CANADIAN MARINE STATUS
AND
TRENDS MONITORING NETWORK

PHASE II

FINAL REPORT

by

LGL LIMITED
environmental research associates
9768 Second Street
Sidney, B.C. V8L 3Y8

Submitted to

Evaluation and Planning, Conservation and Protection
Environment Canada
Pacific and Yukon Region
224 West Esplanade
North Vancouver, B.C. V7M 3H7

LGL Project # EA 577

6 January 1994

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TABLE OF CONTENTS

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1.0 INTRODUCTION

1.1 Background

The federal government, through the Interdepartmental Committee on Oceans (ICO), has placed a priority on ensuring that federal marine programs are delivered in a systematic and well-coordinated manner. A "Framework for the Management of Marine Environmental Quality (MEQ) within the Federal Government" was developed by the ICO Working Group on MEQ, jointly chaired by the Department of Fisheries and Oceans (DFO) and Environment Canada, and submitted to the parent committee in March 1990. The framework was endorsed by the Deputy Ministers and Presidents of 11 federal departments and agencies, and agreement was reached to develop a federal MEQ Action Plan. One of the priorities for the Action Plan is the development of a coordinated national status and trends monitoring capability for the Canadian marine environment.

Previously, Environment Canada's Conservation and Protection Service had adopted a MEQ Management Framework. One action item of the framework was to convene the "Canadian Conference on MEQ" in Halifax in February-March 1988 (see Wells and Gratwick 1988). Two of the recommendations of that conference were accepted as action items by the MEQ Steering Committee of Environment Canada: (1) to conduct a comprehensive assessment of current MEQ and an appraisal of environmental quality information in Canada, and (2) to develop a status and trends monitoring network. The monitoring network was assigned to the Pacific and Yukon Region for development as a national program.

In November 1990, a MEQ Monitoring Symposium was held in Vancouver, with the intention to have leading experts provide a review of factors relevant to the design of a coordinated national program, e.g., monitoring needs and objectives, the state of the art, and technical constraints (see Harding 1990). Following that symposium, the Monitoring Task Force of the Environment Canada MEQ Advisory Group (MEQAG) met with specialist advisors from a number of key federal and provincial agencies to consider monitoring approaches and methods presented at the workshop and to recommend an approach for Canada. Those recommendations and further discussions within MEQAG resulted in a proposal for a status and trends monitoring network: a scientific, operational, and strategic linking of existing monitoring programs of federal and provincial agencies, with selective enhancements (MEQAG 1991). The proposal was accepted by the MEQ Steering Committee and funding was provided for the initial design of the network in 1992.

1.2 Network Development

As a preliminary step in developing the National Marine Status and Trends Monitoring Network, further reviews of the current state and practice of MEQ monitoring and conceptual approaches to ecosystem monitoring were carried out by Harding (1992) and Whitfield *et al.* (1992). The network development is proceeding in five phases, the first three of which are completed or in progress.

Phase I of the development of the network consisted of delineating regions of ecological uniformity in Canada's oceans that would provide a geographical framework for the monitoring network and for State of the Environment (SOE) reporting (Harper *et al.* 1993). Biophysical criteria were developed to create a four-tiered hierarchy: Ice regime and ocean basin defined five "Marine Ecozones"; major oceanic surface current systems and continental margins (continental shelf *vs.* oceanic basin) defined seven more areas to form 12 "Marine Ecoprovinces"; marginal seas (freshwater-dominated, generally semi-enclosed basins) defined six more areas to form 18 "Marine Ecoregions"; and mixing processes, stratification, and smaller-scale currents defined 30 more areas to form 48 "Marine Ecodistricts". The classification system parallels that developed for terrestrial ecological regions by Environment Canada's SOE Reporting office. The report is currently (August 1993) being reviewed and some revisions are anticipated.

Phase II of the development of the monitoring network consists of this report and the consultation process upon which it is based. Consultation was with approximately 70 scientists from various Environment Canada and DFO agencies across the country, although it is the intention that the network will also include provincial, municipal, aboriginal, and academic agencies and institutions. The focus of Phase II has been on evaluating and recommending indicators that will provide information on (1) marine environmental quality (MEQ) and (2) aspects of marine ecosystem structure and function (MESAF) that may contribute to ecosystem health. The terms MEQ and ecosystem health are often used synonymously (Wells 1991). However, a distinction has been made in the development of the network to emphasize the need for a change in direction towards a holistic approach. MEQ, MESAF, and ecosystem health are discussed in Section 1.4.4 of this report, and details of Phase II objectives are given in Section 1.5.

Subsequent phases of the development of the national network are subject to funding and other discussions among partners. **Phase III** will test the design of the national network concept by integrating monitoring activities of federal agencies in the Pacific region. An ecodistrict in each of two marine ecoregions will be selected for monitoring; parameters needed to diagnose ecosystem structure and function will be selected; data sets appropriate to the ecodistrict and parameters will be selected from existing monitoring programs; participating agencies will provide monitoring results for the year and present the results at a workshop; and the workshop proceedings will be published and used to improve the design of the monitoring network, and consider the need for selected enhancements.

Phases IV and V will extend the network to the Atlantic and Arctic regions and to additional ecoregions on each coast.

1.3 Network Purpose and Objectives

The purpose of the National Marine Status and Trends Monitoring Network is to detect change in parameters related to conservation and management of ocean ecosystems, on scales appropriate to management response, regardless of the cause(s) of the change. The objectives of MEQ monitoring programs often include the identification of probable causes in cases where environmental degradation is documented or suspected (e.g., the Gulf of Maine MEQ Monitoring Program; Barchard and Hayden 1990). However, identification of cause ***is not an objective*** of the National Marine Status and Trends Monitoring Network. One reason for this restriction is that trend monitoring detects long-term, large-scale changes in the state of the marine environment and its resources. At this scale, causal relationships between observed environmental changes and site-specific disposal activities will rarely be established (Wolfe and O'Connor 1986). In addition, ecosystem change, especially at the top levels of organization (e.g., populations of top predators), often occurs as a result of multiple causes. Identification of cause is seen as the role of research, not monitoring, although monitoring may stimulate research, e.g., when unexplained trends are detected. Research to understand such trends will often need to be closely coordinated with ongoing monitoring. In addition, monitoring will provide the time series data needed by researchers to investigate causes of long-term changes.

The objectives of developing the monitoring network are as follows:

1. To select, from existing monitoring programs of various agencies, those data sets that may be useful to detect, against a background of natural change, changes in ecosystem structure and function that may result from man's activities;
2. To link the programs operationally (e.g., through joint planning of ship time) and scientifically (e.g., through ensuring that sampling and analysis methods are comparable); and
3. To treat the monitoring results and the activities that support them as a common resource to be shared among agencies and enhanced as necessary to provide reliable information on the quality of the marine environment.

Implicit in the objectives stated above is interpretation and reporting of results. As stated in MEQAG (1991:6), "Products will include synthesized information on MEQ issues for senior managers, reports on program achievements for Parliament, and scientifically credible statistics for national and international SOE reporting for the marine environment. Canadians will have reliable information on the quality of the marine environment and will be able to make more informed personal and corporate decisions, and representations to government."

1.4 Key Concepts

The proposed National Marine Status and Trends Monitoring Network embodies several concepts that are introduced here and discussed further in subsequent sections of this report: network; environmental indicators; integrated monitoring; and environmental quality, ecosystem health, and ecosystem structure and function.

1.4.1 Network

The National Marine Status and Trends Monitoring Network will be a linking of existing monitoring programs of federal and provincial agencies, with selective enhancements. Programs will be linked strategically (by coordinating operational programs of participating agencies, supported by cooperation agreements among participating agencies), scientifically (by nationally consistent sampling and analytical protocols and quality assurance/quality control procedures), geographically (so that data from one program will support another), and ecologically (by adding ecosystem health indices to physical, chemical, and lower trophic level variables). MEQAG (1991) suggested initial tasks to develop the required linkages. It is emphasized here that this is a monitoring network, not a monitoring program. To implement a new, comprehensive national monitoring program would require considerable resources. (For example, it was estimated that to monitor a broad range of indicators to assess status and trends in the Gulf of Maine would cost US$3,000,000 annually.) Recommendations made in this report are limited to indicators of MEQ and ecosystem structure and function for which information can be collected largely from existing monitoring programs.

1.4.2 Environmental Indicators

Environment Canada (1993) provided two useful definitions of an environmental indicator: (1) "a character of the environment that, when measured, quantifies the magnitude of stress, habitat characteristics, degree of exposure to the stressor, or degree of ecological response to the exposure" (from the Council of Great Lakes Research Managers), and (2) "...a measurable feature which singly or in combination provides managerially and scientifically useful evidence of ecosystem quality, or reliable evidence of trends in quality" (from the Intergovernmental Task Force on Monitoring Water Quality).

Indicators (symptoms of ecosystems under stress) were used in Canada's first State of the Environment Report (Bird and Rapport 1986). In 1988, the newly established State of the Environment (SOE) reporting program, under the leadership of Environment Canada and Statistics Canada, suggested that environmental indicators needed to be selected from the masses of environmental data collected by scientists, and provided to decision-makers and the general public in relevant and easily-understood ways. In February 1990, the Indicators Task Force was established. In Canada's Green Plan, released in December 1990, the federal government made a commitment to develop a national set of environmental indicators that, taken together, will provide a "...profile of the state of Canada's environment and indicate trends towards sustainable development" (Environment Canada 1991:iii). In 1993, Eco-Health Branch of Environment Canada's Ecosystem Science and Evaluation Directorate proposed a national framework for developing indicators for evaluating and reporting ecosystem health. The proposed national framework has been approved by the interdepartmental Committee on Water and by the Water Quality Guidelines Task Group of the Canadian Council of Ministers of the Environment (CCME). The framework will be published as a CCME report following final approval by the CCME Environmental Protection Committee in early 1994.

MEQAG (1991) proposed and Harding (1992) elaborated on a core set of indicators for use in the National Marine Status and Trends Monitoring Network. Included were specific measures of ecosystem stressors (contaminant inputs, coastal land use and restructuring), exposure (concentrations of contaminants in water, sediments, and biota), biological response (e.g., biomass, diversity, mortality), and indicators of MEQ. That set of indicators forms a starting point for the evaluation of and recommendations for indicators developed in this report.

1.4.3 Integrated Monitoring

Within Environment Canada, the term 'integrated monitoring' currently is used to refer to the integration of monitoring activities of various groups. The primary objective is to increase efficiency and provide potential cost savings in field sampling, environmental sensing, and analysis operations. A second objective is to add value to existing programs by providing a multi-media and cross-sectoral context in which monitoring may be planned and results interpreted. Both of these objectives apply to the National Marine Status and Trends Monitoring Network.

1.4.4 Environmental Quality, Ecosystem Health, and Ecosystem Structure and Function

In developing the network, distinctions have been made between marine environmental quality (MEQ), marine ecosystem health, and marine ecosystem structure and function (MESAF), to emphasize the need for a change in direction towards a holistic approach. It is intended that the National Marine Status and Trends Monitoring Network will consider both MEQ and MESAF, as defined below. One objective of the network, as stated in MEQAG (1991:3), is to document, on a continuing or periodic basis, aspects of structure and function that may contribute to the health of representative marine ecosystems in the coastal regions of Canada. In this report, the phrase "marine ecosystem structure and function" will be used, rather than marine ecosystem "health".

Wells (1991) discussed the difference between marine environmental quality and marine ecosystem health, noting in summary that "...quality denotes historical change in the condition, whereas health is the present condition and the direction of change". However, he noted that the terms are often used synonymously, and considered them as equivalent in the recent status report on Canadian MEQ (Wells and Rolston 1991). Harding (1992) also discussed the differences, and pointed to the direction that we need to take: "The challenge confronting environmental managers is to move from monitoring of environmental quality, largely centred upon pollutants and their effects at lower trophic levels, to a more integrated approach incorporating attributes of marine ecosystems."

Measures and definitions of human and nonhuman animal health provide useful analogs to the maintenance of ecosystem integrity (Schaeffer *et al.* 1988). Rapport (1989) discussed three approaches to assessing ecosystem health: identification of risks or threats from known stressors; measurement of counteractive capacity to handle stress loadings, or the ability to 'bounce back'; and the 'vital signs' approach. He noted that assessing health commonly involved looking for systems of disease, but argued for a more generic approach, "...the identification of systemic indicators of ecosystem functional (and structural) integrity". He stated that "...ecosystem integrity depends on a small number of critical functions and structures, including maintaining efficiency in energy transfer and nutrient cycling, and maintaining a diverse species assemblage in which the longer-lived and larger life-forms are dominant in the mature phase of ecosystem development". He went on to discuss the following symptoms of "ecosystem breakdown": reduced primary productivity, loss of nutrients, loss of sensitive species, increased instability in component populations, increased disease prevalence, changes in the biotic size spectrum to favour smaller life-forms, and increased circulation of contaminants.

Monitoring programs need to incorporate measures of whole ecosystems to detect and measure ecosystem-level changes resulting from multiple stresses (Harding 1992). Harding classified those attributes as (1) processes (or *functions*) that may lead to ecosystem changes; and (2) the *structural* characteristics and key system attributes of marine ecosystems that identify whether ecosystem change has occurred. He argued that monitoring indicators of ecosystem function would allow intervention before changes in ecosystem structure become inevitable. For example, biomagnification can be detected by measuring contaminant levels in components of a food web before structural change such as reductions in fish, bird, or marine mammal populations result (Whitfield *et al.* 1992). However, Schindler (1987) pointed out that in aquatic ecosystems, structural indicators such as phytoplankton species composition can be better early warning indicators than functional indicators such as primary production, nutrient cycling, and respiration. Natural systems contain feedback mechanisms that buffer them against perturbations. Hence, monitoring ecosystem functions is not always appropriate to detect early signs of impending ecosystem damage (Schindler 1987).

Kelly and Harwell (1989) cautioned against indiscriminate preference for one type of ecosystem attribute over the other, but argued that the increased role of carefully selected functional indicators was warranted because the use of structural indicators was far more prevalent and the two are complementary. Schindler (1987) added that "Changes in ecosystem function, such as production, decomposition, or nutrient cycling, cannot be properly interpreted without analogous information on the organization and structure of the biotic communities which perform the functions."

1.5 Phase II Statement of Work

The following sections are taken verbatim from the Statement of Work that was included in the Request for Proposal for the Phase II study.

1.5.1 Objectives

To propose a set of provisional indicators which may be used to assess **"Marine Environmental Quality"** and **"Marine Ecosystem structure and function"** for each **"Marine Region"** of Canada as determined in the Phase I project.

To delineate stations where intensive and extensive monitoring activities should be applied.

These objectives must be presented in a scientific report.

1.5.2 The Work

1. Conduct a scientific literature search and meet with appropriate scientists of federal, provincial, territorial and aboriginal agencies to obtain their views on parameters necessary for integrated monitoring of **marine environmental quality** and **ecosystem structure and function**. This may require travel to Ottawa, Vancouver, Winnipeg, Montreal, Halifax and Yellowknife. The Scientific Authority will advise on the appropriate scientific and science manager staff to be contacted.

2. Design a monitoring **'network'** which will include

    1. An identification of proposed indicators of (a) MEQ and (b) Ecosystem structure and function. This will include a statement of hypotheses to be tested.

    2. A discussion of how QA/QC can be assured in a network of participating agencies.

3. A proposed list of stations in each Marine Region for extensive monitoring of **marine environmental quality**; identify key reference stations for intensive integrated monitoring of **marine ecosystem structure and function.**

4. A proposal on frequency of sampling for each parameter; number of samples and level of statistical discrimination needed to detect change.

5. Discussion of existing programs which may contribute information to the network.

1.5.3 Crown Input

A Steering Committee will provide information on existing monitoring programs, including location of sampling stations and parameters analyzed from the agencies contacted.

2.0 METHODS

Information was collected through a review of relevant published and unpublished information, and meetings with appropriate Canadian scientists. Documents reviewed are listed in the 'Literature Cited' section. A 'long list' of indicators of MEQ and MESAF was developed from the literature search and used as a basis of discussion in the meetings. Input from appropriate scientists in Canada was solicited through personal contact, especially a series of meetings or workshops held in Nanaimo, Sidney, Winnipeg, Ottawa, Mont Joli, Halifax, Moncton, and St. John's. Direction on whom to see was taken from MEQ regional contacts. Prior to the meetings, background information, the 'long list' of indicators of MEQ and MESAF, and a statement of the meetings' purposes and desired outputs was distributed to the participants. Minutes were kept and are included as Appendix A to this report. Information on existing monitoring or data collection programs of relevance was provided by the MEQ Steering Committee and was solicited during the meetings.

3.0 RESULTS AND DISCUSSION

3.1 Indicators

3.1.1 Environment Canada Perspective

Environment Canada (1993) provided two useful definitions of an environmental indicator: (1) "a character of the environment that, when measured, quantifies the magnitude of stress, habitat characteristics, degree of exposure to the stressor, or degree of ecological response to the exposure" (from the Council of Great Lakes Research Managers), and (2) "...a measurable feature which singly or in combination provides managerially and scientifically useful evidence of ecosystem quality, or reliable evidence of trends in quality" (from the Intergovernmental Task Force on Monitoring Water Quality).

In Canada's first State of the Environment Report (Bird and Rapport 1986), biological indicators used to assess effects of human activity on aquatic ecosystems were discussed. For each of Canada's three marine regions, the state of the ecosystem was described in terms of a group of indicators. ***Atlantic***: primary productivity, biotic composition (fishery landings), biotic size (age-at-catch), disease incidence (shellfish closures/paralytic shellfish poisoning [PSP], furunculosis, and seal worm), and contaminants (shellfish closures/sewage). ***Pacific***: primary productivity, abundance of fish (landings of salmon, herring, and halibut) and numbers of marine mammals (Steller and California sea lions; orcas), biotic size (mean weight or age of landed salmon), diseases (PSP), and contaminants (organics and metals in the Fraser River, shellfish closures/ sewage). ***Arctic***: contaminants (hydrocarbons and metals) and trends in major marine mammal populations (bowhead whale, narwhal, white whale) and fisheries (arctic char). Bird and Rapport (1986) noted that data for many ecological indicators were inadequate, and that it was often necessary to use 'surrogate' measures (e.g., fishery statistics).

In 1990, the Indicators Task Force was established within Environment Canada, in recognition of the need to provide environmental data collected by scientists to decision-makers and the general public in relevant and easily-understood ways. The Indicators Task Force developed a preliminary list of environmental indicators, which included indicators for the atmosphere, water, land, biota, and natural economic resources. Relatively few were for or relevant to the marine environment. They noted, however, that accurate determination of environmental quality of marine resources requires a diverse set of measures, as does a complete picture of MEQ. Kelly and Harwell (1989) agreed, arguing that to characterize the response of an ecosystem to a stress, one must select from a suite of indicators, as indicators are "measures that reflect only some facet of the ecosystem—biotic or abiotic, structural or functional—at some spatio-temporal scale of observation." MEQ indicators on the Indicators Task Force preliminary list (Environment Canada 1991) and others relevant to the marine environment are as follows:

- municipal and pulp and paper mill discharges to coastal waters: TSS and BOD
- volume of significant marine spills
- area closed to shellfish harvesting
- contaminant levels (PCBs, furans, dioxins) in seabird eggs
- biological diversity/wildlife species at risk
- levels of migratory game bird populations
- total commercial fish catches in Canadian waters off the Atlantic coast

MEQAG (1991) proposed and Harding (1992) elaborated on a core set of indicators for use in the National Marine Status and Trends Monitoring Network. Included were specific measures of ecosystem stressors (contaminant inputs, coastal land use and restructuring), exposure (concentrations of contaminants in water, sediments, and biota), biological response (e.g., biomass, diversity, mortality) and indicators of MEQ.

3.1.2 Selection of Indicators

Some common technical difficulties in selecting indicators are (1) designing sampling programs that can detect change and separate human effects from natural variability, (2) interpreting effects in terms meaningful to society, (3) linking monitoring programs with research programs designed to determine the fate and effects of contaminants, and (4) designing monitoring programs to address public concerns directly or for managers or policy makers (NRC 1990).

As a part of the process followed by the federal government's National Environmental Indicators Project, basic selection criteria for a national environmental indicator were identified (Environment Canada 1991). To be considered as an indicator, a measure should be

- scientifically valid
- supported by sufficient data to show trends over time
- representative
- understandable
- relevant to stated goals, objectives, and issues of concern
- have a target or threshold level against which to compare it
- either national in scope or applicable to regional environmental issues of national significance

In addressing the need to monitor human impacts on Marine Environmental Quality and Ecosystem State, the following concerns are most commonly considered and incorporated into monitoring programs (ACMP 1992; NRC 1990; Harding 1990, 1992; MEQAG 1991; Kelly and Harwell 1989):

1. **Linkage with ecosystem processes and other monitoring goals.** Indicators that measure ecosystem structure or function directly describe the state of an ecosystem, whereas measurements at lower levels of biological organization are indirect measures of ecosystem processes. In general, measures at the cellular and individual level have a weak linkage with ecosystem processes, and as the level of organization increases to populations and communities, the linkage becomes stronger. Within a level of biological organization, the strength of the linkage with ecosystem processes varies among indicators. Indicators at the cellular level that measure energy reserves for growth and reproduction link more directly to population, community and ecosystem processes than do other cellular indicators.

2. **Signal-to-noise ratio and sources of natural variation.** The greater the amount of natural variation ('noise') relative to the change resulting from a human impact ('signal'), the more

difficult it is to demonstrate a statistically significant change in an indicator (Nicholson and Fryer 1992). The amount of natural variation in an indicator is an inherent property that cannot be altered although a related factor—measurement error—can be reduced by better measurement techniques. An accurate estimate of the variance is essential, and there must be confidence that the variation is real, not a result of imprecision in sampling or laboratory analysis. The larger the sample size, the better the estimate, although the benefit of additional samples decreases as sample size increases beyond a certain number. Standard statistical tests can be employed to estimate the sample size required to detect a predetermined amount of change in the target variable (Zar 1984). The sampling design would greatly benefit from an understanding of the distribution of variation in time and space so sampling sites and frequency can be made appropriate to the scale of the variation. The accuracy of estimates can be optimized through other decisions about sampling and analysis design, e.g., stratification, weighting by variance, use of covariates.

