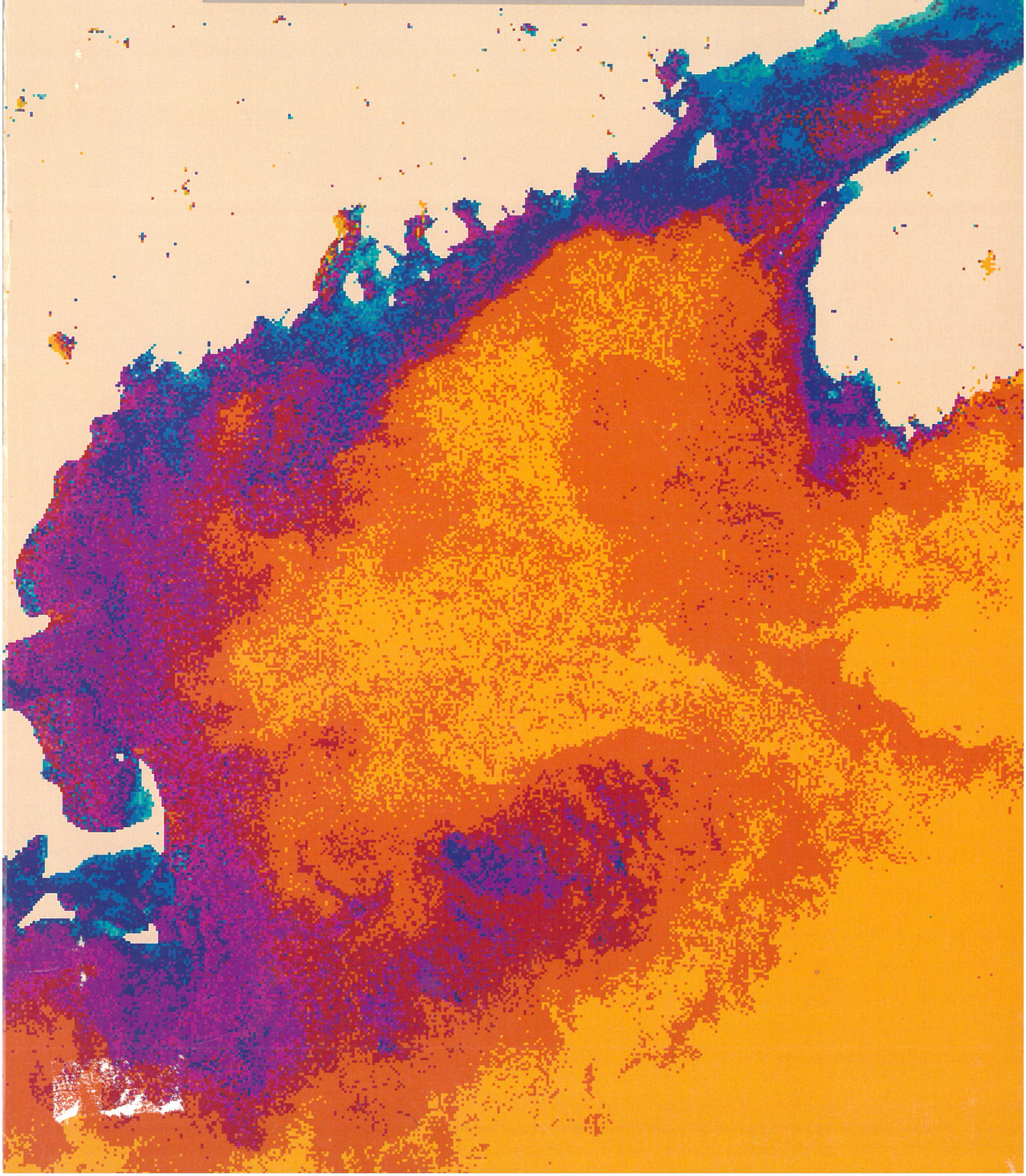
# THE GULF OF MAINE

**MAINE NOVA SCOTIA MASSACHUSETTS NEW BRUNSWICK NEW HAMPSHIRE**

## *Sustaining Our Common Heritage*



**Cover:** *Satellite image depicting phytoplankton pigment distributions in the Gulf of Maine in June 1979. Colors represent different levels of pigment as mg chl a $m^{-3}$. (Courtesy of Bigelow Laboratory for Ocean Sciences, West Boothbay Harbor, Maine).*

# the Gulf of Maine

Maine
Nova Scotia
Massachusetts
New Brunswick
New Hampshire

# Sustaining Our Common Heritage

COMPILED BY:
Katrina Van Dusen and Anne C. Johnson Hayden
Maine State Planning Office
November 1989

# Table of Contents

# *Executive Summary*

Peter Ralston/Island Institute

RECOGNIZING THAT THE Gulf of Maine is a common resource of inestimable value to their residents, the Provinces of Nova Scotia and New Brunswick, the States of Maine and New Hampshire, and the Commonwealth of Massachusetts have joined in a cooperative effort to protect its ecological integrity and the many uses that depend upon its continued good health.

The Gulf is a marine ecosystem defined by currents and tides, nutrient cycles, and the migration of marine animals; it pays no heed to political boundaries separating states, provinces, or nations. The living marine resources of the ecosystem may spend part of their lives in coastal waters and part in offshore waters, part in Canadian waters and part in the waters of the United States; many species of fish, marine mammals, and birds lead transboundary lives. It is important to remember that environmental damage in one part of the Gulf can be felt in another and that a series of seemingly negligible effects can be of major harmful consequence in sum.

This report was compiled to illustrate that the Gulf supports diverse, and sometimes conflicting, uses; that it is an ecosystem that is best managed using ecological principles which do not "see" political boundaries; that the sustained use of the Gulf's resources, not only by present but by future generations, will depend upon wise stewardship of the Gulf environment; that cooperative effort on the part of the bordering States and Provinces will be required to protect the Gulf; and that prevention of degradation is less costly, more efficient, and more effective than remedial programs.

The Gulf of Maine is of great worth not only to the people of the Gulf region who depend upon it for economic, aesthetic, and recreational value, but also to the many others from outside the region who enjoy or profit from its resources. Among the most productive bodies of water on earth, the Gulf has nourished a thriving maritime heritage for several centuries.

The growth of the human population and consequent development in the Gulf region have resulted in a series of insults to the Gulf environment. Tons of raw and partially treated sewage are discharged into the Gulf each day. Industrial discharges and urban and agricultural runoff all introduce toxic contaminants and bacteria to marine and estuarine waters on a chronic, and at times acute, basis. Increased fishing effort has reduced fish stocks to all time lows. Coastal development has encroached on environmentally significant marine wetlands. Accidental spills of oil and other toxic material place additional stresses upon the Gulf environment.

Evidence of these stresses can be found throughout the Gulf. Although limited data exist to assess adequately the environmental quality trends in the Gulf of Maine, the warning signs of degradation are clear in research conducted during the last decade:

— highly industrialized harbors such as Boston and Saint John are seriously degraded; it is unlikely that such places will ever regain all of their natural functions;
— relatively undeveloped embayments, such as Penobscot Bay, exhibit elevated levels of contaminants in sediments;
— sediments in the deep basins of the offshore Gulf of Maine contain low but unnatural concentrations of toxins, indicating that contaminants are being transported throughout the Gulf.

Peter Ralston/Island Institute

While the effects of such stresses are not fully documented, natural processes in the Gulf are clearly being affected:

— certain fish and shellfish exhibit liver lesions, fin rot, and other signs of environmental stress;
— the right whale, piping plover, and other species of wildlife are endangered or declining;
— populations of some commercially valuable fish species depend upon an increasingly limited number of year classes, and some may not be reproducing themselves at all;
— health advisories have been issued in several nearshore regions of the Gulf to protect the public from the hazards associated with swimming in contaminated waters and eating contaminated seafood.

Impacts in the Gulf are not just ecological; coastal economies are affected by environmental degradation in the Gulf:

— the Gulf's fishing economy is in precarious condition because of declining fish stocks;
— several hundred thousands of acres of productive shellfish habitat are closed to harvesting due to sewage contamination, resulting in serious loss of livelihood;
— the public's increasing concern regarding contaminated seafood may be driving down the price of fish and shellfish;
— loss of traditional harvesting jobs has affected the character and economies of coastal communities whose fundamental heritage is maritime.

Of greatest importance for the future is the knowledge that the Gulf of Maine can be protected. While warning signs of environmental deterioration are evident, much of the Gulf remains healthy. Preventive action, however, will be required to maintain the environmental quality of the Gulf, as well as to reverse all trends toward degradation noted in this report. Now is the time to explore opportunities to ensure the continued viability of the Gulf and its many uses.

The Gulf of Maine must be managed as an ecosystem rather than as a series of political jurisdictions. A cooperative environmental strategy is required to direct a Gulf-wide monitoring effort, to provide for pollution abatement and control, and to promote the sustainable use of living resources.

A broad-based understanding of the ecological and economic values of the Gulf is essential for the improved stewardship of the Gulf. A public education effort, including public participation programs, curriculum supplements, films, and educational literature, will impart a greater sense of environmental responsibility among the public and generate support for environmental planning.

Effective management of the Gulf will require ongoing cooperative research on the structure and function of the Gulf ecosystem, as well as on the effects of pollution, habitat loss, and other stresses.

This report is a first step in a multilateral endeavor to improve environmental management of the Gulf. While provincial, state, and federal governments are taking this first step, the assistance of industries, municipalities, conservation groups, and individual citizens will be required if this initiative is to be successful. An unparalleled opportunity still exists to preserve and enhance the Gulf of Maine and its many uses: now is the time to work together to protect this invaluable resource.

# Acknowledgments

THE MEMBERS OF THE Gulf of Maine Working Group who participated in the development of this report include Jerry Choate, New Brunswick Department of the Environment; Barry Jones, New Brunswick Department of Fisheries and Aquaculture; Peter Underwood, Nova Scotia Department of Fisheries; Creighton Brisco, Nova Scotia Department of the Environment; Wayne Barchard, Environment Canada; Brian Nicholls, Fisheries and Oceans Canada; Patricia Hughes, Massachusetts Coastal Zone Management Program; David Hartman, New Hampshire Office of State Planning; James Bernard and David Keeley, Maine State Planning Office; John Pearce and Chris Mantzaris, U.S. Department of Commerce, National Marine Fisheries Service; Rosemary Monahan, Carol Kilbride, and Bart Hague, U.S. Environmental Protection Agency.

Patricia Hughes, Massachusetts Coastal Zone Management Program and Carol Shaw and Peter Stevick, Maine State Planning Office helped research and write this report.

The following people are recognized for their assistance in compiling this report: Brian Marcotte, Robert Lewis and Phil Averill, Maine Department of Marine Resources; Steve Ackelson and Peter Larsen, Bigelow Laboratory for Ocean Sciences; John Sowles, Lee Doggett, and Fred Brann, Maine Department of Environmental Protection; John and Matthew Gleason, Wolf Neck Partnership; Martin S. Hayden, Hayden and Furber; Patience Whitten, U.S. Environmental Protection Agency; Stephanie D'Agostino, New Hampshire Office of State Planning; David Pierce and Leigh Bridges, Massachusetts Division of Marine Fisheries; Chris Kellogg and Lou Goodreau, New England Fishery Management Council; Ronnee Schultz, Bruce Higgins, and Ron Smolowitz, U.S. Department of Commerce, National Marine Fisheries Service; Chris Cooper, J. M. Brewers, and John Kershaw, Fisheries and Oceans Canada; Steve Dickson, Maine Department of Conservation; John Elliott, Canadian Wildlife Service; Andre d'Entremont, Peter Eaton, Larry Hildebrandt, David Wilson, Peter Johnson, Amar Menon, Peter Wells, and Alan McIver, Environment Canada; Russell Belmer and Terrence Fleming, U.S. Army Corps of Engineers; Peter Ricketts and Simeon Roberts, Dalhousie University; Robert Elder, Maine Department of Transportation; Peter Clark, Saint John Port Authority; Dan Belnap, University of Maine; Catherine Enright, Nova Scotia Department of Fisheries; Lt. Susan Woodruff, U.S. Coast Guard; Cliff Sinnott, Rockingham Regional Planning Commission; Dan Farrow, National Oceanic and Atmospheric Administration; Matthew Eddy, Greater Portland Council of Governments; John Nelson, New Hampshire Fish and Game Department; and the Island Institue.

Aline LaChance and Lorraine Lessard, Maine State Planning Office, and Tatiana Bernard provided clerical and editing assistance. Drawings adapted by Michelle Griggs. Maps by Richard Kelly.

Report design by Michael Mahan Graphics, Bath, Maine.

Financial assistance for preparation of this document was provided through the U.S. Department of Commerce, Office of Ocean and Coastal Resource Management, by a grant under the Coastal Zone Management Act of 1972, as amended.

# *Preface*

RECOGNIZING THAT THE Gulf of Maine is a common resource of inestimable value to their residents, the Provinces of Nova Scotia and New Brunswick, the States of Maine and New Hampshire, and the Commonwealth of Massachusetts have joined together in a cooperative effort to protect the ecological integrity of the Gulf of Maine and the many uses that depend upon its continued good health.

This report was compiled to illustrate that the Gulf supports diverse and sometimes conflicting uses; that it is an ecosystem that must be managed using ecological principles which "see" no political boundaries; that the sustained use of the Gulf's resources, not only by ourselves but by future generations, will depend upon our wise stewardship of the Gulf environment; that cooperative effort on the part of the bordering states and provinces will be required; and that prevention of further degradation will be much less costly, more efficient, and more effective than remedial programs.

This report is a first step in a multilateral effort to improve environmental management of the Gulf. While provincial and state governments are taking this first step, the assistance of industries, municipalities, conservation groups, and individual citizens will be required if this initiative is to be a success. An unparalleled opportunity still exists to preserve and enhance the Gulf of Maine and its many uses: now is the time to join together in protecting this invaluable resource.


NIGHTOWL
NIGHTOWL

# Introduction

Peter Ralston/Island Institute

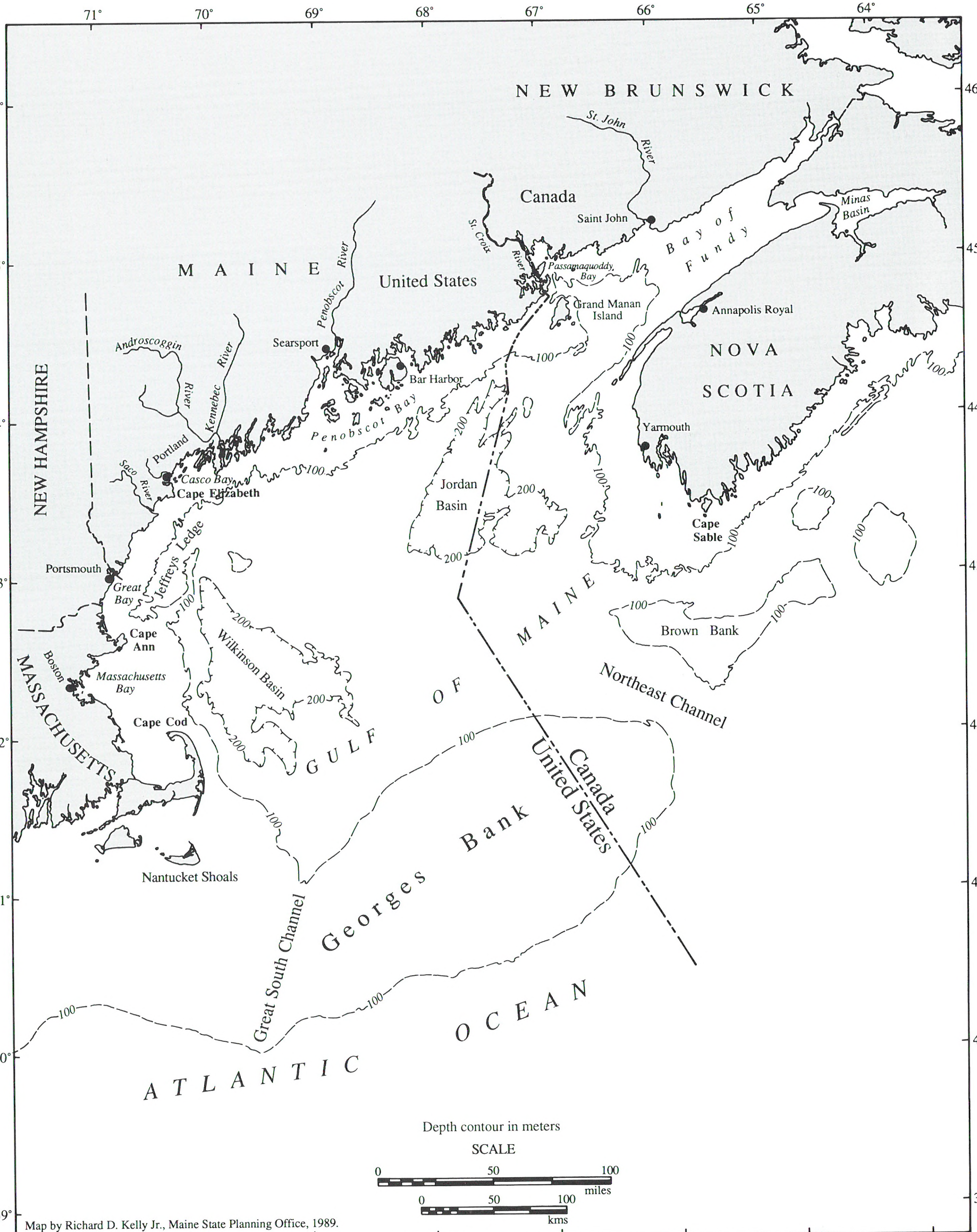
WHAT IS THE GULF of Maine? It is many things: a semi–enclosed sea, almost entirely cut off from the northwestern Atlantic ocean by underwater banks; a marine ecosystem, comprised of a complex web of nutrient cycles, food chains, and energy flows; a source of economic livelihood for many, from fishing to tourism; and a bond between Canadians and Americans, whose common dependence upon it is the basis for a rich and longstanding maritime heritage.

The Gulf of Maine is a resource of unparalleled value for all who border its shores. Its living resources, among the most productive in the world, supported native North Americans and, later, European settlers. Until they were restricted in the 1970s, foreign fishing fleets came from across the world to harvest the abundant supply of fish from Gulf waters. From trawling with highly sophisticated technology to digging clams with a rake, fishing directly supports thousands of the region's inhabitants while fish processing, shipping, selling, and fish preparation supports many hundreds of thousands more.

While fisheries remain the backbone of economic activity in the Gulf, newer, non-consumptive uses of the Gulf's resources are fast growing. Sailing, whale watching, and simply walking on the beach are among the many activities that now attract millions from near and far to the shores of the Gulf, supporting a burgeoning tourist economy in the Gulf region. Aquaculture, the farming of fish and shellfish, has also demonstrated its economic potential in the Gulf, where clean and rich waters provide an ideal environment for the husbandry of marine creatures.

