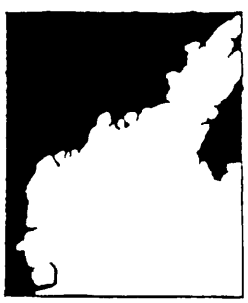
GULF OF MAINE

ENVIRONMENTAL QUALITY MONITORING PROGRAM: An Initial Plan



Gulf of Maine Council on the Marine Environment
June 1991

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EXECUTIVE SUMMARY

The Gulf of Maine is no longer entirely pristine. 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 pathogens to marine and estuarine waters on a chronic, and at times, acute, basis. Increased fishing effort has reduced some fish stocks to all time lows. Coastal development has encroached on environmentally significant marine wetlands. Accidental spills of oils and other toxic material place additional stresses upon the Gulf environment.

To understand and manage the impact of such stresses on the health of the Gulf ecosystem requires accurate understanding of the nature, scale, and impact of environmental perturbations in the Gulf. As a step toward generating the requisite information, the Gulf of Maine Council on the Marine Environment has established a tightly focused and pragmatic environmental quality monitoring plan for the Gulf of Maine, presented in this report. The report is based largely upon a draft prepared for the Council by Camp Dresser and McKee, The Mainewatch Institute and the Research and Productivity Council of New Brunswick (Camp Dresser & McKee, Inc., et al, 1990).

The Gulf of Maine Council on the Marine Environment was established by the Governors of Maine, Massachusetts and New Hampshire, and the Premiers of Nova Scotia and New Brunswick to improve the environmental management of the Gulf of Maine.

The Council has identified assessment of the health of the Gulf as of pressing importance. The Council initiated development of a monitoring program as a first step toward improving environmental management of the Gulf, envisioning a program that will allow evaluation of environmental quality of the Gulf while improving the effectiveness of prevention and remediation efforts.

The monitoring plan is based on a mission statement provided by the Council:

> In support of the Agreement on Conservation of the Marine Environment of the Gulf of Maine, it is the mission of the Gulf of Maine marine environmental quality Monitoring Program to provide environmental and resource managers with information to support sustainable use of the Gulf, and allow assessment and management of risk to public and environmental health from current and potential threats.

The Council charged the Gulf of Maine Working Group, the management component of the Council, and its Monitoring Committee with identifying the environmental quality issues of greatest importance to the Gulf States and Provinces and with developing a monitoring plan leading to a Monitoring Program to address these issues.

As part of this process, a workshop was held in Halifax in early June, 1990 to review a draft report on the proposed Monitoring Program. Scientists, environmental managers and policy-makers from throughout the Gulf region worked together to develop consensus on goals and objectives and to begin the process of identifying priorities and selecting appropriate monitoring methodologies. The current document reflects the results of the workshop. In addition, the plan was reviewed at a the Gulf of Maine Scientific Workshop, held in Woods Hole, Massachusetts, in January, 1991 and at the Canadian Marine Environmental Quality Monitoring Symposium, held in November, 1990.

Three monitoring goals were established:

- *To provide information on the status, trends, and sources of risks to the marine environment in the Gulf of Maine.*

The four objectives developed to meet this goal address indicators of change in environmental quality, the ecological viability of harvested stocks, the identification of causes of degradation and the impacts of environmental catastrophes.

- *To provide information on status, trends, and sources of marine-based human health risks in the Gulf of Maine.*

The three objectives developed to meet this goal address public health risks from pathogens, toxins and biotoxins.

- *To provide appropriate and timely information to environmental and resource managers that will allow both efficient and effective management action and evaluation of such action.*

The three objectives developed to meet this goal address the timely generation of data and information useful to managers and assessment of management actions.

To narrow the scope of the monitoring plan the objectives were ranked in order of importance; the plan was developed to address only the top two objectives. The remaining objectives will be addressed as the Program is implemented and resources are available. In order to rank the priority of the monitoring goals and objectives, a survey was mailed to over 150 scientists, environmental managers, policy makers, and others in the Gulf. The rankings were further discussed at the workshop in Halifax. The two objectives with the highest priority were:

1. To assess the status and trends in the marine environment by monitoring appropriate indicators of change in environmental quality, especially those that will allow identification of the early stages of change.

2. To assess the existing levels, the trends, sources, and economic impacts of acute and chronic risks to human health from toxic compounds transmitted through marine foods and water contact.

Although objectives related to the third goal, effective transfer of information, were included in the survey, workshop participants felt that they could not be ranked along with objectives addressing monitoring activities. Participants felt strongly that this goal should have high priority and that all existing environmental data on the Gulf must be organized, assessed for quality, and made accessible to a wide range of users.

The monitoring plan described in this report outlines only suggested monitoring methods needed to meet the three highest priority monitoring objectives. It then identifies ongoing monitoring programs in the Gulf that are addressing these objectives.

The Monitoring Committee of the Working Group intends this document to establish the broader goals and objectives of a Gulf-wide environmental quality Monitoring Program as the first step in the development of such a program. Further implementation of the Monitoring Program will require identifying gaps in existing monitoring activities, establishing specific monitoring methodologies, setting acceptable levels of precision and accuracy, and developing detailed sampling designs which specify the number of samples to be collected, the exact locations, and the laboratory procedures to be used for analyzing the samples. These are details best left to practitioners in the field to develop consensus on appropriate methodologies and recommend adoption by the Monitoring Program. It is anticipated that several ad hoc committees will be formed to identify specific, implementable monitoring methodologies for the priority objectives identified in the plan. The Monitoring Program will be established as the plan is implemented; in the course of development it will be reviewed and revised as appropriate.

The plan includes identification of the proposed areas where monitoring should take place and the estimated cost of monitoring the appropriate variables. In all cases cost estimates are based on the assumption that the private sector will do the work. It is estimated that monitoring a broad range of indicators to meet the first objective (assessing changes in marine environmental quality) will cost $3,000,000 US annually in the Gulf. This assumes that existing monitoring programs can be modified as needed to collect the appropriate data in their current study areas. The estimated cost for collecting the information needed to meet the second objective (assessing human health risks from toxics) is estimated to be $560,000 US annually. This cost estimate, however, is based on only monitoring the risks of mercury and PCBs, the two of only three toxic compounds for which standards in foods have been developed (PSP is the third). There is a major need to fund additional research to understand the human health risks from other toxic compounds. The costs for meeting the third objective (identifying causes) cannot be estimated at present because the area and scale of environmental changes have not yet been identified.

The plan also outlines four additional aspects of a monitoring program:

- The procedures to facilitate the transfer of information between the scientists analyzing the monitoring data and the environmental managers who will be using the information to develop management actions,

- A possible organizational structure for the monitoring program,

• Guidelines for developing a database for storing the information collected by the monitoring program, and

• An implementation plan incorporating a pilot program utilizing the blue mussel as an indicator organism.

As a strategy for implementation, the plan will build on monitoring activities currently underway in the Gulf. For example, it is anticipated that the Status and Trends Program of the U.S. National Oceanic and Atmospheric Administration will be expanded to answer questions about the health of the larger Gulf ecosystem. Gaps in existing programs will be identified and new programs designed. In addition, the plan will integrate local problems, such as shellfish closures, that occur throughout the Gulf region. Data collected from coastal embayments on toxic contamination, nutrient enrichment, and shellfish and beach closures will be augmented by similar data collected in other industrialized embayments along the Gulf shore. It is our hope that this collective approach will yield better solutions to problems encountered or anticipated in such areas.

The success of this endeavor will depend on:

* the cooperation of States, Provinces and federal agencies in adapting existing monitoring programs to serve the objectives of the Gulf program as well as their own objectives;

* funding for new monitoring to fill gaps identified in existing monitoring activities;

* regional coordination to provide guidance for the development and implementation of the program;

* a database management system that will allow information generated by the monitoring program to be readily available to environmental managers throughout the region; and

* links to a geographic information system such as the "FMG" project developed by Environment Canada, other Canadian federal departments, Universities and provincial agencies.

Implementation of the Monitoring Plan will require considerable time on the part of the Monitoring Committee. It is recommended that at least one full-time person, either funded by the Council or "on loan" from a participating agency, serve as staff to the Monitoring Committee in order to perform the following tasks:

* coordinate work of ad hoc subcommittees
* liaison with existing monitoring programs
* draft annual reports, and
* liaison with Working Group, Data and Information Management Commitee and Scientific Advisory Committee (if established by the Council).

The Monitoring Committee would like to thank all those who provided comments on the draft plan. Many thoughtful comments were received; they have been incorporated in the plan and have resulted in a very much improved final document.

The success of the Monitoring Program will depend upon the informed participation of monitoring professionals, other scientists, environmental managers, and policy-makers. The Monitoring Committee invites further comments on the implementation strategy for the Monitoring Program, incorporated as Section 7 of this document. Please forward your comments to the Monitoring Committee, c/o Maine State Planning Office, Station 38, Augusta, Maine 04333, so that they may be incorporated as the Monitoring Program is implemented and updated.

Gulf of Maine Monitoring Committee

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GULF OF MAINE ENVIRONMENTAL QUALITY MONITORING PLAN

FINAL REPORT

1.0 INTRODUCTION

The Gulf of Maine is a unique marine ecosystem defined by its physical, chemical, and biological conditions. It is a semi-enclosed sea, partially separated from the North Atlantic by underwater banks. With its rich bays and estuaries, extensive watersheds, and diverse ecological communities, the Gulf is one of the most productive marine ecosystems on earth. Many of its species migrate through the Gulf region paying no heed to political boundaries separating states, provinces, and nations. Thus, environmental problems and stresses in one area will affect ecological productivity and stability in other parts of the Gulf.

The Gulf of Maine is more than a productive ecosystem. Both Native American and colonial European cultures settling in the Gulf have been shaped by its environmental and natural resources. The resulting rich and diverse cultural heritage contributes to the region's quality of life. At present, it is home to a large and growing human population that is dependent on the Gulf's environmental quality and natural resources. The Gulf's economic, aesthetic, and recreational values are directly tied to its ecosystem.