The error associated with analytical techniques used for measuring indicators can be significant. Quality assurance (QA) methods must be developed and standard techniques selected by a recognized group of scientific experts, and those methods must be strictly followed. Some of the QA issues include (1) intercomparisons between laboratories and technicians, (2) the selection and use of appropriate reference material, (3) pre-assessment of laboratories to provide reliable and comparable data, and (4) the establishment of QA criteria requirements for all data to be included in a common database (ACMP 1992). Intercomparison exercises have been conducted or planned by laboratories participating in International Council for the Exploration of the Sea (ICES) workshops for the analysis of chlorobiphenyls and PAHs in marine media, trace metals in suspended particulate matter, nutrients in seawater, and activity of ethoxyresorufin-O-deethylase (EROD) in fish livers (ACMP 1992). The ICES Advisory Committee on Marine Pollution (ACMP) has also discussed the need for QA criteria for all stages of monitoring from programme design to the preparation of reports.

The greater the signal-to-noise ratio, the greater the probability of demonstrating a significant change with a given sample size, and the lower the number of samples needed for a given level of sensitivity. Therefore, indicators with high signal-to-noise ratio are especially desirable. Unfortunately, the indicators with the greatest signal-to-noise ratio (e.g. contaminant concentrations, pathological effects) are thought to have weak linkages with ecosystem process and vice versa. Therefore, trade-offs are encountered in selecting indicators at increasing levels of organization.

3. **Sensitivity to human-induced environmental change and response time to impact.** Indicators that respond quickly to an environmental perturbation of human origin and have a large, measurable response are valuable early warning indicators of an environmental stress. Indicators of this type are often specific to a particular contaminant, are cellular, and are far removed from ecosystem processes. An example is the induction of mixed-function oxidase (MFO) activity in organisms exposed to hydrocarbons.

4. **Ease and economy of measurement: field sampling, lab I.D., pre-existing databases, easy process test.** Monitoring programs are always constrained by cost. The more costly the method of measurement, the fewer samples that can be taken per unit cost. Higher costs are often attributable to technologically advanced procedures that require expensive equipment and the employment of highly trained laboratory and field personnel. Measuring trace metals and dioxins in water, sediment or animal tissues is very expensive for this reason. Indicators of organism response to chemical pollutants (e.g, histopathology, toxicity tests, growth) are less expensive and may be desirable in combination with a minimal number of contaminant concentration measurements. Also, it is generally desirable to use indicators that have been used previously and for which the technical details are understood. Databases may already exist for these indicators, the signal-to-noise ratio will be known, and technical difficulties will be minimal.

5. **Knowledge base and understanding of biological significance.** The linkages between an indicator and the monitoring goals are critical to the success of a monitoring program. The assumption is that a change in a selected indicator beyond some threshold is of importance to the viability of a species, the integrity of a community or ecosystem, or human health. The most valuable indicators are those for which (a) the responses of the indicators to a pollutant are known, and (b) the significance of a change in that indicator to organisms, populations, communities, and ecosystems are well understood. Few indicators are understood to this degree.

6. **Reliability and specificity of response to one or many environmental changes.** Indicators that respond consistently to stress of a known kind are considered reliable. This type of indicator is often specific to one contaminant or suite of contaminants (e.g., MFO). Stress-specific indicators are often early warning indicators, but they tend to be poorly linked to ecosystem processes. Although reliability and specificity are desirable in themselves, indicators with these characteristics tend to be unsuitable for measuring overall ecosystem conditions.

7. **Relevance of indicator to specific concerns (end point).** Indicators that are directly relevant to the goals of a monitoring program are the most valuable. Such indicators can be identical to the 'ecological endpoint of concern' (e.g., population levels of endangered species), or closely linked to the endpoint (Kelly and Harwell 1989).

8. **Monitoring feedback to regulation.** A major function of a monitoring program is to provide government agencies with information on MEQ and Ecosystem State for regulatory and decision making purposes. The success of a monitoring program depends on effective communication of monitoring results and implications to science advisors and policy makers, and on the involvement of those individuals in the planning process. Following a recent review of some international monitoring programs, it was concluded that management requirements were inadequately incorporated into the design of monitoring programs, and it was recommended that study goals and an evaluation of the likelihood of success be incorporated at the program design stage (ACMP 1992).

3.1.3 Categories of Indicators

One way of organizing or categorizing environmental indicators is by level of biological or ecological organization. In this section, types of indicators are grouped in such a manner, beginning with measures of stress on biological systems and proceeding through increasingly complex levels of organization to that of most importance here—the ecosystem level.

3.1.3.1 Direct Measures of Pollution & Other Stressors

Direct measures of environmental stressors include habitat loss, contaminants in water and sediment, and concentrations of oxygen, total suspended solids (TSS), nutrients, and coliform bacteria in the water.

An important component of any monitoring program is an understanding of the degree of stress existing in the environment. Information at this level provides no direct measure of biological impact at the cellular, organismal, population or ecosystem level, but relies on scientific knowledge about the effects of contaminants on organisms to evaluate the potential impacts. Stressors are presently measured by government agencies and are used to make decisions on shellfish closures, closing of beaches to bathing (faecal coliforms), and fishery closures (contaminant concentrations after a spill or due to continuous discharge) (Harding 1992). The British Columbia database on faecal coliforms collected by Environment Canada is considered a successful monitoring program (Harding 1990). Indicators of this kind, which are easy to measure and are linked directly to a monitoring goal (human health), are monitored on an ongoing basis.

Measurement of contaminants in water and sediment samples may, in some cases, be a relatively costly undertaking, depending on the purpose of the survey and the suite of contaminants to be analyzed. Costs are high where contaminant concentrations in the environment vary in space and time because large numbers of samples are required to understand the variability. A common approach has been to use a sentinel organism that bioaccumulates contaminants and therefore represents a time average of contaminant levels, interpretation of such data are, however, difficult at present. Biologically-based water and sediment quality guidelines exist or are being developed (see MacDonald *et al.* 1992) which provide a relevant tool for assessing the toxicological significance of contaminants in those media.

3.1.3.2 Cellular Indicators

Cellular indicators commonly measured include mixed function oxidase (MFO), metallothionein, histopathology (e.g., liver lesions in flatfish), genetic change, and bacterial contamination.

Although some cellular measures are sensitive, most of these are sensitive only to specific pollutants and most are poor indicators of ecological significance (Howells *et al.* 1990). Some tests at the cellular level are time consuming, expensive and require extensive training. Classical measures of genetic change (e.g., karyology to detect genetic damage and chromosomal abnormalities) are of this type. However, inexpensive and rapid methods have been developed recently to monitor effects of genotoxins, toxic wastes and radioactivity on fish and wildlife populations (e.g., McBee and Bickham 1988). For example, flow cytometry can be used to demonstrate that the DNA in blood and other tissues of animals exposed to environmental mutagens is significantly different from that in control animals. Thus, natural populations of vertebrate animals can serve as sentinels to warn of the potentially hazardous effects of environmental pollutants.

Enzymes produced in response to the ingestion of a chemical often are only indicators of the uptake of a chemical and do not indicate a negative biological response. Metallothionein in mussels (*Mytilus edulis*) and MFO induction in flatfish (*Platichthys flesus*) are cellular level effects/indicators that are considered valuable indicators for monitoring (Howells *et al.* 1990). MFO is useful because it is less specific and responds to a range of environmental contaminants including some polynuclear aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), and chlorinated dibenzodioxins and dibenzofurans (Addison 1990).

Flatfish are also common subjects of histopathological studies in harbours where contaminants are prevalent in the benthos (e.g., Puget Sound). Flatfish have been found to develop lesions in Puget Sound and Vancouver Harbour at rates as high as 75% (Goyette 1990). Myers *et al.* (1990) suggest that juvenile flounders are preferred subjects for histopathological studies because of their limited migration range. They also suggest non-neoplasm liver lesions are good early indicators of biological damage in wild fish exposed to xenobiotics. Links are known to exist between polycyclic aromatic hydrocarbons and fish liver lesions (Goyette 1990).

Biological effects and contaminants monitoring in the North Sea showed that the level of contaminants in sediments corresponded with MFO activity, cholinesterase inhibition, and degenerative changes in liver cells (lysosomal damage, lesions, increased endoplasmic reticulum) in dabs, *Limanda limanda* (ACMP 1992). However, an inter-laboratory comparison found that MFO activity in dab differed among labs, sexes, and seasons. Similarly, an analysis of disease prelevance in dab from about 800 sampling stations in the North Sea showed that there were interpretation difficulties resulting from the combination of sex, size, and lab differences with insufficient data to calibrate lab differences or avoid pooling. Intercalibration exercises have been planned for MFO activity by participants in ICES working groups in order to rectify this problem (ACMP 1992). Caution must therefore be exercised in interpreting MFO activity data until appropriate QA criteria are tested and approved.

3.1.3.3 Whole Organism Indicators

Indicators at the individual organism level include toxicity tests, developmental abnormalities, scope for growth, nutrition and metabolic energy pools, reproduction (e.g., reduced fecundity in birds and mammals), physiological or biochemical effects in birds and mammals, survival/mortality, behaviour (e.g., avoidance of low oxygen areas), and migration.

Survival and reproduction effects can link directly with population impacts and thus higher level effects. However, survival and reproduction effects are not commonly monitored. Scope for growth was found to be responsive, ecologically significant, and easily measured in mussels (Howells *et al.* 1990). Adams *et al.* (1990) suggest that "MFO enzymes and DNA integrity can be used as indicators of direct exposure to contaminants while indicators of nutrition and metabolic energy pools serve as useful indicators of indirect contaminant effects on organisms". Recent studies on flatfish have shown a possible association between exposure to contaminants and impaired ovarian maturation and failure to spawn, and that levels of plasma estradiol and hepatic MFO activities are useful predictors of these effects (Collier *et al.* 1993). Strong linkages have also been made between levels of organochlorines in the environment, concentrations in eggs of oceanic and coastal marine birds, and their hatching success (Noble 1990).

Contaminants and other pollutants are likely to affect growth of an organism if energy expenditure or energy intake is affected. For example, an inverse relationship exists between tributyltin concentrations in tissues and growth rate of the mussel *Mytilus* sp. (Salazar and Salazar 1990).

Most toxicity tests are conducted in the laboratory under controlled conditions of light, temperature, oxygen, salinity, and exposure concentration and time (exceptions are microbial community respiration tests carried out *in situ*). Only a few species are tested routinely, and test organisms are often reared in the laboratory. In this way, comparisons can be made between contaminants and sample sites, and threshold levels can be established for regulatory and decision-making purposes. The disadvantage is the difficulty in extrapolating from laboratory test results to the natural environment. Simultaneous studies are often conducted on community parameters in an attempt to relate toxicity test results with impacts on species assemblages at the sample site (Cross *et al.* 1990; Gillam 1990).

3.1.3.4 Population Indicators

Common population indicators include age structure, abundance, biomass, and recruitment.

Few population indicators have been measured as part of an environmental monitoring program. Population parameters are potentially more easily measured and less subject to natural variation in stable, long-lived, low fecundity species, e.g. certain benthos (Howells *et al.* 1990) and certain seabirds. In addition, species with stable populations, higher rates of production, and large biomass compared to the total in that ecosystem are preferred choices as indicators of higher level processes. The impact of environmental stressors on population parameters (e.g., recruitment, abundance) is more clear than for higher level indicators (Harding 1990).

Many population parameters (abundance, age/size structure, recruitment) are well documented for some commercially- and recreationally-important species, including some of those that are benthic and sessile (e.g., clams) and of those that are motile and pelagic (e.g., salmon). Such data may be useful for monitoring MEQ or ecosystem state. Populations of some species warrant close attention as candidates for the monitoring network because of the availability of information, because of their high intrinsic importance as food, and because the species may be endangered or play important roles in the marine ecosystem. It is likely that harvests have greater impacts on these populations than do other types of stress.

Monitoring of seal and cetacean population abundances, despite their low rate of reproduction, are ongoing in the North Sea because of their susceptibility to heavy metal and organochlorine uptake, their vulnerability to entanglement in fishing nets, and the occasional occurrence of mass mortality from diseases such as the 1988 outbreak of phocine distemper virus (ACMP 1992). The combination of population assessment and measurement of contaminant levels in tissues has been used for management purposes to classify seal and cetacean populations according to the level of available information and the degree of concern. Population status is classified as (1) no cause for concern, (2) exposed to specific threats (e.g., organochlorine), (3) not satisfactory (low population abundance and high levels of contaminants in tissues), or (4) more information is needed to determine status. Direct cause and effect studies in the field are lacking (ACMP 1992).

3.1.3.5 Community Indicators

Community indicators include species composition (by numbers or biomass), size structure, species diversity, and community production or respiration.

Community indicators lack specificity with respect to particular pollutants, and vary in sensitivity. But in the nearshore benthic environment where both contaminants and monitoring are concentrated, communities persistently respond to pollutants, and are ecologically significant and measurable; common measures include diversity, abundance and biomass (Howells *et al.* 1990). In general, monitoring of community parameters has been less successful in pelagic and demersal communities than for benthos (e.g., ACMP 1992). Regular monitoring at the community level of organization is common for benthos, and is becoming more so under the requirements of the amended Pulp and Paper Effluent Regulations of the federal *Fisheries Act* (1992). Communities are clearly impacted when smothered by wood fibres from pulp and paper mills or tailings from mines. Data on fish landings and abundances of marine mammals have been substituted for data on community composition in the State of the Environment Report for Canada (Bird and Rapport 1986).

A difficulty with community indicators is that they generally provide no direct basis on which to separate natural from anthropogenic effects (NRC 1990). This will only be resolved by ongoing, replicated monitoring of communities in both impacted and non-impacted sites, coupled with related experimental research efforts where appropriate.

Within any given area, there are many communities, each with many species. It generally is not practical to monitor all communities or all species within a given community on a regular basis. The solution is to chose a group of key species. EPA has selected fish community composition as an indicator in their environmental monitoring program (Paul *et al.* 1990). Polychaetes have proven to be sensitive to organic enrichment and heavy metals, and polychaete community structure has been monitored as an effective indicator of pollutant effects (Bellan *et al.* 1988). The Pielou method, a widely respected approach, involves using the three most dominant species to assess diversity in a community (Clark 1990).

Variability of community-level indicators is high, both in time and space. Variability in benthic communities is less than that in most others because many community members are sedentary. The benthos is, therefore, especially attractive for community level monitoring. Community level indicators of marine demersal and pelagic communities have rarely been studied thoroughly. There is no evidence that benthic community indicators provide insight into those adjacent communities.

3.1.3.6 Ecosystem Indicators

Ecosystem-level indicators include food chain effects (e.g., biomagnification), nutrient dynamics, trophic structure and state, primary productivity and size spectra, biodiversity, energy flow, genotypic/phenotypic diversity, dissolved oxygen, phytoplankton bloom frequency and severity, and levels of major phycotoxins such as PSP, ASP, and DSP.

The monitoring program at the ecosystem level should focus on (1) processes that may lead to ecosystem state changes, e.g., bioaccumulation/biomagnification, toxicity, altered predator-prey patterns, eutrophication, spread of pathogens, or disease; and (2) structural characteristics that indicate when these changes have occurred, e.g., species associations and size spectra (Whitfield *et al.* 1992). However, there is a general lack of information on the feasibility of monitoring ecosystem processes directly (Harding 1992). Whole ecosystem state or process variables like biomass and primary production vary greatly on a seasonal, annual and spatial basis, and thus have a low signal-to-noise ratio.

ACMP (1992) concludes from sampling in the North Sea that nutrient or biomass trend monitoring in water are problematic and are not recommended, unless changes in the deposition rate of organic matter in sediments can be demonstrated. In contrast, primary production may be a useful measure of ecosystem processes, but requires the measurement of phytoplankton primary production over a range of temporal and spatial scales (ACMP 1992).

Biomagnification has been measured for key contaminants in Arctic ecosystems, including man. Pesticides have been found in marine mammals, including belugas, killer whales, porpoises and ringed seals, in the Arctic, B.C. and the St. Lawrence. The presence of significant levels of pesticides in these animals is a result of bioaccumulation up the food chain (Muir and Norstrom 1990). Likewise, pesticides and organochlorine contaminants are commonly found in bird tissues, where they are associated with reduced hatching success and development abnormalities (e.g., Kubiak *et al.* 1989).

The complexity of an ecosystem causes serious problems in choosing appropriate and measurable indicators to describe ecosystem structure and functions. Biological threshold criteria have been developed which incorporate a number of ecosystem-level measurements into one index, e.g., Karr's (1981) Index of Biotic Integrity. However, the value and interpretation of index measures is a subject of much debate in the scientific community; any ecosystem is so complex that it is probable that there is no single index that can indicate its state. One approach is to use the responses of dominant species as ecosystem indicators. Species that contribute more than 20% to the total biomass of a trophic level or provide more than 20% of primary production to an ecosystem are good candidates for monitoring ecosystem processes (Schaeffer 1990).

Changes that are likely to occur in response to stress at the ecosystem level include the following: (1) ecosystems become more open, (2) successional trends reverse, (3) parasitism increases, (4) sensitive genotypes are replaced by more tolerant genotypes, (5) loss of large species, (6) species diversity decreases while abundance of dominant species becomes proportionally higher, (7) increase in proportion of r-strategists (high fecundity, short life), (8) food chain shortens, (9) nutrient loss increases, (10) maintenance to biomass structure (P/B and R/B) ratios increase, (11) nutrient turnover time increases, (12) horizontal transport increases and vertical cycling of nutrients decreases, and (13) sizes of organisms decrease (Odum 1985; Howells *et al.* 1990).

Ecosystem level processes include abiotic as well as biotic components. Information on biological indicators should be supplemented by information on external physical forces like mesoscale ocean temperatures, global and regional air temperatures, and circulation from freshwater runoff.

3.1.4 Hypotheses

In the Statement of Work and in the first stages of this project, the intention was to formulate testable hypotheses for each of the recommended indicators. It was decided, however, in consultation with the Scientific Authority, that formulation of hypotheses was not appropriate here. The objective of this study was not to design a monitoring program, but rather a monitoring network based on existing monitoring programs. For every indicator that is incorporated into the network, one or more testable hypotheses will also be incorporated (if already existing) or re-formulated.

3.1.5 Long List of Indicators

Based on the literature review summarized in Sections 3.1.1 to 3.1.3, a long list of indicators was developed and circulated, with other preparatory material, to the individuals invited to the meetings held as a part of this project. The variables included in the list have all been suggested by various authors as indicators of some aspect of the condition of the marine environment. The purpose of developing and circulating the list was to stimulate conversation at the meetings, and to indicate the types of information that could conceivably be used as indicators in the monitoring network. That list is as follows:

Marine Environmental Quality

- Contaminants in sediment
- Contaminants in shellfish
- Water quality
- Floating debris, oil, etc.
- MFO, metallothionein, histopathology

Marine Ecosystem Structure and Function

Structure	Trophic composition	Exotic *vs.* native species
	Seabird populations	Marine mammal populations
	Fish stocks	Minimum viable population size
	Biodiversity	Size composition
	Genetic diversity	Age structure
	Habitat loss/availability	Habitat fragmentation
	Minimum area requirements	Mortality rate
	Recruitment rate	

Function	Nutrient dynamics	Carbon cycling
	Primary productivity	Rate of decomposition
	Respiration	Eutrophication
	Toxicity	Bioaccumulation/biomagnification
	Growth	Reproduction (mammals, predatory birds)
	Predator-prey relations	Host-parasite relations
	Energy flow	Resilience
	Stability	Retrogression
	Migration	Recruitment

Specific comments about the long list of indicators are contained in the minutes of the meetings (Appendix A). In general, it was felt that most of the indicators of MESAF on the list were not appropriate for the National Marine Status and Trends Monitoring Network. A short list, derived primarily from discussions and comments at the meetings, is given in the next section.

3.1.6 Preliminary Short List of Indicators

Indicators suggested for inclusion in the monitoring network are listed and discussed in this section. The list of indicators is based largely on the results of discussions with the scientists and environmental managers who attended the meetings held as part of this project. Many of the same indicators were suggested at several meetings.

Sets of indicators are included in the suggested indicators, in keeping with the network's focus on integrated monitoring. There are links between most indicators within each of the four sets of indicators, and links among indicators and sets of indicators. The sets of indicators are marine mammal, seabird, and fish communities; biomagnification; contaminant effects at progressive levels of organization; and productivity. If information is available on a number of indicators that are linked together ecologically, it will be easier to interpret observed conditions and changes, and in some cases it will be possible to determine causes. Links between indicators are discussed in this section. Other suggested indicators are marine litter, toxic phytoplankton blooms, and contaminants in mussels (the mussel watch approach).

Most of the major marine environmental issues such as overfishing, contaminant levels and their effects, eutrophication, and climatic change would be addressed by using the four sets of indicators suggested below. There are existing data and/or programs for most indicators in at least some of the regions. The following section (3.2) discusses monitoring programs and available data that are relevant to the suggested indicators.

3.1.6.1 Marine Mammal, Seabird, and Fish Communities

Issue	**Indicators**
1. Seabird community status Marine mammal populations	Population size Reproductive success of selected species with limited ranges and known diets Other variables: egg volume, growth of young, prey proportions? ↓
2. Fish community composition	Fisheries catch data where possible. Link to 1: Is there a change in prey species that may be related to seabird indicators? ↓
3. Other fish data	Condition and weight at age, from commercial catches. Link to 1 and 2: Are there other changes in the attributes of fish populations that may be related to fish catch or seabird populations? ↓
4. Pelagic habitats	Oceanographic data (T, S, currents). Links: Can changes in these explain 1, 2, or 3?

