Tides of Change Across the Gulf

An Environmental Report on the Gulf of Maine and Bay of Fundy

Prepared for the Gulf of Maine Summit: Committing to Change, Fairmont Algonquin Hotel, St. Andrews, New Brunswick, Canada, October 26-29th, 2004

Editors:

Gerald G. Pesch
United States Environmental Protection Agency, ORD/NHEERL/AED, Narragansett, Rhode Island

Peter G. Wells
Environmental Conservation Branch, Environment Canada, Dartmouth, Nova Scotia

Published by:
Gulf of Maine Council on the Marine Environment and Global Programme of Action Coalition for the Gulf of Maine

Tides of Change Across the Gulf. G.G. Pesch and P.G. Wells, Eds. 2004. GOMCME

Environment Canada

Gulf of Maine
Council on the
Marine Environment

Global Programme of Action
Coalition for the Gulf of Maine

TIDES OF CHANGE ACROSS THE GULF

An Environmental Report on the Gulf of Maine and Bay of Fundy

Prepared for the Gulf of Maine Summit: Committing to Change, Fairmont Algonquin Hotel, St. Andrews, New Brunswick, Canada, October 26-29th, 2004.

Editors

Gerald G. Pesch

United States Environmental Protection Agency, Narragansett, Rhode Island

Peter G. Wells

Environmental Conservation Branch, Environment Canada, Dartmouth, Nova Scotia

Published by:

Gulf of Maine Council on the Marine Environment

and

Global Programme of Action Coalition for the Gulf of Maine

August, 2004

This is a publication of the Gulf of Maine Council on the Marine Environment. For additional copies or information, please visit the Gulf of Maine Council website (www.gulfofmaine.org) or contact:

Michelle Tremblay
Gulf of Maine Council Program Coordinator
Naturesource Communications
P.O. Box 3019
Boscawen, NH 03303

OR

The Editors

Dr. G.G. Pesch
Environmental Protection Agency
Narragansett, RI

Dr. P.G. Wells
Environment Canada
Dartmouth, NS

CITATION:

G.G. Pesch and P.G. Wells. (Eds.). 2004. Tides of Change Across the Gulf. An Environmental Report on the Gulf of Maine and Bay of Fundy. Prepared for the Gulf of Maine Summit: Committing to Change, Fairmont Algonquin Hotel, St. Andrews, New Brunswick, Canada, October 26-29th, 2004. Gulf of Maine Council on the Marine Environment and the Global Programme of Action Coalition for the Gulf of Maine. 81p. www.gulfofmaine.org.

ISBN: 0-662-38258-7

Cat. No: CW66-242/2004E

Table of Contents

Preface

The Gulf of Maine Summit: Committing to Change conference, being held in St. Andrews, New Brunswick from October 26 through 29, 2004, seeks to produce a shared vision for the Gulf's future. The Gulf is at a critical juncture, with new management approaches needed to protect its valuable ecosystems for generations to come.

This report is for all those who share in the Summit's goals:

- to develop a vision and plans for improving the Gulf's environmental quality;
- to build upon the many watershed forums that have been held since 2002;
- to advocate for enhanced science, management and policy in the Gulf region;
- to celebrate 15 years of cooperation and policy development among the states and provinces bordering the Gulf;
- to integrate local, traditional, and historical knowledge with scientific knowledge to describe the Gulf's condition; and
- to invite all to join in stewardship and care for the Gulf and its living resources.

To inform discussions at the Summit, this report summarizes results from watershed forums held over the past two years and provides in-depth chapters on several key issues facing the Gulf: land use; contaminants and pathogens; and fisheries and aquaculture.

The report also highlights the accomplishments of individuals, organizations and institutions who are working hard to protect the Gulf's environment. Some of their achievements span the past 15 years, dating back to the Gulf of Maine Council's formation in 1989. The Summit affords a chance to celebrate the progress made to date and explore the opportunities that lie ahead.

Our hope is that this report will help Summit participants in their discussions and ongoing efforts to ensure the health and vitality of the Gulf, and contribute to our knowledge of how the Gulf is changing and why.

Gerald Pesch Peter G. Wells

Gerald Pesch and Peter Wells
Editors

List of Contributors

Norval Collins (Chapter 4)
CEF Consultants Limited
5443 Rainnie Drive
Halifax, Nova Scotia B3J 1P8
(ncollins@cefconsultants.ns.ca)

Elizabeth A. Della Valle, AICP (Chapter 4)
24 Pine Lane
Cumberland Foreside, ME 04110
(BethDellaValle@maine.rr.com)

Patricia R. Hinch (Chapter 7)
Nova Scotia Department of Environment and Labour
6th Floor, 5151 Terminal Road
Halifax, Nova Scotia B3J 2T8
(hinchpr@gov.ns.ca)

Steve H. Jones (Chapter 5)
Jackson Estuarine Laboratory
Allan Point
University of New Hampshire
Durham, NH 03824
(shj@hypatia.unh.edu)

David Keeley (Coordination and Funding)
Maine State Planning Office
184 State Street
38 State Street Station
Augusta, ME 04333-0038
(david.keeley@state.me.us)

Kathy Mills (Chapter 6)
Fernow Hall
Department of Natural Resources
Cornell University
Ithaca, NY 14853
(kem21@cornell.edu)

Pamela Person (Chapter 3)
Global Programme of Action Coalition
479 Back Ridge Road
Orland, ME 04472
(phppwp@aol.sm)

Gerald G. Pesch (Chapters 2, 8; Editor)
Atlantic Ecology Division
EPA ORD/NHEERL/AED
Environmental Protection Agency
27 Tarzwell Drive
Narragansett, RI 02882
(pesch.gerald@epamail.epa.gov)

Peter G. Wells (Chapters 1, 7, 8; Editor)
Coastal Water and Science Section
Ecosystem Science and Information Division
Environmental Conservation Branch
Environment Canada
Dartmouth, Nova Scotia B2Y 2N6
(peter.wells@ec.gc.ca)

Acknowledgements

Many people were involved in the preparation of this report. The GOM Summit Organizing Committee, members of GPAC and GOMC, were supportive from the beginning, starting at St. Andrews, NB, August 2003, where everyone debated the proposed project. David Keeley, Maine State Planning Office, applied his many talents, found funding for it, and assisted in many other ways. GOMC, NOAA, and EPA OW NEP are greatly thanked for their financial support. Janice Harvey (CCNB) and Barry Jones contributed substantially to the conduct of the GPAC Forums and the preparation of their reports. The authors, contractors, and reviewers are thanked for their knowledge, skills and commitment, ensuring that the report was authoritative and well written. The following persons or groups technically reviewed portions or all of this report, or arranged for the report's review. Some reviewers chose to remain anonymous. The Summit organizers are very grateful for these special efforts which include: RARGOM (re. Dr. J. Runge (UNH)); Bradford Butman, USGS, Woods Hole; Norval Collins, CEF Consultants, Halifax; Dr. David Dow, NMFS, Woods Hole; GOMC WG (re P.R. Hinch, NSDEL, Chair); Dr. Diane Gould, US EPA, Boston; Nell Halse, NB Salmon Growers Association; Elizabeth Hertz, SPO, ME; Marianne Janowicz, ELG/EGL, New Brunswick; David Keeley, SPO, ME; Patricia King, Halifax; Linda Mercer, DMR, ME; Kathy Mills, Cornell University, Ithaca; Bob O'Boyle, DFO, Bedford Institute of Oceanography; Dr. J. Ollerhead, Mount Allison University, Sackville; Dr. J. Pesch, Environmental Protection Agency; Pam Person, GPAC, Maine; Dr. Jeffrey Runge, UNH; Henry Russell, AFA/APA, New Brunswick; Dan Schick, DMR, ME; Dr. Susan Shaw, Marine Environmental Research Institute, Maine; John Sowles, DMR, ME; Michelle L. Tremblay, GOMC, Concord, NH; Dr. P.G. Wells, Environment Canada. The following individuals engaged in helpful discussions, provided original data, and reviewed section drafts to improve the fisheries chapter: Toby Balch, Karen Coombs, David Dow, Lewis Flagg, Wendy Gabriel, Stratis Gavaris, Deirdre Gilbert, Barry Hargrave, Dvora Hart, Russell Henry, J. J. Hunt, Justin Huston, Margaret Hunter, Joe Idoine, Bruce Joule, Peter Lawton, Ralph Mayo, Gary Melvin, Linda Mercer, Jerry Moles, Loretta O'Brien, Bill Overholtz, Doug Pezzack, Fred Serchuk, Cindy Smith, Stephen Smith, John Sowles, Margaret Spring, Rob Stephenson, Hal Walker, and Carl Wilson. The comments of numerous reviewers improved this chapter. The NH State Government (Portsmouth, NH), the Jackson Estuarine Laboratory (Adams Point, Durham, UNH) and the EPA Atlantic Ecology Laboratory, (Narragansett, RI) provided the editors with quiet working space for editorial meetings, and their employers (the United States Environmental Protection Agency and Environment Canada) supported the enterprise. The team at Battelle are thanked for their many efforts with layout, design of the cover, and production. The editors take responsibility for any errors in fact or interpretation.

The Editors
August 2004.

Dedication

This report is dedicated to the memory of Rachel Carson, upon the 40th anniversary of her death in 1964. Carson was a citizen of the Gulf of Maine and is a global environmental icon. She spent summers at West Southport, near Boothbay Harbour, Maine, where she gathered many ideas and facts from her experiences along the shoreline. Carson's books, including *The Edge of the Sea, Under the Sea Wind, The Sea Around Us,* and the very influential *Silent Spring,* popularized the oceans and threats to them. Our report and the Gulf of Maine Summit Conference continue her commitment to the coasts and oceans, recognizing the essential role of individuals and communities in their future protection and conservation.

INTRODUCTION

1. Documenting Change in the Gulf of Maine

The Gulf of Maine, Bay of Fundy and their watersheds (see Figure 1.1) form a coastal region in the northwest Atlantic Ocean renowned for its diverse array of wildlife habitats and natural resources. Native people have inhabited the region for 10,000 years, with European settlers joining them over the last 400 years. Increased human settlement gave rise to industrial use and resource harvesting that have depleted and polluted many of the region's ecosystems. Extensive coastal development has diminished wildlife habitat and biodiversity, introduced invasive species, and led to chemical and industrial contamination. Accelerating global climate change may intensify human impacts, alongside natural changes that are occurring within the Gulf's ecosystems (209; 210; 128).

Figure 1.1 Gulf of Maine, Bay of Fundy, and their Watersheds.

Fortunately, scientists and citizens are gaining a better understanding of how human activities are affecting the Gulf region. Recent reports document ecological conditions on Georges Bank (10) and in the Gulf of Maine (44; 99; 231; 234; 268), Bay of Fundy (92; 210), Atlantic Canada (71), and the North Atlantic (207; 235). Local governments and environmental organizations have published additional studies on many bays and estuaries within the region (e.g., 7; 103; 140; 191; 282). Collectively, these reports help bring attention to critical issues facing the Gulf and may help to improve conditions in some ecosystems. Reports can constitute a first step toward increased research and monitoring, improved education and outreach, and more effective management of natural resources.

To supplement reports already compiled, the Global Programme of Action Coalition for the Gulf of Maine (GPAC) undertook a project entitled "The Gulf of Maine Summit: State-of-the-Environment Reporting from the Bottom Up" (see Chapter 3). GPAC organized a series of watershed forums throughout the Gulf of Maine, between May 2002 and December 2003, producing reports from each region on the status of the Gulf. Working in cooperation with the Gulf of Maine Council on the Marine Environment (GOMC), GPAC has contributed information from its watershed forums as background for the Summit (see Appendix A).

Deliberations at the Summit should help guide the future programs of the GOMC and GPAC, as well as hundreds of related efforts by individuals and partner organizations throughout the Gulf region. Summit organizers hope that the conference dialogue will foster a renewed commitment to protect the Gulf region's ecosystems and natural resources through cooperative action.

To help conference participants understand the dynamic forces at work in the Gulf region, this report examines how environmental, economic and social trends are influencing three high-priority concerns in the Gulf region: land use; contaminants (including sewage, nutrients, pathogens and mercury); and fisheries and aquaculture. Carefully selected indicators for these topics help to provide historical context, reveal current conditions and track progress. Ideally, indicators are simple measures of natural ecosystems that represent complex phenomena in easily understood terms (Pesch, G., pers. comm.; also see 217 and 274). Data on key indicators are affirmed by case studies that appear in sidebars. Both the sidebars and primary text seek to present an objective look at complex issues, leaving readers free to derive their own opinions and positions.

The issues and indicators included in this report emerged from several recent workshops focused on Gulf monitoring and indicators. These discussions were part of an ongoing effort to link the region's coastal and offshore monitoring programs in order to produce more reliable data and improve environmental reporting (95; 33; 127; 80; see www.gulfofmaine.org).

Each of the three "issue" chapters draws on original data, information gathered at the GPAC forums, and current literature (along with helpful input from peer reviewers). The chapters are structured around four guiding questions that may help to mobilize public and political support for needed actions and solutions:

- What are the current conditions in the Gulf and its coastal regions?
- What caused those conditions?
- What trends do the key indicators reveal?
- What is being done to reverse negative trends and what further action is needed?

In addition to the chapters on land use, contaminants, and fisheries, this report provides a concise description of the Gulf, and highlights of the GPAC watershed forums held during 2002 and 2003. The report ends with an overview of recent successes addressing regional environmental issues, and a report summary. A glossary/list of acronyms is included to assist readers, along with a bibliography listing cited literature, recommended readings and web sites. Chapters 3 and 7 include references to additional information that can be obtained on the accompanying CD or on the GOMC website (www.gulfofmaine.org).

2. The Gulf of Maine Ecosystem

The Gulf of Maine, including the Bay of Fundy, is one of the world's most biologically productive environments (see www.gulfofmaine.org). Bordered by land to the north and west, it is nearly cut off from the Atlantic Ocean to the south and east by Browns Bank, Georges Bank and Nantucket Shoals (see figure 2.1). The Gulf of Maine represents one of the largest semi-enclosed coastal seas in North America, having a circulation pattern that resembles a large estuary (with lighter freshwater moving seaward at the surface and heavier, more saline water moving landward at deeper levels). The fresh waters that drain into the Gulf represent a vast land area (of 69,115 square miles, or 179,000 square kilometers) covering much of Nova Scotia, New Brunswick, Maine, New Hampshire, and Massachusetts, along with a small portion of southern Quebec. (see figure 1.1)

Studies have shown that the Gulf of Maine and Bay of Fundy constitute a single hydrologic system that is nearly in resonance with the semi-diurnal tides (93). Consequently the Bay of Fundy has the world's highest tides, up to 17-18 meters (55-62 feet) in the upper bay (132), with an influence all the way to Georges Bank. The Bay of Fundy's powerful tidal surges help fuel the counterclockwise movement of surface waters in the Gulf. Fresh water from the Gulf's major rivers, particularly the St. John and Penobscot, add momentum to this movement. Surface waters circle the entire Gulf in about three months.

Beyond runoff from rivers and watersheds, the major water masses entering the Gulf come through the Northeast Channel and over the Scotian Shelf. The river runoff and Scotian Shelf water are relatively fresh and cool, whereas water entering through the Northeast Channel from the Atlantic Slope tends to be warmer and salty (27).

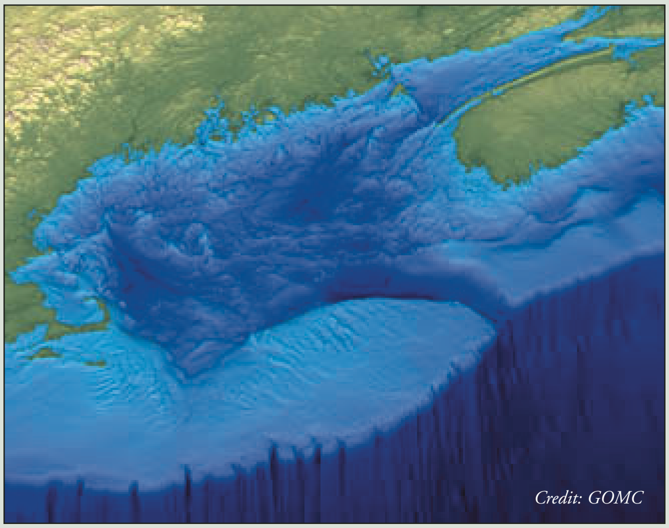


Figure 2.1. Relief graphic for the Gulf of Maine/Bay of Fundy

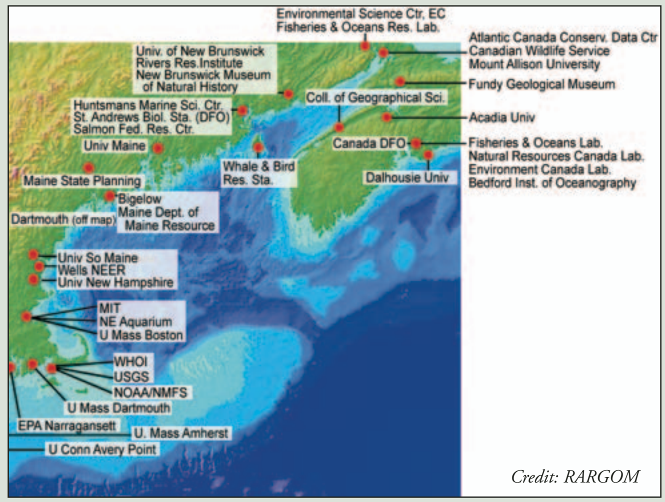
Due to its oceanographic features, the Gulf of Maine is a biologically diverse and productive sea, from its intertidal zones to its deeper waters. Where strong currents bring well-mixed, nutrient-rich water to the Gulf's shallow areas, a rich array of species thrive.

Wildlife abound throughout the Gulf Region because it is a biogeographic transition zone between boreal and north temperate biomes, where many species are at either the northern or southern limits of their range (241). Occasionally, gyres of the Gulf Stream even carry in subtropical marine species for short periods.

The biological diversity and oceanographic dynamics of the Gulf have been the subject of much research over the past century. Many core concepts in biological and physical oceanography were developed or critically evaluated in the Gulf of Maine, and some of the marine laboratories along its shores date back to the late 1800s. That tradition of thorough research continues today, with the Gulf ranking among the world's most intensively studied seas. (see Figure 2.2) For more than a decade, research has been conducted on a regional scale to better understand how the Gulf functions as a system. The Regional Marine Research Program (RMRP) and numerous scientific workshops and symposia have received support from the GOMC, the Regional Association for Research on the Gulf of Maine (RARGOM), and federal agencies in the U.S. and Canada, particularly the National Oceanic and Atmospheric Administration (NOAA). Current regional research efforts are focused on integrating monitoring programs, developing better environmental indicators, promoting a region-wide agreement to share scientific data, and using the Gulf of Maine Ocean Observing System (GOMOOS) as a regional hub for scientific collaboration and as a link to national and international Ocean Observing Systems.

Research has shown that the Gulf's open waters are relatively clean, with significant contamination limited to some embayments and harbors (210; 208). However, the experience of other semi-enclosed seas around the world that have water residence times of a year or more (as the Gulf of Maine does) indicates that the Gulf is vulnerable to eutrophication and accumulated toxic compounds. These problems have surfaced already in many other large estuaries and coastal seas, such as the Chesapeake Bay, North Sea, Baltic Sea, Black Sea, and Mediterranean Sea (36).

Recognizing the potential for significant human impacts in the Gulf of Maine, this report focuses on three areas where that effect may be greatest: land use; contaminants and pathogens; and fisheries and aquaculture. These priority topics were selected by the GOMC following extensive discussions with individuals, organizations, and communities of interest, particularly GPAC. The focus on these three areas is not intended to diminish the many other concerns facing the Gulf. Summit organizers hope that conference discussions and subsequent work may lead to a series of reports that can address a broader range of Gulf-related issues.



Credit: RARGOM

Figure 2.2. Research Institutes around the Gulf of Maine

The GPAC Forums

3. State of the Gulf: Reporting from the Bottom Up–Results of the GPAC Community Forums

Introduction

The Global Programme of Action Coalition for the Gulf of Maine (GPAC) was started in 1996 as a regional pilot project, supported by the North American Commission for Environmental Cooperation (CEC) of the North America Free Trade Agreement (NAFTA). It is one of the first such projects launched under the United Nations Global Programme of Action (GPA) to Protect the Marine Environment from Land-based Activities (254), which was adopted by 105 nations in November 1995. GPAC seeks to determine how the GPA can be implemented in the Gulf of Maine and Bay of Fundy region, and has received recognition for its program from the UN GPA office in the Hague.

In May 2001, GPAC launched "The Gulf of Maine Summit: State of the Environment Reporting from the Bottom Up," an initiative to foster public education on threats that land-based activities pose for the marine environment. GPAC held a series of regional watershed forums around the Gulf in 2002 and 2003, reports of which are included on the CD accompanying this report.

The GPAC forums sought to raise awareness of the Gulf, "creating a greater connection to and a sense of ownership of the Gulf of Maine ecosystem, elements that are necessary to ensure its sustainability."(86). GPAC held twelve forums throughout the Gulf watershed (in all five jurisdictions), in addition to related events: the New Hampshire Estuaries Project's State of New Hampshire Estuaries Conference; the Boston Harbor Islands Science Symposium; the public participation processes of the Conservation Council of New Brunswick and Clean Annapolis River Project; and workshops held by the Marine Resource Center in Cornwallis, Nova Scotia. Coastal agency and non-governmental organization personnel from several regions (Massachusetts, New Hampshire, and the St. Croix and Quoddy region) summarized conditions of the coastal environment through a summary matrix used at the Forums. Those summaries are available in a separate report (211).

BOX NOTE: Most of the references in this chapter come from the report, *The Gulf of Maine Summit: State of the Environment Reporting from the Bottom Up: Summary Reports & Matrices from United States and Canadian Regional Forums and Meetings* (211). More detailed information on some of the forums can be found on the web site www.gulfofmainesummit.org (98).

Almost a thousand people attended the GPAC forums and related events, or worked on the summary matrices. The forums, held close to "home watersheds," allowed for participation by a diverse group of citizens including scientists, fishermen, town planners, code enforcement officers, students, teachers, business people, conservationists, and government officials.

Collaborative Work on Water-Quality Monitoring

Several groups joined forces to launch a water-monitoring initiative in Blue Hill Bay, Maine. Blue Hill Heritage Trust (a local land trust), the Blue Hill Harbor Committee, and Friends of Blue Hill Bay started water-quality monitoring in the spring of 2004, led by the Marine Environmental Research Institute. The collaborative project also drew support from other local water-monitoring organizations [e.g. Union River Watershed Association; MDI Water Quality Coalition; Maine Department of Environmental Protection]. Participants in the new monitoring initiative began to collaborate after attending the November 2002 "Common Water-Common Ground" GPAC Regional Watershed Forum.

Researching Threats to Habitat

The U.S. Endangered Species Act has enhanced Atlantic Salmon restoration efforts in Maine's eight remaining salmon rivers by forming watershed councils with paid staff who are improving riparian and aquatic zones, and learning about anadromous fish habitats (including identification of major threats). For example, council staff discovered that "hanging culverts" (road culverts so far out of the water that fish cannot move up or downstream) are a major impediment to fish passage. Now these culverts are being replaced.

The coordinating organization that oversees the Downeast salmon rivers and watershed councils is SHARE (Salmon Habitat and River Enhancement Project). SHARE was the convener for the Washington County GPAC Forum in January 2003.

An Aid to Natural Resource Planning

The Boston Harbor Islands Science Symposium in October 2003 marked the unveiling of the Boston Harbor Islands Inter-tidal Classification System which maps 13 kinds of substrate and 32 types of biological communities. The new system, developed cooperatively by the National Park Service, New England Aquarium and Massachusetts Audubon, could be used throughout the Gulf of Maine to guide natural resource management decisions and the design of long-term monitoring programs.

The Forum Process

The "From the Bottom Up" Regional Watershed Forums offered a new way to learn about Gulf-wide issues based on the premise that local and regional knowledge is valuable to state, provincial, and national leaders. Three organizing principles guided the forums:

- Local groups were invited to organize and convene the forums so as to assure local acceptability and participation. Much of that organizing work was provided "in-kind" by the convening organizations.
- The forums all used a consistent but flexible format outlined in the *Handbook for Forum Conveners.*
- Findings from each forum were reported using a consistent and practical approach based on the Bay of Fundy Coastal Forum, "Taking the Pulse of the Bay," May 15-16, 2002 (276). This format evolved into the GPAC indicator matrix, drawing on the U.S. Environmental Protection Agency's Mid-Atlantic Integrated Assessment (MAIA) Condition of the Estuaries matrix and "traffic light" colors (263). A Facilitator's Guide was written to aid groups in understanding this matrix approach.

Matrix Colors and Terms

Red:	Definite problem	DK = Not enough data
Orange:	Definite to moderate problem	NA = No answer/not applicable
Yellow:	Moderate problem	? = Unsure
Light Green:	Moderate to no problem	Black type –Sub-region or issue that is noteworthy
Green:	No problem	
White:	No answer in that category	

Please note: Forum participant selected the matrix colors signifying their level of concern based on a combination of data, local knowledge and observation, family history and best personal and/or professional judgment. Therefore, each matrix reflects the collective level of concern among forum participants based on their knowledge and perceptions of local problems. In addition, the US Forum participants were asked to choose a color illustrating a comparison with conditions 15 years ago.

Forum Results for Land Use and Water/Riparian Zones

Matrices for "changes in land use and integrity of water and riparian zones" are shown below, using two indicators: clearing and development of natural areas, and erosion and deposition changes.

United States: Specific land use issues, where noted, are shown in regional matrices

CHANGES IN LAND USE AND INTEGRITY OF WATER & RIPARIAN ZONES-US	US Gulf of Maine	Massachusetts	New Hampshire	Penobscot Bay & River	Blue Hill Bay to Taunton Bay	Downeast Salmon Rivers & Cobscook Bay
Clearing & Development of Natural Areas	Southern and central Maine coast severe			Enforcement not done land conservation helps	Union River Bay and Frenchman Bay severe	
Erosion & Deposition Changes	Percent of watershed paved		Severe on Coast with high percent of watershed paved			

U.S.-Canada Border Region: Specific land use issues, where noted, are shown in regional matrices

CHANGES IN LAND USE & INTEGRITY OF WATER & RIPARIAN ZONES-US/ CANADA BORDER AREAS	St Croix River & Estuary	Upper Saint John River
Clearing & Development of Natural Areas		Dams & urban & residential development of concern, also agriculture and forestry uses.
Erosion & Deposition Changes		Erosion due to water level changes at head ponds. Plus forestry and agricultural operations.

Canada: Specific land use issues, where noted, are shown in regional matrices

CHANGES IN USE OF WATER & RIPARIAN ZONES IN CANADA	Bay of Fundy	Quoddy Region	Lower Saint John River	Inner Bay of Fundy	Minas Basin	St. Mary's Bay	Lobster Bay/ Yarmouth
Clearing & Development of Natural Areas		Severe throughout region	Saint John Harbour & Kennebecasis & Nerepsis Rivers	Shepody Bay severe	Southern Bight severe	Clearcutting/ topsoil depletion/wells going dry	Poor in Upper Watershed
Erosion & Deposition Changes		Passamaquoddy Bay and L'Etang Estuary severe	Nerepsis & Kennebecasis Rivers severe	Shepody Bay severe	Southern Bight and Cobequid Bay severe	Red Head & wharves	Poor in Upper Watershed

Watershed-Scale Planning

The organization Floating Classroom conducted an informative workshop entitled "Watershed Mapping Activity" at the Hancock County Youth Forum in Maine. This was sponsored by GPAC. Students had to choose where to place industry, housing, roads and sewer treatment plants, based on watershed concerns such as water sources, streams and wildlife needs. This useful exercise could be replicated with all age groups and Planning Boards. **The participants did not complete a matrix, as with most forums. The detailed report is available from GPAC.**

Forum Results for Contaminant Issues

Forum participants assessed water quality based on their knowledge of bacterial levels, nutrient levels, quality of sediments, and the presence and concentrations of chemical contaminants.

United States: Specific water-quality issues, where noted, are shown in regional matrices

WATER QUALITY ISSUES IN UNITED STATES	US Gulf of Maine (6)	Massachusetts	New Hampshire (7)	Penobscot Bay and River	Blue Hill Bay to Taunton Bay	Downeast Salmon Rivers & Cobscook Bay
BACTERIA	Harmful Algal Blooms			Penobscot River & Upper Bay	Union River Bay and Frenchman Bay	
NUTRIENTS				Penobscot River & Upper Bay	Frenchman Bay	
SEDIMENTS				Penobscot River & Upper Bay	Frenchman Bay	
TOXIC CONTAMINANTS				Penobscot River & Upper Bay		Saltwater, Dennys River, Pleasant River

U.S.-Canada Border Region: Specific water-quality issues, where noted, are shown in regional matrices

WATER QUALITY ISSUES IN US/CANADA BORDER REGIONS	St. Croix River & Estuary	Upper Saint John River
BACTERIA	Main Stem & Oak Bay	DK
NUTRIENTS	Main Stem & Oak Bay	DK DK
SEDIMENTS	NA	DK
TOXIC CONTAMINANTS	NA	

Canada: Specific water-quality issues, where noted, are shown in regional matrices

WATER QUALITY ISSUES IN CANADA	Bay of Fundy	Quoddy Region	Lower Saint John River	Inner Bay of Fundy	Minas Basin	St.Mary's Bay	Lobster Bay
BACTERIA	Not done at this Forum	Passamaquoddy Bay & L'Etang Estuary	Saint John Harbour	Shepody Bay/ Cumberland Basin	Inner Minas Basin	Raw sewage and fish plants	
NUTRIENTS		Passamaquoddy Bay & L'Etang Estuary	Saint John Harbour & Kennebecasis River	Shepody Bay/ Cumberland Basin	Inner Minas Basin		Yarmouth
SEDIMENTS		Passamaquoddy Bay & L'Etang Estuary	Saint John Harbour & Nerepis River	Shepody Bay/ Cumberland Basin	DK Inner Minas	Sawdust from mill Clearcutting, Particulate from quarry	
TOXIC CONTAMINANTS		Passamaquoddy Bay & L'Etang Estuary			Metals DK organics	Shipbuild-ing. Quarry particulate. Oil spill. Road salt	

Forum Results for Fisheries

Three major sections of the matrix dealt with fisheries: "Changes in Species," "Changes in Resource Use," and "Presence of Critical Habitats and Natural Areas." This section provides overall rankings from two sections of the matrix, and specific comments on fisheries issues if they were noted in the regional reports. Changes in species and in resource use are noted below in the following matrix, which considered plants, marine mammals and fisheries.

United States: Specific fisheries issues, where noted, are shown in regional matrices

CHANGES IN SPECIES ISSUES IN US REGIONS	US Gulf of Maine	Massachusetts	New Hampshire	Penobscot Bay & River	Blue Hill Bay to Taunton Bay	Downeast Salmon Rivers & Cobscook Bay
POPULATIONS	Commercial/ Recreational fish species		Harvestable oysters & clam density	Fish-problem in all areas. Shellfish – problem except Western Bay. What is effect of toxins? What is effect of predator/prey relationships on food chain.		Depletion of numbers of fish. Lower pH affects gill formation on salmoids-can't survive less than 5.0 – 4.2 on Machias River. Loss of native species.
DIVERSITY	DK		NA			
DOMINANCE		NA	NA			
INVADERS	DK			Green Crab and Toledo worm		Introduction of invasive species
CHANGES IN RESOURCE USE						
SHIFT IN TARGETED SPECIES	Single species. Harvest until depleted (ex. cod, urchins)		NH coast	DK but urchins gone		Loss of native species

U.S.-Canada Border Region: Specific fisheries issues, where noted, are shown in regional matrices

CHANGES IN SPECIES ISSUES IN US/CANADA BORDER REGIONS	St. Croix River & Estuary	Upper Saint John River
POPULATIONS		
DIVERSITY		NA
DOMINANCE		NA
INVADERS		Muskellunge
CHANGES IN RESOURCE USE		
SHIFT IN TARGETED SPECIES		

Canada: Specific fisheries issues, where noted, are shown in regional matrices

CHANGES IN SPECIES ISSUES IN CANADIAN REGIONS	Bay of Fundy	Quoddy Region	Lower Saint John River	Inner Bay of Fundy	Minas Basin	St. Mary's Bay	Lobster Bay/ Yarmouth
POPULATIONS	Not done at this forum.	All commercial & anadromous fish populations have dramatically declined in last 100 years.	SJ Harbour & Musquash Harbour & Nerepsis River & Coastal Bay of Fundy – significant declines in fish populations	Serious decline in cod. More lobsters perhaps due to loss of cod. Less spawning & feeding area for wild salmon. 4 million farmed salmon killed. Scott's Bay. Herring increasing.	Sturgeon, shad and alewives dramatic decline. Fish & herring stocks declining. Is Windsor Causeway causing reduced species? Lobsters increasing in Minas Channel	Depletion of herring stocks. Bacterial pollution of clam-flats.	Upper watershed – severe decline of wild salmon and trout due to high pH and metals
DIVERSITY		Loss of biodiversity through over fishing	No answer		Don't know		
INVADERS		Green crab not a problem – aquaculture escapees a problem		? Aquaculture escapees outnumber wild	Green crab & chain pickerel	Bilge from quarry ships	Pickerel & small mouth bass in Upper Watershed/Japanese Shoe Crab in Coastal Fringe
CHANGES IN RESOURCE USE							
SHIFT IN TARGET SPECIES		Fishing lower and lower on food web. Aquaculture supplanted herring weirs.	All show strong shifts except Loch Lomond	Fisheries management restrictions/ decisions causing harm.	Definite for groundfish. No problem for lobster	Lobster fleet moving down the Bay of Fundy- more effort	Shift from salmon and trout to chain pickerel & eels in Upper Watershed. Coastal – loss of groundfish. Lobster vital economic sector.

Matrices were produced for the presence of critical habitats related to fisheries and land use. Different habitats vital for various life stages of finfish and shellfish, such as wetlands, spawning/nursery areas and nesting/foraging areas, can be affected by land-use changes and are therefore noted in these regional matrices.

United States: Specific fisheries and land-use issues, where noted, are shown in regional matrices

PRESENCE OF CRITICAL HABITATS IN US REGIONS	U.S. Gulf of Maine	Massachusetts	New Hampshire	Penobscot Bay &River	Blue Hill Bay to Taunton Bay	Downeast Salmon Rivers & Cobscook Bay
BENTHIC	Trawling			?	Frenchman Bay severe	Salt water severe
WETLANDS	Degradation & loss of habitat		176.5 acres salt marsh restored by removing tidal restrictions	scarce and poorly protected	Frenchman Bay severe	
SEAGRASS	water quality degradation due to watershed development					
NESTING/FORAGING		DK				
SPAWNING/NURSERY	DK				Union River Bay severe	Machias and E. Machias Rivers severe

U.S.-Canada Border Region: Specific fisheries and land use issues, where noted, are shown in regional matrices

PRESENCE OF CRITICAL HABITATS IN US-CANADIAN BORDER REGIONS	St Croix River and Estuary	Upper Saint John River
BENTHIC		Siltation due to dams/forestry/ reservoirs
WETLANDS		Dams and reservoirs have changed wetlands – some larger/ some drowned
SEAGRASS		
NESTING/FORGING		
SPAWNING/NURSERY		Major concern for anadromous fisheries

Canada: Specific fisheries and land use issues, where noted, are shown in regional matrices

PRESENCE OF CRITICAL HABITATS IN CANADIAN REGIONS	Bay of Fundy	Quoddy Region	Lower St. John-Kennebecasis	Inner Bay of Fundy	Minas Basin	St. Mary's Bay	Lobster Bay/ Yarmouth
BENTHIC	Not done at this forum.		Nerepis River severe	Shepody Bay & Cumberland Basin - severe		Scallop dragging severe	
WETLANDS				historic loss of 85% of wetlands in last 300 years	Minas Channel, Southern Bight and-Central Minas Basin	Cottages and land sales	concern in coastal fringe and Yarmouth urban
SEAGRASS		L'Etang Estuary severe	Kennebecasis River severe	NA	NA	DK	
NESTING/FORAGING						DK	
SPAWNING/NURSERY		L'Etang Estuary & Pas-samaquod-dy Bay -severe	Kennebecasis River severe	Shepody Bay & Cumberland Basin – severe due to loss of fish passage/access	DK - but tidal barriers are severe	DK - but haddock nursery destroyed	concern in Upper watershed

Forum participants designated 14 issues as "no problem" (green) in the entire Gulf of Maine region, and designated 41 issues as a "definite problem" (red). Indicators in the "Changes in Use and Integrity of Water and Riparian Zones" matrix revealed eight "definite problems" (red), five related to "clearing and development of natural areas." The "definite problem" ranking often was based on one or more of four issues – sprawl, cottages, paved areas, and non-point source pollution occurring in specific sub-regions.

Within the "water quality" section of the matrices, "definite problems" (red) were specific and sub-regional indicating that each jurisdiction has contaminated "hot spots." Overall, the water-quality issues shown on the full matrix are designated 'definite to moderate' (red, orange, and yellows).

There were 26 "definite problems" (red) — some from each jurisdiction — designated for fisheries within the "Changes in Species," "Shift in Targeted Species," and "Presence of Critical Habitats or Natural Areas" sections of the full matrix. The "fisheries issue" is a major concern throughout the Gulf of Maine, but different regions have problems specific to their setting.