The Gulf's ecosystem is under increasing and cumulative stress as human populations increase, and as related development expands in the Gulf of Maine. Pollution, habitat destruction, and overharvesting threaten the Gulf's human and environmental "health". Human health is threatened in some coastal areas by raw or partially treated sewage and industrial discharges. Toxic contaminants are found in the Gulf's deepest basins. Sediments in several of its harbors contain exceptionally high levels of toxic substances. Increased fishing effort has contributed to all time low numbers in some fish stocks, and coastal development has destroyed environmentally important wetlands. Native species such as the piping plover have become endangered because of steady and cumulative habitat loss. These problems threaten the Gulf's ecosystem and the livelihood and health of its people.

1.1 Gulf of Maine Council on the Marine Environment

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 agreed to a cooperative effort to protect the Gulf of Maine environment. An agreement signed by these five jurisdictions in December 1989 establishes a Gulf of Maine Council on the Marine Environment, recognizing that the ecological integrity of the Gulf of Maine supercedes all other interests. As a link between the many state, provincial, and federal agencies involved in the Gulf of Maine, the Council will facilitate ongoing and future efforts by the five jurisdictions to maintain and enhance the Gulf's marine ecosystem, its natural resources, and environmental quality. Specifically, the Council will provide assistance and coordination for research, monitoring, and management; dissemination of scientific data; improved state, provincial, and federal

communications; and heightened public awareness. A Working Group was established in 1989 to implement Council policy.

1.2 The Roles of Environmental Management and Monitoring

Early human cultures attempted to manage the natural environment and to use its resources on a predictable basis. Over time, as humans became more effective in manipulating natural environments and in harvesting their resources, unforeseen or detrimental impacts became apparent. Management then became necessary to reduce these impacts. Native Americans, for example, adopted hunting and fishing strategies to sustain game species as well as to harvest them. Early European settlers to New England sometimes managed fisheries by establishing seasonal and numerical limits. As human populations increased, their impacts on the natural environment have become more diverse and less predictable so that environmental quality and ecological integrity are now threatened on local, regional, national, international and even global levels.

Operational definitions of environmental management and monitoring are needed in order to develop a common conceptual framework. For the purposes of this plan, environmental management is defined as:

> "The process of protecting, maintaining, exploiting, restoring, and/or sustaining long term environmental quality, biodiversity, and natural resources by maintaining ecosystem integrity."

Modern environmental managers must address human and environmental health issues as well as resource needs. Management efforts have become increasingly focused on maintaining ecological integrity as a means of protecting environmental quality and natural resources.

Effective management, however, cannot be accomplished without environmental monitoring. At a time when single species resource harvesting was the major management concern, monitoring tasks were much more simple -- to estimate species populations, reproductive rates, and, perhaps, habitat requirements. Today, however, environmental monitoring has expanded in complexity and scope to address diverse management needs.

Questions raised by managers, which effective monitoring can help address, range from broad and long-term issues such as: what would be the consequences to the Gulf of Maine of extracting petroleum from Georges Bank, of a one meter rise in sea level, and of doubling the size of the human population in the Gulf region? to specific and short-term issues such as: what is the source of toxins found in Saint John Harbour sediments, are shellfish in Portland Harbor safe to eat, and is the environmental quality of Massachusetts Bay adversely affected by anthropogenic activities?

Information is needed in order to develop sound management approaches to these and other issues. Monitoring can provide information on the sources of disturbances and how they impact ecological integrity and resources, on the ecosystem and compnent resources themselves, and on how the disturbances are changing with time. It is the purpose of a

monitoring program to provide this necessary information to managers, scientists and policy makers.

The following definition of environmental monitoring was adapted from Environment Canada's definition of environmental effects monitoring (Anon. 1986):

> "A program of observations for the purpose of determining whether the presence, or change in the incidence, of a factor(s), has adversely affected human health, or critical biological processes, or the physical and/or chemical nature of an ecosystem."

Monitoring is an integral component of environmental management because it identifies the problems that need managing, assesses the significance of impacts on an ecosystem, and then assesses whether management actions taken are effective or if, in deed, management actions are indicated. The data acquired are needed for a number of different management functions. These include:

- To inventory ecological resources and define ecological integrity,
- To understand the status and trends in physical, chemical, and biological components of the ecosystem,
- To identify threats to resources and ecological integrity,
- To assess the significance of the threats,
- To establish the sources of the threats,
- To follow trends in both the resources and the threats, and
- To assess the effectiveness of management actions taken to reduce the threats.

Environmental monitoring is closely linked to environmental management and scientific research. The three activities are interactive and form a feedback loop. A diagram of how monitoring is integrated with management is shown in Figure 1.

Monitoring involves the assessment of the physical, chemical, and biological aspects of ecosystems to assess ecosystem integrity and how it changes in time. Because monitoring an ecosystem is extremely difficult, efforts are often focused on specific physical, chemical or biological indicators that are used as analogies for the entire system. Managers use this information to identify environmental problems.

Research is needed to improve understanding of anthropogenic change in environmental quality and of naturally occurring variablity; greater knowledge in these areas will improve the value of monitoring data and indicators. In turn, monitoring data can also be of use to scientists concerned with both basic and applied research. Beyond this, the monitoring plan does not make a distinction between research and monitoring. Monitoring can include both systematic assessment of primary and secondary variables and hypothesis testing.

If monitoring is to be a useful management tool, however, it has to fulfill other purposes as well. These include providing information on the disturbances that can cause changes in ecosystem integrity. Identifying feasible remedial actions is also an important part

of management. Finally, monitoring is needed to assess if specific management interventions are effective at reducing, or eliminating, the disturbances that are affecting ecosystem integrity.

1.3 Gulf of Maine Environmental Quality Monitoring Plan

1.3.1 Mission Statement

Recognizing that an overall monitoring plan is a necessary first step in improving environmental management in the Gulf, the Gulf of Maine Working Group established a Monitoring Committee charged with developing a Gulf of Maine environmental quality Monitoring Program. Their mission statement is as follows:

> *In support of the Agreement on Conservation of the Marine Environment of the Gulf of Maine, it is the mission of the Gulf of Maine environmental quality Monitoring Program to provide environmental and resource managers with information to support sustainable use of the Gulf, and allow assessment and management of risk to public and environmental health from current and potential threats.*

1.3.2 Goal Statement

The Committee, after a review of existing programs and much discussion, defined three goals for the Monitoring Program:

1. To provide information on the status, trends, and sources of risks to the marine environment in the Gulf of Maine.

2. To provide information on the status, trends, and sources of marine-based human health risks in the Gulf of Maine.

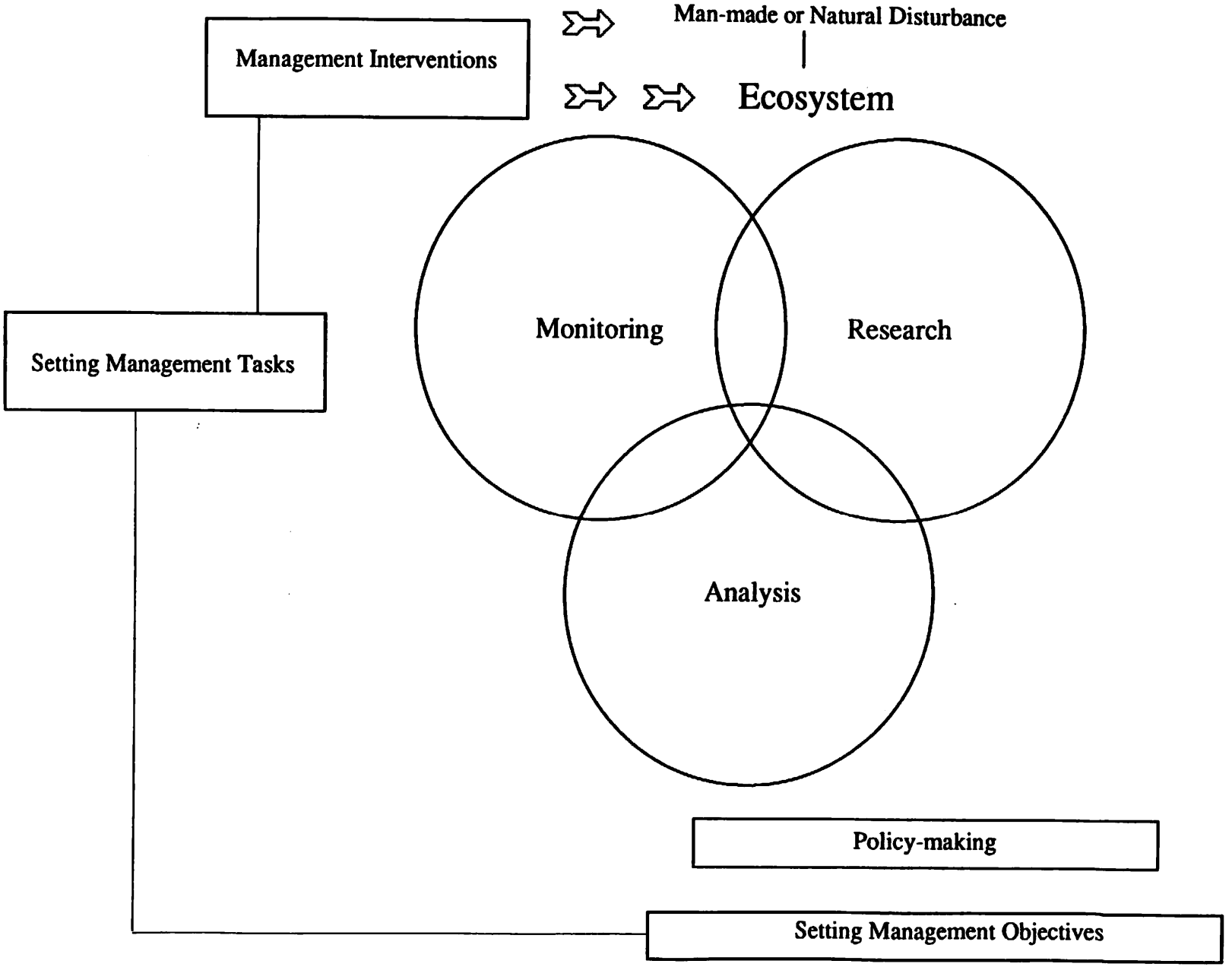


Figure 1 Integration of Monitoring & Research in Environmental Management

3. To provide appropriate and timely information to environmental and resource managers that will allow both efficient and effective management action and evaluation of such action.

