EMERGING ISSUES – *CIRCA* 2010

STATE OF THE GULF OF MAINE REPORT

Gulf of Maine Council on the Marine Environment

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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.

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1. Issue in Brief

This paper discusses some of the emerging issues around the Gulf of Maine (including the Bay of Fundy). The focus is on the environment and natural resources, covering the watersheds (lands and waters), estuaries, coastal and offshore waters, and how society is responding to their care. The topics covered are not definitive as some issues may be missing and very likely, some are not yet predicted, i.e., the unknown unknowns (Garrett 1992; Myers 1995). The paper is meant to stimulate thoughtful and multidisciplinary discourse about challenges confronting the Gulf of Maine and to stimulate further decisive action for follow-up research, information synthesis, policy making, management planning, and education.

Emerging issues are defined by Munn et al. (1999) as "an issue, positive or negative, which is not yet generally recognized but which may have significant impact on human and/or ecosystem health in the 21st Century ... an emerging issue is associated with one or more of the following: a) political, social, economic , financial, institutional or technological developments that may cause changes in trends of human activities …; b) new evidence or theory that suggests potentially large environmental change, but which is currently either not widely accepted, or is considered unproven …; and c) lack of adequate policy, action or leadership on an existing issue, which may become more significant or more urgent in the future. An emerging issue is not necessarily an issue no one has heard of, or that comes as a shocking surprise". The emerging issues clearly include those of pressures (i.e., human activities), impacts (i.e., environmental change), and societal response, following the DPSIR (driver-pressure-state-impact-response) framework (see www.gulfofmaine.org/state-of-the-gulf/framework.html).

The criteria for choosing the issues include (Pederson 2009):

- Already recognized issues that need additional research and/or management and policy action;
- New or overlooked topics critically important to integrated coastal and ocean management (ICOM) and ecosystem based management (EBM) in the Gulf;
- Issues of importance to the maximum number of stakeholders in the region; and
- Issues offering opportunities for collaborative efforts.

Table 1 presents the already recognized issues that have emerging components. The paper describes some of these issues and additional new ones. Given the size of the Gulf and its ecological and jurisdictional complexity, the issues will vary in priority from place to place. As well, not all of the emerging issues are equivalent temporally, some need immediate attention and some will take decades to resolve.

Table 1: Recognised marine and coastal environmental issues in the Gulf of Maine and related emerging issues.

	KNOWN IMPACTS	EMERGING ISSUES
Aquaculture (see also Aquaculture in the Gulf of Maine)	• Pesticide and pharmaceutical use • Organic discharge • Parasitic infections and introductions • Impact of escapees on native stocks • Loss of marine space to other users	• Long-term, sub-lethal effects of the chemicals combinations (e.g., endocrine disrupting chemicals) (see also Section 3.4) • Offshore finfish aquaculture
Commercial Fisheries (see also Commercial Fisheries and Fish Stock Status)	• Overfishing of target species • Destruction of habitat by fishing gear • Entanglement of marine mammals • Bycatch • Change in pelagic trophic structure • New pathogens, with unknown human health and ecological health consequences	• Fishing "down" the food chain – impact of increased invertebrate fisheries • Emerging fisheries • Sustainable fisheries • Ecosystem–based fisheries management (see also Section 4.4)
Petroleum Exploration and Development (including transportation and LNG terminals)	• Habitat degradation and loss • Contamination of living resources • Vessel collisions with right whales	• Large increase in marine traffic • Impact of a large spill in the Gulf of Maine (particularly on shallow banks) • Exploration of Georges Bank (see also Section 3.3)
Mining (minerals and aggregates)	• Habitat destruction and degradation • Contamination of rivers, lakes, wetlands and estuaries • Degradation of beaches • Decreased water and sediment quality	• Offshore exploration and mining (see also Section 2.3)
Coastal Development and Land Use (see also Coastal Development and Land Use)	• Degradation and destruction of coastal habitats • Loss of species diversity • Decreased water quality • Decreased air quality • Loss of public access to resources	• The effect of coastal development combined with climate change and sea level rise • Changes in demographic patterns
Habitat Change (see Coastal Ecosystems and Habitats; Marine Ecosystems and Habitats)	• Degradation and loss of habitats including: eelgrass beds, salt marshes, riparian habitat, beaches, mud flats, etc. • Loss of biodiversity	• The effect of coastal development combined with climate change and sea level rise • Preservation of man-made habitats of cultural and economic significance (e.g., Acadian dyke-lands) • Increased network of protected areas • Increased protection of species at risk (see also Section 3.2)
Invasive Species (see Invasive Species)	• Loss of biodiversity • Widespread degradation of habitats • Economic and aesthetic impacts	• Introduction of new species, with unknown ecological and economic consequences
Industrial Chemicals and Effluents (see also Toxic Contaminants)	• Decreased water and sediment quality • Acute toxicity leading to mortality of organisms • Chronic sub-lethal effects on organisms • Bioaccumulation of toxic chemicals	• New synthetic chemicals • Cumulative sub-lethal effects (see also Section 3.4)
Eutrophication (see Eutrophication)	• Oxygen depletion in fresh and marine waters • Aesthetic impacts • Decreased recreational value • Health risks due to toxic algal blooms	• Interaction of increased nutrients and increased algal blooms with warming waters due to climate change
Microbial Pathogens (see Microbial Pathogens and Toxins)	• Human health impacts • Closure of bathing beaches • Shellfish closures • Uptake in the food chain	• New pathogens, with unknown human health and ecological health consequences