The overall matrix for the Gulf of Maine region follows. Some areas (e.g., Southern Maine, Casco Bay, and Merrymeeting Bay in Maine, and the offshore Bay of Fundy) still have no matrix data: the information listed here marks the beginning of an iterative process, with more forums planned for the future.

The GPAC forum process, although highly successful for identification and discussions of issues, had some drawbacks. The matrix process, adapted from that of EPA, was complicated by conveners and participants having varying degrees of knowledge about the questions asked and issues listed. The forums also were too short in time to explore complex issues adequately. Finally, some organizations that would have had much to contribute did not participate due to overloaded agendas, lack of funding, lack of interest, or not being contacted. Thus, all areas in the U.S. region were not covered and the matrices were only partially completed for the open Bay of Fundy.

The forums did succeed, though, in confirming GPAC's belief that local knowledge and caring about the marine environment are key to ensuring future protection. Forum participants who lacked formal training in marine or watershed ecology often shared a unique and valuable perspective on their watershed, based on careful observations and their extended experience in the particular outdoor location. Coupled with scientific data, that intimate knowledge of Gulf region watersheds can help lead to sound resource management decisions. Forum participants, in turn, had a chance to learn more about local issues and the Gulf of Maine from a variety of marine experts. In two regions, participants even established new coalitions to work on watershed and marine issues.

Holding the forums in regional locations enabled individuals and organizations to participate who have not historically been interested or involved in Gulf-related issues. The forums encouraged sharing of knowledge across sectors (business, non-governmental organizations and government) and across media (land, air, freshwater, marine). The common questions and common matrix, although met with a varied knowledge base, provided an insightful baseline on the perceived risks associated with Gulf-wide issues; as such, it was an valuable although incomplete exercise in risk communication. The forums offered insights into how diverse members of the public view Gulf-related issues, evaluate relative risks and describe their concerns.

Some of the innovative actions reported in the Forums and meetings, when shared in reports, on web sites, and at the Gulf of Maine Summit, may offer new ways to proceed — assuring better stewardship of the Gulf in the years ahead. In this regard, the reader is encouraged to read the individual Forum reports, available at the Summit.

FOOTNOTES FROM THE UNITED STATES AND CANADIAN GPAC MATRICES

Footnotes from the United States Gulf of Maine Coastal Forum matrix:

(1) Bacteria divided into human pathogens and harmful algal blooms

(2) Benthic Habitat divided into intertidal soft, intertidal hard, nearshore and offshore

(3) Nesting and foraging divided into mainland and coastal island

(4) Populations divided into the following taxa: algae commercial, seagrasses non-utilized, plankton non-utilized, invertebrates recreational-commercial, invertebrates non-utilized, fishes recreational-commercial, fishes non-utilized

Footnote from the Penobscot Bay Forum matrix:

(5) Populations divided into the following taxa: fish, shellfish, birds, mammals, and plants

Footnote from the Blue Hill-Taunton Bay forum matrix:

(6) Red except for Taunton Bay which was green

Footnotes from the Minas Bay Forum matrix:

(7) Targeted species changes by the following groups: pelagic, groundfish, sharks and rays, lobsters, clams, baitworms, agricultural species, and forestry species

(8) Species introductions divided into marine, freshwater and land

United States and Canadian GPAC Matrices

Indicator	Gulf of Maine US	Mass	New Hamp	Pen Bay	Blue Hill/ Taun Bay	Wash Cty	St Croix	Up St John	Quod Regn	Lowr St. John	Inner Bay of Fundy	Minas Basin	St. Mary's Bay	Lobster Bay
Water Quality														
Bacteria	(1)							DK						
Nutrients								DK						
Sediments							NA	DK						
Toxic contaminants					(6)		NA	DK						
Presence of Critical Habitats or Natural Areas														
Benthic habitat	(2)			?										
Wetlands	NA													
Seagrass														
Nesting & foraging areas	(3)	DK												
Spawning & Nursery Areas														
Changes in Species														
Populations	Taxa (4)			Taxa (5)										
Diversity	?							NA				DK		
Dominance		NA						NA				?		
Invaders	?													
Changes in use and integrity of water and riparian zones														
Clearing and development of natural areas														
Erosion and deposition changes														
Changes in Resource Use														
Shift in targeted species												(7)		
Species introduction														

Note: Forum participants selected the matrix colors signifying their level of concern based on a combination of data, local knowledge and observation, family history and best personal and/or professional judgment. Therefore each matrix reflects the collective level of concern among forum participants based on their knowledge and perceptions of local problems. US participants also assigned colors based on comparisons with their knowledge or perceptions of conditions 15 years ago.

Stresses on the Gulf

4. Land Use

The Gulf of Maine has attracted and held us to its shores for centuries – first, to harvest its bountiful marine resources and abundant woodlands; later to work in its vibrant coastal cities and mill towns; and more recently to live and play in its traditional villages and beautiful harbors, beaches, and islands in search of a slower pace of life. But because of our desire to be close to the Gulf, we are undermining its health.

Whether through the simple decision to convert a seaside cottage into a year-round home or build a house on a 2 or 3 acre (0.8 to 1.2 hectare) wooded lot in the country; to locate a business near a shoreline to access cooling process water or meet the needs of tourists; or to build new roads and schools in areas that were formerly rural or sparsely developed, we are impacting the environment of the Gulf of Maine. Each of these decisions may seem innocuous, in fact, rather nice to most of us. But the cumulative effect of these decisions is not – stressing the water, air, and land that feed and surround the Gulf. And the threat of these stresses is likely to expand and accelerate over the coming years given the way in which we are developing – consuming large land areas in suburban patterns with exponential growth in automobile use and disruption of habitat.

If these development trends continue, many watersheds, and their waters, habitats, and biological communities, will fundamentally change in character and quality. If we are to protect the ecosystems of the Gulf of Maine, reconfiguring and containing growth is not just an option. It is a necessity.

Development within the Gulf Region: A Historical Perspective

Native Americans

With the retreat of the last ice age, nomadic hunters followed large game animals into the Gulf of Maine region. By 10,000 years ago, Native American populations had expanded beyond the supply of large game species and were forced to adopt a more varied diet (162). They turned to the bounty of the Gulf, and the waters that fed it, to add to the deer, bear, beaver, and moose they hunted and the berries and nuts they gathered.

Approximately 6000 years ago, established groups of hunters lived in particular river valleys or on estuaries in which they knew where smelt, shad, alewives, sturgeon, and salmon were in the spring, where berries grew in the summer, and where eels were in the fall. They collected scallops, crabs, clams, and oysters from the shallows of the Gulf's coastline. By 4000 years ago, they were putting to sea in large birch bark or dugout canoes to fish for giant swordfish. By 2000 years ago, shellfish was a regular, and important, part of their diet.

Then 800 to 2500 years ago south of the Kennebec River, natives began to plant corn, beans, and squash in fields they cleared by burning forested areas along the shores of the coast and rivers. This early agriculture had surprisingly little impact on the environment because the Native Americans cleared and cultivated land only for a few years before abandoning it back to the forest, clearing new fields to meet their needs (162).

Native Americans used the forest primarily for firewood to heat their wigwams and smoke their food, but also to provide wood for fishing weirs and lodges, nuts for food, roots for thread, pitch for caulk, bark for medicine, and to support the game they hunted. Their need for a continuous and convenient source of firewood ensured that they moved their villages throughout the year, changing sites from year to year to encourage the growth of wild plants for food.

South of the Kennebec, vast tracts of forest were burned twice a year to keep down brush and allow grasses and berries to flourish to feed themselves and the game they hunted. The burns changed the mix of forest species to those that are fire tolerant. Massachusetts, and other southern New England states, were a "cultivated wilderness" of small fields, berry patches, and managed forests. "When the first Europeans explored these shores, the coastal islands of the Kennebec, the land sloping down to coastal bays and inlets, the land at the mouths of rivers, and the entire mainland shore of Massachusetts Bay was planted with corn or made up of old cornfields growing blueberries and strawberries. Forests had been cut back until they began some distance from the shore. This situation, [was] perfect for European settlers who could plant on land the Indians had cleared without the labor of clearing forests" (162).

Except for tended riverbank vineyards and a few blueberry and strawberry patches, the land north of the Kennebec was not farmed – the growing season being too short to justify the necessary labor. Native Americans in this region of the Gulf continued to hunt game, fish the waters and shores of the Gulf, and gather nuts and berries.

Colonial Settlement and Marine Trade

Europeans were first drawn to the Gulf's shores in search of fortune, religious freedom, or a new life. Again, the bounty of the Gulf served these peoples well.

Settlements grew up near natural salt and fresh water marshes, especially beside cleared fields in the southern region to feed cattle. In the upper reaches of the Bay of Fundy, a vast network of dikes was constructed to convert tidal salt marshes into farmland and harvest hay for export.

Cod was plentiful and well-suited to salt curing – essential for the long shelf-life necessary for export. Salt hay and cod were the first steps in a maritime enterprise that would bring the region two centuries of prosperity.

By the 1730s, shipbuilding in the Gulf grew up to support the salt cod trade with Europe and the wine islands, a natural market for white oak barrel staves. By the late 1740s, trade with the West Indies was brisk. The forests of the Gulf provided all manner of wood products for export. Cod and surplus products from thousand of farms were shipped from the handful of seaports on harbors and major rivers that today remain the major cities of the Gulf. The products were exchanged for letters of credit and molasses, which along with cod, were then traded with Great Britain, Ireland, and southern Europe for salt, iron, glass, molasses, spices, and imported fabrics the settlers could not produce themselves. These products, later supplemented with granite, lime, and ice, further fueled New England's shipbuilding industry, which in turn, promoted economic growth and industrialization of the region (21).

Settlers cleared large areas of the forest for wood products and masts for export. Rivers were dammed to power sawmills, the first one constructed in 1634 (162). The region's demand for lumber appeared inexhaustible. Every town had at least one sawmill, with sawdust dumped into the adjoining mill stream. Forested areas were also cleared to create farm fields for new settlers, adult offspring of the original settlers, and to replace fields whose nutrients were exhausted. Without forests to bind the soil, there was considerable erosion of topsoil that, along with discarded sawdust, silted up coastal streams, rivers, shallow harbors, spawning and nursery areas, forever changing the ecology and physiography of these ecosystems. Trout and salmon abandoned these streams or failed to reproduce.

Aware of the demand on forest resources, the British Crown in 1691 reserved large pines in the Gulf's forests for ship masts. Trees were cut, skidded by oxen to water, and floated down stream to port towns. Mast traders moved slowly north from the Merrimack River and by the mid-eighteenth century, Falmouth (now Portland), Maine was the major masting port (111).

Post-War and Industrialization

As Table 4.1 illustrates, lumbering and agricultural clearing gained momentum during the 1800s (283). Although maritime trade was a significant part of its economy, the Gulf, in the early decades of the century, was clearly an agrarian society.

After the Wars of Independence and 1812, many ports were closed to US ships. Trade and cod fishing collapsed for a time. The Gulf's rich, inshore fishing grounds supplied local demand until the 1830s, when inshore stocks began to be depleted. Cod fishing resumed in the 1840s (162) and US fishermen started fishing the waters of George's Banks. With the advent of ice and railroads, fresh fish, more profitable than preserved cod, was shipped by refrigerated railcars to more distant markets and small Gulf ports that specialized in salt cod again lost their markets.

Spurred on by the Industrial Revolution that was taking hold in Great Britain, entrepreneurs in the Gulf began to develop an industrial base of their own in the late 1790s. Fueled first by water power and later by steam, the economy of the Gulf was changing and with it, its environment.

Shoe making, precision engineering, clothing, wool and cotton textile, and later paper manufacture became an important

Table 4.1: Land Use in New England, 1770-1979

	Units	1770	1880	1940	1979
Population	(millions)	0.5	4.0	8.4	12.2
Number of Farms		80,000	200,000	135,000	25,570
Area of Tillable	(Thousands of acres)	2,000	13,570	6,850	2,700
Land and Pasture	(Thousands of hectares)	809	5,492	2,772	1,090
Area of Forested	(Thousands of acres)	36,400	23,536	29,762	30,984
Land	(Thousands of hectares)	14,730	9,525	12,044	12,539
Areas of Urban and	(Thousands of acres)	100	500	2,000	5,000
Developed Land	(Thousands of hectares)	40	202	809	2,023

Source: Adapted from Irland, 1982.

part of the region's economy. With cheap labor, provided by immigrants, and abundant sources of power, New England inventors and entrepreneurs transformed old mercantile cities into manufacturing centers. Larger dams were built along coastal and, later, inland rivers. Chemicals, dyes, and bleaching agents were dumped into the rivers, along with sewage from burgeoning mill towns – to the detriment of those waters, and ultimately the Gulf.

Agriculture, which spread from the richest river valleys to thin-soiled mountains and marginal lands, shifted to perishable products and wool to feed the mills. Continued expansion of farming and loss of woodlands caused a decline in the amount and type of wildlife in the region. Large predators remained only in the remote woodlands of the northern areas of the Gulf by the end of the 19th century.

"The year New England was linked to western cornfields by rail, 1841, was the year that saw more Massachusetts workers employed in manufacturing than in farming. Less than a third of the working population of the commonwealth labored on farms that year, somewhere between a third and a half worked in manufacturing, with the remainder distributed among fishing, paid domestic work, the professions, transportation, and commerce" (162). Grazing of sheep and cutting of forests to ironworks and construction and operation of the railroad continued erosion of thin topsoil into adjacent streams and the Gulf.

By the 1840s white pine in Maine's forests began to run short. By the 1870s 1,000 active sawmills were operating and almost no large-diameter white pine or red spruce were left near a river. Large and highly capitalized pulp mills were built DownEast and parts of Maine's forests became paper plantations (162).

The region's hilly landscape, cut up by streams and swamps, lent itself to small-field agriculture. Mechanized farming and refrigerated railway cars changed agriculture forever and by the end of the US Civil War, farmers were abandoning farms for work in the mills. Abandoned fields and hillsides reverted to white pine.

At century end, shoes, textiles, and precision engineering were mature industries. Small mills were abandoned for large ones in cities. Upwardly mobile immigrants and ambitious youth finding few opportunities, moved west to found new farms and industries. Environmental impact from industry hailed from the larger cities.

The Twentieth Century

After 1880, farms declined in size and number by 1940, more dramatically thereafter (see Table 4.1). Forested land increased as fields reverted to woods and urban areas expanded.

Electrification brought more dams, sited along nearly all rivers in the Gulf. Fish ways were developed in the 1920s, helping restore runs of anadromous fish. Many dams remain today: 1,579 in Massachusetts, 2,506 in New Hampshire, and in Maine 782 (see Figure 4.1). The Bay of Fundy has barriers and dams on many rivers (223), but no accurate count of the total exists for New Brunswick and Nova Scotia.

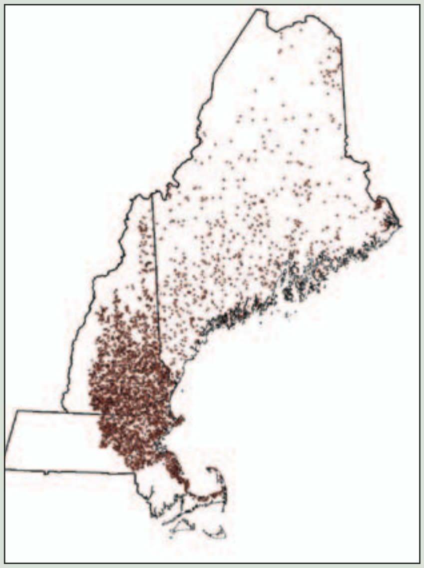


Figure 4.1. Dams within the Gulf of Maine Watershed.

By 1920, there was still approximately 2 million acres (0.8 million hectares) of "virgin" forest in New England, but harvesting was occurring 3.5 times faster than replacement. By the 1940s, 38 percent of the forests were less than 20 years old and many states were forced to import wood (111). In Canada, much of the abandoned farm and forest land reverted to the Crown (McInnis Leek 2004) and over harvesting was limited to areas near water transportation. New Brunswick and Nova Scotia helped supply New England's needs.

Though small, privately held woodlots of 50 to 100 acres (20 to 40 hectares) dominated southern Maine and Nova Scotia, mechanization changed interior Maine and New Brunswick forests dramatically after World War II. Motorized chainsaws and off-road vehicles enabled loggers to tackle rugged and, historically, inaccessible, terrain. But as long as the virgin forests of the west met demand for wood, the Gulf's remaining forest areas were only lightly cut. "Cutting declined from its turn-of-the-century rate in the middle decades of the century, when more wood grew each year in Maine than was harvested. In about 1970, demand caught up with dwindling supply, and the loggers came back to Maine…For the first time since the turn of the century, in the 1970s more wood left the Maine woods every year than was being grown (162).

Changes in technology also impacted fisheries – first, with steam-powered vessels in the late nineteenth century, then in the 1920s with the advent of quick-freezing of fish and packaging of sardines in tins. Except for major processing ports, the fleet faded to inshore day boats meeting local markets for fresh fish "(162)". After World War II, the US fleet shrank further with expanded Canadian, Icelandic, and Norwegian supply of frozen fish. Soviet gill-netters and side trawlers took 63,000 metric tons of herring from the Georges bank in 1961 (162). By 1973, an international fleet caught 1.15 million metric tons of fish on the bank. In 1973, the US adopted the Magnuson Fisheries Conservation and Management Act, extending territorial waters to 200 miles (322 kilometers) offshore and the New England Fishery Management Council has attempted to manage stocks since.

Population and density grew moderately in the twentieth century (see Figures 4.2 and 4.3). By 1940, two-thirds of the population lived in coastal counties of the Gulf in a limited number of discrete centers, fueled by industrialization of its shores. Population continued to migrate from rural to urban areas, following employment opportunities and services.

Settlement patterns began to change after World War II, spurred by federal housing policies and construction of the US Interstate and Trans-Canada highways. Housing rates increased dramatically and changes in household size and structure prompted demand for new housing types. Increased prosperity led to construction of vacation and retirement homes in settings near recreational amenities (48). Improved road conditions and the proliferation of automobiles reduced travel times and hastened the spread of development in "bedroom communities" and second homes in rural areas.

The US states saw little rise in urban population, but areas around urban centers grew markedly, with people opting to work, but not live, in cities. The four counties around Boston grew from 1.7 to 3.5 million between 1900 and 2000. Other major cities of the Gulf (Portland, Saint John, Moncton) saw similar patterns of metropolitan growth.

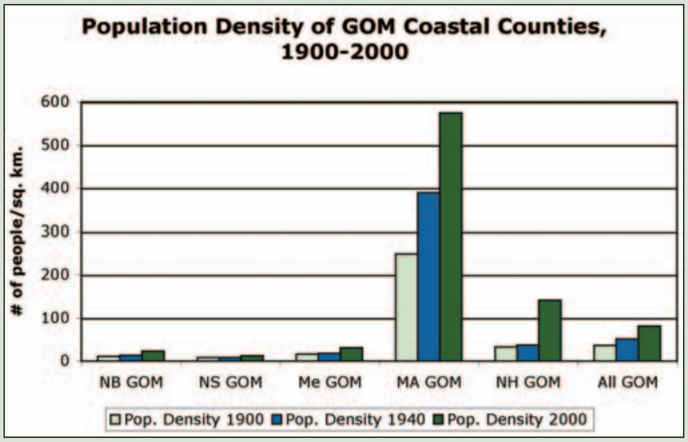


Figure 4.3. Population Density of Gulf of Maine Coastal Counties, 1900 – 2000.

Dispersal of development into rural lands, commonly known as "sprawl," is now a defining feature of the Gulf's landscape. Rural population, far from city centers, fell as residents migrated to cities for work. But rural areas close to work centers developed into suburban subdivisions and retail strips (see Figure 4.4). Most development still occurred on the coast (40 percent of land area) where more than two-thirds of jobs and business establishments are located and about 58 percent of the population now live. By 2025, the population of the Gulf is expected to increase by approximately 600,000 people.

While growth trends in the Canadian provinces are mixed, the US states are growing and likely to continue to do so. Most of that growth (95 percent) is residential (see Table 4.2).

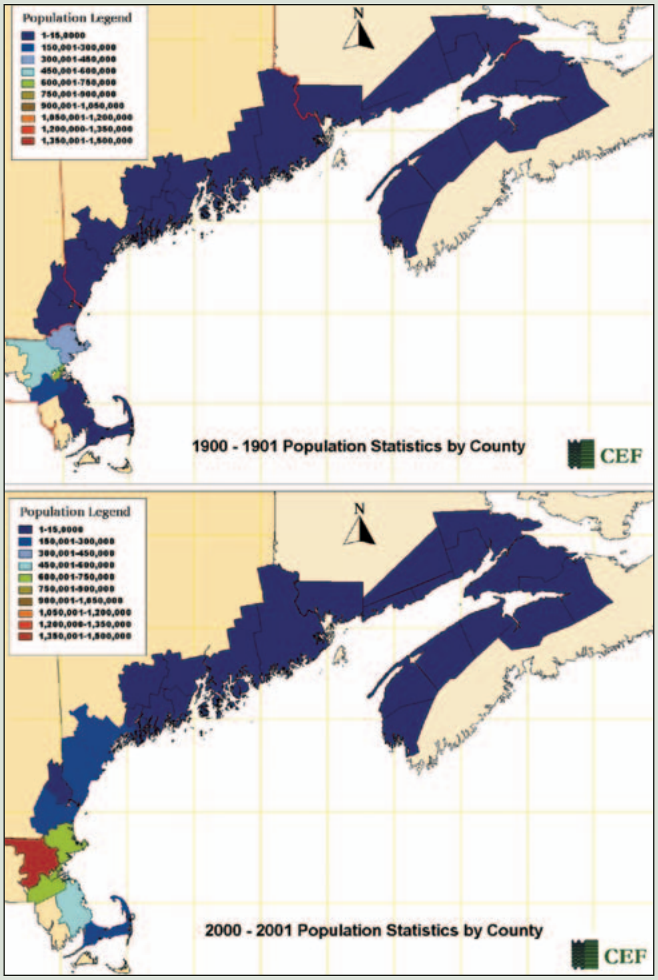


Figure 4.2. Population Statistics by County (source: Communications, Environmental and Fisheries Consultants).

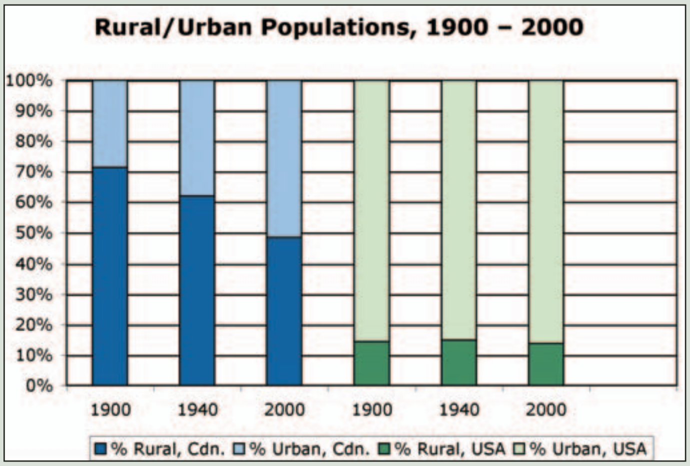


Figure 4.4 Rural versus Urban Populations, 1900 – 2000.

Table 4.2: Development Permits Issued in US Coastal Counties of the Gulf of Maine, 1970-1989

State	Residential	Non-Residential Permits	Percent Residential/Non-Residential
Maine	93,637	6,484	93.5 %
New Hampshire	57,044	2,564	95.7 %
Massachusetts	442,299	20,528	95.6 %

Source: Culliton et al, 1992

Impacts of Current Development Patterns

"The most obvious manifestation of growth is the physical expansion of metropolitan regions and coastal resort areas – the strips of restaurants, gas stations, and car dealerships that line the major roads of all coastal cities, and the vast expansion of housing subdivisions visible from the air. It is not obvious, however, that this expansion is unprecedented and that its continuation will have disastrous effects on coastal ecosystems" (16).

Population is often used as an indicator of the magnitude of human impacts on the environment. However the number of residents provides only part of the picture of impacts on the health of the Gulf. Other factors include where people live, what they do, and how they get around. Population statistics do not include the large number of seasonal residents and visitors who frequent the Gulf. Nor do the statistics take into consideration the amount of land that is taken up by development or the need to drive everywhere to satisfy even the most basic of daily needs.

The fastest growing towns within expanding metropolitan areas are the low density new suburbs, 10 to 25 miles (16 to 40 kilometers) distant from traditional metropolitan centers. Their growth is made up of disconnected housing subdivisions, shoulder-to-shoulder single family homes along formerly rural roads, isolated house lots on abandoned farm fields, strip malls and big

This series of maps illustrates Maine's development trends since 1940 and projects what its settlement pattern is likely to look like if current trends continue into the future. In 1940, Maine's urban and suburban population was centralized in a limited number of discrete centers, indicated in red, surrounded by rural areas shown in gray. By 1960, larger blocks of emerging suburbs, the yellow areas, begin to appear. This trend continues in 1970 and 1980, until by 1990 sizable blocks of suburban and urban development are apparent – nearly continuous along the southern coastline and distinct along the State's major highway corridors. Over the 20 years from 1970 to 1990, there was as much land developed as had been developed in the entire history of the State, consuming land four times faster than population growth.

Assuming a constant rate of development based on actual occurrence between 1990 and 1996, by 2010 land consumption by development is projected to double again. By 2020, sprawl is expected to blanket most of the southern part of the State and, by 2050, it will consume Bangor and Penobscot Bay.

Figure 4.5. Patterns of Suburban and Recreational Growth in Coastal Maine, 1940 – 2050 (source: Maine State Planning Office).

box retail. Growth projections for the coast of Maine categorize nearly all of it as "suburban" by year 2050 (see Figure 4.5).

Coastal areas, with prime recreational opportunities and waterfront lands, are particularly popular settings for seasonal residences. Seasonal dwellings along the coast now represents almost one-third of the housing stock in areas like Hancock County, Maine and Barnstable County (Cape Cod), Massachusetts (US Census). In some towns, so many homes are seasonal that they are having difficulty sustaining businesses and services year-round. Many seasonal homes are owned by individuals from away (see Figure 4.6).

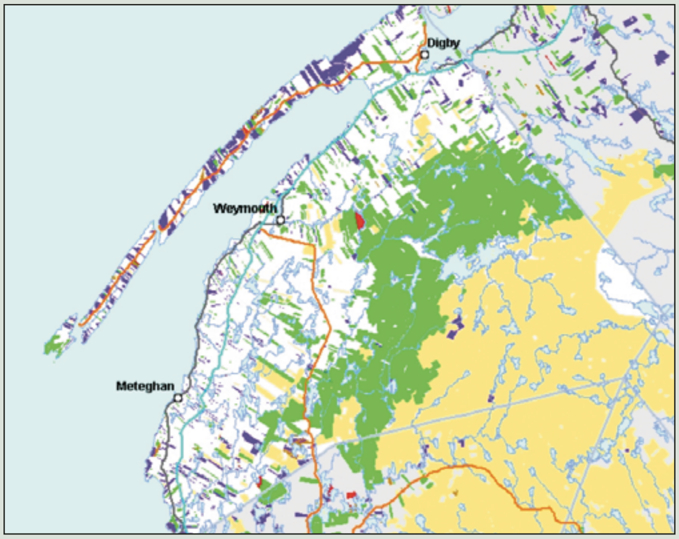


Figure 4.6. Property Ownership in Southwest Nova Scotia. (source: Service Nova Scotia). (note: purple is American-owned land, brown German, green Canadian outside Nova Scotia, and red other).

Development in formerly undeveloped lands dramatically alters the natural landscape – introducing contaminants into the environment, filling wetlands and altering the natural flow of streams and tidewaters, displacing native species and introducing invasive ones, and reducing the diversity of plant and animal species. The Interstate and Trans-Canada highways spawned a network of roads that has fragmented habitat and spread human impacts over the countryside. Along the coast, new roads prompted construction of causeways that have altered many coastal habitats by restricting normal tidal flows. The enduring ecological impacts of major causeways, like those along the Annapolis and Avon Rivers in Nova Scotia, the Petitcodiac in New Brunswick, and the Scarborough Marsh in Maine, make them controversial. The impacts of point and nonpoint sources of pollution, along with changes in coastal habitat, have caused tremendous changes in the environment of the Gulf over the centuries, with corresponding losses and changes in the economy.

"Per capita, coastal residents are consuming more land, driving more, boating more, and generally using more resources than they were 30 years ago" (16).

The Maine State Planning Office indicates that between 1970 and 1990, there was as much land developed as had been developed in the entire history of the State, consuming land four times faster than population growth. This increase in land consumption is a result of consistent decline in development densities. If this trend continues, by 2025, another 2,990 acres (1,210 hectares) of rural land in the Gulf watershed will be consumed. Many coastal metropolitan areas have experienced similar or more consumptive development trends, even in cases where population declined or was stagnant (16). If land was developed at the same rate as population grew, managing its impacts would be a challenge. With developed land outstripping the rate of population growth, the task will be considerably more difficult.

Contamination from Coastal Development

Point Source Pollution

While the Gulf of Maine is considered quite clean compared to other marine waters, population, employment, and urbanization of the watershed create a tremendous, ongoing impact on its ecosystem. Approximately 80 percent of all pollutants entering the Gulf's waters come from urbanized, land-based, point and nonpoint sources (175). The sources are varied and substantial, and all stem from development decisions. Impacts of this pollution are felt in closed shellfish beds and beaches, and changes in fish stocks, distribution, and migration patterns.

There are over 2,000 point sources of pollution in the Gulf – 1,000 industrial facilities, 250 wastewater treatment plants, and 8 power stations in the US, alone, and a concentration of heavy industries and partially treated sewage at Saint John, NB.

Nonpoint Sources of Pollution

Sources of pollution are not limited to discharges from coastal industries and sewage treatment plants. Every time it rains or snow melts, contaminants are swept into water that runs off impervious surfaces (rooftops, roads, and parking lots) and other uses into streams. Bacteria from septic systems and animal wastes; sediment, pesticides, and herbicides from farming, forestry, and construction operations; and toxics, heavy metals, and petroleum products from parking lots, roads, marinas, landfills, and mines move relatively quickly into aquatic systems that feed the Gulf, instead of more slowly moving through soil that captures many contaminants (47).

Many studies conclude that once roads, parking lots, and roofs cover 10 percent of a watershed's acreage, aquatic systems begin to degrade. Changes in particular pollutant levels; changes in the physical structure of streams, creeks, marshes, and rivers; and changes in the number of species and abundance of aquatic life lead to a less diverse, less stable coastal aquatic ecosystem. The 10 percent threshold is an empirical point beyond which ecosystem function, in general, declines because of individual and cumulative stresses.

Impervious surfaces impact watersheds in a number of ways.

Habitat Quality – Runoff flows across the ground faster to reach creeks, rivers, and estuaries. The higher velocity of runoff causes erosion that can alter stream flow patterns and degrade other natural habitats.

Water Temperature – The temperature of runoff rises as it flows across paved roads and parking lots. Increases in temperature can reduce oxygen levels. Since the upper reaches of tidal creeks and marshes often serve as nursery grounds for finfish and shellfish, low or no dissolved oxygen can have important implications for these species and the marine environment.

Pollutants – Runoff transports a vast array of pollutants into the aquatic environment. The most widespread contaminant is nitrogen from fertilizers, sewage treatment plants, car exhaust, and power plants. Excess nitrogen causes algal blooms, which reduce dissolved oxygen levels needed by fish and invertebrates. Algal blooms reduce the amount of sunlight that penetrates the water surface, damaging seagrass beds and other critical habitats. Urban streams have the second highest levels of nitrates and phosphorous, exceeded only by waters adjacent to row crop agriculture (16). Cars and trucks are one of the highest sources of metals in estuaries and nearshore waters.

Aquatic Life – The diversity of aquatic insects like stoneflies, mayflies, and caddis flies fall sharply when imperviousness exceeds 10 percent. Fish and other wildlife depend on these insects, which are at the base of the food chain. Studies reinforce the finding that paved watersheds fail to support a diversity of species, particularly trout, salmon, and other anadromous fish, when imperviousness increases to 10-12 percent and confirm that general degradation of estuaries begins at the 10 percent impervious threshold (16). When it exceeds 15-20 percent, the variety and abundance of food available for juveniles is significantly reduced (16). The 10 percent threshold translates into housing densities of 1 to 2 units per acre (0.4 to 0.8 units per hectare), though lower density on individual septic systems can also cause significant alterations in aquatic ecosystems. One unit per seven acres (1 unit per 2.8 hectares) produces enough bacterial pollution to close shellfish beds.

While impervious cover is the measure used by researchers to determine how development impacts aquatic systems, national land use statistics are reported as “developed” or “undeveloped.” To estimate the percent of impervious cover in a watershed, multiply development statistics by 0.4. A rough estimate of impervious coverage for a typical single family development of 3 to 5 units per acre (1.2 to 2 units per hectare) is 40 percent. The 10 percent impervious cover threshold for damage in a watershed is 25 percent developed (i.e. 25 percent multiplied by 0.4 equals 10 percent).

The Pew Oceans Commission, an independent group of leaders who recently conducted a national dialogue on policies needed to restore and protect living marine resources in US waters, discussed two approaches to managing growth related to the 10 percent threshold (16). One approach is limiting density to very low levels, say one unit per three acres (1.2 hectares), dubbed “hypersprawl.” The other approach is to limit development, overall, in a watershed to 25 percent (the 10 percent impervious threshold).

The Commission acknowledged that current environmental policies may encourage these two approaches as the “ideal pattern of growth” to manage the impacts of nonpoint source pollution, then discards both approaches as viewing the problem in isolation. The Commission concludes that these policies are fiscally, socially, and environmentally unsustainable. They find that the cost of providing services to uniformly low density populations would exceed the tax revenues it generates and that hous-

Increases in Impervious Cover in New Hampshire’s Coastal Watershed

New Hampshire’s 2003 State of the Estuaries report indicates 11,154 acres (4,514 hectares) of impervious surface were added to the coastal watershed between 1990 and 2000, an increase of 2.1 percent (from 4.7 to 6.8 percent coverage). The report notes that the impervious surfaces were not evenly distributed across the watershed. Six of the 37 subwatersheds, most adjacent to the coast or the Route 16 corridor, had impervious cover greater than 10 percent – between 15-20 percent in Hampton Harbor and 20-30 percent in Portsmouth Harbor.

More than a quarter of the 42 towns in the coastal watershed had impervious cover greater than 10 percent. The town with the highest percent impervious cover is New Castle at approximately 30 percent. Portsmouth and Seabrook both have impervious values between 20-30 percent. Dover, Hampton, Newington, and Somersworth had between 15-20 percent. Exeter, North Hampton, Rochester, and Rye had between 10-15 percent. On average, impervious surface per capital increased by 0.05 acres (0.02 hectares) over 10 years. Towns with the largest increases in cover were Newington, Madbury, and Epping where imperviousness per person increased by 0.52, 0.08, and 0.07 acres (0.03 hectares) per person, respectively. Imperviousness per capita increased for all of the towns, even if the change is not statistically significant. The report can be found on-line at www.state.nh.us/nhep.

ing would be prohibitively expensive for a large segment of the population. They also contend that it would ensure total dependence on automobiles, accelerate conversion of rural land, and fragment terrestrial wildlife habitat, all factors that would impact the health of the Gulf.

The Commission finds that cities do not, and should not, grow as clumps of development surrounded by open land, arguing that "a seamless, fine-grained pattern of urban land uses has characterized great and functional cities for thousands of years." It acknowledges that the wide disparity in land value between developable and undevelopable land in a single watershed would create "a political knot that could only be untangled through public purchase of the land to be left open, at costs no city or state/province could afford, and that, ultimately, this approach to protecting aquatic ecosystems runs counter to almost all of the goals, functions, and traditions of real cities." It concludes that the solution is not uniform low density development across metropolitan regions, but traditional, compact development patterns, shaped by regional watershed protection plans (16).

Habitat Degradation from Coastal Development

The people of the Gulf have altered coastal habitat as they deemed necessary over the centuries. Roads, utility corridors, housing and industrial development, marinas, piers, seawalls, filling of wetlands, alterations of tidal flow have all physically displaced wildlife, plants, and marine species and altered their habitat. "At least 50 percent of US coastal wetlands and 85 percent of Bay of Fundy salt marshes have been lost by filling, dyking, dredging, or tidal flow alterations…And over 98 percent of New England's Atlantic Salmon habitat has been removed through dams, barriers and other physical obstacles" (47).

Habitat Fragmentation

Species that aren't displaced by development may still be stressed by the alteration of natural landscapes. Development may replace native vegetation with nonnative species, possibly even monocultures like lawn. It may introduce invasive species. But perhaps most significantly, it cuts up blocks of land that support a wide diversity of species into smaller areas that support considerably fewer species.

Roads interrupt travel corridors, are the means of introducing contaminants into the environment, and provide boundaries that discourage or introduce hazards for certain species traveling on or across them. Development discourages species that have low tolerance for disturbance or those, like bear and bobcat, which require sizable areas to hunt for prey. Smaller blocks of habitat generally do not support as diverse a community of species as larger blocks of undeveloped land (see Figure 4.7).

Loss of Wetlands

The loss of wetlands and salt marshes in the Gulf is of particular concern because of the critical role they play in water purification and control and because they provide critical habitat for diverse wildlife, plant, and fisheries species, including nurseries for many commercially valuable marine species.