This monitoring plan is based on goals and objectives developed in conjunction with the Gulf of Maine Working Group and modified during the Gulf of Maine environmental monitoring workshop held at St. Mary's University in Halifax on May 31 and June 1, 1990.

The plan has been designed to address the following needs:

1. Transboundary: To provide a blueprint and conceptual framework for "generic implementation" of the monitoring plan throughout the Gulf of Maine region across political boundaries. It should also provide a structure for standardizing monitoring methodology and data bases throughout the region.

2. Preventative: To provide for early warning of changes affecting human health, natural resources, and environmental quality so that preventative rather than crisis-oriented management actions may be taken.

3. Ecosystems-oriented: To address both tangible features of ecosystems such as species density and diversity, chemical and physical variables, and less tangible features such as energy flow and nutrient cycling.

4. Cooperative and consensus-building: To develop a plan with input from scientists, managers, and policy-makers who will be its ultimate users, and to foster improved communication and cooperation among these groups. Data should also be made available to scientists to facilitate their research.

5. Management emphasis: To emphasize the timely development of useful information for management decision-making, and for the evaluation and fine-tuning of management actions. Monitoring information must be "accessible" to managers and policy-makers while being scientifically sound and reliable.

6. Use of past and present monitoring efforts and information: To build upon existing efforts and data bases. It will also identify monitoring gaps and areas requiring additional research.

7. To design and implement the Program in such a way that citizens can play an active role in collecting data and evaluating results.

1.3.3 Review of the plan

This report presents the Gulf of Maine environmental monitoring plan. Ongoing monitoring efforts were identified through literature reviews; surveys of scientists, managers, and policy-makers in the Gulf of Maine; through a report produced by the Maine State Planning Office; and through discussions at the monitoring workshop held in Halifax. Ongoing monitoring programs and the methodologies they employ are summarized in Table 1.

Descriptions of several of these programs and the methodologies they employ are found in Maine State Planning Office, 1989. In addition to being a source of data and tested methodologies, many of these programs will, ideally, form the basis of the Monitoring Program. The Monitoring Program will be successful to the extent that it can build on existing activities.

EPA's recently initiated Environmental Monitoring and Assessment Program (EMAP) is not listed in Table 1. It is anticipated that EMAP will expand to the Gulf of Maine in the near future; it will be conducted jointly with NOAA's NS&T program but will focus more broadly on ecosystem health. New National Estuary Programs (also sponsored by EPA) in Massachusetts Bay and Casco Bay will also complement the Monitoring Program.

To be effective, information from the Gulf of Maine Monitoring Program must be readily available to scientists, managers, and policy-makers throughout the region. Suggestions for data management are outlined in Section 4 and suggestions for improving communication and information transfer are outlined in Section 5. These suggestions are based in part on survey results and discussions at the workshop.

Finally, this report contains suggestions for an organizational structure to support the Monitoring Program in Section 6 and suggestions for an implementation process in Section 7. A proposal for a pilot project to test the various aspects of the Program is also presented in Section 7.

The Plan is designed to provide an initial, general framework or blueprint for the Gulf of Maine Monitoring Program based on direction from the Working Group Monitoring Committee and initial input from 64 scientists, managers, and policy-makers. It has been circulated to scientists, managers, and policy-makers for their comments and then modified accordingly. Through the pilot project, critical implementation steps will be tested prior to broader implementation.

The plan, however, does not specify sampling design. This requires statistical and logistic considerations which cannot be specified at this stage in the planning process. Many locations have never been sampled for specific variability. Developing a statistically based sampling design is critical. Many monitoring efforts in the past have not provided the information for which they are established because the data were not statistically defensible (Rosenberg, et al., 1981; Hurlburt, 1984;, NRC, 1990).

1.4 Monitoring Objectives for the Gulf of Maine

Ten objectives have been identified. These are listed below, and form the basis of the monitoring plan described in the following sections.

TABLE 1

This table summarizes the ongoing monitoring programs in the Gulf of Maine that address contaminant and pathogen monitoring. All but four of the programs listed are taken directly from the inventory of monitoring programs done by the Maine State Planning Office ("Marine Environmental Quality Monitoring Programs in the Gulf of Maine: An Inventory", May 1989 DRAFT).

BHMP	Boston Harbor Monitoring Program, New England Aquarium, Northeastern University
Bowdoin	Maquoit Bay Monitoring Program, Bowdoin College, Brunswick, Maine
Cape Cod	Local Water Quality Monitoring Initiatives on Cape Code, Massachusetts
CDEP-S	National Shellfish Sanitation Program, Environment Canada
CWS-T	Toxic Chemicals in Canadian Seabirds, The Canadian Registry of Toxic Chemicals, Canadian Wildlife Service
DFO-PLEMP	Point Lepreau Environmental Monitoring Program, Fisheries & Oceans Canada
F&O-L'Etang	Monitoring of the L'Etang Inlet, Fisheries & Oceans Canada
F&O-PSP	Paralytic Shellfish Poisoning Monitoring Program, Fisheries & Oceans Canada
MA	North Shore Monitoring Program, Massachusetts Audubon Society
MaDEP-S	Massachusetts Shellfish Sanitation Program
MaDEP-PSP	Massachusetts Paralytic Shellfish Poisoning Monitoring Program
MeDMR-PSP	Maine Paralytic Shellfish Poisoning Monitoring Program
MeDMR-S	Maine Shellfish Sanitation Program
MMEMP	Maine Marine Environmental Monitoring Program
MWRA	Massachusetts Bay and Boston Harbor Monitoring, Massachusetts Water Resources Authority
NAQUADAT	National Water Quality Data Bank, Environment Canada
NCPDI	National Coastal Pollutant Discharge Inventory, NOAA
NHDHW-S	New Hampshire Shellfish Sanitation Program
NMFS	Fish Stock Assessments, NOAA/NMFS
NPS-Acadia	Acadia National Park Marine Monitoring Program
NS&T-B	Benthic Surveillance Project of the National Status and Trends Program for Marine Environmental Quality, NOAA
NS&T-MW	The Mussel Watch Project of the National Status and Trends Program for Marine Environmental Quality, NOAA
NURC	Benthic Monitoring Activities, National UnderSea Research Center
ODCA	Ocean Dumping Control Act Monitoring, Environment Canada
RIPS	Regional Inventory of Pollution Sources, Environment Canada
USFWS	Contaminants in Great Bay Shellfish, U.S. Fish & Wildlife Service
USGS	Water Resources Data, U.S. Geological Survey
USMMS	Hydrocarbons in Marine Mammals, U.S. Minerals Management Service

The questions which must be addressed when considering each objective can be categorized in terms of seven factors which include:

1) The variable to be monitored,
2) The sampling medium in which the variable is measured (i.e. soft bottom, hard bottom, tissue etc.),
3) The geographical scale/location where sampling should take place,
4) The field design required to provide the specified precision,
5) The field methods to be used to monitor the variable,
6) The type of data analyses needed to provide the information to answer the monitoring question, and
7) The timing of sampling for variables to be monitored.

A detailed treatment of the questions to be addressed by each objective is provided in Camp Dresser and McKee, et al., 1990.

An important part of the monitoring plan is to identify ongoing monitoring efforts and integrate them into a overall plan structure. Thus, current monitoring efforts that are addressing aspects of the objectives are also listed by the acronym of the sponsoring organization. A key to the acronyms is found in Table 1. The detailed description of ongoing programs and locations where monitoring is occurring is given in Maine State Planning Office, 1989. A summary is shown in Table 2.

1.4.1 Monitoring Objectives for Goal #1: Information on the Marine Environment

1.4.1.1 -- Assess the status and trends in the ecological viability of harvested species, and identify the causes of change, especially those that can be related to harvesting.

The ongoing programs addressing this objective are part of NMFS which samples fish populations along transects extending across the Gulf of Maine. These programs are among several US and Canadaian federal, state and provincial fish stock assessment programs.

1.4.1.2 -- Assess the status and trends in the environment by monitoring appropriate indicators of change in environmental quality, especially those that will allow identification of the early stages of change.