2. Pressures Factors Influencing Trends in Human Activities

2.1 Changes in Coastal Economies

Economies around the Gulf have been changing over recent decades, perhaps more so in Nova Scotia, New Brunswick and Maine than in the southern Gulf, with its larger population base. Huntley (2001) states: "[w]hile resource extraction and processing remain the backbone of maritime economic activity in the Gulf, new uses are quickly growing. Sailing, whale watching, and other non-extractive activities draw millions of visitors to the region every year, supporting a burgeoning tourist economy. Many coastal towns are shifting away from fishing-based economies". North of metropolitan Boston, the driving forces behind the economy are now light manufacturing, retail industries, information technologies, tourism, ecotourism and aquaculture, with fishing a relatively small contributor. For example, the last sardine cannery recently closed in Gouldsboro, ME, bringing an era of canneries to an end (Canfield 2010). Exceptions to this pattern of economic sustainability are the valuable lobster and scallop fisheries and the baitworm industry in Maine and the Bay of Fundy, ship building in several communities, and the heavy industrial development of metropolitan Saint John, NB.

The emerging issue, as shown by the 2007–12 Action Plan (GOMC 2007), is one of "supporting environmentally sustainable, marine-based, economic activity", such as tourism, aquaculture, and marine energy development. The challenge is to maximize the economic benefits while preventing, reducing or containing the negative environmental changes that may accompany such activities.

2.2 Marine Energy

Tidal power development is underway with in-place turbines being tested in the upper Bay of Fundy (Minas Channel, Minas Basin) and off Eastport, ME. The first of three experimental units was placed into the Minas Channel in Fall 2009. Potential effects of the turbines on the environment and vice versa are little understood, but are the subject of new scientific and engineering investigations begun in 2009 (as shown at the Atlantic Geosciences Symposium, Wolfville, NS, February 2010). Environmental concerns include changes in sediments patterns, effects of energy removal from the system on the tides, the direct and indirect effects of the turbines on marine species (fish to mammals), and the effects of turbine farms on local fisheries, especially lobsters (P Hinch, BoFEP, pers. comm., 2009). A turbine field of as many as 150-200 units is proposed for the Minas Channel, removing a large area from the local lobster fishery. This issue is of high priority for the Bay of Fundy, with implications for other parts of the Gulf if some of the modeled predictions of tidal change prove to be true.

The potential impacts and risks associated with offshore wind energy development and the mitigation of impacts are an emerging environmental issue in various locations around the Gulf of Maine, from near Cape Cod shorelines to the Cobequid Hills of Nova Scotia. Wind turbines located on land, and on artificial islands, such as those for the southern Gulf (e.g., the Cape Cod Bay wind field) may affect migratory land and shore birds, pelagic seabirds, bats, shipping movements and people (aesthetics, real estate prices and tourism). Large wind turbine farms are being planned for high elevations in several locations in coastal Nova Scotia. Potential impacts on both ecosystem and human health from wind installations, on land or at sea, are still being hypothesized or are under investigation.

2.3 Marine Mining

The Gulf of Maine has considerable mineral resources (besides oil and gas) including for example: mineral aggregates on the seafloor of the mid to upper Bay of Fundy; trace rare elements in sediment deposits in the Shubenacadie Estuary, Minas Basin, NS; and vast quantities of gypsum and basalt in the coastal lands in south-western Nova Scotia. For the time being, the only new land mining operation to be permitted is the new surface gypsum deposit at Hantsport, NS.

The ecological consequences of mineral extraction, especially from the bottom sediments in mid Bay of Fundy and specific river estuaries, are a potential concern. If new minerals were to be mined from the ocean floor, the concern would be the magnitude of the ecological impacts of surface aggregate removal on the benthic habitats and benthic species. Unique horse mussel reefs might be disturbed or destroyed, and removal of surface consolidated rocks and stones may lead to winnowing of the exposed softer sediments. A similar threat exists for the Shubenacadie Estuary, NS, where disturbance of the sediments by mining and resulting degraded water quality could be detrimental to the migration and survival of local fish such as shad, gaspereau, smelt and salmon, with salmon being a listed species at risk under the Canadian Species at Risk Act.

2.4 Climate Change

Implications of climate change in the Gulf region have been considered for some years (G Lines, Environment Canada, pers. comm., 2009). It has also been reviewed by other local groups (e.g., Frumhoff et al. 2007; Pederson 2009). It is now one of the priority issues for the region, with two theme papers being prepared on it as part of the State of the Gulf of Maine Report (see Climate Change). Concerns exist about sea level rise, coastal erosion, more frequent strong storms, impacts on species distributions, including exotic or invasive species, potential effects on coastal infrastructure, etc., for coastal areas, and for the Gulf's watersheds, changes in hydrodynamics of the watersheds, effects on migratory species such as anadromous and catadromous fish, and movement of pollutants into and through watersheds. As well, there could be changes in the pattern of incoming ocean currents, freshwater runoff, acidification and nutrient distributions, all potentially affecting one or more of the fisheries, coastal development and infrastructure, the timing and extent of harmful algal blooms, exotic species invasions, and the rate of spread of pathogens and disease vectors (Pederson 2009). The rate and degree of acidification (decreased pH) of the Gulf's waters is a major concern as CO_2 levels continue to increase in the atmosphere and surface waters, potentially affecting animals with shells of minerals precipitated from seawater. Because of uncertainties regarding impacts, future climate change research is focusing on both predicting and ameliorating potential impacts, and initiating adaptation strategies.