Within the Gulf region, diking of tidal salt marshes and filling of freshwater wetlands account for the most severe wetland loss. Approximately 9 percent of wetlands in New Hampshire have been lost over the past two centuries, 20 percent in Maine, and 28 percent in Massachusetts (see Table 4.3). Freshwater wetlands, just inland from the coast, have experienced the greatest development pressure (50) from rapid housing growth, increased

Beginning with Habitat

Maine's "Beginning with Habitat" program provides a landscape approach to assess the need and opportunity for wildlife and plant conservation. The goal of the program is to maintain sufficient habitat to support native plant and animal species currently breeding in Maine and is based on the premise that large blocks of land are likely to include a wider diversity of species than smaller blocks. It recognizes that conservation of large habitat blocks also presents an opportunity to promote and preserve active farmland and woodlots, provide recreational opportunities, conserve aquifers, and maintain scenic vistas.

Since most land use decisions are made by individual Maine communities, the program seeks to improve general and specific knowledge of significant habitats, extending protection provided by state shoreland zoning and other natural resource protection laws. Each Maine community is provided with town-specific maps and information that describe significant habitats. Blocks of land are identified by overlaying maps of riparian habitat, high value animal habitat, and "large" habitat blocks with primary land cover types in a geographic information system. If these areas are preserved, the program expects that 80-95 percent of Maine's terrestrial vertebrate species will be protected.

Supplemental maps showing private conservation and public lands; watersheds; wetlands; and habitat for US Fish and Wildlife Service priority trust species are also provided to help communities with land use planning and protection efforts, so that in 50 years, those who want to can still fish, hunt, photograph or watch wildlife, and otherwise enjoy the wealth of a rich and diverse outdoor heritage.

The approach was initially developed by the University of Maine's Cooperative Fish and Wildlife Research Unit, under the direction of the Department of Inland Fisheries and Wildlife. Data on plants, natural communities, and wildlife habitats of national interest were later added by the Maine Natural Areas Program and the US Fish and Wildlife Service.

Figure 4.7. Potential Diversity of Wildlife versus Size (acres) of Undeveloped Blocks of Land.

transportation infrastructure, and new commercial and recreational facilities (88).

Conversion of salt marsh to agricultural land over recent centuries has had lasting impacts on coastal wildlife habitat in Atlantic Canada. A study of birds that breed in salt marsh habitats identified the loss of coastal wetlands in this region as one of the country's most severe. By one estimate, 80-85 percent of salt marshes in the Upper Bay of Fundy has been lost (89,90). Conversion to agriculture, centuries ago, has left a legacy of dikes. In Nova Scotia, 150 miles (241 kilometers) of dikes still protect 43,000 acres (17,402 hectares) of land, along with roads, railroads, and many residential and commercial buildings. In a few settings, efforts are underway to restore salt marsh habitats – by enlarging culvert size, plugging drainage ditches, or through more involved efforts breaching the dikes on unused agricultural lands.

Efforts to restore tidal wetlands have gained support from entities like the Global Programme for Action (GPAC) and the Gulf of Maine Council (GOMC). In June 1999, scientists and resources managers from around the Gulf gathered in Wells, Maine to discuss methods for identifying potential salt marsh restoration and reference sites and for evaluating salt marsh restoration (see Figure 4.8). Two subsequent workshops were held in 2000 and 2003.

Each of the states and provinces bordering the Gulf has introduced measures to minimize wetlands loss. In the US, wetland protection is a joint responsibility of the US Environmental Protection Agency and the Army Corps of Engineers, but state and municipal agencies typically handle routine permitting. In Canada, wetlands are primarily a provincial responsibility, with the federal government conducting research and promoting conservation and management. The size of disturbed wetland requiring a permit varies among jurisdictions (see Table 4.4).

In the US, every alteration to a salt marsh (unless temporary or for restoration) must have an individual federal permit. No salt marsh loss is legally permitted in New England.

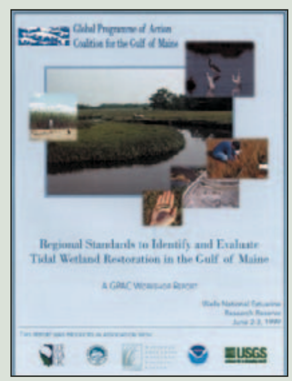


Figure 4.8. Wetlands Restoration Report from Meeting at Wells, Maine, June 1999.

At Risk Species

Coastal counties bordering the Gulf of Maine shelter many species "at risk," as defined by US and Canadian federal governments (see Table 4.5). The number of species has grown over the past two decades. This increase may be due in part to habitat loss, pollution, or other stresses within or beyond the Gulf region. The higher number of species listed in Canada may be due to more species being near the northern edge of their range.

Two major raptors, the Bald Eagle and Peregrine Falcon, whose populations were decimated by the pesticide DDT, are recovering well.

Table 4.3: Wetland Loss in the United States, 1780-1989

State	Total Area (Acres) (Hectares)	Percent Wetland circa 1780s	Percent Wetland circa 1980s	Percent Loss 1780s to 1980s
Maine	21,257,600 8,602,646	30.4 %	24.5%	20 %
New Hampshire	5,954,560 2,409,725	3.7 %	3.4 %	9 %
Massachusetts	5,284,480	15.5 %	11.1 %	28 %

Source: Dahl, 1990

Table 4.4: Size of Wetland Requiring a Permit for Development

Jurisdiction	Area of Affected Wetland Before Individual Permit Required
Nova Scotia	2 hectares (5 acres)
New Brunswick	2 hectares (5 acres)
Maine	no minimum size*
Massachusetts	1 acre (0.4 hectare)
New Hampshire	3 acres: under 5,000 ft^2 is always a state responsibility; between 5,000 ft^2 and 3 acres projects are screened, and EPA has the ability to require a permit.

Land Conservation, Restoration, and Coastal Protection

Protected areas within the Gulf watershed include national, state/provincial, and municipal parks and forests; conservation areas, wildlife management areas, natural heritage areas, nature reserves, migratory bird sanctuaries, private land trust holdings, sites associated with the Convention on Wetlands of International Importance, and heritage rivers. Some areas have complete protection from development and discourage visitation while others accommodate activities such as outdoor recreation or limited resource harvesting.

Some state and local governments are using public funds to purchase development rights to preserve important rural and natural areas. In some cases, land is purchased outright. In others, the right to development all or part of the property is purchased. Massachusetts protected 200,000 acres (80,937 hectares) over 10 years and voted for additional funds in 2002. Maine voters have approved two bonds funding the Land for Maine's Future Program, which has protected more than 192,000 acres (77,700 hectares) at more than 130 sites over the past 16 years.

In recent decades, private land and nature trusts throughout the Gulf have protected hundreds of thousands of acres (tens of thousands of hectares) of natural lands, many privately held, with conservation easements, voluntary legal agreements between a property owner and land trust or government agency that permanently restrict certain land uses and activities.

Nova Scotia's Wilderness Areas Protection Program

Nova Scotia's Wilderness Areas Protection Program demonstrates a growing interest in protecting significant habitats instead of creating parks for recreational use. In the early 1990s, the World Wildlife Fund of Canada launched an Endangered Spaces campaign to commit government to protecting the best remaining wild lands in the provinces. They developed annual report cards of progress to maintain public pressure. In 1994, Nova Scotia prepared a Parks and Protected Areas Assessment Plan for public review and comment and in 1998 adopted the Wilderness Areas Protection Act. Since 1992, the Province has acquired and protected 31 Wilderness Areas, about 5 percent of the provincial landmass. Seven of these areas, comprising over 123,000 hectares (303,940 acres) border the Gulf of Maine. Most areas were already publicly owned, though some were leased to forestry or mining companies. The long term goal of the Program is to protect each distinct landscape in the Province. As of yet, the Tobeatic Wilderness Area is the only area for which a management plan has been finalized to guide management efforts.

Table 4.5. Species At Risk in the Gulf of Maine, 2004
E – Endangered; SP – Special Concern; T – Threatened; V – Vulnerable

Species	Jurisdiction	Listing
Animals – 33 species		
Beetle, American burying *(Nicrophorus americanus)*	MA	E
Butterfly, Karner blue *(Lycaeides melissa samuelis)*	NH	E
Duck, Harlequin *(Historonicus historonicus)*	NS, NB	E
Eagle, Bald (lower 48 States) *(Haliaeetus leucocephalus)*	ME, MA, NH	T
Falcon, Peregrine *(Falco peregrinus anatum)*	NS, NB	T
Lynx, Canada *(Lynx canadensis)*	ME	T
	NS, NB	E
Marten, American *(Martes americana)*	NS, NB	E
Moose (Alces alcesamericana)	NS, NB	E
Plover, Piping (except Great Lakes watershed) *(Charadrius melodus)*	ME, MA, NH	T
	NS, NB	E
Puma (=cougar), Eastern (Puma (=Felis) concolor couguar)	ME, MA, NH	E
Salmon, Atlantic Gulf of Maine Atlantic Salmon (Salmo salar)	ME	E
Sea Turtle, Hawksbill (Eretmochelys imbricata)	MA	E
Sea Turtle, Kemp's Ridley (Lepidochelys kempii)	MA	E
Sea Turtle, Leatherback (Dermochelys coriacea)	ME, MA, NH	E
Sea Turtle, Loggerhead (Caretta caretta)	MA	T
Snake, Eastern Ribbon (Thamnophis sauritus)	NS, NB	T
Sturgeon, Shortnose (Acipenser brevirostrum)	ME, MA	E
Tern, Roseate (northeast U.S. nesting pop.) (Sterna dougallii dougallii)	ME, MA, NS, NB	E
Thrush, Bicknell's (Catharus bicknelli)	NS, NB	SC
Tiger Beetle, Northeastern Beach (Cicindela dorsalis dorsalis)	MA, NH	T
Tiger Beetle, Puritan (Cicindela puritana)	MA	T
Turtle, Blandings (Emydoidea blandingii)	NS, NB	E
Turtle, Bog (=Muhlenberg) (northern) (Clemmys muhlenbergii)	MA	T
Turtle, Northern Redbelly Cooter (Pseudemys rubriventris bangsi)	MA	E
Turtle, Wood (Clemmys inscuopta)	NS, NB	V
Wedgemussel, Dwarf (Alasmidonta heterodon)	MA, NH	E
Whale, Blue (Balaenoptera musculus)	MA	E
Whale, Finback (Balaenoptera physalus)	ME, MA, NH	E
Whale, Humpback (Megaptera novaeangliae)	ME,MA	E
Whale, Right (Balaena glacialis (incl. australis))	ME, MA	E
Whale, Sei (Balaenoptera borealis)	MA	E
Whitefish, Atlantic (Coregonus huntsman)	NS, NB	E
Wolf, Gray Eastern Distinct Population Segment (Canis lupus)	ME, MA, NH	T
Plants – 17 species		
Avens, Eastern Mountain (Geum peckii)	NS, NB	E
Bulrush, Long's (Scirpus longii)	NS, NB	V
Bulrush, Northeastern (Scirpus ancistrochaetus)	MA, NH	E
Coreopsis, Pink (Coreopsis rosea)	NS, NB	E
Crest, Golden (Laphiola aurea)	NS, NB	T
Gentian, Plymouth (Sabatia kennedyana)	NS, NB	E
Gerardia, Sandplain (Agalinis acuta)	MA	E
Lichen, Boreal Felt (Erioderma pedicellatum)	NS, NB	E
Pogonia, Small Whorled (Isotria medeoloides)	ME, MA, NH	T
Lousewort, Furbish (Pedicularis furbishiae)	ME	E
Milk-vetch, Jesup's (Astragalus robbinsii var. jesupi)	NH	E
Pennywort, Water (Hydrocotyle umbellate)	NS, NB	V
Pepperbush, Sweet (Clethra alnifolia)	NS, NB	V
Orchid, Eastern Prairie Fringed (Platanthera leucophaea)	ME	T
Redroot (Lachnanthes caroliana)	NS, NB	T
Rush, New Jersey (Juncus caesarlensis)	NS, NB	V
Spikerush, Tubercled (Eleocharis tuberculosa)	NS, NB	T
Sundew, Thread-Leaved (Drosera filiformis)	NS, NB	E

Source: US Fish & Wildlife, Environment Canada, 2004

Massachusetts' Environmental Bond for Open Space

Between 1991 and 1998, Massachusetts protected more than 100,000 acres (40,469 hectares) through direct purchases, grants to cities and towns, and conservation restrictions, at a cost of $337 million. From 1998 to 2001, it protected another 100,000 acres (40,469 hectares) at a cost of $140 million. Then, in 2002, a coalition of over 190 municipalities, businesses, community, sportsmen, and non-profit conservation organizations, representing over 300,000 Massachusetts citizens, lobbied for passage of the largest and most comprehensive capital authorization for state environmental programs in the State's history. Over $200 million of that bond is earmarked for critical open space protection programs. This unprecedented level of support demonstrates the commitment of Massachusetts citizens to land protection and environmental protection.

Protection programs include matching funds, payments, and purchases to acquire land for conservation or passive outdoor recreation (including coastal and inland wetlands, beaches, ponds, wildlife habitat, greenways, trail corridors, farm, forestlands, and cultural landscapes), landscape-scale resources (minimum of 15,000 acres or 6,070 hectares) for long-term ecosystem viability, biologically significant habitat of native plants and animals, and public drinking water supplies. Funds may also be used to secure conservation restrictions on farms to keep them in agricultural use and in forestlands to encourage sustainable management. In addition, funds may be used to acquire, develop, or improve urban outdoor recreation park land to assure that cities are livable.

The number of local land trusts working around the Gulf has grown dramatically in recent decades, particularly on the US side, with more than 300 land trusts compared to 87 in Canada (218). Summary data from a National Land Trust Census in 2000 listed the three states bordering the Gulf among the top ten in the nation in total number of land trusts. Maine has 95 local and regional trusts, Massachusetts 158, and New Hampshire 45 (134). As of 2000, Maine land trusts had protected 1,114,747 acres (451,122 hectares), Massachusetts 209,967 acres (84,970 hectares), and New Hampshire 288,195 acres (116,628 hectares) (134).

The Nature Trust of New Brunswick has set aside 20 preserves, encompassing 2,000 acres (810 hectares), including 15 coastal islands (which represent 10 percent of the total islands) in the Bay of Fundy. The Nova Scotia Nature Trust launched a private land conservation program in 1997 that has since expanded province-wide.

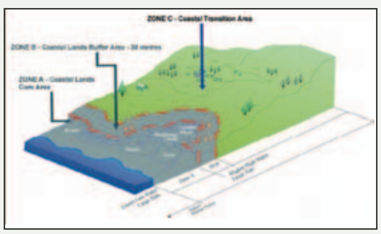
In addition to direct land protection, hundreds of community groups and regional associations around the Gulf are working to protect and restore riverine environments and improve watershed health through a combination of restoration work, pollution abatement, education, water quality monitoring, and, to a lesser degree, land use planning. In recent years, there has been significant networking among the various programs. Many model projects have emerged, including the Maine's "Shore Stewards" training program that provides citizens with intensive training in coastal issues in exchange for a commitment to undertake at least 30 hours of volunteer work on a coastal project in their watershed.

Climate Change

The Canadian Climate Impacts and Adaptation Research Network identified a number of climate change impacts on coastal resources for the Atlantic Region, including impacts from extreme weather events like flooding, storm surges, and hurricanes; impacts of sea-level rise, particularly on erodible natural features, human settlements, and coastal infrastructure; and impacts on wildlife and biodiversity like loss of coastal wetland habitat, fragmentation and isolation of other habitats, invasive

New Brunswick Coastal Areas Protection Policy

Since 1996, New Brunswick has worked to establish the New Brunswick Coastal Areas Protection Policy, which specifies planning controls to protect sensitive areas like sand dunes, coastal marshes, and beaches. This policy, which the Province plans to adopt in 2004, will apply to both private and publicly owned land. Provincial and municipal governments, as well as regional development agencies, will be required to apply universal standards for development activity and approvals.



The Policy divides coastal areas into three zones based on impact sensitivity and storm surge susceptibility (see Figure):

- Zone A, areas closest to the water including beaches, dunes, rock platforms, diked lands, and salt marshes;
- Zone B, buffer areas; and
- Zone C, areas that form a transition from coastal to inland areas.

Restrictions are tightest in Zone A, with progressively more uses allowed in Zones B and C. All salt marshes will require a 30 meter buffer, and all zones will prohibit groynes (jetties); infilling; dredging, excavating, and spoil dumping.

species, and disruption to predator-prey relationships. Other impacts include impacts on agriculture from changing precipitation patterns and impacts on forests, including changes in structure, composition, productivity, regeneration, natural disturbance regimes, pest cycles, and rates of infestation (158).

The US Global Change Research Program predicted that warming trends in New England will profoundly change water resources/coastal, forest, and human health sectors; that regional air quality may worsen; and that economic impacts will be most significant on human health, intermediate on tourism, and least severe on natural resources (266). In urban areas like Boston, increased summer temperatures already are becoming an issue for human health and energy consumption. Warmer conditions in cities can be expected to increase dispersal of populations to suburban and rural settings.

Challenges and Lessons Learned

Fragmented Authority

While federal and state/provincial government influence land use policy by protecting significant environmental and coastal resources, development decisions are largely made at the local level. This fact, itself, presents a challenge to effectively manage growth and its impacts. The situation in the Gulf of Maine is further complicated because the region is controlled by hundreds of municipalities, dozens of counties and metropolitan regions in two countries. To say that authority is fragmented understates the enormity of the challenge to creating a coherent land use policy. The difficulty inherent in collecting Gulfwide data for this report, alone, is an illustration of the complexity of the task without taking into consideration differences in land use law, culture, and traditional use.

Two concerns arise at the local level. First, though the most important decisions about growth are made at the local level, communities do not necessarily understand the implications that their decisions have on the marine environment – which is why most environmental protection rests with state/provincial governments. Second, there is little regional planning and land use management to advance an integrated approach toward development, conservation, and investment in the infrastructure that supports both.

Nonetheless, the authority to manage land use development that can either protect or destroy marine ecosystems and other environmental resources largely remains in the hands of local government. A rigorous public education effort targeted at municipalities and their elected officials may help improve local decisions about land use policy, if it can be translated into action that respects resources and forces that extend beyond municipal boundaries. In spite of the fact that there are few metropolitan authorities in the Gulf, it is at this level that major planning decisions must be made.

States/provinces, and federal governments direct major environmental policy and regulation, which if coordinated and extended to address landscape-scale development patterns, would greatly improve the likelihood of successfully managing the impacts of development on the Gulf. However, states/provinces have steered away from preempting local land use authority, popularly viewed as "home rule." Although some state/provincial coastal and other programs include a link between their programs and local land use management, for the most part, these efforts are fairly tenuous and programs focus on permitting projects like docks, marinas, beachfront erosion control structures, and alteration of wetlands and tidal structures. Cross-disciplinary efforts that link regional planning and land use management to ecosystem health are rare (16).

International and federal directives, along with incentives, enforcement, and measurable standards of performance will likely be necessary to effectively meet the need at hand. Dialogues, such as those undertaken by the Gulf of Maine Council and Global Programme of Action and other regional organizations are critical to coordinating efforts across the various political boundaries of the Gulf. Some of the avenues that might be explored include educational and technical assistance for regional planning, linking watershed planning with existing federal regulatory and funding programs, and developing quantifiable standards for protecting ecosystem health.

Unintended Consequences

The discussion of how to manage impervious cover in watersheds illustrates how well-intended, single purpose, government policies, regulations, and investments can have unintended consequences that subsidize and promote sprawl. Integrating environmental regulations, such as for stormwater, and watershed strategies into state/provincial growth management offers great promise for the cause of marine protection. Other avenues that may be pursued include thinking about, and planning for, unintended consequences up-front, particularly in regulatory and administrative policy areas like tax policy, transportation funding formulas, and capital investment policies.

Assuring that all key players, in and outside of government, are engaged in identifying potential scenarios under existing and proposed policies, regulations, programs, and investments is critical to successfully anticipate unintended consequences. The lenses through which the public, private, and nonprofit sectors view consequences are different, and diversity of perspectives will help avoid missteps in this new area of public policy.

Once integrated policy is developed and adopted, coordination of public agency staff within and across various agencies and levels of government, will be essential to assure that programs are not working at cross-purposes and can be modified, when appropriate, to avoid or address unintended consequences.

Integrated Land Use and Infrastructure Planning and Public Investment

Capital investments in transportation, sewer and water, economic development, housing, schools, safety, and other public buildings can either promote or undermine efforts to manage growth. These investments create magnets for new growth.

Regional, state/provincial, and federal governments that consciously link major capital investments and land use management are far more likely to avoid unintended consequences and promote a pattern of development that reduces stress on the health of the Gulf. Examining tax policy; transportation, aid to education, and other funding formulas for unintended subsidies of sprawl will help identify necessary changes in approach.

Modifying funding formulas so they support the livability of existing compact areas is likely to encourage growth in desired locations. Market research to uncover why people and businesses choose to locate in certain areas will help inform the evaluation and adjustment of investment and regulatory policies.

Careful investment of capital in green infrastructure, both at a landscape-scale to protect natural systems and neighborhood scale to ensure livability, should be integrated with land use to assure they complement growth management objectives.

New Tools

"Land use is visual; land use is local; land use is multidisciplinary. Ultimately, land use education is a challenge of making linkages between causes and effects that appear unrelated, between constituencies that believe they have little in common, and between places that seem to be far apart. Only in the last decade have the tools been widely available to make those links. These new tools offer the prospect to change the way metropolitan regions think about themselves and relate to their environment" (16).

To change growth patterns in the Gulf, people must first understand these patterns and assess alternatives to sprawl. To do this, communities, regions, and states/provinces need meaningful new tools and often lack the resources to develop them.

Geographic information systems (GIS) can be used to visually and quantitatively characterize land use trends and analyze various alternative development futures. Federal governments should support development of GIS models and share them with citizens and governments to help them visualize and analyze long term implications of their decisions about land use policy. Funding should be made available to develop and test models that characterize land use impacts on multiple natural resources, including air, water, terrestrial and aquatic habitats in different parts of the Gulf.

Developing and maintaining a shared database of baseline resource and land use information (building permits, wetland and water course alteration permits, clearcut areas, and other development indicators) could help lead toward more sustainable land use management throughout the region. More consistent, regional information would aid in planning and policy making on all the issues outlined in this chapter. Projects like GRANIT, a cooperative project of the University of New Hampshire and the New Hampshire Office of State Planning, is helpful to environmental protection and is popular. The Conservation Land Viewer (http://granitweb.sr.unh.edu/clv_phase1/viewer.jsp) gets more than 2000 hits per day, according to a 2002 report. The Maine Public Library of Geographic Information (Maine's Geo-Library) is a similar effort with the explicit purpose of coordinating state, regional, and local GIS efforts so that data bases can be shared at any level.

Other new tools worth exploring include:

<u>Financial incentives</u> in support of compact patterns of development – public sewer and water extensions in exchange for minimum densities; green infrastructure to assure the livability of more densely settled areas; master planning of local roadways, downtown cultural development, historic preservation, and affordable housing; preservation of locally designated unfragmented land holdings that have natural resource, environmental, and open space benefits.

<u>Leadership development initiatives</u> that work outside of the current political structure to effect a more collaborative approach among competing municipalities and quasi-governmental districts (school districts, sewer and water districts).

<u>Modernization of state/provincial planning infrastructure</u> – such as regionally compatible Geographic Information Systems; state/provincial planning enabling statutes; and innovative, regionally based mechanisms to plan and implement smart growth strategies.

<u>Promising new tools</u> – such as regional transfer of development rights programs, landscape approaches to habitat protection, and watershed stormwater utilities.

<u>Support natural resource-based</u> industries as a smart growth conservation tool that has some benefits for the natural environment and community character.

Quantifiable Measures of Success

How do we know whether efforts to protect and improve the health of the Gulf of Maine are successful? This question cannot be answered without quantifiable measures of success and measurement of performance to gauge progress and guide future efforts.

At a Gulfwide level, these might include measures of biological diversity, physical structure and habitat quality of streams and rivers, pollutant concentrations, dissolved oxygen and fecal coliform levels. At the regional level, standards might include optimal annual vehicle miles (kilometers) traveled, impervious surface coverage, regional ratios of rate of growth compared to land consumption, percent of capital investment in areas best suited for growth and conservation. At the community level, it might include minimum density of development and employment in certain areas, connectivity of road network, land use mixing – all tied to regional rate of growth and land consumption.

To do this, it will be necessary to develop Gulfwide and/or compatible data sets and studies. Advancements in regional and integrated GIS systems might help foster this.

Sliding Scale of Assessment

Setting aside the tricky issue of international coordination, it is helpful to consider desirable changes in land use policy based on the level of geography one looks at and to consider desirable reforms at each level – regional, neighborhood and site.

At the regional level, it is important to identify those watersheds that are less than 10 percent impervious and attempt to maintain their undeveloped condition – which means that those watersheds with impervious cover above 10 percent should absorb the majority of projected growth over the coming years.

This does not mean that the developed watersheds must be sacrificed. On-site stormwater practices, buffers, new paving techniques, reduced automobile dependency, targeted public investment, and reforms at the neighborhood and site level may help mitigate impacts and maintain livability. Once regions identify the best locations for new development and locations where development should be minimized, states/provinces should adopt regulatory, investment, and land conservation programs to guide growth patterns accordingly.

To maintain undeveloped watersheds, density in developed watersheds must be adequate to meet regional growth projections. In addition to reducing the amount of land consumed by development, density provides opportunity to expand transportation options which reduce impacts from expanding automobile usage. As density and mixing of land uses increase, the number and length of automobile trips decline, and with it air and water pollution (16).

Yet, densities of communities have generally fallen over the decades of the twentieth century as families have moved to large lot subdivisions in the suburbs, seeking privacy, space, better schools, and cheaper land. This trend was accelerated by postwar federal housing and transportation policy that subsidized dispersal of population and by local zoning codes that mandated segregated uses and large lots. Failing to focus on livability, quality of development design, connectivity of streets, parks and open spaces, buffering and sensitive mixing of uses has helped create the public "reflex" of opposing compact patterns of development. There is a great need for public education about the impacts of current development patterns and the benefits of denser communities from an environmental, but also a fiscal and social perspective. New tools may help communities visualize environmental, design, social and economic advantages of more compact and well designed neighborhoods.

At the site level, it is important to continue to use Best Management Practices (BMPs). Much has been done to prepare BMPs to address the quantity and quality of runoff from development. This effort must now be balanced with necessary changes at the neighborhood and regional scales to avoid "hypersprawl." This may best be done by integrating land use planning and watershed planning (see sidebar on An Integrated Land-Use Agenda).

Promising Strategies

In summary, a number of promising strategies should be explored.

<u>Regulation</u> – Adjustment of federal, state/provincial, and local regulations to address fragmented authority, unintended consequences, density, and integrated regional land use and watershed protection plans that are facilitated and encouraged at the federal, state/provincial level, and developed and implemented at the regional and local level.

<u>Investment</u> – Modification of the way investment decisions are made to assure that capital investments which encourage and subsidize growth are limited to areas where growth is desired. People should still be allowed to live where they choose, but they should bear the financial consequences of those decisions rather than expect society, as a whole, to pay for them. An exception to this rule should be to support households and workers in natural resource-based industries to buffer them from the fiscal burden of living in remote rural areas. Capital investment in the livability of compact areas should be made to draw and retain people in compact settlements.

<u>Land</u> – Investments in conservation of critical rural areas and significant habitats should reflect and be integrated with planning and investment at the regional and local levels.

<u>Public Education</u> – This is key. For sprawl, after all, is a product of the market place, in which thousands of people make everyday decisions they think are in their best interests. Without change at the individual level, sprawl cannot be directed to less harmful patterns of land use. A large scale public education campaign targeting local officials, state/provincial and federal agencies and representatives, and the public is a necessary ingredient for success. It should focus on the need to raise general awareness of the impact of development decisions on the health of the Gulf. It should address the public's fear of density. It should focus on the need to invest in creating livable communities and to adopt integrated regional planning and investment strategies.

An Integrated Land-Use Agenda

Marine-protection strategies cannot stop with site-level practices at the water's edge. They must reach inland to incorporate regional and neighborhood land-use reforms. These reforms should be imbedded in the comprehensive plans and zoning ordinances of coastal cities, towns, and counties. However, regions must seek to achieve many other goals besides environmental ones, such as the provision of affordable housing, the promotion of economic development, and the protection of historic landscapes. During the regional-planning process, the protection of coastal aquatic ecosystems should be shaped by, and then merged with, these other regional concerns. A regional watershed protection plan should have the following elements:

Regional

1) Characterize the watersheds within the region as developed or undeveloped, identifying the watersheds that are currently less than ten percent impervious and those that are more than ten percent impervious.
2) Assign growth to the developed watersheds first. Then assign any growth that cannot be accommodated in developed watersheds to a limited number of undeveloped watersheds. The watersheds to be developed will be determined by their ecological importance and also by other regional growth considerations, such as the value of terrestrial ecosystems, the economic development potential as determined by proximity to roads and rail lines, and the disposition of landowners in the area toward preservation and development.
3) Adopt policies that maintain impervious surfaces in undeveloped watersheds at less than ten percent. [private conservation easements, purchase of development rights, infrastructure planning, urban service boundaries, rural zoning (20 to 200 acres per unit, or 8 to 81 hectares per unit, depending on the area), urban growth boundaries].
4) Ensure that local governments zone to provide adequate land for future development within developed or developing watersheds.

Neighborhood

1) Allow residential densities that support transit and reduce vehicle trips per household and minimize land consumption. The minimum density for new development should be 7 to 10 net units per acre (2.8 to 4 net units per hectare).*
2) Require block densities that support walking and reduce the length of vehicle trips. Cities that support walking and transit often have more than 100 blocks per square mile (approximately 39 blocks per square kilometer).
3) Connect the street network by requiring subdivision road systems to link with adjacent subdivisions.
4) Integrate houses with stores, civic buildings, neighborhood recreational facilities, and other daily or weekly destinations.
5) Incorporate pedestrian and bike facilities into new development and ensure these systems provide for inter-neighborhood travel.
6) Encourage and require other design features and public facilities that accommodate and support walking by creating neighborhoods with a pleasing scale and appearance. (e.g., short front-yard setbacks, neighborhood parks, alleys, and architectural and material quality).

Site

1) Require the most effective structural storm-water practices to be applied, especially focusing on hot spots such as high-volume streets, gas stations, and parking lots.
2) Establish buffers and setbacks that are appropriate for the area to be developed—more extensive in undeveloped watersheds than in developed watersheds. In developed watersheds, buffers and setbacks should be reconciled to other urban design needs such as density and a connected street network.
3) Educate homeowners about their responsibility in watershed management, such as buffer and yard maintenance, proper disposal of oil and other toxic materials, and the impacts of excessive automobile use.

Source: (16)

** A density that approximates traditional development of the region may be more appropriate for smaller communities – e.g., in the 3 to 5 units per acre (1.2 to 2 units per hectare) range. Appropriate densities should be derived from a combination of assessments of projected growth that must be accommodated as well as from actual estimation of density of existing traditional compact areas within the region.*

5. Contaminants and Pathogens

Introduction

Generations of human activity around the Gulf have produced elevated levels of contaminants in some coastal waters and sediments. Contaminants are potentially harmful substances in the natural environment that are present at concentrations above natural background levels. When present at concentrations that cause impacts they are considered pollutants. Pollutants are of concern to both human health and to ecosystems because of their potential health effects on humans, other forms of life, and the well-being of ecosystems. Likewise, there are concerns about microbial pathogens associated with point and non-point pollution sources.

Over recent decades, the level and variety of contaminants entering the Gulf of Maine has changed markedly. Passage of the U.S. Clean Water Act in 1972 helped reduce the volume of industrial and municipal discharges while improving the quality of water treatment prior to discharge. In Canada and the US, source control programs have been effective in maintaining better levels of treatment of discharges.

While progress has been made at reducing such "point" sources of pollution, "nonpoint" sources of pollution have increased. These diffuse forms include atmospheric deposition from local and distant sources; runoff from landfills, roads and agricultural areas; discharges from marine vessels; and contaminated groundwater seepage. Growth in coastal populations around the Gulf, increased development, and changes in land use have all contributed to nonpoint source pollution, raising the contaminant load entering estuarine and coastal ecosystems. Natural systems have some capacity to absorb contaminants without undue harm, but that capacity has been overtaxed in many settings.

Based on discussions with scientists, policy-makers and citizens around the Gulf, the GOMC identified sewage, nutrients and mercury as the three contaminant problems of greatest concern to the Gulf (96). Sewage and nutrients were indicted because they contain a number of potential contaminants: nutrients include nitrogen, phosphorus, and trace elements, while sewage has nutrients, microbial pathogens and a broad spectrum of other contaminants. This chapter focuses on the three primary contaminant problems, leaving discussion for future forums of other important contaminants, particularly persistent organic compounds.

Current Status

Sources of contaminants

Contaminants enter the Gulf of Maine from point sources such as wastewater treatment facilities (WWTF) and industries, and from nonpoint sources such as atmospheric deposition (due to power plants, incinerators, and automobile exhaust) and storm water runoff from urban and agricultural areas.

Sewage

Sewage is regionally ubiquitous with both ecological and human health implications. Untreated sewage contains pathogens, heavy metals, toxic organic chemicals, organic and inorganic nutrients, suspended solids, debris, pharmaceuticals and other organic compounds of concern (130). As of 1991, 378 facilities circling the Gulf discharged approximately 305 billion gallons (1.17×10^{12} liters) of wastewater treatment effluent into the Gulf of Maine each year (204). Nearly half of that volume (130 billion gallons or 500×10^{9} liters) entered Boston Harbor from Massachusetts Water Resources Authority (MWRA) facilities. Since 1991, wastewater flow has increased at most U.S. WWTFs: for example, the nine facilities in coastal New Hampshire increased their flow volume roughly 20 percent in the decade preceding 2001, while the MWRA facility flow decreased slightly (280).

Effective treatment approaches serve to reduce contaminants from wastewater, most commonly suspended solids and biological oxygen demanding organic wastes. For example, even though the overall flow of effluent has decreased only a small amount, improved treatment by the MWRA facility has decreased the discharge of suspended solids from ~110 metric tons per day in 1991 to ~30 metric tons per day in 2002 (280). In contrast to WWTFs where improved treatment has reduced contaminants, other WWTFs in the Gulf still discharge untreated sewage. In Saint John, New Brunswick, 42% of sewage is discharged raw without treatment into the Bay of Fundy (11).

To limit the amount of contaminants entering receiving waters from sewage, both the U.S. and Canada have state and provincial permitting programs that regulate levels of pathogens, suspended solids and organic nutrients (commonly referred to as "biological oxygen demanding" substances or BOD) – all of which are common in untreated sewage discharge. However, many other contaminants are not routinely included in discharge permits – such as inorganic nutrients (nitrogen, phosphorus), pharmaceuticals, antibiotics, environmental estrogens and other substances that can mimic hormones and disrupt endocrine systems (130).

Because there are so many different types of contaminants in sewage, it has been necessary to develop unique indicators to help track its presence. In Boston Harbor, caffeine in seawater (238), linear alkyl benzenes and coprostanol in combined seawater overflow (CSO) effluent (70) and *Clostridium perfringens* in sediments (141) have been used as sewage indicators. *C. perfringens* is a pathogenic bacterium present in sewage and fecal matter that can survive disinfection processes and persist for long periods in the marine environment. Studies at Boston's MWRA facility have shown increased levels in sediments near a new outfall pipe exposed to effluent, and decreases in sediments at harbor sites where the outfall formerly was located. C. perfringens has also been used in Portsmouth Harbor and Penobscot Bay sediments, to determine the spatial distribution of sewage contamination in surface sediments and in sediment cores to determine historic sewage contamination with depth (117, 12).

Bacterial Indicators of Fecal Contamination

Hundreds of pathogenic species of bacteria and other microbial pathogens have been found in estuarine and marine environments. Some are present naturally, but the majority of diseases are caused by pathogens from sewage and non-human feces that have contaminated water or shellfish. Government programs attempt to monitor marine waters to protect public health. However, they do not measure pathogens directly because there are so many different pathogens and measurement methods are difficult and expensive. This creates a complex problem for protecting human health: how can surface waters be adequately classified when threatened with such a diversity of potential pathogens?

Most programs rely on fecal indicators, microorganisms that are consistently present in feces at high concentrations, can be measured easily at affordable costs, and can signal the presence of pathogens and the threat of disease (255). Water-quality standards used to trigger closures of shellfish beds and beaches are based on epidemiological studies of indicator concentrations associated with disease incidence. Despite their many documented limitations (94; 269), indicators such as fecal coliforms, *Escherichia coli* and *E. nterococci* generally have been effective at preventing water-borne bacterial illnesses.

Microbial pathogens

Pathogens are microorganisms that can cause disease. The most common microorganisms that are human pathogens are bacteria, viruses and protozoa. Pathogens in the Gulf of Maine may cause human diseases from exposure to contaminated shellfish and water. Each state and province reports on the incidence of infectious diseases, but this information is not categorized in enough detail to identify incidences associated with marine waters and shellfish consumption (189; 184). For example, the Maine Bureau of Health attempts to list causal organisms and probable sources, but the majority of outbreaks and incidences are of unknown cause and source (142).

Most microbially-polluted marine waters are impacted by land and freshwater sources. Indicator organisms and pathogens from sewage do not survive well in estuarine and marine waters, nor do most of them survive WWTF disinfection processes. Treated WWTF effluent that is a low-level source of contamination during routine conditions can cause significant contamination when rainfall events overload treatment capacity and discharge untreated sewage (22).