But the Gulf is worth much more to us than its value in economic terms. Millions are attracted to its shores to live. Recreational opportunities, diverse and beautiful scenery, open space, abundant wildlife, and the sense of a wilderness relatively untrammelled by man all add to the exceptional quality of life experienced by residents, whether they live on the shore or not. The vitality of the Gulf environment is reflected in our own lives; we are enriched by the successful migration of a salmon, the dance of sunlight on the sea, and the grace of a shearwater as it skims the waves.

Today, evidence is accumulating that the health of the Gulf may be at risk. Pollution, habitat destruction, and overuse of resources pose threats to the ecological integrity of the Gulf, once thought to be immune from degradation. Trace amounts of toxic contaminants have been detected in the deepest parts of the Gulf; some industrialized harbors exhibit exceptionally high levels of contaminants, and lesions associated with contamination have been found in some fish. Throughout the extent of the Gulf's shoreline, sewage pollution has resulted in the closure of thousand of acres of productive shellfish flats; some swimming beaches have also been closed; commercial fish stocks are at an all time low; and several species of wildlife are endangered due to loss of habitat. Much of the degradation apparent in the Gulf is the cumulative result of a series of events. We cannot point at one oil spill, one industrial


NEW BRUNSWICK
St. John River
Canada
Saint John
St. Croix River
Passamaquoddy Bay
Bay of Fundy
Minas Basin
MAINE
United States
Penobscot River
Grand Manan Island
Annapolis Royal
NOVA SCOTIA
Searsport
Bar Harbor
Androscoggin River
Kennebec River
Penobscot Bay
Portland
Saco River
Casco Bay
Cape Elizabeth
NEW HAMPSHIRE
Yarmouth
Jordan Basin
Cape Sable
Portsmouth
Great Bay
Jeffreys Ledge
Cape Ann
Wilkinson Basin
GULF OF MAINE
Brown Bank
Northeast Channel
Boston
Massachusetts Bay
MASSACHUSETTS
Cape Cod
Canada
United States
Nantucket Shoals
Georges Bank
Great South Channel
ATLANTIC OCEAN
100
200
Depth contour in meters
SCALE
0 50 100 miles
0 50 100 kms
Map by Richard D. Kelly Jr., Maine State Planning Office, 1989.
71° 70° 69° 68° 67° 66° 65° 64°
46° 45° 44° 43° 42° 41° 40° 39°

**For the purposes of this report the Gulf of Maine is broadly defined and considered to include the Bay of Fundy to the north and Georges Bank to the south, as well as the Gulf proper. This corner of the ocean is often referred to as a "sea within a sea", because its waters are separated from the Atlantic Ocean by the submerged plateaus of Georges Bank and Browns Bank and are isolated by temperature and salinity differences from the rest of the Atlantic. For the majority of its perimeter the Gulf is surrounded by land — three New England states and two Maritime provinces.**

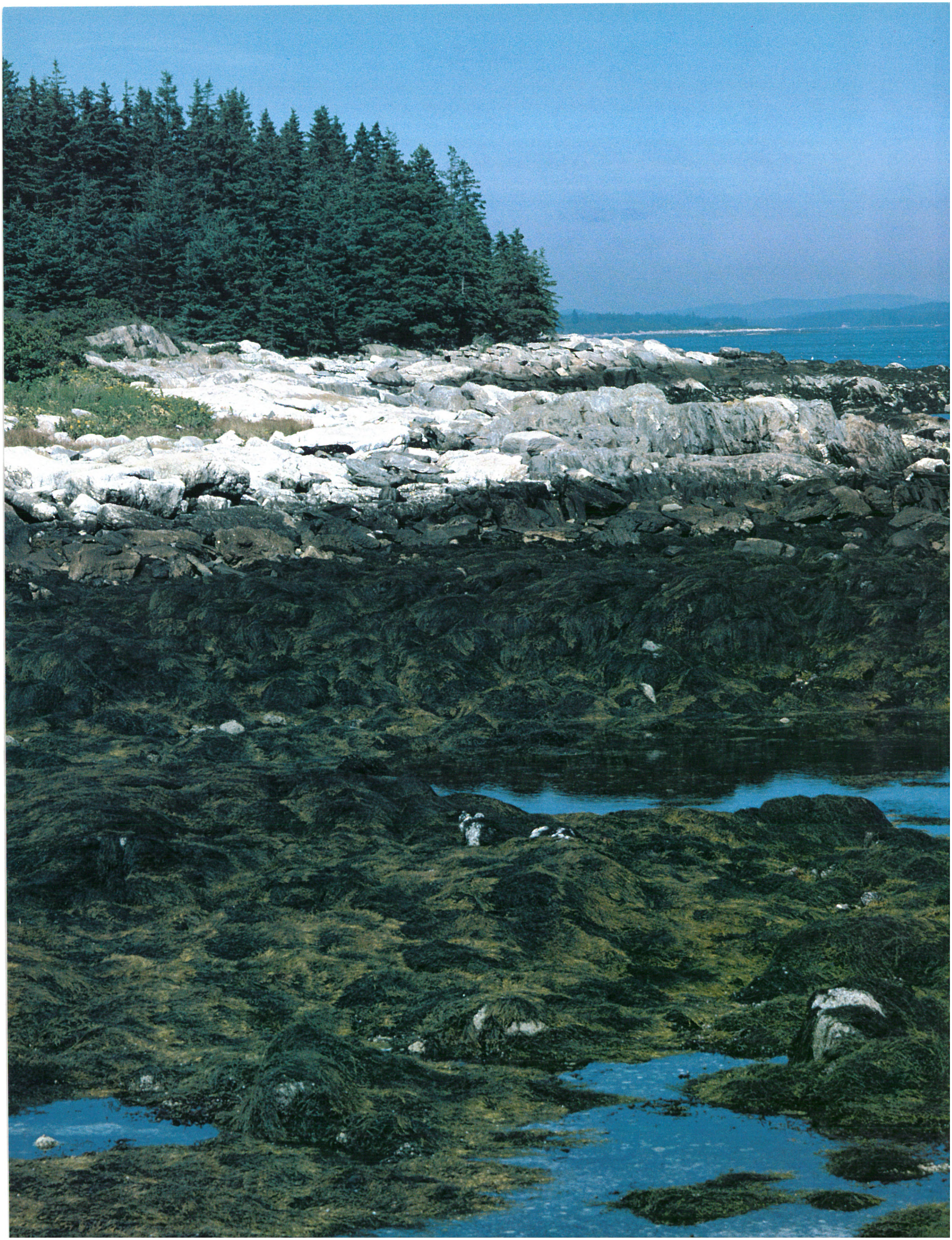
discharge, or one development project to explain this evidence of environmental harm. While the loss of one wetland may have a negligible impact on the whole system, the cumulative impact of extensive wetland loss, which has occurred and continues to occur in the Gulf region, can have a deleterious effect on the functioning of the entire ecosystem. While there is insufficient data to assess the overall threat to the Gulf, a disturbing pattern is emerging: as more people crowd the shores of the Gulf, more degradation appears to be occurring. The evidence noted above must be taken as an early warning sign: now is the time to act to preserve and protect the Gulf and the important role it plays in our lives.

Many think of the sea as an independent environment unaffected by the land, but in fact, the Gulf and the land that surrounds it are closely linked. The cycle, in which water is evaporated from the surface of the sea, deposited upon the land in the form of snow or rain, and carried back again to the ocean, links land and sea. Water returning to the sea carries with it a load of sediment, organic matter, and nutrients. Productivity in the Gulf is greatly enhanced by this introduction of terrestrial nutrients. However, it is the same returning water that carries life-giving nutrients that also frequently ushers in a host of damaging contaminants and wastes generated by human activities. Thus, the health of the Gulf is closely tied to the terrestrial environment that surrounds it on three sides - especially to the activities of those who live and work on its shore. As the population of the Gulf region grows, greater and greater demands are placed upon the Gulf's ecosystem: development activities alter or destroy natural habitats and processes, more sewage and industrial waste are generated, and more resources are harvested. Ironically, as we are drawn to the natural resources of the Gulf and become dependent upon them, we simultaneously threaten the Gulf's continued viability.

The Gulf is a marine ecosystem defined by currents and tides, nutrient cycles, and the migration of marine animals; its natural processes pay no heed to political boundaries that separate states, provinces, or nations. Many species of fish, marine mammals, and birds inhabiting the Gulf region lead transboundary lives, spending part of their life cycle in coastal waters and part in offshore waters, part in Canadian waters and part in the waters of the United States. Even sedentary species such as clams and barnacles rely on currents that circulate in the Gulf to ensure the dispersion of their young. Threats to the Gulf environment also ignore political boundaries; contaminants move with winds and waters regardless of political jurisdictions. The loss of a particular habitat can affect the Gulf-wide occurrence of a species that relies upon it. It is important to remember that environmental damage in one part of the Gulf can be felt in another and that a series of seemingly negligible effects can be of major harmful consequence in sum.

The continued health and increased use of the Gulf's resources requires us to manage it as a marine ecosystem, not as a number of separate and competing entities. The Gulf cannot be successfully utilized and protected on a piecemeal basis. We share the responsibility for sustaining the bounty of the Gulf's resources now and for future generations.

How is that responsibility discharged? It requires sincere commitment of governments, industries, citizens — in short, all of us. The effort will demand change, in some cases major adaptation, but none greater than facing the impact of serious environmental degradation that would result if present trends are allowed to continue. Changes will occur as a result of choices - choices that we make in our everyday lives, choices about how we use our natural resources and how we dispose of our wastes. As we commit ourselves to assessing our role in the use and degradation of the Gulf, we will begin to understand our responsibility for its wise stewardship and protection.



CHAPTER ONE

# The Gulf as an Ecosystem

THE GULF OF MAINE ecosystem is made up of a diversity of marine habitats tied together by ocean currents circling the waterbody. The combined productivity of seaweeds, salt marsh grasses, and phytoplankton is as great as any comparable area in the world, and provides the foundation of the Gulf's biological abundance.

Maine Critical Areas Program

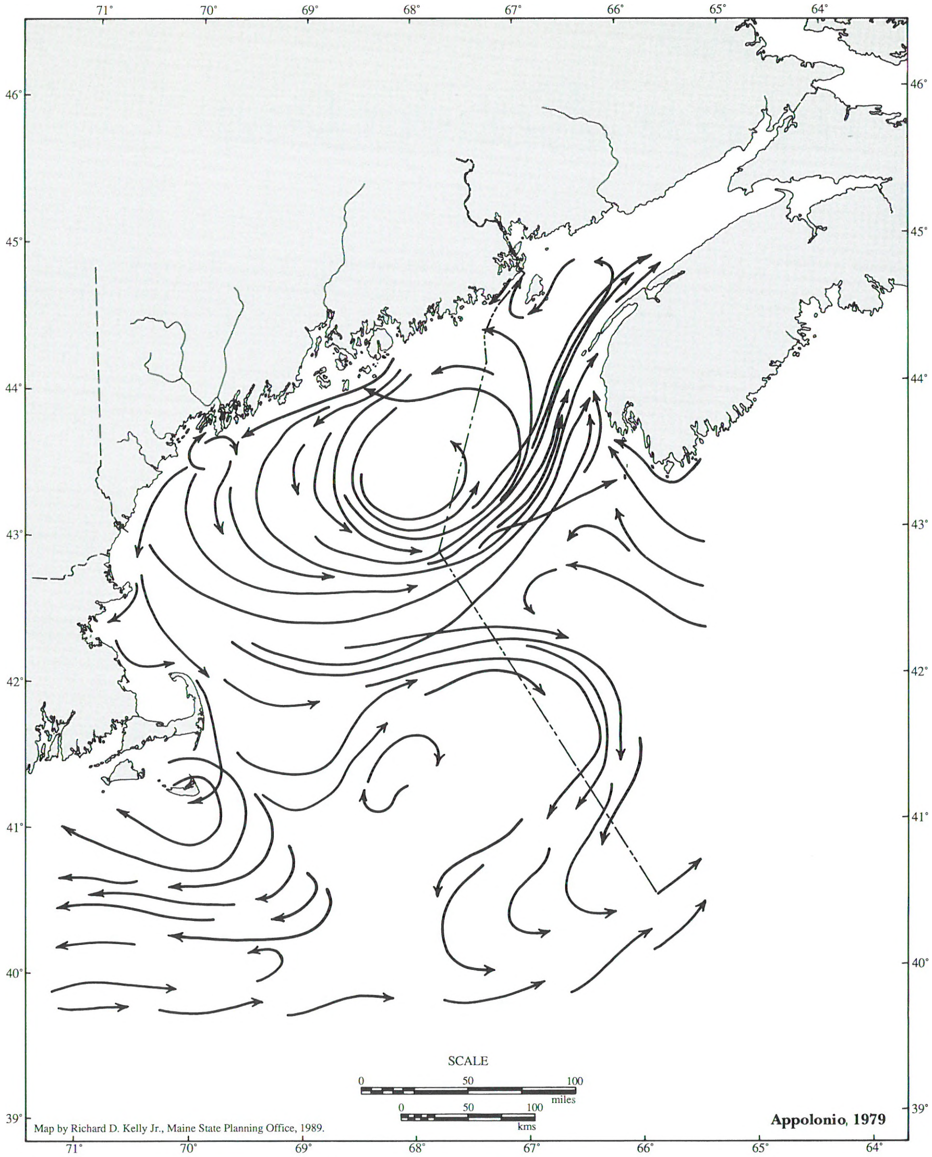
## GEOLOGIC HISTORY

Fifteen million years ago the area where the Gulf of Maine is now located was a gently sloping, submerged platform similar to the continental shelf off the mid-Atlantic states today. Later, the region was exposed as dry land and eroded by streams, which carved out the basin that eventually became the Gulf and created the deep incision that is now the Northeast Channel. Glaciers covered the region during the last one to two million years, further scouring out the Gulf of Maine basin and depositing outwash to form Georges Bank.

When the last of the glacial ice retreated about 13,000 years ago, sea level was much lower than at present. Georges Bank was exposed as dry land, first as a cape extending from the mainland and then as an island. Georges Bank and the depressed mainland were flooded when the glaciers melted and retreated to the north. About 12,500 years ago, the site of what is now Portland, Maine was under at least 160 feet (50 meters) of water and the sea reached as far as 60 miles (100 kilometers) inland from the present coastline. Since then, sea level has fallen, but is now rising again at a rate of about one foot (30 centimeters) a century.

Today, water depths in the region vary from 1,237 feet (377 meters) in the deepest basin of the Gulf to 761 feet (232 meters) in the Northeast Channel, to as shallow 13 feet (4 meters) on the crest of Georges Bank. Between these extremes, the seabed is characterized by a diverse collection of ridges, banks, gorges, and deeps, and is covered by sediments varying from bedrock to sand, gravel, shell, and mud.

The coastline of the Gulf of Maine reflects the geologic history of the region - smooth and beach-lined or indented and rockbound, depending on the hardness and texture of the bedrock, where the glaciers deposited their loads of sediments, and how the sediments have since been reworked. The southern coast of the Gulf of Maine, between Cape Cod, Massachusetts, and Cape Elizabeth, Maine is characterized by long sandy beaches, soft cliffs and bluffs, and an occasional rocky headland. There are numerous barrier beaches protecting extensive salt marshes lying behind them.




**Water Circulation on the Gulf of Maine**

*Some water breaks away from the counter clockwise Gulf of Maine gyre off the western tip of Nova Scotia and flows into the Bay of Fundy. Water flows back into the Gulf on the Bay's northern edge. Water also breaks off the Gulf current on its southern edge to join the current circling Georges Bank. Water that does not complete the circuit around Georges Bank spills off into the Northeast Channel or flows south to the mid-Atlantic.*

**Annual Production Estimates for Various Shelf Ecosystems**

| Trophic Level | Mid- Atlantic Bight | Georges Bank | Gulf of Maine | Scotian Shelf | North Sea | Bering Sea |
|---|---|---|---|---|---|---|
| *Primary Production* | 3,103 | 3,342 | 2,566 | 2,280 | 2,280 | 1,824 |
| *Zooplankton* | 357 | 487 | 574 | 411 | 400 | 307 |
| *Benthos* | 210 | 111 | 98 | 82 | 125 | 149 |
| *Fish and Squid Early 1960s* | 32 | 86 | 32 | 34 | 27 | |
| *Early 1970s* | 25 | 52 | 26 | 21 | 24 | 61 |

(kcal/m²)

Sherman et al, 1988

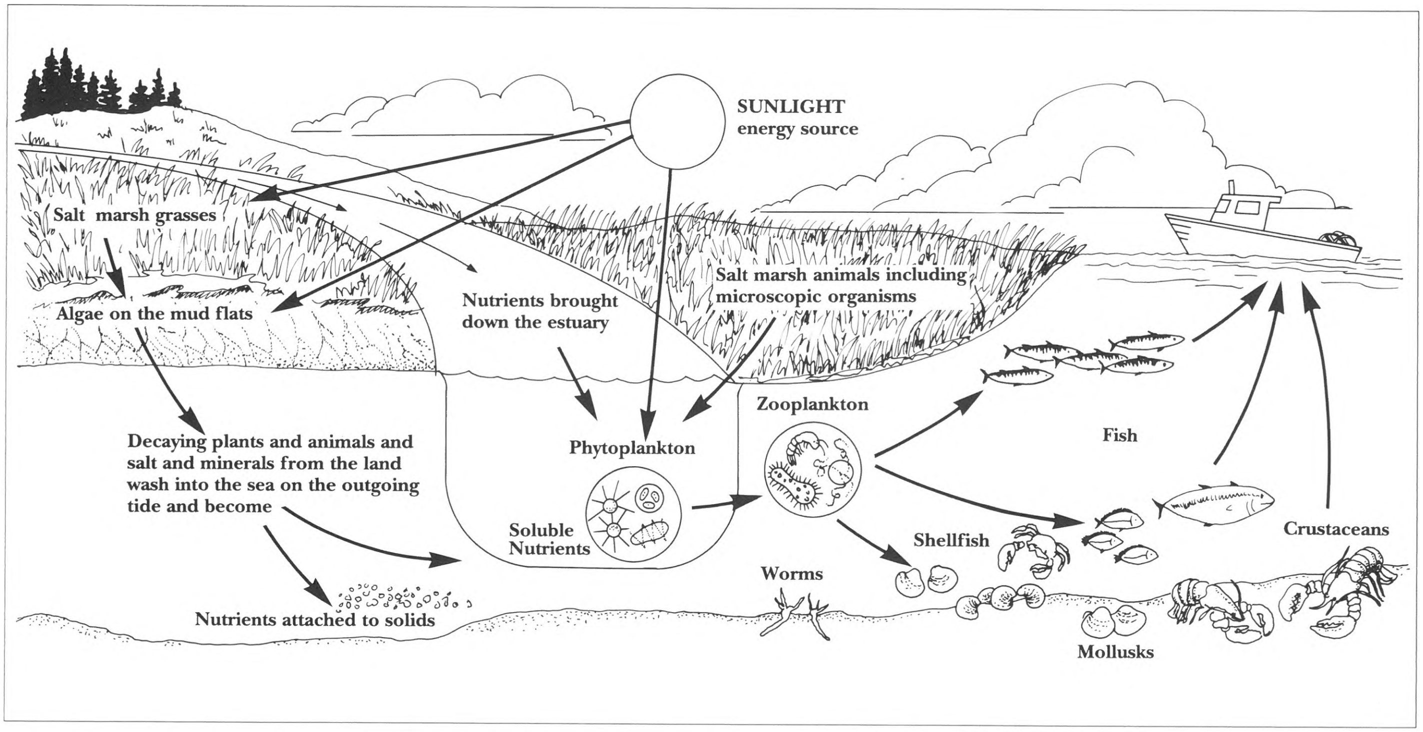
Between Cape Elizabeth and Passamaquoddy Bay at the mouth of the Bay of Fundy is an extraordinarily rugged, indented, rockbound stretch of coast. In the many bays, coves, and inlets are thousands of islands and ledges. Much of this coast lacks the sediment necessary for sand beaches or salt marshes to develop because the exposed bedrock is primarily granite and erodes very slowly. Often referred to as a drowned coastline, the present-day shoreline evolved when rising sea levels flooded prehistoric river valleys.