The status of seabird and marine mammal communities indicates overall habitat condition including food availability, disruption of nesting or calving habitat by industry and human presence, effects of contaminants, effects of offshore mortality from such hazards as oil spills and drift nets, and natural variation. If a change in seabird or marine mammal communities is observed, the effect may be explained by information on fisheries, oceanographic conditions and productivity, contaminants, and effects of contaminants.

Changes in seabird populations may lag behind changes in causative factors (e.g., by as much as 15 years for murres) because seabirds are long-lived and have low natural mortality rates (5-10% annually) (T. Lock, pers. comm.). Changes in such populations indicate that a significant change in ecosystem state has occurred. Reproductive success is a better indicator than population size because the time lag between cause and effect is not so great. The ideal seabird monitoring program would include measurements of population size at widely distributed "extensive" study sites plus reproductive success at "intensive" study sites.

In the Arctic, marine mammals fill the niches that, in temperate waters, are normally occupied by large pelagic and benthic fish. In addition, arctic marine mammals are used as food by native people. In all oceans, populations of marine mammals, like seabirds, are affected by the overall state of the marine environment. The abundance of fish-eating mammals is affected by the supply of fish, and the distribution of planktivorous baleen whales is strongly affected by the locations of areas with high densities of zooplankton. Additional rationale for including marine mammals in the monitoring network is their high profile with the public. In most people's eyes, a report on marine environmental quality would be incomplete if it did not address marine mammals.

Data on the human catch and condition of fish indicate food availability for seabirds and large fish only in a general way. Catch and catch per unit effort are affected by market demand and quotas as well as the abundance of the fish. There is information on the catch of some commercially-important forage species such as herring and capelin, but little information on other forage species such as sand lance and cunner. Thus, it will not always be possible to relate data on seabirds and to existing data on fish. Long-term oceanographic data sets have been and can be analyzed to indicate changing climatic conditions that could affect seabirds and fish.

3.1.6.2 Biomagnification

Indicators

Contaminants in sediments or water → fish 1 → fish 2 → seabird → humans
→ marine mammal → humans

Some contaminants are greatly magnified through the food chain; some others are not. Many organic contaminants show biomagnification in the food chain. There also can be some food chain enrichment of heavy metals. However, metals such as mercury and zinc are accumulated via direct uptake and only small amounts are passed via the food chain (Forstner and Wittmann 1972). If there is biomagnification, then each link in the food chain should show an increasing body burden of contaminants. However, some animals that are low in the food chain can also show high body burdens of contaminants. Mussels and some other filter feeding invertebrates can accumulate large quantities of contaminants because they process a great deal of water. Benthic invertebrates that ingest sediment can also have high body burdens of contaminants. High levels of contaminants in top level predators are of great concern because these are consumed by humans. Tuna and swordfish can have very high levels of heavy metals. Arctic marine mammals are consumed by people. High body burdens of some heavy metals, organochlorines and other substances pose a serious health risk to humans.

Contaminants that are measured often include polycyclic aromatic hydrocarbons (PAH), organochlorine compounds, PCBs, DDT, other pesticides, dioxin/furans, organotins, chromium, copper, lead, nickel, cobalt, vanadium, zinc and mercury. Other parameters of local concern are also measured in some areas.

Fish-eating birds are good indicators of lipophilic chemical contamination. These types of chemicals are bioconcentrated in bird eggs at levels up to 2.5 x 10^7 times ambient concentrations in water (Fox *et al.* 1991).

Not all species are suitable for monitoring. A fish or bird that is a seasonal visitor to Canadian waters may not reflect background levels of contaminants in Canadian waters. However, there may be some utility in measuring contaminant levels on arrival and departure to estimate short-term accumulation. The body burden of contaminants in young salmon will reflect conditions in the stream in which they were reared, while that of older salmon will reflect conditions in the sea-life area. When dealing with contaminants, questions about relationships between contaminants and marine environmental quality must be formulated. The appropriate contaminant and species must then be selected to answer the questions. Some questions could be framed around considerations such the following:

- Does the top level predator feed in a pelagic food web (e.g. auk → small fish → zooplankton)?
- Does the top level predator feed in a benthic food web (e.g. flatfish → polychaetes → sediment)?
- Is the top level predator a seasonal visitor (contaminant level on arrival → contaminant level on departure)?
- Does the top level predator roam up and down the coast and integrate contaminants from many areas or does it remain in a small area and indicate local contamination?
- How quickly is the contaminant depurated and/or broken down in the animal (slowly → recent historical view; quickly → high levels are evidence of continuous or recent episodic input)?

An important question that should be addressed by research involves linkages between contaminant levels and effects, especially at higher trophic levels. In the Gulf of St. Lawrence and in the Arctic, there remains a problem with tying health problems (e.g., in humans or white whales) to contaminant levels. If the same species are used for the community, biomagnification and effects sets of indicators, then relationships among contaminant levels, effects and populations may become apparent.

The sources of the contaminants in top trophic levels need to be identified. Contaminants in top trophic levels should be linked with multiple point source discharges and non-point source discharges so that mangers can take remedial actions. It would be nearly impossible to pin point the source of contaminants in a far-ranging predator. The monitoring network should be designed so that point sources and multiple sources of input are identified and the amount of contamination that they produce is quantified. In this way the sources of contaminants in top-level predators could be identified.

3.1.6.3 Contaminant Effects at Progressive Levels of Organization

Indicators
Contaminant → DNA effects → MFO induction → Pathology → Abnormalities → Population effects → Community effects → Ecosystem effects

Contaminant effects begin at several levels of organization within an animal. Subtle but measurable DNA effects can occur quickly. These are largely reversible if the contaminant is removed. If it is not removed, then pathological signs such as external and internal tumours and lesions can become apparent. MFO induction and other biochemical and physiological changes also occur in animals. Other visible signs are abnormalities such as crossed bills in birds. These diseases reduce the survival chances of the individuals affected, which may lead to population effects. In polluted areas, pollution-tolerant species often replace pollution-sensitive species and this causes a change in community composition.

The purpose of the network is to detect change in the condition of the marine environment regardless of the cause. However, the importance of research was noted in the development of the network concept and in meetings held as part of this study. Each linkage shown above represents an area where research could support or explain monitoring results. Research is needed to establish linkages, either to explain changes observed through monitoring, or to verify the importance/predictive capability of early warning indicators. Research will be useful in separating effects caused by contaminants from those caused by natural or other phenomena. Identification of cause-and-effect linkages would allow extrapolation from one area to another (e.g., intensive sites to extensive sites), and would allow monitoring to be focused on the lower levels without losing ecological relevance.

Ideally, all linkages would be monitored, and contaminant effects in an area over time could be assessed. This could be done by considering which signs of contamination are evident and which are not. Example results of a hypothetical monitoring program are as follows: **Year 1**: MFO induction, DNA abnormalities and nothing else; **Year 5**: MFO, DNA, tumours and lesions; and **Year 10**: Fish 1 and 2 replaced by Fish 3. For a spatial analysis, locations could be substituted for years. This type of approach was used by McCain *et al.* (1988) to evaluate pollution-related problems near four major population centres along the U.S. west coast.

In practice, the above type of monitoring program may be too expensive to implement. A flexible, step-wise approach could be used. Contaminants could be monitored first. If contaminants are not present, then no other monitoring is done. If contaminants are present, then DNA and/or MFO are measured. If those cellular indicators show effects, then population-level indicators are used, and so on. One disadvantage to this approach is that the latter types of data will not be available for the early years, making interpretation extremely difficult.

Canadian MEQ Guidelines, which are biologically based, can be used to help interpret the toxicological significance of contaminants in the marine environment. These guidelines can also be used to help identify priority sites and priority contaminants, thus focussing the need for more detailed examinations.

This set of indicators would complement the previous two sets (biomagnification and vertebrate communities) if the same species were used.

3.1.6.4 Productivity

Nutrient levels → Phytoplankton production → Zooplankton production
↓
Decomposition (e.g., bacteria in sediment)

Cultural eutrophication—the addition of excess nutrients to waterbodies from human activities—is a problem in some areas that have limited circulation and limited water exchange with the open sea. Increased nutrient concentrations can lead to increased productivity, which can upset the natural balance and lead to changes in the basic community composition of the plankton. Changes in the plankton can be harmful to human consumers (e.g., toxic phytoplankton blooms) or can in turn affect other organisms. On the other hand, increased productivity may benefit species in marine ecosystems, including those used or valued by humans.

This set of indicators is directly and closely linked to the vertebrate community indicators. Large scale climatic fluctuations (e.g. El Niño) can affect primary production and have effects throughout the food chain. Failures of fisheries and failure of seabirds to reproduce sometimes can be linked to these types of climatic change. In addition, changes in the physical properties of the water column and/or of the zooplankton community can lead to dominance by predatory zooplankters that can decimate populations of fish larvae, leading to reduced fish stocks in future years. Changes in the zooplankton community can also affect food supply for larval fish and, thus, their survival.

3.1.6.5 Marine Litter Surveys

Marine litter, especially that made of plastic and fishing nets, is of increasing concern worldwide. Plastic is slow to degrade and will persist for long periods of time. Its presence degrades the aesthetics of an area. Discarded or lost fishing nets and certain types of plastic are a hazard to fish, seabirds, sea turtles, and marine mammals.

3.1.6.6 Toxic Phytoplankton Blooms

The incidence of paralytic shellfish poisoning (PSP) is increasing worldwide (Therriault and Levasseur 1992). Amnesic shellfish poisoning was recently discovered on both the east and west coasts of Canada and there were domoic acid crises on Prince Edward Island in 1987 and off California in 1991. The PEI incident involved shellfish poisoning. The California incident involved seabirds that ate anchovies that had eaten a diatom which produces the acid (Wright 1992). Mariculture operations, seabirds, fish, and ultimately human health are at risk from paralytic and other types of shellfish poisoning. Some researchers believe that sewage and contaminants in freshwater inflows are factors that contribute to the development of toxic phytoplankton blooms. A recent workshop on harmful marine algae (Therriault and Levasseur 1992) recommended that monitoring programs be undertaken or continued, that a study group be established to consider database management, and that the feasibility and necessity of long-term monitoring stations be investigated.

3.1.6.7 Mussel Watch

Mussels are being used as sentinel organisms and for monitoring in many areas. Mussels filter a great deal of water and retain many contaminants in their tissues. Thus, they are excellent integrators of low concentrations of contaminants in water. A mussel watch network consists of a number of stations at which mussels are routinely collected for analysis of relevant contaminants. The U.S. mussel watch program monitors DDT, PCBs, chlordane, TBT, PAHs, and 10 trace metals (O'Connor 1992).

A panel meeting with the Aquatic Toxicity Workshop in November 1990 decided that a mussel watch program would serve for protection of human health as well as for environmental status and trends monitoring. If a pilot program is successful, then consideration will be given to expanding the monitoring network (see Appendix E for details).

3.2 Preliminary Inventory of Existing Programs

Existing monitoring or data collection programs are central to the concept of a monitoring network. Relevant programs are carried out by federal departments (especially Environment and Fisheries and Oceans); provincial, territorial, and municipal government ministries; aboriginal agencies; and the private sector. All of those opportunities for information exchange and resource sharing should be explored in developing the monitoring network. In addition to ongoing or planned monitoring programs, the network should include data collection initiatives that may be modified to be appropriate for the network. Even where such initiatives do not produce the types of data required, they may offer opportunities for field work or laboratory analysis at little or no cost to the status and trends monitoring network.

According to the Terms of Reference for this study, the MEQ Steering Committee was to provide information on existing monitoring programs. All information for the Arctic and Pacific that was provided by the Steering Committee is included in Appendices C and D; the information provided for the Atlantic was a reference to the Atlantic Coastal Zone Database Directory (ACZISC 1992), and relevant parts of that directory are in Appendix B. Some additional background information of relevance is in Appendices E, F and G. The information in Appendices B to G is summarized in Table 1 for each suggested indicator, together with information on existing programs of relevance provided by participants at the meetings held as a part of this study, and scientists in LGL offices. The information summarized in Table 1 and in the appendices is not complete. Most information reviewed in this study is from federal government programs, and even as such it is incomplete. Also, the data supplied provide insufficient information about the nature of many programs and the kinds of information that they generate to allow an evaluation of their suitability for the monitoring network.

It became apparent during the final stages of this project (i.e. final report preparation) that too little effort had been allocated to the "discussion of existing programs which may contribute information to the network", one of several objectives of Phase II of the development of the network. In retrospect, this task, including assembly of additional data on existing monitoring programs, should have been identified at the outset as the primary objective of the study. The next phase of the development of the National Marine Status and Trends Monitoring Network should focus on collection of detailed information about monitoring programs of relevance.

The following discussion deals only with existing monitoring programs that are directly related to the preliminary short list of indicators discussed in preceding sections. It is only an overview of some of the important existing programs. Table 1 is organized by indicators, with existing monitoring programs listed beside each relevant indicator. Whenever possible, descriptions of the existing programs were placed in the Appendices. It is suggested that this table be circulated to relevant government agencies for additions.

3.2.1 Marine Mammal, Seabird and Fish Communities

1a. Seabird community status—population size, reproductive success of selected species with limited ranges and known diets (other variables: egg volume, chick growth, prey proportions?).

There appear to be sufficient data on the community status and population sizes of colonial seabirds for the eastern Arctic, Pacific and Atlantic. These data are collected routinely by CWS.

Table 1. Existing monitoring programs of relevance to the short list of MESAF and MEQ Indicators. The indicator, species/parameter, location, time series available, and agency doing the work are shown. Numerical notes refer to the notes that follow the table; alphabetic notes refer to Appendices A to which provide more details on most of the programs.

Issue	Indicator	Species	Location	Time	Agency	Note	Comments
Marine Mammals	Population size	Whales, seals	Atlantic	1950's-P	DFO	B, 22	
			Pacific				
		Whales, seals	Arctic	25 yr +	DFO, GNWT	15, 21	
Seabird Communities	Population size	Seabirds	Eastern Arctic	1971-P	CWS	B, F, 14	All major colonies
		Waterfowl	NS, PEI, NB	1966-P	CWS	B	Few since 1986
		Seabirds	Atlantic Canada	1971-P	CWS	B, F, 14	All major colonies
		Seabirds	Pacific coast	1982-86	CWS	B, F, 14	All major colonies
	Reproductive success	Seabirds	Atlantic Canada	1971-P	CWS	B, 14	Seabird colonies
	Egg volume	-	-	-	-		
	Chick growth	-	-	-	-		
Fish Community	Catch data	All species	Atlantic Canada	30 yr+	DFO/NAFO	B, 1	Commercial species
		Capelin	Nfld/Lab/Gulf	1972-P	DFO	2	
		Herring	Nfld/Gulf/NB	~1970-P	DFO		
		All salmon	Pacific coast	1950-P	DFO		All areas with salmon
		Pacific herring	Pacific coast	1951-P	DFO	3	
		Groundfish	Pacific coast	1954-P	DFO	4	All coastal areas
		Anadromous fish	Western Arctic	1988-P	IJC	14	Mackenzie R./Amundsen
	Condition	Rare	Pacific coast	-	DFO		Not routinely used
		Rare	Atlantic coast	-	DFO		Not routinely used

Table 1. Continued.

Issue	Indicator	Species	Location	Time	Agency	Note	Comments
	Weight at age	Most species	Atlantic coast	30 yr +	DFO	1	Commercial species
		All salmon	Pacific coast	1950-P	DFO		All areas with salmon
		Pacific herring	Pacific coast	1951-P	DFO	3	
		Groundfish	Pacific coast	1954-P	DFO	4	All coastal areas
Oceanographic	Temperat./Salinity	Bottle Sampling	Atl/Pacif/Arct	1905-P	DFO	B	Histor Arch., Ottawa
Data		CTD	Atl/Pacif/Arct	1970's-P	DFO	B	Histor Arch., Ottawa
		various	Atlantic Canada	1780-P	DFO	B	
		All methods	Scotian Shelf	1912-P	DFO	B	
		Lighthouse stns.	Pacific coast	1950-P	DFO	C	
		Ocean Station P	One oceanic stn	1956-P	DFO	C	
		La Parouse Bank	SW Vanc. Island	1985-P	DFO	C	
	Temperature	Bathythermograph	Atl/Pacif/Arct	1960-P	DFO	B	Histor Arch., Ottawa
		Inshore time series	Atlantic Canada	1978-P	DFO	B	
	Currents	La Parouse Bank	SW Vanc. Is	1985-P	DFO	B	
Biomagnif-	Sediment	Metals	Baffin Bay	1980-84	DFO	B, 12	
ication		PAH/metals/organoCl	Gulf region		IML	B, 6	
		Metals, PAH	Labrador to NB	1970-P	DFO	B	
		Metals/Organics	St of Georgia	1985-P	Env Can	C, 8	+B.C. Min Enir.
		Metals/Organics	Vanc/Esquimalt	1992-P	Env Can	C	

Table 1. Continued.

Issue	Indicator	Species	Location	Time	Agency	Note	Comments
	Sediment	Metals/Organics	Disposal Sites	1987	Env Can	C, E, 18	Proponents
		Metals/Organics	Various Arctic	1975-P	DFO	13	
	Small fish	Metals/Pesticides	Gulf Region	1983-P	DFO	B	
		PAH/metals/organoCl	Gulf region	-	IML	B, 6	
		Metals, PAH, others	N Scotia/Fundy	-	DFO	B, 7	
		Various	Arctic, var.	1975-P	DFO	13	Var species & contam
Biomagnif-ication	Large fish	Metals/Pesticides	Gulf Region	1983-P	DFO	B	
		PAH/metals/organoCl	Gulf region	-	IML	B, 6	
		Metals/PAH/others	N Scotia/Fundy	-	DFO	B, 7	
		Metals/Organics	St of Georgia	1985-P	Env Can	C, 8	+B.C. Min Enir
		Metals/Organics	Vanc/Esquimalt	1992-P	Env Can	C, 10	
		Organics	Pulp/Paper Mills	?	Env Can	E	All across Canada
		Various	Arctic, var.	1975-P	DFO	13	Var species & contam
	Seabirds	Metals, organoCl	Atlantic Canada	1968-P	CWS	F, 9	
		Organics	Pacific coast	1968-P	CWS	F, 9	
		Organics	Eastern Arctic	1975-P	CWS	F, 9	
	Marine Mammals	Seals-PCB/DDT/MFO	N Scotia/Gulf	1972-P	DFO	B	
		Various	Arctic, var.	1975-P	DFO	13	Var species & contam
		PCB/metals/dioxin	B.C. coast	1985-P	DFO	C	

Table 1. Continued.

Issue	Indicator	Species	Location	Time	Agency	Note	Comments
Contaminant effects	MFO induction	Seals-PCB/DDT/MFO	N Scotia/Gulf	1972-P	DFO	B	
		Herons	St of Georgia	1988-P	CWS	C	
		Fish	Gulf	1993-	DFO	A, B	
	Pathology	Fish diseases	Scotia-Fundy	1974-P	DFO	B, 5	
		Fish Autopsies	Pulp/Paper mills	?	Env Can	E	All across Canada
		Flatfish	St of Georgia	1988-P	Env Can	C	+B.C. Min. Envir.
	DNA effects	-	-	-	-		
	Abnormalities	-	-	-	-		
	Population effects	-	-	-	-		
	Community effects	-	-	-	-		
	Nutrients	Nutrients, chl a	SW Bay of Fundy	1987-P	DFO	B	
Productivity	Nutrients/ Productivity	Nutrients, Prod	Atlantic Canada	1973-P	DFO	B, 17	
		Ocean Station P	One oceanic stn	1956-P	DFO	C	
		La Parouse Bank	SW Vanc. Is	1985-P	DFO	C	
		Coastal B.C.	10 Stations	1981-P	DFO	C	
	Zooplankton Production	Ocean Station P	One oceanic stn	1956-P	DFO	C	
		La Parouse Bank	SW Vanc. Is	1985-P	DFO	C	
		Coastal B.C.	10 Stations	1981-P	DFO	C	
	Decomposition	-	-	-	-		

Table 1. Continued.

Issue	Indicator	Species	Location	Time	Agency	Note	Comments
MEQ Indicators	Beach litter	Persistent litter	Sable Is, NS	1984-P	Env Can	11	Beach survey
		Persistent litter	Scotia/Fundy	?	DFO		Research vessels
		Persistent litter	B.C. Coast	?	Env Can	16	
	Toxic Phytoplankton	Coastal B.C.	3-4 sites	1992?-P?	Env Can	A, E, G, 19	
		NS, Que, Gulf	44 Sites	1987-P	DFO	A, E, G, 19	
		New Brunswick	PSP monitoring	1943-P	DFO	20	PSP values in clams
	Mussel Watch	Blue mussels	Few sites in NF	1983-P	Env Can	A, E	

Notes for Table 1.

[1] Recorded by NAFO sub-area (Figure 1). Species and locations for which statistics are available are (Locations: NS = Nova Scotia, NB = New Brunswick, NF = Newfoundland, L = Labrador, n = north, e = east, s = south.):

Arctic char L
Atlantic salmon L to NB
Alewife NS, NB
Blueback herring NS, NB
Atlantic cod L, NF, NS, Gulf
Haddock NF, NS Gulf
Pollock NF, NS
Redfish L, NF
American plaice L, NF, Gulf
Witch flounder L, NF, Gulf
Atlantic halibut NF, NS, Gulf
Greenland halibut Gulf
Yellowtail flounder NF
Roundnose grenadier L, nNF
Silver hake NS
White hake Gulf
Argentine NS
Capelin L, NF
Atlantic herring Gulf, seNF, NS
Atlantic mackerel L to NB

[2] Capelin fisheries are market driven and thus, catch statistics are more a reflection of the market than of abundance of capelin.