In areas where sewage treatment is effective, contaminants come from sources other than WWTFs and are typically at highest concentrations during wet weather (116; 124). Non-WWTF sources include CSOs, sewage treatment and storm water infrastructure (illicit and cross connections in storm pipes), on-site septic systems and overboard (untreated) discharges, and illegal direct discharges such as boat discharges and ice fishing. CSOs can be pollution sources during rain events and contribute extensive contamination to Boston Harbor (153), where efforts are underway to implement a CSO control plan. Leaky sewage infrastructure, especially in aging sewer systems, can also cause contamination even during dry weather (123). Apart from sewage infrastructure, storm water pipes in urban areas that carry contaminated runoff and have illicit or leaky sewage pipe connections can also contribute significant amounts of bacteria to tidal waters (120; 116). Rainfall can also wash bird feces from roof tops and pet waste from sidewalks into storm pipes (118). Agricultural runoff, particularly in livestock areas, also can carry microorganisms into nearby waterways (123).

Large ocean-going ships have been implicated in the discharge of untreated sewage and gray water into coastal waters. These discharges have had negative impacts on shoreline water quality. In one week, a 3000-passenger cruise ship can generate 210,000 gallons of sewage and 1,000,000 gallons of untreated gray water that can be legally discharged three miles from US shorelines (212). Cruise ship discharges are becoming an increasing source of concern in the Gulf, particularly in communities like Bar Harbor, Maine where up to 80 cruise ships now visit Frenchman Bay each summer. Discharges from recreational craft and fishing boats are also a concern in many coastal settings, particularly popular harbors and shallow areas with minimal water circulation. (243). Even though sewage pump-out facilities are present at most marinas, boaters may still disregard laws prohibiting direct discharges. Safety zones are usually imposed to prohibit shellfish harvesting from areas around marinas (168).

Impacts on swimming beach water quality

The US national water quality inventory report for 2000 showed that pathogens were by far the leading cause of impairment of US coastal waters (257). The presence of pathogens can limit recreational use, particularly swimming, in populous coastal areas. In the Gulf of Maine, recreational swimming beaches on marine waters are monitored in the 5 jurisdictions, although the monitoring and management strategies differ. Following recommendations from the U.S. Environmental Protection Agency (USEPA) (255), Maine, New Hampshire (258) and, more recently, Massachusetts (152) all use enterococci as the fecal indicator. New Brunswick relies on *Escherichia coli* as a fecal indicator, as do Nova Scotia health authorities.

The elevated levels of bacterial pollution that cause beach closures can be hard to trace, given the variety of potential sources: storm water runoff, CSOs, sewer line breaks, waterfowl, domestic animals, agricultural practices, septic systems, and unknown pollution sources (262; 152). Recent studies conducted in New Hampshire suggest that wild animals, birds and livestock, in addition to humans, are common sources of fecal contamination at coastal beaches (125;122).

The U.S. Beaches Act of 1997 has helped initiate and support beach monitoring activities in the states bordering the Gulf. In Massachusetts, both state and local agencies monitor beaches (152). The New Hampshire Department of Environmental Services conducts beach monitoring through the Public Beach Inspection Program, posting warnings after rainfall events greater than 0.5 inches (1.3 cm.) within 300 feet (91 meters) on both sides of storm drains, rivers and outlets to coastal lagoons and marshes. Maine's Coastal Beach Monitoring Program relies on citizen volunteers, and has grown in recent years to include 31of the most visited beaches in 15 towns and state parks (with an additional 5 of the remaining 15 beaches targeted for monitoring in 2004) (E. Stancioff, Univ. of Maine Cooperative Extension, pers. comm.).

During the 2002 beach season, the USEPA began uploading data onto its web site on beach monitoring, closures and sampling in the three Gulf of Maine states (258). The agency also summarized data for the Northeastern U.S. (Virginia to Maine) in the National Coastal Condition Report II (262). Those data covering ongoing monitoring at coastal beaches track 7 settings in Maine (York and Cumberland counties, only), 13 in New Hampshire, 225 in the Gulf of Maine portion of Massachusetts, and 6 in New Brunswick. Testing results showed violations of water-quality standards in each state, no violations in New Brunswick, and beach closures in Massachusetts and Maine (Figure 5.1). Out of 4,106 samples tested in 2002, 120 (3 percent) violated water-quality standards. Overall, closures occurred at 46 out of 225 beaches (20 percent). New Hampshire has not had a marine beach closure in more than a decade (188). Around Boston Harbor, improving sewage treatment methods and relocating of the MWRA effluent pipe have helped reduce microbial concentrations, but shoreline pollution sources still cause beach closures and related losses in recreational and economic opportunities (154).

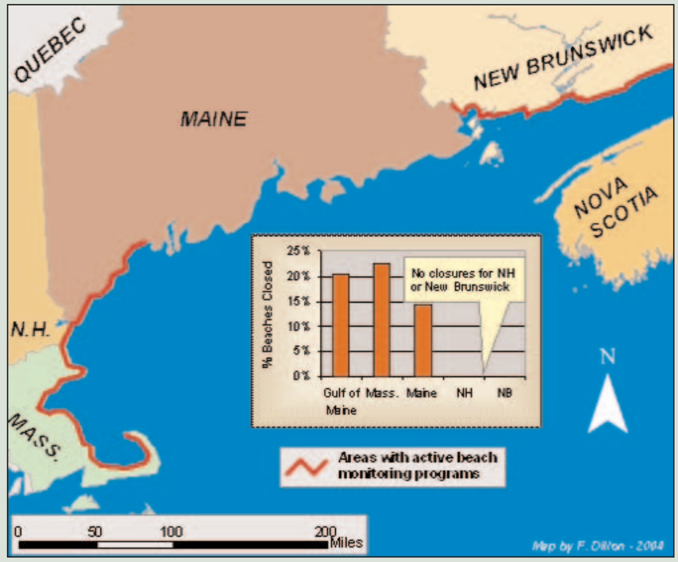


Figure 5.1. Percentage of beaches with closures in 2002-03

Impacts on water quality in shellfish harvesting areas

In Canada and the US, shellfish harvesting areas are classified as approved or prohibited, or they have other classifications that limit harvesting. These classifications are based primarily on levels of bacterial pollution measured in overlying waters, although other types of pollution can also limit harvesting. The National Shellfish Sanitation Program (NSSP) and the Canadian Shellfish Sanitation Program (CSSP) set harmonized fecal coliform standards and support uniform assessments between jurisdictions to allow for export of commercial harvests across national, state and provincial borders. Even those areas that have the most favorable classification of "approved" are subject to temporary closures following heavy rainfalls (i.e. they can grow and harvest shellfish for direct consumption and marketing under most conditions).

Several summaries of shellfish classification areas in the Gulf of Maine have been prepared. Areas classified as approved and prohibited for Massachusetts, Maine and New Hampshire in 1985, 1990 and 1995 were summarized by Horsley and Witten (108), based on data from 5 year summaries published by NOAA (173,174). In Atlantic Canada, the number of shellfish bed closures has steadily increased from 1940 to 1997 (159). A Gulf of Maine Council document from 2001 summarized classified areas for the 3 states, and New Brunswick and Nova Scotia for 1995 and 1999 and showed an increasing trend in upgraded classifications for the whole Gulf. Data from these reports and more recent (2001-03) information based on newer state and provincial agency data are summarized in Figure 5.2. Since 1995, >75% of all classified shellfish areas have been classified as

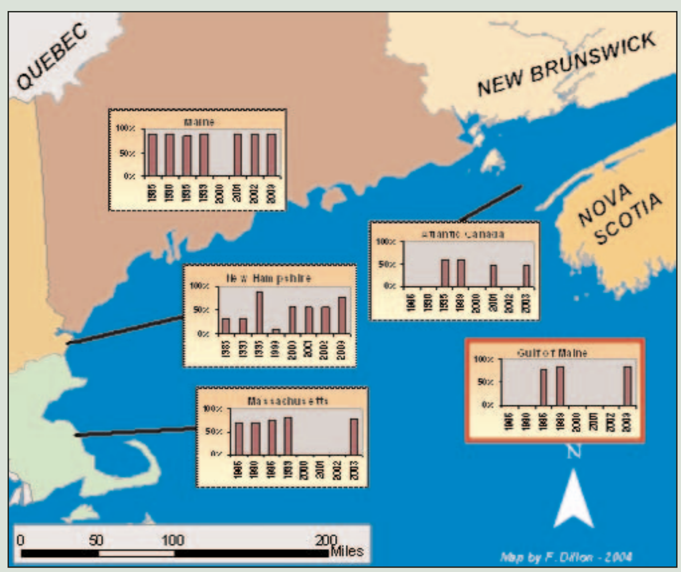


Figure 5.2. Percent of shellfish acreage classified as 'approved': 1985-2003

Tracking Sources of Contamination

Traditional methods of assessing water quality are limited in their ability to determine contaminant sources. Indicator bacteria do not signal whether the fecal contamination is due to humans, birds, pets or other mammals.

More precise methods of determining those sources now are being pioneered. Microbial Source Tracking (MST) methods seek to indicate the exact sources and how much each source contributes. Several recent reviews of these methods weigh the benefits, costs and limitations of each approach (228; 150; 240; 250), and recent workshops around the Gulf are providing information on potential regional uses of MST.

MST is being used at several sites around the Gulf. In the Charles River and the north shore area of Massachusetts, scientists have used a DNA fingerprinting method called 'rep-PCR' to track sources of *E. coli.* In the Bay of Fundy, scientists are using 'pulse-field gel electrophoresis' to track sources of *E. coli* in Nova Scotian shellfish waters (226). The University of New Hampshire has used 'ribotyping' (DNA fingerprinting) of *E. coli* extensively over the past three years to determine pollution source species at ocean beaches, tidal rivers, storm water drains and in shellfish waters in New Hampshire and southern Maine (125; 122; 118). Data from these studies are helping to focus efforts to eliminate pollution sources and save time and resources in monitoring programs.

approved, and there has been a progressive increase in upgraded classifications over the past 10 years accompanying improvements in water quality as provinces and states work to identify and eliminate pollution sources. However, increased coastal development and use of septic systems can increase contamination and impact shellfishing throughout the Gulf of Maine, as it has in the Bay of Fundy (11), threatening to reverse progress to date. Improved detection methods for pathogens such as viruses will help to protect shellfish consumers. Some new approaches for identifying sources of fecal contamination can also save time and resources (see Tracking Sources of Contamination side bar).

Nutrients

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

No direct public health effects are caused by nutrients, rather, most impacts are on other living resources as a result of eutrophication. Eutrophication is the "accelerated production of organic matter, particularly algae, in a waterbody" (25), causing increased oxygen demand, decreased dissolved oxygen in the water and hypoxia (lack of oxygen) in fish tissue as the organic matter decays. This also leads to blooms of toxic and nuisance algae, changes to bottom and phytoplankton communities, and degradation of algal and sea grass beds. Nutrient over-enrichment can also stimulate the growth of some naturally-occurring bacterial pathogens such as *Vibrio vulnificus* and *Vibrio parahaemolyticus* in the Gulf of Maine (126, 236).

The processes by which nutrients have environmental impacts are relatively complex; no single measurement can serve to indicate the severity of effects. Some indicators of nutrient effects in water include dissolved oxygen, chlorophyll concentrations, nutrient concentrations and nutrient loading, but many more can be used (25; 244). The extent to which nutrients cause these problems can depend on such geographic variables as tidal flushing, freshwater inflow, and the depth and configuration of embayments (244; 220).

Nutrients and related water quality problems are not commonly listed by state and provinces as reasons for impaired use of coastal waters in the Gulf but their impact is growing. Because nitrogen is generally considered the most common limiting nutrient for primary production and is of greatest concern in the Gulf of Maine (279), most of the discussion in this section will focus on nitrogen.

Nutrient sources, loading and fate

The most significant nitrogen sources in the Gulf of Maine are different for the deep water portion of the Gulf compared to smaller coastal and estuarine areas. This is because most of the nitrogen entering the Gulf of Maine comes from the nitrogen contained in continental slope water, or ocean water from the deep continental slope bordering the Gulf (253). Important sources in estuaries and some particular embayments include wastewater, runoff, atmospheric deposition (from combustion of fossil fuels) and other sources (244). Most estuaries in the Gulf are less susceptible to eutrophication than estuaries elsewhere in the US because of the high degree of tidal flushing, considerable depth and generally low freshwater input (due to small watersheds) in the Gulf (244; 220; 24).

Several studies have assessed how much different sources contribute to nitrogen loading in Gulf of Maine estuaries. One study estimated an overall mass balance for the Gulf of Maine, calculating total nitrogen input at 2,680,730 metric tons per year, with offshore (slope) waters contributing 93.7 percent, atmospheric sources 4.9 percent, coastal point sources 0.9 percent, rivers 0.4 percent, and finfish aquaculture 0.1 percent. These estimates did not account for non-point sources of nitrogen. An inventory of the coastal point sources (204) estimated that 91 percent of that nitrogen input came from WWTFs, and

9 percent from industries (half of that from pulp and paper operations). Eighty percent of all the point sources lie within four watersheds: Massachusetts and Sheepscot bays and the St. John and Merrimack rivers. According to this model of nitrogen-loading in the Gulf, Massachusetts accounted for 58 percent of the total load, Maine 22 percent, New Hampshire 9 percent, New Brunswick 8 percent and Nova Scotia 3 percent.

Another study concluded that municipal wastewater effluent is Atlantic Canada's largest source of nitrogen loading, accounting for 5,500 metric tons in 1996 (112). Agricultural use of fertilizers increased between 1981 and 1996 but there was a corresponding decrease in use of manure. The only "anomaly" observed in nutrient data around the Bay of Fundy was elevated ammonium concentrations in Passamaquoddy Bay which was attributed to aquaculture (277).

An estimate of annual nitrogen loading for five Gulf of Maine estuaries between 1988 and 1994 found that atmospheric nitrogen appeared to be the largest source for less developed estuaries like Penobscot Bay and the Saco and Sheepscot rivers in Maine, whereas wastewater was most significant in Massachusetts Bay. Both sources appeared to be equally important in Maine's Casco Bay, a finding confirmed by a subsequent study (described below). By tracing nitrogen loading trends from 1900-1994, that study concluded that overall nitrogen loading has increased dramatically in all five estuaries during the last century, but the rate of increase tapered off in recent years and even decreased in Massachusetts Bay and in the Merrimack River.

Researchers have completed localized assessments of nitrogen loading as well. In New Hampshire's Great Bay Estuary, WWTFs account for 41 percent of nitrogen loading, with atmospheric deposition adding 11 percent and nonpoint sources, including rivers, contributing 48 percent (116). Direct measurements of nitrogen loading from New Hampshire's WWTFs have confirmed that estimate to be relatively accurate (22). Other studies confirmed that effluent from storm water pipes (part of the nonpoint sources cited above) is a significant source of nitrogen loading to estuarine waters near urban areas of coastal New Hampshire (115; 116).

A study of Casco Bay, Maine estimated that 30-40 percent of annual inorganic nitrogen loading to the bay is from wet and dry atmospheric deposition, with the balance coming from WWTFs (224). An even greater fraction (roughly 70 percent) of the total nitrogen loading would be atmospheric if all deposition within the entire watershed reached Casco Bay.

The MWRA developed a eutrophication model and nutrient-loading estimates for Massachusetts and Cape Cod bays (110). In 1999, it estimated that 46 percent of nitrogen loading was from the MWRA's wastewater treatment facilities, 13 percent from other WWTFs, 26 percent from atmospheric deposition, and 15 percent from rivers and nonpoint sources.

Recently, the National Coastal Assessment (NCA) Program in the U.S. has generated extensive data at many sites for total dissolved inorganic nitrogen (DIN) in estuaries along the Gulf of Maine. The concentrations are depicted in Figure 5.3 using the condition criteria from the USEPA National Coastal Condition Report II (24, 262). Concentrations over 0.5 mg N/L (red) are considered poor, under 0.1 mg N/L (green) good and levels between these values (yellow) as fair. Except for the Great Bay Estuary on the New Hampshire and Maine border, no sites had "poor" DIN concentrations. Two-thirds of sites had concentrations suggesting good conditions, with 30 percent of the sites (many in Great Bay Estuary) listed as fair. The readings appear to be higher in Great Bay and other New Hampshire sites because small tributaries there have less tidal mixing and higher freshwater nitrogen inputs, in contrast to the generally more well-mixed, open water estuarine sites in Maine and Massachusetts.

Overall, these data suggest that the problem of nutrient enrichment and eutrophication in the Gulf of Maine is not yet widespread. Nitrogen inputs could decline in the future if nutrient discharges can be controlled and if other nutrient fluxes to the Gulf of Maine do not increase (244). Eutrophication is likely to remain a concern, though, for smaller, more enclosed estuaries, particularly those subjected to increases in urbanization,

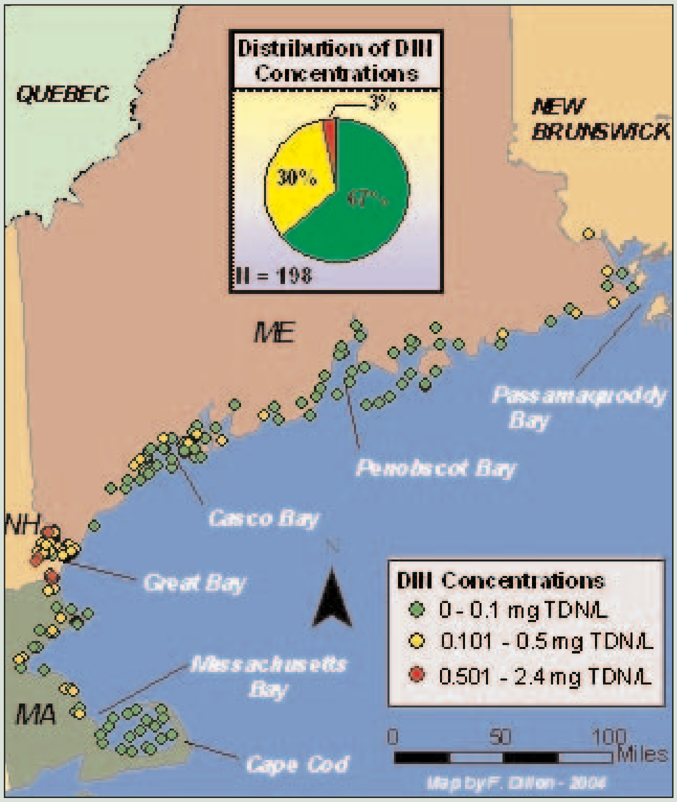


Figure 5.3. Total dissolved inorganic nitrogen (DIN) in surface water at sites in ME, NH and MA: 2000-01

WWTF loading and finfish aquaculture (due to the potential for increased nutrient inputs from fish food and fecal matter (18) — see Chapter 6). By pinpointing nitrogen sources, effective monitoring and research may help to minimize nitrogen loading over time.

Mercury

The presence, transport and fate of toxic chemicals in the Gulf Region have been studied for more than half a century. In recent years, mercury has become the heavy metal of greatest concern due to its prevalence in Gulf ecosystems, its tendency to bioaccumulate in organisms and also biomagnify (occurring in greater concentrations in organisms higher up the food chain), and its high toxicity.

Mercury can be present in several different forms. Methylmercury is the most toxic and the dominant form found in fish tissue (20; 101). Mercury can cause serious neurological and developmental effects, posing the greatest risks for recreational and subsistence fishers who consume fish frequently, and for developing fetuses and young children (87; 256), although prenatal risks associated with fish consumption are in question (166).

All the jurisdictions surrounding the Gulf of Maine have taken action to reduce mercury use and decrease environmental releases, especially since the adoption of the Mercury Action Plan in 1998 by the Conference of the New England Governors and Eastern Canadian Premiers (42; 43; 144; 197). The Canadian Environmental Protection Act (CEPA) lists mercury as a "CEPA-toxic" chemical, and its environmental release is of special concern in Atlantic Canada (42; 35).

The following sections describe some research findings to date on the sources and movement of mercury within Gulf region ecosystems. Further studies are underway to better understand where mercury ends up in the marine environment, the relative significance of natural and anthropogenic sources, the contribution of freshwater inputs to coastal areas, and how mercury affects marine organisms and the Gulf ecosystem (73).

Sources and loading

While industrial and municipal sources (such as chlor-alkali industries, paint-containing mercury additives and pharmaceuticals) were once the dominant source of mercury entering the Gulf, the primary pathway today is through atmospheric deposition (from municipal and medical waste combustion, utility and non-utility fuel combustion, and manufacturing). A 1996 study concluded that most of North America's atmospheric mercury is from incineration of solid waste (in contrast to Asia and Eastern Europe where coal combustion is the dominant source) (214). Roughly 60 percent of the atmospheric sources lie within the Gulf of Maine region, with the balance coming from other states and provinces (197; 19). Most of the 778 kg [354 pounds] of on-site mercury releases in the four provinces of Atlantic Canada during 2000 were due to utilities, waste treatment and disposal, metal ore mining and chemical manufacturing (72).

In 1999, Maine attributed roughly 70 percent of its estimated mercury emissions to commercial and industrial boilers, with an additional 21 percent coming from area sources such as residential boilers and wood stoves (145). These sources of atmospheric deposition contributed 1,500 pounds (680 kg) in 1999, with municipal and industrial wastewater discharges from 149 Maine facilities contributing another 30.5 pounds (13.8 kg) of mercury per year (as of 1998) (145). Other sources released approximately 180 pounds (82 kg) of mercury annually to Maine's land, water and air. Estimates for mercury loading to Casco Bay showed wet and dry atmospheric deposition (84-92%) to be of far greater importance than discharges from WWTFs (224).

Air masses that reach the Bay of Fundy tend to have elevated levels of mercury, much of which is deposited on coastal forests through rainfall, fog or dry deposition (284). Studies in New Brunswick have shown that coastal forests tend to intercept more mercury than inland areas, and softwood forests more than mixed and hardwood forests, which in turn intercept more than open land.

Mercury entering the Gulf through WWTF effluent has diminished due to improved treatment technologies. By one estimate, WWTFs discharged 1,280 pounds (581 kg) of mercury to the Gulf of Maine in 1991 (204), with roughly 230 pounds of that attributable to flow from MWRA facilities. Recent improvements (in 2000-2003) in secondary treatment have since reduced the MWRA amounts to between 26 and 40 pounds (12-18 kg) per year (280). Among Maine's 149 WWTFs, those with secondary treatment had one-fifth the concentration of mercury in effluents evident in facilities with only primary treatment (144).

Storm water runoff in urban areas can be a significant source of mercury to coastal waters. Storm water and dry weather flow discharged from pipes in two coastal New Hampshire cities revealed mercury concentrations in excess of state water quality criteria, with loading from individual pipes at rates up to approximately 100 grams per hour during runoff events (120; 116).

Historical sources of mercury pollution have left many riverine and estuarine sediments contaminated. A compilation of historical sediment data for states bordering the Gulf found the highest levels of mercury in harbor sediments from Boston and Stonington (Maine) (28). Other data suggest the highest sediment mercury level is probably at the site of the former HoltraChem chlor-alkali plant on the Penobscot River in Orrington, Maine. Sediment concentrations downstream of this facility were several orders of magnitude above any other site in the U.S. (108). Prior to its shutdown in August 2000, the HoltraChem plant was the single largest source of mercury release in Maine (144). Numerous studies confirm elevated levels of mercury in many sediments around the Gulf, including much of the Great Bay Estuary in Maine and New Hampshire (121), and inner Passamaquoddy Bay in New Brunswick (276).

Status and trends

The NCA program measured mercury in sediments at 179 sites in the Gulf of Maine in Massachusetts, New Hampshire and Maine during 2000-2001 (261). The highest concentration, 2.2 µg/g, was in Boston Inner Harbor (Figure 5.4). Average concentrations for each state suggested consistently elevated concentrations in New Hampshire compared to Maine and Massachusetts, probably as a result of most New Hampshire sites being located in one impacted estuary (Great Bay). Using sediment contamination criteria developed by Long et al. (139), 50 sites exceeded the Effects Range Low (ER-L) level (0.15 µg/g) and two sites, both in Boston Harbor, exceeded the Effects Range Median (ER-M) level of 0.71 µg/g. Other areas with concentrations > ER-L level were located in Casco Bay, Penobscot Bay and north of Boston. Mercury concentrations in sediments around the new MWRA outfall pipe have not increased since discharge began (141).

Studies have tracked levels of mercury in Gulf organisms as well. The most extensive ongoing assessment has been the Gulfwatch mussel monitoring program which has found elevated mercury levels in blue mussel tissue at almost every one of its 70 test sites around the Gulf (34; 119). A summary of 55 Gulfwatch sites spanning the years 1993-2001 reveals that average mercury concentrations are elevated (i.e., more than 0.23 µg/g dry weight (NOAA Mussel Watch median + 1 standard deviation value; 200), (Figure 5.5). The highest concentrations were at sites in Great Bay (New Hampshire), Casco Bay (Maine), and coastal Nova Scotia. Mercury concentrations have decreased at five sites where annual sampling occurs (less data were available for the other sites), with significant decreasing trends from 1993-2001 at sites off Digby, Nova Scotia and Hospital Island, New Brunswick (Figure 5.6).

Maine conducts some mussel monitoring as well. In 2001, scientists sampled mussels at 11 sites and compared their find-

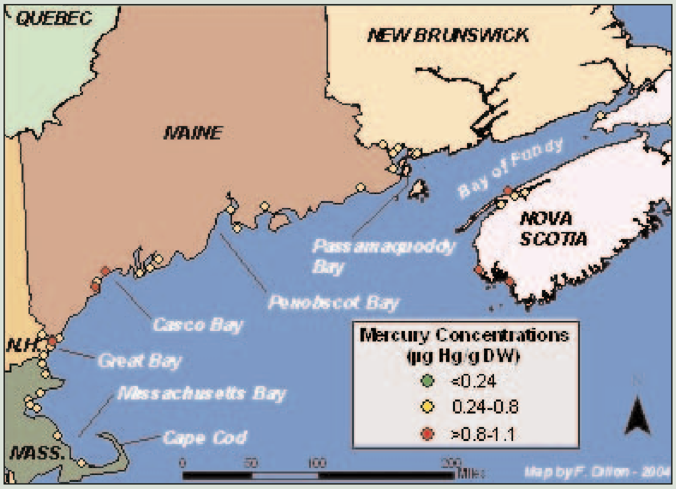


Figure 5.5. Average mercury concentrations in blue mussels: Gulfwatch 1993-2001

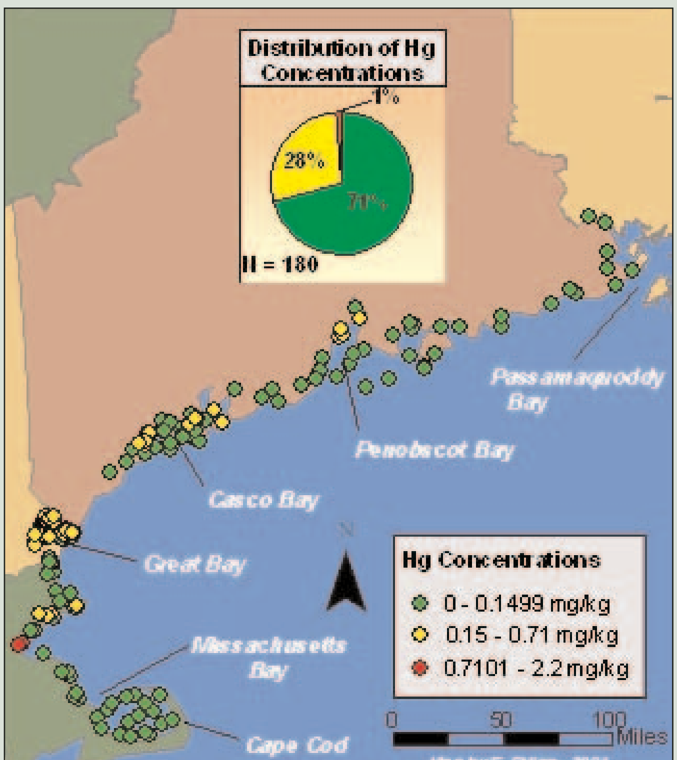
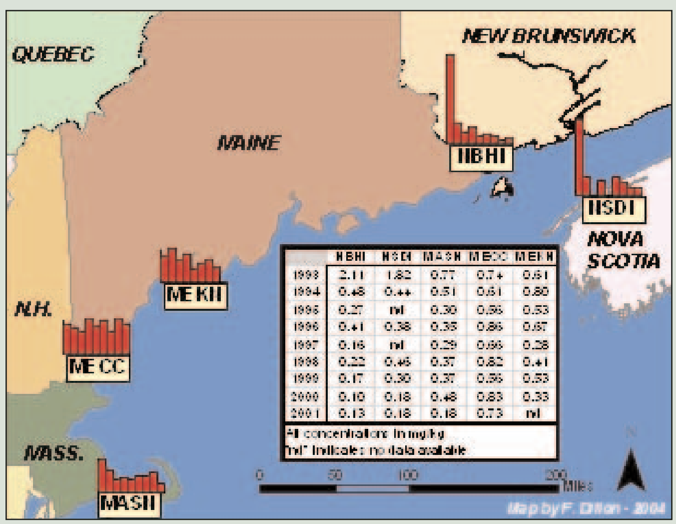


Figure 5.4. Concentrations of mercury in sediments: NCA 2000-01



	NBHI	NSDI	MASH	MECC	MEKN
1993	2.11	1.82	0.77	0.74	0.61
1994	0.48	0.44	0.51	0.61	0.80
1995	0.27	nd	0.30	0.56	0.53
1996	0.41	0.38	0.35	0.86	0.67
1997	0.16	nd	0.29	0.66	0.28
1998	0.22	0.46	0.37	0.82	0.41
1999	0.17	0.30	0.37	0.56	0.53
2000	0.10	0.18	0.48	0.83	0.33
2001	0.13	0.18	0.18	0.73	nd

All concentrations in mg/kg
"nd" indicates no data available

Figure 5.6. Mercury concentrations at Gulfwatch 'benchmark' sites: 1993-2001

ings to data collected in the late 1980s (144). Mercury concentrations were highest (over 0.4 μg/g dry weight) at a site in Kittery in the Great Bay Estuary, at the mouth of the Penobscot River in Stockton Springs, and in the Sheepscot River estuary.

The National Oceanic and Atmospheric Administration (NOAA) has the longest data record of mussel monitoring from its Mussel Watch program which is conducted at 15 sites in the Gulf of Maine. NOAA has also conducted sediment analysis for mercury at 13 of these sites. Through 1999, Dover Point in New Hampshire had the highest average concentration in mussel tissue. Mussels from eight sites consistently have had elevated levels of mercury (more than 0.23 μg/g dry weight) and O'Connor (200) reported increasing levels at Sears Island, Maine (PBSI) and Hingham Bay, Massachusetts (BHHB) (Figure 5.7). Although a site in Dorchester Bay, Massachusetts (BHDB) continues to have the highest sediment concentration among the 13 sites, the mercury in sediments there and at the PBSI site decreased between 1986 and 1997.

Biological Exposure and Effects

The tendency of mercury to accumulate in the tissues of organisms and "biomagnify" in the food chain is confirmed by the high concentrations found in birds and animals that feed toward the top of the food chain. A Bay of Fundy study found that methylmercury concentrations increased from 0.33 μg/g wet weight in phytoplankton to 726 μg/g wet weight for bluefin tuna (100). Organisms at intermediate trophic levels, including zooplankton, macrozooplankton, krill and herring, had intermediate and increasing methylmercury concentrations.

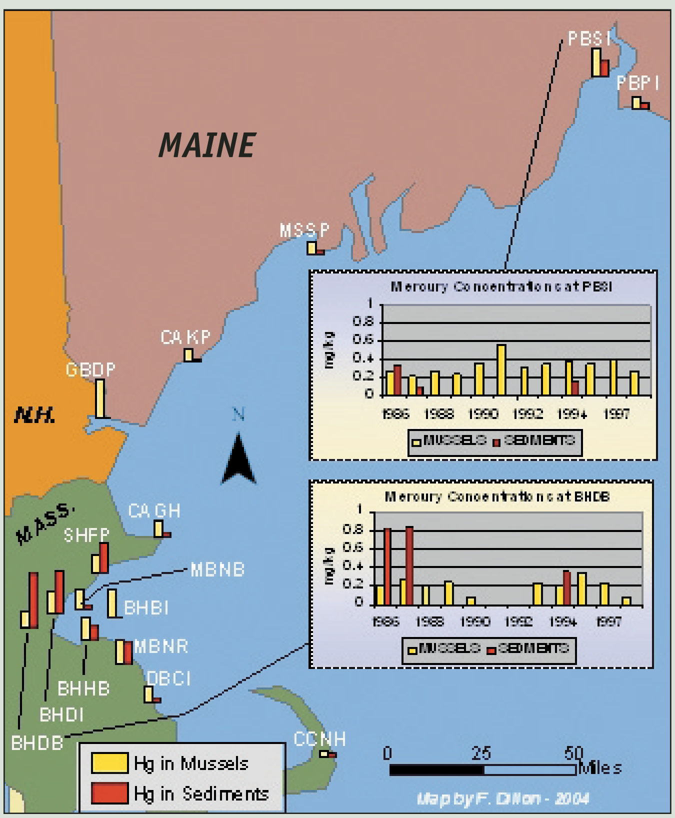


Figure 5.7. Mercury concentrations in mussels and sediments: NOAA Mussel Watch 1986-99

Wild animals and birds that routinely consume fish, such as loons, ospreys, river otters, minks, eagles and seals, are especially susceptible to accumulating high mercury concentrations. Scientists are working to locate and standardize existing data for mercury in freshwater, sediment and biota through the Northern States Research Cooperative (NSRC) Mercury Research Group. Some of the accumulated data include information on organisms in coastal sites (see studies cited below), including several older studies of eagles (198).

Researchers have found that common loons in southwestern New Brunswick and southwest Nova Scotia have very high levels of mercury in their blood compared to those elsewhere in North America (73). Rising rates of atmospheric deposition are well-documented in this area, but the relative importance of local and distant anthropogenic and natural sources remains unclear (72). The ability of Canadian loons to nest and raise their young is inversely related to blood mercury levels (73), a correlation that is being closely monitored. The highest concentrations of mercury in the blood and eggs of common loons found in the U.S. were taken from loons at two lakes located near seacoast New Hampshire (78). Spatial analysis suggests that the high levels are related to local, major emission sources in southern New Hampshire.

A recent study assessed mercury levels in the livers of Gulf harbor seals (230) and found high concentrations (93 μg Hg/g wet weight) that exceeded international action levels for liver injury in mammals. The highest levels were detected in seals in Penobscot Bay, Maine, suggesting possible inputs from local industrial sources. Mercury levels in seal hair sampled around the Gulf were similar in concentration to levels reported in eastern Canadian harbor seals in 1973—suggesting mercury's sustained presence in the food chain.

Mercury toxicity from seafood consumption is of increasing concern to humans, especially pregnant women, nursing mothers, young children, and both recreational and subsistence fishers. Stimulated by a recent series of fish consumption advisories from the U.S. Food and Drug Administration, nearly all states (including those bordering the Gulf of Maine) have now adopted mercury advisories for both marine and freshwater species (260). In Canada, both Nova Scotia and New Brunswick have province-wide advisories for freshwater sports fish that designate which species and what size ranges are of concern.

Future Projections

Contaminants rarely occur in isolation and part of the challenge involved in monitoring and controlling them involves learning what mixtures of chemicals are present, and how they act in combination. The cumulative, long-term effects of these contaminant mixtures are not well understood. Nor is there sufficient understanding of how other biological, chemical and physical stresses and factors come into play. For example, pesticides and other chemicals that occur at "sub-lethal" concentrations may be more toxic to amphibians in combination with predator cues (216), illustrating the subtlety of environmental interactions.

The jurisdictions around the Gulf are making headway in monitoring and reducing point sources of pollution (through life cycle management programs and other means), but non-point sources such as atmospheric deposition and storm water runoff continue to pose management challenges. As this chapter indicates, the research needed to guide future management is underway, and some regions are moving toward integrated monitoring (involving standardizing methods, distributed databases, resource sharing and complementary assessment approaches) to help achieve common management goals. The Gulf of Maine Council is supporting these efforts through various workshops and pilot projects. To succeed, integrated monitoring will require improved ecosystem-based indicators for the presence and impacts of sewage and its pathogens, nutrients and mercury. A full understanding of contaminants in the Gulf will also require increased research on their transport, transformations, bioavailability and biological effects.

From the human health standpoint, epidemiological information is generally non-existent in the region, even for clearly defined populations affected by mercury contamination such as recreational and subsistence fishers. Improved tracking of disease incidence from exposure to pathogens and toxic chemicals is essential for protecting public health and tracking improvements associated with management actions.

6. Fisheries and Aquaculture

Historical Perspectives

More than 400 years ago, early explorers around the Gulf of Maine reported finding marine waters teeming with life. Pods of whales surrounded their boats (207); sturgeons were so numerous that they were navigational hazards in estuaries (5); and cod, which grew more than six feet in length, could be harvested merely by lowering baskets into the water (133). Turtles, Atlantic salmon, striped bass, lobsters, eels, and oysters all were abundant (5, 207).

Responding to reports of bountiful fish, fleets from Spain, France, England and Portugal began traversing the Atlantic Ocean and filling their ships with cod for European markets. Later, permanent settlers established colonies along the Gulf of Maine coast, trusting that the abundant fisheries would sustain them. Cod, in particular, provided both a means of sustenance and a marketable commodity that advanced the region's economic development (133).