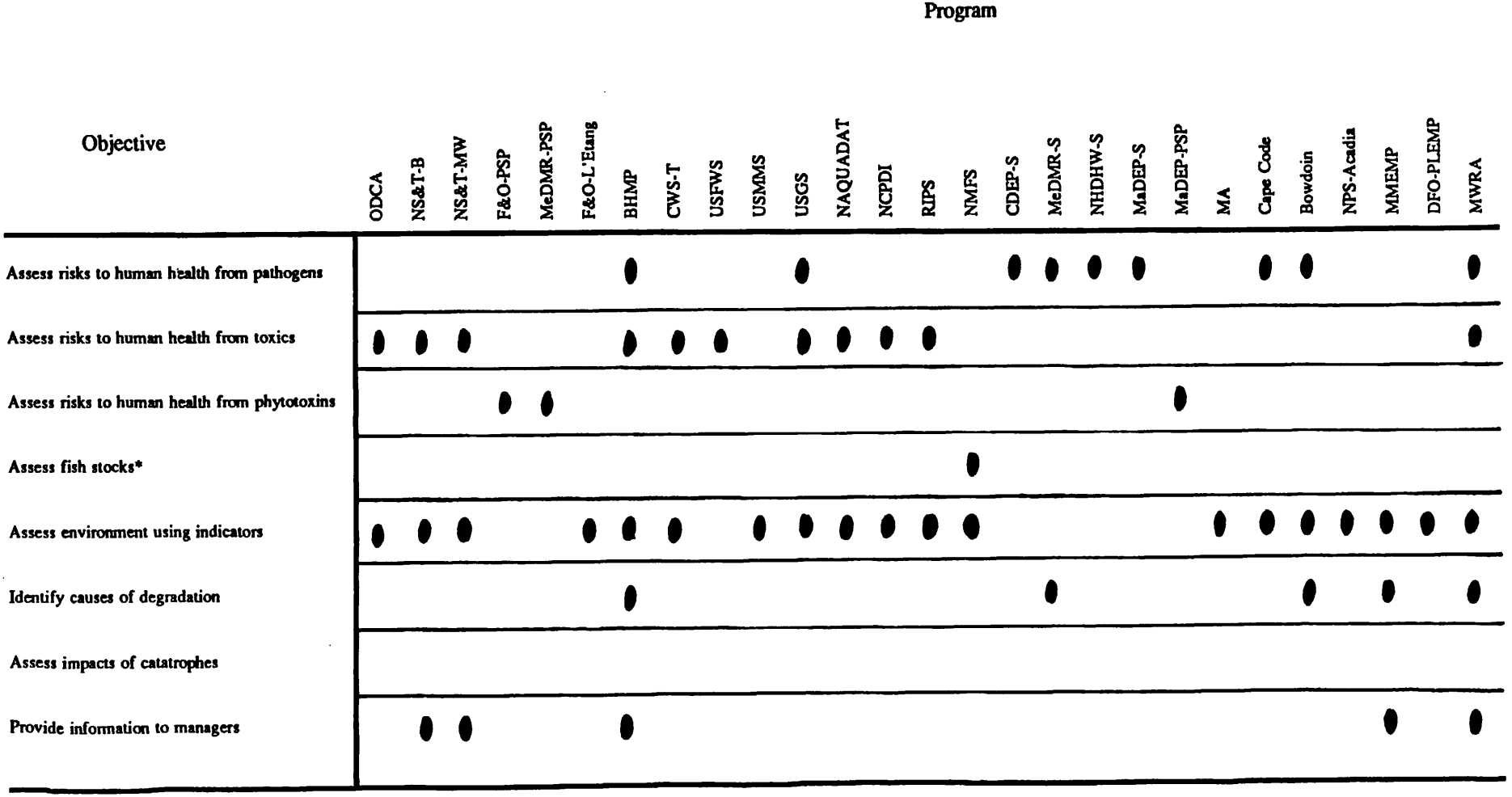
Ongoing programs addressing this objective include: MMEMP, ODCA, NS&T-B, NS&T-MW, F&O-L'Etang, BHMP, CWS-T, USMMS, USGS, NAQUADAT, NCPDI, NMFS, Cape Cod, MWRA and Bowdoin.

1.4.1.3 -- In cases where environmental degradation is suspected, identify the probable causes, especially as they reflect anthropogenic impacts and cumulative effects.

Site specific management programs focussed on identifying sources of degradation exist or are planned for Massachusetts Bay, Casco Bay and the L'Etang Estuary. Of the ongoing programs, BHMP and MWRA address this objective.

TABLE 2

Matrix showing which ongoing monitoring programs meet proposed Gulf of Maine monitoring objectives. Programs are identified by acronym which is described in Table 1.



*Many programs provide data on fish stocks in the Gulf of Maine; they are largely excluded from this table.

1.4.1.4 -- Assess the impacts of environmental catastrophes in relation to monitoring of existing conditions.

No ongoing programs are addressing this objective.

1.4.2 Monitoring Objectives for Goal #2: Information on Human Health Risks

1.4.2.1 -- Assess the existing levels, the trends, sources, and economic impacts of acute and chronic risks to human health from pathogens in the marine environment.

Ongoing programs addressing this objective include: USGS, CDEP-S, MeDMR-S, NHDHW, MaDEP-S, Cape Cod, Bowdoin, BHMP and MWRA.

1.4.2.2 -- Assess the existing levels, the trends, sources, and economic impacts of acute and chronic risks to human health from toxic compounds transmitted in the marine environment.

Ongoing programs addressing this objective include: ODCA, NS&T-MW, CWS-T, USFWS, USGS, NAQUADAT, NCPDI, BHMP and MWRA.

1.4.2.3 -- Assess the existing levels, the trends, sources, and economic impacts of acute and chronic risks to human health from biotoxins transmitted through marine foods.

Ongoing programs addressing this objective include: F&O-PSP, MeDMR-PSP, MaDEP-PSP.

1.4.3 Monitoring Objectives for Goal #3: Information Exchange

1.4.3.1 -- Provide information generated by monitoring activities to resource and environmental managers in a format that will allow risk assessment, assessment of catastrophes, and the design of appropriate rehabilitation, mitigation, damage avoidance, and other management actions.

No ongoing programs are addressing this objective although several programs including BHMP and MWRA have generated and disseminated data reports. MWRA is also developing a Geographic Information System for Massachusetts and Cape Cod Bays.

1.4.3.2 -- Provide timely analysis, interpretation and presentation of monitoring results; including analysis of point and nonpoint source contamination on appropriate geographical scales and evaluations of the monitoring program itself relative to developing management needs.

See 1.4.2.3 above

1.4.3.3 -- Assess the impact and effectiveness of environmental management actions on risks to public health, the viability of harvestable resources, ecosystem integrity, and local economies as measured by the indicators and models used in the monitoring program.

Of the ongoing programs MWRA is addressing this objective.

2.0 MONITORING METHODS

Monitoring of the marine environment has been ongoing in one form or other since the nineteenth century. Numerous methods have been developed to collect and interpret ecological data.

The range of approaches and methods used in environmental monitoring is well illustrated in the series of monitoring experiments conducted in the North Sea and U.S. coastal areas in attempts to measure the effects of petroleum exploitation. Summaries of this work are provided in LGL et al., 1985; McIntyre, 1984; Carney, 1987.

The plethora of environmental effects monitoring techniques which have emerged have been reviewed several times (c.f. McIntyre and Pearce, 1980; White, 1984); however, it was not until recently that a series of comprehensive comparisons have been conducted under the sponsorship of the Intergovernmental Oceanographic Commission (IOC, 1986). Three comparative workshops have now been completed. The results of the first are reported in Bayne et al., 1986. The NOAA National Status and Trends Program provides an excellent example of a thoughtful and scientifically defensible approach to environmental quality monitoring; methodologies used in this program continue to be developed and tested.

The Gulf of Maine Monitoring Program will identify specific methodologies based on consultations with experts drawn from agencies represented on the Working Group and others, as appropriate. Every effort will be made to ensure that the methods selected for the Council's Program are comparable to those already in use in other monitoring programs throughout the Gulf. Indeed, the Council's Program is designed to draw upon these existing programs as much as possible.

3.0 MONITORING PLAN

3.1 Priority Ranking of Monitoring Objectives

Establishing a monitoring program that addresses all the questions for meeting the objectives outlined in Section 1.4 is not a reasonable goal that can be achieved in the near future. Organizational, jurisdictional, and financial constraints limit the actual monitoring that can be reasonably accomplished. As a result, one of the tasks in developing a monitoring plan is to establish priorities for implementing monitoring activities.

To achieve a broad consensus of what the monitoring priorities should be in the Gulf, an informational survey was sent to over 150 regulators, environmental managers, and scientists. The respondents were asked to rank the three goals and the different objectives in terms of their importance. The survey used (and a detailed analysis of the results) is given in Camp Dresser and McKee, et al., 1990. The priority rankings developed from the survey were then discussed at the workshop in Halifax.

The results from both the survey and workshop can be synthesized to yield the following priorities for the Monitoring Program.

- The goals, as defined on page 4, were ranked in the following order:

    1) to provide information on the status, trends, and sources of risks to the marine environment in the Gulf of Maine;
    2) to provide information on the status, trends, and sources of marine-based human health risks in the Gulf of Maine; and
    3) to provide appropriate and timely information to environmental and resource managers that will allow both efficient and effective management action and evaluation of such action.

- Of the ten objectives listed for these goals the following four were ranked highest:

    1) monitoring indicators of change in environmental quality;
    2) assessing risks to public health from toxics;
    3) monitoring viability of fish stocks; and
    4) assessing causes of environmental degradation.

- The health risks from pathogens were also considered to be important by survey respondents but the ranking of this objective was not clear. This question was clarified at the workshop where a consensus was reached that pathogen monitoring is important, but should not be a focus for the Gulf of Maine Monitoring Program because ongoing programs are collecting data over a large area of the Gulf on this question. For this objective, the Gulf-wide Program can use the existing information to provide managers with the required direction. Similarly, fish stock assessments are already conducted by several state, provincial and federal agencies.

- Although objectives addressing the goal of information transfer were included in the survey, conference participants felt that they could not be ranked along with objectives addressing monitoring activities. Workshop participants strongly believed that information transfer should have a high priority. In particular, the consensus at the conference was that one of the first tasks of the Monitoring Program should be to compile and make available a comprehensive directory of all the existing scientific information on the Gulf; maintaining the directory, a "database of databases", should then continue to be a high priority for the Council.

These results indicate that, given limited resources, monitoring activities in the Gulf of Maine should initially be focused on assessing the environment by monitoring indicators of change in environmental quality and assessing human health risks from toxic compounds. This conclusion is based on an estimate of what can be reasonably accomplished in the next five years, and an estimate of costs for the monitoring needed to address these two objectives (discussed below).

Although there was a general agreement at the workshop that monitoring to achieve these two objectives is important, and would easily use all the financial resources available, the other objectives should not be put aside until the first objective is achieved. Opportunities for addressing the remaining objectives should be fostered.

The following sections present a plan for meeting the two priority objectives by complementing existing monitoring efforts, by developing new monitoring tasks, and by developing a research program to address monitoring questions for which methods do not yet exist.

3.2 Monitoring Plan for Priority Objectives

3.2.1 Monitoring Questions for First Priority Objective

Table 3 summarizes the proposed monitoring questions for the first priority objective and the monitoring methods needed. In this initial phase of the Monitoring Program, the recommendation is to focus on two indicators species (winter flounder and mussels) and three ecosystem function indicators (benthic community structure, nutrient levels, and dissolved oxygen). These indicators were chosen to allow the integration of the new Monitoring Program with ongoing efforts to monitor for these indicators in some locations of the Gulf already. In addition, the field and laboratory methods for measuring these parameters are well established. It is recommended, however, that ad hoc subcommittees or groups of experts be convened by the Council to address these and other indicators and details of their implementation, since no consensus was achieved at the workshop on this issue and more detailed discussion is required among the responsible agencies prior to program implementation. The Monitoring Committee will work with the ad hoc subcommittees to develop testable hypotheses as the starting point for monitoring activity.