The Bay of Fundy was shaped primarily by faulting and subsequent erosion by the glaciers. It is known for its extreme tidal range which can be up to 50 feet (15 meters). The shoreline of the Bay is characterized by red sandstone cliffs and hard volcanic rocks. Swift tidal currents erode the softer headlands, providing sediments to the floor of the Bay and the immense mudflats that occur in some places.

## Oceanography

Two currents dominate water circulation in the Gulf of Maine region: a counter clockwise gyre in the Gulf and an adjacent clockwise gyre over Georges Bank. Several factors contribute to the Gulf of Maine gyre. These include the spring runoff from the region's rivers, daily tides, inflow around southwest Nova Scotia of water originating in the Gulf of Saint

**Estuaries are a critical source of nutrients for the Gulf of Maine ecosystem.**




Lawrence, and inflow of dense deep water through the Northeast Channel. It takes about three months for water to circulate around the periphery of the Gulf. These circling currents tie together all the parts of the Gulf ecosystem.

Across the Gulf there are enormous variations in temperature, salinity, density, and nutrient content of the water, depending on location, time of year, and water depth. Nutrients tend to become trapped in deeper waters. Where tides, currents, and bottom topography combine to induce mixing of bottom and surface waters, biological productivity is highest. In estuaries and certain offshore areas, usually near underwater banks, vertical upwelling brings cold, salty, nutrient-enriched bottom water to the surface. Offshore areas known to be strongly affected by vertical mixing include the area off the southwestern coast of Nova Scotia between Cape Sable and Yarmouth, and off the Maine coast from Grand Manan Island south as far as Matinicus Island. Deep water from the Gulf of Maine, pushed onto Georges Bank, is a source of nutrients for the highly productive Bank. Many estuaries are doubly enriched; rivers carry nutrients washed off the land downstream to their mouths, where they mix with upwelling deep ocean water.

The primary producers that are the foundation of the Gulf of Maine's biological abundance include single-celled plants, called phytoplankton, and macroalgae, or seaweed. In spring and summer, when nutrients abound in sunlit waters, phytoplankton bloom in huge numbers. In the offshore waters of the Gulf, the areas of highest productivity occur over the central portion of Georges Bank, with the lowest levels of productivity found in the deep waters of the Gulf of Maine and along the southern edge of Georges Bank. In comparison with other shelf ecosystems, all of the Gulf of Maine region has high primary productivity levels.

Seasonal phytoplankton blooms are followed by population explosions of zooplankton, microscopic animals that graze on the phytoplankton. The dominant component of the zooplankton community are copepods, the principal food for larval fish. This cycle forms the base of the flourishing food chain that sustains the fish, marine mammals, and birds of the Gulf.

## HABITATS OF THE GULF

Variations in tidal energy, nutrient availability, ocean currents, and sediment type combine to produce the composite of habitats that is the Gulf ecosystem.

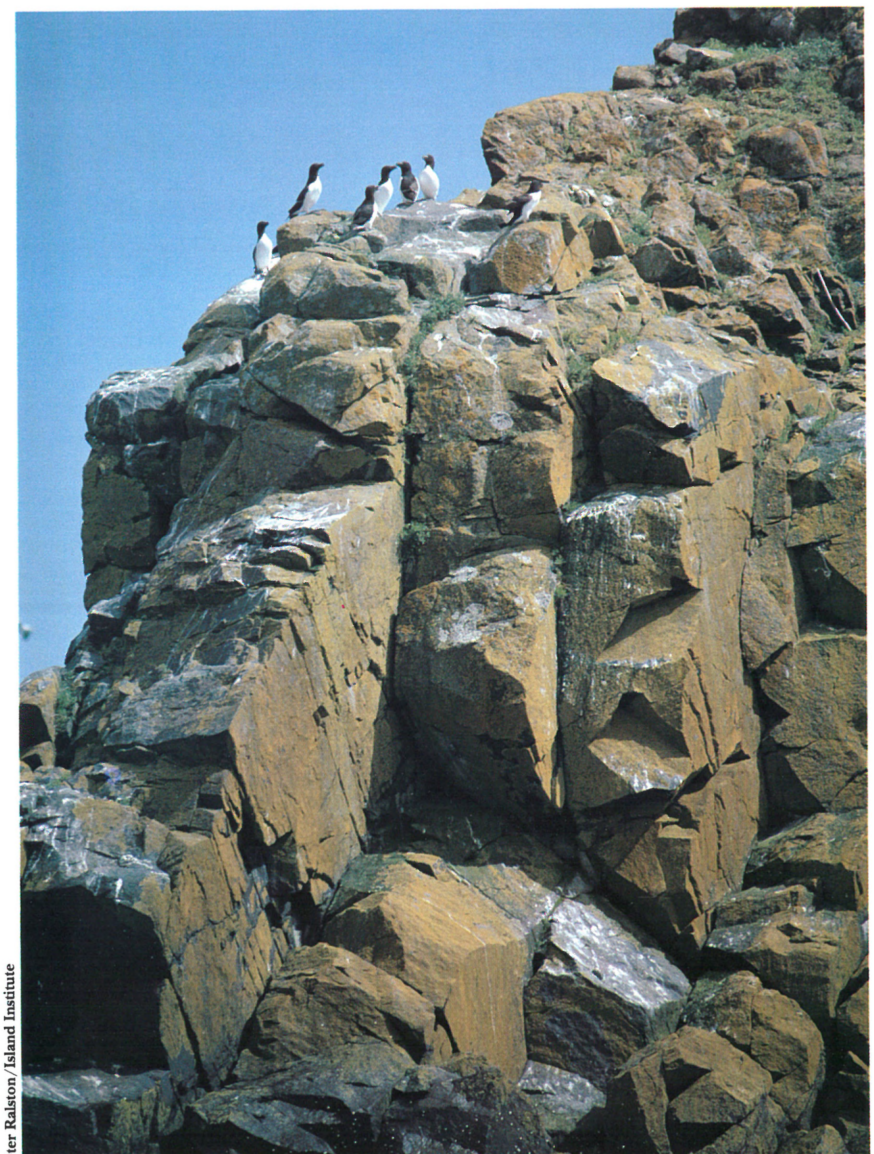
Estuaries, where fresh river water mixes with the salty ocean, are exceedingly productive habitats, serving as an important link in the Gulf ecosystem. Seasonal phytoplankton blooms make estuaries a desirable nursery for the planktonic larvae of many benthic invertebrates such as worms, mollusks, and crustaceans, as well as for juvenile fish. The region's estuaries are thought to be vital at some life stage to about 70% of the fish species of commercial interest along the Gulf coast.

Salt marshes and tidal flats are characteristic features of the region's bays and estuaries. Mud flats occur in shallow and protected waters, and develop by deposition of fine sediments. Where flats are shallow enough in slope for emergent plants to grow, the upper portions develop into a salt marsh. Wetland plants provide food and cover for both marine and terrestrial organisms, trap sediments and anchor substrate, and add nutrients to

**Rocky intertidal shores are one of the most characteristic features of the Gulf shoreline, and comprise an expansive habitat because of the region's large tidal range.**


Maine Critical Areas Program

*Humpback whale near Jeffereys Ledge.*


Peter Ralston/Island Institute

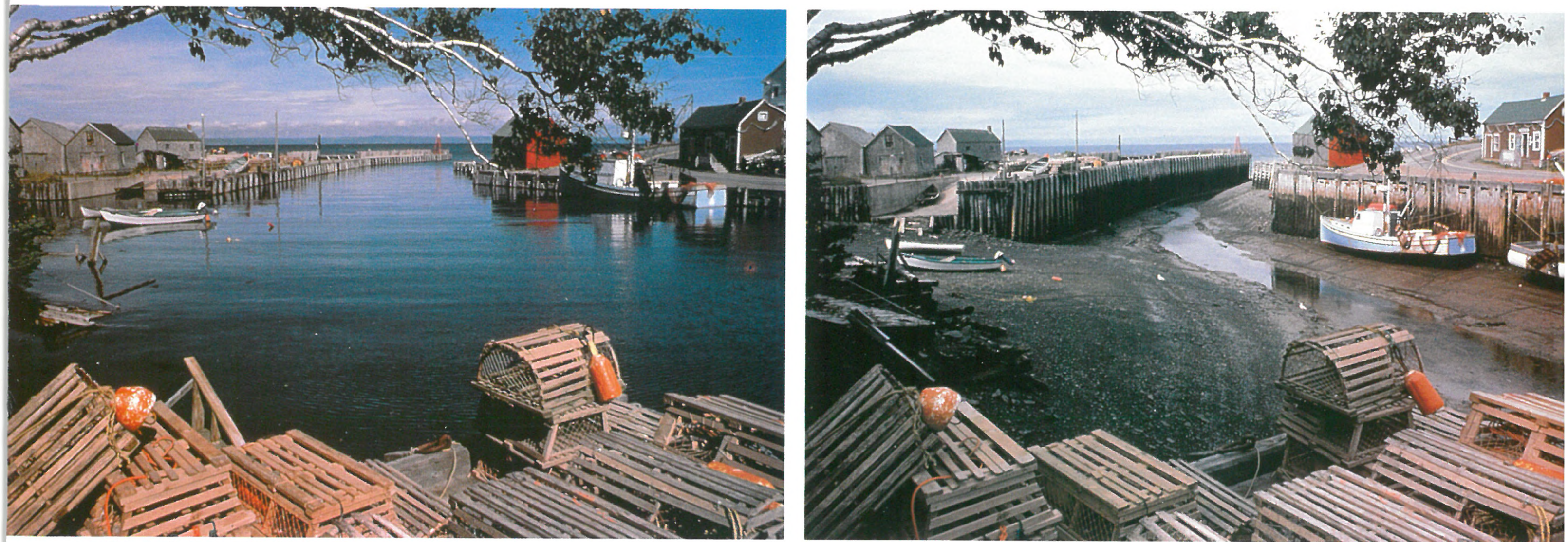
*Razorbill auks on Old Man Island off Cutler, Maine*

the system through decomposition. Small invertebrates live in the mud and creeks of salt marshes and are consumed by fish, crustaceans, and breeding and migrating birds. Terrestrial mammals such as raccoons, foxes, and mink also feed in or near salt marshes and exposed tidal flats.

The non-estuarine habitats of the nearshore Gulf of Maine - beaches, rocky intertidal shores, nearshore subtidal areas, islands, and offshore areas also play important roles in sustaining the ecosystem.

Rocky intertidal shores are one of the most characteristic features of the Gulf shoreline, and comprise an expansive habitat because of the region's large tidal range. Like beaches, they are usually high energy environments that only certain organisms can tolerate. The plants and animals that live on rocky shores, including rockweed, barnacles, periwinkles, and mussels, have adapted means of adhering to hard surfaces. Other animals survive by living in crevices and tide pools.

The Gulf shoreline includes a great number and variety of beaches - sand, gravel, cobble, and boulder. Animals that live on beaches are adapted to a constantly shifting world. Microorganisms and tiny invertebrates living between sand grains and a burrowing crustacean are the dominant organisms of the region's sand beaches. Surf clams are one of the few larger



Fisheries & Oceans Canada

*Tidal extremes at Halls Harbour, Nova Scotia in the Bay of Fundy.*

organisms making their home on the subtidal portions of sand beaches. Razor clams and quahogs are common in the sandier flats, while soft shelled clams and marine worms can be found in mudflats. Many shore birds are especially well adapted to capturing the small animals living on beaches and flats.

More than 3,000 islands dot the periphery of the Gulf of Maine. Sandy barrier islands are common in Massachusetts, such as Monomoy, off Cape Cod, and Plum Island, north of Cape Ann. However, the vast majority are rocky outcrops of varying sizes, many located along the Maine coast. Islands support a multitude of nesting seabirds, seals, and shellfish. Due to geographic isolation, islands often have unique vegetative communities and rare plant species.

The shallow marine subtidal habitat contributes to the productivity of the Gulf ecosystem in several ways. It is home to a variety of macroalgae, including kelp and eel grass; their distribution is dependent on bottom substrate and penetration of sunlight. Marine organisms find food and protection in these seaweed beds. Organisms common to the subtidal habitat of the Gulf include sea urchins, starfish, and sand dollars - favorite finds of people exploring tidepools. Sea scallops, winter flounder, and lobster, all of commercial importance, are found both in nearshore subtidal areas, as well as along the bottom of offshore waters. Some animals migrate inshore in summer to reproduce in the relatively rich and temperate waters of the shallow subtidal area. Others, such as shrimp, migrate inshore in the winter to reproduce.

The abundance of commercially valuable fish has made the offshore habitat of the Gulf of Maine famous on both sides of the Atlantic. Productive waters over submerged offshore banks sustain a variety of marine life - benthic invertebrates, fish, marine mammals, and birds.

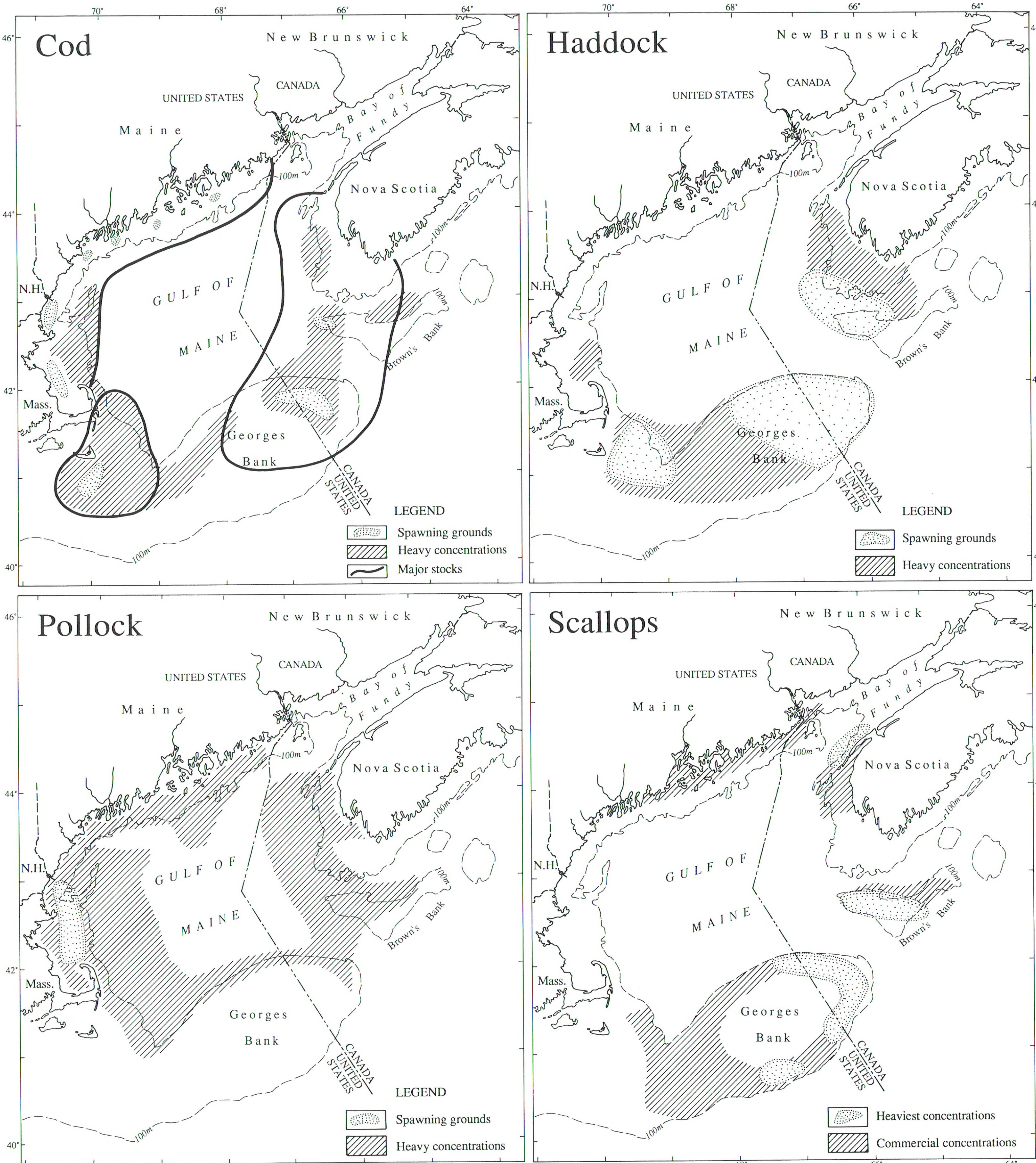
## Fish

The Gulf of Maine region supports hundreds of species of fish and shellfish. The fish can be described as one of two types: pelagic, or those that live in the water column, or demersal, those that live on or near the seabed. The more common pelagic fish of the Gulf region include sharks, herring, menhaden, capelin, mackerel, bluefin tuna, swordfish, and bluefish. Most of the pelagic fish have definite seasonal movements, usually in response to changing water temperature. Some move between inshore and offshore, others migrate north to the Gulf region as the water warms each summer.

Demersal fish, often called groundfish, include cod, haddock, hake, pollock, whiting, and cusk, as well as the flatfish, including halibut and the flounders. The distribution of demersal fish is affected more by the substrate of the bottom than by changes in temperature. Some of these fish are found exclusively on the bottom, feeding on benthic organisms, while others are found both along the bottom and in the water column. Other demersal organisms of commercial value include northern shrimp, squid, lobsters, crab, and sea scallops.

Some general observations can be made about the spatial distribution of fish across the Gulf region. In the inshore Gulf, cod, haddock, blackback flounder, and other flounders are predominant. In the deep water Gulf, the principal species are American plaice, witch flounder, redfish, white hake, and cusk. In central Georges Bank, cod, haddock, blackback and yellowtail flounders, and pollock are dominant. On the Northeast Peak of Georges Bank, sea scallops are dominant, with seasonal abundances of groundfish such as cod and haddock. Some fish stocks undertake seasonal movements, crossing the boundary between the United States and Canada.