In the centuries following early settlement, fishing practices in the Gulf of Maine changed dramatically. Steam trawlers replaced sailing vessels; use of hand gear gave way to large nets and mechanized operations; and fishermen began harvesting a more diverse array of species. The Gulf's fisheries continued to support local communities while still attracting fishing fleets from around the world. By the 1960s, the size of fleets and vessels and the technology for capturing fish had increased so much that harvesting capacity exceeded available stocks: roughly 300 ships, mostly from Eastern Europe, were taking more than 310 million pounds of fish each year from the Gulf of Maine region (45). This heavy harvest threatened the survival of important fish stocks, such as cod, haddock, and herring, and triggered major changes in fishery management as nations established rights to govern the marine commons (45, 199).

The United States and Canada first claimed jurisdiction over fishing activities within 3 miles of the coastline in 1822, and that limit was extended to 12 miles in the 1940s. However, many valuable fishing grounds remained well beyond this zone, leaving American and Canadian ships to compete with foreign fleets farther offshore. Responding to this competition and to the declining stocks of commercial species, the United States and Canada chose in 1976 to exert their sovereignty over waters out to 200 miles. However, one of the most prized fishing areas in the Gulf of Maine region—Georges Bank—lay within 200 miles of both countries. A subsequent decision by the International Court of Justice, in 1984, established the Hague Line which divided Georges Bank between the U.S. and Canada (10, 133).

Expanding the zone of national sovereignty was expected to help maintain fish stocks while enabling local fishermen to accrue a larger share of the profits from fisheries. Envisioning great potential for an expanded domestic fleet, following the exclusion of foreign competition, U.S. and Canadian governments began offering subsidies that encouraged more individuals to enter the fisheries and to construct larger, more efficient boats. Within eight years, domestic fleets had grown substantially and key stocks, including groundfish, could not keep pace (45).

Steady declines in many commercial stocks then prompted reductions in fishing pressure through measures such as catch limits, size requirements and reduced harvesting seasons. While some stocks have begun showing signs of recovery, changes measured over relatively short time periods can suffer from the "shifting baseline syndrome"—in which members of the present generation use stock sizes and composition known during their lifetimes as reference points to assess the current fisheries status (205). This approach fails to recognize that fish stocks and communities historically may have been dramatically different. An appreciation for the historical abundance and condition of fishery resources, even using anecdotal information that predates scientific studies, can provide essential background for evaluating ecosystem health.

Current Status of the Gulf of Maine Fisheries

Commercial Fisheries

Commercial fisheries in the Gulf of Maine target a wide variety of fish and invertebrate species (Table 6.1). The multispecies groundfish[1] fishery has been the region's most valuable traditionally, but in recent years many gadoids (fish related to cod) and flounders have been overfished, while the economic importance of crustacean and shellfish fisheries has grown. In 2002, American lobster landings were valued at $470 million USD, while the combined value of all groundfish species harvested from the Gulf represented $155 million USD (55, 171).

Total landings of all species in the Gulf of Maine region have fluctuated over recent decades (Figure 6.1)—rising from the mid-1970s to 1980 (as domestic fleets grew in size and efficiency), remaining stable during much of the 1980s, and then declining in the latter portion of that decade through the 1990s. The downturn reflected stock declines and resulting management measures. The following case studies reflect some of the dynamics behind recent shifts in population and harvesting of four species.

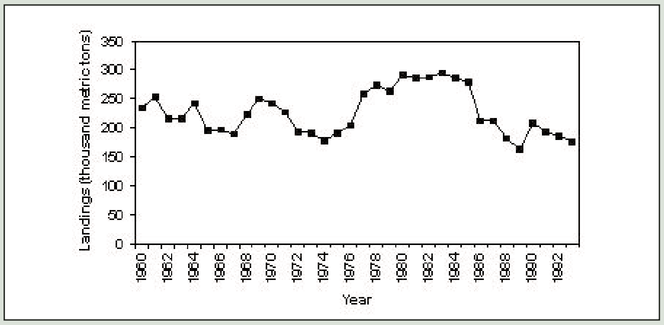


Figure 6.1. Total Gulf-wide landing of all species by all fishing nations (NAFO 2004).

Table 6.1. Major categories of organisms harvested in commercial fisheries in the Gulf of Maine and examples of species within each category.

Groundfish—A group of finfish that live on or near the substrate, including gadoids (species related to cod) and flounders.		
• Atlantic cod	• Haddock	• Hakes (red, white, silver)
• Goosefish	• Pollock	• Ocean pout
• American plaice	• Winter flounder	• Yellowtail flounder
Diadromous fish—Species of fish that migrate either from the ocean to freshwater (anadromous) or from freshwater to seawater (catadromous) to spawn.		
• American eel	• American shad	• Atlantic salmon
• Alewife	• Blueback herring	• Rainbow smelt
Pelagic fish—Fish that swim in the water column, often forming large schools.		
• Atlantic herring	• Atlantic mackerel	
Elasmobranchs— Cartilaginous fishes that may remain near the substrate or swim in the water column; species bear few young, which are either born live or from large eggs.		
• Spiny dogfish	• Winter skate	• Barndoor skate
Shellfish—Bivalve invertebrates whose bodies are enclosed by two shells.		
• Sea scallop	• Ocean quahog	• Surf clam
Other invertebrates—		
• American lobster	• Northern shrimp	• Green sea urchin
• *Illex* squid	• *Loligo* squid	• Baitworms

Atlantic Cod

Historically, Atlantic cod *(Gadus morhua)* ranked as one of the most abundant species in the Gulf of Maine and constituted the mainstay of the region's commercial fisheries (133, 39). Cod are harvested by a variety of methods, with otter trawls, gillnets, and hook-and-line gear now accounting for most of the catch (2; S. Gavaris, pers. comm.). Landings of cod by all gear sectors increased through the 1970s, declined in the early 1980s, and surged again in the late 1980s (Figure 6.2). However, as exploitation rates reached high levels in the early 1990s, substantial declines were evident both in biomass of cod stocks and in commercial fishery landings (2).

The New England Fishery Management Council began limiting the cod catch in 1982, using a combination of trip limits, minimum size limits, gear restrictions, and time and area closures (156). The U.S. government subsequently conducted three "buy-back" programs to permanently remove vessels from the fishery (92, 41). Canada has assigned quotas to individual fishermen and community boards, and has closed spawning areas to fishing for half of each year (156; J. J. Hunt and S. Gavaris, pers. comm.). Recent indices of cod biomass and abundance in the Gulf of Maine region show an increase (54, 196, 56), but the stock biomass remains well below rebuilding targets.

Atlantic Herring

Atlantic herring *(Clupea harengus)* is a pelagic, schooling fish that is widely distributed over the continental shelf from Labrador to Cape Hatteras (202). Atlantic herring was among the first species to be commercially harvested in the Northwest Atlantic (58). Today, herring in the Gulf of Maine region are captured in a variety of fixed and mobile gear, including weirs, purse seines, midwater trawls, and gill nets (186, 57, 58). Most of the Gulf's herring fisheries are along the immediate Gulf coast, in the Bay of Fundy, and off Southwest Nova Scotia (195, 57). Herring are processed into sardines or frozen fillets, used as bait in the lobster fishery, and sold as roe in Asian markets (248, 186).

Over the past four decades the abundance and landings of herring have fluctuated considerably. Landings peaked at 663,000 metric tons in 1968, due to the combined efforts of the U.S. and Canadian fleets as well as a large foreign fleet that exploited offshore waters (249, 203). Throughout the 1970s, landings declined substantially due to the collapse of herring populations on Georges Bank and new management measures that restricted foreign access to the fishery (202, 58). Herring abundance has grown dramatically in recent years and is not considered overfished at present (202). While offshore areas may sustain greater harvests, herring may be fully exploited in the Gulf's nearshore waters (3).

American Lobster

American lobster *(Homarus americanus)* supports one of the most valuable fisheries in North America, and 47 percent of its harvest occurs within the Gulf of Maine's coastal waters. Lobsters are also harvested along the continental shelf margin, using both traps and bottom trawls (138). Landings have risen markedly since the 1970s (Figure 6.4), but the timing of major increases has varied across different Gulf regions (52, 53, 8). Landings in the Bay of Fundy rose almost four-fold in the mid- to late-1990s (52), while they leveled off and even declined in the Gulf's southern nearshore regions (R. Glenn, pers. comm.). Gulfwide, recent lobster landings have been the highest ever recorded.

Overall stock abundance has remained high despite increasing fishing effort, suggesting to some that favorable environmental conditions during the past two decades may have boosted the lobster population (138, 8). Since these conditions cannot be controlled, some people advocate for a precautionary approach that would adjust landing levels but might reduce the risk of a fishery collapse (8).

Sea Scallops

Shallow waters in the Gulf of Maine are home to myriad shellfish of commercial importance, including sea scallops *(Placopecten magellanicus)*. Sea scallops are most commonly found and harvested in waters less than 100 meters (328 feet) near the edge of the Gulf and by offshore ledges and banks (102; D. Schick and S. Smith, pers. comm.). Many scallopers harvest on a part-time basis and pursue other species as well: in the Bay of Fundy, however, a fleet of full-time scallopers accounts for the majority of the harvest (102, 59). There are limited seasons for scalloping in specific areas of the Bay of Fundy. However, fishermen in the Full Bay Fleet, which accounts for most of the har-

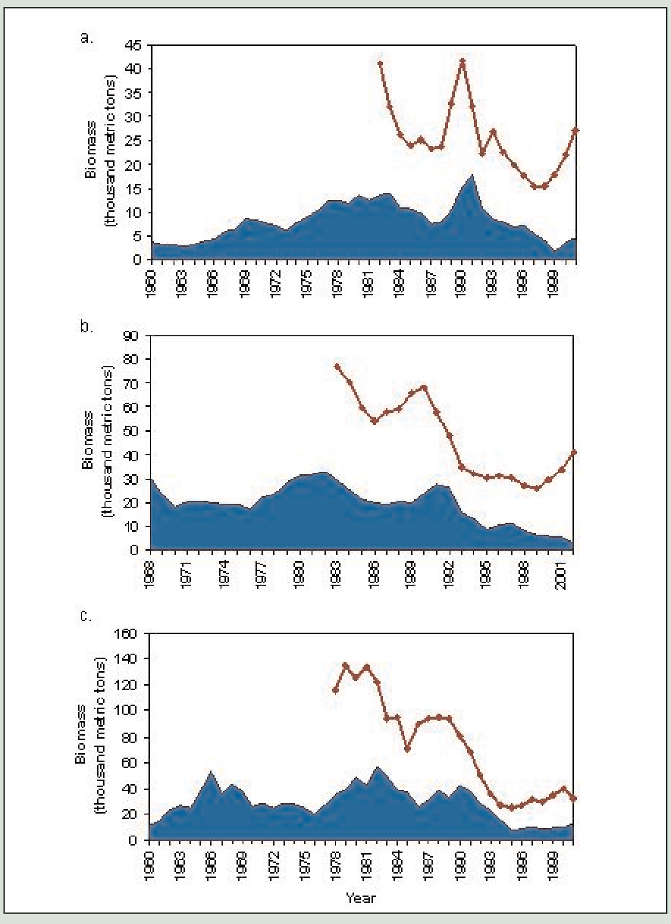


Figure 6.2. Landings (blue area) and estimated stock biomass (red line) of cod in a) the Gulf of Maine, b) the Bay of Fundy and Nova Scotia, and c) Georges Bank. Panel c shows landings and stock biomass from the U.S. (landings-hatched lines, biomass-squares) and Canadian (landings-solid blue, biomass-diamonds) portions of Georges Bank. Compiled from data in Clark *et al*. 2002, NEFSC 2002, and Hunt *et al.* 2003.

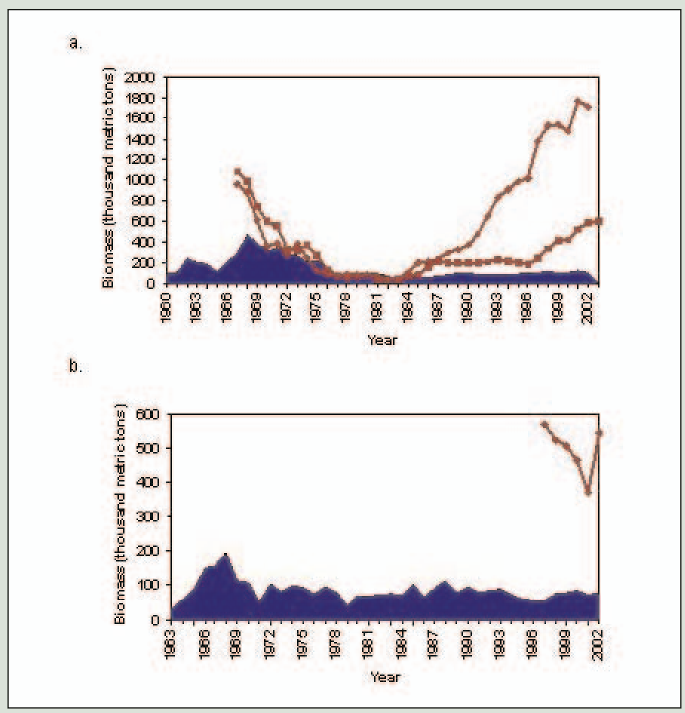


Figure 6.3. a) Total landings (blue area) and spawning stock biomass (red line) of herring in the Gulf of Maine and Georges Bank. The line with diamond markers reflects spawning biomass estimated from a Forward Projection Analysis; the line with square markers shows spawning biomass estimated using a Virtual Population Analysis model. Compiled from data in NEFSC 1998 and Overholtz *et al.* 2004. b) Total landings (blue area) and spawning stock biomass (red line) of herring in the Bay of Fundy and Southwest Nova Scotia. Biomass time series derived from acoustics survey data. Compiled from Stephenson *et al.* 2000 and DFO 2003c.

vest, can fish year round by rotating between different areas. Further, there are two areas that are open year round with no rotational requirements.

Within the Gulf of Maine and Bay of Fundy, sea scallop landings rose between the late 1990s and 2002, following a trend of declines since 1988 (102, 242) (Figure 6.5). Landings from Georges Bank are substantially higher, and vessels from ports within the Gulf of Maine contribute to a portion of the total landings. The biomass of scallops on Georges Bank has increased since the mid-1990s due to effort reduction measures, such as limitations on days at sea, caps on the number of crew, increased mesh size requirements in the gear, and strong recruitment (102, 63). In addition, sea scallop biomass increased notably in areas closed to protect groundfish stocks in the U.S. portion of Georges Bank (164, 102).

Shifting to "Underutilized" Species

The term "underutilized species" is applied to marine organisms that may be common but have little commercial value. Fishermen typically ignore these species until a new market increases demand. For example, lobstermen in the Gulf region once considered green sea urchins to be worthless pests. In Japan, though, urchin roe is considered a delicacy, and when sea urchin landings there declined in the 1980s, export markets developed rapidly in the Gulf of Maine (252). By 1995, the sea urchin fishery in Maine was worth more than $35 million, second in value only to the lobster fishery (147). Similarly, in the Bay of Fundy, sea urchin harvests rose from 47 metric tons in 1986 to nearly 1000 tons in 1993 (14).

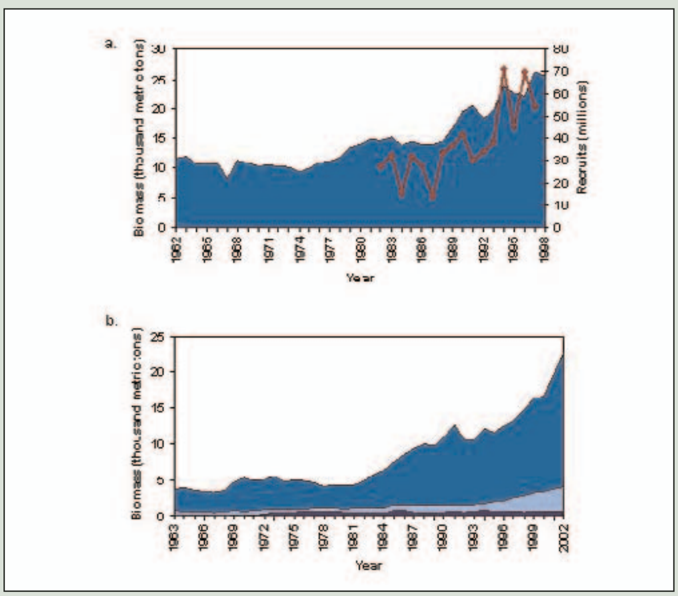


Figure 6.4. a. Landings (blue area) and recruitment estimates (red line) of lobster in U.S. waters of the Gulf of Maine. b. Landings of lobster in Southwest Nova Scotia (medium blue), Bay of Fundy (light blue), and offshore (dark blue). Compiled from data in ASMFC 2000 and provided by D. Pezzack.

While certain species may be considered "underutilized" from an economic perspective, they may be fully utilized from an ecological perspective (in that they play significant roles in the marine ecosystem and may supply food for commercially harvested species) (Case Study 6.1). Fisheries that target species at low levels of the food chain risk reducing supplies for species at higher-trophic levels, unless consideration is given to maintaining a biomass that sustains both ecological and human needs. Fisheries that target apex predators, such as sharks, can disrupt ecosystems by eliminating the natural controls on middle predators.

Recreational Fisheries

Recreational fishing is popular throughout the Gulf of Maine region, with anglers fishing from shore, private boats and chartered boats in each of the bordering states and provinces (Table 6.2). Personal expenditures for equipment, tackle, lodging, boat rentals, docking fees and other costs associated with a fishing trip are sizeable when aggregated across all recreational fishing trips, as Table 6.2 demonstrates (245). Many anglers come from other regions to fish in the Gulf, generating substantial direct and indirect economic inputs to local, state, and provincial economies (245, 172, 60).

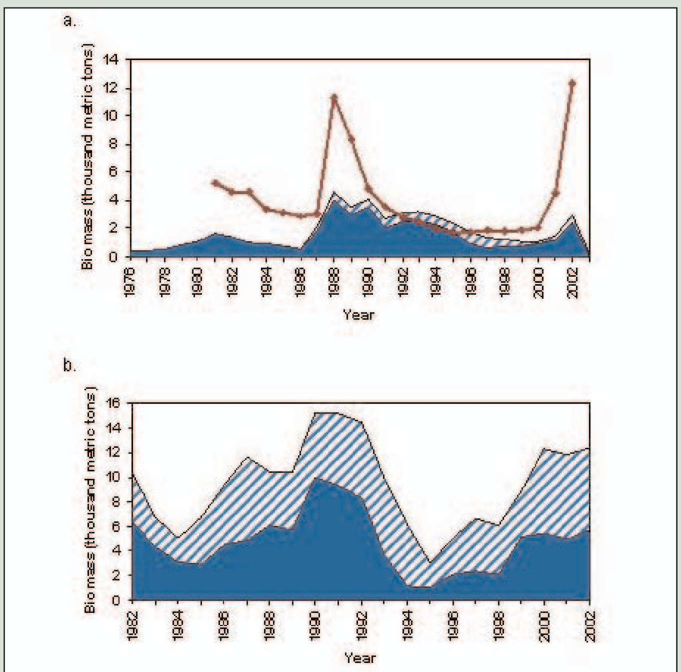


Figure 6.5. a. Landings and estimated stock biomass of sea scallops in the Bay of Fundy and Southwest Nova Scotia (landings—solid blue area, biomass—red line) and the U.S. portion of the Gulf of Maine (landings—hatched blue). Stock biomass estimates shown include scallops in a portion of Scallop Production Area (SPA) 1 and SPA 4 in the Bay of Fundy. b) Landings of sea scallops in the U.S. (solid blue) and Canadian (hatched blue) portions of Georges Bank. Compiled from data in Robert *et al.* 1999, Smith and Lundy 2002, DFO 2003j, and provided by D. Hart.

Table 6.2. Recreational anglers and expenditures in states and provinces bordering the Gulf of Maine. The number of resident and non-resident anglers in 2002 is shown for Maine, Massachusetts, and New Hampshire (172); angler numbers for New Brunswick and Nova Scotia reflect resident anglers during 2000[2] (60). Expenditures, in US dollars, account for costs of the trip and associated durable goods; economic expenditure data were not available for Canadian provinces (245).

State or Province	Anglers	Expenditures
Maine	315,558	$63,492,000
Massachusetts	905,914	$486,718,000
New Hampshire	136,634	$47,465,000
New Brunswick	53,132	
Nova Scotia	56,110	

Striped bass is the primary target of most anglers, but other species sought include American shad, cod and other groundfish, bluefin tuna, bluefish, herring, and mackerel (146). Many residents and visitors also harvest shellfish from nearshore waters, including clams, mussels, oysters and scallops.

Marine Aquaculture

Aquaculture Production

Aquaculture represents the fastest growing sector of world fisheries. Between 1996 and 2001, world marine aquaculture production increased by 40% (83); in the Gulf of Maine, an even larger increase in aquaculture production has occurred (Figure 6.6). In 2001, aquaculture production was 53% greater than in 1996 (61, 148). Commercial development of the aquaculture sector within the Gulf of Maine began in the 1970s (23). Aquaculture efforts have focused on a variety of species, including Atlantic salmon, steelhead trout, rainbow trout, striped bass, scallops, mussels, oysters, and nori (a seaweed) (26). More recently, species such as halibut, cod, haddock, sturgeon, soft-shell clams, irish moss and sea urchins have been cultured (264; R. Henry and J. Huston, pers. comm.).

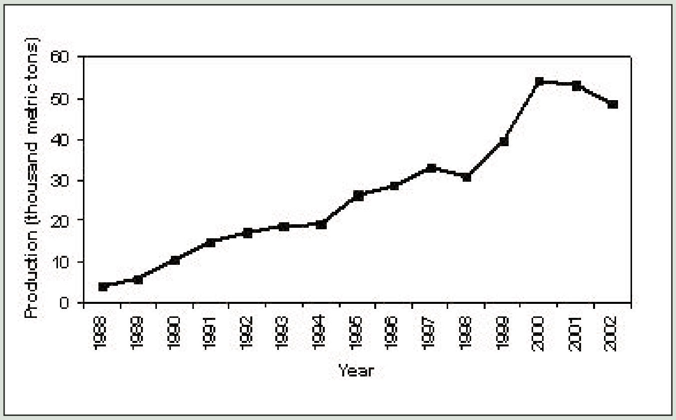


Figure 6.6. Finfish aquaculture production in Maine, New Brunswick, and Nova Scotia. Compiled from DFO 2003g and Maine DMR 2004b

Currently, Atlantic salmon is the dominant species produced within the Gulf of Maine. In 2002, aquaculture facilities in Nova Scotia, New Brunswick, and Maine produced 48,600 tons of Atlantic salmon, which was valued at around $194 million USD (61, 84, 148). Shellfish, namely quahogs, oysters, and mussels, are cultured in Massachusetts and Maine (J. Moles, pers. comm.; 84); clams are grown in Gulf of Maine waters off Nova Scotia (R. Henry, J. Huston, and T. Balch, pers. comm.).

Aquaculture and the environment

Aquaculture yields many economic and social benefits to small coastal communities throughout the Gulf of Maine. However, there are concerns that aquaculture may induce environmental changes or displace traditional activities from the coastal zone. Just as aquaculture practices vary widely throughout the Gulf of Maine, so do their environmental and social implications. Potential nutrient enrichment is one environmental concern often discussed related to aquaculture, and it has been studied extensively. When present in excessive quantities, nutrients can lead to eutrophication and anoxia. Actual environmental effects vary with large-scale oceanographic and climatic processes as well as with local hydrographic conditions, particularly flushing rates. The potential for nutrient enrichment is controlled by improving feed formulations and husbandry practices (239). Such improvements have reduced feed losses to the environment and improved conversion efficiencies to 1.2-1.5 kg feed per 1 kg salmon growth (31, 225).

Benthic habitat alteration can occur as organic matter from excess feed and fish feces settles to the substrate. This organic material is processed by benthic fauna, including bacteria and polychaete worms. Over-enrichment occurs if the rate of deposition exceeds the rate of decomposition, at which point anoxic conditions develop, bottom-dwelling organisms are displaced, and bacterial (i.e., *Beggiatoa*) mats form (239, 62). In the Gulf of Maine, benthic enrichment effects that have occurred remain localized near fish pens (79, 62); waste accumulation dissipates and the substrate returns to a normal state if the site is fallowed for several months (31). Monitoring and management programs by industry and government address the impacts of benthic enrichment.

Potential genetic and ecological interactions between cultured and indigenous fish also raise concerns, but whether farm-reared fish pose a threat to the genetic diversity of wild Atlantic salmon stocks remains debated in parts of the Gulf of Maine. Although farmed and wild Atlantic salmon are genetically similar (183), inbreeding could alter wild gene pools to some extent, an outcome that poses some concern since wild Atlantic salmon is an endangered species (32, 225, 51). No evidence exists to indicate that salmon escaping from fish farms have adversely affected the wild populations in the Gulf of Maine (N. Halse, pers. comm.). In addition, specific codes of practice by the industry address the issue of escapees from salmon cages (R. Henry, pers.comm.).

Management of fish health at aquaculture sites is an important challenge for government and industry. Infections and parasites that may be transmitted between wild and cultured salmon must be controlled. Antibiotics are administered to cultured fish as needed to prevent and minimize disease outbreaks. To reduce the risk of the pathogenic bacteria developing resistance, antibiotics used in aquaculture require a veterinarian's prescription and are carefully regulated (32). In New Brunswick, the control of diseases is managed by a joint federal-provincial-industry Fish Health Technical Committee. This committee establishes and monitors the results of fish health programs for the industry and recommends actions required under federal and provincial legislation (185).

The presence of trace levels of organic contaminants in farmed salmon has been recognized, as such chemicals are widely present in the environment and accumulate to a certain extent in all animal products (225). A recent study raised human health concerns by showing that farmed Atlantic salmon contained higher levels of some organochlorine contaminants than wild Pacific salmon (106). Interpretation of this finding is controversial, the levels of contaminants measured in farmed salmon remaining orders of magnitude below action levels established by Canadian and U. S. food safety agencies (i.e., U. S. Food and Drug Administration and Health Canada). In an effort to remove contaminants in farmed fish, the aquaculture industry has carefully reformulated feeds. In addition, many experts argue that the health benefits of farmed salmon far exceed any potential risks (237).

Environmental management of aquaculture

Although a number of environmental concerns surround aquaculture facilities and practices, these issues have been and continue to be addressed through coordinated management efforts and ongoing scientific research that involve government agencies, industry representatives and other stakeholders. Careful site selection, routine monitoring, preventative husbandry, and technical solutions have ameliorated many environmental issues related to aquaculture. Throughout the Gulf of Maine region, government agencies at the federal, state, and provincial levels play a role in the approval of proposed aquaculture sites; approval processes also provide for public consultations to incorporate input from a wide variety of stakeholders. To track environmental conditions after sites are developed, government officials and industry representatives have worked together to design protocols for and to implement routine monitoring of a variety of parameters (e.g., benthic communities, dissolved oxygen, metals) around aquaculture operations (T. Balch, K. Coombs, R. Henry, and J. Sowles, pers. comm.).

Interactions between Fisheries and the Ecosystem

Environmental conditions affect the abundance, growth, and geographic distribution of many fish species. Oceanographic currents, depth, bottom type, temperature, and salinity are some of the most important environmental factors to which fish respond (161, 229, 68). Environmental conditions in the Gulf of Maine favor the growth of microscopic phytoplankton, which form the base of the marine food chain, helping to create one of the world's most productive fishing grounds. Phytoplankton live near the water's surface as they require light, but they also need nutrients that accumulate on the ocean bottom. The bathymetry and currents on Georges Bank and in the Gulf's northeast portion continually mix waters from top to bottom, supplying nutrients to phytoplankton in upper portions of the water column. The many rivers that flow into the Gulf also contribute nutrients from upland sources, which become entrained in a cold-water gyre that flows counterclockwise around the Gulf (44, 267).

Other environmental influences, though, can prove detrimental to fish in the Gulf of Maine. Colder than normal temperatures can reduce the growth rate and reproductive success of certain species, including cod, plaice, and capelin (66). Warm temperatures may affect the population abundance, spatial distribution, and maturity rates of species living near the southern extent of their range–such as Northern shrimp (D. Schick, pers. comm.). Oceanic currents can push larval fish out of the Gulf and into the Atlantic Ocean, a situation that proves particularly damaging to species with short spawning seasons (229, 68).

Human-induced environmental changes also affect fish in the Gulf of Maine. Global climate change may alter the distribution, growth, recruitment, and trophic interactions of fish and invertebrates (163, 66, 67). Dams and shoreline development can damage or restrict access to upstream habitats that are used by anadromous species, thereby affecting the spawning success and juvenile survival rates of these fish (213; Case Study 6.2).

Fisheries can induce biological and physical changes in marine ecosystems by selectively removing target species, altering community composition and species interactions, and disturbing benthic habitats (e.g., 82, 113, 181). In the Gulf of Maine, fishing has removed many large predatory finfish, causing a decrease in the abundance and size of target species (246).

Fishing affects non-target species through community changes and incidental catches. As populations of groundfish declined in the Gulf of Maine region, elasmobranchs (specifically skates and dogfish) became dominant in the fish community (Figure 6.7) (155, 233). And when fisheries removed large quantities of herring and mackerel, sand lance abundance increased dramatically (81).

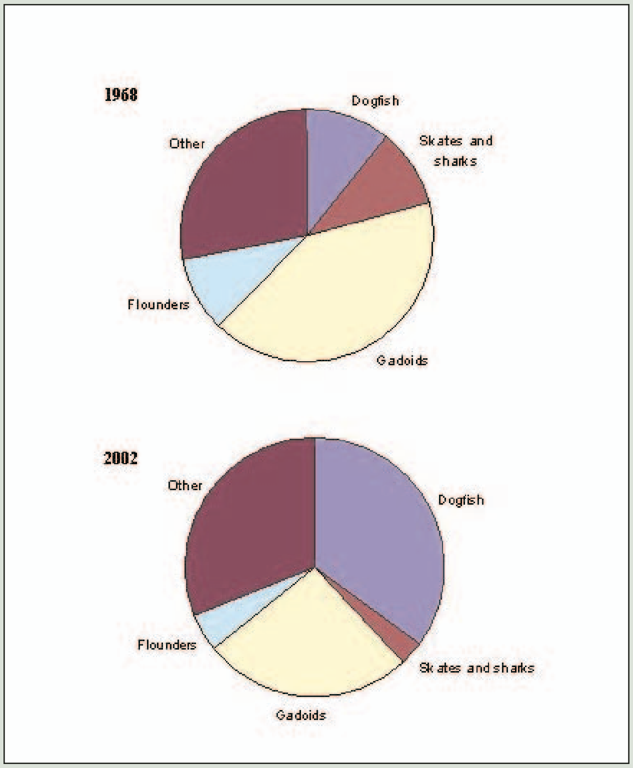


Figure 6.7. Changes in community composition of fish in the Gulf of Maine region from 1968 to 2002. Compiled from bottom trawl survey data collected by the Northeast Fisheries Science Center.

The capture and discard of unintended species remains a problem in the Gulf of Maine, as it is worldwide, but researchers are exploring and developing new gear technologies to reduce by-catch in commercial fisheries. Incidental catches and entanglements of marine mammals, seabirds, and sea turtles pose special concerns (212). The population of North Atlantic right whales, for example, currently numbers around 300 individuals. More than half of these whales bear marks and scars indicating previous encounters with fishing gear (131); some whales die from these encounters, although ship strikes pose the greatest mortality threat (129).

Gear used in fisheries, particularly trawls and dredges, can affect marine ecosystems by altering physical aspects of benthic habitats, e.g.—removing bottom-dwelling organisms, smoothing the substrate, and reducing bottom roughness (9, 181). While most systems can recover from occasional disturbances, repeated trawling and dredging causes a shift from large- to small-bodied organisms in the benthic community (181); reduces species richness and diversity (40); and decreases the productivity of benthic habitats (114, 181).

Future Directions and Needs

Fisheries are apt to remain an important component of social structures and local economies in the Gulf of Maine region. Yet there is greater awareness than ever before of the ecological constraints on capture fisheries and aquaculture. The perils of overfishing are widely recognized, following substantial declines and long recovery periods in the region's herring and cod stocks. Declines in anadromous fish populations have confirmed that critical habitat loss diminishes the resilience of many species. A substantial increase in the region's aquaculture development has heightened awareness of the balance that must be maintained with environmental and cultural concerns.

Issues of ecological and economic sustainability are inseparable for the Gulf's fisheries. Resource users, managers, scientists and other stakeholders must seek to balance both goals—developing innovative ways to continue deriving socio-economic benefits from fisheries while rebuilding and maintaining fish stocks and avoiding unacceptable ecological impacts. Potential solutions may involve collaborations that leverage existing resources, create area management strategies, and forge ecosystem-based approaches.

Collaboration is growing among many stakeholder groups around the Gulf of Maine, fueled by a desire for innovative research and management options. Cooperative research efforts between fishermen and government agencies have enabled studies of fish populations, habitats, and movements that extend beyond the scope of regular governmental surveys and address research priorities expressed by fishermen (182). Cooperative programs also enhance capacities for environmental monitoring. Within the aquaculture industry, for example, government officials and facility operators have worked together to conduct research on a diverse array of aquaculture issues as well as to design and implement routine benthic monitoring protocols. Continued collaboration among government agencies, fisheries and aquaculture industries, and other stakeholder groups will be needed to advance research on the cumulative impacts that multiple human activities have on the coastal zone.

Area Management

Fishery management strategies in the future may incorporate area management (sometimes referred to as zoning) which designates specific uses for marine areas. This approach, currently employed in the Maine lobster fishery, enables resource users to exercise greater autonomy in management of certain areas (149). It also may help resolve conflicts that arise among competing user groups, such as disputes involving aquaculture facilities sited near areas traditionally used by fixed-gear harvest fisheries (247, 46). Area-based approaches might incorporate closed areas to protect marine habitats from fishing gear impacts, provide refugia for species targeted by fisheries, and promote the recovery of fish stocks (212). Effective use of area management strategies requires establishing goals and priorities for the use of coastal and marine areas through multi-stakeholder processes; evaluating the life history and habitat requirements of fishery species; mapping marine habitats and their associated biotic communities; and understanding variations in population growth rates among different habitats.

Ecosystem-based Management

Ecosystem-based management approaches recognize that fisheries do not function in isolation; they affect and are affected by the surrounding ecosystem. This broader context provides more integrated perspectives on fisheries, complementing the current single-species focus (in which decisions rarely consider environmental processes or their effects on fisheries). Going beyond the fishery-ecosystem dynamic, a full ecosystem approach would attempt to understand the interactions with—and cumulative effects from—multiple human activities, including those in coastal watersheds and ocean waters.

To date, most steps toward integrating ecosystem considerations into fisheries management have focused on multi-species interactions and habitat protection (in rivers, estuaries and the open ocean). For example, managers consider the importance of Atlantic herring as prey for other fish and marine mammals when determining allowable commercial fishery harvests (187). An increasing emphasis on habitat protection is being incorporated into federal legislation in both the U.S. (Sustainable Fisheries Act) and Canada (Oceans Act).

While greater attention to multi-species interactions and habitat protection will benefit fisheries, ecosystem-based management approaches need to integrate a broader array of factors—recognizing that ecosystems involve the interactions within the entire food web (from bacteria to whales) as well as physical environmental conditions and myriad human stakeholders. Canada's Ocean Strategy offers a holistic approach to integrated management that encompasses multiple human activities within the coastal zone and marine waters (65). It seeks to develop a comprehensive vision for ocean management that accommodates myriad human activities (e.g., aquaculture, traditional fisheries, oil and gas development, marine transportation, coastal tourism) while enhancing the quality of the marine environment (65). A similar integrative framework for ocean management has been proposed by the U.S. Commission on Ocean Policy (265).

Resource managers around the Gulf are taking some steps to implement ecosystem-based management, and their efforts will benefit from additional research to characterize habitats, species interactions, and fishery effects on non-target species (164, 136). In addition to more comprehensive data, this management shift will involve assessing the different values that stakeholders place on aspects of the ecosystem, creating conflict resolution protocols when competing goals arise, and developing a unified perception of what ecosystem-based management entails.

Ecosystem indicators offer one tool for tracking fishery-ecosystem interactions. Indicators may be based on fisheries status (207), marine populations and communities (136), or socio-economic conditions and human aspects of fisheries (222). A combination of indicators representing these three sectors may be necessary to provide a comprehensive portrayal of changes in fisheries and the ecosystem.

Indicators must be carefully selected so that they are sensitive to change, feasible to measure, ecologically meaningful and interpretable, and able to incorporate uncertainty (136). It is important to understand whether specific indicators respond to human-induced changes associated with fishery activities, human-induced environmental changes or natural environmental fluctuations. The temporal and spatial scales at which indicators are monitored become a concern as well, given the variability and uncertainty associated with data on marine populations, communities and fisheries. Existing technologies that gather fisheries and ecosystem data[3] in near real-time may advance monitoring capabilities for tracking certain indicators.

A joint Canadian/American initiative is underway within the Gulf of Maine region to evaluate monitoring infrastructure that could support ecosystem-based management and to develop a suite of indicators that could guide fisheries management (R. O'Boyle, pers. comm.). Additional research is needed to establish suitable reference points for interpreting indicators in the context of management actions and for evaluating progress in reaching management objectives. Reliable ecosystem indicators could help stakeholders track changes and monitor progress toward their goals (164, 136, 137).

Fisheries in the Gulf of Maine will remain a vital part of the region's heritage. Managers and stakeholders are rising to challenges to design innovative management strategies for fisheries and aquaculture that balance economic and ecological sustainability. Cooperation between government agencies, resource users, and other stakeholders will help turn management approaches that are novel ideas at present into future realities.