3. Impacts Environmental Change

3.1 Understanding Change in the Gulf's Ecosystem

In the Gulf ecosystem, major and probably irreversible changes have taken place in some habitats and trophic levels in the 400 years since European settlement. Some have natural causes, many do not. Changes include: the marked reduction of salt marshes due to dyking in the upper Bay of Fundy; the 200 years of ecosystem and food web changes in the Quoddy region due to land use and fishing (CCNB 2002; Lotze et al. 2004); the changes in pelagic fish species and pelagic food chains in the Gulf and on Georges Bank due to fishing, and the presence and bioavailability of highly persistent industrial chemicals in waters and sediments. The coastal and offshore ecosystems as a whole have been much changed during this time, fishing pressures, development of coastal land, and pollution being the main influences.

Various types of stresses occur in the ecosystems of the Gulf, some re-occurring and overlapping. Ecologists, fisheries biologists and ecotoxicologists have two major concerns:

- What is the resiliency of the Gulf of Maine ecosystems and their components (see Holling 1973, 2001)? Resiliency is the capacity of a system, an ecosystem or a social system to face change through adaptation, innovation or transformation (Francis 2010; Ross 2010).
- Are there recovery thresholds and what are they? Thresholds are levels of a stressor (e.g., chemicals, nutrients, habitat change) above which recovery from the change or disturbance does not take place. This concern is currently expressed in terms of tipping points and tipping elements in ecosystems (Lenton et al. 2008; NSF 2009; McCarthy 2009; Foley 2010). Tipping elements are defined as "subsystems of the earth system that are at least sub-continental in scale and can be switched, under certain circumstances, into a qualitatively different state by small perturbations" (McCarthy 2009). A classic example of a non-recovering

> species and its pelagic ecosystem is the east coast cod (*Gadus morhua*) and the north-west Atlantic; fish stocks on the Grand Banks, once considered inexhaustible, have not recovered from collapse caused primarily from over-fishing.

An example of incremental or cumulative change due to human activity in the Gulf ecosystem over the past 100-150 years is change caused by the construction of dams on rivers, and causeways and other barriers on estuaries, throughout the Gulf of Maine watersheds (Wells 1999, 2000; Percy and Harvey 2000). Dams and causeways, collectively called barriers, have had direct and indirect effects on the movement of fish upstream and downstream in waterways, with effects of their populations (e.g., middle Bay of Fundy salmon, and eels), as well as many other effects (e.g., changed sedimentation patterns, hydrologies and water quality). Dam and causeway impacts remain throughout the Gulf as a system-wide threat to the health of estuaries and rivers, and need to be continually addressed and mitigated, as at Cheverie Creek, NS, and several restored rivers in Maine and Massachusetts.

Another example is the incremental effect of clear-cutting forests over the past 200+ years. The effects on watersheds include changed water quality, with detrimental effects on salmonids and other migratory fish. Although now more controlled in the New England states, this method of forest harvesting still occurs in New Brunswick and Nova Scotia, with bare recognition or control of the side effects on aquatic ecosystems and the whole landscape. A need exists to inventory and document such region-wide changes, consider their interactions and impacts, and implement strategies to combat them. In the past, economies have taken precedence over ecologies, often with large-scale effects on the Gulf's ecosystems as a whole; the challenge is to find a better balance.

The Gulf of Maine offshore ecosystem is not stationary; it changes naturally over time (J Hare, RARGOM 2009). Changes in the Gulf may be of three kinds: incremental and slow; disruptive and faster; and transformative, involving changes in the structure of relationships across scales (Gunderson and Holling 2001; Holling 2001; Holling, as cited in Ross 2010). Some of these changes are related to basin-scale, upstream forcing events involving Labrador Current and Gulf Stream systems, which will affect lower trophic levels in particular (J Hare, RARGOM 2009). In the Gulf of Maine intertidal biota, the spring blooms of phytoplankton, the nepheloid layer (bottom water with high levels of sediment), the nutrient regime, and biodiversity in general, have changing patterns, and are all currently under study to detect and interpret unusual variation if and when it occurs (RARGOM 2009). A key recent observation is that the nepheloid layer moves algal cysts around the Gulf, influencing locations of toxic algal bloom breakouts (C Pilskain and B Keafer, RARGOM 2009), a clear linkage of current science to a major health and economic concern. The Gulf of Maine Research Institute

(GMRI) in Portland, ME, has been set up with the goal of understanding and predicting change in the Gulf of Maine ecosystem, and the factors that drive that change (GMRI 2009).