In Table 3 the method variables are more specifically defined to reflect current knowledge of how ecological stress is measured using the individual indicators. Variables are listed as examples of those which could be monitored. In their review, the ad hoc

subcommittees, as described above, may identify different or additional variables. For example, a tiered approach to assessing stress in populations may also include several blood plasma parameters, including mixed function oxidas (MFO). The ad hoc committees should identify ancillary variables to be monitored to provide additional information. For example, bioburden data and condition index measurements may make gonadal indices more meaningful. Also, sediments may play an important role as a unifying parameter. Finally, it is unlikely that every priority pollutant will be monitored each year; initial data should used to develop a "short list."

The monitoring plan for the first priority objective, therefore, is to collect data on the parameters listed using the methods described. The monitoring plan for this objective, however, requires that levels of "significant environmental degradation" be established so testable hypotheses can be defined. Because there is currently no consensus on what constitutes a significant degradation or what is a significant indication of stress in the Gulf of Maine, it is recommended that these also be defined as soon as possible in some consensus building forum such as a multi-disciplinary workshop.

TABLE 3: Monitoring Methods for Addressing the First Priority Objective: Ecosystem Indicators

Monitoring Question	Variable	Scale/Locations	Medium	Field Methods	Frequency	Data Analyses
1. In what areas of the Gulf do winter flounder show signs of stress?	mixed function oxidases histology	All parameters should be be monitored in the following locations:	liver	trawls	annual	statistics
2. What are the trends in measures of stress?	mixed function oxidases		liver	trawls	annual	statistics
3. What disturbances can be correlated with stress?	priority pollutants	• Boston Harbor • Mouth of Merrimack River • Mouth of Piscataqua River • Casco Bay	sediments	cones	annual	statistics
4. In what areas of the Gulf do mussels indicate there are significant levels of environmental stress?	gonadel index priority pollutant	• Penobscot Bay • Boothbay Harbor • Cobscook Bay • Machias Bay	tissue	collect on rocks	annual	statistics
5. What are the trends in measures of stress?	gonodal index priority pollutants	• Frenchman Bay • St. Croix River • St. John Harbor	tissue	mark/recapture	bi-annual	statistics
6. What disturbances can be correlated with this stress?	priority pollutants phytoplankton species	• Chignecto Bay • Minas Basin • Avon River	water sediments	water bottles cores	monthly	statistics
7. What areas of the GOM are nutrient enriched?	ammonium, nitrate, phosphate, chlorophyll concentration	• Annapolis Basin • St. Mary's Bay • Yarmouth Harbor • Stellwagen Bank	water	water bottles	monthly for 1 year	statistics
8. What are the trends in nutrient levels?	ammonium, nitrate, phosphate, chlorophyll concentration	• Jeffries Ledge • Georges Bank	water	water bottles	quarterly	statistics
9. In what areas of the GOM does the benthic infaunal community shoe signs of stress?	benthic invertebrates		sediments	grabs ($0.05m^2$)	quarterly	Food Web Models Keystone Species Models Multivariate analysis
10. What are the trends in indicators of benthic stress?	benthic invertebrates		sediments	grabs	quarterly	Food Web Models Keystone Species Models Multivariate analysis
11. What disturbances can be correlated with with benthic stress?	organic content dissolved oxygen		sediments water	grabs DO meter	annual weekly	
12. In what areas of the GOM are the levels of dissolved oxygen depressed?	dissolved oxygen		water	DO meter	weekly	statistics
13. What are the trends in DO levels?	dissolved oxygen		water	DO meter	weekly	statistics
14. What disturbances can be correlated with depressed DO levels?	BOD organic carbon phytoplankton populations		water sediments water	water bottles cores water bottles	weekly annual weekly	statistics

3.2.2 Identifying Causes of Degradation

Identifying the causes of environmental degradation was also an objective that was identified by the Working Group. Although it was ranked fourth overall, it is directly linked to the first objective, and needs to be addressed as more information becomes available. The following is an outline for a general approach to address this objective for the five indicators (all except nutrients) that are not direct measurements of a disturbance. The sources of high nutrient levels can be identified by collecting and analyzing water samples at increasing distances from the original point where elevated levels were measured.

1. Based on local knowledge develop hypothesis with regard to the causes. The survey of possible causes should include, but not be limited to, waste discharge, nonpoint discharges, harvesting methods, filling or dredging, land use activities in watershed, recreational activities and shipping activities.

2. Define the monitoring parameters best suited for testing hypotheses.

3. Develop criteria for either rejecting or accepting hypotheses.

4. Specify the sampling design needed.

5. Test hypotheses by collecting and analyzing data.

3.2.3 Monitoring Questions for the Second Priority Objective

The second priority objective relates to the health risks of toxic compounds. Table 4 summarizes the monitoring questions for this objective and the monitoring methods needed. At present only some aspects of this objective can be met through monitoring because few toxic compounds have been adequately studied to understand at what concentrations the compounds pose a health risk. This is especially true for exposure through contact activities such as swimming. A major research need, not just in the Gulf of Maine but nationally and internationally, is to identify the health risks associated with contact and ingestion of different concentrations of the many toxic compounds present in the marine ecosystem. Existing risk analyses are extremely imprecise. Another major research need is to develop methods for assessing the socio-economic impacts of marine related human illness from toxics. The monitoring plan summarized in Table 5 is therefore limited to collecting data on the two priority pollutants for which U.S. and Canadian public health agencies have developed action levels in marine foods: mercury and PCBs.

3.3 Additional Monitoring Needs for Priority Objectives

3.3.1 Monitoring Environmental Indicators

Table 2 shows that there are 15 ongoing programs that are monitoring the environment using certain variables. Although many of the existing programs are addressing some of the questions in some areas of the Gulf, the coverage is not complete especially as it relates to geographical locations. Table 5 lists the major geographical regions in the Gulf where

environmental indicator monitoring should be taking place and the variables needed. Additional sites in the central Gulf of Maine should also be included as the Monitoring Program evolves. The Program should take advantage of NOAA, DFO, NURC, provincial, state and private research and monitoring cruises in this area to supplement monitoring activities to achieve priority objectives. Locations and variables that are currently being monitored in ongoing programs are identified with the initials of the organization doing the monitoring, as referenced in Table 1.

TABLE 4

Monitoring Methods for Addressing the Second Priority Objective: Health Risks from Toxics

Monitoring Question	Variable	Scale/Locations	Medium	Field Methods	Frequency	Data Analyses
1. In what areas of the GOM is mercury in marine foods at or near 1 ppm?	mercury	Boston Harbor Portsmouth, NH Portland, ME Rockland, ME St. John, NB Moncton, NB Minas Basin	tissue of commercially and recreationally harvested fish and shell-fish (such as swordfish, tuna, lobsters, tomalley, striped bass, blue fish)	trawling, digging hook and line	annual	statistics
2. In what areas of the GOM are PCBs in marine foods at or near 2 ppm?	PCBs	Yarmouth, NS		trawling, digging, hook and line	annual	statistics
3. Are there any trends in mercury levels?	mercury			trawling, digging, hook and line	annual	statistics
4. Are there any trends in PCB levels?	PCBs			trawling, digging, hook and line	annual	statistics
5. In what areas of the GOM might mercury reach 1 ppm in foods in the near future?	mercury		water sediments	bottles cores	annual annual	statistics statistics
6. In what areas of the GOM might PCBs reach 2 ppm in foods in the near future?	PCBs		water sediments	bottles cores	annual annual	statistics statistics
7. What are the sources of PCB contamination?	PCBs	(where concentrations are near or exceed action levels)	water air deposition	bottles collected in discharge/point and non-point	when action levels are exceeded	statistics
8. What are the sources of mercury contamination?	mercury		water air deposition	bottles collected in discharge/point and non-point	when action levels are exceeded	statistics

*** Action levels are per unit wet weight ***

TABLE 5

Locations and variables for the primary objective of the GOM monitoring program. Ongoing programs that are contributing are identified by the acronym of the sponsoring organization. Blanks indicate where the parameters are not being monitored.

	Histology	Mixed Function Oxidase	Priority Pollutants	Gonadal Indices	Phytoplankton	Nutrients	Benthics	Organic Carbon	Dissolved Oxygen	BOD
Boston Harbor	NST	NS&T-B	NST/BHMP	NS&T-MW BHMP	BHMP	BHMP		NS&T	BHMP	NCPDI/MWRA
Merrimack River	NST-B	NS&T-B	NST/USGS			USGS		NS&T		NCPDI
Piscataqua River			USGS			USGS				NCPDI
Casco Bay	NST-B	NS&T-B	NST-B	NS&T-MW		NCPDI	MMEMP	NS&T		NCPDI
Penobscot Bay	NST-B	NS&T-B	NST-B	NS&T-MW		NCPDI		NS&T		NCPDI
Boothbay Harbor			NCPDI				MMEMP			NCPDI
Machias Bay	NST-B	NS&T-B	NST/CWS							
Cobscook Bay										
Frenchman Bay	NST-B	NS&T-B	NST-B					NS&T		
St. Croix River estuary			CWS			NAQUADAT			F&O-L'Etang	
St. John Harbor			NAQUADAT			NAQUADAT				
Chignecto Bay										
Minas Bay			CWS							
Avon River			DOE			NAQUADAT				
Annapolis Basin										
St. Mary's Bay										
Yarmouth Harbor			ODCA							
Stellwagen Bank					NMFS				NMFS	
Jeffries Ledge					NMFS				NMFS	
Georges Bank					NMFS				NMFS	

The blanks in Table 5 indicate the variables that are currently not being monitored at specific locations, and indicate what is needed for a Gulf-wide coverage to meet the objective. The Monitoring Program to be developed for the Gulf of Maine Council should include collecting the data to eliminate these voids.