Case Study 6.1. Effects of a Baitworm Fishery on Migratory Shorebirds

Fisheries for "underutilized" species may result in broad ecosystem consequences that extend well beyond the target species or its predators/prey to include physical changes and complex species interactions. In the Bay of Fundy, for example, a baitworm fishery developed in 1985 after populations of worms were depleted farther south along the Atlantic coast. This fishery targets bloodworms *(Glycera dibranchiata)* to supply bait for recreational anglers. Because bloodworms burrow into mudflats, harvesting involves turning over the top 10-20 cm (4-8 inches) of mud. The process that exposes bloodworms for harvest destroys burrows and habitats of other organisms, suspends sediment and destabilizes the mudflat (15).

Another mudflat resident, the tiny amphipod *Corophium volutator*, serves as important prey for semipalmated sandpipers, shorebirds that rely on the Bay of Fundy in their southward migration. Each year, 2-3 million sandpipers (75 to 90 percent of the world's population) stop to feed on *Corophium* in the Bay of Fundy (15). Within the first year after a bloodworm harvest, the density of *Corophium* declines by 30 percent among adults and 55 percent among juveniles. The decline in available prey reduces the feeding ability of sandpipers by two-thirds (232). The secondary effects of the baitworm fishery on *Corophium* and sandpipers highlight the importance of considering potential indirect ecological implications when developing fisheries for underutilized species.

Case Study 6.2. Dam Removal Benefits Anadromous Fish

Anadromous fish species in the Gulf of Maine, such as striped bass, Atlantic salmon, sturgeon, American shad, blueback herring, alewife, and rainbow smelt, migrate as adults from the open ocean into estuaries and rivers to spawn. For decades, their upstream ascent in many rivers has been blocked by dams. These impoundments, used to generate electricity or power mills, have altered riverine habitats and diminished water quality. In some locations, efforts are now underway to remove dams and restore formerly rich fisheries.

Along the Kennebec River in Maine, the lowest dam–Edwards Dam–was constructed in 1837, prompting a precipitous drop in anadromous fish populations. In 1999, Edwards Dam was removed after the Federal Energy Regulatory Commission ruled that the environmental benefits of the dam's destruction exceeded returns from its continued operation. Its removal opened 20 miles of the Kennebec to anadromous fish, encouraging the return of sturgeon, alewife, shad and other species to this reach of the river (1).

The impounded pool behind the dam was restored to a flowing river, complete with rapids, and small islands. Water quality improved as flow increased through the previously impounded area. Emergent vegetation became reestablished along the river's edge, providing important nursery habitat for juvenile fish. These ecosystem changes enhanced the benefits to anadromous species associated with dam removal (1).

Notes

1 Groundfish include a suite of bottom-dwelling finfish: American cod, haddock, yellowtail flounder, pollock, winter flounder, windowpane flounder, witch flounder, American plaice, redfish, white hake, Atlantic halibut, ocean pout, silver hake (whiting), red hake, cusk, and offshore hake.

2 Marine recreational fishing data for New Brunswick and Nova Scotia cannot be partitioned between the Gulf of Maine, Gulf of St. Lawrence and the Atlantic coast. Reported numbers of anglers include those that fished on the combined coasts.

3 The Gulf of Maine Ocean Observing System (GoMOOS) collects environmental data on an hourly basis, and fishery scientists may benefit from collaborations to use these data.

ACHIEVEMENTS

7. Recognizing Achievements, Celebrating Successes

Having been studied thoroughly for more than a century, the Gulf of Maine is one of the best known seas in the world. Pioneering marine scientists (such as Henry Bigelow, A.G. Huntsman, and Bev Scott) have helped produce a wealth of scientific data describing the Gulf's coastal and offshore species and habitats. Building upon this venerable legacy, scientists and policy-makers today face the challenge of identifying new threats and preventing unwanted ecological change. Efforts to manage the Gulf's valuable natural resources are aided by a high level of public, institutional and political awareness, as well as a legal framework that extends across all levels of government.

Work to protect and restore the Gulf has increased markedly over recent decades, particularly since the Gulf of Maine Council on the Marine Environment (GOMCME) formed in 1989. This chapter highlights recent environmental advances, celebrating the outstanding efforts of many (but by no means all) individuals and organizations. The stories presented here augment the "The Wall of Achievements" that will be on display at the Gulf of Maine Summit conference. Detailed achievements submitted by many groups can be found in Appendix 2 on the accompanying Summit CD.

Notable Achievements

The work accomplished to date by hundreds of volunteer and nongovernmental groups throughout the Gulf watershed (see Table 7.1 and Appendices) provides cause for optimism about the Gulf's future. Groups are engaged in a wide array of projects, including research, education, water-quality monitoring, habitat restoration, land stewardship, river restoration, beach and trail maintenance, energy conservation, and protection and recovery of living resources (such as shellfish, salmon and seals). These diverse volunteer initiatives have built their capacity over time through training and improved facilities, and now engage countless citizens in vital work to sustain the Gulf's health and biological diversity. Improved networking has helped many of these efforts share resources and increase their effectiveness. The case studies included in this chapter illustrate the variety of volunteer, nongovernmental programs at work in the region (including one of the Gulf Summit's primary hosts, the Global Programme of Action Coalition (GPAC).

The other primary Summit sponsor, GOMCME, is celebrating its 15th year as a collaborative, international coastal management program (Table 7.2). The Council provides a forum for discussing issues of concern around the Gulf and for recommending actions for change. The GOMC deserves credit for producing the widely read Gulf of Maine Times, coordinating the ongoing Gulfwatch monitoring program, providing grants that support community-based environmental initiatives, and giving annual awards recognizing pioneering forces for change. The Council has also been recognized for contributing innovative approaches to coastal zone policy and management (e.g., 177; 178; 180).

Among the jurisdictions bordering the Gulf, all levels of government are engaged in work to conserve, protect and restore coastal watersheds (see Table 7.3). Programs to improve water quality are conducting assessments and addressing point sources of pollution (e.g., the state-of-the-art treatment now being done on wastewater discharged into Boston Harbor). In association with community groups, many governmental programs are now monitoring non-point sources of pollution as well, such as contaminants in river water and bacteria in shellfish beds.

At a Gulfwide level, governmental research is focused on such topics as the potential impacts of climate change, excess nutrients (and the harmful algal blooms to which they contribute), and invasive marine species (transported into the Gulf through ballast water discharges). Governments have taken a lead role in conserving key sections of the Gulf's coastline and watershed, and are accelerating those efforts to keep pace with rapidly spreading development. Policy changes are also being made at many levels. One significant recent achievement was the successful relocation of the main shipping lane on the Bay of Fundy to protect the endangered Northern Right Whale.

The achievements made by volunteer and governmental projects to date bode well for the long-term care of the Gulf's ecosystems. Those engaged in stewardship of the Gulf region have demonstrated exceptional dedication and their continuing commitment will help to guide actions undertaken in the coming years.

Seeking Long-term Solutions

To ensure that all those working on Gulf-related concerns are pulling together in the same direction and are informed of each others' efforts, a better system is needed to track progress and resolve problems. Such a system would help to ensure that local, short-term projects are all contributing toward regional, long-term solutions. Creating this system might include a variety of steps: 1) complete the existing inventory of Gulf-related projects and continue networking, especially with the habitat and chemical monitoring programs; 2) establish a system, potentially through GOMCME, to periodically report on Gulf-related issues (particularly environmental health); and 3) draw together diverse interests to periodically discuss progress, challenges and programmatic gaps, and to update Gulfwide action plans. The Gulf of Maine Summit: Committing to Change presents an opportunity for this kind of valuable dialogue, celebrating the many achievements to date and seeking solutions to the challenges that remain.

Table 7.1 Selected Achievements of Community Groups and Other Non-Governmental Organizations, Across Jurisdictions (see full submissions in Appendices)

Maine

Casco Bay Estuary Project

1. re-opened over 300 acres of soft–shell clam resources.
2. funded local land trusts and municipalities to permanently protect over 2000 acres of coastal habitat.
3. hosted conference "Storm-water Management in Cold Climates" (2003) and facilitated development of a regional storm-water management plan.

The Chewonki Foundation, Wiscasset

- created Pathways to a Sustainable Future educational program – a 10 year program to promote understanding and appreciation of sustainable energy and natural resource management.
- established the Centre for Environmental Education to provide travelling natural history programs and residential environmental education camps for over 30,000 children per year.

Massachusetts

Essex County Greenbelt Association, Inc.

- conserved thousands of acres of salt marsh and established criteria for protection of land of ecological, agricultural and scenic importance.
- produced curriculum guides on land conservation issues for secondary school children.

New Brunswick

Nature Trust of New Brunswick

- established 11 nature preserves of 750 acres on the mainland and islands in the Bay of Fundy.
- conducted an annual island stewardship program to clean up islands in Passamaquoddy Bay of litter and debris.

Atlantic Salmon Federation (a regional organization)

- removed the Edwards Dam on the Kennebec River, ME, giving sea-run fish access to the river's upper reaches and creating habitat for striped bass and shad.
- conducted research to maintain the wild genetic stock of salmon in the Magaguadavic River, and developed acoustic transmitters for tracking migration patterns of smolts.

New Hampshire

Coastal Conservation Association of New Hampshire

- removed obstructions in smelt spawning areas on the Winnacut River, as part of habitat restoration project.
- monitored operations of dams on rivers leading to the Great Bay Estuary, to enhance restoration of shad, alewife and river herring populations.

Nova Scotia

Clean Annapolis River Project

- operated a volunteer-based, water quality monitoring program since 1992, training >300 volunteers.
- practised habitat restoration – restored >10,000 m of fish habitat; planted >15,000 trees in riparian zones; fenced 10,000 m of stream bank; constructed >100 ha of wetlands; protected 20 ha of salt marsh with stewardship agreements.

Ecology Action Centre

- completed a tidal barrier audit of Minas Basin, prepared a database and identified potential restoration sites.
- conducted the Cheverie Creek Pilot Restoration Project, involving GOMC protocols.

Table 7.2 Selected Achievements of Gulf of Maine Council (1989-2004)

1. Conducted core programs: Gulf of Maine Times, Gulfwatch chemical monitoring, a grants programs, an awards program, and an active web site.

2. Produced three 5-year Action Plans, resulting in the following projects:
   - description of significant habitats and species;
   - habitat restoration strategy and projects;
   - increased understanding of aquaculture-environment interactions;
   - program on aquatic nuisance species;
   - marine debris program and celebration of International Year of the Ocean 1998;
   - assessment of coastal and marine legislation;
   - launch of a eutrophication assessment pilot project;
   - initiation of a sewage management implementation plan;
   - community outreach, including support of volunteer networking and monitoring;
   - formal cooperative agreement with RARGOM (i.e., university research);
   - communications - public education and participation committee work;
   - science translation (e.g., fact sheets);
   - inventory of land-based pollution sources;
   - more than 60 workshops, symposia, and public forums; and
   - publication of many reports.

3. Recognition of Council in studies of ocean policy, stewardship and research completed by the National Research Council/National Academy of Sciences. Additional advice on coastal and ocean priorities, provided to the Council for Environmental Cooperation (of NAFTA), the U.S. Oceans Commission, and GPAC.

4. Selected Publications – Economic Prospects of the Gulf of Maine (1995); Habitat Identification of Critical Species in the Quoddy Region of the Gulf of Maine (1997); Mercury Deposition in the Gulf of Maine (1998); Sewage Management in the Gulf of Maine (2002).

Table 7.3 Selected Achievements of Governmental Agencies (see Appendices for full submissions)

State and Provincial

Massachusetts Dept. of Environmental Protection
- surface water quality assessment reports
- support of habitat contaminants projects in GOM watershed
- completion of water quality restoration plans
- conduct of the NPDES program for WWTPs along the coast
- support of combined sewer overflow construction projects

Federal

Environment Canada
- support of ACAP in Bay of Fundy, and BoFEP

NCCOS, Centre for Sponsored Coastal Ocean Research
- studies on the ecology and oceanography of toxic algal blooms
- studies of ecosystem dynamics of Georges Bank and GOM
- conduct of a GOM Modeling/Management Workshop
- conduct of climate-based forecasts of the GOM ecosystem

NOAA, National Ocean Service Office of Response and Restoration, and National Marine Fisheries Service Restoration Centre
- development of a GOM Restoration Web Site Portal for coastal habitat restoration projects.

NOAA, Fisheries
- conduct of a local fisheries knowledge project, Maine.

Case Study 1.
Global Programme of Action Coalition for the Gulf of Maine (GPAC): 1996-2004

GPAC, a bi-national and cross-sectoral organization, works collaboratively to implement the United Nations Global Programme of Action (GPA) to Protect the Marine Environment from Land-based Activities. GPAC has worked to develop consensus on priority land-based activities that affect the Gulf ecosystem. It is taking action to curb harmful impacts and encouraging others to do the same. GPAC has applied the GPA methodology to the Gulf of Maine, working to:

1) identify and assess problems, reaching consensus on 15 priority environmental issues common throughout the Gulf region;
2) establish management priorities through five background papers, and set management objectives; and
3) evaluate and select strategies and measures through five pilot projects.

The GPAC Task Groups have completed projects from 1999-2002, including –

1) publishing and distributing a brochure 50 Ways to Save the Gulf of Maine;
2) holding workshops in 1999 on coastal wetland restoration to develop uniform regional protocols, and on the effects of low-trophic level harvesting;
3) holding a workshop in 2000 to assess governance structures in the Gulf of Maine;
4) initiating "From the Bottom up—State of the Gulf of Maine Regional Watershed Forums and Summit Project," which is leading to greater awareness of priority environmental issues within the Gulf watershed; and
5) co-hosting the 2004 Gulf of Maine Summit.

Case Study 2.
Sentinelles Petitcodiac Riverkeeper – New Brunswick [http://www.petitcodiac.org]

Sentinelles Petitcodiac Riverkeeper (SPR) advocates for restoration of the Petitcodiac River, designated Canada's Most Endangered River in 2003. In March 2000, SPR launched a campaign supporting a proposal to replace the existing causeway with a partial bridge. It successfully gathered sufficient community support for the proposal, propelling the project onto its next phase (a three-year, $4 million environmental impact assessment).

In 2000 and 2001, the SPR began investigating the discharge of toxic substances (landfill leachate and textile mill effluent) into tributaries of the Petitcodiac River. Their findings led to Environment Canada to impose charges and court fines in excess of $1 million, and order elimination of these discharges.

From 2000-2002, with help from hundreds of volunteers, SPR retrieved more than 44,000 pounds of debris from nine streams in the Petitcodiac River watershed. SPR has completed two comprehensive project assessments, as well as exploring the potential for decommissioning two abandoned dams. It is now raising funds to have the dams removed.

Case Study 3.
National Oceanic and Atmospheric Administration (NOAA) Fisheries – Local Fisheries Knowledge Project

High school students in Ellsworth and Jonesport-Beals Island, Maine, are collecting information on local fisheries through interviews with community residents and fishermen. Implemented and funded in partnership with the Rural School and Community Trust and NOAA Fisheries, the Local Fisheries Knowledge Project involves "place-based learning," giving students a chance to work on important community issues that could benefit fisheries management. This model project is helping to improve students' skills in research, publication, and presentation while contributing to a larger cumulative research database designed by NOAA for scientific and public use. This experience may encourage students to pursue their education, leading some into careers of science or research. The program provides a means of sharing local fisheries and marine knowledge with the scientific community and it encourages collaboration between fishermen and scientists.

Case Study 4.
North Mountain Old Forest Society (NMOFS) – Nova Scotia

The NMOFS, a nonprofit group founded in January 2001, seeks to foster the long-term well-being of privately owned woodlands and the recovery of old forest ecosystems in Nova Scotia. Funded through Eco-Action 2000, 32 woodlot owners in coastal communities of North Mountain came together to undertake restoration actions in the forest ecosystems which they steward. They used selected harvesting and reintroduction to restore native Acadian tree species; established more than 300 nest boxes for five bird species that rely on large-diameter dead trees for cavity nesting; and explored conservation easements to guarantee long-term protection.

Finding little convenient information available on Acadian forest restoration, NMOFS applied for funding to create a technical guide on restoring natural Acadian forest ecosystems. Funded by Nova Forest Alliance, the NMOFS is creating an ongoing database as well of available knowledge on Acadian forest ecosystems.

Case Study 5.
Friends of Acadia – Maine

Friends of Acadia (FOA) is dedicated to protecting the beauty, ecological vitality, and cultural distinctiveness of Acadia National Park through advocacy, trail and carriage road maintenance, and fundraising for crucial projects. In 2003, FOA sponsored roughly 1,800 volunteers who contributed 11,000 hours to maintain the park's trail and carriage road system and clear litter from gateway roads on Mount Desert Island.

2003 marked the fifth season of operation for the Island Explorer propane-powered bus system, supported by FOA, L.L. Bean, Acadia National Park, Maine Department of Transportation, U.S. Department of Transportation, Downeast Transportation, local towns, businesses, and area visitors. The system carried 340,336 passengers, successfully reducing volatile organic compounds (VOCs) and nitrogen oxides (NOx) by approximately 9.3 tons and eliminating an estimated 12,000 private vehicle trips in the park.

Plans for a visitor information center/multi-modal transportation hub just off Mt. Desert Island will help connect the intercity bus service with airports and potentially rail and ferries, while providing parking for commuters. The planned center will significantly reduce traffic congestion and air pollution on Mt. Desert Island and in Acadia National Park, one of the most heavily visited parks in the nation.

Case Study 6.
Eastern Charlotte Waterways Inc. – New Brunswick

Eastern Charlotte Waterways, Inc. launched a cooperative bacterial program to assess and monitor 1300 km of the southern New Brunswick coastline, and to assist in managing the soft-shell clam resource. More than 1,500 acres of shellfish harvesting areas have been reopened since the program began.

The Lepreau Salt Marsh Restoration Project successfully removed tons of garbage and redirected a freshwater system to its natural course. An Adopt-a-Shoreline program begun in 1999 encouraged the aquaculture industry to adopt shorelines adjacent to their operations and annually maintain those sites. Since then, businesses have adopted more than 30 beaches.

ECW chaired the Southwest New Brunswick Clam Resource Committee which obtained a research and development lease in Lepreau Harbour for developing enhancement techniques to sustain the soft-shell clam. The methods devised there may be applied to other coastal areas.

In 1999-2000, ECW conducted a third-party audit of the rockweed harvest in response to community concerns about the possible impacts of rockweed harvest on marine ecosystems. The ECW also compiles traditional ecological information in GIS format to aid coastal managers in decision-making.

Case Study 7.
Marine Environmental Research Institute (MERI) – Maine

Over the past 14 years, MERI has conducted ecotoxicological studies of environmental pollutants in marine mammals as part of its work to protect the marine environment and human health through scientific research, education and public outreach. Its program currently focuses on how endocrine-disrupting contaminants are affecting Northwestern Atlantic coast pinnipeds.

In 2001, the nonprofit MERI established the Center for Marine Studies in Blue Hill as a resource center to expand research capacity in the Gulf of Maine. That same year, MERI launched a monitoring effort entitled "Seals as Sentinels for the Gulf of Maine Ecosystem" that assesses persistent organic pollutants (POPs) and heavy metals in harbor seals and gray seals in the Gulf of Maine. In 2002, MERI convened the Gulf of Maine Forum: Protecting Our Coastal and Offshore Waters.

Since 1992, MERI has led ecologically sustainable ecotourism programs on 17 uninhabited islands in Blue Hill Bay and Eggemoggin Reach. MERI sponsors a year-round Ocean Environment Lecture Series and a distinguished speaker series honoring the late Professor Elizabeth Mann Borgese (of the International Oceans Institute in Halifax, NS).

The organization serves as liaison for communities affected by heavy metal contamination from the Callahan Mine Superfund Site in Brooksville. MERI also has launched a water-quality monitoring program in the Blue Hill Bay watershed, and conducts phytoplankton monitoring through the Maine Shore Stewards program.


1032254
KISMET

SUMMARY

8. Seeking "2020 Vision" for the Gulf of Maine

Tides of Change across the Gulf

As Summit participants discuss the issues covered in this report, and others, it is crucial to keep in mind that the Gulf of Maine, including the macro-tidal Bay of Fundy, is a very dynamic coastal ecosystem. The Gulf region's many habitats have changed over recent centuries; they continue to change in response to natural phenomena and human activities; and they will keep changing in the future, partly in response to the unpredictable effects of global climate change. An appreciation for the dynamic properties of the whole ecosystem and these layers of change must inform our work as we plan for the Gulf's future.

The Gulf of Maine Summit has two primary goals: (1) to renew our collective commitment as we work to protect the Gulf's vital ecosystems and accommodate sustainable uses; and (2) to act in ways that prevent unwanted change and ensure that the Gulf's natural resources, living and non-living, including those in the watersheds of the Gulf, are managed wisely into the future. The Summit's primary organizers, the Gulf of Maine Council on the Marine Environment (GOMC) and the Global Programme of Action Coalition for the Gulf of Maine (GPAC), seek to realize these goals through a "grassroots" process that engages individual citizens in communities throughout the Gulf watershed. While governments and organizations play important roles in effecting change, essential work is done by individuals and communities. A belief in the power of citizens to effect positive change motivated the planning of this Summit. We hope that the conference will help participants recommit themselves and their communities to enhancing the Gulf's future.

Working toward Constructive Action

The GPAC watershed forums preceding the Gulf Summit touched on a diversity of issues facing all or part of the Gulf of Maine region. Those gatherings confirmed the need for continued site-specific knowledge and experience, and countless pairs of eyes to monitor and respond, protect and conserve. Ultimately, the ideal might be to have a formal, networked system of long-term research, monitoring, assessment and reporting, involving all stakeholders, and more effective ways of periodically engaging citizens, policy-makers and decision-makers within Gulf jurisdictions. The model such a system might take, if supported, could be a topic for the Summit.

In terms of the three priority issues described in Chapters 4-6, there are unlimited opportunities for constructive action. Development pressures are intensifying along the coast, and better ways are needed to manage sprawl and minimize habitat fragmentation. While improvements are being made in sewage treatment, other chemical contaminants and pathogens continue to present major risks – both to humans and wildlife – and argue for more attention to be paid to the many linkages, some well-known, between ocean and human health. Once-bountiful fisheries have been depleted, and restoration efforts may not succeed in rebuilding stocks to their former levels; in just a few hundred years of exploitation, the ecology of the sea has been markedly changed. Coastal aquaculture, although full of promise as a source of jobs and high-quality protein, needs to be undertaken in an environmentally sensitive manner and in the context of comprehensive coastal zone management.

While the Gulf of Maine's ecosystems face major challenges, there is already a strong tradition of protection, conservation and restoration work within the region. Many citizens and groups are engaged in constructive projects, working for the improved health of the Gulf. The Gulf can be returned to full health, its ecosystem integrity at least partially restored, its recovery fueled by the personal dedication of all those who care about the Gulf's future.

Looking Ahead – the Need for 2020 Vision

The Summit marks the 15th anniversary of the Council's regional efforts to address issues and initiate co-management in the Gulf of Maine. It marks almost 10 years of GPAC's work with coastal communities. Looking ahead 15 years, to the year 2020, we need clarity of vision and a renewed commitment to work collectively on projects that will revitalize and sustain the Gulf's natural ecosystems, from the land to the sea.

The Summit will generate a more complete list of possible actions (new and continued). This short list is meant only to help generate discussion:

- Each individual, organization and agency participating in the Summit could commit to taking specific actions over the next 15 years, priorizing them so as to make steady progress throughout the period.
- Governments and communities could explore ways to enhance educational outreach related to the Gulf of Maine – carrying information from the Summit out to schools, universities, youth groups, adult education programs, and others.
- The Internet allows for greatly increased networking opportunities among those working on Gulf-related issues, and new web sites could be created and linked to foster greater public engagement.
- Holding a Gulf Summit conference every five years would help to keep people informed and motivated, recharging their local efforts. Additional Summit meetings would provide valuable guidance for GOMC and GPAC and could help generate additional reports on Gulf-related issues. Summit conferences also help to keep Gulf-related issues in front of citizens and decision-makers.
- Planning other regional and local events (tied to research reports or tracking indicators, for example) should help ensure that everyone in the region develops "2020 vision" for the Gulf of Maine.

The tides of change sweep across the Gulf of Maine. But our combined wisdom, knowledge, commitment and energies exemplified by a successful Summit and follow-up actions can assure its future as a living, healthy and productive ecosystem. Its future is in our hands, each and everyone of the citizens of the Gulf.

9. Literature Cited

(1) American Rivers. 2004. Edwards Dam, Kennebec River, Maine. <http://www.americanrivers.org/index.php?module=HyperContent&func=display&cid=2652> Accessed 26 March 2004.

(2) Anderson, E. D., K. D. Friedland, and W. J. Overholtz. 1999a. Northeast pelagic fisheries. In: NMFS. Our Living Oceans: report on the status of U. S. living marine resources, 1999. U. S. Department of Commerce, NOAA Technical Memorandum NMFS-F/SPO-41. p 99-102.

(3) Anderson, E. D., R. K. Mayo, K. Sosebee, M. Terceiro, S. E. Wigley. 1999b. Northeast demersal fisheries. In: NMFS. Our Living Oceans: report on the status of U. S. living marine resources, 1999. U. S. Department of Commerce, NOAA Technical Memorandum NMFS-F/SPO-41. p 89-97.

(4) APHA. (American Public Health Association). 1992. Standard Methods for the Examination of Water and Wastewater. APHA, AWWA, WEF. APHA, Wash., DC.

(5) Apollonio, S. 2002. Hierarchical perspectives on marine complexities: searching for systems in the Gulf of Maine. New York: Columbia University Press. 229 p.

(6) Arlinghaus, R. and T. Mehner. 2003. Management Preferences of Urban Anglers: Habitat Rehabilitation Versus Other Options. Fisheries 28(6): 10-17.

(7) Atkinson, J., P.M. Brooks, A.C. Chatwin and P. Shelley. 2000. *The Wild Sea. Saving Our Marine Heritage.* Conservation Law Foundation, Boston, MA. 120p.

(8) Atlantic States Marine Fisheries Commission (ASMFC). 2000. American Lobster Stock Assessment Report for Peer Review. ASMFC Stock Assessment Report No. 00-01 (Supplement), Washington, D.C. 532 p.

(9) Auster, P. J., R. J. Malatesta, R. W. Langton, L. Watling, P. C. Valentine, C. L. S. Donaldson, E W. Langton, A. N. Shepard, and I. G. Babb. 1996. The impacts of mobile fishing gear on seafloor habitats in the Gulf of Maine (Northwest Atlantic): implications for conservation of fish populations. Reviews in Fisheries Science 4: 185-202.

(10) Backus, R.H and D.W. Bourne. (Eds.). 1987. *Georges Bank.* The MIT Press, Cambridge, MA and London, UK. 593p.

(11) Bangay, G. 2002. Canadian keynote address. Pp. 4-5, In: Sewage Management in the Gulf of Maine: Workshop Proceedings. Hinch, P.R., S. Bryon, K. Hughes and P.G. Wells (Eds.). Gulf of Maine Council on the Marine Environment, www.gulfofmaine.org.

(12) Banks, E.M. 1999. Distribution of heavy metals and *Clostridium perfringens* in the recent sediments of Penobscot Bay, Maine. M.S. thesis. Department of Earth Sciences, University of New Hampshire, Durham, NH.

(13) Barber, K. (Ed.). 1998. The Canadian Oxford Dictionary. Oxford University Press, Toronto, Oxford, New York.

(14) Bay of Fundy Ecosystem Partnership (BoFEP). 1996. Expanding Fundy's harvest: targeting untapped treasures. Fundy Issues #10. <http://www.bofep.org/underuti.htm> Accessed 15 February 2004.

(15) Bay of Fundy Ecosystem Partnership (BoFEP). 1999. Keystone *Corophium:* master of the mudflats. Fundy Issues #13. <http://www.bofep.org/Publications/Fundy%20issues/corophiu.htm> Accessed 12 March 2004.

(16) Beach, Dana. 2002. *Coastal Sprawl: The Effects of Urban Design on Aquatic Ecosystems in the United States.* PEW Oceans Commission, Arlington, Virginia: 32p.

(17) Bigelow, H. 1927. Physical oceanography of the Gulf of Maine. Bulletin of the United States Bureau of Fisheries. 40 (2), 511 – 1027p.

(18) Bliven, S. 1998a. Scoping paper 1: Sewage and eutrophication. Working paper for the Global Program of Action Coalition for the Gulf of Maine. Commission for Environmental Cooperation, Montreal, CA.

(19) Bliven, S. 1998b. Scoping paper 2: Toxics. Working paper for the Global Program of Action Coalition for the Gulf of Maine. Commission for Environmental Cooperation, Montreal, CA.

(20) Bloom, N.S. 1992. On the chemical form of mercury in edible fish and marine invertebrate tissue. Can. J .Fish. Aquat. Sci. 49: 1010-1017.

(21) Boeri, D. and J. Gibson. 1976. "Tell it Goo-Bye Kiddo": The Decline of the New England Offshore Fishery. International Marine Publishing Company, Camden, Maine: 154 p.

(22) Bolster, C.H., S.H. Jones and J.M. Bromley. 2003. Evaluation of wastewater treatment discharge on estuarine water qual-

ity. Final report. New Hampshire Department of Environmental Services and New Hampshire Estuaries Project, Portsmouth, NH.

(23) Brennan, W. J. 1999. Aquaculture in the Gulf of Maine: a compendium of federal, provincial, and state regulatory controls, policies, and issues. Prepared for the Gulf of Maine Council on the Marine Environment. <http://www.maine.gov/dmr/aquaculture/aqtaskforce/briefing/brennan.pdf> Accessed 2004 March 12.

(24) Bricker, S.B., C.G. Clement, D.E. Pirhalla, S.P. Orlando and D.R.G. Farrow. 1999. National estuarine eutrophication assessment: Effects of nutrient enrichment in the Nation's estuaries. National Ocean Service, National Oceanic and Atmospheric Administration, Silver Spring, MD.

(25) Bricker, S.B., J.G. Ferreira and T. Simas. 2003. An integrated methodology for assessment of estuarine trophic status. Ecol. Modell. 169: 39-60.

(26) Brown, J. A. 1997. Aquaculture in the Gulf of Maine. In: Wallace, G. T. and E. F. Braasch, editors. Proceedings of the Gulf of Maine Ecosystem Dynamics: a scientific symposium and workshop. September 16-19, 1996, St. Andrews, NB. Regional Association for Research on the Gulf of Maine, RARGOM Report 97-1. p 233-241.

(27) Brown, W.S., and Beardsley. 1978. Winter circulation in the western Gulf of Maine: Part 1. Cooling and water mass formation. J. Phys. Oceanogr. 8:265 – 277.

(28) Buchholtz ten Brink, M.R., Manheim, F.T., Mecray, E.L. , Hastings, M.E., and Currence, J.M., along with Farrington, J.W., Fredette, T.J., Jones, S.H., Liebman, M.L., Larsen, P.F., Smith L., W., Tripp, B.W., Wallace, Jr., G.T., and Ward, L.G., 2002, Contaminated sediments database for the Gulf of Maine, U.S. Geological Survey Open-file Report No. 02-403, Online at http://pubs.usgs.gov/of/2002/of02-403/.

(29) Burgess, N.M. and B.M. Braune. 2001. Increasing trends in mercury concentrations in Atlantic and Arctic seabird eggs in Canada. Poster. 11th Annual meeting of SETAC Europe, May 6-10, 2001, Madrid, Spain.

(30) Campbell, D.E., 1986. Process variability in the Gulf of Maine – a macroestuarine environment. Pages 261 – 274 in Estuarine Variability. Academic Press, New York, NY.

(31) Canadian Aquaculture Industry Alliance. 2004. Facts regarding farmed salmon issues in Canada. <http://www.aquaculture.ca/> Accessed 7 June 2004.

(33) Chandler, H. 2001. Marine monitoring programs in the Gulf of Maine. Manuscript Report. Maine State Planning Office and Gulf of Maine Council, Augusta, ME. 115p.

(34) Chase, M. E., S.H. Jones, P. Hennigar, J. Sowles, G.C.H. Harding, K. Freeman, P.G. Wells, C. Krahforst, K. Coombs, R. Crawford, J. Pederson and D. Taylor. 2001. Gulfwatch: Monitoring spatial and temporal patterns of trace metal and organic contaminants in the Gulf of Maine (1991-1997) with the blue mussel, *Mytilus edulis* L. Mar. Poll. Bull. 42: 490-504.

(35) Chevrier, A. and P.A. Topping. 1998. National Guidelines for Monitoring Dredged and Excavated Material at Ocean Disposal Sites. Environment Canada, Marine Environmental Division. 27 p.

(36) Christensen, J.P., D.B. Smith, and L.M. Mayer. 1992. The Nitrogen Budget of the Gulf of Maine and Climate Change. Proceedings of the Gulf of Maine Scientific Workshop. Published by the Urban Harbors Institute, University of Massachusetts at Boston, Boston, MA.

(37) Cicin-Sain, B. and R.W. Knecht. 1998. Integrated Coastal and Ocean Management. Concepts and Practices. Island Press, Wash., DC. 517p.

(38) Clark, D. S., S. Gavaris, and J. M. Hinze. 2002. Assessment of cod in Division 4X in 2002. Canadian Science Advisory Secretariat Research Document 2002/105. <http://www.dfo-mpo.gc.ca/csas/Csas/English/Research_Years/2002/2002_105e.htm> Accessed 16 February 2004.

(39) Collette, B. B. and G. Klein-MacPhee. 2002. Bigelow and Schroeder's Fishes of the Gulf of Maine, 3rd ed. Washington, D. C.: Smithsonian Institution Press. 748 p.

(40) Collie, J. S., G. A. Escanero, and P. C. Valentine. 1997. Effects of bottom fishing on the benthic megafauna of Georges Bank. Marine Ecology Progress Series 155: 159-172.

(41) Commercial Fisheries News. 2001. NMFS launches $10 million groundfish permit buyback. Commercial Fisheries News 28(9): 1.

(42) Conference of New England Governors and Eastern Canadian Premiers (CNEGECP). 1998. Mercury Action Plan. Conference of New England Governors and Eastern Canadian Premiers, Boston, MA.

(43) Conference of New England Governors and Eastern Canadian Premiers (CNEGECP). 2002. Report to New England Governors and Eastern Canadian Premiers on the mercury project. Boston, MA.

(44) Conkling, P. W. (Ed.) 1995. From Cape Cod to the Bay of Fundy: an environmental atlas of the Gulf of Maine. Cambridge, MA: MIT Press. 258 p.

(45) Conkling, P. W. 1999. Islands in time: a natural and cultural history of the islands of the Gulf of Maine. Rockland, ME: Island Institute. 319 p.

(46) Conkling, P. W. 2000. Fish or foul? Will aquaculture carve out a niche in the Gulf of Maine? Maine Policy Review 9(2): 12-19.

(47) Crighton, S. and R. Sturtevant. 1998. *Protecting the Gulf of Maine from Land-based Activities: A Working Meeting to Develop Strategies and Actions,* Scoping Paper 3: Coastal Development: 44 p.

(48) Culliton, T.J., J.J. McDonough, III, D.G. Remer, and D.M. Lott. 1992. Building Along America's Coasts: 20 Years of Building Permits, 1970-1989. National Oceanic and Atmospheric Administration, Strategic Environmental Assessments Division, Rockville, MD: 49p.

(49) Dahl, T.E. 1990. Wetlands Losses in the United States 1780s to 1980s. US Department of the Interior, Fish and Wildlife Service, Washington, DC: 13p.

(50) Dahl, T.E. 2000. Status and Trends of Wetlands in the Conterminous United States 1986 to 1997. US Department of the Interior, Fish and Wildlife Service, Washington, DC: 82p.

(51) DFO. 1999. Interaction between wild and farmed Atlantic salmon in the Maritimes provinces. DFO Maritimes Regional Habitat Status Report 99/1E.

(52) DFO. 2001a. Bay of Fundy Lobster (LFAs 35, 36, 38). DFO Science Stock Status Report C3-61. <http://www.dfo-mpo.gc.ca/csas/Csas/status/2001/SSR2001_C3-61e.pdf> Accessed 16 February 2004.

(53) DFO. 2001b. Southwest Nova Scotia Lobster (Lobster Fishing Area 34). DFO Science Stock Status Report C3-62. < http://www.dfo-mpo.gc.ca/csas/Csas/status/2001/SSR2001_C3-62e.pdf> Accessed 16 February 2004.

(54) DFO. 2002. Southern Scotian Shelf and Bay of Fundy Cod (Div. 4X/5Y). DFO Science Stock Status Report A3-05 (2002) (Revised). < http://www.dfo-mpo.gc.ca/csas/Csas/status/2002/SSR2002_A3-05_E.pdf> Accessed 28 February 2004.

(55) DFO. 2003a. Statistical Services. Commercial landings statistics. <http://www.dfo-mpo.gc.ca/communic/statistics/commercial/landings/seafisheries/index_e.htm> Accessed 28 February 2004.

(56) DFO. 2003b. Eastern Georges Bank Cod. DFO Science Stock Status Report 2003/040. <http://www.dfo-mpo.gc.ca/csas/Csas/status/2003/SSR2003_040_E.pdf> Accessed 28 February 2004.

(57) DFO. 2003c. 4VWX herring. DFO Science Stock Status Report 2003/027. <http://www.dfo-mpo.gc.ca/csas/Csas/status/2003/SSR2003_027_E.pdf> Accessed 25 March 2004.