3.2 Protecting and Conserving Habitats and Biodiversity

Protecting, conserving and restoring marine habitats, and describing, studying and protecting the biological diversity in the Gulf remain top management priorities (GOMC 2004; Palumbi et al. 2009). These priorities are fundamental to maintaining the overall health of the region. Salt marshes are identified as being of great concern (GOMC 2004) due to large losses caused by unmanaged coastal development in the southern and central coastal Gulf of Maine, and by historical dyking in the middle to upper Bay of Fundy. Salt marsh restoration is a priority in several locations, from southern Maine's coastal reserves, which are encircled with urban development, to New Brunswick (Musquash) and Nova Scotia (Cheverie Creek; Walton River) where the aim is to open up estuaries. There are several needs: to understand climate impacts on restoration efforts; to strengthen policy and regulatory frameworks related to salt marshes; to monitor progress; to have databases for projects, and to communicate continually to the public about the ecological roles and value of salt marshes (Anon. 2007).

Submerged aquatic vegetation (e.g., eelgrass) is also a priority for protection (GOMC 2004), as are mudflats, shellfish beds, and shallow to deep benthic habitats. There is a need "to determine the scientific criteria for measuring habitat integrity – both quality and spatial extent – at various geographic scales" (GOMC 2004). Habitat conservation and restoration remain a priority for the Gulf of Maine Council on the Marine Environment (GOMC 2001, 2007). The challenge is one of keeping up momentum on the issue, identifying new sites for research and conservation attention, monitoring indicators of condition, and managing the issue comprehensively for the region.

Habitat protection and maintaining biodiversity are very closely linked, and the rich diversity of organisms of the Gulf requires full description and awareness of the need to protect their habitats from human-induced alterations. Not surprisingly, biodiversity is threatened by habitat modification and loss, as well as by non-indigenous (invasive) species, environmental contamination and pollution, and nutrient enrichment (GOMC 2004). The needs identified in a 2004 user survey are still valid, including: evaluation of biodiversity on a regional scale; evaluate effects of habitat change on diversity, and relate biodiversity to ecosystem function and resilience (NRC 1995; GOMC 2004). The evaluation of biodiversity on a regional scale is being carried out by the Census of Marine Life program down the Discovery Corridor (Palumbi et al. 2009; Worm et al. 2006; GOMA 2008; L Incze et al., RARGOM 2009). The challenge is how to conserve and protect biodiversity that is incompletely known, and how this incomplete knowledge affects our ability to apply ecosystem approaches to environmental and fisheries management; i.e., how do agencies apply EBM for an incompletely known and continually changing ecosystem? Mechanisms are also needed to ensure that research, description, and inventory of biodiversity are continued with maximum support and expertise.

Impacts of Gulf of Maine fishing practices on ocean habitats and biodiversity, including non-target species, need to be understood and ameliorated. Together with climate change, fishing is recognized as a major driver of ecosystem change on the oceans (Cohen and Langton 1992; GMRI 2009; Worm et al. 2009). Society needs to reduce this 400 year-long pressure on the biodiversity of the Gulf. The region is well situated with its marine institutes to study this stressor and make recommendations for reducing impacts (e.g., GMRI in Portland, ME).

Another emerging area of biodiversity research addresses the social and institutional dynamics of endangered species protection and recovery. In Canada, it is too early to note the social and ecological impacts of new legislation (i.e., the Species at Risk Act). One can anticipate substantial links with existing work on the following: survival of coastal communities; the sustainability of fisheries systems including human as well as marine populations; the inter-generational tradeoffs involved in protecting species or regions on which existing communities depend for their livelihoods; and the growing body of work applying the precautionary principle to coastal issues (OMRN 2003). Two other biodiversity research areas are priorities:

- Related to fisheries, a need exists to better understand intra-specific biodiversity, a formerly ignored characteristic of exploited populations (Stephenson and Kenchington 2000).
- Related to the deeper parts of the Gulf of Maine, the deep sea biodiversity of the Gulf is not well understood, especially species associated with hard corals in the deep canyons and abyssal areas.

3.3 Hydrocarbons (Transport and New Sources)

General shipping and the bulk carriage of hydrocarbons in tankers, including crude oil, refined products and liquefied natural gas (LNG), occurs in the Gulf (see The Gulf of Maine in Context). This presents ecological risks due to operational or accidental discharges and spills (e.g., loss of the Irving barge *Shovel Master* in November 2008 off south-western Nova Scotia), accidental explosions, and ship strikes on marine mammals. The shipping lanes into the Bay of Fundy have been changed recently by the International Maritime Organization (IMO) in response to concerns about ship strikes on right whales during the summer and early fall. An emerging issue is the capacity of the outer Bay of Fundy to withstand the impacts of LNG tanker traffic, should ships be allowed to transit Head Harbor Passage en route to coastal Maine. The impact of increased shipping traffic overall on marine mammals, particularly right whales, as the regional economy grows and ports such as Boston, Portland and Saint John become busier, is uncertain.