In addition to collecting data on environmental indicators on a local basis, the Gulf of Maine Monitoring Program must collect synoptic data in order to measure not only environmental quality in areas of known human influence but also the general health of the ecosystem. This should include the measurement of key physical environmental variables (water temperature and salinity, river discharge) at some representative locations in both the nearshore and offshore regions. The sampling strategy should be designed on the basis of physical oceanographic considerations, and should consider the value of continuing existing long time series such as ongoing measurement of: discharge by the Saint John River and five New England Rivers; coastal sea surface temperature at Boothbay Harbor and St. Andrews; coastal salinity at Boothbay Harbor; monthly temperature and salinity profiles at at the mouth of the Bay of Fundy; and temperature, salinity and plankton data on the NOAA/NMFS ship-of-opportunity transect between Boston and Halifax. In addition, temperature, salinity and river discharge should generally be included in the monitoring for environmental indicators and human health risks. In the longer term, monitoring of circulation patterns and transport rates in key areas is desireable.

Although the present monitoring plan does not propose that the Council initiate any synoptic data collection from ships or by remote sensing because of the costs involved, it is important that opportunities for collecting this data be exploited. With new satellites that can monitor general environmental indicators on a large-scale (i.e. temperature, chlorophyll) the Council should be prepared to fund the analysis of such data as it is collected. Ships of opportunity, for example, fish stock assessment cruises, and aircraft using remote sensing should also be readily available to collect appropriate samples. The Gulf-wide indicators will be extremely useful in assessing long-term trends in the environment. Furthermore, every attempt should be made to coordinate data collection with ongoing research programs. All researchers in the Gulf should be informed with regards to the data needs of the Monitoring Program, and should be requested to collect as much data, both synoptic and localized, as possible. In turn, data collected by the Program should be made readily available to interested researchers.

3.3.2 Monitoring for Human Health Risks

Eight locations were identified as sites where there is an ongoing, or potential risk to public health from toxics because they are near large population centers or industries with a significant potential for pollution from toxics. These locations include:

Boston Harbor, MA	Rockland, ME (Penobscot Bay)
Portsmouth, NH (Piscataqua River)	Saint John, NB
Portland, ME (Casco Bay)	Moncton, NB
Bath, ME (Kennebec River)	Yarmouth, NS

The Bath and Rockland sites are at the mouths of major estuaries. Minas Basin, NS is proposed as a control site; it is very rural and relatively pristine.

Of the ongoing programs, the National Status and Trends program is collecting relevant data in Boston Harbor. Data collected in the other seven programs listed in Table 2 are not specific to permit health risk assessments.

The Gulf of Maine monitoring plan for addressing this objective is to establish permanent monitoring of the edible tissues of shellfish, bottom fish, and the sediments in the eight locations currently not being monitored. Migratory and offshore species, such as tuna, should also be monitoried. The analyses should at least include PCBs and mercury (Hg) in tissue since these are the only two contaminants for which action levels have been developed (in addition to PSP). If funds permit, however, the laboratory analyses of the edible tissues should include the full range of contaminants (EPA priority pollutants, PAHs, metabolites of organic compounds). A program very similar to this has been implemented by the Maine Department of Environmental Protection ("Maine's Marine Environment: A Plan for Protection"). To date the program includes extensive sampling in five coastal embayments and mussel-watch type sampling at 26 sites along the Maine Coast. This program should be used as the basis for expanding into other regions in the Gulf.

To improve the human health risk assessments the sampling should be focused on the areas from which fish and shellfish are currently being taken for consumption and from areas where water contact sports are taking place where there is reason to believe that contamination may exist.

3.5 Estimated Cost of Monitoring for Priority Objectives

3.5.1 Cost for Monitoring Ecosystem Indicators

The frequency of sampling for all the variables listed in Table 3 is annual or more frequent. The costs are, therefore, estimated on an annual basis. Table 6 shows the cost estimate for sampling each variable at each location. The totals for each row and column represent the estimated cost for monitoring each variable at all locations and all variables at one location. The totals for the rows are not the sum of the costs for sampling and analyzing all parameters, but reflect the cost savings that might be accrued by sampling for several different variables using the same methods.

The cost estimates presented are to be used only to provide a very rough approximation of the annual costs of a monitoring program to address the first priority issue. All estimates reflect costs as if work was to be done by contract. The one factor that has a significant effect on costs that cannot be estimated at present is the number of samples that need to be collected for each variable at a location to provide statistically significant information. Sample numbers need to be developed at the sampling design stage. The initial estimate of the annual costs for monitoring the region to meet the first priority objective is in excess of $3,000,000 US (1990). However, given the uncertainty in the number of samples required the actual costs may range from 75% to 150 % of the tabulated values.

TABLE 6

Estimated costs (in thousands $) for different variables and locations to meet the first priority objective.

	Histology	Mixed Function Oxidase	Priority Pollutants	Gonadal Indices	Phytoplankton	Nutrients	Benthics	Organic Carbon	Dissolved Oxygen	BOD	TOTAL**
Boston Harbor	NST/BHMP	25	NST/BHMP	10	BHMP	BHMP	50	25	BHMP	NCPDI	100
Merrimack River	NST	25	NST/USGS	10	50	USGS	50	20	3	NCPDI	120
Piscataqua River	25	25	USGS	10	50	USGS	50	10	3	NCPDI	140
Casco Bay	NST	25	NST	10	100	NCPDI	100	10	3	NCPDI	225
Penobscot Bay	NST	25	NST	10	50	NCPDI	50	10	3	NCPDI	120
Boothbay Harbor	25	25	NCPDI	10	30	15	50	10	3	NCPDI	140
Machias Bay	NST	25	NST/CWS	10	30	15	50	10	3	15	140
Cobscook Bay	25	25	30	10	50	15	50	10	3	15	200
Frenchman Bay	NST	25	NST	10	30	15	50	10	3	15	130
St. Croix River estuary	25	25	CWS	10	100	NAQUADAT	50	10	F&O	15	200
St. John Harbor	25	25	NAQUADAT	10	50	NAQUADAT	100	10	3	15	200
Chignecto Bay	25	25	30	10	50	15	50	10	3	15	180
Minas Bay	25	25	CWS	10	100	25	100	25	3	15	250
Avon River	25	25	DOE	10	30	NAQUADAT	50	10	3	15	150
Annapolis Basin	25	25	30	10	30	10	50	10	3	15	180
St. Mary's Bay	25	25	30	10	30	15	50	10	3	15	180
Yarmouth Harbor	25	25	ODCA	10	30	10	25	10	3	15	150
Stellwagen Bank	25	25	30	10	NMFS	40	50	20	NMFS	30	180
Jeffries Ledge	25	25	30	10	NMFS	40	50	20	NMFS	30	180
Georges Bank	25	25	30	10	NMFS	40	100	20	NMFS	30	180
TOTAL	350	500	210	200	760	255	1075	270	45	155	3345

*DO costs are estimated assuming monitoring will be done by volunteers.

**Total costs estimated based on savings possible by combining sampling methods.

Another assumption made in the cost estimate is that existing programs are collecting all of the data needed in the locations identified in Table 5. This may not be the case if the pilot sampling studies indicate more intense sampling is needed to provide the necessary data to test hypotheses. If additional data, or modifications in method, are needed that cannot be incorporated in the ongoing programs, additional funds will be required.

It is recommended that investigators connected with ongoing monitoring efforts be asked to participate in, and coordinate with, the ad hoc subcommittee developing the sampling design for monitoring the relevant variables.

3.5.2 Cost for Monitoring Human Health Risks from Toxics

Assuming the data collected by NOAA's National Status and Trends program in Boston Harbor are statistically adequate for risk analyses, the estimated cost for monitoring to meet the third priority objective is $560,000/year. The costs for assessing human health risks from mercury and PCBs in marine foods are estimated at $70,000/year at each location listed in above. Protocols developed by the FDA, ICES, DFO and the Canadian Department of Health and Welfare should be used. Pilot studies may also be needed to establish additional, appropriate sampling protocols and should be integrated with the data needs of risk analyses.

The largest funding requirement, however, to meet this objective is for research. Little is known about the human health risks of the many toxic contaminants found in marine foods, and at what concentrations these risks are manifest. This information is critical in developing a monitoring program that addresses contaminants other than mercury of PCBs. The Council will probably wish to bring this need to the attention of potentially responsible agencies.

4.0 DATABASE MANAGEMENT

The success of the Monitoring Program will, to a large degree, depend on implementing a workable database system where data and information from all monitoring efforts can be stored and retrieved. Inadequate database management and data accessibility have been identified as major problems in previous monitoring programs (NRC, 1990).

Establishing and managing a database was one of the major topics discussed at the Gulf of Maine monitoring workshop. Key issues discussed were the type of information that would be useful to users, potential data structures, quality control, and continuity. Likely users identified at the conference include environmental managers, policy-makers, scientists, planners, educators, developers, libraries, and the environmental community.

A regional database must provide useful and reliable information. It cannot simply be a repository for raw data. Both the quality of the data and the quality of the interpretations are critical. The following levels of information and their likely users were identified at the workshop.

Raw Data: useful to a few scientists, but does not provide useful information to other users.

Processed Data: useful to some scientists and managers, but not to others.

Report Data: useful to many scientists and managers, to some policy-makers, and to some other users.

Assessments: useful to almost all users.

At its first meeting following the Halifax workshop, the Gulf of Maine Council has created a Data and Information Management Committee to oversee development of a Gulf-wide data base system or network.

Questions raised at the workshop regarding links to a regional GIS such as the FMG project, the need for an electronic mail system and bulletin board, the importance of data quality control and the merits of on-line data exchange were referred to the Data and Information Managemnt Committee for their consideration.

Workshop participants also recommended that a first task in the development of a regional database or network should be to identify existing data on the Gulf, develop an audit trail and to develop procedures to provide access to the data by all interested parties. One recommendation of the workshop was that the Gulf of Maine Council fund a compilation and review of existing data before funding any new monitoring efforts.

Finally, workshop participants recommended the following tasks to ensure adequate archiving of data:

TASK 1: Develop a database dictionary which defines data variables to be collected by monitoring activities. The dictionary should be expandable to accommodate new parameters introduced by future monitoring efforts and be formatted to include socio-economic parameters as well as biological, chemical, and physical ones.

TASK 2: Define database elements to include: 1) provisions for unique sample identification, 2) a bibliographic reference number, 3) definition of the information needs the data addresses, 4) provisions (where practical) for units conversion, and 5) an assessment of "data quality" including methods citation and detection limits.