[3] St of Georgia, w coast Vancouver Is., Queen Charlotte Is., Prince Rupert and Central Coast.

[4] Lemon sole, lingcod, Pacific cod, sablefish, red snapper, flounder, idiot fish, silver perch, smelts, walleye pollock, dogfish, hake, halibut, dover sole.

[5] Autopsies are done.

[6] Measured at industrial outfalls only.

[7] Mercury, lead, arsenic, pesticides, PCB's, PAH's, dioxins, furans, sulfites.

[8] At industrial sites some controls. Sediments: dioxins/furans, PAH, PCB, trace metals, organotin, chlorophenol. Large Fish (starry flounder, english sole): metals, dioxins/furans, PCB's

[9] See Noble and Elliott 1986 for details.

[10] Sediments and flatfish: chlorophenols, chlorinated anisoles, PCB's, organotins, phthalate esters, PAH's, pesticides and metals.

[11] See Lucas 1992 for details.

[12] Chromium, copper, lead, nickel, cobalt, vanadium, zinc.

[13] Various species of fish and mammals at various locations analyzed for various contaminants, see Muir et al (1992) for a review.

[14] Gaston 1992.

[15] Data collected by the Inuvialuit, see Fabijan 1991a,b,c.

[16] Not yet up and running.

[17] Compilation of data only, not a monitoring program.

[18] Cadmium, mercury, PCBs, total PAHs, low molecular weight PAHs, high molecular weight PAHs, and total organic carbon. Uptake and effects in selected species will also be monitored. Control sites will be monitored.

[19] Bugden et al. (1992).

[20] see Eddy 1992.

[21]. Populations of bowhead whales in the Beaufort Sea are monitored regularly off Barrow, Alaska, as they migrate past. Portions of eastern Arctic whale populations monitored at irregular intervals. Seal populations are not monitored throughout the arctic. Catch data of variable completeness are available for many species.

[22] Some populations of some species are measured annually. Others are measured at variable intervals.

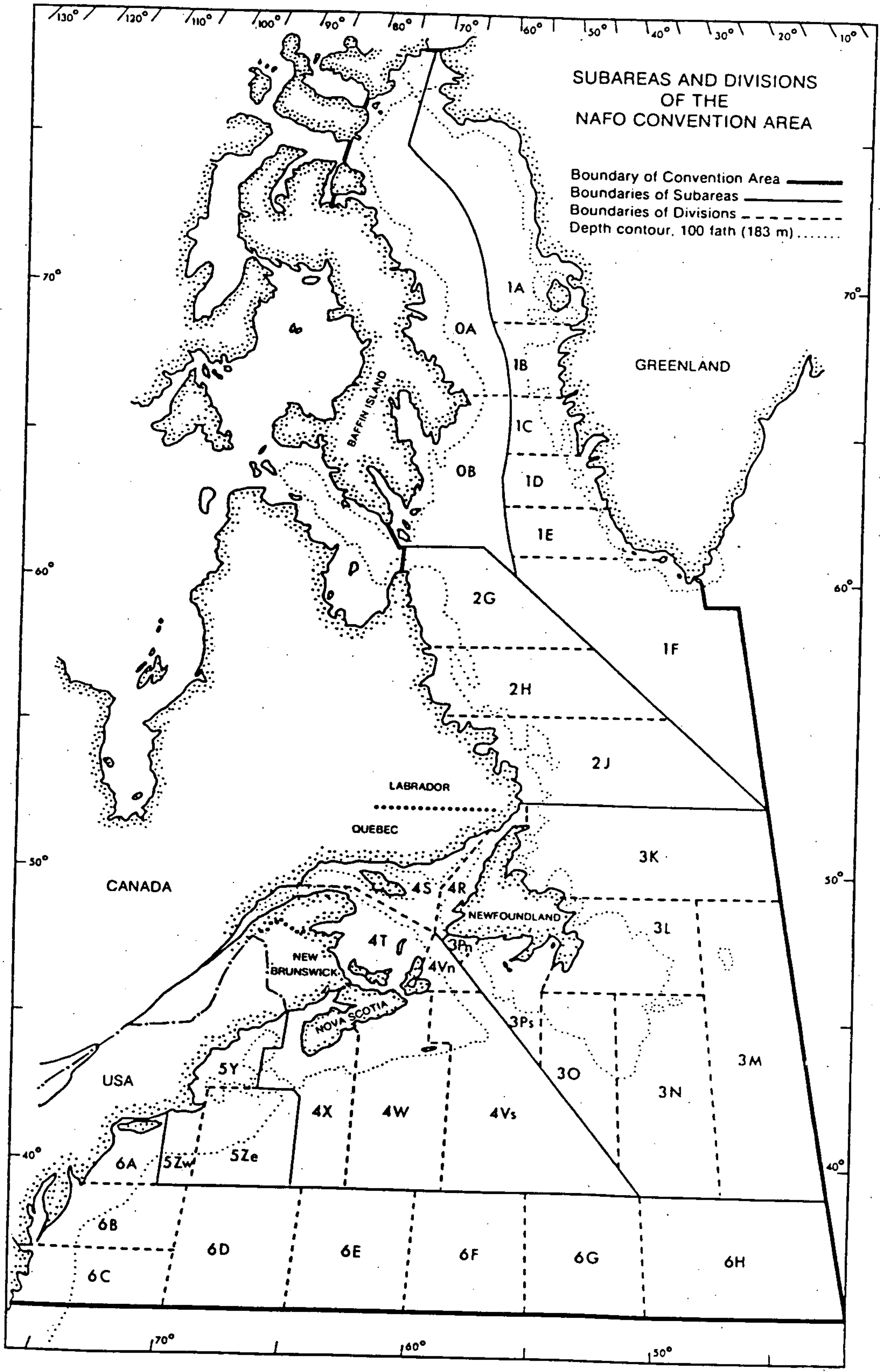

Figure 1. Subdivisions used by the Northwest Atlantic Fisheries Organization for reporting the commercial catch.

They are limited in geographic coverage to areas with bird colonies (see Appendix F). Reproductive success is monitored on the east coast.

Censuses of other seabirds away from colonies and of marine waterfowl are carried out less frequently and the geographic coverage is spotty (Appendix B). Those data are probably not amenable for inclusion in a monitoring network. Even if data were available, they would not be as useful as colony data. Colonies are fixed in space and birds return to the colony year after year. The distributions of seabirds away from colonies and of other sea-associated birds could be affected by many factors, only a fraction of which are of interest in relation to MEQ. Thus, the 'signal-to-noise' ratio of data collected away from colonies would be lower than that from colonies.

1b. Marine mammal community composition

DFO estimates population sizes of marine mammals. Most surveys are not done on a routine or comprehensive basis. However, in some cases sufficient historical and current data are available to allow these estimates to be used in a manner similar to the population estimates for birds and large fish.

Marine mammal populations are monitored on the east coast. Some species are monitored annually and some are monitored at irregular intervals. Populations of arctic marine mammals, especially beluga whales, narwhals, bowhead whales, and walruses, are estimated at irregular intervals, generally for only a portion of the overall range in any one year. Catch data of variable completeness are available for many species.

2. Fish community composition — from fisheries catch data where possible. Is there a change in seabird prey species that may be related to 1a?

Catch data for commercial species are collected by DFO and the North Atlantic Fisheries Organization (NAFO) on the east coast, and by DFO on the west coast. The east coast data are reported by NAFO subarea (Fig. 1). These subareas can be allocated to the marine ecoregions or ecodistricts defined in Phase I of this study, but in some case boundaries will overlap. Salmon catch data are available for many streams on both the Atlantic and Pacific Coasts. The salmon datasets go back 20 to 40 years.

There are catch data for herring on both coasts of Canada and for capelin in the Newfoundland area. These fish are important forage species for seabirds. However, population sizes of sand lance, cunner and other species that are important in the diets of birds and large fish are not measured. Thus, fish catch data will yield only limited information on the relationships between seabirds and their prey. These data will not normally be adequate to link seabird (or marine mammal) abundances to abundances of their fish prey.

The only available catch data for the Arctic are for anadromous fish. There are no population estimates for the Arctic cod, the only pelagic species of note and a mainstay in the diet of fish-eating birds and marine mammals in the Arctic.

3. Other fish data—condition, weight at age, from commercial catches. Are there other changes in fish that may be related to 1 or 2?

The condition of fish in the commercial catch is not routinely estimated.

Weight at age is routinely collected for fish on the Atlantic and Pacific coasts. Weight at age data for herring and groundfish have been collected for 40 years on Pacific coast. Weight at age for salmon may be more a reflection of conditions far out to sea than of those in Canadian waters.

4. Oceanographic data (T, S, currents). Can these explain 1, 2, or 3?

Temperature and salinity data have been collected for many years on all of the coasts of Canada. Data for all areas have been compiled by the Historical Archives Section of DFO in Ottawa. Most data are from various special-purpose cruises and projects, and were not collected routinely and consistently over the years. However, there are large quantities of these data, especially for the east coast. A historical analysis of the entire dataset would require vast resources. An analytical strategy could be as follows:

- Link the databases to a GIS,
- Using the GIS/database determine the resolution of the data (ecoprovince, ecodistrict) for Canadian waters,
- Select the classification levels (ecoregions or ecodistricts; Harper *et al.* 1993) to be monitored based on the quantity of available data and an estimate of future data availability,
- Select which ecoregions (districts) will be used,
- Select and group the data for the areas to be used,
- Analyze the data,
- As new data are collected, add them to the subset used in the initial analysis.

Large quantities of data are needed for analysis of possible climatic change. For optimum sensitivity, the data should be collected repeatedly at consistent places and times with consistent methods. The quantity and distribution of data will determine the spatial resolution that can be achieved. It is likely that the resolution will be different for different areas. It may be possible to treat some areas at the ecodistrict level and others only at the ecoregion or ecoprovince level.

The west coast lighthouse dataset and the inshore time series on the east coast are worthy of note. These data are collected at the same locations year after year.

3.2.2 Biomagnification

Contaminants in sediments or water → fish 1 → fish 2 → seabird
→ humans
→ marine mammal → humans

Contaminant data from sediments and large fish are available for the Atlantic and Pacific coasts and for scattered locations in the Arctic. The Atlantic and Pacific data appear to be sufficient to address the relationship between contaminants in sediment and groundfish.

There is good information on contaminant levels in birds from the Pacific and Atlantic coasts and in the Eastern Arctic. Contaminants in seabirds are monitored at colonies.

There is a lack of monitoring-type information on contaminant levels in small fish, with the possible exception of commercial herring. Thus, monitoring-type data on species that are important in the diets of birds and large pelagic fish are sparse.

Contaminants in fish are monitored by the inspection branch of DFO. The commercial catch is sampled, so data on contaminants in fish may be available at the ecodistrict level and certainly at the ecoregion level. The bird data are available for areas where there are colonies. The spatial resolution of the sediment data will have to be investigated.

Data on contaminants in arctic marine mammals have been compiled by Muir *et al.* (1992) and by the Arctic Data Compilation and Appraisal Program. The data on contaminants in Arctic marine mammals are sufficient for inclusion in the database; however, they may have to be compiled at large spatial scales.

3.2.3 Contaminant Effects at Progressive Levels of Organization

Contaminant → DNA effects → MFO induction → Pathology → Abnormalities
→ Population effects → Community effects

DNA effects are not currently being monitored. A relatively new technique for detecting effects of low-level stress is being studied at Institut Maritime de Québec (E. Pelletier, pers. comm.). An automated, inexpensive and effective method is now available for monitoring genetic damage (e.g., McBee and Bickham 1988), although it has not yet been applied to most of the specific kinds of animals that may need to be monitored.

MFO induction is monitored at a few places in a few species. Although there have been many research studies of MFO induction, it appears that most of these have not involved the systematic, repeated sampling necessary for monitoring.

Fish pathology is routinely monitored in commercial species by DFO. Similar work is also done by Environment Canada in the Strait of Georgia.

At this time, there are too few data and too few documented linkages to make this set of indicators of immediate use beyond the disciplines within which the individual programs were established. However, existing programs could form the basis for an expanded contaminant monitoring network. Data formats, the database structure and coding procedures should be developed and standardized so consistent reporting and storage systems are operational before many data are collected.

3.2.4 Productivity

Nutrient levels → Phytoplankton production → Zooplankton production
↓
Decomposition (e.g., bacteria in sediment)

There is a long time series of data on nutrients and primary productivity. Many of these data are "spot measurements"; often the data were not collected repeatedly at the same stations over prolonged periods. Geographic coverage is limited. As in the case of the temperature and salinity data, the database should be linked to a GIS so stations can be assigned to geographical units.

Zooplankton production is measured routinely at two locations on the Pacific Coast. There are many zooplankton data for the Atlantic Coast, but they does not appear to have been put into a comprehensive database.

3.2.5 Marine Litter Surveys

Two programs are operational on the east coast. A program is planned for the west coast but is not yet operational. These data will likely have to be compiled within large geographic units.

3.2.6 Toxic Phytoplankton Blooms

These are being monitored at 44 sites along the east coast. A new program to monitor 3-4 sites on the west coast is just beginning.

3.2.7 Mussel Watch

The program is not yet operational in Canada. The program is scheduled to begin soon with implementation a small pilot program. If results are satisfactory, then the program may be expanded. This program has the potential of yielding some the best information of relevance to the Status and Trends Monitoring Network

3.3 Quality Assurance and Quality Control (QA/QC)

Environment Canada and DFO (1993) define QA/QC as follows:

> *"Quality assurance (QA) encompasses a wide range of internal and external management and technical practices designed to ensure data of known quality commensurate with the intended use of the data."*
>
> *"Quality control (QC) is an internal aspect of quality assurance. It includes the techniques used to measure and assess data quality and the remedial actions to be taken when data quality objectives are not realized."*

To bring together a number of individual programs with diverse objectives into a coherent network, the programs will first require adequate QA/QC programs to maintain their own objectives. Some existing programs will already have QA/QC procedures adequate for their own disciplinary purposes; other programs will require the development or improvement of their QA/QC programs. Then the individual QA/QC programs will have to be adapted to fit a newly-designed network QA/QC program. This must provide assurance that the contributing datasets can be compared either directly or after documented correction factors are applied. In general, this will require inter-calibration exercises and/or the use of Standard Reference Materials and standard procedures. These can apply to population measurements as well as contaminant measurements.

A survey of the existing monitoring programs, including their QA/QC procedures, is needed as the first step in this process. Specific QA/QC recommendations must be based on existing programs. A proposed survey form is given below. This form is designed primarily for projects involving collection of samples in the field followed by later laboratory analysis. Before the survey is done, a parallel form should be developed for programs involving field observations:

PROPOSED MONITORING PROGRAM QA/QC SURVEY

In proposing a national monitoring network it is important that the QA/QC programs of existing monitoring programs are known. The following questions are intended to provide us with an overview. Please respond with reports or other documentation describing your program if possible.

1. What is the goal of the monitoring program?

2. What is the formal plan for the program?
   Is the plan upgraded as results become known?

3. Are the protocols used standard methods or in-house developments?
   If standard methods, please list; if in-house methods, please attach a copy of the methods.

4. What procedures are used for the preparation of sample containers?
   Are sample containers checked periodically for contamination?

5. Are field staff specifically trained for sample collection?
   Are field logs kept in original form?
   Are standardized logs and/or anecdotal logs used?

6. Are sample locations known and recorded to a level of precision that will permit return to the exact spot? What method of positioning is used? Are the sample locations referenced to a survey benchmark?
   Are sampling times recorded?
   Are water levels, sea conditions, and ice conditions recorded for the time of sampling?
   Are field blanks taken? Are replicate samples taken?

7. Is there an audit trail, with signatures, for all sample transfers and activities, from collection to final report?
   Do the protocols include time limits for travel and storage?

8. Does the laboratory maintain a complete QA/QC program?
   Does the laboratory use a standard methods manual or maintain its own, and are the methods adhered to absolutely?
   Is calibration internal or external, and how often is calibration performed?
   What level of blank inclusion is there?
   How many analytical replicates are done; are they done on all samples or on a subset of samples?
   What Standard Reference Materials (SRMs) are available, and which are used?

Is the method detection limit reported with each sample batch?
Are control charts maintained?
What limits are accepted in the control charts?

9. Are data validity checks maintained during data transfer?
Do data reports include QA/QC information?
What level of data censoring occurs at each transmission; e.g., from analyst to laboratory manager; from laboratory manager to client, etc.
Are computational procedures listed in the methods?
Can a final datum be associated unequivocally with a specific sample?
Are data checked for comparison to historical data and to SRMs?
Are outliers flagged and checked or redone?
What is done about suspect data?

10. In what form are the data available outside the prime institution?
If electronic forms are available, what are they and what information do they include?

11. If summaries are available, what statistical procedures were used to generate the summaries?
What hypotheses were defined for the statistical analysis?
Were the procedures tested for utility? (e.g., were the data sets checked for scedasticity; were the tests performed on appropriately transformed data?)

12. Do the reports properly relate the data to the goal of the program, and is the plan modified in light of the most recent data?
Do the reports include the necessary assurance that the user may have confidence in the report?

13. Is the program reviewed to ascertain that the goal is being met?

It is recommended that the above survey form, and the corresponding version for field observation programs, first be reviewed by MEQ Steering Committee members and revised if appropriate. The forms should then be presented to the managers of the various monitoring programs or data collection initiatives that have been deemed appropriate for inclusion in the network. It will probably be necessary to devise a method to encourage potential respondents to complete and submit the forms. After the information has been collected on the various programs, it will be possible to (1) further evaluate the programs' suitability as a part of the network, (2) make recommendations, where required, to improve the quality and consistency of data being collected by individual programs and, therefore, the network as a whole, (3) consider funding or carrying out selected enhancements to QA/QC procedures for individual programs or the network as a whole, and (4) describe the QA/QC procedures that are common to the programs that comprise the network.

3.4 Proposed Stations

The geographical framework for MEQ monitoring was described by Harper *et al.* (1993). Biophysical criteria were used to delineate five marine ecozones, 12 marine ecoprovinces, 18 marine ecoregions, and 48 marine ecodistricts. Examples of the four levels of area, from ecozone to ecodistrict, are as follows: Pacific, Pacific Shelf, Strait of Georgia/Puget Sound, Juan de Fuca Strait.

It is Environment Canada's intention that the Marine Status and Trends Monitoring Network operate at the "Marine Ecoregion" level. The objectives of this phase (Phase II) of the development of the network include proposing indicators of MEQ and MESAF for each marine ecoregion, and a list of stations in each marine ecoregion. However, the results of the meetings (Appendix A) and the preliminary inventory of existing programs (Table 1) suggest that there are no indicators that are presently being monitored systematically in each ecoregion. For example, seabird colonies are monitored routinely and systematically, but seabird colonies are not found in each ecoregion. A detailed inventory and evaluation of existing monitoring programs is needed, but the information available at this time suggests that to extend sampling coverage for even one variable (indicator) to each ecoregion would require funding measures far beyond those available for the 'selected enhancements' that are envisaged for the network.

The monitoring programs and databases listed in Table 1 are relevant on spatial scales that differ among indicators and among species within indicators. Some indicators are currently monitored at the ecodistrict level (e.g., catch of fish) and some only at the ecoprovince level (e.g., contaminants in Arctic marine mammals). Others are measured at the ecodistrict level in some areas and at the ecoregion level in other areas. Existing databases must be inventoried in detail to identify the locations, frequencies and intensities of present sampling efforts for each indicator and to select stations for inclusion in the monitoring network. This step is linked to the next one, the determination of numbers of samples to be used. In some cases (e.g. contaminants in fish), several stations may need to be pooled to yield a statistically valid sample for monitoring. In some cases and for some indicators, the required sample size will affect the geographical resolution of the network.

3.5 Number and Frequency of Sampling

Because this is a monitoring network rather than a monitoring program, it is not appropriate to make specific recommendations for the network as a whole about sampling design (e.g., number and frequency of sampling), especially in advance of a detailed review of existing monitoring programs. Once the detailed inventory of monitoring programs is completed, it will be possible to evaluate the adequacy of the sampling designs of the individual programs and of the overall mosaic of existing programs that will form the network. Given data on the existing sampling intensity and frequency, it will be possible to predict the level of change in indicators that could be detected over a given number of years, and to make recommendations about improvements to the design. Some general recommendations are included in this section.

The intensity and frequency of sampling will depend on the indicator and parameter to be monitored, its present frequency of measurement, its anticipated rate of change, its natural within- and among-population variability, and logistical and cost considerations.

Some parameters are measured infrequently and are population estimates. Some of these parameters only need to be measured at annual or longer intervals. The "sample" size is one for each census period. However, most population estimates are based on sampling rather than a complete census of the entire population, so sampling concepts must still be considered. The catch of fish is measured daily, reported monthly and needed annually. There are voluminous data on fish catch, so sample size is usually not an issue. Abundance of birds is monitored at intervals of one to ten years. Enough colonies are monitored at short intervals to detect large scale change within one to two years.

In most cases, sample sizes greater than one are required. Where that is the case, standard statistical methods can be used to determine the sample size needed to detect a change of a given magnitude over a given time period with a given degree of confidence. For the purposes of detecting climatic change, temperature and salinity have to be measured very frequently (e.g. daily at a single location or at numerous locations within a large area). Climatic change is a slow process; however, the data must be of sufficient quantity and quality to allow long-term effects to be distinguished from the considerable "noise" caused by diurnal, seasonal and other short term effects. An analysis of required sample size for the temperature/salinity data (or most other types of data) would ask the question "what magnitude of change could be detected within ___ years given the natural variability of the data?". Conversely, one could ask how many years of monitoring would be required in order to detect the change if change were occurring at a specified rate, given the natural variability. These types of statistical power analyses could help determine which datasets to use. Some datasets may be so "noisy" that only very large scale changes could be noticed.