The oil and gas issue, a major concern the Gulf in the 1980s, will recur soon due to renewed interest by the oil sector in further developing regional resources. The Georges Bank moratorium has been reconsidered in Canada, with an extension to 2015 now decided. Ecological risks associated with oil and gas exploration and development in the offshore are well understood environmentally and economically due to extensive research and reviews since the 1970s, and considerable experience in the offshore worldwide. Along with operational discharges, spills, blowouts at the well head and pipeline breaks are all possibilities (GESAMP 2007), and risks increase for off-shelf, deep-water operations, as shown by the BP Deepwater Horizon blowout in the Gulf of Mexico, April 2010. In the upper Bay of Fundy, gas reserves sit under coastal lands, but no attempt has yet been made to further explore them. Finally, this issue also concerns operational and accidental oil spills of varying size, a continuous risk given the numbers of tankers and other ships transporting crude oil and refined products to and from Saint John, Portland and Boston. The ecological risks are well understood, emergency response organizations are in place, but there is great reliance on technology to reduce risks and manage accidents. The ecological risks are real, especially at the entrance of the Bay of Fundy during the summer months when whales such as the northern right whale, finbacks and humpbacks, and other marine mammals, frequent the area, and in the southern Gulf in areas of high biodiversity (Stellwagen Bank and Georges Bank). Also, seabirds and shorebirds frequent the Gulf region in huge numbers, seasonally or year-round, and they are highly vulnerable and sensitive to oil spill events.

Another emerging issue is the impacts of oil and gas pipelines in the Gulf if they are developed to bring oil and gas resources from the Scotian Shelf and Georges Bank. Pipelines are only partially buried on the bottom, leading to potential interference with the movement of benthic species (e.g., lobsters and fishing gear). Pipelines were considered an emerging issue in an ocean zoning forum in 2002 (Courtney and Wiggin 2003).

3.4 Chemical Contaminants (Fate and Effects)

The Gulf is exposed to a wide range of toxic chemicals, including persistent organic pollutants (POPs), as shown by: the ongoing Gulfwatch monitoring program with blue mussels, *Mytilus edulis* (Chase et al. 2001); studies on marine mammals (Shaw et al. 2006, 2007, 2008); studies on specific inputs of pesticides and therapeutics from salmon aquaculture facilities (Burridge et al. 2000; Wells 2010; M. Burt, University of New Brunswick, pers.comm., 2010); and recent reviews (Wells et al. 1997; Jones, cited in Pesch and Wells 2004; Percy 2006, 2008; Pederson et al. 2009, in prep.). The Gulf's ecosystems are still exposed to low levels of polychlorinates biphenyls (PCBs), dichlorodiphenyltrichloroethane

(DDT), DDT residues, and organotins, decades after banning their use. Mercury, from automobiles and industrial sources such as coal-fired electrical generating power plants, has accumulated in pelagic food chains and its risk (levels of exposure, potential toxic effects) to biota is being investigated (GCH Harding, Bedford Institute of Oceanography, pers. comm., 2010). Many persistent and bioaccumulative industrial chemicals in the Gulf's ecosystem are likely not yet characterized for risks to biota and human health (Shaw et al. 2006, 2007, 2008; Gulfwatch Committee, pers. comm., 2010), as they are being found elsewhere. These would include nanomaterials, plasticizers (phthalates), toxaphenes, alkylated phenols, polybrominated diphenyl ethers (PBDEs), silicon-based compounds, and other POPs. Concerns about endocrine disrupting chemicals (EDCs), such as pharmaceuticals, estrogens and personal care products, are recent and evidence of their discharge exists from analyses of raw and treated sewage. There is a need to ensure that sufficient monitoring across key species and food chains occurs for these substances, and that additional marine environmental quality guidelines are established in both countries to interpret the risks of detected levels, for both ecosystem and human health.

A long-term issue for the Gulf, and a theme running throughout the GOMC action plans, has been reducing the impact of land-based activities on coastal organisms and ecosystems. In this context, there are concerns of the ecological risks associated with new chemicals primarily originating from point sources (industrial, home, municipal) and non-point sources on land (agricultural lands, managed forests). Emerging chemicals would include those listed above, as well as atrazine (a common herbicide), bisphenyl a (a widely used component of plastics), dioxin like compounds, non-ionic organics, triclosam (an antimicrobial agent), and the myriad of trace chemicals found in municipal sewage effluents.

Estuarine and near-shore waters are a dynamic chemical soup of very low (ng/l or µg/l) levels of hundreds of synthetic chemicals, from households, industries, and municipal sources. There is generally little knowledge about their fate, bioavailability and toxic effects, direct (lethal and sublethal), indirect (sublethal), and interactive. There is a special need to characterize the risks to biota in the heavily populated coastal areas of Boston, Portland and Saint John, and around the prolific salmon aquaculture sites of southwestern New Brunswick and northern Maine (Haya et al. 2001; Hargrave 2005; Halwell 2008).

Environmental problems associated with industrial chemical and effluent discharges have been studied and acted upon from a regulatory perspective for almost 50 years, involving government and industry in both the US (under the National Pollutant Discharge Elimination System) and Canada (under the Fisheries Act and the Canadian Environmental Protection Act, amongst others). However, chemicals still enter watersheds from many upstream industrial operations (e.g., pulp mills, forestry operations with pesticides, and municipalities). Along the coast, sewage effluents enter the Gulf from several hundred sewage treatment plants, and from untreated sources. Boston now has an advanced tertiary treatment plant with offshore discharge for its six million residents, with a corresponding improvement of the water quality of Boston Harbor and Massachusetts Bay. Refineries discharge treated but contaminated wastewaters into the Bay of Fundy, at Saint John, and into the southern Gulf. Trace chemical monitoring by the GOMC Gulfwatch mussel monitoring program shows that the inshore ecosystem is exposed to a myriad of toxic chemicals (the Environmental Protection Agency, EPA, standard list). Other persistent industrial chemicals that are not monitored routinely are shown to be present from research studies (e.g., PBDEs in seals; alkylphenols in mussels; mercury in the marine food chain). The emerging issue associated with persistent chemical contaminants and other characteristics (e.g., high temperature, high biological oxygen demand, low salinity) of municipal and industrial effluents is that the overall ecological risks of low level chemical exposure in the Gulf are largely unknown.

