruption or destruction of fish habitat. Again, there are numerous tools in place across all five provinces and states bordering the Gulf of Maine that focus on regulating a range of pollutants and wide variety of activities that can result in pollutants entering the environment or in the alteration or destruction of coastal habitat.

5.2 HABITAT PROTECTION AND CONSERVATION AREAS

The conservation of marine habitat by restricting human activities in specific geographic areas can occur through several different legal mechanisms, such as the formal designation of parks or protected areas, conservation areas, fisheries closure areas, or through the use of zoning as enabled by marine management legislation (e.g. see Courtney and Wiggin 2003). This is facilitated by various pieces of legislation at the federal, provincial/state and municipal levels. At a more local level, habitat protection programs include the designation of easements and purchase of key habitat areas.

Legislation can be targeted at species groups in coastal environments (e.g., the State of Maine shorebird habitat protection regulations) or at specific species of concern (e.g., the Canadian Species at Risk Act that allows for the designation and protection of critical habitat). At the international level, the Ramsar Convention facilitates the designation of wetlands of international importance. Table 4 lists the existing prominent conservation areas within the coastal areas of the Gulf of Maine.

Table 4: Coastal federal and state/provincial conservation areas within the Gulf of Maine.

JURISDICTION	PROTECTED AREAS Protected Areas	Wildlife Refuges, Management Areas and Sanctuaries	International Ramsar Sites
Nova Scotia	• Chignecto Isthmus Wilderness Area • Joggins Fossil Cliffs (UNESCO World Heritage Site)	• Chignecto Wildlife Management Area • Minas Basin Wildlife Management Area • Hackmatack and Round Lakes Game Sanctuary • Amherst Point Migratory Bird Sanctuary • Kentville Migratory Bird Sanctuary	• Chignecto • Southern Bight-Minas Basin
New Brunswick	• Musquash Protected Natural Area • Gooseberry Cove Protected Natural Area • Little Salmon River Protected Natural Area • Whitehorse Island Protected Natural Area	• Tantramar Marshes National Wildlife Area • Shepody Bay National Wildlife Area • Grand Manan Migratory Bird Sanctuary • Machias Seal Island Migratory Bird Sanctuary	• Mary's Point • Shepody Bay
Maine	• Wells National Estuarine Research Reserve	• Cross Island National Wildlife Refuge • Petit Manan National Wildlife Refuge • Franklin Island National Wildlife Refuge • Seal Island National Wildlife Refuge • Pond Island National Wildlife Refuge • Moosehorn National Wildlife Refuge • Rachel Carson National Wildlife Refuge	
New Hampshire	• Great Bay National Estuarine Research Reserve	• Great Bay National Wildlife Refuge	
Massachusetts	• Stellwagen Bank National Marine Sanctuary	• Monomoy National Wildlife Refuge • Nantucket National Wildlife Refuge • Normans Land Island National Wildlife Refuge • Parker River National Wildlife Refuge • Thacher Island National Wildlife Refuge	

Note: There are a large number of coastal federal and provincial/state parks within the Gulf of Maine. For brevity, these are not included as conservation areas within Table 4.

5.3 HABITAT RESTORATION

Habitat restoration is important to improve the function and provision of ecosystem goods and services from previously degraded habitats. A wide range of activities have been undertaken, typically with the involvement of both government and non-government organizations. A habitat restoration strategy has been developed for the Gulf of Maine Council (GOMC 2004). Restoration projects have been conducted and are ongoing throughout Nova Scotia, New Brunswick, Maine, Massachusetts and New Hampshire. The purpose of the Gulf of Maine Habitat Restoration Strategy is to provide a means to focus efforts on a common set of goals and objectives (GOMC 2004). The strategy details restoration opportunities and priorities for coastal habitats. Examples include the removal of tidal restrictions, ditches, dykes and fill affecting salt marshes, and reseeding and transplantation to replace lost seagrass habitat.

TIDAL RESTRICTIONS

The Bridge Creek Salt Marsh Restoration Project, within the Town of Barnstable, was one of the most complex salt marsh restorations ever undertaken in Massachusetts. The overall project consisted of replacing an existing 36-inch culvert beneath an active railroad line with a large concrete box culvert, and an existing smaller box culvert beneath a state road with a larger concrete box culvert. The completed project restored tidal flushing to approximately 40 acres of degraded salt marsh, which lies within a designated Area of Critical Environmental Concern. The total cost of the project was approximately $1.5 million, with funds provided by various private, state and federal sources, including the GOMC-NOAA Habitat Restoration Partnership.