Sea herring and menhaden are seasonally abundant throughout the Gulf region, particularly in nearshore waters. Spawning stocks of herring occur off southwest Nova Scotia, along the coast of Maine, and on Jeffreys Ledge and Nantucket Shoals; a rebuilding stock exists on the northern

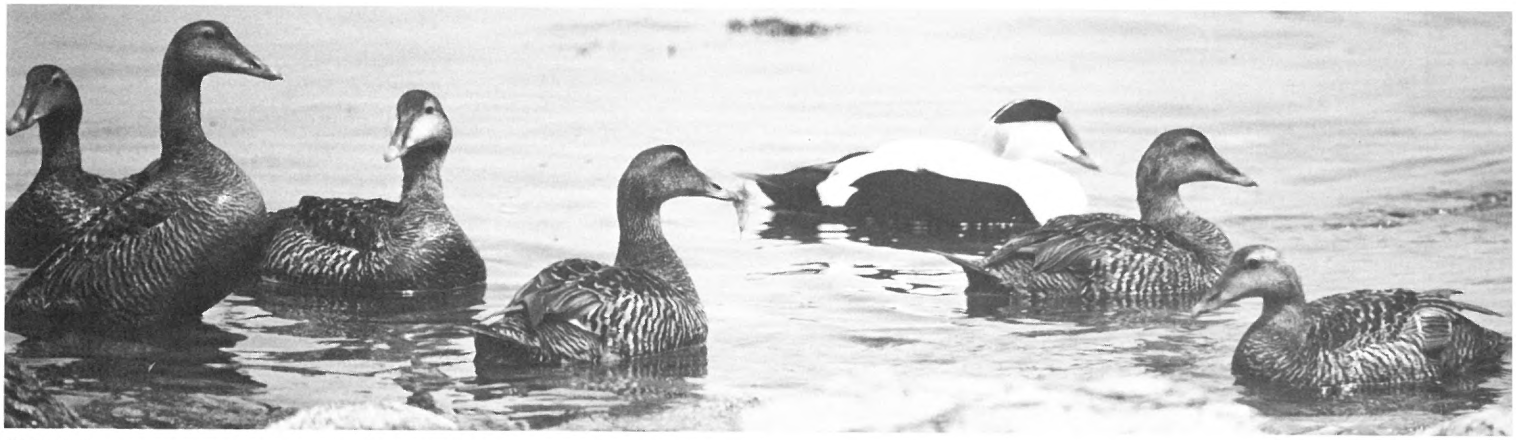



Map by Richard D. Kelly Jr., Maine State Planning Office, 1989.

Source: Maine Department of Marine Resources

*Distribution in the Gulf of Maine of four species of commercial interest. Some stocks of each are concentrated in an area that crosses the international boundary.*

**The Gulf of Maine provides critical habitat for the northern right whale, the most endangered of all the marine mammals found in the region.**



*Eider ducks*

Chris Ayres

edge of Georges Bank. These stocks mix and are found throughout the Gulf region at various times of the year.

## MAMMALS

More than 18 species of marine mammals are present in the Gulf of Maine at some time during the year. Spring is the season of highest abundance for whales, dolphins, and porpoises, coinciding with the period of the greatest annual upwelling in Gulf waters. Georges Bank serves as a major feeding area and nursery, and also as a "refueling" site for some species migrating through to the Gulf of Maine, Bay of Fundy, Scotian Shelf, and other areas. Overall numbers decline in the winter, as many species migrate back to southern breeding grounds, sometimes as far as the West Indies (e.g., humpback whales).

The Gulf of Maine provides critical habitat for the northern right whale, the most endangered of all the marine mammals found in the region. Between April and July, these animals concentrate around Nantucket Shoals and the Great South Channel, west of Georges Bank, and they are found at the mouth of the Bay of Fundy from late summer into the fall. Females winter and give birth to young off the coast of Georgia, but the males' wintering areas are uncertain.

## BIRDS

The varied habitats of the Gulf of Maine are breeding and feeding grounds for a huge abundance and diversity of birds. Shorebirds find food in the mudflats and sand beaches of the Gulf as they migrate between their Arctic breeding grounds and southern areas. Sanderlings, semipalmated sandpipers, short–billed dowitchers, and black-bellied plovers are especially common. The piping plover and least tern are the only shorebirds that nest on the sand beaches of the Gulf.

Great blue herons, osprey, and bald eagles feed and breed in and near the Gulf's estuaries. Herons feed on crustaceans and small fish in the shallows and usually breed in large rookeries on islands or on the edges of swamps or marshes. Osprey feed and hunt in the quiet waters of bays and estuaries, and usually nest nearby. Eagles mate for life and usually nest high in a live tree.

The Gulf's shallow subtidal habitat supplies food for diving ducks, including eiders, buffleheads, goldeneyes, scoters, oldsquaw, and mergansers. Although only eiders breed in the Gulf region, most of these ducks spend all but the breeding season along the shores of the Gulf, feeding on small fish and invertebrates.

All seabirds breed on coastal islands or protected promontories. Some, like puffins, shearwaters, auks, and petrels, live at sea except when breeding. Early settlers and fishermen looking for food, bait, and feathers decimated populations of some seabirds by the end of the 1800s. Seabirds are now protected by law and their populations are recovering.

## CONCLUSION

The Gulf of Maine ecosystem is comprised of a series of interconnected habitats, forming the basis of human economic activity in the Gulf region. People who live on the shores of the Gulf of Maine have long appreciated its biological wealth. Many have nourished themselves and made a livelihood from its bounty. However, the sustained use of the Gulf's resources will require new attention to their management.

CHAPTER TWO

# The Value of the Gulf of Maine

THROUGHOUT HISTORY, the Gulf of Maine has been most widely known and most consistently valued for its fishery resources. As early as 5,000 years ago, prehistoric peoples fished the Gulf in dugout canoes for cod and haddock. European explorers discovered the Gulf's wealth in the 1500s and returned year after year to harvest fish and carry their catch back to Europe. In the last half of this millenium, permanent inhabitants settled near the Gulf, making their livelihood from the wealth of natural resources in the region. As we approach the 21st century, these resources still figure prominently in the lives and economy of Gulf residents.

Peter Ralston/Island Institute

*Salmon aquaculture operation in Eastport, Maine*

## FISHING

The Gulf of Maine supports nearly 20,000 fishermen, fishing approximately 300 Canadian and 1,350 American boats, as well as about 4,000 lobster boats between the two countries. In 1988, landings for the region totaled nearly 1.2 billion pounds (529,000 metric tons), worth approximately $650 million U.S. ($798 million C).

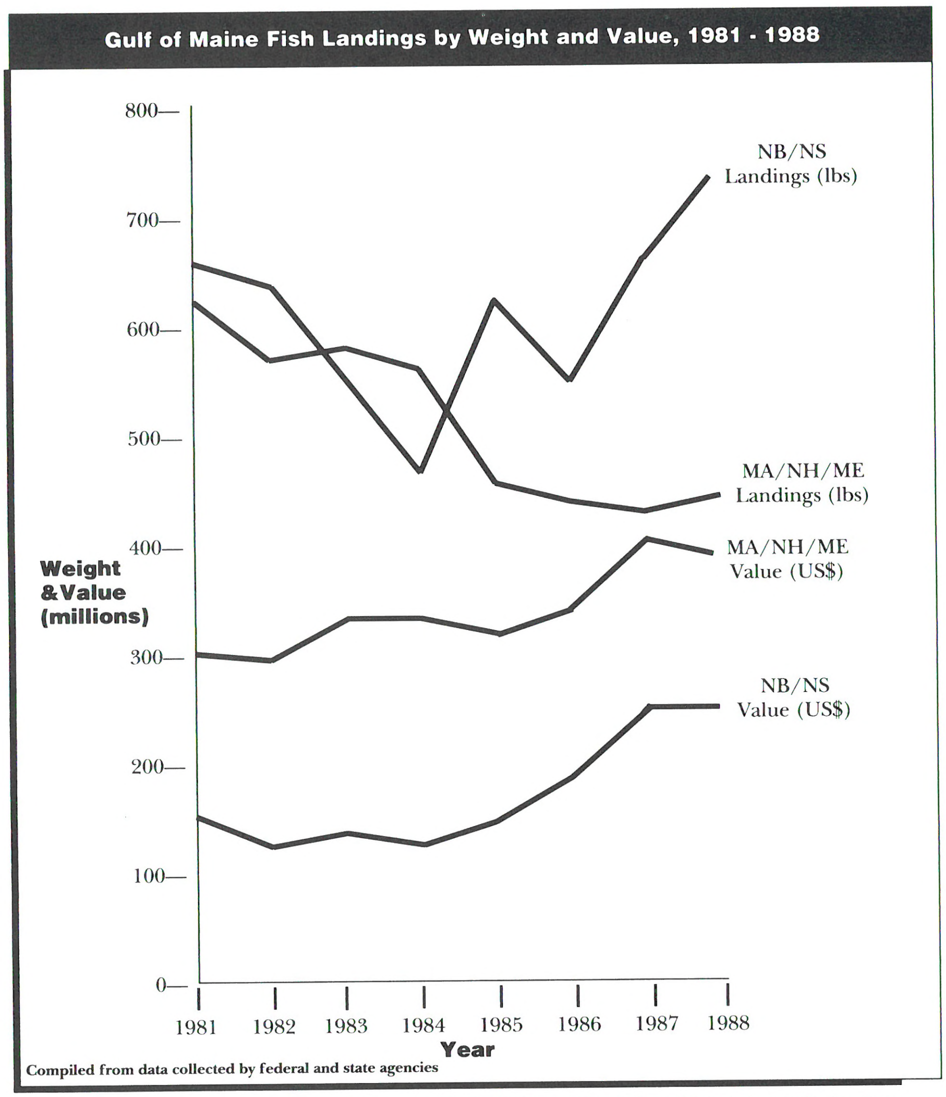
The fishing industry supports many more people than just the fishermen themselves; almost an equal number work at fish processing jobs. Thousands of others are employed building and repairing boats, selling fuel and supplies, and buying and selling fish. In some communities along the southwest coast of Nova Scotia, approximately 75% of the population is directly dependent on commercial fishing. The annual value of the fishing industry to the regional economy is as much as three times the value of the fish landed - approximately two billion dollars.

In 1977, both Canada and the United States extended their fisheries management jurisdiction to 200 miles offshore. Fishing by foreign vessels, which had been intensive in the region, was largely precluded. Fishing in the Gulf of Maine and on Georges Bank has doubled since 1977 as U.S. and Canadian fishermen have intensified their effort in order to take advantage of exclusive rights to fish stocks.

When Canada and the United States extended their jurisdictions, both nations claimed Georges Bank. Attempts to negotiate a fisheries agreement allowing mutual access to Georges Bank failed. In October 1984, the International Court of Justice decided on a boundary line that divided jurisdiction over Georges Bank between the two countries. Canadian landings have increased since gaining exclusive access to the rich groundfish and scallop grounds on the Northeast Peak of Georges Bank.

Peter Ralston/Island Institute

**Many new marine resource harvesting and cultivating ventures are being initiated. Among these are the harvesting of sea urchins and seaweed, and the cultivation of fish and shellfish.**




*The rise in Canadian landings, by weight, since 1984 probably can be attributed to gaining exclusive access to the Northeast Peak of Georges Bank after resolution of the international boundary dispute. The decrease in U.S. landings reflects a decrease in groundfish stocks, as well as loss of access to the Northeast Peak. Value in both countries has increased in response to high demand. The reason for the difference in value between Canadian and U.S. catch is uncertain; it may reflect that the majority of Canadian fish is frozen while U.S. fish is sold fresh. In addition, valuable shellfish species make a greater proportion of the total catch in the U.S. than in Canada.*

U.S. fish catch in the Gulf of Maine region has declined during the last decade. Landings of cod, haddock, and flounder have experienced the greatest decline. Until a recent price downturn, limited supplies of these historically popular groundfish species led to increased prices. Shellfish landings by weight, and to a certain degree by value, have increased.

Although stocks of traditionally fished species appear to be dwindling, new markets have arisen for previously underutilized species such as pollock, hake, and cusk. Many new marine resource harvesting and cultivating ventures are being initiated. Among these are the harvesting of sea urchins and seaweed, and the cultivation of fish and shellfish.

The sea urchin fishery in Maine has grown over the last couple of years to an estimated annual value of two to three million dollars (U.S.) in 1988. Most sea urchins are harvested by divers and exported to Japan where the roe is considered a delicacy.

In Nova Scotia, the seaweed harvest tripled between 1985 and 1988, growing from 15.4 million pounds (7,000 metric tons) to 55 million pounds (25,000 metric tons). Rockweed and Irish moss are processed into thickeners for food and industrial uses. It is likely that seaweed harvesting will

| Gulf of Maine Aquaculture Harvest by Weight and Value of Selected Species, 1988 | Salmon | Trout | Mussels | Oysters | Quahogs | Total Value by State |
|---|---|---|---|---|---|---|
| **Mass.** | | | | 250 tons/225 mT<br>$550,000 (US)<br>$676,5000 (C) | 8,000 tons/7,200 mT<br>$12.4 million (US)<br>$15.3 million (C) | $12.95 million (US)<br>$15.97 million (C) |
| **New Hampshire** | | | | 2 tons/1.8 mT<br>$5,500 (US)<br>$6,765 (C) | | $5,500 (US)<br>$6,765 (C) |
| **Maine** | 500 tons/450 mT<br>$5 million (US)<br>$6.2 million (C) | 5 tons/4.5 mT<br>$40,000 (US)<br>$49,200 (C) | 1,295 tons/1,166 mT<br>$740,000 (US)<br>$910,200 (C) | 60 tons/54 mT<br>$180,000 (US)<br>$221,400 (C) | | $5.96 million (US)<br>$7.38 million (C) |
| **New Brunswick** | 3,850 tons/3,500 mT<br>$34.96 million (US)<br>$43 million (C) | | | | | $34.96 million (US)<br>$43 million (C) |
| **Nova Scotia** | 30 tons/27 mT<br>$252,033 (US)<br>$310,000 (C) | 215 tons/195 mT<br>$1.08 milion (US)<br>$1.33 million (C) | 1,650 tons/1,500 mT<br>$1.63 million (US)<br>$2 million (C) | 55 tons/50 mT<br>$91,057 (US)<br>$112,000 (C) | | $3.05 million (US)<br>$3.75 million (C) |
| **Total Weights** | 4,380 tons/3,977 mT | 220 tons/198 mT | 2,945 tons2,666 mT | 367 tons/331 mT | 8,000/7,200 mT | |
| **Total Value (millions)** | $40.21 (US)<br>$49.5 (C) | $1.12 (US)<br>$1.38 (C) | $2.37 (US)<br>$2.91 (C) | $0.83 (US)<br>$1.02 (C) | $12.4 (US)<br>$15.3 (C) | $56.93 (US)<br>$70.1 (C) |

Compiled from data collected by federal, state, and provincial agencies

expand into other areas of the Gulf because these plants flourish throughout the Gulf's expansive rocky intertidal habitat.

Although a variety of fish and shellfish rearing projects have been attempted in the Gulf region over the last century, it was not until the 1970s that more intensive efforts were initiated. In the 1980s, the aquaculture industry has expanded greatly and further growth is projected in the next decade. Currently, there are aquaculture operations in all of the Gulf jurisdictions, raising primarily Atlantic salmon, rainbow trout, mussels, oysters, and quahogs. The culture of sea scallops, bay scallops, halibut, and bait worms is also being investigated. Over 200 leases or grants have been given to individuals or companies to raise finfish and shellfish in Gulf waters or on the seabed.

Recreational fishing is popular in the Gulf of Maine and generates significant economic activity. The fishery in New Brunswick and Nova Scotia is largely for Atlantic salmon caught in coastal rivers. New Brunswick estimates this fishery, along its Bay of Fundy shore, to be worth three to five million Canadian dollars each year.

In the New England states there were at least 9 million recreational saltwater fishing trips made in 1985. These trips resulted in an estimated catch of more than six million fish in Maine, one half million in New Hampshire, and over 15 million in Massachusetts. The principal species caught were mackerel and cod, as well as flounder, pollock, and bluefish. Massachusetts estimates that nearly 790,000 saltwater fishermen spent $803 million (U.S.) in the state in 1987.

### TOURISM

Seaside resorts on Cape Cod, in New Hampshire, southern Maine, and Bar Harbor became popular in the mid 1800s, and were frequented by the wealthy families of Boston, New York, and Philadelphia. Transportation improvements, particularly rail service and later the construction of highways, enabled more people to escape from the cities to vacation along the coast. Changing socio-economic conditions following World War II led to increased leisure time and income - and to mass tourism.

Today over a billion people come to the Gulf of Maine coast each year to enjoy the pristine environment, the varied land and seascapes, the cultural and historical attractions, and the many recreational opportunities the Gulf has to offer. In 1988, approxi-

Tourism Nova Scotia

*Passenger ships are not as common as they once were; however ferries still provide a link to the mainland for the many island communities of the Gulf, as well as between Nova Scotia and New Brunswick. Each year approximately 100,000 people travel by ferry between Canada and the U.S.* The Scotia Prince, *above, travels between Portland, Maine and Yarmouth, Nova Scotia during the summer months. Cruise ships — a recent and growing addition to the tourist trade — made over 100 visits to Gulf ports in 1988.*

Tourism Nova Scotia

*Whale watching is a growing activity in the Gulf of Maine. Here a whale is spotted off Brier Island, Nova Scotia. During 1986 more than 40 vessels carrying approximately 1 million persons cruised the Jeffreys Ledge and Stellwagen Bank areas in search of whales. Revenues in 1986 from whale watching operations in the southern Gulf of Maine are estimated at $16 million U.S.*

mately 4.5 million people visited Acadia National Park in Maine, an increase from 3.3 million visitors in 1980, making it the second most visited national park in the United States. Cape Cod National Seashore attracted 5.2 million visitors in 1988, up over one million people since 1980. Fundy National Park has held relatively constant at between 650,000 to over 700,000 visitors over each of the last ten years.

Second home development is increasing, as more people seek the quality of life provided by a home on the coast. Although summer houses have been common along the shores of the Gulf for the last century, the building boom of the 1980s dramatically increased the number of second homes between Cape Cod and mid–coast Maine.

Tourism is big business in the Gulf of Maine; it is a major contributor to state and provincial economies. Tourist dollars are an important

**People are moving to parts of the Gulf region in unprecedented numbers. A recent forecast predicts that the metropolitan area defined by seacoast New Hampshire and southern Maine is one of four in the U.S. that will double in population between 1985 and 2005.**

source of revenue to coastal towns, many of which have shifted from fishing-based to tourism-based economies. The tourism industry on Cape Cod accounted for $1.5 billion (U.S.) in 1985, representing 75% of the Cape's economy.

## QUALITY OF LIFE

The value of the Gulf in terms of enhancing the quality of life in the region is nearly impossible to measure, but this factor is very important in generating economic activity. People like to live near the ocean. A recently published survey of homebuyers in Maine found that 73% preferred an ocean view. Few people can afford to live on the water, but many want to live near the coast because they are enamored of the character of the region's coastal fishing communities, its working waterfronts, and the rural areas where open space and farmland characterize the shorefront.