TASK 3: Define the structure of an exchange format in terms of record length, field size, and data codes for parameters and data elements developed under Task 1.

It is recommended that the data exchange format developed by NOAA for marine toxic substances and pollutants be used as the basis for the Gulf of Maine format. The NOAA format, however, needs to be expanded to include formats for socio-economic data and for information on the results of the data analyses, and possibly physical and geological data.

TASK 4: Ensure that data collected in previous and ongoing programs in the Gulf of Maine are available in databases that are compatible with the one developed in Task 1. This may require funding to translate existing data into compatible formats.

5.0 INFORMATION TRANSFER

To be effective, environmental monitoring and environmental management must be closely linked by multiple feedback loops. Monitoring is not an end in itself; it provides the means by which management questions are defined, and management actions evaluated. In turn, management needs must provide the focus for monitoring efforts and for development of hypotheses to be tested by collecting data. The real value of monitoring occurs when a problem is identified or predicted and action taken to correct it. An interactive process is necessary to maintain the flow of information between monitoring, research and management efforts.

The interactive process is based on good communication between all groups involved, from the managers and policy-makers, to the scientists and concerned citizens. Environmental management issues and questions must be clearly defined by managers and policy-makers in consultation with scientists, concerned citizens, and interested public and private organizations. On the other hand, the monitoring efforts needed to address the management questions must be clearly defined by scientists in consultation with the other groups.

Developing a monitoring effort that meets the management questions requires that scientists and managers define, in advance, the action levels and the sampling design to be used. Defining these factors in advance, however, requires prior information from research, and frequently, pilot studies on the variables to be monitored. As monitoring proceeds, results that are adequately analyzed and interpreted must be provided to managers and policy-makers in a timely manner. Monitoring is also needed to evaluate and fine-tune management actions. Performance levels should be established in advance, as objectively as possible, and additional sampling programs implemented to evaluate the actions. There must be mutual understanding by scientists, environmental managers, and policy-makers of monitoring results and there must also be agreement regarding their significance.

5.1 Information Transfer as a Monitoring Goal

Unfortunately, many previous monitoring efforts have not been effective because the importance of the communication/cooperation process was not adequately understood or emphasized. In a recent review of monitoring programs a committee of the National Research Council concluded:

> "Many monitoring programs are ineffective because they devote too little attention to the formulation of clear goals and objectives, technical program design, and the translation of data into information that is relevant and accessible to decision makers and the interested public." (NRC, 1990)

To overcome this common problem the Working Group Monitoring Committee has identified the information transfer/communication issue as the third major goal of the Monitoring Program. The goal is to "provide appropriate and timely information to environmental and resources managers that will allow both efficient and effective management actions and evaluation of such action."

The information presented in this report relative to this monitoring goal comes from the experiences of the contractors, literature review, the results of the survey and the results of the workshop. Administrators and policy makers consider this goal more important, overall, than do researchers and educators. Also, respondents of the survey who spend the majority of their time on management activities ranked the goal of information transfer of higher importance than did respondents spending more time on research, writing, and educational activities.

5.2 Maintaining and Improving the Transfer of Information

The objectives developed to meet the third goal (see section 1.4) define the important steps in the information transfer process. The first objective of providing information to resource and environmental managers in a format that will allow appropriate management actions, emphasizes the need to plan and implement monitoring activities in ways that provide useful information to managers. This means that action levels and sampling design need to be established that specifically answer management questions. In addressing environmental health, this may mean that cause and effect studies be supplemented by probability-based risk assessments, as used in the management of public health. The information coming from a monitoring program should be concise, carefully interpreted in a manner relevant to the management issue, and its statistical reliability should be documented. Whenever possible, the information should be deposited in a database that is accessible to other managers and scientists in the region.

The second objective, that of providing timely analysis and interpretation, reflects the fact that management decisions often have to be made on a schedule that is different than one that best meets scientific needs. Thus, schedules and formats for monitoring results should be agreed upon at the time that a sampling design is developed. This will avoid any future misunderstandings between the scientist doing the monitoring and the managers who will be having to make management decisions of the basis of the results.

If a monitoring program is to provide useful information, activities must be extended over long periods of time. As a program develops there is need to refine the process of collecting and analyzing data. The third objective, that of refining and updating the Monitoring Program, emphasizes the need for ongoing communication between scientists and managers to improve the process based on a continuous evaluation of monitoring results. Although this objective was ranked the lowest in importance by the respondents to the survey, it will become more important as the coordination and cooperation in monitoring efforts in the Gulf of Maine increase.

As management activities become more extensive in the Gulf, it becomes increasingly important to evaluate them; not only in terms of effectiveness, but also in terms of overall environmental impacts (the fourth objective under this goal). Poorly planned or implemented management actions can degrade or destabilize environmental quality, natural resources, and ecological integrity, as easily as other anthropogenic causes. Management actions should be based on reliable monitoring information, firmly linked to scientific principles and appropriate pilot studies. They should be reviewed objectively by an interdisciplinary group of scientists, managers, and policy-makers in order to obtain the broadest possible perspective.

5.3 Facilitating Information Transfer in the Gulf of Maine

Four major communication processes have been identified that are essential for the effective transfer of information in a monitoring program for the Gulf of Maine. These are listed below in order of current effectiveness as judged by survey respondents:

- Ongoing and new monitoring efforts and techniques must be interrelated and coordinated among the scientists involved.

- Interpretation and understanding of monitoring results must be consistent among those involved.

- Monitoring needs and priorities must be mutually understood and agreed to by scientists, policy-makers, and managers.

- Historic and ongoing monitoring results must be used as a common information base in planning, implementing and evaluating policies and management strategies.

The need to improve the use of existing data was strongly supported at the workshop. A strong consensus was reached that the synthesis of existing data should be given the highest priority in the Monitoring Program. This finding was reiterated by the Gulf of Maine Scientific Workshop, held in January, 1991. To aid in the widespread distribution of data and information, the Monitoring and Data and Information Committees should work together to ensure that existing and new data are compiled on maps using a standard GIS such as the FMG project.

Based on these results and discussion at the workshop, mutual communication and understanding between scientists, managers, and policy-makers needs to be increased significantly in the Gulf region if a monitoring program is to be successful. The use of monitoring information in policy and management development is one area of mutual understanding in need of improvement.

To achieve these improvements different forms of communication were considered. These included: conferences, annual symposia, person-to-person contacts, interorganizational meetings, professional journals, newsletters, popular press, and training seminars. Respondents to the survey ranked person-to-person contacts as the most effective form of communication, followed by interorganizational meetings and annual symposia. The popular press was considered the least effective at communicating information. Based on these results, it is recommended that a major emphasis of the Gulf of Maine Monitoring Program should be organizing meetings that bring scientists, managers, and policy-makers together to discuss the information needs of all parties involved, and to resolve any misunderstandings. In addition, results of the Program should be submitted to professional journals whenever appropriate; publication will ensure the credibility of the Program, a permanent record of the results, and their wide availability.

Information transfer, however, does not only include effective communication among those directly involved in collecting data and managing the resource, but also involves the general public. Public support is critical in maintaining the necessary political and funding support. It is also critical because public cooperation in reducing human impacts and in volunteer efforts are a significant factor in the success of environmental management and monitoring programs.

Such public support must be based on understanding and mutual trust. As monitoring programs are planned, scientists, managers, and policy-makers must also plan means of communicating and explaining the results to the public. This is identified as a major goal of the draft Action Plan for the Gulf of Maine Program, and should not be forgotten in the detailed implementation of a monitoring program.

Suggestions for an organizational structure that will meet these information transfer objectives are presented in the following section.

6.0 STRUCTURE OF MONITORING PROGRAM

To successfully implement a monitoring program many tasks need to be accomplished, as has been described in this plan. Suggestions for an organizational structure to support a Gulf-wide program are outlined in Figure 2 and are based on a review of other programs as well as the survey and the workshop.

As noted in Figure 2, it is recommended that the Gulf of Maine Council establish a Scientific Advisory Committee to provide scientific review of Gulf Program inititaives, including monitoring activities.

The Monitoring Committee, as currently constituted, provides guidance to the Council on program implementation, ongoing program management, information needs, monitoring objectives and questions. To this end, the Committee should address the following tasks:

Design

- review management questions and frame hypotheses;
- establish sampling design and field laboratory methods for each monitoring task (including supervision of ad hoc committees on methodology);
- determine the precision and accuracy of data needed to answer each monitoring question;
- establish action levels;
- prepare strategy for public involvement in Monitoring Program;

Implementation

- prepare and review proposals for monitoring;
- identify new monitoring methods and integrate them into ongoing monitoring programs;
- identify potential funding needs and sources;
- establish intercalibration procedures among laboratories;
- assure quality control;
- provide interpretation of the data coordinated and collected by the Program with respect to Program objectives;
- coordinate Gulf of Maine monitoring with ongoing monitoring programs.

Information Transfer

- organize symposia, workshops and other activities to facilitate information transfer;
- publish a newsletter;
- publish annual "State of the Gulf" reports;

Review

- prepare annual progress reports on the results of the Program;
- regularly survey scientists and managers on the effectiveness of the Monitoring Program; and
- review and update Monitoring Program on a regular basis.