(58) DFO. 2003d. Atlantic herring: Georges Bank, Nantucket Shoals, Gulf of Maine stock complex. DFO Science Stock Status Report 2003/028. <http://www.dfo-mpo.gc.ca/csas/Csas/status/2003/SSR2003_028_E.pdf> Accessed 25 March 2004.

(59) DFO. 2003e. Scallop Production Areas (SPAs) in the Bay of Fundy. DFO Science Stock Status Report 2003/025. <http://www.dfo-mpo.gc.ca/csas/Csas/status/2003/SSR2003_025_E.pdf> Accessed 25 March 2004.

(60) DFO. 2003f. Statistical Services. 2000 survey of recreational fishing in Canada. <http://www.dfo-mpo.gc.ca/communic/statistics/recreational/canada/2000/Summary/tables_e.htm> Accessed 2 March 2004.

(61) DFO. 2003g. Statistical Services. Aquaculture. <http://www.dfo-mpo.gc.ca/communic/statistics/aqua/index_e.htm> Accessed 12 March 2004. Gulf of Maine Council on the Marine Environment. www.gulfofmaine.org

(62) DFO. 2003h. A scientific review of the potential environmental effects of aquaculture in aquatic ecosystems. Volume I. Far-field environmental effects of marine finfish aquaculture (B. T. Hargrave); Ecosystem level effects of marine bivalve aquaculture (P. Cranford, M. Dowd, J. Grant, B. Hargrave, and S. McGladdery); Chemical use in marine finfish aquaculture in Canada: a review of current practices and possible environmental effects (L. E. Burridge). Canadian Technical Report of Fisheries and Aquatic Sciences 2450: ix + 131 p.

(63) DFO. 2003i. Salmon holding capacity in Southwestern New Brunswick. Canadian Technical Report of Fisheries and Aquatic Sciences 2489: iv + 60 p.

(64) DFO. 2003j. Georges Bank scallop. DFO Science Stock Status Report 2003/038. http://www.dfo-mpo.gc.ca/csas/Csas/status/2003/SSR2003_038_E.pdf Accessed 16 June 2004.

(65) DFO. 2003k. Canada's Ocean Strategy. Fisheries and Oceans, Ottawa, ON.

(66) Drinkwater, K. F. 2002. A review of the role of climate variability in the decline of Northern cod. American Fisheries Society Symposium 32: 113-130.

(67) Drinkwater, K. F., A. Belgrano, A. Borja, A. Converi, M. Edwards, C. H. Greene, G. Ottersen, A. J. Pershing, and H. Walker. 2003. The response of marine ecosystems to climate variability associated with the North Atlantic Oscillation. In: Hurrell, J. W., Y. Kushnir, G. Ottersen, and M. Visbeck, editors. The North Atlantic Oscillation: climatic significance and environmental impact. Washington, D.C.: American Geophysical Union. p 211-234.

(68) Drinkwater, K. F. and D. G. Mountain. 1997. Climate and oceanography. In Boreman, J., B. S. Nakashima, J. A. Wilson, and R. L. Kendall, editors. Northwest Atlantic groundfish: perspectives on a fishery collapse. Bethesda, MD: American Fisheries Society. p 3-25.

(69) Easton, M. D. L., D. Luszniak, and E. von der Geest. 2002. Preliminary examination of contaminant loadings in farmed salmon, wild salmon and commercial salmon feed. Chemosphere 46: 1053-1074.

(70) Eganhouse, R.P., and Sherblom, P.M., 2001, Anthropogenic organic contaminants in the effluent of a combined sewer overflow: impact on Boston Harbor. Mar. Environ. Res. 51: 51-74.

(71) Environment Canada. 1994. *State of the Environment in the Atlantic Region.* Environment Canada, Dartmouth, NS. 457 p.

(72) Environment Canada. 2002a. National Pollutant Release Inventory: Regional synopsis for the Atlantic Provinces. Environment Canada, Dartmouth, NS.

(73) Environment Canada. 2002b. Mercury in Atlantic Canada: A progress report. Environment Canada, Dartmouth, NS.

(74) Environment Canada. 2003. Species at Risk Act. A Guide. October 2003. Environment Canada, Ottawa, ON. 17 p.

(75) Environmental Department of the Passamaquoddy Tribe at Pleasant Point and Cobscook Bay Resource Center. 2001. *Identifying Pollutants in Species Regularly Consumed by Native Americans in the Passamaquoddy Bay Region. Results of the Toxics Monitoring Program.* Environmental Department of the Passamaquoddy Tribe at Pleasant Point. Perry, ME. 26 p.

(76) EPA. 1998. Condition of the Mid-Atlantic Estuaries. EPA 600-R-98-147. Nov., 1998.

(77) EPA. 2004. www.epa.gov/maia/html/glossary.html

(78) Evers, D.C. 2001. Assessing the potential impacts of methylmercury on the Common Loon in southern New Hampshire. Biodiversity Research Institute, Falmouth, ME.

(79) Findlay, R. H., L. Watling, and L. M. Mayer. 1995. Environmental impact of salmon net-pen culture on marine benthic communities in Maine: a case study. Estuaries 18: 145-179.

(80) Finlayson, C. 2003. Inventory of Environmental Monitoring Programs in the Gulf of Maine and Long Island Sound. Manuscript Report. Gulf of Maine Council on the Marine Environment, Environmental Quality Monitoring Committee, Maine State Planning Office, Augusta, ME. 52p.

(81) Fogarty, M., E. Cohen, W. Michaels, and W. Morse. 1991. Interactions among herring, mackerel, and sand lance in the Northwest Atlantic. ICES Marine Science Symposium 193: 120-124.

(82) Fogarty, M. J. and S. A. Murawski. 1998. Large-scale disturbance and the structure of marine systems: fishery impacts on Georges Bank. Ecological Applications 8 (Suppl. 1): S6-S22.

(83) Food and Agriculture Organization (FAO). 2002. The state of world fisheries and aquaculture. <ftp://ftp.fao.org/docrep/fao/005/y7300e/y7300e00.pdf> Accessed 12 March 2004.

(84) Gardner Pinfold Consulting Economists Ltd. 2003. Economic impact and viability of marine aquaculture in Maine. Prepared for Maine Department of Marine Resources. <http://www.maine.gov/dmr/aquaculture/aqtaskforce/Gardner%20Pinfold%20Aquaculture%20Study%20Final.pdf> Accessed 12 March 2004.

(85) GESAMP. 1997. Opportunistic settlers and the problem of the ctenophore *Mnemiopsis leidyi* invasion in the Black Sea. Reports and Studies GESAMP No. 58, IMO, London, UK. 84p.

(86) Global Programme of Action Coalition for the Gulf of Maine. 2001. *The Gulf of Maine Summit: State of the Environment Reporting from the Bottom Up. A Handbook for Forum Conveners.* GPAC Conservation Council of New Brunswick. 18 pages.

(87) Goldman, L.R. and M.W.Shannon. 2001. Technical report: Mercury in the environment: Implications for pediatricians. Pediatrics 108: 197-205.

(88) Good, J.W., J.W. Weber, J.W. Charland, J.V. Olson and K.A. Chapin. 1997. State coastal zone management effectiveness in protecting estuaries and coastal wetlands: A national overview. Oregon Sea Grant, Oregon State Univ., Corvallis, OR. 283p.

(89) Gordon, D.C. Jr., and P.C. Cranford. 1994. Export of organic matter from a macrotidal saltmarsh in the upper Bay of

Fundy, Canada. Pages 257-264 in Mitsch, W.J. (ed.). Global Wetlands. Elsevier Science, Amsterdam.

(90) Gordon, D.C. Jr. and M.J. Dadswell. (Eds.). 1984. Update of the marine environmental consequences of tidal power development in the upper reaches of the Bay of Fundy. Can. Tech. Rept. Fish. Aquat. Sci. 1256. 686p.

(91) Gough, J. and T. Kenchington. 1995. A Glossary of Fisheries Science. Terms in Common Use in the Scotia-Fundy Region. Fisheries and Oceans, Communications Branch, Halifax, NS. 45 p.

(92) GPO (Government Printing Office). 2001. Northeast multi-species fishery; fishing capacity reduction program. Federal Register 66(244): 65454-65459. Dec. 19, 2001. <http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=2001_register&docid=01-31262-filed.pdf> Accessed 25 March 2004.

(93) Greenberg, D.A., and D.R. Lynch. 1992. Review: Gulf of Maine Circulation Modeling. Proceedings of the Gulf of Maine Scientific Workshop. Published by the Urban Harbors Institute, University of Massachusetts at Boston, Boston, MA.

(94) Griffin, D.W., E.K. Lipp, M.R. McLaughlin and J.B. Rose. 2001. Marine recreation and public health microbiology: Quest for the ideal indicator. BioScience 51: 817-825.

(95) Gulf of Maine Council on the Marine Environment (GOMCME). 1989. Marine environmental quality monitoring programs in the Gulf of Maine: an Inventory. Gulf of Maine Council on the Marine Environment, Augusta, ME.

(96) Gulf of Maine Council on the Marine Environment (GOMCME). 2001. Action Plan 2001-2006. GOMCME, Concord, NH. 31p. http://www.gulfofmaine.org/council/action_plan/.

(97) Gulf of Maine Council on the Marine Environment (GOMCME). 2004. Habitats. <http://www.gulfofmaine.org/knowledgebase/aboutthegulf/habitats/default.asp> Accessed 30 March 2004.

(98) Gulf of Maine Summit. www.gulfofmainesummit.org.

(99) Gulf of Maine Working Group. (GOMWG). 1989. *The Gulf of Maine; Sustaining Our Common Heritage.* Maine State Planning Office, Augusta, ME. 63p.

(100) Harding, G., J. Daizel and P. Vass. 2003. Preliminary results of a study on the prevalence and bioaccumulation of methylmercury in the food web of the Bay of Fundy, Gulf of Maine, p. 73-74. In Collaborative Mercury Research Network (COMERN) 4th Annual Congress. November 5-7, 2003, St. Andrews, NB. COMERN, Montreal, Quebec.

(101) Harris, H.H., I.J. Pickering and G.N. George. 2003. The chemical form of mercury in fish. Science 301: 1203.

(102) Hart, D. 2001. Sea scallops. Status of Fisheries Resources off the Northeastern United States. <http://www.nefsc.noaa.gov/sos/spsyn/iv/scallop/> Accessed 22 February 2004.

(103) Harvey, J., D. Coon, and J. Abouchar. 1998. *Habitat Lost: Taking the Pulse of Estuaries in the Canadian Gulf of Maine.* The Conservation Council of New Brunswick, Fredericton, NB. 81p.

(104) Haskell, B.D., B.G.Norton and R. Costanza. 1992. Introduction. What is ecosystem health and why should we worry about it? Pages 3-20 in Ecosystem Health. New Goals for Environmental Management. R. Costanza et al., Island Press, Wash., DC.

(105) Hildebrand, L. and E. Noreena. 1992. Approaches and progress toward effective integrated coastal zone management. Mar. Pollut. Bull. 25(1-4):94-97.

(106) Hites, R. A., J. A. Foran, D. O. Carpenter, M. C. Hamilton, B. A. Knuth, and S. J. Schwager. 2004. Global assessment of organic contaminants in farmed salmon. Science 303: 226-229.

(107) Hodgson, E., R.B. Mailman and J.E. Chambers. (Eds.). 1998. Dictionary of Toxicology. 2nd Edition. Groves Dictionaries Inc., New York, NY. 504p.

(108) Horsley & Witten, Inc. 1998. Impacts of contaminants on the resources of the Gulf of Maine. Working paper. Commission for Environmental Cooperation, Montreal, Canada.

(109) Hunt, J. J., B. Hatt, and L. O'Brien. 2003. Population status of Eastern Georges Bank cod (Unit Areas 5Zj,m) for 1978-2004. Canadian Science Advisory Secretariat Research Document 2003/096 < http://www.dfo-mpo.gc.ca/csas/Csas/DocREC/2003/ RES2003_096_E.pdf> Accessed 16 February 2004.

(110) HydroQual. 2003. Bays Eutrophication Model (BEM): Model verification for the period 1998-1999. Boston: Massachusetts Water Resources Authority. Report ENQUAD 2003-03. 318 p.

(111) Irland, L.C. 1982. Wildlands and Woodlots: The Story of New England's Forests. University Press of New England, Hanover, NH: 217 p.

(112) Ironside, G. 2001. Nutrients in the Canadian environment: Reporting on the state of Canada's environment. Environment Canada, Ottawa, ON.

(113) Jackson, J. B. C., M. X. Kirby, W. H. Berger, K. A. Bjorndal, L. W. Botsford, B. J. Bourque, R. H. Bradbury, R. Cooke, J. Erlandson, J. A. Estes, T. P. Hughes, S. Kidwell, C. B. Lange, H. S. Lenihan, J. M. Pandolfi, C. H. Peterson, R. S. Steneck, M. J. Tegner, R. R. Warner. 2001. Historical over-fishing and the collapse of coastal ecosystems. Science 293: 629-638.

(114) Jennings, S., J. K. Pinnegar, N. V. C. Polunin, and K. J. Warr. 2001. Impacts of trawling disturbance on the trophic structure of benthic invertebrate communities. Marine Ecology Progress Series 213: 127-142.

(115) Jones, S.H. 1998. Storm-water contamination of New Hampshire coastal surface waters. Final report. NH Office of State Planning/Coastal Program, Concord, NH. 72 p.

(116) Jones, S.H. 2000. A Technical Characterization of Estuarine and Coastal New Hampshire. The New Hampshire Estuaries Project, Portsmouth, NH.

(117) Jones, S.H. 2002. Sewage, bacteria and ecosystem health. Pp. 17-18, In: Sewage Management in the Gulf of Maine: Workshop Proceedings. Hinch, P.R., S. Bryon, K. Hughes and P.G. Wells (Eds.). Gulf of Maine Council on the Marine Environment, www.gulfofmaine.org.

(118) Jones, S.H. 2003. Tracking Bacterial Pollution Sources in Stormwater Pipes. Final Report. New Hampshire Estuaries Project, Portsmouth, NH.

(119) Jones, S.H., M. Chase, J. Sowles, P. Hennigar, N. Landry, P.G. Wells, G.C.H. Harding, C. Krahforst and G.L. Brun. 2001. Monitoring for toxic contaminants in *Mytilus edulis* from New Hampshire and the Gulf of Maine. J. Shellfish Res. 20: 1203-1214.

(120) Jones, S.H. and H.E. Gaudette. 2001. Storm-water-related bacterial and trace metal contamination of New Hampshire tidal rivers. New Hampshire Coastal Program/Office of State Planning, Portsmouth, NH.

(121) Jones, S.H. and N. Landry. 2000. The New Hampshire *Gulfwatch* Program: 1998. New Hampshire Department of Environmental Services, Concord, NH.

(122) Jones, S.H. and N. Landry. 2004. Tracking Bacterial Pollution Sources in Little Harbor and the New Hampshire Atlantic Coast Tributaries. Final report. New Hampshire Department of Environmental Services, Concord, NH.

(123) Jones, S.H. and R. Langan. 1994. Assessment of non-point source pollution in tributaries to the Great Bay Estuary. Final Report. NH Office of State Planning/Coastal Program, Concord, NH.

(124) Jones, S.H. and R. Langan. 1996. Assessment of non-point source pollution in tributaries entering Great Bay. Final Report. NH Office of State Planning/Coastal Program, Concord, NH. 67 p.

(125) Jones, S.H., S. Summer and J. Connor. 2004. Identify and Mitigate Bacterial Sources at Public Beaches Using Microbial Source Tracking. . Final report. New Hampshire Department of Environmental Services, Concord, NH.

(126) Jones, S.H. and B.W. Summer-Brason. 1998. Incidence and detection of pathogenic *Vibrio* sp. in a northern New England estuary, USA. J. Shellfish Res. 17: 1665-1669.

(127) Jones, S.H. and P.G.Wells. (Eds.). 2002. Gulf of Maine Environmental Quality Monitoring Workshop, April 30-May 1, 2001. Summary Report. Gulf of Maine Council on the Marine Environment, Durham, NH and Dartmouth, NS. Nov. 2002. 37p.

(128) Karl, T.R. and K. E. Trenberth. 2003. Modern global climate change. Science 302 (5651):1719-1723.

(129) Knowlton, A.R. and S.D. Kraus. 2001. Mortality and serious injury of northern right whales *(Eubalaena glacialis)* in the western North Atlantic Ocean. Journal of Cetacean Research and Management (Special Issue)2: 193-208.

(130) Kolpin, D.W., E.T. Furlong, M.T. Meyer, E.M. Thurman, S.D. Zaugg, L.B. Barber and H.T. Buxton. 2002. Pharmaceuticals, hormones and other organic wastewater contaminants in U.S. streams, 1999-2000: A national reconnaissance. Environ. Sci. Technol. 36: 1202-1211.

(131) Kraus, S. D. 1990. Rates and potential causes of mortality in North Atlantic right whales *(Eubalaena glacialis)*. Marine Mammal Science 6: 278-291.

(132) Ku, L.F., D.A. Greenberg, C.J.R. Garrett, and F.W. Dobson. 1985. Nodal modulation of the lunar semidiurnal tide in the Bay of Fundy and the Gulf of Maine. Science 230: 69.

(133) Kurlansky, M. 1997. *Cod: a biography of the fish that changed the world.* New York: Walker and Company. 294 p.

(134) Land Trust Alliance website, www.lta.org and personal communication with Maine Coast Heritage Trust.

(135) Lewis, R.A. 1998. Lewis' Dictionary of Toxicology. Lewis Publ, Boca Raton, FL. 1127p.

(136) Link, J. S. 2002. What does ecosystem-based fisheries management mean? Fisheries 27(4): 18-21.

(137) Link, J. S., J. K. T. Brodziak, S. F. Edwards, W. J. Overholtz, D. Mountain, J. W. Jossi, T. D. Smith, and M. J. Fogarty. 2002. Marine ecosystem assessment in a fisheries management context. Canadian Journal of Fisheries and Aquatic Sciences 59: 1429-1440.

(138) Lockhart, F. and B. Estrella. 1997. Amendment 3 to the interstate fishery management plan for lobster. Washington, D. C.: Atlantic States Marine Fisheries Commission. 36 p.

(139) Long, E.R., D.D. MacDonald, S.L. Smith and F.D. Calder. 1995. Incidence of adverse biological effects within the ranges of chemical concentrations in marine and estuarine sediments. Environ. Management 19: 81-97.

(140) Lotze, H. and I. Milewski. 2002. Two hundred years of ecosystem and food web changes in the Quoddy Region, outer Bay of Fundy. A report of the Conservation Council of New Brunswick, Fredericton, NB. Feb. 2002. 188p.

(141) Maciolek, N.J., R.J. Diaz, D. Dahlen, B., Hecker, E.D. Gallagher, J.A. Blake, I.P. Williams, S. Emsbo-Mattingly, C. Hunt and K.E. Keay. 2003. 2002 Outfall benthic monitoring report. Boston: Massachusetts Water Resources Authority. Report ENQUAD 2003-13.

(142) Maine Bureau of Health (MEBH). 2001. Reportable infectious diseases in Maine: 2001 summary. Maine Bureau of Health, Division of Disease Control, Augusta, ME.

(143) Maine Department of Environmental Protection (MEDEP). 2002a. State of Maine 2002 Integrated Water Quality Monitoring and Assessment Report. Document No. DEPLW0633. Maine Department of Environmental Protection, Augusta, ME.

(144) Maine Department of Environmental Protection (MEDEP). 2002b. Shellfish tissue analysis, p. 1.2-1.8. In, 2001 Surface Water Ambient Toxic monitoring program, Maine Department of Environmental Protection, Augusta, ME.

(145) Maine Department of Environmental Protection and Maine State Planning Office. MEDEP&SPO. 2002. Mercury in Maine: A status report. Maine Department of Environmental Protection and Maine State Planning Office, Augusta, ME.

(146) Maine Department of Marine Resources. 2003. Recreational Saltwater Fishing Newsletter 8(1). 8 p.

(147) Maine Department of Marine Resources. 2004a. Commercial fisheries landings. <http://www.maine.gov/dmr/commercialfishing/comfishlandings.htm> Accessed 11 March 2004.

(148) Maine Department of Marine Resources. 2004b. Maine finfish aquaculture harvest 1988-2002. <http://www.maine.gov/dmr/aquaculture/lease_inventory/Finfish%20Harvest%20Chart.htm> Accessed 12 March 2004.

(149) Maine Department of Marine Resources. 2004c. Lobster management. <http://www.maine.gov/dmr/lobstermanagement.htm> Accessed 29 March 2004.

(150) Malakoff, D. 2002. Microbiologists on the trail of polluting bacteria. Science 295: 2352-2353.

(151) Marine Environment Research Institute. www.meriresearch.org

(152) Massachusetts Department of Public Health (MDPH). 2003. Marine and freshwater beach testing in Massachusetts: 2002 season. Massachusetts Department of Public Health, Boston, MA.

(153) Massachusetts Water Resources Authority (MWRA). 2003. Combined sewer overflow control plan: Annual progress report 2002. Boston: Massachusetts Water Resources Authority.

(154) Massachusetts Water Resources Authority (MWRA). 2002. The State of Boston Harbor Report: Mapping the Harbor's Recovery. http://www.mwra.state.ma.us/harbor/html/2002-09_sections.htm (3/23/04).

(155) Mayo, R. K., M. J. Fogarty, and F. M. Serchuk. 1992. Aggregate fish biomass and yield on Georges Bank, 1960-87. Journal of Northwest Atlantic Fishery Science 14: 59-78.

(156) Mayo, R. and L. O'Brien. 2000. Atlantic cod. Status of Fisheries Resources off the Northeastern United States. <http://www.nefsc.noaa.gov/sos/spsyn/pg/cod/> Accessed 22 February 2004.

(157) McInnis Leek, Nancy. Nova Scotia Department of Natural Resources, July 2004, personal communication.

(158) McKenzie, K. 2003. C-CIARN Annual Report, 2002-2003. Dalhousie University, Halifax.

(159) Menon, A. 1997. Shellfish water quality protection program. Environment Canada, Dartmouth, NS.

(160) Mosher, B.W. 1995. Assessment of atmospheric non-point source nitrogen input to the Great Bay watershed and estuary. Final report. New Hampshire Coastal Program, Office of State Planning, Concord, NH.

(161) Mountain, D. G. and S. A. Murawski. 1992. Variation in the distribution of fish stocks on the northeast continental shelf in relation to their environment, 1980-1989. ICES Marine Science Symposium 195: 424-432.

(162) Muir, D. 2000. *Reflections in Bullough's Pond: Economy and Ecosystem in New England,* University Press of New England, 312 p.

(163) Murawski, S. A. 1993. Climate change and marine fish distributions: forecasting from historical analogy. Transactions of the American Fisheries Society 122: 647-658.

(164) Murawski, S. A. 2000. Definitions of overfishing from an ecosystem perspective. ICES Journal of Marine Science 57: 649-658.

(165) Murawski, S. A., R. Brown, H.-L. Lai, P. J. Rago, and L. Hendrickson. 2000. Large-scale closed areas as a fishery management tool in temperate marine systems: the Georges Bank experience. Bulletin of Marine Science 66: 775-798.

(166) Myers, G.J., P.W. Davidson, C. Cox, C.F. Shamlaye, D. Palumbo, E. Cernichiari, J. Sloane-Reeves, G.E. Wilding, J. Kost, L. Huang and T.W. Clarkson. 2003. Prenatal methylmercury exposure from ocean fish consumption in the Seychelles child development study. The Lancet 361: 1686-1692.

(167) North Atlantic Fisheries Organization (NAFO). 2004. NAFO Annual Fisheries Statistics Databases. <http://www.nafo.ca/activities/FRAMES/AcFrFish.html> Accessed 7 June 2004.

(168) Nash, C. 2003. The New Hampshire Department of Environmental Services Shellfish Program: 2002 Annual Report. New Hampshire Department of Environmental Services, Concord, NH.

(169) National Land Trust Census, Land Trust Alliance. Website, www.lta.org and Maine Land Trust Network Directory 2001.

(170) National Marine Fisheries Service (NMFS). 1999. Ecosystem-based fishery management. A report to Congress. National Marine Fisheries Service, Ecosystems Principles Advisory Panel. U. S. Department of Commerce, NOAA, NMFS.

(171) National Marine Fisheries Service (NMFS). 2003a. Fishery Statistics & Economics. Commercial fisheries. <http://www.st.nmfs.gov/st1/commercial/index.html> Accessed 28 February 2004.

(172) National Marine Fisheries Service (NMFS). 2003b. Fishery Statistics & Economics. Marine recreational fisheries. <http://www.st.nmfs.gov/st1/recreational/index.html> Accessed 15 February 2004.

(173) National Oceanic and Atmospheric Administration (NOAA). 1991. The 1990 national shellfish register of classified estuarine waters. National Oceanic and Atmospheric Administration, Rockville, MD.

(174) National Oceanic and Atmospheric Administration (NOAA). 1997a. The 1995 national shellfish register of classified estuarine waters. National Oceanic and Atmospheric Administration, Silver Spring, MD.

(175) National Oceanic and Atmospheric Administration. (NOAA). 1997b. Gulf of Maine Land-Based Pollution Sources Inventory: Non-point Sources of Pollution. http://sposerver.nos.noaa.gov/projects/gomaine/np_source.html

(176) National Oceanic and Atmospheric Administration (NOAA). 2004. National Status and Trends Program Mussel Watch Web site: http://nsandt.noaa.gov/asp_files/get_sites_list.asp?Program=MW (accessed- 4/21/04).

(177) National Research Council (NRC). 1995. Improving Interactions Between Coastal Science and Policy. Proceedings of the Gulf of Maine Symposium. National Academy Press, Wash., DC. 259p.

(178) National Research Council (NRC). 1997. Striking a Balance. Improving Stewardship of Marine Areas. National Academy Press, Wash., DC. 177p.

(179) National Research Council (NRC). 1999. Sustaining marine fisheries. Washington, D. C., National Academy Press. 148 p.

(180) National Research Council (NRC). 2000. Bridging Boundaries through Regional Marine Research. National Academy Press, Wash., DC. 115p.

(181) National Research Council (NRC). 2002. Effects of trawling and dredging on seafloor habitat. Washington, D. C., National Academy Press. 125 p.

(182) National Research Council (NRC). 2003. Cooperative research in the National Marine Fisheries Service. Washington, D. C., National Academy Press. 132 p.

(183) National Research Council (NRC). 2004. Atlantic salmon in Maine. Washington, D. C., National Academy Press. 240 p.

(184) New Brunswick Department of Health and Wellness. (NB DHW). 2003. 2002-2003 Annual report. New Brunswick Department of Health and Wellness, Fredericton, NB.

(185) New Brunswick Salmon Growers Association. 2004. New Brunswick Salmon Growers Environmental Policy and Codes of Practice. NBSGA, Letang, NB. Version 1.0 June 2004.

(186) New England Fishery Management Council (NEFMC). 1999. Final Atlantic herring fishery management plan incorporating the environmental impact statement and regulatory impact review. Volume 1. <http://www.nefmc.org/herring/index.html> Accessed 12 February 2004.

(187) New England Fishery Management Council (NEFMC). 2003. The role of Atlantic herring, *Clupea harengus,* in the Northwest Atlantic Ecosystem. Draft report. <http://www.nefmc.org/herring/index.html> Accessed 30 March 2004.

(188) New Hampshire Department of Environmental Services (NHDES). 2004. 2004 Section 305(b) and 303(d) consolidated assessment and listing methodology. NHDES-R-WD-04-5. New Hampshire Department of Environmental Services, Concord, NH.

(189) New Hampshire Department of Health and Human Services (NHDHHS). 2004. Quarterly communicable disease report. January 22, 2004. New Hampshire Department of Health and Human Services, Concord, NH.

(190) New Hampshire Environmental Protection. www.state.nh.us/nhep.

(191) New Hampshire Estuaries Project. (NHEP). 2003. *State of the Estuaries.* 2003. NHEP, Portsmouth, NH. 32p.

(192) Newman, M.C. and M.A. Unger. 2003. Fundamentals of Ecotoxicology. 2nd Edition. Lewis Publishers, Boca Raton, FL. 458p.

(193) Nielsen, N.O. 1999. The meaning of health. Ecosystem Health 5(2):65-66.

(194) NOAA (National Oceanic and Atmospheric Administration). 1997. *Gulf of Maine Land-Based Pollution Sources Inventory: Nonpoint Sources of Pollution.* http://sposerver.nos.noaa.gov/projects/gomaine/np_source.html .

(195) Northeast Fisheries Science Center (NEFSC). 1998. Draft report of the 27th Northeast Regional Stock Assessment Workshop (27th SAW): Stock Assessment Review Committee (SARC) Consensus Summary of Assessments. NEFSC Ref. Doc. 98-15.

(196) Northeast Fisheries Science Center (NEFSC). 2002. Assessment of 20 Northeast groundfish stocks through 2001: a report of the Groundfish Assessment Review Meeting (GARM), NEFSC, Woods Hole, MA, October 8-11, 2002. NEFSC Ref. Doc. 02-16. <http://www.nefsc.noaa.gov/nefsc/publications/crd/crd0216/> Accessed 21 February 2004.

(197) Northeast States for Coordinated Air Use Management (NESCAUM). 1998. Northeast States and Eastern Canadian Provinces Mercury Study. Northeast States for Coordinated Air Use Management, Boston, MA.

(198) Northern States Research Cooperative Mercury Research Group (NSRC). 2004. Web site. http://www.briloon.org/bri/workinggroups/nsrc.htm (Accessed-4/21/04).

(199) Nova Scotia Department of Agriculture and Fisheries. 2002. 4-H Fisheries Project. "Unit 1: The Commercial Fishery. Sea Salt and Sweat—Nova Scotia's Offshore Fishing History." <http://www.gov.ns.ca/nsaf/4h/manuals/fisheries/unit1a.pdf> Accessed 27 February 2004.

(200) O'Connor, T. 1998. Chemical contaminants in oysters and mussels. [On line] In NOAA's State of the Coast Report. National Oceanic and Atmospheric Administration, Silver Spring, MD. URL: [April 11, 2004] http://oceanservice.noaa.gov/websites/retiredsites/supp_sotc_retired.html

(201) Ollerhead, J., P.W. Hicklin, P.G. Wells and K. Ramsey. (Eds.). 1999. Understanding Change in the Bay of Fundy Ecosystem. Proceedings of the 3rd Bay of Fundy Science Workshop, April 1999. Environment Canada – Atlantic Region, Occasional Report No. 12. 143p.

(202) Overholtz, W. 2000. Atlantic herring. Status of Fisheries Resources off the Northeastern United States. <http://www.nefsc.noaa.gov/sos/spsyn/pp/herring/> Accessed 22 February 2004.

(203) Overholtz, W.J., L.D. Jacobson, G.D. Melvin, M. Cieri, M. Power, D. Libby, and K. Clark. 2004. Stock assessment of the Gulf of Maine - Georges Bank Atlantic herring complex, 2003. Northeast Fisheries Science Center Reference Document 04-06. 290 p.

(204) Pait, A.S. 1994. Gulf of Maine Point Source Inventory, A summary by watershed for 1991. National Oceanic and Atmospheric Administration, Rockville, MD.

(205) Pauly, D. 1995. Anecdotes and the shifting baseline syndrome of fisheries. Trends in Ecology and Evolution 10: 430.

(206) Pauly, D., V. Christensen, J. Dalsgaard, R. Froese, F. Torres Jr. 1998. Fishing down marine food webs. Science 279: 860-863.

(207) Pauly, D. and J. MacLean. 2003. *In a Perfect Ocean. The State of Fisheries and Ecosystems in the North Atlantic Ocean.* Island Press, Wash., DC. 175p.

(208) Pearce, J.B. 2000. The Gulf of Maine and Georges Bank. Chapter 19 in *Seas at the Millenium: An Environmental Evaluation,* edited by C. Shephard. Elsevier Science Ltd., Amsterdam.

(209) Pearce, J.B. and G. Wallace. 1995. The health of the Gulf of Maine ecosystem: cumulative impacts of multiple stressors. Regional Association for Research on the Gulf of Maine (RARGOM) Report 95-1. Dec. 1995. 15p.

(210) Percy, J.A., P.G.Wells, A.J. Evans. (Eds.). 1997. Bay of Fundy Issues: A Scientific Overview. Environment Canada - Atlantic Region, Occasional Report No. 8, Sackville NB and Dartmouth, NS. 191p. (reprinted May 2002).

(211) Person, P. and J. Harvey. 2004. *The Gulf of Maine Summit. State of the Environment Reporting from the Bottom Up – Summary Reports & Matrices from United States and Canadian Regional Forums and Meetings.* GOMCME, Concord, NH.

(212) Pew Oceans Commission. (POC). 2003. America's Living Oceans: Charting a Course for Sea Change. Arlington, VA. <http://www.pewoceans.org/oceans/> Accessed 25 March 2004.

(213) Pfafflin, J.R., P. Baham and F.S. Gill. 1996. Dictionary of Environmental Science and Engineering. Gordon and Breach Publ., Amsterdam. 181 p.

(214) Pirrone, N., G.J. Keeler and J.O. Nriagu. 1996. Regional differences in worldwide emissions of mercury to the atmosphere. Atmospheric Environment 30: 2981-2987.

(215) Power, M. J., R. L. Stephenson, L. M. Annis, F. J. Fife, K. J. Clark, and G. D. Melvin. 2003. 2003 Evaluation of 4VWX herring. Canadian Stock Advisory Secretariat Research Document 2003/035. <http://www.dfo-mpo.gc.ca/csas/Csas/DocREC/2003/RES2003_035_E.pdf> Accessed 25 March 2004.

(216) Relyea, R.A. 2003. Predator cues and pesticides: A double dose of danger for amphibians. Ecol. Applications 13: 1515-1521.

(217) Rice, J.C. 2003. Environmental health indicators. Ocean and Coastal Management 46:235-259.

(218) Rierden, A. 2003. Profile: Bill Ayer, the Nature Trust of New Brunswick. Gulf of Maine Times Volume 7, No. 2. http://www.gulfofmaine.org/times/summer2003/ayer.html (last accessed June, 2004).

(219) Robert, G., G.A.P. Black, M.A.E. Butler, and S.J. Smith. 2000. Georges Bank scallop stock assessment-1999. Canadian Stock Assessment Secretariat Research Document 2000/016 http://www.dfo-mpo.gc.ca/csas/Csas/English/Research_Years/2000/2000_016e.htm Accessed 16 June 2004

(220) Roman, C.T., N. Jaworski, F.T. Short, S. Findlay and R.S. Warren. 2000. Estuaries of the northeastern United States: habitat and land use signatures. Estuaries 23: 743-764.

(221) Rondeau, D., S. El-Batrik and G.C. van Kooten. 2002. A benefit-cost framework for optimal ecosystem preservation. Report to the FPPC, Victoria, November: 82 p.

(222) Rudd, M.A. 2004. An institutional framework for designing and monitoring ecosystem-based fisheries management policy experiments. Ecological Economics 48: 109-124.

(223) Ruggles, C.P. and W.D. Watt. 1975. Ecological Changes Due to Hydroelectric Development on the Saint John River. J. Fish . Res. Board Can. 32: 161-170.

(224) Ryan, P.A., H.R. Hafner and S.G. Brown. 2003. Deposition of pollutants to Casco Bay. Final Report STI-902150-2209-FR2. Casco Bay Estuary Project, Portland, ME.

(225) Salmon of the Americas. 2004. <http://www.salmonoftheamericas.com> Accessed 7 June 2004.

(226) Sanford, S. and G. Bezanson. 2003. *Escherichia coli* DNA typing: An evaluation of its potential as a tool for bacterial source tracking during an investigation of fecal pollution in the Thorne's Cove (Nova Scotia) clam harvesting area. Progress report. Shellfish Section, Environmental Protection Branch, Environment Canada, Dartmouth, NS.

(227) Schaeffer, D.J., E.E. Herricks and H.W. Kerster. 1988. Ecosystem health: 1. Measuring ecosystem health. Environmental Management 12:445-455.

(228) Scott, T.M., J.B. Rose, T.M. Jenkins, S.R. Farrah and J. Lukasik. 2002. Microbial source tracking: Current methodology and future directions. Appl. Environ. Microbiol. 68: 5796-5803.

(229) Serchuk, F. M., M. D. Grosslein, R. G. Lough, D. G. Mountain, and L. O'Brien. 1994. Fishery and environmental factors affecting trends and fluctuations in the Georges Bank and Gulf of Maine Atlantic cod stocks: an overview. ICES Marine Science Symposium 198: 77-109.

(230) Shaw, S.D. 2002. An investigation of persistent organic pollutants (POP) and heavy metals in tissues of harbor seals *(Phoca vitulina concolor)* and gray seals *(Halichoerus grypus)* in the Gulf of Maine. Final report. Maine Department of Environmental Protection, Augusta, ME. 16p.

(231) Shaw, S.D. 2003. Summary Report: Gulf of Maine Forum 2002: Protecting Our Coastal and Offshore Waters. Marine Environmental Research Institute, Blue Hill, ME., 21p.

(232) Shepherd, P. C. F. and J. S. Boates. 1999. Effects of a commercial baitworm harvest on semipalmated sandpipers and their prey in the Bay of Fundy hemispheric shorebird reserve. Conservation Biology 13: 347-356.

(233) Sherman, K. 1994. The changing ecosystem. Maritimes 37(1): 3-6.

(234) Sherman, K., N.A. Jaworski, and T.J. Smayda. 1996. *The North-East Shelf Ecosystem. Assessment, Sustainability and Management.* Blackwell Science, Cambridge, MA. 564p.