The region's high quality of life, augmented by its ties to the Gulf of Maine, is a recognized asset. A recent study by the Eastern Maine Development Corporation found that 69% of the 400 chief executives they surveyed, representing nearly 70% of the state's businesses, believed quality of life to be the most significant advantage to a Maine business location. People are moving to parts of the Gulf region in unprecedented numbers. A recent forecast predicts that the metropolitan area defined by seacoast New Hampshire and southern Maine is one of four in the U.S. that will double in population between 1985 and 2005.

Peter Ralston/Island Institute


*Joint ventures are a new trend in fish processing in the Gulf of Maine. American and Canadian vessels catch fish that are offloaded onto foreign vessels. In recent years, Massachusetts and Canada have had processing agreements with East Germany and the Soviet Union for herring. Since 1988, Maine has had processing agreements with the Soviet Union for menhaden.*

## SHIPPING

In the 1800s, ships carried salt cod, lumber, and granite from New England and the Maritimes across the Gulf of Maine to destinations in other parts of the U.S. and Canada, as well as to foreign ports, bringing back sugar, tea, and rum. Although the cargo has diversified, shipping, particularly of petroleum products, continues to be an important use of the Gulf.

## ENERGY AND MINERAL EXPLORATION

Over the last thirty years, there have been a number of proposals to drill for oil and gas in the Gulf region. In 1981 and 1982, five American companies drilled eight wells on Georges Bank, but oil and gas were not found in exploitable quantities. However, petroleum has been found near Sable Island, Nova Scotia to the east of the Gulf. At present there is oil industry interest in proceeding with oil and gas exploration on both the U.S. and Canadian parts of Georges Bank, but concerns about the potential environmental impacts of drilling operations have slowed any specific plans. Resource estimates for the region have varied enormously. The U.S. Department of the Interior estimates that a portion of Georges Bank may be underlain by 20 million barrels of oil and 0.5 trillion cubic feet of natural gas. Canadian Oil and Gas Lands Administration estimates for an adjacent area are much greater - one to two billion barrels of oil and five to ten trillion cubic feet of gas. The Gulf of Maine proper has never been considered a good prospect for oil and gas, but some interest in the Bay of

Chris Ayres

*Tourist and residents enjoy one of the Gulf's many sandy beaches.*

**Tourism in the Gulf Of Maine**

| | # Non-resident *Tourists/Year* | Tourist Expenditures *(millions)* | Direct+Indirect *# Jobs* |
|---|---|---|---|
| Massachusetts | 22.6 million (State) | $4,210 [1] | 88,000+ |
| New Hampshire | 2.11 million (coast) | $334.2 (coast) | 53,500 (state) |
| Maine | 6.3 million [2] | $920 (coast) | 57,600 |
| New Brunswick | 2.5 million | $38 (Fundy region) | 19,200 |
| Nova Scotia | 1.2 million [3] | $280.9 (Fundy region) | 12,900 |

1. Includes Barnstable County, Middlesex County, and Boston/Cambridge area; state total for direct tourist expenditures was $6.2 billion in 1987.
2. State total, August 1984-July 1985.
3. May- October only (province total, non-residents).

**Sources:** Massachusetts Department of Tourism; *Boston Globe*, May 1987; University of New Hampshire, Department of Leisure Management & Tourism; Maine Department of Tourism; *New Brunswick Tourism Statistics Manual*; Nova Scotia Department of Tourism & Culture.

**Cargo Traffic in the Major Ports in the Gulf of Maine**

**Total Cargo (Imports + Exports)**
*million short tons (metric tons)*

| | Petroleum & Fuel Oils | % of Total | Dry Cargo | Total |
|---|---|---|---|---|
| Boston | 18.4 (16.7) | 87% | 2.7 (2.5) | 21.1 (19.2) |
| Portsmouth | 1.5 (1.3) | 43% | 2.0 ( 1.8) | 3.5 (3.1) |
| Maine[1] | 11.1 (10.1) | 93% | 0.86 (0.78) | 12.0 (11.0) |
| Saint John | 12.6 (11.4) | 77% | 3.9 (3.5) | 16.4 (14.9) |

1. Maine ports include Portland, Searsport, Eastport, Winterport, and Bucksport. Portland handles the dominant share of petroleum cargo traffic; Searsport and Bucksport have lesser roles.

Sources: U.S. Army Corps of Engineers; Maine DOT; Massport, Boston; Saint John Port Authority; Statistics Canada.

Fundy has been expressed recently.

Extensive sand and gravel deposits lie on the seabed of the Gulf of Maine. To date, no mining has taken place, but it is likely that in the future it will become economically favorable to exploit these offshore resources.

### TIDAL POWER

The pilot facility at Annapolis Royal, Nova Scotia is one of three tidal power stations currently in operation worldwide, generating 17.8 megawatts of electricity. Tidal power facilities have been considered at other sites on the Bay of Fundy as well, but several environmental, economic, and political issues remain to be resolved before construction proceeds.

### WASTE DISPOSAL

The Gulf of Maine is also valued for its ability to assimilate our wastes - sewage, industrial effluent, air pollutants, and urban and other runoff. Quantifying that value is currently next to impossible.

Over the years, society has often found that ocean disposal is a simple and apparently economical way to get rid of wastes, but the true cost of disposal, including the loss of other valued uses that are precluded by waste disposal, is rarely calculated. A low sewer bill may represent economic efficiency from the perspective of the sewage treatment plant operator, but if shellfish harvesting is severely limited

Chris Ayres

*Ship and boat building and repair are an important activity on the Gulf's waterfront; use of the Gulf's resources drives demand for these services. Bath Iron Works, a federal defense contractor, is Maine's largest private employer. The vast majority of the region's facilities are much smaller operations, many of which are feeling pressure to sell to developers planning to construct non-water dependent projects such as homes and restaurants.*

by bacterial pollution from the sewage treatment plant, the cost to society is not reflected in that bill.

For example, in a recent study evaluating the true cost of sewage disposal in the Ipswich and Newburyport area of Massachusetts, the cost of allowing continued sewage discharges was estimated at $700,000 (U.S.), equal to the benefits to the community of a harvestable shellfish resource. Estimates for removing the discharges were $200,000. In such cases, it is more efficient for society to clean up the discharges and produce additional benefits from a clam fishery than it is to maintain low sewage disposal costs by providing inadequate treatment.

It is possible to conduct this kind of analysis for relatively discrete situations - one bay, one form of pollution. When it comes to a water body the size and complexity of the Gulf of Maine, which has experienced longterm chronic and cumulative stress from human activities, such cost-benefit assessments are not easily completed.

## CONCLUSION

Putting a total price on the value of the Gulf is essentially unfeasible; by conventional analysis it would probably be measured in billions of dollars. But, in another sense, the Gulf is literally invaluable. More than a collection of commodities and services, it is an ecosystem with a life of its own, integrally connected to our quality of life.

The economics of the Gulf are constantly changing. As we enter the 1990s, commercial fishing is facing shrinking stocks and competition over access to waterfront facilities. Ship and boat building and repair are being threatened by the high price of waterfront property. Demand for new and competing uses of the waterfront, such as for homes and restaurants, is generated by the region's relatively high quality of life and is affecting the traditional balance of economic activity in the Gulf region as well as its environmental quality. The change in land use patterns is more intense along the Gulf's southwestern shore and has been spreading to the east.

Although uses of the Gulf and their relative value are evolving, nearly all depend upon environmental integrity as a necessary prerequisite for viability. Fishing, including the promising new aquaculture industry, is most dependent on a pristine environment. The high quality of life in the region, a heritage that is treasured by long-time inhabitants and that also attracts tourists and new residents, is tied to the availability and abundance of natural resources. Changing land use patterns throughout the region have uncertain economic and environmental implications. Even though many uses are dependent on a healthy environment, all of the uses discussed above involve potential or certain environmental risks. These risks are discussed in the next chapter.

CHAPTER THREE

# *Stresses on the Gulf*

HUMAN USE OF THE GULF of Maine and the land that surrounds it puts stress on the marine environment by altering habitat, introducing contaminants, and influencing population dynamics. Stress has escalated as use of both land and water has intensified. The stresses discussed in this chapter include the physical alteration of coastal land; "nonpoint sources" of pollution, including small, dispersed sources and all kinds of runoff; "point sources" including industrial, sewage, and other large volume discharges; ocean dumping; accidental spills; offshore oil and gas exploration; and the harvesting of marine resources.

Katrina Van Dusen

Land use patterns on the shores of the Gulf of Maine have been strongly influenced by economic forces and natural resource conditions. Historically, industries were oriented towards the natural resources - fishing, agriculture, timber, quarrying - and depended on coastal waters for transportation and shipping. Rivers flowing into the Gulf provided power to run lumber, grain, and textile mills. Urban areas were concentrated around major ports such as Boston, Portsmouth, Portland, and Saint John, while the remaining coastline was interspersed by small fishing and farming communities. Transportation improvements in the 1950s altered the traditional development patterns, as highways and automobiles facilitated urban expansion and suburban sprawl along the Gulf's southwest shore.

The population of the Gulf region is growing approximately twice as fast in the states as in the provinces. Growth rates for 1980-1986 vary from 17% in Rockingham County, New Hampshire to a net population loss in Cumberland County, Nova Scotia. In 1986, population in the region's coastal counties was approximately 95,000 in Nova Scotia, 134,000 in New Brunswick, 320,000 in Maine, 167,000 in New Hampshire, and 3,877,000 million in Massachusetts, for a Gulf-wide population of 4,593,000.

Recent population and economic growth has dramatically changed the types and intensities of land use in parts of the Gulf region. In general, the amount of land that has been developed in the past thirty years is much greater along the southwestern part of the Gulf coast than in the northeast part. Typically, agricultural land has been lost while the amount of forested land has remained relatively stable and developed land has increased.

Bob Moore

**Most rivers contribute significantly to the pollutant load of coastal waters; it is estimated that the Merrimack River's contribution of metals to Massachusetts Bay may be of the same magnitude as the Boston Harbor sewage outfall.**

Peter Ralston/Island Institute

*One of the numerous paper mills located on the rivers flowing into the Gulf. In the last twenty years, sizable reductions have been made in levels of biological oxygen demand and suspended solids in mill discharges. Metals and organic compounds are also discharged by paper and pulp mills.*

## *Lead in Boothbay Harbor Attributed to Nonpoint Sources*

Bob Moore

Boothbay Harbor, Maine was chosen as a "control site" by the National Marine Fisheries Service in a survey of metals in organisms and sediments of Atlantic coastal waters of the U.S. in 1982. Surprisingly, lead levels in Boothbay Harbor crabs ranked second highest of all the study sites, with levels as high as in organisms from New York City and Philadelphia. Further study of historic activity in this small, resort town with a year round population of 2,300 showed that neither the town's sewage treatment plant, nor any intensive industrial activity were the source of the lead. Probably urban runoff washed the lead from automobile exhausts and crankcase oil drippings into the harbor. In July and August, over 5,000 cars per day pass through Boothbay Harbor. Lead-laden paint chips and sand-blasting waste from several boatyards may also have contributed to the lead load.

Fisheries and Oceans Canada

*Fish processing plants, like this one in Nova Scotia, are common along the Gulf coast. Effluents from these plants discharge substantial loadings of oxygen demanding matter, suspended solids, oil and grease, fecal bacteria, and certain organic and inorganic compounds. Often, the problem of odors and flies around these operations, especially fish meal plants, receives more community response than the problem of effluent discharges, which are usually considered only to have localized impact on water quality.*

waters. A nationwide survey of pesticide use in the estuarine drainage areas of the U.S. found that lands draining into New England estuaries have low pesticide use, less than 200 pounds applied per square mile per year, as compared to Chesapeake Bay, where 1,500 pounds are applied per square mile per year. However, like other nonpoint sources, agricultural and forestry runoff has not been well quantified in the region, but it may be important given the large area of forest and agricultural land that drains into the Gulf of Maine.

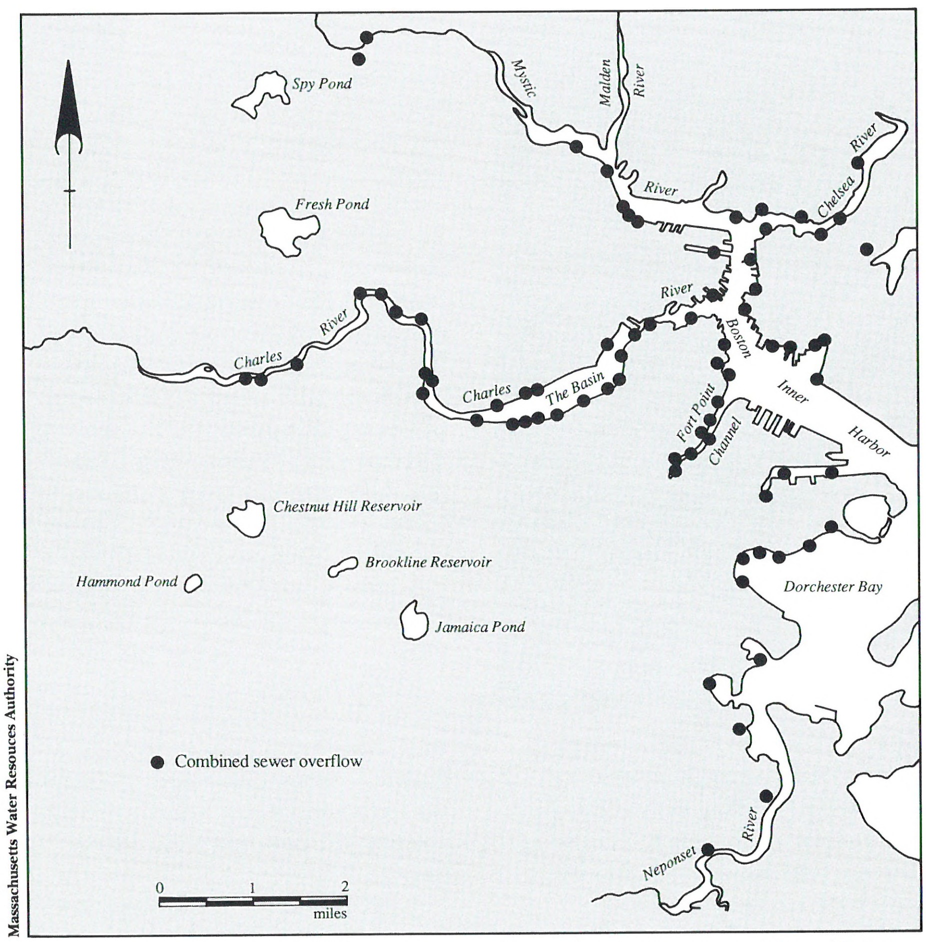
In addition to runoff that carries residues from the application of pesticides, accidental spills and leaks, as well as improper storage, handling and disposal also contribute pesticides to the watersheds of the Gulf.

Failing and inadequate residential septic systems introduce nitrogen, phosphorous, chlorine, viruses, and bacteria into coastal waters. Although there are many other sources of bacteria, including municipal sewage systems, combined sewer overflows, runoff, wildlife, and boats, assessments of the relative contributions of different sources have found home systems to be significant contributors of bacteria to certain areas. Attempts have been made to clean up or eliminate the discharge of untreated sewage from homes in all of the Gulf jurisdictions, but problems persist. Illegal "straight pipes" still exist throughout the region. In Maine, 3,000 residential discharges have been permitted; it is estimated that only one half of them function properly at any given time and that nearly all fail at some point.

Many of the pollution sources discussed thus far have been land-based, but there are also many water-based sources. Boating and shipping activities contribute bacteria and nutrients, oily wastes, debris, and lead, copper, and tributyl tin from bottom paints to the Gulf's pollutant load. As recreational boating activity in the region has increased, the overboard discharge of sewage in congested harbors and popular cruising anchorages has become a concern, especially in areas with commercial shellfish beds.

Oily bilge water is often discharged from vessels delivering oil and other cargo to and from the region's ports. Although U.S. and Canadian law and an international treaty now restrict the amount of petroleum that can be discharged with bilge water, lack of enforcement makes it likely that some petroleum still reaches Gulf waters from this source.

**Most sewage treatment plants are designed primarily to treat the oxygen-demanding organic load and bacterial and viral pollutants in domestic wastewater; they are not designed to handle complex industrial effluents.**



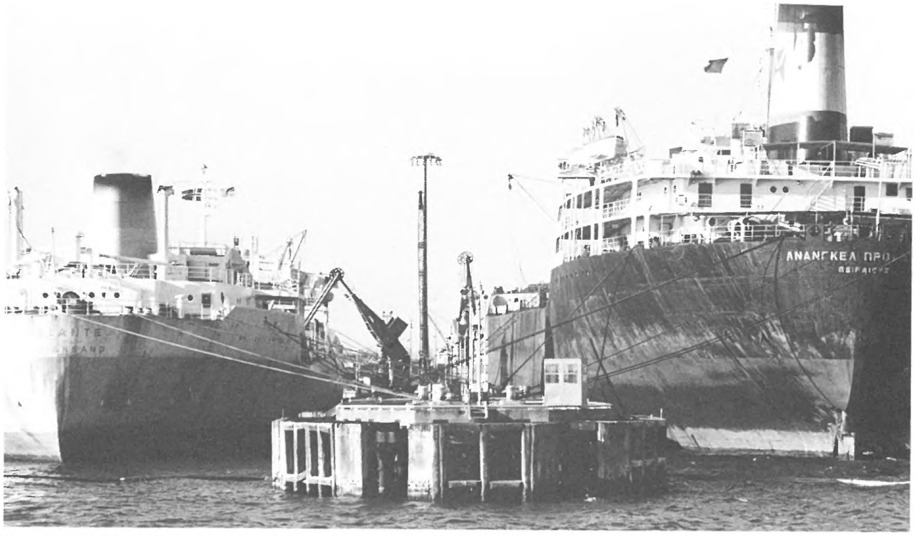

*Over 90 combined sewer overflows (CSOs) contribute significant volumes of raw sewage to Boston Harbor.*

The abundance of beach- and boat-generated debris floating in the Gulf and washing up on shore is a growing concern because it is unsightly, poses a danger to wildlife, and can be a hazard to mariners. The magnitude of this problem was made evident in 1988 when volunteers collected an average of 233 pounds of trash per mile (66 kg/km) from the shorelines of Maine and Massachusetts. Over 40% of the trash was plastic, which degrades very slowly. Efforts are being made in Canada and the U.S., as well as by international treaty, to regulate the dumping of ship-generated garbage at sea.

Runoff from boatyards and marinas, and leachate from creosoted pilings and boat hull paint, contribute hydrocarbons, lead, copper, and tributyl tin to the marine environment. Hull paints containing tributyl tin are regulated, but not yet eliminated in the Gulf region. These paints are designed to retard the growth of organisms that foul boat bottoms, but they can affect non-target organisms as well.