The mobility of many animals and small differences in sediment type or hydrography can mean large differences in contaminant levels. The number of samples to be taken in each different circumstance needs to be determined using local data, a rigorous statistical approach, and due regard for the process of hypothesis formation (Green 1979; Rose and Smith 1992). Each situation will be different and the number of samples needed to detect a given change with a specified power needs to be determined for each circumstance, e.g. each species x contaminant combination (Green 1989; Peterman 1990). Results of previous studies using similar methods, or results of pilot studies, can be used to determine the required sample size.

Nutrients, primary productivity and zooplankton productivity should be monitored at intervals determined by the biological season. Sampling should be intense in spring and fall during the bloom and then less frequent during the remainder of the summer. Sampling in late fall, winter and early spring could be done at monthly or bimonthly intervals. Procedures for estimating sufficient sample size would be the same as those described for temperature and salinity.

Many of the types of data summarized in Table 1 were collected at irregular intervals. In this case, analytical methods appropriate to irregularly spaced data need to be used for the analysis of historical data (e.g., Bodo 1989).

The proposed Canadian mussel watch program provides an opportunity to do some ground-up planning for a component of the network. For example, sample sizes required at each location should be determined during the pilot project. Ideally, dozens of locations should be monitored on each coast. Mussels are not found in most regions of the Arctic. Shallow water (3-5 m water depth) filter-feeding bivalves could be used. The numbers of samples to be collected in an initial pilot program could be based on the procedures and results of U.S. program, and then refined based on analysis of the results of the Canadian pilot study.

3.6 Data Coordination

Wolfe and O'Connor (1986:882) noted that, as early as 1981, "...the U.S. Federal Marine Pollution Plan...concluded that the greatest needs in marine monitoring in the U.S. were for improved coordination among existing monitoring programs and for the establishment of regional data management systems so that the existing information can be retrieved and used more effectively." One important aspect of the proposed Canadian monitoring network is that information will be contributed to a central repository by numerous workers in numerous disciplines. It was appealing to many of the scientists at the meetings that all of the data will be available to each contributor soon after collection.

The Status and Trends Monitoring Network will be collecting data from numerous departments and agencies. It is recommended that each department enter its data into its own database, store them and retrieve them. Virtually all database programs can exchange data with one another. However, the database structures used for most datasets will be different from one another (e.g., one will have depth in column 6, another in column 12). Some databases will be "flat" and some will be relational. In addition, different databases will use different species codes, methods codes, analysis codes, and gear codes.

Some databases, such as the CWS bird data, are standardized across the country and can be used as is. New programs such as the mussel watch will, presumably, use the same database structure across the country. Most of the other existing databases differ across regions. For example, contaminant data collected on the east *vs.* the west coast, and even those for different parts of the east coast, are in different formats. These data formats will have to be standardized at some stage. There are three options for standardization:

1. Departments and agencies adopt a standardized database structure for similar data,
2. Departments and agencies retain their various database structures and codes but convert data to an agreed-upon network structure before sending them to the central depository, or
3. The central repository receives data in the individual department's varying formats and then converts them to the network structure.

Whatever option is selected, the standardization of a format among several departments for numerous kinds of data will be an expensive, time consuming and probably controversial task. This type of integration was recently done for the Long Range Transport of Acidic Pollutants (LRTAP) database. The main advantage of a common database is that it offers participants easy access to all relevant data from across the country. Because of the advantages and eventual cost savings, we highly recommend that all departments collecting similar information use a standardized database. In the interest of economy, the best existing database could be selected for use and modified to accommodate the needs of other users and the overall network.

Some data are collected repeatedly at specific stations and locations (e.g., Ocean Station P). Some data are collected irregularly and almost anywhere within a large geographic area (e.g., contaminants in the Arctic). In some cases, a time series of data is taken within an ecoprovince or ecoregion. It may be desirable to link the database to a GIS. Geographically uncontrolled monitoring data can be assigned to ecoregions or other geographic sub-divisions for analysis. In addition, the GIS could be used to pool data for similar areas. If, at some time in the future, it was decided to reorganize the geographic boundaries of the monitoring program, then use of a GIS would facilitate the process of reassigning stations to regions.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The project achieved its primary goal of proposing a set of provisional indicators to assess marine environmental quality and marine ecosystem structure and function. Meetings were held across the country to discuss indicators. During the project, a consensus on the use of the provisional indicators appeared to have been achieved. A preliminary inventory of databases relevant to the indicators was conducted and gaps in current monitoring programs relative to the provisional indicators were identified.

This study could not meet two of the project terms of reference: (1) "a proposed list of stations in each Marine Region for extensive monitoring of marine environmental quality; identify key reference stations for intensive integrated monitoring of marine ecosystem structure and function", and (2) "a proposal on frequency of sampling for each parameter; number of samples and level of statistical discrimination needed to detect change". We did not have enough information on the existing programs that will comprise the basis for the monitoring network to address those two terms of reference. Furthermore, as shown below, the amount of work needed to determine sample size and station location was well beyond the scope of the study. Addressing those two (and other) aspects of monitoring program design would require a complete and detailed inventory of all databases containing monitoring data. In the paragraphs that follow, we suggest an approach to collecting this information.

4.1 Short List of Indicators

A preliminary short list of indicators was developed from a literature review and meetings with federal government scientists in a number of locations across Canada. That list is included and discussed in Section 3.1.6 of this report. It is recommended that the list be further shortened and focused by conducting a detailed review of existing monitoring programs and databases, as described below. Some of the suggested indicators likely will be dropped because existing programs are not providing enough relevant information to warrant their inclusion in a national monitoring network. With a shorter list of indicators supported by a reasonable existing information base, it will be possible to allocate any available resources to providing selected enhancements where they will provide the most benefit to the program. In refining the preliminary short list, consideration should be given to

- the frequency and numbers of samples collected *vs.* the frequency and numbers needed to detect changes of relevant magnitudes and rates,
- the actual spatial coverage of the data *vs.* what is relevant and needed,
- the practicality of reallocating sufficient supplemental resources to programs with deficiencies in spatial or temporal coverage,
- the availability of similar data in all marine regions, and
- availability of linkages between indicators, if needed.

4.2 Inventory of Existing Programs

Based on the preliminary inventory conducted as a part of this study, existing monitoring programs appear to be sufficient to measure some of the indicators included in the preliminary short list. However, there are some notable gaps in coverage, especially those dealing with the effects of contaminants and with the abundance of forage fish that are preyed upon by seabirds, large fish, and marine mammals. The collection of data on forage fish would be very expensive. Many of the productivity indicators are not collected in a routine manner at consistent locations.

The next phase of the network development should be a detailed inventory of databases and programs that contain or generate data of relevance to the monitoring network. The information collected about each program should include

- Kinds of data collected
- Collection methods, numbers of replicates, numbers of sites,
- Sampling locations,
- Frequency of sampling, and years of data
- Analytical methods and reporting units,
- QC/QA procedures, and
- Changes over the years in locations, frequency of sampling, methods, etc.

Where the information is in a database, the information collected during the recommended inventory of existing programs should also include

- Type of computer system,
- Database type,
- Specifics about the database structure,
- Size of the database, and
- Codes used in the database.

These questions could be added to an expanded QC/QA questionnaire.

The information for each existing program considered for use in the monitoring network should be assembled into a database directory similar to the Atlantic Coastal Zone Database Directory (ACZISC 1992). Reports and papers dealing with the databases or presenting results of the programs should also be collected. All this information can then be used to evaluate each database and program for its suitability for inclusion in the monitoring network.

4.3 Proposed Stations

Some of the data collected in existing monitoring programs will allow monitoring at small spatial scales (ecodistricts), whereas other data will allow monitoring only at large spatial scales. The sampling locations that would be documented during the detailed inventory of databases should be entered into a database, linked to a GIS, and plotted. The spatial resolution available for each indicator could then be determined and the distribution of stations could then be evaluated in terms of what is needed. If there are more stations than necessary in the same area, some might be moved to improve coverage in other areas.

4.4 Number and Frequency of Sampling

Because it is a network of existing monitoring programs (rather than a monitoring program) that is being developed, and because a detailed inventory of existing programs is not available, it is not possible to make specific recommendations about sampling design (e.g., number and frequency of sampling). During the detailed inventory of databases and programs, the number and frequency of sampling associated with each program in each sampling location should be recorded. The amount and/or rate of change in indicators that could be detected with the existing sampling strategy could then be determined only if respondents also provide detailed data on sampling variability over space and time, and if the budget is adequate to allow power analysis of these data. Decisions should then be made about (1) the feasibility of using some of the different indicators already being measured, and (2) the desirability of adjusting sample numbers or frequency as an enhancement to the network.

4.5 Quality Assurance and Quality Control (QA/QC)

Specific QA/QC recommendations for the monitoring network must be based on existing programs. Therefore, a survey of QA/QC procedures used in the existing monitoring programs is recommended as the first step in developing a QA/QC program for the network. One format for a proposed QA/QC survey form is included in Section 3.3. It is recommended that this and other related forms first be reviewed by MEQ Steering Committee members and then presented to the managers of the various monitoring programs or data collection initiatives that have been deemed appropriate for inclusion in the network. Once the information has been collected on the various programs, it will be possible to (1) further evaluate the programs' suitability as a part of the network, (2) make recommendations, where required, to improve the quality of data being collected by individual programs and, therefore, the network as a whole, (3) consider selected enhancements to QA/QC, and (4) describe the QA/QC procedures that are common to the programs that comprise the network.

4.6 Data Coordination

The monitoring network should, ideally, make use of a common database and common database structure to store and retrieve the monitoring data. This database should be linked to a GIS. In this way data that were collected at a number of locations could be assigned to a geographic region and spatial control of the database could be maintained. The GIS could also be used to depict the monitoring results on maps.

The main advantage of a common database is that it allows access to all data by all users. This uniformity in data is critical to the success of the network. The monitoring data can then be presented as coloured graphs and maps in a State of the Environment Report. However, it is the in-depth analysis of those data done by government, university, and consulting scientists that will yield the greatest benefit. For the first time, many of them will be able to gain access to all of these various data types, and they will be in one format. The results obtained by the individual and collective work of these people with a large database will greatly enhance the value of the network.

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APPENDIX A: Minutes of MEQ Phase II Meetings, 12-25 March and 18 June 1993.

Halifax, BIO, 22 March 1993

NAME	DEPARTMENT	DISCIPLINE/SPECIALTY
Louise White	Marine Chemistry/DFO	Green Plan Environ. Assessment
Wayne Barchard	EP/EC	Marine Ecology
Alan Gray	EP/EC	Environmental Management
Tony Lock	CWS/EC	Seabirds
Roger Percy	EP/EC	Nat. Sensitivity Mapping
Geoff Howell	WRD/EC	Aquatic Chemistry/GIS
Larry Hildebrand	C&P Atlantic	Marine Environmental Quality

GENERAL

Indicators and monitoring program design must be tied to issues; most monitoring programs are not designed to answer specific questions, but should be

Ecoregions should not be used as a design framework, i.e. the network should not be designed around the spatial framework. Is it even realistic to attempt to distribute sampling effort evenly among the ecoregions?

Is it the intention of the Network to monitor for trends or for patterns and changes? Also, it was pointed out that status and trends are two different things.

Atlantic issues were identified as follows:

- Fish stock declines: why? fishing pressure or environmental factors (e.g., climate, currents, cold water influx)?
- Aquaculture—spread of diseases, impact on the environment
- Blooms of toxic phytoplankton—spread, geographically and new types. Causes—ballast water, eutrophication, or both?
- Gross distortions at the top end of the food web (seabird community structure), attributable in part to pollution (e.g., debris, oil) but largely to fisheries: (1) The part of the catch that's discarded (30-40%) leads to increases in gulls and concomitant decreases in other species that breed on the same habitat, and (2) taking mid-water fish such as cod, haddock, and pollock 'liberates' large numbers of small fish (e.g., *Ammodytes*), leading to increases in cormorants (and grey seals) and changes in the distribution of kittiwakes. Economic pressure will result in increased fishing for smaller fishes from a lower trophic level (e.g., *Ammodytes* and capelin), thus direct competition with seabirds and marine mammals.

Integrated monitoring is needed to interpret observed changes and to determine causes. We should be able to identify the problem but also to identify causes and derive remedies. Without knowledge about linkages and underlying processes, we can't extrapolate from intensive sites to extensive sites. Research must support monitoring. Examples:

- The Gulf of Maine program uses mussel scope for growth as the indicator, but there is not enough money to also monitor potential causes of changes in scope for growth, e.g., food, temperature, light penetration, contaminants.

- Acid Rain (LRTAP): the link between deposition and salmon abundance/productivity is not well established
- The link between seabird communities and fish communities is intuitively obvious (see above) but not documented.

A perceived institutional/administrative barrier to establishment of the network concerns cooperation among scientists working on an integrated monitoring team: federal research scientists need to publish frequently, and publications from integrated, long-term programs would be infrequent. Also, such teams will need to be made up of individuals from across the organization(s), whereas funding flows down.

It likely will be necessary to monitor different indicators in different regions, because (1) species differ, (2) issues differ, and (3) methods of measurement vary with institution and situation.

Integration in the monitoring network must extend to the data interpretation stage.

SUGGESTED INDICATORS

Seabirds

Changes in seabird and marine mammal populations lag behind the cause (e.g., 15 years for murres) because they are long-lived and have low mortality rates (5-10% annually); such changes are 'smoking gun indicators' in that they indicate that a significant change in ecosystem state has occurred.

Reproductive success, therefore, is a better indicator. Seabird eggs are easy to monitor because of colonial breeding. Open ocean birds are most vulnerable because of their low fecundity (usually 1 egg) and, therefore, limited powers of rehabilitation.

An intensive site for seabird monitoring would have to be a large area, across the species' range.

The ideal seabird monitoring program would include measurements of population size at extensive sites, and reproductive success at intensive sites (all birds banded, over many years)

MFO

MFO induction is an early warning indicator, as it indicates impact at a reversible stage. The next step, pathology, is a 'smoking gun' indicator.

MFO induction is one of few indicators where cause can be established. However, are linkages between MFO, pathology, population and community effects established?

Mike Wong at ESED is setting guidelines (limits) for MFO; those (presumably conservative) limits could simply be used in the absence of established linkages between MFO, pathology, population and community effects.

It was noted that Jack Uthe, who was not present, might argue against the use of MFO induction as an indicator.

Nutrients vs. Productivity

From an acid rain perspective, it was argued that simple, lower-level indicators are better indicators, especially at extensive sites, because (1) inherent variability is higher in biological indicators than in chemical indicators, and (2) our understanding of biological processes is not as good as that for chemical processes. Where linkages have been established, or where research can be applied at intensive sites to establish them, we should monitor the simplest indicator. E.g., monitor nutrients in lakes rather than productivity or fish community composition.

Economic Indicators

Commercial catch

Money or manpower spent in oil spill cleanup

Biodiversity

Biodiversity is important and politically correct, but how do we measure it?

EXISTING MONITORING PROGRAMS

Seabirds

There is a poor historic database for populations of most seabird species (short time frame, too few samples). There has been no integrated monitoring at seabird colonies (birds, fisheries, oceanography, contaminants). CWS samples colony size and reproductive success, but needs to do more.

CWS conducts a beached bird program only in south Nfld., and even there, there is no commitment to a long-term program.

Stations

The Atlantic Coastal Action Plan is establishing 13 marine quality monitoring sites, with the intention of conducting intensive sampling.

The only existing intensive sites in the region are 'hot spots' (e.g., Halifax Harbour).

The Latang estuary, an aquaculture site, has been well studied (circulation modelling, contaminants, etc.)

General

The recently-published Atlantic Coastal Zone Database Directory identifies available databases of relevance to the network. Follow-up will be required to obtain details of the available data.

Existing monitoring programs (including sites) cannot be changed to accommodate the Network; most have institutional ties (e.g., federal-provincial agreements)

Most information is available for commercial species or species 'assigned' to particular agencies (e.g., seabirds). Little information is available on other marine species of importance (e.g., cunner, *Ammodytes*). Acoustic surveys are conducted for capelin, but coverage is sparse

It was suggested that lessons could be learned from other long-term monitoring programs, such as those in the North Sea, Baltic, and Mediterranean. Most of that information is in the grey literature but is available at BIO. Wayne Barchard and Louise White agreed to sent selected reports to William Cross.

Moncton, Environment Canada, 23 March 1993

NAME	DEPARTMENT	DISCIPLINE/SPECIALTY
Ross Alexander	DFO	Habitat Science
Tom Clair	EC	Ecosystems (FW & Marine)
Hugh O'Neill	EC	Ecosystems (FW & Marine)

GENERAL

What question are we trying to answer: simply to describe status and trends?

A perceived value of the network is that it highlights the need for long-term programs, allowing departments to keep long-term programs in place beyond the usual 5-year funding cycle

SUGGESTED INDICATORS

Again (see Halifax Meeting minutes), the acid rain experience argues for the use of simple indicators (i.e. alkalinity rather than fish communities). Phytoplankton, zooplankton, fish don't work. After years of monitoring, community effects cannot be demonstrated in the field.

In general, it was felt that few of the MESAF indicators on the long list provided in the background information were of any practical value for monitoring. Comments included

- of the 'Structure' indicators, only size composition and age structure are reasonable
- measuring mortality rates is feasible for fish, but doing so for zooplankton would be a major research effort
- indicators like energy flow or carbon cycling are too difficult to measure

Fish stocks are the best indicator of ecosystem structure because much work has been done, and the data are easy to interpret

Ease of measurement is the most important criterion for selecting indicators

EXISTING MONITORING PROGRAMS

BIO has been doing work on phytoplankton respiration in the Bedford Basin for a long time

DFO Moncton has started doing some research on MFO induction

All DFO Scotia/Fundy research vessels fill out forms on persistent debris; Ross is attempting to institute the same system for Moncton

Dow Chemical is also monitoring the occurrence of persistent debris—need more information

Fish contaminant information is available from DFO landed fish inspections; also referred to

Richard Addison

Data integration and QC/QA are good for the 'fish stocks vs. climate' issue (see Tom), but there is no database integration, consistent QC/QA, or list of stations for MEQ indicators

Pulp and Paper EEM regulations may be relevant (Technical Guidelines are in final draft form), and similar regulations are in the works for metal mines

Data Repository for the region will be at WRD/Monitoring and Evaluation Branch, Moncton

St. John's, 25 March 1993

NAME	DEPARTMENT	DISCIPLINE/SPECIALTY
John Christian	LGL	Marine Ecology
Eugene Lee	LGL	Marine Ecology
Kathy Penney	EP/EC	assessment
Mark Yeates	CPS/EC	assessment
John Chardine	CWS/EC	seabird biology, marine ecosystems
Gordon Pelly	EP/EC	ocean dumping, toxins, regulations

GENERAL

Considerable overlap between MEQ, MESAF Structure, and MESAF Function indicators. Difficulty is encountered when attempting to integrate 'final list' of indicators into a monitoring network that minimizes redundancy and cost YET maximizes meaningful information and efficiency. Must get a firm handle on all available data.

Point made that the design of this monitoring network must avoid as much redundancy as possible. An example of typical redundancy is contaminant levels in eggs of capelin-feeding seabirds and contaminant levels in capelin.

SUGGESTED INDICATORS

Concern was expressed regarding the absence of 'contaminants in higher trophic levels' in the MEQ list. Fairly lengthy discussion on the use of seabirds as indicators of marine environmental quality. Point made that seabirds are actually samplers of MEQ. Availability of samples when using seabirds far better than for other biota. Migration can pose problems when interpreting data. Therefore seabird species selection very important.

Consensus that any indicator associated with a parameter that is able to be measured repeatedly should be listed under MEQ (e.g., seabird populations, mortality rates, recruitment rates). MESAF indicators were seen as being measured at a point in time.

Should be monitoring air quality as it relates to the marine environment.

Resource abundance and biodiversity are the best integrated measures of marine environmental quality.

'Exotic vs. native species' should be removed from the list for the Newfoundland area.

Some of the indicators on the list should be grouped (e.g. nutrient dynamics, primary productivity, eutrophication).

Should size composition and age structure be separate indicators?

Is genetic variability actually included under biodiversity? What is an optimum level of genetic variability within a population? How do we discriminate between 'within population' and 'between population' genetic variability?

EXISTING MONITORING PROGRAMS

There exists a 20 year database on contaminant levels in seabird eggs. Also data from feather analysis although this is much more specific (Hg and heavy metals). Limited data on 'chick growth'.

'Operation Cleanfeather', the seabird beach survey, has been in effect since 1984.

There are plans for a plastics monitoring program for Newfoundland, probably commencing in 1997, on southern beaches. Beaches from Ferryland (about 40 miles south of St. John's) around the Avalon to Come-by-Chance are being monitored for oil contamination.

Environment Canada has a 10-year database on contaminant levels in blue mussels at relatively few sites in Newfoundland. Working on classification system of shellfish areas. Data are limited but it is a start.

The only government sediment information is from dredging projects. However, the exhumation and displacement of the sediment pretty much eliminates data validity. EP just commencing to use post-dredging data i.e. follow-up analysis.

Essentially no water analysis done in the marine environment in Newfoundland. Concentration to now has been on fresh water. Plans to begin marine water analysis are at embryonic stage. Water quality should include physical oceanographical characteristics as well (i.e. salinity, temperature, ice conditions, etc.). Good database for these oceanographic parameters. Mark Yeates intends to provide data collected in nearshore waters at Gros Morne and Terra Nova Parks.

Question as to whether there exists pre-contamination data for many of the parameters.

CWS is presently compiling a database on seabird populations across the country (may be 5 to 10 years away from completion).

Data on seabird colonies in the eastern Arctic are directly relevant to Atlantic seabird data.

Should be marine mammal population data available - DFO has been conducting seal surveys (Question as to the validity of this seal data).

John Lien has been collecting blubber samples from entrapped whales for biopsy. Problem with whale data lies in the large scale migrations of these animals (i.e. what is the contaminant source?).