3.5 Emerging Diseases in Marine Organisms

Marine diseases, naturally occurring and induced by introduced species and pollutants, can affect invertebrates, fish, turtles, birds, and marine mammals in the Gulf. Some emerging diseases in the sea are also linked to climate warming (Harvell et al. 1999, 2002). Examples include avian influenza, scallop and lobster diseases (hence affecting valued fisheries resources), and various pathologies in other molluscs (mussels) and fish such as flounders, including malignant tumours. Marine diseases are generally more prevalent near industrialized and urban areas (GESAMP 1990), and downstream from such urbanization, as with the beluga whales in the St Lawrence River estuary. Mortalities may occur, especially in areas of high levels of chemical contamination. Little is known about this problem in the Gulf, except that summarized by Epstein et al. (1998). A marine organism disease survey of coastal sites in the Gulf would establish a data base on the types and frequencies of marine diseases across a range of indicator organisms, with a focus on higher trophic level species that are being studied already (e.g., salmonids, striped bass, flounders, sharks, turtles, seabirds, shorebirds, seals, porpoise, whales).

3.6 Addressing Cumulative Effects of Multiple Stressors

Cumulative change or impacts measurement is an emerging issue for two reasons: it is a proxy for overall coastal condition and it is complex and multi-faceted. In the Gulf of Maine many coastal areas are declining in health due to overuse (Pesch and Wells 2004). There is continued growth of coastal human populations and development, traditional and new fisheries, the tourism sector, heavy industrialization, and aquaculture, as examples of stressors. All of these occur against a backdrop of the subtleties of climate change.

Cumulative effects are due to many human uses of the environment occurring together, or sequentially, in the same location. Stressors often function at low levels, acting with different modes of action, at different spatial and temporal scales, on different structural and functional components of the exposed ecosystems. Cumulative change or effects in coastal watersheds and waters are difficult to observe or measure, either spatially or temporally, without large, long-term, multiple variable/stressor databases. Exceptions are the cumulative impacts of coastal development (measured by photography or mapping surveys over decades), shellfish bed closures (monitored annually for decades), and reductions in certain species (e.g., mid-bay population of Atlantic salmon in the Bay of Fundy). Generally cumulative change/impacts are subtle, not visible (in the Gulf of Maine itself) and require sensitive, continuous measurement.

Two examples illustrate the complexity but urgency of addressing this issue:

- Continued massive coastal development (building suburbs, paving, infilling, restructuring water courses, etc) - According to the Massachusetts Ocean Management Task Force (2004), some of the future developments that may contribute to cumulative impacts in Massachusetts waters in the future are: "energy facility development; desalination plants; sound pollution; increasing shellfish aquaculture and fish farm development; and continued construction of docks, piers and floating hotels".
- Effects of single sector fisheries - In Canadian waters, one of the key challenges of integrated ocean management is assessing the cumulative impacts of fisheries on the Gulf's ecosystems (F. Scattalon, RARGOM 2009), the limitations being the scale of effects and availability of related data.

Both examples illustrate the daunting task of being able to detect, control and reduce cumulative effects in Gulf's waters. There is a need to instruct managers and policy makers on the dimensions and complexity of measuring the effects of multiple stressors and a need for improved methodologies and data for conducting cumulative impact assessments (GOMC 2004).

4.1 Information Management

The need to improve regional information management and dissemination is an ongoing one (GOMC 1991; RARGOM 1997). "The 21st Century will be known for knowledge-based integrated management of ocean resources, that portends a new role for marine science" (Pickrill, in Noji et al. 2006). The Gulf region is an information rich area due to over 150 years of work at many universities, research institutes, and community based organizations (Backus and Bourne 1987; Pesch and Wells 2004).

RARGOM (1997) recommended that "regional organizations should establish, maintain and enhance the information infrastructure useful to managers". Since that report, many databases and information sources on the Gulf have become available, but they remain dispersed and uncoordinated, the efforts of ACZISC and COINAtlantic (Halifax, NS), the GOMC information committees and the Bay of Fundy Ecosystem Partnership (BoFEP) notwithstanding. This situation was obvious during the review of GOMC publications (Cordes et al. 2006), and the identification of Gulf information sources (Parker et al. 2007). A linked network of the many existing and developing repositories is required to offer direct searching capability and retrieval of information.

Efficient and timely access to the ever expanding information base on the Gulf of Maine is requested by program managers, policy makers, educators, and researchers, for rapid resolution of issues. This need has also been identified by the Millennium Ecosystem Assessment (MEA 2005) and COMPASS (2007). The Fundy Information Collaboratory (Toms 2007), underway by BoFEP, shows promise as a pilot information project showing what the Gulf needs. Information management has increased recognition as a key emerging issue for the sustainability of the Gulf and other coastal and marine waters (see also www.eiui.ca). New information management techniques are available for use within and between studies and programs; these could include social networking, participatory GIS, and on-line mapping (P Boudreau, COINAtlantic, pers. comm., 2010).