## Industrial Discharges

While pulp and paper mills and fish processing plants are the primary industrial dischargers to the Gulf from Canada, there are a greater variety of industrial operations discharging into the U.S. waters of the Gulf. These include tanneries, textile mills, metal



Chris Ayres

*The risk of oil spills from tankers and barges increases when vessels are in port and during transfer operations.*

fabricating and finishing operations, and chemical, plastics, rubber, electronics, and equipment manufacturing plants. Many industrial plants have cleaned up their waste streams during the last twenty years, in response to public pressure and government regulation, but they still discharge, legally, a wide array of metals, petroleum hydrocarbons, and other toxic contaminants. There are an estimated several hundred industries that pump waste directly into the coastal waters of the Gulf, but the vast majority of industrial effluent in the U.S. flows into municipal sewage treatment systems. Approximately 6,000 industries in the greater Boston area send their wastes to the sewage treatment facilities at Deer and Nut Islands in Boston Harbor. It is estimated that each day over a ton of toxics is discharged into Boston Harbor from these two facilities alone. Most sewage treatment plants are designed primarily to treat the oxygen-demanding organic load and bacterial and viral pollutants in domestic wastewater; they are not designed to handle complex industrial effluents.

Pulp and paper mills are one of the primary kinds of industrial operations discharging effluent into Gulf waters. Historically, pulp and paper mill effluent has been characterized by high biological oxygen demand (BOD) levels, which depletes dissolved oxygen in water, and high levels of suspended solids (SS) that settle out to form sludge beds and disrupt benthic habitat. In the last twenty years, sizable reductions have been made in levels of these "conventional" pollutants in mill discharges. For example, between 1972 and 1982, point source pollution on the Saint John River, where there are five mills, was reduced by 88% in terms of BOD loading, and by 82% in terms of SS discharged.

In addition to BOD and SS, chromium, copper, lead, mercury, and zinc are typically found in effluent from pulp and paper mills. Concern has been expressed in the last decade that the use of chlorine in pulp bleaching has resulted in discharge of as many as 9,000 chlorinated organic compounds; some, such as dioxin and furan, are among the most toxic compounds known.

### SEWAGE TREATMENT

Like control of industrial discharges, sewage treatment has been improved and expanded in recent decades. In New England, most municipal sewage receives primary treatment, and much secondary. In the provinces, many small communities have sewage treatment systems, while many larger cities, including Saint John, have collection systems that provide little or no treatment. In 1985, approximately 55% of the population of the Atlantic provinces was served by sewers, but only 20% of the wastewater was treated; wastes generated by about 788,000 people were discharged without treatment.

Although the majority of the population of the Gulf is serviced by sewer systems, the volume of sewage received by many treatment plants is in excess of their designed capacity. Some plants, especially the facilities in the Boston area, are antiquated and cannot properly handle the demands placed on the system. In Boston and Salem, Massachusetts sewage treatment plants separate out sludge, but then discharge it into the ocean at high tide, an ineffective process at best.

In many areas, storm drains are connected to sanitary sewers, causing sewage treatment systems to become overloaded after rainstorms. This results in raw sewage being discharged into the Gulf through storm drains known as "combined sewer overflows" (CSOs). CSOs in Boston and Portland, as well as almost every smaller sewage district, discharge large amounts of nutrients and bacteria from sanitary wastes, metals and toxics from industrial waste, and metals, oil, and other hydrocarbons from street runoff.

Most sewage treatment plants disinfect their effluent with chlorine, but the discharge of chlorine is a growing concern because of its potential toxic effects on marine organisms.

Massachusetts CZM

*Numerous environmental safeguards were required during exploratory drilling by the Alaskan Star and other vessels on Georges Bank in 1981 and 1982.*

Tourism Nova Scotia

## *Pollution in Rural Annapolis Valley*

Along the Canadian shore of the Gulf, nonpoint source pollution is generally less of a concern because land is not being developed as rapidly as in the New England states. However, pollution problems in the Annapolis Valley estuary in Nova Scotia demonstrate that in rural areas many smaller pollution sources can have a cumulative impact, particularly on an enclosed bay. Discharges from poorly functioning sewage treatment plants and runoff from agricultural activities, including numerous livestock operations, are contributing to bacterial contamination and nutrient and pesticide loadings in the estuary. Problems associated with pesticides and groundwater contamination are also being examined at selected sites in the Valley. The presence of contaminants throughout the Valley has restricted the use of its waters for fishing, swimming, and drinking.

In 1989 the Annapolis Valley Affiliated Boards of Trade decided to undertake a cooperative venture involving both those interests causing and affected by contamination and directed at resolution of some of the pollution problems.

### POWER PLANTS

There are numerous coal, oil, and nuclear power plants, as well as one tidal power facility, along the Gulf of Maine coast. These facilities are not major contributors of pollutants to the marine environment, but cooling waters, used in all but the tidal power facility, cause thermal pollution and resulting localized impacts. Cooling waters can contain elevated levels of metals, contributing to the total contaminant load in the Gulf. The pollutants contained in air emissions from these facilities may ultimately reach the waters of the Gulf of Maine. PAHs from the burning of coal and oil reach the Gulf through precipitation and runoff. Sulphur dioxide emissions are a leading cause of acid rain.

The stresses caused by the tidal power facility at Annapolis, Nova Scotia do not result from any discharge, but from the alteration of tidal currents. Larger tidal power projects proposed for the upper Bay of Fundy could significantly increase tidal range throughout much of the Gulf. Resulting changes in currents, temperature, and upland flooding would have a significant effect on the Gulf ecosystem.

### OCEAN DISPOSAL

Ocean disposal of wastes are regulated in Canada and the U.S. and by international convention. At present, the vast majority of ocean disposal in the Gulf

Fisheries & Oceans Canada

*More U.S. and Canadian fishermen than ever are plying the Gulf's waters in search of fish. These boats are tied up in a Nova Scotia harbor.*

region is of dredged materials. Dredging is undertaken to improve and maintain navigation channels and mooring areas for commercial and recreational boats. A large maintenance dredging project in Portland Harbor deposited nearly 1.1 million cubic yards (840,000 cubic meters) of dredge spoils in the Gulf in 1980, a substantial amount of the total 2.3 million cubic yards (1.75 cubic meters) dredged by the U.S. Army Corps of Engineers in Maine between 1950 and 1981. There are four major disposal sites in the New England region of the Gulf. Disposal permits for small projects have been granted for other areas on a one-time-only basis.

Canadian dredging projects in the Gulf region average less than 26,000 cubic yards (20,000 cubic meters), and maintenance projects occur less frequently than in New England, due to different oceanographic and sedimentation characteristics. Saint John Harbour is the only area that requires annual maintenance dredging (averaging 500,000 cubic meters per year) due to siltation from the Saint John River. Disposal sites are not used for more than one year at a time, resulting in a large number of small disposal areas scattered throughout Canadian waters. Studies conducted on material dredged from Saint John Harbour have indicated minimal contamination.

Both dredging and dumping of the spoils can put stress on the marine ecosystem. Pollution can be spread by moving sediments contaminated with PAHs, PCBs, and metals from harbors and bays to clean, open ocean areas. Pollutants sequestered in bottom sediments can be released from the sediments when they are disturbed or exposed by dredging activity. Bottom-dwelling communities are temporarily, and sometimes permanently, destroyed both in the area that is being dredged and in the area where the dredged material is disposed. Dredging can also cause increased erosion of coastal land because it disrupts natural sedimentary processes.

### OIL SPILLS

More oil enters the marine environment than any other toxic contaminant. Marine transportation is responsible for 46% of the worldwide input of oil into the oceans. Only 29% of this input is from accidental spills; the majority of the input is from the chronic discharge of oil from vessel and port operations. However, accidental oil spills are a longstanding public concern because of their catastrophic impact on the marine environment.

A number of oil spills have occurred in the last three decades in the Gulf region. In addition to the huge spill of 7.6 million gallons (28.9 million liters) from the *Argo Merchant* off Cape Cod in 1976, in the past twenty years several large spills ranging from 200,000 to well over 600,000 gallons (0.8 to 2.3 million liters) have occurred in New Hampshire and Maine - particularly in Portsmouth and Portland Harbors. Saint John experienced a major spill in the early 1970s, prompting an agreement between the U.S. and Canadian Coast Guards to cooperate in oil spill cleanups in the Gulf region.

The two federal governments have recognized that many oil and chemical spills can be prevented through training, vessel inspections, construction and equipment standards, and traffic regulations and guidelines that prevent collisions and groundings. Regulations are also in place to reduce operational discharges of oil. However, the experience from recent spills, the *Exxon Valdez* in Alaska in particular, has shown that, despite efforts to minimize the risk of an accident, such risk cannot be completely eliminated.

### ENERGY AND MINERAL EXPLORATION

There is no ongoing exploration for energy or mineral resources in the Gulf, although it has occurred in the past and will most likely occur again in the future. The potential impacts of offshore oil and gas exploration include: loss of access by fishermen to the seabed and waters around a drilling operation; damage to fishing gear from debris jettisoned overboard from a drilling rig or supply vessel; and

**Harvesting effort by U.S. and Canadian fishermen in the Gulf of Maine has doubled since 1977.**

Portland Press Herald

*Some of the region's fish stocks are at record low levels.*

Chris Ayres

*Possible effects of aquaculture operations relate to the deposition of fecal matter and waste food beneath the pens; the depletion of dissoved oxygen levels; nutrient enrichment; and the introduction of antibiotics and hormones into the water column. Careful selection of pen sites reduces the potential for stress.*

adverse effects on the marine environment from routine discharges or oil spills. Oil and gas development and production activities result in chronic discharges of petroleum hydrocarbons throughout the life of the field. The potential for these activities to have an impact has been reduced by government regulation and industry cooperation in both Canada and the U.S.

The potential environmental impacts of offshore sand and gravel mining in the region has not been studied extensively. Initial environmental concerns focus on the disruption of benthic habitat by dredging operations and the effects on marine organisms of suspended matter settling on the seafloor.

### HARVESTING OF FISHERY RESOURCES

Intensive levels of fish harvesting effort have taxed the ability of commercial stocks in the Gulf to sustain themselves. In the 1960s and 1970s intensive fishing in the Gulf by fleets from other countries depleted stocks. The cutback on foreign fishing in the region in 1977 provided the stocks with only temporary relief. Harvesting effort by U.S. and Canadian fishermen in the Gulf of Maine has doubled since 1977. For example, the number of New England-based otter trawlers, doubled between 1976 and 1984. For many species of fish, stocks in the Gulf and on Georges Bank are now at record low levels.

**The Maine Geological Survey estimates that mean sea level will rise by 1.6 to 2.4 feet (48 to 72 centimeters) in Portland, and 2.3 to 4.8 feet (69 to 144 centimeters) at Eastport, Maine in Passamaquoddy Bay over the next century.**

Chris Ayres

*Important wetland functions are being disrupted by small-scale, incremental coastal development.*

Extensive efforts are being made in the Gulf region, some of them cooperatively among the U.S. and Canadian governments and fishermen, to improve fish harvesting technology so that it selectively harvests the species and size of animal desired without damaging younger fish, other species, and bottom habitat, a longstanding concern. For example, lobster traps now have escape vents that allow the release of undersized lobsters. Shrimp fishermen from New England have begun use of a special separator trawl net in the spring to minimize the number of juvenile fish, especially flounder, that are caught and thereby killed. Ongoing U.S./Canada cooperative research to improve the selectivity of gear used to catch groundfish involves experimenting with different net mesh sizes, shapes, and colors.

Relative to other parts of the world, the killing, injuring, or entangling of marine mammals, birds, and turtles in fishing gear occurs infrequently in the Gulf. However, the U.S. government has imposed new reporting requirements on the groundfish and mackerel fisheries in the Gulf of Maine because their incidental take of marine mammals may be high enough to be of concern.

Aquaculture is a relatively new activity in the Gulf of Maine, and any stress it might put on the waters and other uses of the Gulf are not yet well documented. Possible effects relate to: the deposition of fecal matter and waste food beneath the pens; the depletion of dissolved oxygen levels; nutrient enrichment; the introduction of antibiotics and hormones into the water column; the introduction of non-indigenous fish; and the spread of viral and bacterial diseases from hatcheries to coastal waters. Careful selection of pen sites in areas where there is adequate circulation and flushing, and avoidance of shallow, constricted embayments may reduce these potential problems.

## Sea Level Rise

Scientists predict rapid and unprecedented changes in the earth's climate due to pollution-induced changes in the composition of atmospheric gases. Average temperatures are predicted to rise by 0.5 degrees F. (0.3 degrees C.) per decade, 10 to 50 times faster than anything in recorded history. The "greenhouse effect" has major implications for the Gulf of Maine. Global warming will cause sea water to expand and thus sea level will rise. The Maine Geological Survey estimates that mean sea level will rise by 1.6 to 2.4 feet (48 to 72 centimeters) in Portland, and 2.3 to 4.8 feet (69 to 144 centimeters) at Eastport, Maine in Passamaquoddy Bay over the next century. Warmer temperatures could affect the Gulf of Maine fisheries by making the Gulf a less suitable habitat for cold water species.

## Conclusion

Despite successful efforts during the last two decades to minimize some of the major stresses on the Gulf, many smaller, dispersed activities are having a cumulative impact on the ecosystem. Sewage and industrial treatment have been widely installed or upgraded, but contaminants reaching the Gulf from nonpoint sources are largely unchecked; large scale development of wetlands and beaches has been limited by regulation, but important wetland functions are being disrupted by small-scale, incremental coastal development; most foreign fish processing ships have been excluded from Gulf waters, but effort by U.S. and Canadian fishermen has doubled during the last ten years. The challenge of the 1990s is to address these sources of stress, as well as to continue to eliminate point sources.

Nova Scotia Power Commission

*The tidal power plant that currently operates on the Annapolis River in Nova Scotia has affected local current patterns, caused upstream riverbank erosion, killed fish passing through the turbines, altered the natural deposition of sediments, and influenced the soft shell clam fishery in the Annapolis Basin.*

with sediments, however, such data do not provide information on the impact of contaminants.

Mussels from three Boston Harbor stations were among the most contaminated, in terms of PAHs, in a nationwide "mussel watch" program.

In 1984, Casco Bay recorded the highest levels of lead, the third highest levels of silver, and the fifth highest level of zinc in fish livers in a survey of contaminants in United States fish. Elevated metal concentrations were detected in mussels from Penobscot Bay in the late 1970s, and again in the late 1980s.

Evidence of metals in fish tissues can be misleading. Scallops collected from Browns Bank, where sediments revealed no contamination, had higher levels of cadmium in their tissues than scallops from a highly impacted site. This phenomenon may be explained by differing nutritional conditions, rather than anthropogenic sources of the metal.

In 1984, years after a near total ban on the use of DDT in North America, livers of fish sampled in Boston and Salem Harbors contained significant concentrations of DDE, the primary form of DDT in environmental samples. Boston Harbor samples contained nearly twice the level of pesticides found in any other site in the United States.

PCBs, also banned in North America, are found in tissues at concentra-

New Hampshire Office of State Planning

## *Loss of Eel Grass Beds Affects Productivity in Great Bay*

The loss of eel grass beds in New Hampshire's Great Bay has been linked to pollution from the surrounding areas, and from a natural wasting disease. Without the eel grass to trap soil particles and anchor the estuarine substrate, many acres of shellfish beds have been buried by shifting sediments. The populations of small fish and other organisms that form the bottom of the aquatic food chain have declined, resulting in a less diverse and productive estuarine ecosystem. The annual economic benefit of healthy eel grass beds has been estimated at $71 million (U.S.).

Flis Schauffler

*Since use of the pesticide DDT was banned in the 1970's, the osprey population of the Gulf has increased. Bald eagles are also re-establishing themselves, especially in the Passamaquoddy Bay area.*

tions greater than those of chlorinated pesticides by an order of magnitude or more. Declines in the levels of PCB in the eggs of seabirds have been evident since 1972. This same decreasing trend was noted even near highly contaminated sites in Massachusetts. The reverse trend was observed in mussel tissues from Penobscot Bay. Levels of PCBs in mussels taken from Sears Island in 1986 were more than twice the level of those taken at the same site ten years earlier. Elevated concentrations of PCBs have been measured in lobster and flounder from Quincy Bay, in Massachusetts.

Chlorinated dioxins are relatively insoluble and collect in fatty tissue. Elevated levels of chlorinated dioxins have been detected in fish from the Androscoggin River and in herring gull eggs from the Bay of Fundy.

DDT, Dieldrin, and other pesticides have been detected in the eggs of seabirds from Canadian nesting colonies. Since these birds feed over wide ranges of the Gulf and are near the top of the food chain, pesticide levels in their tissues most likely represent Gulf-wide trends rather than local conditions in the vicinity of the colonies.

### Excess nutrients

Nutrients are vital for plant growth; the availability of nitrogen and/or phosphorus is often a limiting factor in the production of plant matter in the ocean. However, excess nutrients can lead to disruption of the plankton community and water quality problems when algal "blooms" clog waters and result in oxygen depletion. The Gulf of Maine is well flushed and has, to date, experienced few problems with excess nutrients, or eutrophication. As coastal populations grow and ever greater amounts of nutrient-rich sewage are discharged to marine waters, the risk of water quality problems grows, particularly in embayments where flushing and currents are restricted. Eutrophication may play a role in the incidence of toxic "tides," including red tide, which result in the closure of thousands of acres of clam flats each summer.

In 1988, a bloom of a toxic marine alga, *Gymnodinium nagasakiense*, in the upper reaches of Casco Bay caused a major die-off of lobsters, clams, worms, and other benthic organisms. While nutrient runoff has been blamed for the bloom, few data exist to substantiate the claim.

Fish culture may contribute to eutrophication. Poorly sited farms have resulted in the smothering of bottom dwelling organisms by settling organic matter, reduced dissolved oxygen levels, and nutrient enrichment.

### Habitat loss and impairment

Wetlands can produce more organic matter than they consume; they supply vital nutrients to adjacent coastal waters. Other wetland functions which can be lost to filling or dredging include filtering of pollutants, flood storage, and shoreline protection. Wetland loss also affects the wide variety of wildlife that depends upon salt marshes, beaches, and other wetlands for vital nesting and feeding habitat. Gulf populations of least terns, piping plovers, and other birds are threatened by encroaching development. Only 300 pairs of piping plovers remain in the Gulf of Maine; almost half of the worldwide population.

A recent study of the right whale reported that 35% of right whale deaths resulted from collisions with vessels and entanglement with fishing gear. Although marine mammals are

**While overharvesting may be the greatest factor in the decline of fish stocks in the Gulf of Maine, the cumulative impact of pollution and habitat loss is most likely taking its toll as well.**

Tourism New Brunswick

## *Human Activities have Cumulative Impact on Saint John Fishery*

Environmental quality in Saint John Harbour may be an example of the cumulative effects of a variety of anthropogenic stresses. A declining fishery originally led some to blame extensive dredging for the loss. Later, it became clear that dredging alone was not responsible. Natural processes, accelerated by onshore development; the growth of Saint John's pulp, paper, fishing, and refining industries; causeway and wharf construction and disposal of untreated sewage most likely all contributed to the decline of the fishery in question.

fleets exploited a broad array of species on the Bank. Stocks recovered briefly when the efforts of distant water fleets were restricted in 1977; however, an increase in U.S. and Canadian fishing effort has lead to a second decline. Dogfish and skates now represent about 70% of the total Georges Bank finfish biomass.