Mont-Joli, Institut Maurice Lamontagne, 24 March 1993

NAME	DEPARTMENT	DISCIPLINE/SPECIALTY
Jon Percy	Fisheries & Oceans	Biol. Oceanography/Arctic
Ted Packard	Fisheries & Oceans	Biol-Chem. Processes, enzymes, CO_2 prod.
Marcel Fréchette	Fisheries & Oceans	Bivalve Population dynamics
Daniel Gauthier	Fisheries & Oceans	Fish Habitat/EA (hydro, ballast water)
Richard Arthur	Fisheries & Oceans	Parasitology-tax, ecol, life cycles: fish/marine mammals
Yves Gratton	Fisheries & Oceans	Physical Oceanography
Catherine Couillard	Fisheries & Oceans	Ecotox; histol/fish health Biochemical indices
Jean Piuze	Fisheries & Oceans	Contaminants: Issues & Policy
Alain Vézina	Fisheries & Oceans	Biological Oceanography
Charles Gobeil	Fisheries & Oceans	Chemistry
Suzan Dionne	Canadian Parks Service	Resource Management
Normand Doucet	Fisheries & Oceans	Head, Hydrographic Data Acquisition
Lyse Goelbout	Fisheries & Oceans	Biological Oceanography
Bernard Morin	Fisheries & Oceans	Groundfish Stock Assessment Biologist
Gilles-H. Tremblay	Fisheries & Oceans	Chemical Oceanography
Emilien Pelletier	Institute Maritime de Québec	Organometallic Chemistry
Maurice Levasseur	Fisheries & Oceans	Biol. Oceanography
Jeffrey Runge	Fisheries & Oceans	Biol. Ocean. - Plankton
Jacques A. Gagné	Fisheries & Oceans	Fisheries Oceanography

GENERAL

It was suggested that MESAF indicators measure instantaneous state changes that cannot be related to long-term change, whereas MEQ indicators measure long-term change.

We must know what questions are being asked so that we can derive a reasonable list of indicators; the MEQ list is 'trim', the MESAF list is huge. It would be preferable to have a broader range of MEQ indicators and a few MESAF indicators.

An emerging fisheries-related issue is 'ghost fishing' by lost fishing gear (much of it intentionally lost when old, and replaced by insurance). It has become so bad in Baie de Chaleurs that the fishermen want the bottom cleared, as the lost gear interferes with fishing.

Research is needed to establish linkages, either to explain changes observed through monitoring, or to verify the importance/predictive capability of early warning indicators.

SUGGESTED INDICATORS

General

Again (see Halifax and Moncton), it was argued that chemical measurements were more appropriate as indicators because of inherent variability in populations and communities, even over long periods of time. A 12-year study of fauna attached to navigation buoys was cited, and the progressive, year-to-year changes that were found.

It was also suggested that we need both 'total health' indicators (e.g., seabird eggs) and measurements of physical and chemical variables (e.g., long-term temperature fluctuations), the latter to provide explanations.

The medical-ecosystem analogy was discussed. It was suggested that overall health be assessed first (e.g., litter, deformities or tumours in biota), and then specific tests (blood, etc.) be based on the overall diagnosis.

More generally, a stepwise approach was suggested: e.g., measure contaminants; if present measure appropriate biochemical indicator; if present, measure population, etc.

The monitoring network was compared to a toolbox, rather than just one tool; different tools would be used to answer different questions. Also, it was noted that when all you have is a hammer, everything tends to become a nail.

Heat Content was suggested as an indicator of health and possibly climate change. Heat transfer from the atmosphere to the ocean would also be required to calculate a heat budget for the Gulf.

Biomagnification

Contaminants in sediment, fish, seabirds, and humans (see existing programs)

It was noted that there remains a problem with tying health problems (e.g., human, white whale in the Arctic) to contaminant levels.

Zooplankton

Zooplankton biomass and productivity; the GLOBEC program perspective is that zooplankton are an intermediate link between physical processes and fisheries; annual fluctuation in *Calanus* (the dominant genus in the North Atlantic and the Gulf) biomass is suggested as the cause of fluctuations in recruitment variability in Norwegian cod. Eggs and nauplii are important to a number of species of fish.

Egg viability is also an issue, as they are very sensitive to contaminants.

Annual change in zooplankton biomass can readily be measured using continuous plankton recorders (CPR) towed from ships of opportunity.

Eutrophication

Nutrients as indicators of eutrophication, toxic algal blooms, and anoxia in deep water. Oxygen content was also discussed as an indicator of eutrophication (it is suspected that deep water in the Gulf has low oxygen content because of eutrophication in surface waters). Nutrients are preferred because they are an early warning, unlike decreased oxygen or anoxia. Anoxia could exclude fish from deep water, or anoxic water could be upwelled, causing fish kills.

It was suggested that a long-channel nutrient transect be established. More realistically, nutrient measurements could be added to the Canadian Monitoring Program for Harmful Algae (see below).

Toxic Algae

Incidence of toxic algal blooms (see existing programs)

Phytoplankton Biomass

Total phytoplankton biomass should be monitored; we can all see a forest die, but not so for the 'forests' of the marine ecosystem.

DNA adducts

This is a relatively new technique for detecting effects of low-level stress being studied at IMQ. E.g, benzo-a-pyrene attaches to a DNA molecule. This condition has been found in white whales and other marine mammals. Effects are not known; genetic effects are possible, as are effects delayed for generations.

Groundfish Stocks

Should be measured with surveys rather than landings (see existing programs).

MFO Induction

One advantage of MFO is that it indicates a suite of contaminants; levels and types of contaminant input can be expected to change over time. However, we cannot make quantitative predictions about effects (e.g., on reproduction) from MFO measurements. It should be monitored, but it must be realized that it responds to a narrow suite of contaminants.

We need to have information on specific types of contaminants so that we can choose the appropriate biochemical/pathological indicator.

Pathology

To the long list of MEQ indicators should be added epidemiology, gross pathology (rate of disease, deformity, tumours, etc.) and general health.

EXISTING MONITORING PROGRAMS

5-year Gulf Monitoring Program to begin next week. Physical program beginning field work, biological program will spend the first year selecting indicators and stations. Its purpose is to look at long term changes and inter-annual variability in the Gulf and, to some extent, the Scotia-Fundy region.

Station 27 off St. John's—long-term oceanographic data set

Beach surveys for litter are conducted on Sable Island regularly (ref. Rod Paterson, Ottawa).

Zooplankton

Jeffrey Runge at IML is participating in GLOBEC, an international (and U.S.) program looking at zooplankton. A new program, 'GLOBOCOP', is being developed: coordinated monitoring of populations of North Atlantic *Calanus* spp. Jeffrey is working in the Gulf, intends to monitor *Calanus* variability using CPR. The Gulf Region has decided not to fund CPR, but the issue is still under discussion. There is one station off Rimouski where productivity and egg viability is being studied.

A North Atlantic CPR program has been conducted from the U.K. since the 1930s, and it shows long-term trends. Funding has dried up; sample processing is expensive and apparently the only expertise is in Britain (squished zooplankton specialists), but there may be ways to automate the process. There is an interest in developing the expertise and methodology in Canada.

Jon Percy at IML is looking at *Calanus* production in the Arctic.

Biomagnification

Last year, IML started a 5-year Green Plan study of contaminants (metals, OCs, dioxin) in sediment (accumulation in the Laurentian trough) and fish (mostly commercial spp., including cod, flounder, shrimp) in the Gulf. Such information is not available for previous years.

Two years ago, CWS started a monitoring program for contaminants in Arctic Tern eggs in the Gulf from Montreal to Iles de Madeleine.

Toxic Algae

Canadian Monitoring Program for Harmful Algae: 50 stations sampled for phytoplankton, temperature, and salinity; nutrients and chlorophyll *a* are also sampled at some stations. More could be done with the data.

Water Levels

100 year's data; 41 stations in the Gulf, all nearshore. Program is being downsized to 15 or 20 stations; modernized equipment is being installed that will also measure T and S.

Groundfish surveys have been conducted in the Gulf since 1978 and 1984 (two programs). Each trawl also measures T, S, O_2; all species are weighed; garbage is also weighed.

Ottawa, Conservation & Protection, 25 March 1993 0900

NAME	DEPARTMENT	DISCIPLINE/SPECIALTY
John Karau	C & P	MEQ
Tony Gaston	CWS	Seabirds

GENERAL

Availability of other disciplines' data in real or near-real time would be a real benefit from the network; e.g., the most recent sea surface temperature data available through MEDS are from 1989; seabird monitoring needs more up-to-date data.

An example of an ecosystem state change occurred in the Gulf of Alaska over the past 2 decades: after some dramatic event in the late 1970s, pollock became dominant in its trophic level, northern sea lion became endangered, and reproductive success of seabirds decreased.

Hypotheses and Expectations: What are the questions we are trying to answer in 5 or 10 years' time? If the model is too elaborate, there will be a gap between expectations and the ability to deliver.

We need to make a clear distinction between monitoring and research. Monitoring will tell us what's happening, research will tell us why.

We can use an iterative/stepwise approach: e.g., 1. Is biomagnification occurring? 2. Are there effects on reproduction (e.g., crossbills in cormorants)? 3. Are there population effects?

The stepwise approach can be either bottom-up (e.g. above) or top-down.

SUGGESTED INDICATORS

Including biomagnification in the monitoring network would largely be an information compilation exercise.

For seabirds: egg volume, chick growth rate, prey proportion in diet, reproductive success

EXISTING MONITORING PROGRAMS

Dumpsite program in 1993 will focus on Point Grey off Vancouver, B.C.; Baie de Chaleurs, Québec; and Saint John Harbour, New Brunswick.

Shellfish program → fecal coliform

Mussel watch: body burdens, scope for growth

CWS seabird monitoring stations are in the recently published 'Seabird Trends'; see Colin Heslop or Judith Kennedy.

Ottawa, SOE/ESED, 25 March 1993 1100

NAME	DEPARTMENT	DISCIPLINE/SPECIALTY
Don McGirr	Environment Canada	Eco-Health Branch
Robert Audet	Environment Canada	Indicator Program
Patricia Roberts-Pichette	Environment Canada	Ecosystem Monitoring & Analysis
H. Hirvonen	Environment Canada	Ecosystem Monitoring & Analysis

GENERAL

SOE's Ecosystem Monitoring and Analysis Branch will fund research to provide answers; that program will not proceed until the monitoring network design is complete.

The phrase 'ecosystem health' implies a value judgement; 'ecosystem change' is better. How can we judge 'ecosystem integrity'? Does the loss of the American chestnut change ecosystem integrity? Will the zebra mussel find a niche, and will we adjust to its presence and the change that it causes?

SUGGESTED INDICATORS

Decomposition: Where is biomass accumulating, and is it changing over time?

We must be able to detect small, cumulative changes occurring gradually over time, and to identify cyclical phenomena as such.

Native vs. Exotic Species: species distributions may be changing as a result of ocean current or temperature changes associated with global climate change.

Populations, Population Structure, Reproduction: is it enough to look at primary production and top consumers? Antarctic krill are neither, but of critical importance to that ecosystem. *Calanus* may play a similar role in temperate waters.

The Indicator Program's list includes biomass and productivity; contaminants in fish and sediment; habitat change/coastal development; and year class and condition of fish

What is the best measure of primary productivity: PSP, chl *a*, toxic blooms, species composition (i.e., partitioning of biomass)? Multi-component research is now being conducted in B.C.; that may be a part of the monitoring network once every 5 or 10 years.

Eco-Health Branch is starting to develop ecosystem indicators, working on a framework paper (Kevin Brady); ESED is developing marine water and sediment quality guidelines

Ottawa, Fisheries and Oceans, 25 March 1993 1400h

NAME	DEPARTMENT	DISCIPLINE/SPECIALTY
Ron Pierce	Fisheries and Oceans	Ocean. and Contaminants
Rod Paterson	Fisheries & Oceans	Ocean. and Contam. Branch
Barry Hobden	Fisheries & Oceans	Ocean. and Contam. Branch
Hugh Bain	Fisheries & Oceans	Biological Sciences
Jim Powell	Fisheries & Oceans	Ocean. and Contam. Branch

GENERAL

To be convincing, ecosystem health could be assessed by trends in a number of variables pointing in the same direction.

SUGGESTED INDICATORS

Frequency and duration of shellfish closures (*E. coli*)

Frequency of occurrence of pollution events such as closures attributable to chemicals, discovery of 'hot spots'

Primary productivity: we're close to being able to monitor through satellite imagery (algorithms developed by Trevor Platt *et al.*).

Measurements of coastal habitat, e.g., rockweed beds measured at St. Andrews

EXISTING MONITORING PROGRAMS

Marine debris clean up, now administered by Environment Canada: 'Pitch In Canada', a non-profit organization in White Rock, B.C., funded by John Karau's group, conducts systematic beach debris clean-up. Will take a couple of years to get it set up and running.

DFO programs of potential use include measurements of T, S, O2, currents, productivity including toxic blooms; sea surface temperatures and waves measured at lighthouses; fixed and floating buoys (with AES); remote sensing of phytoplankton blooms, oil spills. We need to identify our specific needs, including data format.

There are no long-term stations or programs to assess or monitor fish habitat.

Responses to stress (indicators) are distributed along two axes: sensitivity and ecological relevance. Moving from high to low sensitivity and low to high ecological relevance, there are: biochemical tests; whole organism/physiology; population change; and community responses. In situations where all 4 have been measured, if there is one response, there tend to be 4 (reference?).

EXISTING MONITORING PROGRAMS

Ocean Station Papa: good long term data set; sampling must be continued there on a regular basis, and we must use retrospective analysis of past events (e.g., El Nino) to plan future timing of sampling.

La Perousse plankton work: 2 or 3 years data, sampling 2-12 times a year, doesn't show much in species composition data (Dave Mackas) but does in group composition (e.g., copepod biomass vs. euphausiid biomass; Dan Ware).

Opportunities for data collection:

- cultivate relationships with commercial fisheries
- 'Trawlers of Opportunity' program: CTDs on nets
- B.C. Ferry proposal

CWS new ecosystem-level mandate: what does this mean? CWS needs to coordinate with DFO.

Winnipeg, 18 June 1993

NAME	DEPARTMENT	DISCIPLINE/SPECIALTY
William E. Cross	LGL Limited	Marine Ecology
Martin Bergmann	Central&Arctic-Science	Marine Phytoplankton/Habitat Science
Stuart Innes	"	Marine mammal population assessment & ecology
Barbara Stewart	"	Marine mammal energetics, reproduction, ageing; ADCAP
Rob Stewart	"	Marine mammal energetics, growth, reproduction
Lyle Lockhart	"	Biochemical indicators of contaminant stress; sediment core histories
Doug Chiperzak	"/AFEAR	Arctic marine fisheries assessment, Greenland halibut
Jim Reist	"/Science/Arctic Fish Ecology & Assessment Research	Arctic fish genetics, stock genetics, taxonomy

GENERAL

Is the National Marine Status and Trends Monitoring Network coordinated with the Arctic Environmental Protection Strategy? It has four components: marine quality; AMAP; conservation and protection of ecosystems; pollution/oil spill response.

The long list of MEQ and MESAF indicators is difficult to use: the species/indicator depends on the perspective (i.e. the issue—contaminants, fishing pressure, etc.).

Size composition: someone at Burlington is working on this in freshwater; can predict size composition in certain situations (e.g., Hamilton Harbour), but don't know why (Lyle)

Monitoring per se affects the environment, e.g., as soon as we sample by gill net, we affect the structure of the population we want to monitor. Are observed changes attributable to fishing pressure (commercial or research) or by changes in the environment?

Noise (sonification) as another type of stress.

Fishing/harvest pressure is becoming a bigger issue: exploratory fishing in Hudson Strait; recent inquiry from Rankin Economic development Officer about marketing of Gammarus (or other large amphipods) as pet food; mussel farming proposed for Saniqiluak

Histology samples should be archived for future use

Archiving of data and ensuring availability of data important; also, we should retrieve and analyze historical data; use existing databases as baseline for basis for monitoring

Must choose indicators to document "informative change"; to be simple and sustainable (example of measuring flow/discharge of rivers daily for years)

SUGGESTED INDICATORS

Biomagnification

Rob and Lyle have information for southern Hudson & Beaufort

Keith Hobson has worked with lower trophic levels at Resolute; others (same study?) have worked up the food chain to shorebirds (Birget Braun & Ross Norstrom, CWS Hull) (see Marty)

DFO is strong on marine mammals, weak on fish, and very weak on sediments; part of the problem is lack of ship time

Narwhal and beluga reasonably well studied, targeted for the near future. Have data from 10 years ago, will repeat soon. (Later, Stu mentioned 10 y repeated sampling of ringed seal, Admiralty Inlet, in '93; and near-future sampling of beluga at Arviat and SE Baffin).

Marine mammal management people are monitoring narwhal at Pond Inlet and beluga in the Mackenzie Delta (Barbara)

Beluga and narwhal are migratory, but migration is known and not too far (across ecodistrict boundaries, however)

Ringed seal are better, more sedentary, although they do move; Stu thinks it is immigration/ emigration rather than migration

Bearded seals are best—very limited range, but there are too few of them

Rob has limited data on walrus and clams

Buster has worked (diets? contaminants?) on crustaceans -> cod -> beluga, narwhal, ringed seal

Use fresh prey from stomach contents for contaminant analysis (no sampling effort, direct connection between predator and prey)

Nutrients vs. Productivity

Eutrophication is not an issue in the Arctic

Effects of global warming (via spring melt, runoff, nutrient input); ozone (via light effects on productivity, effects on heat transfer & ice patterns)

Remote sensing of chlorophyll; DFO will have a sensor on one of the satellites to be launched in the next year or two

Other

Sediment profiles/dated cores from depositional environments: setting today's events in historical context and extrapolating into the future. Resolution, however, is 10-20 years.

Meristic characteristics in fish (e.g., asymmetry in fish) indicate habitat destruction

Bone/otolith deposition: microelement analysis (e.g., cadmium) by laser (Rob); stable isotopes; strontium (low in freshwater, high in seawater) shows habitat history of anadromous fish. Can see seasons of deposition in bone; ringed seal is a good species.

Reproduction: Barbara mentioned reproductive failures

Remote sensing of polynias, ice edges; DFO will have a sensor on one of the satellites to be launched in the next year or two

EXISTING MONITORING PROGRAMS

Fisheries

Cambridge Bay fisheries catch monitoring conducted every year

MFO

Reports provided by Lyle; also request annual program summaries from Russel Shearer at DIAND

Marine mammals and freshwater fish; will also be doing Doug's Greenland flounder

Gerry Payne (DFO Newfoundland) working on cancer in arctic animals

Other

Fish pathology, condition: have been consumer reports, e.g., appearance of Mackenzie burbot livers (Dene nation to Brian Wong, Yellowknife), taste, soft flesh

APPENDIX B: Atlantic Databases of Relevance to the MEQ Monitoring Network (from ACZISC 1992).