4.2 Changes in Ocean Governance

A major challenge is how to move towards integrated coastal and ocean management in the Gulf against the backdrop of regional jurisdictional and institutional complexity (RARGOM 2009). Numerous governance models are at play simultaneously in the Gulf of Maine, particularly with five provincial/state jurisdictions and federal involvement (e.g., GOMC, fisheries and ecosystem-based fisheries management, the South West New Brunswick Resource Plan, provincial and state coastal policies, etc.).

The importance of this issue is reflected in how effective the institutional and operational arrangements are in the Gulf of Maine for responding to environmental crises. The US and Canada are well organized federally to counter oil spills, and cooperate across the border on monitoring certain threats (e.g., harmful algal blooms), but the situation is uncertain for other threats. This is important in the context of some of the emerging issues discussed in this paper (e.g., new LNG terminals and tankers, chemical tankers, bulk carriers, fish diseases, and aquaculture impacts).

4.3 Practicing Integrated Coastal and Ocean Management

Although coastal and ocean management is clearly a priority for Gulf of Maine managers (GOMC 2004), there is, as yet, no comprehensive ICOM framework for environmental and resource management in the Gulf of Maine. A framework could ensure that: ecosystem-based management moves forward in a coordinated fashion, with clear goals, objectives and measurable outcomes; that Gulf science be effectively linked to its policy and management, and that addressing issues such as land use and other land-based activities are operationally linked to maintaining the health of estuaries and coastal waters.

Interaction between the GOMC and the Regional Association for Research on the Gulf of Maine (RARGOM) has led to several key science-policy workshops (e.g., RARGOM 1997, 2009; Wallace and Braasch 1997). Such workshops assist in opening up "a more effective process for communicating information needs from policy makers to scientists, and for translating research results into a form that can be used to create effective coastal policy" (NRC 1995). For the Gulf, this mechanism could be institutionalized as a way of tracking progress on ICOM and charting future courses of action.

Marine access and marine spatial planning are also frontline emerging issues. Conflicts regarding marine space have already occurred. For example, there is open water fish aquaculture development along the New Brunswick (Grand Manan Island) and Maine coastlines, with concerns of impacts on local fisheries and ship movements. The mapping of coastal areas needs to be continued for formal allocation of uses. Various jurisdictions are currently investigating marine spatial planning as a tool for managing ocean space (e.g., Fisheries and Oceans Canada, DFO, National Oceanic and Atmospheric Administration, NOAA, and the State of Massachusetts). Under the Massachusetts Oceans Act, the Massachusetts Ocean Management Plan has been developed and was promulgated on December 31, 2009 (see http://www.mass.gov).

4.4 Practicing Ecosystem-Based Management (EBM) and Ecosystem-Based Fisheries Management (EBFM)

"Ecosystem-based management (EBM) focuses on managing human activities, rather than deliberately manipulating or managing entire ecosystems" (COMPASS 2007). It is also called "science-based management" for coastal managers (GOMC 2004). Much has been written about the concept and practice of EBM. In the context of the Gulf of Maine, EBM's components (principles and criteria) still need to be demonstrated and made operational. It is an emerging issue because it is promoted as a new tool for more effective marine environmental protection and conservation in the region, but is yet to be "given legs" and prove its worth. Local, small scale studies may be needed, in bays, inlets and estuaries of the Gulf to provide "understanding on how best to manage the interactions between ecology and human activities" (COMPASS 2007). The benefits of EBM still need to be illustrated in a practical sense and communicated to ocean managers and policy makers.

A cornerstone of EBM is the conservation of biodiversity. Palumbi et al. (2009) state that "conserving biodiversity should become a common aim of EBM for all agencies involved in regulating (uses of) the marine environment" (also see Section 3.2). In Canada, Fisheries and Oceans Canada has taken this description of EBM one step further; it considers "that the three main pillars of EBM from a science perspective are biodiversity, productivity and habitat" (R Stephenson, St Andrews Biological Station, pers. comm., 2009). To ensure that scientific programs contribute to EBM meaningfully and in a timely fashion, Stephenson (RARGOM 2009) described "the need for an umbrella science plan for the Gulf of Maine, with nested plans for three managed activities – metrics, support tools, and methods for evaluating cumulative effects".

Promising tools of EBM include modeling of ecosystem structure and function, habitat mapping, ecosystem level assessment of the Gulf's health, and operational decision support systems (R O'Boyle, RARGOM 2009). It involves getting the Gulf's jurisdictions to move ahead on EBM (M Fogarty, RARGOM 2009). According to Pederson (2009), "NOAA has adopted an ecosystem-based approach to management of the US coastal and marine ecosystems". To support this "the Gulf of Maine Regional Ocean Science Council will identify research efforts to improve integrated, science-based, ecosystem level management in the Gulf of Maine" (Pederson 2009). In summary, the pillars of EBM could be information management, science (biodiversity, productivity and habitat), and support systems, tools and methods. The issue is to agree on these EBM components and move ahead operationally and cooperatively.