Source: http://restoration.gulfofmaine.org/projects/

The primary activity of the Habitat Restoration Committee of the Gulf of Maine Council is through the GOMC-NOAA Habitat Restoration Partnership, which oversees restoration projects supported by that fund in the Gulf of Maine watershed (i.e., the Habitat Restoration Partnership Grants). The Gulf of Maine Habitat Restoration Web Portal serves as a central repository of information, including a restoration project inventory, guidance on project planning, and links to key background information sources. There are numerous local-level restoration programs and individual projects throughout the Gulf of Maine, the Habitat Restoration Web Portal listing over 80 project funded by Habitat Restoration Partnership Grants alone.

5.4 ENVIRONMENTAL MAPPING AND MONITORING

Environmental mapping and monitoring is important to both understand both the current state of coastal habitats within the Gulf of Maine and changes to those habitats over time. For many of the habitats discussed in this theme paper, this critical information is lacking. To help address this gap, there are several initiatives underway. ESIP, as a committee of the Gulf of Maine Council, is developing indicators for the Gulf of Maine and integrating regional data for an internet-based reporting system to support marine ecosystem monitoring. ESIP has identified six indicator areas for study: coastal development, contaminants and pathogens, eutrophication, aquatic habitat, fisheries and aquaculture, and climate change. The Habitat Monitoring Sub-committee of the Gulf of Maine Council is developing a regional strategy for monitoring coastal and marine habitats, as well as regional monitoring plans for specific habitat types. For aquatic habitats, indicators have been proposed for the monitoring and assessment of salt marsh, seagrass and subtidal soft-bottom habitats. Guidelines for restoration monitoring and long-term change analysis of salt marshes are included in Taylor (2008).

INDICATOR SUMMARY

INDICATOR	POLICY ISSUE	DPSIR	TREND*	ASSESSMENT
Location of tidal restrictions	Alteration of coastal hydrology and associated salt marsh habitat	Pressure	+	Fair
Extent and distribution of salt marsh	Effects of climate change through storm events and sea level rise; alteration and destruction of habitat due to coastal development	State	–	Poor
Extent and distribution of eelgrass	Pollution (nutrient loading) and changes in seawater properties (sedimentation, turbidity) due to coastal development and economic activity	State	–	Poor
Abundance of migrating shorebirds	Effects of climate change through storm events and sea level rise; alteration and destruction of habitat due to coastal development	State	–	Poor
Contaminant levels of blue mussel	Contamination of coastal waters due to pollution, and loss of fishery and aquaculture values	Impact	/	Fair

* KEY:
– Negative trend
/ Unclear or neutral trend
+ Positive trend
? No assessment due to lack of data

Data Confidence

- Summary-level information on the status and trends of coastal ecosystems and habitats, and on the biophysical and socio-economic impacts, is largely qualitative. Quantitative information on the distribution and extent of salt marsh and eelgrass habitat is available for the Gulf of Maine. Other quantitative statistical information is site-specific.
- Levels of confidence and error associated with indicators are determined by the resolution of the data layers within the geographic information, and by the research results of the many individual studies that comprise the database.

Data Gaps

- While there have been a number of efforts to map and describe coastal habitats, there remains a need for more a more complete inventory to inform management strategies. This includes information on habitat distribution and abundance, and ecosystem health. Others have pointed to requirements for a wide variety of ecological mapping focused on benthic habitat classification, sensitivity and biodiversity, and mapping of human uses and pressures, such as commercial and recreational fishing, coastal development, runoff and non-point sources of pollution (GOMC 2005).
- There is a paucity of information on the specific relationships between pressures and impacts (e.g., fishing impacts on benthic environments). This prevents the development of robust, quantitative measures and models that, in turn, hinders the development of effective management strategies.
- Other identified research needs include the development of information on: historic ecosystem conditions; geographic representation, connectivity, functionality and resil ience of benthic habitats; and community structure, food webs and trophic interactions (GOMC 2005).

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