These descriptions of databases selected from the Atlantic Coastal Zone Database Directory (ACZISC 1992) were copied directly from the distribution disks

1. **Database Title: Commercial Samples Database**

2. **Contact Person:**
   Kees Zwanenburg
   Marine Fish Division
   Biological Sciences Branch
   Department of Fisheries and Oceans
   PO Box 1006
   Dartmouth, Nova Scotia B2Y 4A2
   Tel (902) 426-3310; Fax (902) 426-1506

3. **Purpose:** To estimate the abundance of fish

4. **Access/Fees/Restrictions:** Through contact person/None/None

5. **Geographical Coverage/Scale:**
   Nova Scotia and New Brunswick - Bay of Fundy and Atlantic Coast of Nova Scotia/ Unit Area

6. **Geographical Referencing:** Unit area; Latitude/Longitude

7. **Period of Record/Update Frequency:** 1948 to present; updated weekly

8. **Format:** Digital

9. **Data Types/Parameters Measured:** Biological/Number of fish at certain sizes, weight, age, sex, species, length frequencies, condition landed, type of gear, landing port

10. **Sampling Procedures:** Fish surveyed at landing port

11. **Program Type:** Monitoring

12. **Size/Growth:** N/A

13. **Environmental Legislation relevant to this data:** N/A

14. **Computer System:** CYBER at BIO, IBM compatible PC

15. **Comments:**

16. **Map indicating areas of data holdings:** 73

1. **Database Title: Fish Health Database - Maritime Provinces**

2. **Contact Person:**
J.W. Cornick
Benthic Fisheries and Aquaculture Division
Biological Sciences Branch
Department of Fisheries and Ocean
PO Box 550
Halifax, Nova Scotia B3J 2S7
Tel (902) 426-8391; Fax (902) 426-8038

3. **Purpose:**
To record inventories of fish disease distribution throughout the Maritime Provinces and provide case file storage and report writing functions

4. **Access/Fees/Restrictions:**
Through contact person/None/Some diagnostic data for clients may be restricted

5. **Geographical Coverage/Scale:** Scotia-Fundy Region

6. **Geographical Referencing:** None

7. **Period of Record/Update Frequency:**
1974 to present; updated daily

8. **Format:** Digital; Hard-copy

9. **Data Types/Parameters Measured:**
Biological/Disease agents

10. **Sampling Procedures:**
Autopsy and bacteriological, virological and parasitological examination of fish

11. **Program Type:**
Monitoring

12. **Size/Growth:**
Approximately 900 records/year

13. **Environmental Legislation relevant to this data:** N/A

14. **Computer System:**
IBM compatible PC, Macintosh

15. **Comments:**
Also includes some chemical and physical data such a temperature, pH and dissolved oxygen

16. **Map indicating areas of data holdings:** 76

1. **Database Title: Distribution of Whales and Seals**

2. **Contact Person:**
Paul Brodie
Habitat Ecology Division
Biological Sciences Branch
Department of Fisheries and Oceans
PO Box 1006
Dartmouth, Nova Scotia B2Y 4A2
Tel (902) 426-6325; Fax (902) 426-7827

3. **Purpose:** To determine the distribution and abundance of whales and seals

4. **Access/Fees/Restrictions:** Through contact person/None/None

5. **Geographical Coverage/Scale:**
Atlantic Provinces - offshore waters and onshore seal colonies

6. **Geographical Referencing:**
None

7. **Period of Record/Update Frequency:**
1950's to present/Variable, although counts of some species of seals are updated annually

8. **Format:**
Hard-copy reports, publications and data files. Data on harp and hooded seals are computerized

9. **Data Types/Parameters Measured:**
Biological/distribution and abundance estimates of whales and seals, especially at areas of food abundance and at seal whelping colonies

10. **Sampling Procedures:**
Strip surveys, field surveys at breeding grounds, aerial and ship borne surveys

11. **Program Type:**
Research and monitoring

12. **Size/Growth:** 5% per year

13. **Environmental Legislation relevant to this data:** Fisheries Act. Possible restriction of gill net fishing during periods of harbour porpoise occupation

14. **Computer System:** Macintosh

15. **Comments:** Contact person has access to several data bases and scientific studies

16. **Map indicating areas of data holdings:** 74

1. **Database Title: North Atlantic Primary Production**

2. **Contact Person:**
Carla Caverhill
Biological Oceanography Division
Biological Sciences Branch
Department of Fisheries and Oceans
PO Box 1006
Dartmouth, Nova Scotia B2Y 4A2
Tel (902) 426-3255; Fax (902) 426-9388

3. **Purpose:**
Study primary production in the ocean

4. **Access/Fees/Restrictions:**
Through contact person/None/None

5. **Geographical Coverage/Scale:**
North Atlantic from Kane Basin to the Caribbean, from Resolute Bay to the Irish Sea

6. **Geographical Referencing:**
Latitude/Longitude

7. **Period of Record/Update Frequency:**
1973 to present; no regular update procedure

8. **Format:**
Digital: flat ASCII files

9. **Data Types/Parameters Measured:**
Chlorophyll "A" concentrations, P_m, alpha, water temperature and depth, nutrients

10. **Sampling Procedures:**
On-site collection

11. **Program Type:**
Research and mapping

12. **Size/Growth:**
2000+ data items

13. **Environmental Legislation relevant to this data:**
N/A

14. **Computer System:** Stardent Unix

15. **Comments:** This database is being converted to a relational database system

16. **Map indicating areas of data holdings:** 85

1. **Database Title: Scotia-Fundy Bottom Trawl Survey Data**

2. **Contact Person:**
Stratis Gavaris, Biologist
Biological Sciences Branch
Department of Fisheries and Oceans
PO Box 210
St. Andrews, New Brunswick E0G 2X0
Tel (506) 529-8854; Fax (506) 529-4274

3. **Purpose:** To collect information on fish distribution and abundance for stock assessment. Fish harvesting and ecosystem monitoring

4. **Access/Fees/Restrictions:**
All requests have to be approved by Science Director in consultation with line management. No formal pricing policy exists. Costs are negotiated on a case by case basis

5. **Geographical Coverage/Scale:** Bay of Fundy, Georges Bank, Gulf of Maine and Scotian Shelf

6. **Geographical Referencing:** Latitude/Longitude

7. **Period of Record/Update Frequency:** 1958 to present; updated several times a year

8. **Format:** Digital on: Tape - 9 track, 1600BPI, 6250BPI
On-line access - DEC VT100, DEC VT220, Kermit, VAX/VMS Pathworks
Hard-copy, In-house software, Commercial software: Oracle V6

9. **Data Types/Parameters Measured:** Location and size of catch, bottom and surface temperatures, number of fish caught, weight caught, length, weight, sex, species, age of individual fish, fish parasites, stomach contents

10. **Sampling Procedures:** Bottom trawl surveys

11. **Program Type:** Research and monitoring

12. **Size/Growth:** 100 Megabytes; 5 Megabytes/year

13. **Environmental Legislation relevant to this data:** Fisheries Act

14. **Computer System:** Host computer: DEC VAX; Operating system: VAX/VMS; Commercial Software: Oracle, RDBMS

15. **Comments:** Although used for stock assessments, can be used to determine fish abundance at offshore developments. Not well suited for localized estimation but adequate for global estimates of large blocks

16. **Map indicating areas of data holdings:** 91

1. **Database Title: Heavy Metal and Pesticides Analysis of Fish and Shellfish**

2. **Contact Person:**
J. MacLean
Inspection Services Branch
Department of Fisheries and Oceans
PO Box 5030
Moncton, New Brunswick E1C 9B6
Tel (506) 851-6563

3. **Purpose:**
Inventory of heavy metal and pesticides in fish product in Gulf Region

4. **Access/Fees/Restrictions:**
Processing establishment information is confidential

5. **Geographical Coverage/Scale:**
Gulf Region sector of the Gulf of St. Lawrence

6. **Geographical Referencing:**
NAFO and Latitude/Longitude where available

7. **Period of Record/Update Frequency:**
1983 to present; updated as required

8. **Format:**
Digital

9. **Data Types/Parameters Measured:**
Numerous heavy metals and pesticides

10. **Sampling Procedures:**
On-site surveys as required

11. **Program Type:**
Monitoring

12. **Size/Growth:** 1,100 records/50-100 records per year

13. **Environmental Legislation relevant to this data:**
Fish Inspection Regulation, Management of Contaminated Fisheries Regulations

14. **Computer System:**
IBM compatible PC
Q&A Software

15. **Comments:**

16. **Map indicating areas of data holdings:** 118

1. **Database Title:** Monitoring Contaminants in the Gulf of St. Lawrence
(New program; not in ACZISC 1992)

2. **Contact Person:**
C. Gobeil
Div. d'Oceanographie Chimique et des Contaminants
IML, C.P. 1000
Mont Joli Quebec
G5H 3Z4

3. **Purpose:** Monitor contaminants in fish sediments and coastal biota near industrial outfalls.

4. **Access/Fees/Restrictions:**

5. **Geographical Coverage/Scale:** Estuary and Gulf of St. Lawrence

6. **Geographical Referencing:**

7. **Period of Record/Update Frequency:**

8. **Format:**

9. **Data Types/Parameters Measured:** Fish: PAH, metals, organochlorines

10. **Sampling Procedures:**

11. **Program Type:** Monitoring

12. **Size/Growth:**

13. **Environmental Legislation relevant to this data:**

14. **Computer System:**

15. **Comments:**

16. **Map indicating areas of data holdings:**

1. **Database Title: Contaminants Database(COD)**

2. **Contact Person:**
   Joseph Southall, Chief
   Planning, Coordination and Review
   Inspection Services Branch
   Department of Fisheries and Oceans
   PO Box 550
   Halifax, Nova Scotia B3J 2S7
   Tel (902) 426-9426; Fax (902) 426-5342

3. **Purpose:**
   Consumer health and safety protection and regulatory compliance and enforcement activities

4. **-Access/Fees/Restrictions:**
   Inspection Services Branch users only

5. **Geographical Coverage/Scale:**
   Scotian Shelf, Gulf of Maine, Bay of Fundy

6. **Geographical Referencing:**
   N/A

7. **Period of Record/Update Frequency:**
   Daily as results become available

8. **Format:**
   Digital, hard-copy and report

9. **Data Types/Parameters Measured:**
   Heavy metals (Mercury, lead, arsenic, cadmium), pesticides contaminants (PCB's, PAH's, Dioxins/furans), additives (Sulfites)

10. **Sampling Procedures:** On-site, UN/FAO Codex Alimentarius Sampling Plans

11. **Program Type:** Monitoring, surveillance, product inspection and export certification

12. **Size/Growth:** 100 Megabytes/year

13. **Environmental Legislation relevant to this data:** N/A

14. **Computer System:** IBM compatible PC - 386, 386SX and 286, dBASE

15. **Comments:**
    Contaminant results of analysis of imported fish products are also maintained in this data base

16. **Map indicating areas of data holdings:** 121

1. **Database Title: Bottle Sampling**

2. **Contact Person:**
Don Spear, Head
Historical Archive Section
Marine Environmental Data Service
Department of Fisheries and Oceans
1202 - 200 Kent Street
Ottawa, Ontario K1A 0E6
Tel (613) 990-0260; Fax (613) 990-5510

3. **Purpose:**
Profile data for temperature, salinity, nutrients and various chemical parameters using bathythermograph for ocean and climate research as defined in the Financial Administration Act

4. **Access/Fees/Restrictions:**
Available to the public with a disclaimer and subject to cost recovery as defined in the Financial Administration Act

5. **Geographical Coverage/Scale:**
40 - 90 degree N, 40 - 180 degree W

6. **Geographical Referencing:**
Latitude/Longitude

7. **Period of Record/Update Frequency:**
1905 to present

8. **Format:**
Digital: Magnetic Disk/Tape; Electronic communication

9. **Data Types/Parameters Measured:** All physical ocean properties vs depth

10. **Sampling Procedures:** Ship borne sampling

11. **Program Type:** Research

12. **Size/Growth:** 200 Megabytes; 150,000 records; 43 attributes per record

13. **Environmental Legislation relevant to this data:** N/A

14. **Computer System:**
VAX 6320 - VMS

15. **Comments:**

16. **Map indicating areas of data holdings:** 123

1. **Database Title: Canadian BT**

2. **Contact Person:**
Don Spear, Head
Historical Archive Section
Marine Environmental Data Service
Department of Fisheries and Oceans
1202 - 200 Kent Street
Ottawa, Ontario K1A 0E6
Tel (613) 990-0260; Fax (613) 990-5510

3. **Purpose:**
Temperature profile data collected using bathythermograph. Current Applications: Ocean and Climate Research

4. **Access/Fees/Restrictions:**
Available to the public with a disclaimer and subject to cost recovery as defined in the Financial Administration Act

5. **Geographical Coverage/Scale:**
40 - 90 degree N, 40 - 180 degree W

6. **Geographical Referencing:**
Latitude/Longitude

7. **Period of Record/Update Frequency:**
1960 to present/Verified as data required

8. **Format:**
Digital and Hard-copy

9. **Data Types/Parameters Measured:**
Temperature vs depth

10. **Sampling Procedures:**
Ship borne sampling

11. **Program Type:**
Research

12. **Size/Growth:** 150 Megabytes; 150,000 records; 43 attributes per record

13. **Environmental Legislation relevant to this data:** N/A

14. **Computer System:** VAX 6320 Mainframe, VMS

15. **Comments:**

16. **Map indicating areas of data holdings:** 125

1. **Database Title: Canadian Temperature and Salinity Data (CTD)**

2. **Contact Person:**
Don Spear, Head
Historical Archive Section
Marine Environmental Data Service
Department of Fisheries and Oceans
1202 - 200 Kent Street
Ottawa, Ontario K1A 0E6
Tel (613) 990-0260; Fax (613) 990-5510

3. **Purpose:**
Contains profiles of temperature, salinity and sometimes other variable such as oxygen as a function of depth. Some profiles will also have associated surface observations of weather.

4. **Access/Fees/Restrictions:**
Available to the public with a disclaimer and subject to cost recovery as defined in the Financial Administration Act

5. **Geographical Coverage/Scale:**
40 - 90 degree N, 40 - 180 degree W

6. **Geographical Referencing:**
Latitude/Longitude

7. **Period of Record/Update Frequency:**
1970's to present. Updated as data are received and processed

8. **Format:**
Digital and Hard-copy

9. **Data Types/Parameters Measured:**
Temperature and salinity vs depth

10. **Sampling Procedures:**
Ship borne sampling

11. **Program Type:** Research

12. **Size/Growth:** 100 Megabytes: 150,000 records; 43 attributes per record

13. **Environmental Legislation relevant to this data:** N/A

14. **Computer System:** VAX 6320 Mainframe - VMS

15. **Comments:**

16. **Map indicating areas of data holdings:** 126

1. **Database Title: Climate Indices Database**

2. **Contact Person:**
Ken Drinkwater, Research Scientist
Physical and Chemical Sciences Branch
Department of Fisheries and Oceans
PO Box 1006
Dartmouth, Nova Scotia B2Y 4A2
Tel (902) 426-2650; Fax (902) 426-7827

3. **Purpose:**
Scientific research

4. **Access/Fees/Restrictions:**
Through contact person/None at present/None

5. **Geographical Coverage/Scale:**
North Atlantic Ocean with emphasis on Northwest Continental Shelves. 10 - 90 degree N, 20 degree E - 90 degree W

6. **Geographical Referencing:**
Latitude/Longitude

7. **Period of Record/Update Frequency:** Varies with data sets. Air temperature at some sites include data from 1780 to present; updated monthly to annually depending on data set.

8. **Format:**
ASCII computer files, digital, hard-copy and reports

9. **Data Types/Parameters Measured:** Monthly or annual values of selected oceanographic, meterological and hydrological data sets. Oceanographic Variables: Sea surface temperature, Temperature and salinity profiles, Position of oceanic fronts, Sea ice and icebergs, Meterological, Air temperatures, Air pressures, Hydrological, River runoff

10. **Sampling Procedures:** Historical data

11. **Program Type:** Research

12. **Size/Growth:** Number of time series - 200-300

13. **Environmental Legislation relevant to this data:** N/A

14. **Computer System:** CDC Cyber, IBM compatible PC; In-house software

15. **Comments:**
A data report on the climate databases including graphical displays and a diskette with the data is planned for publication in 1992.

16. **Map indicating areas of data holdings:** 144

1. **Database Title: Coastal Thermographs**

2. **Contact Person:**
Doug Gregory, Head
Data Management
Physical and Chemical Sciences Branch
Department of Fisheries and Oceans
PO Box 1006
Dartmouth, Nova Scotia B2Y 4E2
Tel (902) 426-8931; Fax (902) 426-2256

3. **Purpose:**
In support of Physical Oceanographic programs on living resources and ocean climate

4. **Access/Fees/Restrictions:**
No policy/Incremental cost at $25/hr technical and at $40/hr professional

5. **Geographical Coverage/Scale:**
Atlantic Canada

6. **Geographical Referencing:**
Latitude/Longitude (point data)

7. **Period of Record/Update Frequency:** 1978 to present; ongoing compilation

8. **Format:** Tape - 1600,6250 - BPI ASCII; Floppy Disk - MS DOS 3.5" and 5.25"; Hard-copy

9. **Data Types/Parameters Measured:**
Fisheries Science
Oceanography - Physical
Physical oceanographic support for shellfish studies and aquaculture.
inshore temperature time series.

10. **Sampling Procedures:** On-site moored instruments

11. **Program Type:** Research

12. **Size/Growth:** 2500 locations; approximately 100 deployments annually

13. **Environmental Legislation relevant to this data:** N/A

14. **Computer System:** Host computer: CDC Cyber; Operating system: NOSVE

15. **Comments:**
Inshore shallow water temperature time series, Scotia-Fundy and Gulf 1978- present, Newfoundland 1978-1987 (more recent data for Newfoundland region available from Northwest Atlantic Fisheries Centre, NWAFC)

16. **Map indicating areas of data holdings:** 145

1. **Database Title: Data Holdings - Marine Chemistry Division, DFO**

2. **Contact Person:**
Dr. J.M. Bewers
Marine Chemistry Division
Physical and Chemical Sciences Branch
Department of Fisheries and Oceans
PO Box 1006
Dartmouth, Nova Scotia B2Y 4A2
Tel (902) 426-2371; Fax (902) 426-7827

3. **Purpose:** To maintain data related to contaminants in fish and in fish habitat collected by the Marine Chemistry Division

4. **Access/Fees/Restrictions:** Through contact person/May be a fee for larger requests/May be restrictions on unverified or uninterpreted data

5. **Geographical Coverage/Scale:**
Scotia-Fundy Region; Atlantic Provinces - offshore and coastal areas including the region from George's Bank to the Labrador Shelf

6. **Geographical Referencing:** Latitude/Longitude

7. **Period of Record/Update Frequency:** 1970 to present/Variable

8. **Format:** Hard-copy, reports, publications and files

9. **Data Types/Parameters Measured:**
Physical, Chemical/ Dissolved oxygen, salinity, temperature; trace metals, radionuclides, organic matter, petroleum hydrocarbons, nutrients

10. **Sampling Procedures:**
Oceanographic Cruises - water column samplers, grab samplers for sediments. Coastal and freshwater survey results (water and sediments). Coring for geochronological measurements

11. **Program Type:** Research, monitoring and survey

12. **Size/Growth:** N/A

13. **Environmental Legislation relevant to this data:** CEPA Part VI, Fisheries Act

14. **Computer System:** IBM compatible PC (under development)

15. **Comments:** Good baseline data for offshore areas, radionuclide data collected near the Pt. Lepreau Nuclear Power Station; Contaminant investigations at selected industrial sites.

16. **Map indicating areas of data holdings:** 146

1. **Database Title: Historical Temperature and Salinity for the Scotian Shelf and the Gulf of Maine**

2. **Contact Person:**
Ken Drinkwater, Research Scientist
Physical and Chemical Sciences Branch
Department of Fisheries and Oceans
PO Box 1006
Dartmouth, Nova Scotia B2Y 4A2
Tel (902) 426-2650; Fax (902) 426-7827

3. **Purpose:** Scientific research

4. **Access/Fees/Restrictions:** Through contact person/None at present/None

5. **Geographical Coverage/Scale:**
Gulf of Maine, Scotian Shelf (38-48 degree N, 55-72 degree W)

6. **Geographical Referencing:** Latitude/Longitude

7. **Period of Record/Update Frequency:** 1912 to present; updated annually

8. **Format:** ASCII computer files, digital, hard-copy and report

9. **Data Types/Parameters Measured:**
Temperature and salinity

10. **Sampling Procedures:**
Historical data collected from BT's, CTD's, Bottles, bathythermographs, conductivity-temperature-depth (CTD) profilers, batfish

11. **Program Type:**
Research and monitoring

12. **Size/Growth:**
3,685,652 records; 178,209 profiles; 138 Megabytes

13. **Environmental Legislation relevant to this data:** N/A

14. **Computer System:**
CDC Cyber, VAX, Sable Stardent; In-house software

15. **Comments:**
Database is still undergoing quality control. It is hoped that it will be available for outside use on a routine basis within a year or so. In future it is anticipated to be available on-line.

16. **Map indicating areas of data holdings:** 148

1. **Database Title: Organochlorine Contaminant Residues and Transfers from Mother to Young in Seals**

2. **Contact Person:**
Richard Addison
Marine Chemistry Division
Physical and Chemical Sciences Branch
Department of Fisheries and Oceans
PO Box 1006
Dartmouth, Nova Scotia B2Y 4A2
Tel (902) 426-3279; Fax (902) 426-7827

3. **Purpose:**
To examine the degree that body burdens reflect background levels of contaminants and to study extent to which plasma and mammary tissue acts as a barrier to the transfer of contaminants.

4. **Access/Fees/Restrictions:** Through contact person/None/None

5. **Geographical Coverage/Scale:**
Eastern Offshore - Sable Island, Gulf of St. Lawrence, Scotian Shelf, Arctic

6. **Geographical Referencing:** N/A

7. **Period of Record/Update Frequency:** 1972 to present

8. **Format:** Hard-copy files and publications and digital

9. **Data Types/Parameters Measured:**
Chemical, DDT, PCB, Mixed-Function Oxidase - enzyme activity in organs such as liver as a result of contaminant exposure

10. **Sampling Procedures:** Samples collected in the field

11. **Program Type:** Research and monitoring

12. **Size/Growth:** 30 records/site/year

13. **Environmental Legislation relevant to this data:**
Canadian Environmental Protection Act, Fisheries Act

14. **Computer System:** IBM compatible PC, Lotus 123, Cyber Mainframe

15. **Comments:** Confidence in data is high. Contaminant body burdens also related to age and sex of individuals in each species. Research on physiology, energetics and biomechanics of marine mammals and their role in understanding the accumulation, processing, and transfer of contaminants.

16. **Map indicating areas of data holdings:** 150

1. **Database Title: Groundfish Data (GFISH)**

2. **Contact Person:**
Bruce Atkinson, Head
Groundfish Division, Science Branch
Department of Fisheries and Oceans
PO Box 5667
St. John's, Newfoundland A1C 5X1
Tel (709) 772-2052; Fax (709) 772-2156

3. **Purpose:**
Groundfish researchers provide biological advice to national and international fisheries managers on the management of commercially and potentially commercially important species of Newfoundland and Labrador.

4. **Access/Fees/Restrictions:**
Through contact person/N.A./Restrictions as imposed by Science Director, Newfoundland Region

5. **Geographical Coverage/Scale:** Newfoundland and Labrador waters

6. **Geographical Referencing:** Specific to data file

7. **Period of Record/Update Frequency:**
1940 to 1992/Update frequency could be daily, weekly, monthly or yearly as required

8. **Format:** Digital; Hard-copies normally not available

9. **Data Types/Parameters Measured:**
Cod - cohort data; age and growth research data; commercial sample data; length-frequencies; tagging data; length-sex-maturity; inshore catch effort; meristics; morphometrics; otolith/weight data; food/feeding; parasites; surveys; oogenesis; catch/effort by set. Rock Cod - age and growth research data; weight data; length-frequencies; length-sex-maturity; catch/effort by set. Arctic Cod -length-frequencies; length-sex-maturity; catch/effort by set. Haddock - age and growth research and commercial data; meristics; length frequencies; length-sex-maturity; parasite data; weight data; catch/effort by set.
Plaice - age and growth research and commercial data; length frequencies; length-sex-maturity; weight data; morphometrics; meristics; stomach contents; food and feeding; catch/effort by set. Flounder - (yellowtail) age and growth research and commercial data; meristics; length frequencies; length-sex-maturity; food and feeding; catch/effort by set. Flounder - (witch) age and growth research and commercial data; meristics; length frequencies; length-sex-maturity; food and feeding; weight data; catch/effort by set. Turbot - age and growth research and commercial data; meristics; morphometrics; length frequencies; length-sex-maturity; food and feeding; stomach contents; weight data; catch/effort by set. Redfish - age and growth research and commercial data; length frequencies; parasite examinations; length-sex-maturity; food and feeding; meristics; otolith and weight data; body proportions; morphometrics; gas bladder musculature; catch/effort by set. Halibut - age and growth research and commercial data; food and feeding;

catch/effort by set. Hake - length frequencies; length-sex-maturity; catch/effort by set. Lumpfish - length frequencies; length-sex-maturity; tagging; catch/effort by set. Pollock - parasite data; length frequencies; catch/effort by set. Other - grenadier length frequencies; skate length frequencies; wolffish length frequencies; juvenile fish length-sex-maturity data, length frequencies, food and feeding, stomach contents, age and growth research data; oogenesis; foreign observer program.