The trend within the fishing community in the Gulf is to adopt EBFM (NEFMC 2005). Amongst the emerging issues of EBFM are the needs for "integrated, multi-fishery protection of sensitive habitat, quantifying links between habitat and productivity, and obtaining more information on food webs, particularly geographic and seasonal information on predator-prey relationships". In support of EBFM, seabed mapping is a useful tool for "a greater understanding of spatially and temporally explicit ecosystem components, processes and services. A habitat classification scheme, covering water column and bottom, would aid the process of developing a functional equivalency of habitats for fished and non-fished areas" (Noji et al. 2006). A guiding EBFM framework could help set priorities and integrate research, habitat classification and mapping activities.

A revitalized approach to EBFM in the Gulf is needed (S McGee, RARGOM 2009), including "adequate monitoring across fisheries, flexible management plans, improved inter-jurisdictional coordination, and resource sharing". Given the historic impact of fisheries on the Gulf's marine ecosystems (biomass removal, ecosystem change, effects of gear, ship-related pollution), communication and operational collaboration between practitioners of EBFM with those of EBM, ICOM and marine protected areas (MPAs) should occur. Only in this way will there be assurance of sustained abundance, resilience and diversity of the Gulf's fisheries and non-fisheries species in intact ecosystems (M Fogarty, RARGOM 2009), albeit greatly changed ones.

4.5 Promoting Protected Areas in the Gulf

There are many protected coastal areas around the Gulf, from the Cape Cod National Seashore and Stellwagen Bank National Marine Sanctuary off Massachusetts, to the coastal reserves and parks of coastal Maine, to the Fundy National Park and the provincial parks of both Canadian provinces (e.g., Five Islands Provincial Park, NS; New River Beach Provincial Park, NB). There are also national and international wildlife reserves in the upper Bay of Fundy. Some of the protected areas are official MPAs under the Oceans Act (Canada), such as Musquash Marsh, near Saint John, NB. Some are simply designations, without legal protection, such as the Fundy Biosphere Reserve centred on Chignecto and Shepody Bays, and the Right Whale Sanctuary at the mouth of the Bay of Fundy. Coastal protected areas have been shown to work in many locations, protecting fish populations and specific ecosystems such as coral reefs. Protected areas should include representative and critical benthic habitats, supported by GIS and ocean mapping tools and services (Lubchenco et al. 2003; Noji et al. 2006), as well as fish closure areas, covering critical habitat for growth and reproduction (Noji et al. 2006).
In the Gulf, there is currently an uncoordinated patchwork of the various areas, established with specific objectives (e.g., protection of mudflats and salt marshes, and protection of migratory shorebirds, whales, and islands, etc.). The emerging issue is the need to officially create a network of protected areas. A network would make it possible to determine if the areas collectively are offering sufficient protection of critical habitats, species at risk, and resource species across the Gulf, and if and where other areas are needed. An outstanding question to address is whether migration corridors of various species are being adequately protected by such a network, as many species move in and out of the Gulf seasonally (e.g., fish, turtles, birds, mammals). As well, critical habitats for reproduction, nursing, feeding and

resting need to be part of the network (e.g., mudflats, wetlands, offshore upwelling areas). Given the usual size restrictions to protected areas, a network of critical coastal habitats is essential to the health of the Gulf of Maine.

4.6 Recognizing Links between Ecological and Human Health

The connections between human health and ecosystem health are well recognized (Di Giulio and Monosson 1996; Epstein et al. 1998; Wells 2005, 2009; Myers 2009). Recent ocean and human health initiatives, in the US and elsewhere, make the case for maintaining healthy oceans primarily through concerns for human health protection, especially through safe seafood and clean water. Responsible agencies state that public health protection depends in part on living in healthy and functioning ecosystems. Although anthropocentric, this approach resonates well with the public and policy makers and there is a need to articulate this approach in the Gulf region. The obvious and well-known associations between human health and ecosystem health are with molluscan shellfish safety (i.e., absence or acceptably low levels of pathogens, algal toxins and chemical contaminants), and with coastal water quality safety (i.e., swimming and boating). Other associations are air quality, the quality of other foods (e.g., fish, crustaceans), the importance of aesthetics of the coastal environment to the public generally, and effects of climate change on the welfare of coastal communities and their infrastructure. This emerging issue has a number of immediate research needs, such as monitoring and modeling phytoplankton, contaminant and nutrient patterns in coastal waters year-round in order to predict harmful algal bloom occurrences in advance; interpreting the health significance of trace organic contaminants in fishery and aquaculture products; monitoring more closely the numerous pathogens detected in beach and swimming areas; controlling and reducing sewage discharges into the Gulf; and educating citizens on the issue of healthy oceans.

4.7 Understanding and Communicating Ecosystem Services

Ecosystem services are basically the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life. The challenge is communicating the concept and value of the Gulf's ecosystem services to policy makers, decision makers and the public. This should begin with the scientific community bringing the concept of ecosystem services actively into discussions of biodiversity, EBM and EBFM. The linkages between biodiversity and ecosystem services especially need to be better understood and communicated for the Gulf. For example, in general, the benefits of diversity and ecosystem services include recovery from fisheries collapses, invasion resistance, habitat protection, waste removal and recreation (Palumbi et al. 2009). The crucial links between marine biodiversity, ecosystem services and EBM in the Gulf need to be further explored and communicated to policy makers dealing with fisheries, the environment, and the economy. The value of the services of a healthy Gulf of Maine in dollars is in many billions; by other measures, the value of a healthy Gulf is inestimable.

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