(235) Sherman, K. and H.R. Skjoldal. (Eds.). 2003. Large Marine Ecosystems of the North Atlantic. Changing States and Sustainability. In press……

(236) Shiaris, M.P., Rex, A.C., Pettibone, G.W., Keay, K., McManus, P., Rex, M.A., Ebersole, J. and Gallagher E. 1987. Distribution of indicator bacteria and *Vibrio parahaemolyticus* in sewage polluted inter-tidal sediments. Appl. Environ. Microbiol. 53: 1796-1761.

(237) Sidhu, K.S. 2003. Health benefits and potential risks related to consumption of fish or fish oil. Regulatory Toxicology and Pharmacology 38: 336-344.

(238) Siegener, R. and R.F. Chen. 2002. Caffeine in Boston Harbor seawater. Mar. Pollut. Bull. 44: 383-387.

(239) Silvert, W. and J. W. Sowles. 1996. Modelling environmental impacts of marine finfish aquaculture. Journal of Applied Ichthyology 12: 75-81.

(240) Simpson, J.M., J.W. Santo Domingo and D.J. Reasoner. 2002. Microbial source tracking: State of the science. Environ. Sci. Technol. 36: 5279-5288.

(241) Sinclair, M., S. Wilson, and D. v. Subba Rao. 1992. Overview of the Biological Oceanography of the Gulf of Maine. I Proceedings of the Gulf of Maine Scientific Workshop, January 1991, Woods Hole, Massachusetts. Ed by Jack Wiggins and Christopher N.K. Mooers. Published by Urban Harbors Institute, University of Massachusetts at Boston, Boston, MA.

(242) Smith, S. J. and M. J. Lundy. 2002. Scallop Production Area 3 and Scallop Fishing Area 29: stock status and forecast. Canadian Scientific Advisory Secretariat Research Document 2002/017 <http://www.dfo-mpo.gc.ca/csas/Csas/DocREC/2002/RES2002_017e.pdf> Accessed 5 March 2004.

(243) Sobsey, M.D., R. Perdue, M. Overton and J. Fisher. 2003. Factors influencing faecal contamination in coastal marinas. Wat. Sci. Technol. 47: 199-204.

(244) Sowles, J.W. 2001. Nitrogen in the Gulf of Maine: Sources, susceptibility & trends, pp. 3-15, In: 2001: Managing nitrogen impacts in the Gulf of Maine. White Paper #1. Cooperative Institute for Coastal and Estuarine Technology, University of New Hampshire, Durham, NH.

(245) Steinback, S., B. Genter, and J. Castle. 2004. The economic importance of marine angler expenditures in the United States. NOAA Professional Paper, NMFS 2. http://spo.nwr.noaa.gov/pp2.pdf Accessed 4 June 2004.

(246) Steneck, R. S. 1997. Fisheries-induced biological changes to the structure and function of the Gulf of Maine ecosystem. In: Wallace, G. T. and E. F. Braasch, editors. Proceedings of the Gulf of Maine ecosystem dynamics: a scientific symposium and workshop. September 16-19, 1996, St. Andrews, NB. Regional Association for Research on the Gulf of Maine, RARGOM Report 97-1. p 153-167.

(247) Stephenson, R. L. 1990. Multiuse conflict: aquaculture collides with traditional fisheries in Canada's Bay of Fundy. World Aquaculture 21(2): 34-45.

(248) Stephenson, R. L., D. E. Lane, D. J. Aldous, and R. Nowak. 1993. Management of the 4WX Atlantic herring *(Clupea harengus)* fishery: an evaluation of recent events. Canadian Journal of Fisheries and Aquatic Sciences 50: 2742-2757.

(249) Stephenson, R. L., M. J. Power, K. J. Clark, G. D. Melvin, F. J. Fife, T. Scheidl, C. L. Waters, and S. Arsenault. 2000. 2000 evaluation of 4VWX herring. Canadian Science Advisory Secretariat Research Document 2000/065. <http://www.dfo-mpo.gc.ca/csas/ Csas/DocREC/2000/PDF/2000_065e.pdf> Accessed 16 February 2004.

(250) Stewart, J.R., R.D. Elledner, J.A. Gooch, S. Jiang, S.P. Myoda and S.B. Weisberg. 2003. Recommendations for microbial source tracking: Lessons from a methods comparison study. J. Water and Health 1: 225-231.

(251) Sunderland, E.M. and G.L. Chumura. 2000. An inventory of historical mercury emissions in Maritime Canada: implications for present and future contamination. The Science of the Total Environment 256: 39-57.

(252) Taylor, P.H. 2004. Green gold: scientific findings for management of Maine's sea urchin fishery. Maine Department of Marine Resources, Boothbay Harbor, Maine.

(253) Townsend, D.W. 1998. Sources and cycling of nitrogen in the Gulf of Maine. J. Mar. Systems 16: 283-295.

(254) United Nations Environment Programme. www.gpa.unep.org

(255) United States Environmental Protection Agency (USEPA). 1986. Ambient Water Quality Criteria for Bacteria-1986. EPA-440/5-84-002. United State Environmental Protection Agency-Region 1, Boston, MA.

(256) United States Environmental Protection Agency (USEPA). 2000. Guidance for assessing chemical contaminant data for use in fish advisories. Volume 2. Risk assessment and consumption limits. 3rd Edition. EPA 823-B-00-008. United States Environmental Protection Agency, Washington, DC.

(257) United States Environmental Protection Agency (USEPA). 2002a. National Water Quality Inventory: 2000 Report. EPA-841-R-02-001. Office of Water, Washington, DC.

(258) United States Environmental Protection Agency (USEPA). 2002b. National Health Protection Survey of Beaches for the 2001 Swimming Season. Web site: http://yosemite.epa.gov/water/beach2002.nsf (accessed- April 18, 2004).

(259) United States Environmental Protection Agency (USEPA). 2003a. Bacterial water quality standards for recreational waters (freshwater and marine waters) status report. EPA-823-R-03-008. United States Environmental Protection Agency, Washington, DC.

(260) United States Environmental Protection Agency (USEPA). 2003b. Update: National listing of fish and wildlife advisories. EPA Fact Sheet. EPA-823-F-03-003. United States Environmental Protection Agency, Washington, DC.

(261) United States Environmental Protection Agency (USEPA). 2004a. National Coastal Assessment, Northeast Region Data Pages. Web site: http://www.epa.gov/emap/nca/html/regions/northeast.html (Accessed-4/18/04)

(262) United States Environmental Protection Agency (USEPA). 2004b. Draft National Coastal Condition Report II. EPA-620/R-03/002. United States Environmental Protection Agency, Washington, DC.

(263) United States Environmental Protection Agency Office of Research and Development. 1999. *MAIA Project Summary - Condition of the Mid-Atlantic Estuaries.* US EPA, Washington, DC. 6 p.

(264) University of New Hampshire. 2004. Open Ocean Aquaculture. <http://www.ooa.unh.edu> Accessed 17 March 2004.

(265) U.S. Commission on Ocean Policy. 2004. Preliminary Report of the U.S. Commission on Ocean Policy – Governors' Draft. www.oceancommission.gov/documents/prelimreport

(266) USGCRP (United States Global Change Research Program). 2002. The New England: Regional Assessment of The Potential Consequences of Climate Variability and Change: Foundation Document. http://www.necci.sr.unh.edu/reports.html (last accessed June, 2004).

(267) Wahle, R. A. 2000. Fisheries in a sea of change: ecology and oceanography of New England's fishing grounds. Northeastern Naturalist 7: 317-328.

(268) Wallace, G.T. and E.F.Braasch. (Eds.). 1997. Proceedings of the Gulf of Maine Ecosystem Dynamics. A Scientific Symposium and Workshop, 16-19 Sept., 1996, St. Andrews, NB. Regional Association for Research on the Gulf of Maine, RARGOM Rept. 97-1. 352p.

(269) Watkins, W.D. and W. Burkhardt. 1996. New microbiological approaches for assessing and indexing contamination loading in estuaries and marine waters, pp. 241-263. In: Sustainable Development in the Southeastern Coastal Zone. Vernberg, F.J., W.B. Vernberg and T. Siewicki (Eds.). Belle W. Baruch Institute for Marine Biology and Coastal Research, Columbia, SC.

(270) WCED. (The World Commission on Environment and Development). 1987. *Our Common Future.* Oxford University Press, Oxford, New York. 383p.

(271) Websters Third New International Dictionary. 1966. G. & C. Merriam Company, Publishers, Springfield, MA.

(272) Weinberg, J. R., T. G. Dahlgren, K. M. Halanych. 2002. Influence of rising sea temperature on commercial bivalve species of the U. S. Atlantic coast. American Fisheries Society Symposium 32: 131-140.

(273) Wells, P.G. 1999. Environmental impacts of barriers on rivers entering the Bay of Fundy. Canadian Wildlife Service Technical Report Series No. 334, Canadian Wildlife Service, Ottawa, ON. 43p.

(274) Wells, P.G. 2003a. Assessing health of the Bay of Fundy – concepts and framework. Mar. Pollut. Bull. 46:1059-1077.

(275) Wells, P.G. 2003b. State of the marine environment reports – a need to evaluate their role in marine environmental protection and conservation. Mar. Pollut. Bull. 46(10):1219-1223.

(276) Wells P.G., G.R. Daborn, J.A. Percy, J. Harvey, and S.J. Rolston. (Eds.). 2004. Health of the Bay of Fundy: Assessing Key Issues. Proceedings of the 5th Bay of Fundy Science Workshop and Coastal Forum, "Taking the Pulse of the Bay", Wolfville, Nova Scotia, May 13-16, 2002. Environment Canada-Atlantic Region, Occasional Report No. 21, Environment Canada, Dartmouth, Nova Scotia and Sackville, New Brunswick, 416 p.

(277) Wells, P.G., P.D. Keizer, J.L. Martin, P.A. Yeats, K.M. Ellis and D.W. Johnston. 1997. The chemical environment of the Bay of Fundy. Chapter 3, In, Bay of Fundy Issues: a scientific overview. Percy, J.A., P.G. Wells and A.J. Evans (Eds.). Workshop Proceedings, Wolfville, N.S., January 29-February 1, 1996. Environment Canada Atlantic Region Occasional Report No. 8, Environment Canada, Sackville, NB.

(278) Wells, P.G. and S.J. Rolston. (Eds.) 1991. Health of Our Oceans. A Status Report on Canadian Marine Environmental Quality. Environment Canada, Ottawa and Dartmouth, NS. 186p.

(279) Werme, C. and M.S. Connor. 2001. Assessing, monitoring and controlling nitrogen pollution in the Gulf of Maine, pp. 16-27, In: 2001: Managing nitrogen impacts in the Gulf of Maine. White Paper #1. Cooperative Institute for Coastal and Estuarine Technology, University of New Hampshire, Durham, NH.

(280) Werme, C. and C.D. Hunt. 2003. Outfall monitoring overview. Boston: Massachusetts Water Resources Authority. Report ENQUAD 2003-12.

(281) Whitelaw, E. 2000. Breaching Dam Myths. Oregon Quarterly, Autumn 2000. http://www.bluefish.org/damyth.htm

(282) Wilbur, R. and J. Harvey. 1992. *Voices of the Bay. Reflections on Changing Times along Fundy Shores.* The Conservation Council of New Brunswick, Fredericton, NB. 86p.

(283) Williams, M. 1989. *Americans and Their Forests: A Historical Geography.* Cambridge University Press, New York: 599 p.

(284) Zhang, C., C. Ritchie, F.R. Meng and P.A. Arp. 2003. Fundy coastal case study. Hg levels in forests and moss: A geospatial analysis, p. 71-72. In, Collaborative Mercury Research Network (COMERN) 4th Annual Congress. November 5-7, 2003, St. Andrews, NB. COMERN, Montreal, Quebec.

10. Suggested Further Readings

Note: This is a small selection of available literature and web sites pertinent to the topics discussed in this report. The reader is encouraged to seek further information of interest.

The Gulf of Maine and Its Issues
Atkinson, J., P. M. Brooks, A.C. Chatwin and P. Shelley. 2000. *The Wild Sea. Saving Our Marine Heritage.* Conservation law Foundation, Boston, MA. 120p.

Backus, R.H and D.W. Bourne. (Eds.). 1987. *Georges Bank.* The MIT Press, Cambridge, MA and London, UK. 593p.

Conkling, P.W. (Ed.). 1995. *From Cape Cod to the Bay of Fundy. An Environmental Atlas of the Gulf of Maine.* The MIT Press, Cambridge, MA., London, UK. 258p.

EPA. 2001. *National Coastal Condition Report.* EPA-620/R-01/005. US EPA, Wash., DC. 204p.

Gulf of Maine Council on the Marine Environment. 2004. www.gulfofmaine.org

Konrad, V., S. Ballard, R. Erb and A. Morin. 1989. *The Gulf of Maine: Sustaining Our Common Heritage.* Maine State Planning Office, Augusta, Maine, and the Canadian-American Center of the University of Maine. 270p.

Sherman, K., N.A. Jaworski, and T.J. Smayda. (Eds.). 1996. *The Northeast Shelf Ecosystem.* Blackwell Science, Cambridge, MA. 564p.

Wallace, G.T. and E.F. Braasch. (Eds.). 1997. *Proceedings of the Gulf of Maine Ecosystem Dynamics.* A Scientific Symposium and Workshop. 16-19 Sept, 1996. St Andrews, NB. RARGOM Report 97-1. 352p.

The Bay of Fundy and Its Issues
Buzeta, M.-I., R. Singh and S. Young-Lai. 2003. *Identification of Significant Marine and Coastal Areas in the Bay of Fundy.* Canadian Manuscript Report of Fisheries and Aquatic Sciences 2635. 177p plus appendices.

Harvey, J., D. Coon and J. Abouchar. 1998. *Habitat Lost: Taking the Pulse of Estuaries in the Canadian Gulf of Maine.* Conservation Council of New Brunswick, Fredericton, NB. 80p.

Percy, J.A., P.G. Wells and A.J. Evans. (Eds.). 1997. *Bay of Fundy Issues: A Scientific Overview.* Environment Canada – Atlantic Region, Occasional Report No. 8. 191p. (reprinted April 2002).

Thurston, H. 1990. *Tidal Life. A Natural History of the Bay of Fundy.* Camden House Publ. Camden East, ON. 167p.

The Land-Based Activities Issue
GESAMP. 2001. *A Sea of Troubles.* GESAMP Report and Studies No. 70, United Nations Environment Programme, The Hague. 35p.

GESAMP. 2001. *Protecting the Oceans From Land-Based Activities.* GESAMP Report and Studies No. 71, United Nations Environment Programme, The Hague. 162p.

UNEP. 2003. *National Programmes for Action.* www.unep.org

United Nations. 1992. *Agenda 21.* United Nations, New York, NY.

Weber, P. 1994. Safeguarding oceans. Chapter 3 in State of the World 1994. Brown, L.R. et al., Eds., W.W Norton and Co., New York, London.

Stresses on the Gulf - Land Use
Abramovitz, J.N. 1998. *Taking a Stand: Cultivating a new Relationship with the World's Forests.* Worldwatch Paper 140, Worldwatch Institute, Wash., DC. 84p.

Gardner, G. 1997. Preserving global cropland. Chapter 3 in State of the World 1997. Brown, L.R. et al. (Eds.). W.W Norton and Co., New York, London.

O'Meara, M. 1999. Exploring a new vision for cities. Chapter 8 in State of the World 1999. Brown, L.R. et al. (Eds.). W.W Norton and Co., New York, London.

Sampat, P. 2003. Scrapping mining dependence. Chapter 6 in State of the World 2003. Gardner, C. et al. Eds., W.W Norton and Co., New York, London.

Sheehan, M. O'Meara. 2001. *City Limits. Putting the Brakes on Sprawl.* Worldwatch Paper 156, Worldwatch Institute, Wash., DC. 85p.

Stresses on the Gulf – Contaminants and Pathogens
Larsen, P. F. 1992. Marine environmental quality in the Gulf of Maine: a review. Rev. Aquat. Sci. 69 (1):67-87.

McGinn, A.P. 2000. Phasing out persistent organic pollutants. Chapter 5 in State of the World 2000. Brown, L.R. et al. (Eds.). W.W Norton and Co., New York, London.

McGinn, A.P. 2002. Reducing our toxic burden. Chapter 4 in State of the World 2002. Flavin, C. et al. (Eds.). W.W Norton and Co., New York, London.

Pierce, R.C., D.M. Whittle and J.M. Bramwell. (Eds.). 1998. *Chemical Contaminants in Canada's Aquatic Ecosystems.* Fisheries and Oceans, Ottawa, ON.

Stresses on the Gulf – Fisheries and Aquaculture

Apollonio, S. 2002. *Hierarchical Perspectives on Marine Complexities: Searching for Systems in the Gulf of Maine.* New York: Columbia University Press.

Boreman, J., B. S. Nakamshima, J. A. Wilson, and R. L. Kendall. 1997. *Northwest Atlantic Groundfish: Perspectives on a Fishery Collapse.* Bethesda, MD: American Fisheries Society.

Dobbs, D. 2000. *The Great Gulf: Fishermen, Scientists, and the Struggle to Revive the World's Greatest Fishery.* Island Press, Washington, DC.

McGinn, A.P. 1998. Promoting sustainable fisheries. Chapter 4 in State of the World 1998. Brown, L.R. et al. eds. W.W Norton and Co., New York, London.

Pauly, D. and J. Maclean. 2003. *In a Perfect Ocean: the State of Fisheries and Ecosystems in the North Atlantic Ocean.* Washington: Island Press.

Pikitch,, E.K. et al. 2004. Ecosystem-based fishery management. (Policy Forum. Ecology). Science 305:346-347.

The Future of the Gulf

Bright, C. 2000. Anticipating environmental surprise. Chapter 2 in State of the World 2000. Brown, L.R. et al. (Eds.). W.W Norton and Co., New York, London.

Bright, C. 2003. A history of our future. Chapter 1 in State of the World 2003. Gardner, C. et al. Eds., W.W Norton and Co., New York, London.

Brown, L.R. and E.C. Wolf. 1988. Reclaiming the future. Chapter 10 in State of the World 1988. Brown, L.R. et al. (Eds.). W.W Norton and Co., New York, London.

Fisheries and Oceans Canada. 2002. *Canada's Oceans Strategy. Our Oceans, Our Future.* Fisheries and Oceans Canada, Oceans Directorate, Ottawa, ON. 30p.

Fujita, R. 2003. *Heal the Ocean. Solutions for Saving Our Seas.* New Society Publ., Gabriola Island, BC. 226p.

Gulf of Maine Council on the Marine Environment. www.gulfofmaine.org

Marx, W. 1999. *The Frail Ocean. A Blueprint for Change in the New Millennium.* Hartley and Marks Publishers, Inc, Vancouver, BC. 272p.

McGinn, A.P. 1999. Charting a new course for oceans. Chapter 5 in State of the World 1999. Brown, L.R. et al. (Eds.). W.W Norton and Co., New York, London.

Pew Oceans Commission. 2003. *America's Living Oceans. Charting a Course for Sea Change.* A Report to the Nation. Pew Oceans Commission, Arlington, VA.

US Commission on Ocean Policy. 2004. Preliminary Report on the US Commission on Ocean Policy, Governor's Draft. US Commission on Ocean Policy, Wash., DC. April 2004.

11. List of Acronyms

ACAP – Atlantic Coastal Action Program (of Environment Canada).
ASMFC – Atlantic States Marine Fisheries Commission.
BoFEP – Bay of Fundy Ecosystem Partnership.
C-CIARN – The Canadian Climate Impacts and Adaptation Research Network.
CEC – Commission for Environmental Cooperation (under NAFTA)
CEPA – Canadian Environmental Protection Act
CSO – combined sewage overflow.
CSSP – Canadian Shellfish Sanitation Program.
DIN – total dissolved inorganic nitrogen.
DDT - dichlorodiphenyltrichloroethane.
DFO – Department of Fisheries and Oceans (Canada)
EC – Environment Canada
EPA - Environmental Protection Agency (USA).
ER-L – effects range low level.
ER-M – effects range median level.
GESAMP – the United Nations Joint Groups of Experts on the Scientific Aspects of Marine Environmental Protection (formerly…….Marine Pollution).
GOM – Gulf of Maine.
GOMCME/GOMC - Gulf of Maine Council on the Marine Environment.
GOMOOS – Gulf of Maine Ocean Observing System.
GPA – Global Programme of Action to Protect the Marine Environment from Land-based Activities
GPAC - Global Programme of Action Coalition (on the Gulf of Maine).
IPCC – International Program on Climate Change.
MDPH – Massachusetts Department of Public Health.
MEBH – Maine Bureau of Health.
MST – microbial source tracking.
MWRA – Massachusetts Water Resources Authority.
NACP – National Coastal Assessment Program.
NAFTA – North America Free Trade Agreement.
NEFMC – New England Fisheries Management Council.
NEFSC – New England Fisheries Science Center.
NGOs – non-governmental organizations.
NMFS - National Marine Fisheries Service.
NOAA – National Oceanographic and Atmospheric Administration.
NSRC – Northern States Research Cooperative (Mercury Research Group).
NSSP – National Shellfish Sanitation Program.
POPs – persistent organic pollutants.
RAMSAR – the Convention on Wetlands of International Importance (Ramsar Conference).
RARGOM – Regional Association for Research on the Gulf of Maine.
RMRP – Regional Marine Research Program.
SAR – species at risk.
SARA - the Species at Risk Act (Canada).
UNFCCC – United Nations Framework Convention on Climate Change.
WWTF – wastewater treatment facility.

12. Glossary

Algal bloom – dramatic increase in growth of phytoplankton. Subsequent decay of algae can reduce dissolved oxygen levels in water below the threshold needed by some species of fish and invertebrates.

Amphipod – a small shrimp-like crustacean (Phylum Arthropoda, Class Crustacea, Order Amphipoda) that lives on or in the sediments of both freshwater and marine waters.

Anadromous - refers to fish, such as salmon, that spawn and spend the early part of their life history in fresh water and estuaries, and their adult life in the ocean.

Anthropogenic – originating from human activity, not naturally occurring.

Barachois – as in pond, means a shallow coastal lagoon or pond created by the formation of a sandbar a short distance offshore from a beach. (Barber 1998).

Bathymetry – the measurement of depths of water in oceans, seas, and lakes. (Websters 3rd).

Benthic – bottom-dwelling. Refers to plants or animals that live in or on the bottom of an aquatic environment.

Bioaccumulation – the uptake and storage of chemicals (e.g. DDT, PCBs) from the environment by animals and plants. Uptake can occur through feeding or direct absorption from water or sediments (EPA 1998).

Bioavailability - the potential or tendency of a xenobiotic substance to enter and to interact physiologically with a living system as distinct from its presence or concentration in the immediate environment. (Lewis 1998).

Biomagnification – the progressive increase in the concentration of chemical contaminants (e.g. DDT, PCBs, methyl mercury) from the bottom to the top of the food web (EPA 1998).

Biodiversity – biological diversity. (Lewis 1998). The variety and variability among living organisms and the ecosystems in which they occur (www.epa.gov).

Biogeography - the science of the geography of living species, populations and communities in relation to their origins and the influence of past and present geographic and environmental factors (including chemical substances) that have shaped their distributions, habitats, and relationships at present or historically, in an evolutionary framework. (Lewis 1998).

Biomass – the total weight of living material of a specified type in a given area or for a given population or community. (Lewis 1998).

Biomes – major biotic units characterized by plant and animal communities having similarities in form and environmental conditions. For example, one of several immense terrestrial regions, each characterized throughout its extent by similar plants, animals, climate, and soil type. (Wells and Rolston 1991).

Boreal – of the North or northern regions. (Barber 1998).

Causeway – a raised road across a low or wet place, or piece of water. (Sykes 1978, in Wells 1999).

Cetacean – the group of marine mammals (Order Cetacea) that includes whales, porpoises and dolphins.

Change – the action of making something different in form, quality, or state: the fact of becoming different. (Websters 3rd).

Climate change - refers to changes in long-term trends in the average climate, such as changes in average temperatures. In IPCC usage, climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. In UNFCCC usage, climate change refers to a change in climate that is attributable directly or indirectly to human activity that alters atmospheric composition. (PEW Center on Global Climate Change).

Coliforms - coliform bacteria. A group of bacteria primarily found in human and animal intestines and wastes, and widely used as indicator organisms to show the presence of such wastes in water and the possible presence of pathogenic (disease-producing) bacteria (EPA 1998).

Coastal – the region extending seaward and inland from the shoreline that is influenced by and exerts an influence on the uses of the seas and their resources and biota. (Wells and Rolston 1991).

Coastal zone - various definitions. In practice, the coastal zone (or area) may include a narrowly defined area about the land-sea interface of the order of a few hundreds of metres to a few kilometres, or extend from the inland reaches of coastal watersheds to the limits of national jurisdiction in the offshore. The definition will depend upon the particular set of issues and geographic factors which are relevant to each stretch of coast. (Hildebrand and Norrena 1992).

Coastal zone management – a term meant to encompass management of all uses in the coastal zone, but it does not necessarily emphasize integration among uses and policies. First used in the United States in context of the 1972 Coastal Zone Management Act. (Cicin-Sain and Knecht 1998).

Contaminants – potentially harmful substances or agents in the natural environment that are present at concentrations above natural background levels, and below levels known to cause adverse effects.

Coprostanol – is the hormone 5b-cholastan-3b-ol; it is the main sterol of the faeces produced by the reduction of cholesterol by intestinal bacteria. (www.dictionarybarn.com).

Cumulative Effects – (or cumulative action) - any result of repeated equivalent exposures to a biologically active agent or stimulus in which the effect of any subsequent exposure is more pronounced than that of the initial exposure. (Lewis 1998).

Demography – the statistical study of the characteristics of human populations, especially with reference to size and density, growth, distribution, migration and vital statistics, and the effect of all of these on social and economic conditions. (Websters 3rd).

Developed land – land in residential, commercial, industrial, recreational, institutional, transportation or utility use.

Diversity – the condition or quality of being diverse; variety. (Barber 1998).

Dry deposition – (1) all materials deposited from the atmosphere in the absence of precipitation; (2) the process of such deposition. (Pfafflin et al. 1996).

Ecological change - a change in the health or quality of an ecosystem. Ecological change can be gradual or abrupt. It occurs naturally, occurs due to anthropogenic activities, or occurs due to a combination of natural and human-derived stresses. It can be subtle and takes place over various temporal and spatial scales. (adapted from Wells 2003).

Ecological footprint - is an accounting tool for ecological resources. Categories of human consumption are translated into areas of productive land required to provide resources and assimilate waste products. The ecological footprint is a measure of how sustainable our lifestyles are. (www.ire.ubc.ca/ecoresearch/ecoftpr.html).

Ecosystem – a natural unit formed by the interaction of a community of plants and animals with their environment (physical and biological) (EPA 1998).

Ecosystem health – is defined in terms of four characteristics applicable to any complex system – sustainability, activity, organization and resilience. An ecological system is healthy and free of distress syndrome if it is stable and sustainable – that is, if it is active and maintains its organization and autonomy over time, and is resilient to stress (from Wells 2003, based on Schaeffer et al 1988 and Haskell et al 1992).

Effluent – any fluid discharged from a given source into the external environment; commonly refers to wastes discharged into surface waters or to wastewater (treated or untreated) that flows from a treatment plant, sewer or industrial outfall into a lake or waterway. (Lewis 1998).

Electrophoresis – migration of suspended or colloidal particles in a liquid such as rubber latex, due to the effect of potential difference across immersed electrodes. The migration is toward electrodes of charge opposite to that of the particles. (Hawley 1971).

Enterococci – bacteria found in the faeces of most humans and many animals that are used as a fecal indicator in coastal waters. There are two types of enterococci associated with normal healthy people and which also occasionally cause human disease. They are called *Enterococcus faecalis* and *E. faecium.* (Association of Medical Microbiologists).

Epidemiology – the science that deals with the incidence, distribution and control of disease in a population (as of animals or plants); the ecology of a disease or pathogen. (Websters 3rd).

Estuary (estuaries) – regions of interaction between rivers and near-shore ocean waters, where tidal action and river flow mix fresh and salt water. Such areas include bays, mouths of rivers, salt marshes, and lagoons (EPA 1998).

Eutrophication – a condition in an aquatic ecosystem where high nutrient concentrations stimulate blooms of algae (e.g. phytoplankton), and algal decomposition may lower dissolved oxygen concentrations (EPA 1998).

Food web – an assemblage of organisms in an ecosystem, including plants, herbivores, and carnivores, which show the relationship of "who eats whom" (EPA 1998).

Gadoids – fish related to cod, including rockling, hake, haddock and pollock. Gadidae is the more inclusive family of codfishes (Scott and Scott 1988).

Geographic Information Systems (GIS) – technology that stores, manipulates, and displays data geographically. Can be used to characterize and evaluate land use options visually and quantitatively over time.

Groundfish – bottom-dwelling finfish (bony fish or teleosts).

Groyne – a rigid structure built out at an angle from a shore to protect the shore from erosion by currents, tides, and waves or to trap sand (as for making a beach). (Websters 3rd).

Gulfwatch – the blue mussel contaminants in tissue monitoring program in the Gulf of Maine and Bay of Fundy, conducted by the Gulf of Maine Council on the Marine Environment.

Habitat – the place where a population or community (i.e. an assemblage of micro-organisms, plants and animals) lives and its surroundings, both living and non-living (EPA 1998).

Hague Line – the international boundary between the United States and Canada on the east coast of North America, as determined by the World Court in The Hague in 1984. The line crosses the Gulf of Maine and Georges Bank.

Health – freedom from or coping with disease on the one hand (the medical view), and the promotion of well-being and productivity on the other (the public health view); "in essence, there are two dimensions of health – the capacity for maintaining organization or renewal, and the capacity for achieving reasonable human goals or meeting needs" (Nielsen 1999, in Wells 2003).

Heavy Metal – a term without a clear definition, but generally those metals that are of toxicological significance such as mercury, chromium, cadmium, arsenic and lead. They are extremely important environmental poisons and are the most extensively investigated. (Lewis 1998).

Hectare – 10,000 square meters, or 2.471 acres.

Hot spot – a commonly used, slang expression denoting a geographic area of extensive contamination, pollution, or other disturbance e.g. an industrialized harbour or a toxic waste site.

Hypersprawl – residential development at densities of one unit per three acres or less.

Impervious coverage – paved or hardened surfaces such as roof tops, roads and parking lots that water cannot penetrate. Percentage in watershed is one indicator used to determine health of aquatic ecosystems.

Indicators – in an environmental context, they are measurable features of natural ecosystems that provide scientific and managerial information about the current status and change over time i.e. trends, of each ecosystem.

Invasive species – an exotic or introduced species, plant or animal, that has been deliberately or accidently transported and released into a foreign environment through human activities and has successfully taken hold in that environment, causing ecological damage in the process. Ecologists refer to introduced species as biological invasions. (GESAMP 1997).

Linear alkyl benzene – (also, alkyl sulphonate, linear), a straight-chain alkylbenzene sulfonate; a detergent specially tailored for biodegradability. (Hawley 1971).

Monitoring – testing on a routine basis, with some degree of control, to ensure that the quality of water or effluent has not exceeded some prescribed criteria range. (Wells and Rolston 1991). Measuring, usually over time, the concentration of substances in either environmental media or living organisms. (Hodgson et al. 1998).

Nutrients – essential chemicals (e.g. nitrogen, phosphorus, carbon) from the environment needed by plants and animals for maintenance and growth. Excessive amounts of nutrients can lead to degradation of water quality by promoting excessive growth, accumulation, and subsequent decay of plants, especially algae (phytoplankton) (adapted from EPA 1998).

Pathogenic - causing or capable of causing disease (Websters 3rd).

Phylum – a major taxonomic unit comprising organisms sharing a fundamental pattern of organization and presumably a common descent (Websters 3rd).

Phytoplankton – small i.e. microscopic, often single-celled plants that live suspended in bodies of water, freshwater or marine.

Point-source pollution – refers to a source of pollutants from a single point of conveyance, such as a pipe. For example, the discharge from a sewage treatment plant or factory is a point source (EPA 1998).

Pollutants – chemical or physical agents that cause adverse or harmful effects to organisms (plants or animals). To be distinguished from contaminants whose levels are below those demonstrated to cause adverse effects.

Pollution – the UN GESAMP definition, widely accepted and in legal usage, is 'the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as to harm living resources and marine life, be hazardous to human health, hinder marine activities, including fishing and other marine uses, or impair the quality of sea water and reduce amenities'. (Wells and Rolston 1991).

Protozoa – a phylum of microscopic unicellular and acellular organisms, that include sporozoans, flagellates and ciliates.

Recruitment – when fish survive egg, larval and juvenile stages, and grow big enough to be caught in the fishery, they are "recruited" to the fishable stock. For some stocks, they must also move from the nursery grounds to the fishery grounds. (Gough and Kenchington 1995).

Refugia – refugium – an area that has escaped ecological changes occurring elsewhere and so provides a suitable habitat for relict species (species thought to have been more widespread in the past but now, usually because of climate change, have a discontinuous breeding distribution). (www.dictionary.reference.com).

Riparian – of or relating to or living or located on the bank of a watercourse (as a river or stream) or sometimes a lake. (Websters 3rd).

Risk – the possibility of loss, injury, disadvantage, or destruction. (Websters 3rd). As used in risk assessments, the probability or likelihood of some adverse consequence occurring to an exposed human or to an exposed ecological entity. (Newman and Unger 2003).

Risk communication - a science-based approach for communicating effectively in high concern situations. It provides a set of principles and tools for meeting those challenges. (Center for Risk Communication, www.centerforriskcommunication.com)

Roe – fish eggs, such as those from sturgeon or herring, with considerable commercial value.

Sediments – mud, clay, silt, sand, shell debris and other particles that settle on the bottom of rivers, lakes, estuaries and oceans, often accumulating to considerable depths.

Shellfish – bivalve molluscs (invertebrates) that have a shell, such as scallops, quahogs, oysters, clams and mussels. The term is sometimes used popularly to include crustaceans such as shrimp, lobsters, and crabs that have shell-like external skeletons.

Shifting baseline syndrome – a shifting baseline that develops as members of the present generation (of fisheries biologists) use stock sizes and composition known during their lifetimes as reference points against which to compare the current status of fisheries. (D. Pauly). The principle can also apply to practitioners of environmental monitoring.

Species – a group of individuals similar in certain morphological and physiological characteristics that are capable of interbreeding and are reproductively isolated from all other such groups (EPA 1998).

Species at risk – in Canada, know as species of special concern. A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats. (Environment Canada 2003).

Sprawl – low density development scattered across large land areas beyond the reach of municipal services.

Stakeholder – a person or people who will be affected by a project or can influence it, but who are (may) not be directly involved with doing the project work. Adapted from www.isixsigma.com/dictionary.

Stock – a population of fish of one species found in a particular area, which is used as a basic unit for fisheries management. All of the fish in a stock should share similar growth and migration patterns. (Gough and Kenchington 1995).

Stress – the state or condition of strain and especially of intense strain. (Websters 3rd). Any factor (external or internal) that disturbs the equilibrium of a system. (Lewis 1998).

Sublethal – less than lethal; pertaining to an agent or stimulus below the level of intensity, concentration, or amount that can cause death. (Lewis 1998). Refers to effects of stressors that act on biological processes such as behaviour, growth, development and reproduction, as opposed to lethal effects or mortality.

Sublethal concentrations – concentrations of substances or agents above background levels that can cause sublethal (i.e. non-lethal) effects on organisms or their populations.

Sustainability – the process of conserving an ecological balance by avoiding depletion of natural resources. (adapted from Barber 1998). Sustainable (adjective) refers to development. Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. (WCED 1987).

Target species – species or species group targeted for capture or monitoring.

Total Suspended Solids (TSS) – "total solids" is the term applied to the material residue left in the vessel after evaporation of a sample and its subsequent drying in an oven at a defined temperature. Total solids includes 'total suspended solids', the portion of total solids retained by a filter. (APHA 1992).

Toxic substances or chemicals – chemicals (single or as mixtures) that are poisonous, carcinogenic, or otherwise directly harmful to plants and animals at low levels. Formally considered by regulatory agencies as the category of chemicals and chemical mixtures that are persistent, bioaccumulate and are toxic at low levels, and hence of potential concern to the environment.

Traffic Light Approach – an approach developed by the USEPA to assign colours designating condition or level of severity of coastal variables e.g. oxygen concentration, turbidity, chlorophyll, benthic condition. Each colour represents a specific range of measures for a particular variable. When used by a general audience, the collective opinion of the group leads to the color assignment for a particular issue or stress.

Trophic level – a grouping of organisms that uses the next lower grouping of organisms as a food source. Used to describe the location on a food web where organisms feed.

Watershed – the entire area of land whose runoff of water, sediments, and dissolved materials (e.g. nutrients, contaminants) drain into a river, lake, estuary or ocean (EPA 1998).

Water quality objective – numerical concentration limit or narrative statement that has been negotiated to support and protect the designated uses of water at a specified site.

Water quality standard – an objective that is recognized in enforceable control laws of a level of government.

Wetlands – land areas along fresh and salt water (coastal wetlands, such as salt marshes, bogs, tidal basins, and mangrove swamps) that are flooded all or part of the time. (modified from Wells and Rolston 1991).

Zooplankton – small, sometimes microscopic, animals that float or swim weakly in the water column. Found in all aquatic systems.

Photos on the cover and pages 1, 4, 5, 16, 17, 52, 53, 58, and 59 were supplied by Ed Geis of the Maine Coastal Program.

Gulf of Maine
Council on the
Marine Environment