Along with the changes in biomass and species composition there have been changes in the age structure of various finfish stocks in the Gulf of Maine. A striking example of the change in age structure is the witch flounder. In 1980, there were fish as old as 22 years; by 1985, the oldest fish were 20 and there were no three year olds; in 1987, the age classes only included fish from 5 to 18 years old.

Exploitation can also lead to the replacement of one species by another. For example, the increase in the sand launce population, evident in recent years, may have been made possible because its more efficient competitors

Maine Department of Marine Resources

*This juvenile Atlantic sturgeon, ensnared in plastic debris, was caught in the Kennebec River, Maine.*

and/or predators (herring and mackerel) were decimated by the distant water fleets during the 1960s.

### CUMULATIVE IMPACTS

The impact of environmental stresses of all types can be cumulative. The impact of a particular contaminant on an individual organism, population, or community cannot adequately be assessed without also considering the other types of stresses that are present. An organism may be tolerant of any single stress, but two or more such burdens may impair its ability to function naturally. The marine environment contains many natural stresses: daily and seasonal changes in temperature, changes in salinity, winds, currents; tides, and periodic exposure to air; anthropogenic stresses add to the burden of a marine organism attempting to acclimate and thrive in a variable environment.

Cumulative impact may explain ecological changes for which there is no apparent single cause. For example, five years of sampling indicates that, for unknown reasons, sea scallops from deepwater sites in the Gulf of Maine are nutritionally deficient and lack the glycogen reserves necessary for spawning. These populations apparently are not reproducing themselves.

Unusual algal blooms may also indicate that the marine ecosystem is out of balance. Blooms of the red tide organism and other toxic algal species are of concern not only for their impact on shellfisheries but because they may be symptomatic of environmental stress. In 1989, red tide reached sufficiently high concentrations on Georges Bank to require limitations on the harvest of shellfish.

Obvious sources of ecological stress may mask the role played by other impacts. While overharvesting may be the greatest factor in the decline of fish stocks in the Gulf of Maine, the cumulative impact of pollution and habitat loss is most likely taking its toll as well.

### PUBLIC HEALTH

Shellfish contaminated with sewage and runoff represent a potential threat to public health; however, rigorous monitoring and control programs provide adequate safeguards throughout the Gulf region. Swimming is prohibited at several beaches in the Gulf region. On any given day during the summer, approximately 30% of Boston Harbor beaches are closed to swimming. In Maine, in 1988, swimming standards were exceeded for the first time at some beaches. The Annapolis Basin, in Nova Scotia, was also closed to swimming in 1989.

Excessive body burdens of toxins can present a health hazard to consumers of fish and shellfish. Fish pose less of a threat than shellfish because toxic compounds usually accumulate in organs, such as the liver, that are not normally consumed. Shellfish, by contrast, are usually consumed whole.

In 1989, limitations on consumption of shellfish from the Piscataqua River, on the Maine-New Hampshire border, were recommended due to lead contamination from a nearby toxic waste dump.

PAH concentrations in the tomalley of lobsters from Quincy Bay warrant a consumption advisory.

Fish from Maine's Androscoggin River have accumulated chlorinated dioxins; fishermen are warned to limit the number of fish they consume from the river.

### IMPACTS UPON AESTHETIC AND RECREATIONAL USES

Environmental degradation diminishes the quality of life of the region's residents. Oil slicks and industrial and sewage outfalls make boating and other recreational uses of coastal waters unappealing. Recreational fishing and shellfishing are severely impacted in the Gulf's coastal communities by sewage contamination and population declines.

One effect of intense growth in coastal regions is the littering of the shores and marine waters that results from increased use of the coastal region. Non-biodegradable trash, especially plastics, is one form of marine pollution that is readily visible.

**Employment is directly related to volume of landings: one estimate from Nova Scotia links 28 full-time jobs to every 1,000 metric tons (1,968,000 pounds) of fish harvested.**

Chris Ayres

**Shellfish Closures in the Gulf of Maine**

| Region | Productive Acreage | % Restricted |
|---|---|---|
| Massachusetts [1] (1984) | **8,170** | 83% |
| New Hampshire (1989) | **3,420** | 100% |
| Maine (1988) | **49,000** | 25% |
| Nova Scotia (1985) | **26,671** | 15% |
| New Brunswick (1985) | **9,702** | 32% |

[1] North Shore and Boston Harbor.

Floating and submerged debris and shoreline litter also presents hazards to boaters, fishermen, and beachwalkers.

## ECONOMIC IMPACTS

The region's fishing industry initially benefited from restrictions on foreign harvests established in 1977; landings and value both increased. Between 1978 and 1988, the number of fish processing plants in the Scotia-Fundy region doubled, from 187 to 374. However, landings of traditonal species from the Gulf of Maine soon began to fall. For example, haddock landings declined from an annual average of 6,800 metric tons in the early 1980s to 829 metric tons in 1987. Declines in fish landings in the early 1980s were initially offset by an increase in value; recently, however, value has also declined for some important species. Employment is directly related to volume of landings: one estimate from Nova Scotia links 28 full-time jobs to every 1,000 metric tons (1,968,000 pounds) of fish harvested. Although landings in Nova Scotia and New Brunswick increased between 1984 and 1988, due to expanded access to Georges Bank and harvesting of under-utilized species, the trend appears to be reversing. In the summer of 1989, several hundred plant workers were temporarily or permanently laid off in Nova Scotia as stricter catch quotas were imposed in response to stock declines.

Pollution and habitat loss can also have economic consequences. For example, the toxic effects of PAH contamination can impair the ability of a fish stock to reproduce itself. The economic impacts of habitat destruction may not be immediately apparent; they must be estimated by figuring the replacement cost of the role coastal wetlands play in commercial and sport fisheries, aquaculture, agriculture, peat harvesting, recreation and tourism, water quality control, shoreline protection, and flood control. The relationship between estuaries and fisheries productivity is clear: the U.S. National Marine Fisheries Service estimated an annual loss to U.S. fisheries of $208 million between 1954 and 1978 due to the destruction of estuarine wetlands systems.

Sewage pollution, red tide, and other biotoxins cause restrictions on shellfish harvesting throughout the Gulf region. Unlike toxic contamination, sewage pollution affects humans more than marine organisms; as a result, its effects are primarily economic. The trend toward increasing shellfish closures led Maine to pass legislation in 1987 to sharply curtail the discharge of sewage to shellfish flats.

In 1988, medical wastes washed up on the shores of New York and New Jersey, causing public beach closures and economic losses in the billions of dollars to coastal communities heavily dependent on tourism. A similar decrease in the recreational value of the Gulf's shores would seriously affect local and regional economies. Toxic pollution also affects the market for fish; concern for healthful food may already be dampening consumer enthusiasm for seafood. If public faith in the cleanliness and safety of the Gulf's resources is not upheld, adverse economic consequences are likely.

Portland Press Herald

*Plastic and other trash is one form of marine pollution that is readily visible. Floating and submerged debris and shoreline litter present hazards to boaters, fishermen, and beachwalkers.*

Contaminated seafood, loss of recreational opportunity and the degradation of marine and coastal environments lower the quality of life in the region and decrease its attractiveness to residents; development, the recreation industry, and the second home market all suffer.

## Conclusion

In general, the Gulf appears to be in good health; however, some coastal areas are degraded and certain fish stocks no longer support a commercial fishery. Locally, uses of marine waters are restricted. Some contaminants are evident at least in trace amounts throughout the Gulf.

The complexity of the marine ecosystem makes it difficult to differentiate effects of stress from natural variability. Research is needed to determine the ecological effects, both short and long term, of such environmental stresses as contamination, habitat loss, and overharvesting. Greatly increased monitoring is needed to fill in the gaps in data regarding the extent and type of stress in the Gulf. Without such information, protection efforts will remain unfocused.

CHAPTER FIVE

# Summary and Future Outlook

THE GULF OF MAINE is of great worth not only to the people of the Gulf region who depend upon it for economic, aesthetic, and recreational value, but also to the many others who enjoy or profit from its resources. Among the most productive bodies of water on earth, the Gulf has nourished a thriving maritime heritage for several centuries.

The growth of the human population and concommitant development in the Gulf region have resulted in a series of stresses that impinge upon the Gulf environment: tons of raw and partially treated sewage are discharged into the Gulf each day; industrial discharges, urban runoff, and agricultural practices all introduce toxic contaminants and bacteria to marine and estuarine waters on a chronic, sometimes acute basis; increased fishing effort has reduced fish stocks to all time lows; development in the coastal zone has encroached on environmentally significant marine wetlands; and accidental spills of oil and other toxic material place additional stresses upon the Gulf environment.

Evidence of these stresses can be found throughout the Gulf. Although limited data exist to adequately assess the trends in environmental quality in the Gulf of Maine, the warning signs of degradation are clear in the research results of the last decade:

Save the Harbor, Save the Bay

— highly industrialized harbors such as Boston and Saint John are seriously degraded; it is unlikely that such places will ever regain all of their natural functions;
— relatively undeveloped embayments, such as Penobscot Bay, exhibit elevated levels of contaminants in sediments;
— sediments in the depositional basins of the offshore Gulf of Maine contain small but abnormal amounts of toxins, indicating that contaminants are being transported throughout the Gulf.

While the effects of such stresses are not fully documented, natural processes in the Gulf are clearly being affected:

— certain fish and shellfish exhibit liver lesions, fin rot, and other signs of environmental stress;
— the right whale, piping plover, and other species of wildlife are endangered or declining;
— populations of some commercially valuable fish species depend upon an increasingly limited number of age classes, and some may not be reproducing themselves at all;

Peter Ralston/Island Institute

**"We need to stop looking at environmental issues as though they were court cases. We need, instead, to think of ourselves as homeowners buying insurance. You don't insure against the absolutely predictable. You protect agains the possible. Nor do you wait to establish causality. You recognize that ownership — and stewardship over the environment — involves risk-taking. So defend yourself against large and irreversible damages."** RUSHWORTH KIDDER

Jim Rollins, Bigelow Lab

Maine State Planning Office

*The first Gulf-wide shoreline cleanup was held in the fall of 1989.*

Maine Critical Areas Program

— apply the concept of sustainable us to the management of the Gulf's ocea and coastal resources;

— reverse the trend of shellfish closures by controlling sewage discharges to coastal waters;

— abate and prevent nonpoint sourc pollution by managing land use activities that introduce contaminants to the Gulf;

— abate and prevent point source pollution by eliminating combined sewer overflows, developing and implementing more effective wastewater treatment technology, and enforcing industrial pretreatment;

— control disposal of persistent plastics and litter;

— identify habitats of Gulf-wide significance that should be protected as marine sanctuaries, including wetlands, and habitat for threatened marine mammals, birds, fish, and other living resources;

A broad-based understanding of th ecological and economic values of the Gulf is essential for the improved stewardship of the Gulf. To increase public awareness, it will be necessary t improve *public education*, to:

— develop curriculum supplements, school programs, videotapes, public service announcements, brochures, and public participation programs;

Peter Ralston/Island Institute

— compile fisheries and other statistics on a Gulf-wide basis, and make them readily available;
— publish a popularized version of a Gulf of Maine atlas;
— conduct annual, Gulf-wide shoreline cleanups;
— develop a citizen's guide to environmentally sensitive land use practices.

Effective management of the Gulf will require ongoing *cooperative research* on the structure and function of the Gulf ecosystem as well as on the effects of pollution, habitat loss, and other stresses. To improve our understanding of the Gulf, it will be necessary to:

— establish regional research priorities, standardized sampling and analytical methods, and a cooperative research strategy;
— conduct research on the sources and fates of contaminants in the Gulf ecosystem and develop techniques for assessing their ecological and cumulative effects;
— evaluate indicators of chronic contaminant effects and hazards to human health;
— conduct research that identifies favorable approaches to resolving the Gulf's pressing management issues.

Much is already being done to protect and enhance the Gulf environment. Billions of dollars are being invested in expanding and improving sewage treatment. To restore populations of salmon and other fish, millions of smolts are released in the Gulf's estuaries each year and fish ladders are being installed in many dams. Hundreds of volunteers have participated in shoreline cleanup efforts; the first Gulf-wide cleanup was held in the fall of 1989.

Many are also capitalizing on sound opportunities to benefit from the Gulf's resources: aquaculture and tourism are representative of new and expanded economic activities that thrive on a healthy environment and are prepared to meet the challenge of sustainable development.

The future depends on our ability to foster partnerships that bridge the Gulf, to fathom the complexity of its ecosystem, and to mitigate the stresses we impose upon it. The rewards of such endeavors will be immense; the consequences of complacency, if we do not act, will be equally great.

# References


**Chapter One**

Apollonio, S., 1979. *The Gulf of Maine.* Courier-Gazette, Inc., Rockland, Maine.

Berrill, M., and D. Berrill, 1981. *The North Atlantic Coast: Cape Cod to Newfoundland.* Sierra Club Books, San Francisco.

Cerulo, M., and W. Hancock, 1986. "The Mixing of the Waters: An introduction to the oceanography of the Gulf of Maine." *Habitat*, Vol. 3, No. 7, August 1986, pp. 16-21.

Doggett, L., and J. Sowles, 1989. *Maine's Marine Environment: A Plan for Protection.* Report to 114th Legislature, Maine Department of Environmental Protection, Bureau of Water Quality Control, Augusta, Maine.

Emery, K.O., 1987. "Georges Cape, Georges Islands, and Georges Bank." in: Backus, R.P., and D.W. Bourne, (Eds.). *Georges Bank.* MIT Press, Cambridge, Massachusetts, pp. 38-39.

Fefer, S.I., and P.A. Schettig, 1980. *An Ecological Characterization of Coastal Maine Northeast of Cape Elizabeth, Vol. 2.* U.S. Department of Interior, Fish & Wildlife Service, Northeast Region (FWS/OBS-80/29), Newton Corner, Massachusetts.

Jacobson, H.A., G.L. Jacobson, Jr., and J.T. Kelley, 1987. "Distribution and Abundance of Tidal Marshes Along the Coast of Maine". *Estuaries*, Vol. 10, No. 2, pp. 126-131.

New England Fishery Management Council and Mid-Atlantic Fishery Management Council. 1985. "Fishery Management Plan Environmental Impact Statement, Regulatory Impact Review, and Initial Regulatory Flexibility Analysis for the Northeast Multi-Species Fishery," Saugus, Massachusetts.

_________________________. 1986. "Supplemental Fishery Management Plan," Saugus, Massachusetts.

Rosenfeld, M., M. George, and J.M. Therune, 1988. "Evidence of Autumnal Harbor Seal, *Phoca vitulina*, Movement from Canada to the U.S.," *Canadian Field-Naturalist*, Vol. 102, No. 3, pp. 527-29.

Sherman K., M. Grosslein, D. Mountain, D. Busch, J. O'Reilly, and R. Theroux. "The Continental Shelf Ecosystem Off the Northeast Coast of the United States." In: Postma, H., and J.J. Zijlstra, Elsevier. 1988. "Ecosystems of the World." *Continental Shelves*, 27.

Strategic Assessment Branch, 1989. *National Estuarine Inventory Data Atlas, Vol. 3: Coastal Wetlands — New England Region.* National Oceanic and Atmospheric Administration, Rockville, Maryland.

Uchupi, E., and J.A. Austin, Jr., 1987. "Morphology." in: Backus, R.P., and D.W. Bourne, (Eds.). *Georges Bank.* MIT Press, Cambridge, Massachusetts, pp. 25-30.

Winn, H.E., J.H.W. Hain, M.A.M. Hyman, and G.P. Scott, 1987. "Whales, Dolphins, and Porpoises," in: Backus, R.P., and D.W. Bourne, (Eds.). *Georges Bank*, MIT Press, Cambridge, Massachusetts, pp. 375-382.

**Chapter Two**

Bernstein, R. "Maine Divers Jump into the Urchin Roe Market." *National Fisherman*, May 1989, pp. 14-17.

Center for Marketing Research, 1986. *Maine Tourism Study 1984-85, Vol. II: Economic Analysis*. Prepared for Maine State Development Office, Univ. of Wisconsin-Parkside, Kenosha, Wisconsin.

Charles River Associates, 1988. *Cape Cod Economic Analysis Input– Output Model.* Cambridge, Massachusetts.

Colgan, C.S., 1988. "Waste Disposal Issues in the Gulf of Maine," in: *Conference Proceedings on the Value of the Gulf of Maine*, Portland, Maine, October 28, 1988.

Dominie, H., and J. Scudder, 1987. *Land Use and Cumulative Impacts of Development: A Study Summary.* Maine State Planning Office, Augusta, Maine.

DPA Group, Inc., 1987. *Georges Bank, Canadian Fisheries, and Proposed Oil and Gas Exploration.* Final report prepared for the Gulf of Maine Advisory Committee, Dartmouth, Nova Scotia.

_________________________, 1988. *Georges Bank: Proposed Oil Exploration and Concerns for New Brunswick's Fisheries and Marine Environment*. Prepared for New Brunswick Department of Fisheries, Fredericton, New Brunswick.

Eaton, P.B., L.P. Hildebrand, and A.A. d'Entremont, 1986. *Environmental Quality in the Atlantic Region 1985.* Environment Canada, Environmental Protection Service, Atlantic Region, Dartmouth, Nova Scotia.

Elder, R.D., 1989. "Analysis of 1988 Cargo at Maine Ports." Maine Department of Transportation, Memorandum.

Enright, C., 1989. "Aquaculture in Nova Scotia." Nova Scotia Fisheries, Halifax, Nova Scotia.

"Announcement of Stellwagen Bank (Massachusetts) as an Active Candidate for Designation as a National Marine Sanctuary: Intent to Prepare a Draft Environmental Impact Statement and Management Plan; Public Scoping Meeting. "*Federal Register*, Vol. 54, No. 74, April 19, 1989. pp. 15787-15790.

Ferland, J.G., J.A. Wilson, and C.R. Newell, 1989. "State of Maine Aquaculture Development Strategy: Preliminary Draft." Maine State Planning Office, Augusta, Maine.

Fiander-Good Associates, Ltd., and Washburn & Gillis Associates, Ltd., 1988. "Economic Assessment of Salmonid Cage Culture Industry in Southwestern New Brunswick." Fredericton, New Brunswick.

Kelley, J.T., A.R. Kelley, and O.H. Pilkey, Sr., 1989. *Living with the Coast of Maine.* Duke University Press, Durham, North Carolina.

Maritime Research Management Service, 1982. *Nova Scotia Fisheries Atlas.* Prepared for Nova Scotia Department of Fisheries, Halifax, Nova Scotia.

Massachusetts Port Authority, 1988. "Year End Report: 1988." Boston, Massachusetts.

National Marine Fisheries Service, "Commercial Fishery Landings by State, 1981-1988," Resource Statistics Division, Wood Hole, Massachusetts.

New England Fishery Management Council and Mid-Atlantic Fishery Management Council, 1985. "Fishery Management Plan, Environmental Impact Statement, Regulatory Impact Review, and Initial Regulatory Flexibility Analysis for the Northeast Multi-Species Fishery," Saugus, Massachusetts.