Gulf of Maine Program Organizational Chart

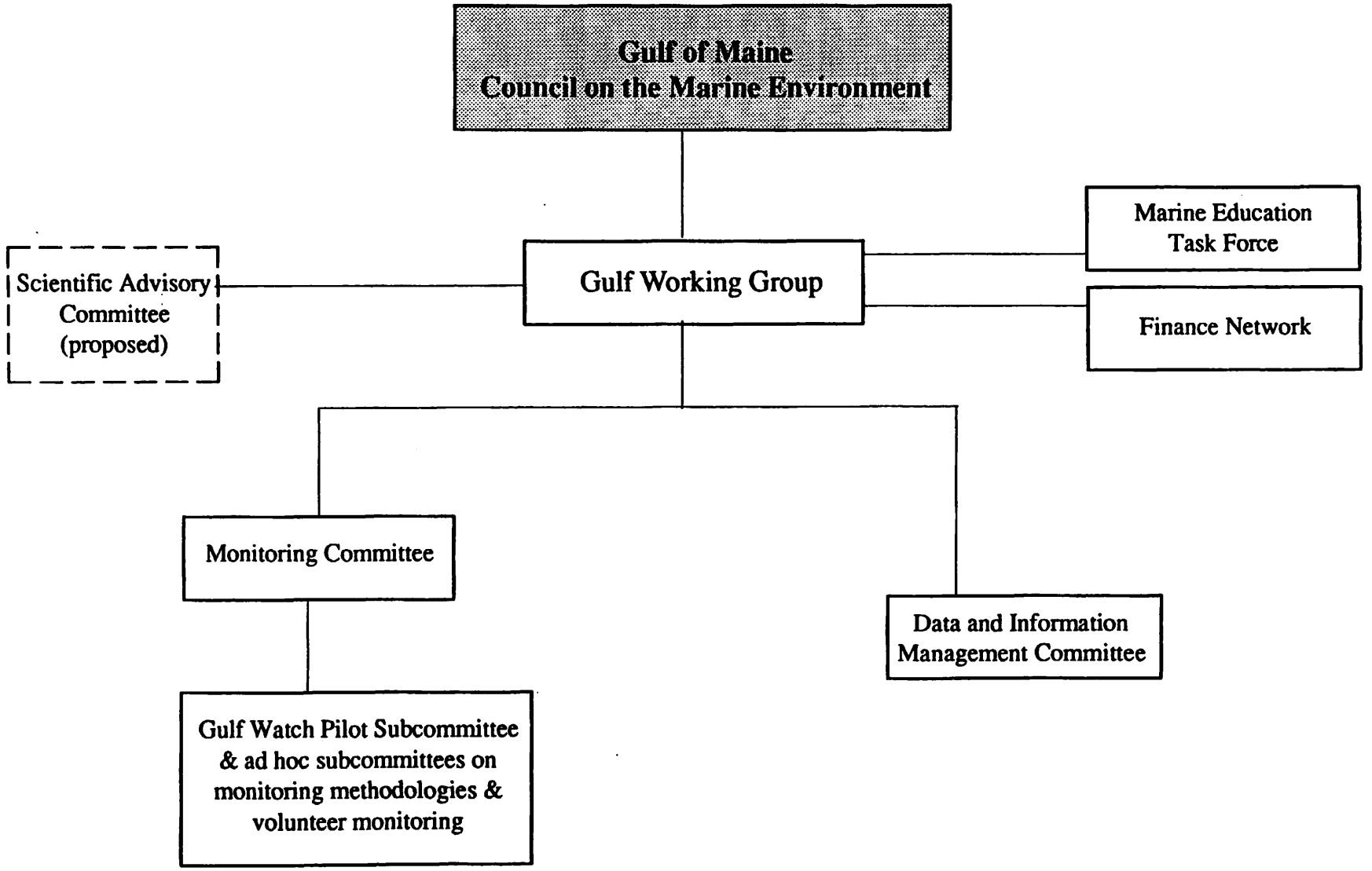


Figure 2 Organizational Structure for Gulf of Maine Monitoring Program

The Data and Information Management Committee should address the following Tasks:

- define user groups;
- develop format for database;
- compile existing data into database;
- maintain the database bulletin board;
- specify information levels for database;
- develop expert systems of data interpretation for environmental managers;
- ensure that newly collected monitoring data are incorporated into the database; and
- manage the database or its interactive network.

7.0 PROCESS FOR IMPLEMENTING MONITORING PROGRAM

This chapter forms the basis of an implementation strategy to be acted on by the Council at its June, 1991 meeting.

Implementation of the Monitoring Plan will require considerable time on the part of the Monitoring Committee. It is recommended that at least one full-time person, either funded by the Council or "on loan" from a participating agency, serve as staff to the Monitoring Committee in order to perform the following tasks:

* coordinate work of ad hoc subcommittees,
* liaison with existing monitoring programs,
* draft annual reports, and
* liaison with Working Group, Data and Information Management Commitee and Scientific Advisory Committee (if established by the Council).

The following recommendations for implementing a Gulf of Maine Monitoring Program have been developed from a review of other monitoring efforts, as well as the survey and workshops held in Halifax and Woods Hole. The process for implementing the Program is outlined as a series of tasks that need to be accomplished. These tasks should be initiated as soon as possible, and, to a certain degree, can be done concurrently, depending on the resources and time available.

Task 1: Design Program elements to address the priority objectives of the plan.

Task 1.1 -- Identify areas of focus within top two monitoring priorities: indicators of risks to the marine environment and marine-based risks to public health from toxics. Translate public and management concerns into issues and questions.

Task 1.1.1 -- Develop a priority list of hypotheses.

Task 1.1.1.1 -- Solicit recommendations from GEEP, ICES and others.

Task 1.1.2 -- Establish/nominate ad hoc subcommittees to develop consensus on appropriate methodologies.

Task 1.2 -- Develop sampling strategy to address hypotheses.

Task 1.3 -- Define acceptable decision criteria for use by managers in assessing monitoring data.

Task 2: Establish additional components of the Program.

Task 2.1 -- Develop appropriate quality assurance/quality control measures.

Task 2.2 -- Develop and implement a plan for citizen/volunteer participation in the Program.

Task 2.3 -- Establish process for periodic review of the Monitoring Program to allow for revisions as necessary.

Task 2.3.1 -- Recommend to the Council that a Scientific Advisory Committee be established to review and evaluate the Monitoring Program on an on-going basis.

Task 2.4 -- Work with Data and Information Management Committee to ensure that proposed Gulf of Maine data management network/system serve the needs of the Monitoring Program.

Task 2.4.1 -- Establish mechanism for analyzing and generating information from monitoring data and disseminating it to managers, scientists, the public and other interested parties.

Task 2.4.2 -- Monitor the effectiveness of the information transfer process between all parties, and make changes as needed.

Task 3: Implement Gulf-wide pilot and demonstration monitoring project using mussels as indicators of ecosystem health. This pilot project will serve to integrate several ongoing projects with the monitoring goals developed and will address a regional management issue of general interest in the Gulf of Maine. A program using mussels has been chosen for the pilot since several Working Group members either already conduct similar programs or monitor shellfish growing areas for protection of human health thereby facilitating implementation of a Gulf-wide program for little additional resources.

Task 3.1 -- Develop consensus among scientists, managers, and policy-makers on the specific questions to be addressed by the monitoring, and the information needed to answer the questions.

Task 3.2 -- Confirm the scope of existing programs and gain a consensus on cooperation among the responsible agencies.

Task 3.3 -- Determine compatible/comparable methods among coordinated programs.

Task 3.4 -- Develop a consensus on a priori action decision points (action levels).

Task 3.5 -- Develop a sampling design considering ongoing and historic data, and the statistical requirements of the hypothesis being tested. The sampling design should include standardized methods, QA/QC procedures, the type of data analyses to be done, and a schedule and format for reporting information to managers and policy-makers. Preliminary information collected through a pilot study or by analyzing results from ongoing programs should be used to integrate data collection with data analysis to optimize the information content of the data and minimize costs.

Task 3.6 -- Develop a pilot-scale database management system.

Task 3.6.1 -- Task the Data and Information Management Committee with serving the needs of the pilot project as a test for development of full scale support of the Monitoring Program.

Task 3.7 -- Provide managers with information as specified and use the results to improve implementation of the full-scale Monitoring Plan.

Task 3.8 -- Use monitoring information to develop management actions, and then track the effectiveness of the actions.

Task 3.9 -- Prepare final report.

Task 3.9.1 -- Task a Scientific Advisory Committee (if established) with conducting an evaluation of the pilot project.

Task 4: Implement monitoring to test hypotheses developed in Task 1.

Task 4.1 -- Develop a tiered and/or phased approach to initiating monitoring activity that can be implemented within available resources.

Task 4.2 -- Convene meeting of managers of ongoing monitoring activities to identify opportunities for cooperative action.

Task 4.3 -- Use results of meeting of managers of ongoing monitoring activities and recommendations of ad hoc subcommittees to identify appropriate, initial monitoring activities.

Task 4.4 -- Identify responsible parties for all relevant existing monitoring plans and gain agreement on, and initial commitment to, participation in the Gulf-wide Program.

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APPENDIX A

Glossary

Action Level -- The critical value of an environmental variable, which if exceeded, indicates that a significant change has occurred in human health risks, environmental quality, or natural resources. Such exceedances indicate the need for some management action.

Action Plan -- A compilation of agreed-upon goals and objectives and the specific strategies and actions that will achieve the objectives for each goal including a timetable for accomplishment.

Database -- A compilation of data and information that is organized in such a way that the data can be sorted by different subjects, variables, or other conditions.

Ecological Viability -- The natural interrelationships that exist between organisms and their environment.

Ecosystem -- Self-regulating community(s) of living organisms interacting with one another and with their non-living environment.

Environmental Management -- The process of protecting, maintaining, restoring, and/or optimizing long term environmental quality, biodiversity, and natural resources by maintaining ecosystem integrity.

Environmental Monitoring -- A program of observations for the purpose of determining whether the presence, or change in the incidence, of a factor(s), has adversely affected human health, critical biological processes, or the physical, chemical, geological nature of an ecosystem.

Goal -- General statement that describes what the human community would like to achieve. A goal reflects a joint vision for a specific or general purpose.

Habitat -- The parts of the environment in which an organism lives and with which it interacts.

Hypothesis -- A statement whose probability of being true or false can be established using statistical procedures applied to collected data.

Keystone Species -- A species that, through its role in the ecosystem, controls the presence, absence, or abundance of other species, especially if these other species are not directly linked to it in a predator-prey relationship.

Objective -- Specific, measurable, milestones that incrementally attain long-term goals as they are achieved.

Sustainable development -- Use of resources in a manner that meets present needs and assures resources for use by future generations.

Trophic Level -- A group of organisms which are on the same level in the transformation and transfer of energy in the ecosystem. An example is the primary production level, or the level at which photosynthesis occurs and light energy in transformed into chemical energy in the form of carbohydrates.

Variable -- A factor, feature, or element in the ecosystem that can change and take on different values.