________________, 1986. "Supplemental Fishery Management Plan," Saugus, Massachusetts.

Reiser, A., J. Spiller, and D. VanderZwaag, 1986. "Environmental Decisionmaking in a Transboundary Region." *Lecture Notes on Coastal and Estuarine Studies,* Vol. 20, Springer-Verlag, New York.

U.S. Army Corps of Engineers, 1987. *Waterborne Commerce Report, Vol. I: North Atlantic Region.* Waltham, Massachusetts.

U.S. Department of Commerce, 1986. "Marine Recreational Fishery Statistics Survey, Atlantic and Gulf Coasts, 1985." Current Fisheries Statistics No. 8327, Washington, D.C.

U.S. Department of the Interior, 1988. *North Atlantic Oil & Gas Lease Sale 96. Draft Environmental Impact Statement,* Minerals Mangement Service, MMS 88-0001, Vienna, Virginia.

**Chapter Three**

Arbuckle, J., and M. Lee, 1987. *The Cumulative Impacts of Development in Maine: A Study of Habitat Changes in Five Coastal Towns.* Maine State Planning Office, Augusta, Maine.

Arthur Lerman Associates, and the Mahoosuc Corp., 1982. "A Dredge Management Study for Maine Phase II: A Dredge Management Mechanism." Maine State Planning Office, Augusta, Maine.

Befort, W., A.E. Luloff, and M. Morrone, 1987. "Land Use Change: Rockingham County, New Hampshire 1953-1982." New Hampshire Agricultural Experiment Station, Research Report No. 112, Univ. of New Hampshire, Durham.

"Canada, US to jointly test gear," *Sou'wester,* June 1, 1989.

Colgan, C.S., and S.J. Adams, 1989. "Economic Growth Trends on the Gulf of Maine Littoral." Maine State Planning Office. In press.

Cohen, E.B., and R.W. Langton, 1989. "The Ecological Consequences of Change in Fish Stocks Due to Fishing in the Gulf of Maine." Northeast Fisheries Center and Maine Department of Marine Resources. In press.

Crawford, J., 1987. "The DAMOS Program." *Environmental Effects of Dredging,* U.S. Army Corps of Engineers Information Exchange Bulletin, Vol. D-87-2, Waltham, Massachusetts.

Doggett, L., and J. Sowles, 1989. *Maine's Marine Environment: A Plan for Protection.* Report to the 114th Legislature, Maine Department of Environmental Protection, Bureau of Water Quality Control, Augusta, Maine.

Dominie, H., and J. Scudder, 1987. *Land Use and Cummulative Impacts of Development: A Study Summary.* Maine State Planning Office, Augusta, Maine.

Eaton, P., L.P. Hildebrand, and A.A. d'Entremont, 1986. *Environmental Quality in the Atlantic Region 1985.* Environment Canada, Environmental Protection Service, Dartmouth, Nova Scotia.

Environment Canada, 1987. *A Profile of Important Estuaries in Atlantic Canada.* Environmental Quality Division, Dartmouth, Nova Scotia.

Gordon, D.C. (Ed.), 1988. "An Assessment of the Possible Environmental Impacts of Exploratory Drilling on Georges Bank Fishery Resources." Canadian Technical Report of Fisheries and Aquatic Sciences No. 1633, Department of Fisheries & Oceans, Bedford Institute of Oceanography, Dartmouth, Nova Scotia.

Hankin, A.L., L. Constantine, and S. Bliven, 1985. *Barrier Beaches, Salt Marshes, and Tidal Flats: An Inventory of the Coastal Resources of the Commonwealth of Massachusetts.* Lloyd Center for Environmental Studies, South Dartmouth, Massachusetts.

Kaltofen, M., and I. Kessel, 1989. *Boston Harbor Toxics Project: Third Annual Report on Toxic Discharges into Boston Harbor.* National Toxics Campaign, Boston, Massachusetts.

Kelley, J.T., A.R. Kelley, and O.H. Pilkey, Sr., 1989. *Living with the Coast of Maine.* Duke University Press, Durham, North Carolina.

MacConnell, W., 1975. "Remote Sensing 20 Years of Change in Massachusetts, 1951/52-1971/72." Mass. Agricultural Experiment Station, Research Bulletin No. 630, Univ. of Massachusetts, Amherst.

Maine Geological Survey, 1989. "Global Warming: Maine's Experience." Department of Conservation, National Governors' Conference on Global Warming, February 28, 1989.

Management Committee, Massachusetts Bays Program, 1989. "Massachusetts Bays Nomination Package for the National Estuary Progam," Boston, Massachusetts.

MIT Sea Grant, 1989. "Sleuths Stalk Pollutants in Massachusetts Bay." *Quarterly Report,* Vol. 11, Issue 1, Cambridge, Massachusetts.

National Oceanic and Atmospheric Administration, 1982. "Individual Pipe Records from Facilities in Maine, New Hampshire, and Massachusetts." Data from the original National Coastal Pollutant Discharge Inventory facility file, U.S. Dept. of Commerce, NOAA, Strategic Assessment Branch.

____________________, 1988. "Individual Facility Records for Maine, New Hampshire, and Massachusetts." Data from the Permit Compliance System file, U.S. Dept. of Commerce, NOAA, Strategic Assessment Branch, Rockville, Maryland.

New England Fishery Management Council and Mid-Atlantic Fishery Management Council, 1985. "Fishery Management Plan, Environmental Impact Statement, Regulatory Impact Review, and Initial Regulatory Flexibility Analysis for the Northeast Multi-Species Fishery," Saugus, Massachusetts.

New England River Basins Commission, 1981. "Dredging Management: Data and Analysis for the New England/Long Island Sound Region." Technical Assistance Report, Dredging Management Program, Boston, Massachusetts.

Office of Technology Assessment, 1984. *Wetlands: Their Use and Regulation.* U.S.Congress, OTA-0-206, Washington, D.C.

O'Hara, K.J., R. Bierce, and P. Debenham, 1988. "Trash on America's Beaches: A National Assessment."Center for Marine Conservation, Washington, D.C.

Pait, A.S., D.R.G. Farrow, J.A. Lowe, ad P.A. Pacheco, 1989. *Agricultural Pesticide Use in Estuarine Drainage Areas.* The National Coastal Pollutant Discharge Inventory, NOAA. Rockville, Maryland.

Parametrix, 1989, Draft Programmatic EIS, Fish Culture and Floating Net Pens, prepared for Washington State Department of Fisheries.

Reiser, A., J. Spiller, and D. VanderZwaag, 1986. "Environmental Decisionmaking in a Transboundary Region." *Lecture Notes on Coastal and Estuarine Studies,* Vol. 20, Springer-Verlag, New York.

Ricketts, P.J., and J. Hutchings, 1986. "Major Energy Projects in the Gulf of Maine Region," In: Reiser, A., J. Spiller, and D. VanderZwaag, 1986. "Environmental Desicionmaking in a Transboundary Region." *Lecture Notes on Coastal and Estuarine Studies,* Vol. 20, Springer-Verlag, New York.

Smolowitz, R.J., 1983. "Fisheries Engineering and its Role in Resource Management." Reprint from *Marine Technology Society Journal,* Vol. 17, No. 1

____________________, and F.M. Serchuk, 1988. "Marine Fisheries Technology in the United States: Status, Trends and Future Directions." In: *Proceedings of the Oceans '88 Conference,* Baltimore, Maryland, Oct. 31-Nov. 2, 1988.

Stevens, L.. "Gillnetters have Frequent Marine Mammal Take." *Commercial Fisheries News,* March 1989, p. 10.

U.S. Environmental Protection Agency and National Oceanic and Atmospheric Administration, November, 1987. "Strategic Assessment of Near Coastal Waters: Northeast Case Study, Interim Draft," Boston, Massachusetts.

Uthe, J.F., and V. Zitko, 1988. "An Overview of Marine Enviromental Quality Issues on the Atlantic Coast of Canada." In: Wells, P., and J. Gratwick, (Eds.), 1988. *Canadian Conference on Marine Environmental Quality: Proceedings.* Halifax, Nova Scotia,, pp. 199-202.

Waldichuk, M., 1988. "The Nature and Extent of Marine Contamination Caused by Land-Based Sources in Canada". In: Wells, P.G., and J. Gratwick, (Eds.). "Canadian Conference on Marine Environmental Quality: Proceedings", Halifax, Nova Scotia, pp. 75-135.

Wells, P.G., L. Harding, J. Karu, and G. Packman, 1987. "Marine Environmental Quality in Canada". Environment Canada, CH2498-4/87/0000, Dartmouth, Nova Scotia.

Widoff, L., 1988. *Maine Wetlands Conservation Priority Plan.* Maine Bureau of Parks & Recreation, Maine State Planning Office, Augusta, Maine.

**Chapter Four**

Angus, R.B., C.M. Hawkins, P. Woo, and B. Mullen, 1985. "Soft-shell clam survey of the Annapolis Basin, Nova Scotia - 1983." Canadian Manuscript Report of Fisheries and Aquatic Sciences, #1807, Halifax, Nova Scotia.

Backus, R.P., and D.W. Bourne, (Eds.), 1987. *Georges Bank.* MIT Press, Cambridge, Massachusetts.

Bird, P.M., and D.J. Rapport, 1986. *State of the Environment Report for Canada.* Canadian Government Publishing Centre, Hull, Quebec.

Card, D.J., L.T. Stockwell, E.S. Gilfillan, 1984. "Oil Pollution Research: 1984." Department of Enviromental Protection, Bureau of Oil and Hazardous Materials Control, Augusta, Maine.

Committee on Merchant Marine & Fisheries, 1988. "Coastal Waters in Jeopardy: Reversing the Decline and Protecting America's Coastal Resources". Oversight report, Serial No. 100-E, U.S. Government Printing Office, Washington, D.C.

Connell, D.W., and G.J. Miller, 1984. *Chemistry and Toxicology of Pollution.* John Wiley & Sons, New York.

Department of Fisheries, Wildlife, & Environmental Law Enforcement, 1985. *Massachusetts Marine Fisheries: An Assessment at Mid-Decade, November 1985.* Massachusetts Executive Office of Environmental Affairs, Boston, Massachusetts.

Doggett, L., and J. Sowles, 1989. *Maine's Marine Environment: A Plan for Protection.* Report to the 114th Legislature, Maine Department of Environmental Protection, Bureau of Water Quality Control, Augusta, Maine.

Dominie, H., and J. Scudder, 1987. *Land Use and Cumulative Impacts of Development: A Study Summary.* Maine State Planning Office, Augusta, Maine.

Eaton, P.B., L.P. Hildebrand, and A.A. d'Entremont, 1986. *Environmental Quality in the Atlantic Region 1985.* Environment Canada, Environmental Protection Service, Atlantic Region, Dartmouth, Nova Scotia.

Gaskin, D.E., undated. "Status Report on the Right Whale: *Eubalaena glacialis*," unpublished report to Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ontario, Canada.

Goldberg, E.D., M. Koide, V. Hodge, A.R. Flegal, and J. Martin, 1983. "U.S. Mussel Watch: 1977-1978 Results on Trace Metals and Radionuclides." *Estuarine, Coastal and Shelf Science,* Vol. 16, pp. 69-93.

Johnson, A.C., P.F. Larsen, D.F. Gadbois, and A.W. Humason, 1985. "The Distribution of Polycyclic Aromatic Hydrocarbons in the Surficial Sediments of Penobscot Bay (Maine, USA) in Relation to Possible Sources and to Other Sites." *Marine Environmental Research,* Vol. 15, pp. 1-16.

Larsen, P.F., and J.A. Topinka, (Eds.), 1984. "Fundy Tidal Power Development: Preliminary Evaluation of its Environmental Consequences to Maine." Technical Report No. 35, Bigelow Laboratory for Ocean Sciences, West Boothbay Harbor, Maine.

__________________, D.F. Gadbois, and A.C. Johnson, 1985. "Observations on the Distribution of PCBs in the Deepwater Sediments of the Gulf of Maine." *Marine Pollution Bulletin,* Vol. 16, No.11, pp. 439-442.

Lyons, W.B. and H.E. Gaudette, 1979. "Sediment Geochemistry of Jeffreys Basin, Gulf of Maine: Inferred Transport of Trace Metals." *Oceanologica Acta,* Vol. 2, No. 4, pp. 477-481.

Management Committee, Massachusetts Bays Program, 1989. "Massachusetts Bays Nomination Package for the National Estuary Program," Boston, Massachusetts.

Marine Environmental Quality Advisory Group. MS 1989. *Marine Environmental Quality in Canada - Status and Priorities*, Draft 2. Edited by P.G. Wells and S. Rolston. Conservation and Protection, Environment Canada, Ottawa.

National Marine Fisheries Service, 1983. "Fisheries of the United States, 1982". U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

National Oceanic & Atmospheric Administration, 1988. "A Summary of Selected Data on Chemical Contaminants in Sediments Collected During 1984, 1985, 1986, and 1987." NOAA Technical Memorandum NOS-OMA-44, U.S. Department of Commerce, Rockville, Maryland.

National Oceanic & Atmospheric Administration, 1989. *Status of the Fishery Resources Off the Northeastern United States for 1988*, NOAA Technical Memorandum, NMFS-F/NEC-63, U.S. Department of Commerce, Woods Hole, Massachusetts.

New Hampshire Department of Environmental Services, Department of Health and Human Services, and Department of Fish and Game, 1989. "Interagency Report on the Shellfish Waters of New Hampshire." Concord, New Hampshire.

Nisbet, I.C.T. and L.M. Reynolds, 1984. "Organochlorine Residues in Common Terns and Associated Estuarine Organisms, Massachusetts, USA, 1971-1981." *Marine Environmental Research*, Vol. 11, pp. 33-66.

Noble, D.G. and J.E. Elliott, 1986. *Environmental Contaminants in Canadian Seabirds, 1968-1984: Trends and Effects.* Technical Report Series No. 13, Canadian Wildlife Service, Ottawa, Ontario.

Rivard, D., W.D. McKone, and R.W. Elner, 1988. *Resource Prospects for Canada's Atlantic Fisheries, 1989-1993.* Department of Fisheries & Oceans, Ottawa, Ontario.

Rubec, C.D.A., P. Lynch-Stewart, G.M. Wickware, and I. Kessel–Taylor, 1988. "Wetlands Utilization in Canada." Reprint from *Wetlands in Canada*, National Wetlands Working Group, Canada Committee on Ecological Land Classification, Polyscience Publications, Inc., Canada.

U.S. Environmental Protection Agency, 1989. *Region I Near Coastal Waters Strategy.* Draft February 1989, Region I, Boston, Massachusetts.

Widoff, L., 1988. *Maine Wetlands Conservation Priority Plan.* Maine Bureau of Parks & Recreation, Maine State Planning Office, Augusta, Maine.

Wilson, R.C.H., and R.F. Addison, (Eds.), 1984. *Health of the Northwest Atlantic.* Department of the Environment, Department of Fisheries & Oceans, Dartmouth, Nova Scotia.

### Suggested Readings

Apollonio, S., 1979. *The Gulf of Maine.* Courier-Gazette, Inc., Rockland, Maine.

Backus, R.P., (Ed.), 1987. *Georges Bank.* MIT Press, Cambridge, Massachusetts.

Berrill, M., and D. Berrill, 1981. *The North Atlantic Coast: Cape Cod to Newfoundland.* Sierra Club Books, San Francisco.

Bigelow, H.B., and W.C. Schroeder, 1953. *Fishes of the Gulf of Maine.* U.S. Fish & Wildlife Service.

Eaton, P.B., L.P. Hildebrand, and A.A. d'Entremont, 1986. *Environmental Quality in the Atlantic Region 1985.* Environment Canada, Environmental Protection Service, Atlantic Region, Dartmouth, Nova Scotia.

Doggett, L., and J. Sowles, 1989. *Maine's Marine Environment: A Plan for Protection.* Report to the 114th Legislature, Maine Department of Environmental Protection, Bureau of Water Quality Control, Augusta, Maine.

Kelley, J.T., A.R. Kelley, and O.H. Pilkey, Sr., 1989. *Living with the Coast of Maine.* Duke University Press, Durham, North Carolina.

# Glossary

**Aquaculture** - the organized cultivation of marine plants and animals for human use and consumption.

**Benthic** - bottom-dwelling.

**Biomass** - the weight of all or selected living material in a unit area at a given instant in time.

**Copepods** - herbivorous, microscopic crustaceans on which many larger fish and other marine animals feed.

**Cumulative Impacts**-those impacts on the environment that result from the incremental impacts of an activity when added to the impacts of other past, present, or foreseeable future activities.

**Demersal** - living on or near the sea bed.

**Diadromous** - fish that migrate between freshwater and saltwater to spawn (salmon, shad, striped bass, alewives, herring).

**Ecosystem** - a community of living plants and animals that interact with one another and their physical environment. The entire Gulf of Maine can be considered as a single ecosystem comprised of many interconnected ecosystems such as rivers, bays, estuaries, beaches, and islands.

**Effluent** - any matter that enters the environment from a specific source; the term generally refers to waste water from a sewage treatment or industrial plant.

**Estuary** - any confined coastal water body which acts as a transition zone between fresh- and saltwater.

**Eutrophication** - an increase in the concentration of nutrients in bodies of water due to natural causes, human influence, or a combination of both; the resulting increase in productivity of aquatic plants depletes dissolved oxygen, reduces water quality, and kills aquatic organisms.

**Gyre** - a circular flow of water.

**Nonpoint Source** - dispersed sources of pollution that do not enter the water at discrete or identifiable locations.

**Pathogens** - substances which cause disease.

**PAHs** - polycyclic aromatic hydrocarbons are cancer-causing substances that are released during the combustion of wood and petroleum products, and other materials. PAHs enter the aquatic environment through fallout, surface runoff, or industrial effluents.

**PCBs** - polychlorinated biphenyls; nondegradable liquids used in electrical transformers, capacitors, adhesives, lubricants, etc. that are of enviromental concern due to their wide dispersal, chronic toxicity, and their ability to accumulate in the food chain. PCBs are no longer manufactured, but are still in use.

**Pelagic** - living in the water column

**Persistent** - compounds that are not readily degradable by physical, chemical, or biological processes.

**Point Sources** - direct discharge of pollutants into the water by a single source of conveyance, such as a pipe from a sewage treatment plant or a factory.

**Productivity** - rate of formation of organic matter averaged over some determined period of time, such as a day or year.

**Recruitment** - number of young annually added to a population.

**Red Tide** - the concentration of certain toxin-producing dinoflagellates (microscopic plankton) which contaminate filter–feeding shellfish.

**Salt Marsh** - a saltwater wetland characterized by non-woody vegetation such as grasses and sedges.

**Sublethal** - below the concentration that directly causes mortality. Exposure to sublethal concentrations of substances may impact an organism by lowering its ability to fight disease, feed, reproduce, or escape predators.

**Wetland** - land in which the soil is saturated throughout the year and supports aquatic and semi-aquatic vegetation.

**Zooplankton/Phytoplankton** - minute forms of animal/plant life which swim or drift in aquatic environments.