10. **Sampling Procedures:**
The sampling procedures used are specific to the type of research being conducted. Information on sampling procedures would have to be dealt with individually

11. **Program Type:** Research and surveys

12. **Size/Growth:**
3.36 million records in 234 files; growth specific to file

13. **Environmental Legislation relevant to this data:** N/A

14. **Computer System:** VAX/VMS

15. **Comments:** None

16. **Map indicating areas of data holdings:** 169

1. **Database Title: Canadian Wildlife Service Seabird Colony Registry**

2. **Contact Person:**
Dr. D.N. Nettleship or Dr. J.W. Chardine
Canadian Wildlife Service, Environment Canada
Bedford Institute of Oceanography
PO Box 1006
Dartmouth, Nova Scotia B2Y 4A2
Tel (902) 426-3274

3. **Purpose:**
Database will be used as a tool to manage populations of seabirds in Canada. It will address the need for efficient access to high volume of data on seabird colonies in response to information requirements of environmental emergencies and impact assessment, studies of distribution and abundance, population monitoring, interactions with fisheries, etc.

4. **Access/Fees/Restrictions:** Access: Through contact person; Fees: At this time, no charge; Restrictions: None

5. **Geographical Coverage/Scale:**
Northwest Atlantic Ocean including Atlantic Canada and the Gulf of St. Lawrence, the eastern Canadian Arctic and western Greenland; it is planned to make the SCR a national database and include data on seabird colonies from across Canada.

6. **Geographical Referencing:**

7. **Period of Record/Update Frequency:** Database under development at present (Dec. 1988). Database will eventually hold all historic and contemporary data on seabird colonies and will be continually updated as new data are gathered.

8. **Format:** Digital: Relational, multi-table database. Will be implemented on IBM and Macintosh systems.

9. **Data Types/Parameters Measured:** Census data for seabird colonies; census methodology; physical data on colony location, personal data on observers; bibliographic data

10. **Sampling Procedures:** Will vary depending on source of data. Standard methods have been used for data held by CWS. Database will record census methodology and a data quality code resulting from an assessment of method, census conditions, etc.

11. **Program Type:** Wildlife management, research including survey and monitoring, distribution and abundance.

12. **Size/Growth:**

13. **Environmental Legislation relevant to this data:**

14. **Computer System:** Host computer: IBM-AT; Software: dBASE III+

15. **Comments:** Our long coastline provides breeding habitat for some of the world's largest and most important seabird populations. Furthermore, outside the breeding season, our ocean waters provide abundant food for seabirds from around the world. Seabirds at sea data have been computerized by the CWS, but colony data have not. Upon completion, the Seabird Colony Registry will provide an important management tool in the conservation and protection of breeding seabirds both in the Atlantic Region and in Canada as a whole.

16. **Map indicating areas of data holdings:** 1

1. **Database Title: Coastal Waterfowl Survey**

2. **Contact Person:**
Bruce Johnson/Myrtle Bateman
Canadian Wildlife Service
Environment Canada
PO Box 1590
Sackville, New Brunswick E0A 3C0
Tel (506) 536-3025; Fax (506) 536-3028

3. **Purpose:**
To document bird distribution and abundance in coastal waters; raw data only

4. **Access/Fees/Restrictions:**
Access: Through contact person, Fees: None, Restrictions: None

5. **Geographical Coverage/Scale:**
Nova Scotia, Prince Edward Island, New Brunswick - uneven coverage

6. **Geographical Referencing:**
Numbered survey blocks; no graphics

7. **Period of Record/Update Frequency:**
1966 to present; few surveys flown since 1986
No set survey program

8. **Format:** Digital

9. **Data Types/Parameters Measured:**
Biological: Number of birds, location, time of survey, pre- and post-season counts

10. **Sampling Procedures:** Aerial surveys

11. **Program Type:** Monitoring

12. **Size/Growth:**
Size not changing

13. **Environmental Legislation relevant to this data:**
Migratory Birds Convention Act

14. **Computer System:**
Software: dBASE IV

15. **Comments:**
Database is uneven in coverage; many areas have limited coverage.

16. **Map indicating areas of data holdings:** 29

1. **Database Title: Colonial Birds Inventory in the Maritimes - Atlantic Canada**

2. **Contact Person:**
Bruce Johnson/Randy Hicks
Canadian Wildlife Service
Environment Canada
PO Box 1590
Sackville, New Brunswick E0A 3C0
Tel (506) 536-3025; Fax (506) 536-3028

3. **Purpose:**
To maintain an inventory of bird populations at nesting colonies in the Maritime Provinces

4. **Access/Fees/Restrictions:**
Access: Through contact person
Fees: None
Restrictions: None

5. **Geographical Coverage/Scale:**
Nova Scotia, Prince Edward Island, New Brunswick - primarily coastal areas

6. **Geographical Referencing:**

7. **Period of Record/Update Frequency:**
1960s to present
Updated annually when possible

8. **Format:**
Hard-copy: Binder format on topographic charts

9. **Data Types/Parameters Measured:**
Biological: Number of breeding pairs, location of colonies

10. **Sampling Procedures:**
Ground and aerial surveys and reports from volunteer observers

11. **Program Type:** Surveys

12. **Size/Growth:** Minimal growth

13. **Environmental Legislation relevant to this data:** Migratory Birds Convention Act

14. **Computer System:**

15. **Comments:**
Data available in summary form on sheets organized by mapsheet number of the National Topographic System.

16. **Map indicating areas of data holdings:** 29

1. **Database Title: Environmental Contaminants in Seabirds**

2. **Contact Person:**
Dan Busby
Canadian Wildlife Service
Environment Canada
PO Box 1590
Sackville, New Brunswick E0A 3C0
Tel (506) 536-3025; Fax (506) 536-3028

3. **Purpose:**
To monitor trends in contaminant concentrations in seabirds and to determine threats to the health of seabirds

4. **Access/Fees/Restrictions:**
Access: Through contact person
Fees: None
Restrictions: Requests screened by originator of the data

5. **Geographical Coverage/Scale:**
Atlantic provinces - seabird colonies in coastal areas and offshore islands; St. Lawrence River, Québec

6. **Geographical Referencing:**

7. **Period of Record/Update Frequency:**
1968 to present, Updated every 4 years

8. **Format:** Digital, Reports

9. **Data Types/Parameters Measured:**
Chemical: DDT, PCB and other organochlorine compounds; some heavy metal data

10. **Sampling Procedures:**
Egg collection from Atlantic Puffin, Leach's Storm-Petrel, Double Crested Cormorant and occasionally Herring Gulls

11. **Program Type:** Monitoring

12. **Size/Growth:**

13. **Environmental Legislation relevant to this data:**

14. **Computer System:**

15. **Comments:** Good indicator of trends in space and time of levels of organic contaminants in the environment

16. **Map indicating areas of data holdings: 30**

1. **Database Title: National Registry of Toxic Chemical Residues**

2. **Contact Person:**
Brian Wakeford
Canadian Wildlife Service
Environment Canada
Ottawa, Ontario K1A 0H7
Tel (819) 997-1410; Fax (819) 953-6612

3. **Purpose:** To maintain an inventory of toxic chemical concentrations in wildlife for officials investigating the effects of environmental contaminants

4. **Access/Fees/Restrictions:** Access: Through contact person; Fees: None; Restrictions: Data "on-hold" for impending publication, need written permission from the originator for release

5. **Geographical Coverage/Scale:** Canada - concentration of toxic chemicals in wildlife samples across Canada including the four Atlantic Provinces

6. **Geographical Referencing:** Latitude/Longitude in degrees and minutes

7. **Period of Record/Update Frequency:** 1963 to present; updated based on production of data and conversion of data to digital format (weeks to months)

8. **Format:** Digital

9. **Data Types/Parameters Measured:** Chemical: Toxic constituents in birds and mammals - parameters include: organochlorine pesticides, PCBs, mercury, lead, cadmium, dioxins

10. **Sampling Procedures:** Standardized according to Canadian Wildlife Service manuals; quality control procedures (blind in-house and standard reference samples)

11. **Program Type:** Research, monitoring and survey

12. **Size/Growth:** 8% annual growth

13. **Environmental Legislation relevant to this data:** Canadian Environmental Protection Act

14. **Computer System:** Host computer: Microcomputer; Operating system: MS DOS; Software: dBASE; under conversion to Informix (Lab Vantage LIMS System)

15. **Comments:** Database is a repository for information on wildlife specimens analyzed for toxic chemicals by the Canadian Wildlife Service; there is data on more than 30,000 specimens representing 327 species. Approximately 1 month should be allowed for delivery of information after request is made.

16. **Map indicating areas of data holdings:** 2

1. **Database Title: NAQUADAT (National Water Quality Data Bank)**

2. **Contact Person:**
Tom Pollock
Water Resources Directorate
Environment Canada
310 Baig Boulevard
Moncton, New Brunswick E1E 1E1
Tel (506) 851-6606; Fax (506) 851-6608

3. **Purpose:**
To maintain an inventory of ambient water quality across Canada

4. **Access/Fees/Restrictions:**
Access: Through contact person
Fees: None
Restrictions: None

5. **Geographical Coverage/Scale:** Canada, including fresh, estuarine and marine waters

6. **Geographical Referencing:** Latitude/Longitude of sampling points

7. **Period of Record/Update Frequency:** 1960 to present; Variable update, but frequent

8. **Format:** Digital; Hard-copy: Annual summary reports

9. **Data Types/Parameters Measured:**
Physical: Flow, water depth
Chemical: Approximately 150 water quality parameters including nutrients, metals, pesticides, and other organic contaminants

10. **Sampling Procedures:** Variable but the majority are grab samples from surface water - some automatic water quality samples and a small number of composite samples

11. **Program Type:** Monitoring with some research and survey data

12. **Size/Growth:**

13. **Environmental Legislation relevant to this data:**

14. **Computer System:** Host computer: CYBER mainframe (Ottawa); Operating system: Software:

15. **Comments:** NAQUADAT is in the process of changing from System 2000 to Oracle. Good source of baseline water quality data; most extensive water quality database in Canada. Several federal and provincial government agencies contribute to NAQUADAT.

16. **Map indicating areas of data holdings:** Not shown

1. **Database Title: Toxic Chemicals Database (NAQUADAT)**

2. **Contact Person:**
Hugh O'Neill
Waters Resources Directorate
Environment Canada
310 Baig Boulevard
Moncton, New Brunswick E1E 1E1
Tel (506) 851-6606; Fax (506) 851-6608

3. **Purpose:** To monitor ambient concentrations of toxic chemicals in water, sediments and fish in the Atlantic Provinces

4. **Access/Fees/Restrictions:** Access: Through contact person
Fees: None
Restrictions: None

5. **Geographical Coverage/Scale:**
Atlantic Provinces - freshwater and estuaries

6. **Geographical Referencing:**
Latitude/Longitude of sampling points

7. **Period of Record/Update Frequency:**
Early 1970s to present
Very few areas resampled, although information for other areas added each year

8. **Format:** Digital

9. **Data Types/Parameters Measured:** Chemical: Biological: Pesticides, PCB, PAH, chlorophenols and other organic contaminants in water, sediments and fish

10. **Sampling Procedures:** Largely grab sampling - hand seine and gill nets are used to catch fish

11. **Program Type:** Monitoring and survey

12. **Size/Growth:**

13. **Environmental Legislation relevant to this data:** Canadian Environmental Protection Act (CEPA); Pest Control Products Act

14. **Computer System:** Host computer: VAX 750; Operating system: Software: RS1, Oracle

15. **Comments:** Interpretive data are available through a report series; although much of this data is on NAQUADAT, this system is easier to access.

16. **Map indicating areas of data holdings:** 3

1. **Database Title: Atlantic Canada Water Quality Monitoring Program for Mussel Growers**

2. **Contact Person:**
Mike Brylinsky
Acadia Centre for Estuarine Research
Acadia University
Wolfville, Nova Scotia B0P 1X0
Tel (902) 542-2201; Fax (902) 542-3466

3. **Purpose:**
To assess water quality at mussel aquaculture sites across the region, and to relate water quality to mussel settlement, growth and survival

4. **Access/Fees/Restrictions:**
Access: Through contact person and project sponsors
Fees: None
Restrictions: None

5. **Geographical Coverage/Scale:**
Atlantic Provinces - coastal and estuarine water throughout the region

6. **Geographical Referencing:**

7. **Period of Record/Update Frequency:** October 1987 to present
Updated continuously

8. **Format:** Digital

9. **Data Types/Parameters Measured:**
Physical: Stability of stratification
Chemical: Temperature, salinity, secchi depth, suspended particulate matter, particulate organic carbon
Biological: Chlorophyll, mussel growth and size, spatfall times and densities, gonad weights, glycogen contents

10. **Sampling Procedures:** Bi-weekly sampling by mussel growers according to standardized methods

11. **Program Type:** Research and monitoring

12. **Size/Growth:**

13. **Environmental Legislation relevant to this data:**

14. **Computer System:** Host computer: CYBER 180; Operating system:;Software: Fortran

16. **Map indicating areas of data holdings:** None

1. **Database Title: Fisheries Statistics of the Northwest Atlantic**

2. **Contact Person:**
Tissa Amaratunga
Assistant Executive Secretary
Northwest Atlantic Fisheries Organization (NAFO)
PO Box 638
Dartmouth, Nova Scotia B2Y 3Y9
Tel (902) 469-9105; Fax (902) 469-5729
Telex 019-31475

3. **Purpose:**
Optimum utilization, rational management and conservation of the fishery resources

4. **Access/Fees/Restrictions:**
Access: Through contracting party to the NAFO Convention
Fees: None
Restrictions: Subject to Convention and/or approval by the NAFO governing bodies

5. **Geographical Coverage/Scale:** Northwest Atlantic

6. **Geographical Referencing:** Statistical areas/Latitudes/Longitudes

7. **Period of Record/Update Frequency:** Ongoing and computer updated since 1960; some earlier data in hard-copy

8. **Format:** Digital: Reports; Hard-copy: Reports

9. **Data Types/Parameters Measured:**
Fishery statistics: catch and effort data in ranging degrees of detail
Biological data by fish species: inventory
Oceanographic data: inventory
Fishing vessel: listing

10. **Sampling Procedures:** National report submissions

11. **Program Type:** Data management and stock assessments

12. **Size/Growth:** About 17,500 records consistently Monthly and annual reports; bulletins published on an annual basis

13. **Environmental Legislation relevant to this data:** N/A

14. **Computer System:** Host computer: IBM PC; Operating System: MS DOS; Software: dBASE III

16. **Map indicating areas of data holdings:** 25

1. **Database Title:** Environmental Monitoring Program, Phytoplankton, Physical and Chemical Oceanography

2. **Contact Person:**
Jennifer Martin, Biologist and David J. Wildish, Research Scientist
Aquaculture and Invertebrate Fisheries Division
Biological Sciences Branch
Department of Fisheries and Oceans
PO Box 210
St. Andrews, New Brunswick E0G 2X0
Tel (506) 529-8854; Fax (506) 529-4274

3. **Purpose:**
To advise and provide an early warning to the aquaculture industry, to monitor impacts of salmonid aquaculture

4. **Access/Fees/Restrictions:**
Through contact person/No charge

5. **Geographical Coverage/Scale:**
Southwestern Bay of Fundy

6. **Geographical Referencing:** N/A

7. **Period of Record/Update Frequency:** 1987 to present; on-going update

8. **Format:** Hard-copy: technical report

9. **Data Types/Parameters Measured:**
Phytoplankton distribution and abundance, salinity, temperature, dissolved oxygen, chlorophyll a, nutrients

10. **Sampling Procedures:** On-site sampling

11. **Program Type:** Monitoring and research

12. **Size/Growth:** N/A

13. **Environmental Legislation relevant to this data:** N/A

14. **Computer System:**
Host computer: VAX 6210, IBM compatible PC
Operating system: VMS
In-house software: Foxpro, Quattro Pro

15. **Comments:**

16. **Map indicating areas of data holdings:** 75

APPENDIX C: Pacific Coast Databases of Relevance to the MEQ monitoring network.

MARINE MONITORING PROGRAMS- PACIFIC REGION

ENVIRONMENT CANADA- ENVIRONMENTAL PROTECTION

PROGRAM TITLE: SHELLFISH AND AQUACULTURE

PROGRAM HEAD: HAL NELSON

ADDRESS: 224 West Esplanade
North Vancouver,
B.C. V7M 3H7
TEL: 604 - 666-2947
FAX: 604 - 666-9107

ASSOCIATED MARINE MONITORING PROJECTS:

PR-033 Shellfish Growing Area Survey- Field programs

Pursuant to the requirements of the national shellfish sanitation program and the U.S. - Canada bilateral agreement, conduct and report on certification surveys of commercially harvested bivalve molluscan shellfish growing areas to determine their sanitary quality. Provide classification recommednations to DFO for closure/opening action. Conduct annual "key station" monitoring at approxiamately 800 sites. Conduct tissue sampling in support of national "Contaminants in Shellfish" sampling program.

PR-035 Aquaculture and Microbiology Operations

Provide advice on finfish aquaculture referrals and recommend/implement monitoring programs to assess the impact on federally managed resources. Provide microbiological analytical services and expertise in support of regional, national and international programs. Maintain and update QA/QC programs for the laboratory , including methodology development.

PR-063 Shoreline Programs: Comprehensive Sanitary Surveys

The shoreline component of the sanitary survey are conducted pursuant to the National Shellfish Sanitation Program and the Canada-U.S. bilateral agreement. This project includes 10 comprehensive surveys, 2 detailed studies and 1 special study to identify and evaluate actual and potential pollution sources to shellfish harvesting and growing waters in the interest of protecting public health.

STATION LOCATIONS AND SURVEY HISTORY ARE ATTACHED

MARINE MONITORING PROGRAMS - PACIFIC REGION

ENVIRONMENT CANADA - ENVIRONMENTAL PROTECTION

PROGRAM TITLE: OCEAN DUMPSITE MONITORING

PROGRAM HEAD: DIXIE SULLIVAN ADDRESS: 224 West Esplanade
North Vancouver, B.C.
V7M 3H7
TEL: 604 - 666-2730
FAX: 604 - 666-7294

PROGRAM OBJECTIVES:

Dumpsite monitoring is an integral part of managing waste disposal activities in the marine environment. The objectives are to ensure compliance with CEPA, to verify predictions of dumpsite conditions after disposal, and to provide data to the public and regulatory agencies to assess environmental impact. The Ocean Dumping Control Action Plan is a Green PLan initiative which requires disposal site monitoring.

In the Pacific and Yukon Region, major ocean dumpsites are designated by the Regional Ocean Dumping Advisory Committee (RODAC). At each dumpsite, a grid of sediment stations was established to allow repeat surveys. Since 1987, 17 dumpsites have been monitored for sediment metal chemistry.

In 1989, as a result of a program evaluation, it was recommended that a policy as well as quidelines and procedures for monitoring ocean dumpsites be developed. It was recommended that a minimum level of monitoring be required at disposal sites where dumping of substances of concern has occurred.

National dumpsite monitoring quidelines are being developed.

BASELINE STUDIES AND RESEARCH

A survey of benthic sediment metal chemistry was conducted on the west coast in B.C. between Jervis Inlet and Prince Rupert in 1987-1988. The study was designed to examine background concentrations of trace metals in locations removed from anthopogenic inputs. Grab and core samples were collected in 37 inlets and analysed for mercury (Hg), cadmium (Cd), lead (Pb), copper (Cu) and zinc (Zn). Cadmium was detected at levels that exceeded Ocean Dumping criteria for ocean disposal at depths from 0-100cm at numerous locations in the survey area.

The National Ocean Dumping Control Act Research Fund (ODCARF), created in 1976 to promote and support directed research studies on a broad range of ocean disposal subjects, was discontinued in 1989. Green Plan funding presently supports applied research on ocean disposal issues.

A program evaluation was conducted in 1989 and the executive summary of that evaluation is available upon request.

PROGRAM INFORMATION:

Attached are the following figures and tables:

1. FIGURE 1 - Vancouver Island and B.C. South Coast - Active Dumpsites
2. FIGURE 2 - Fraser River Dumpsites
3. FIGURE 3 - Point Grey Ocean Disposal Site Benthic Stations
4. TABLE 1 - Pacific and Yukon Active Ocean Dumpsite
5. TABLE 2 - Benthic Sediment Chemistry Surveys Since 1980 For Pacific Coast Dumpsites
6. TABLE 4 - Point Grey Dumpsite Study Summary 1975-1989
7. TABLE 5 - Point Grey Dumpsite Stations Sampled 1975-1989

1993-1994 Monitoring Program:

MARINE MONITORING PROGRAMS - PACIFIC REGION

ENVIRONMENT CANADA - CANADIAN WILDLIFE SERVICE

PROGRAM TITLE: STRAIT OF GEORGIA - TOXIC CHEMICALS MONITORING

PROGRAM HEAD: JOHN ELLIOT/ PHIL WHITEHEAD

ADDRESS: P.O. BOX 340
DELTA, B.C. V4K 3Y3
TEL: 604 - 946-8546
FAX: 604 - 946-7022

ASSOCIATED MARINE MONITORING PROJECTS:

The CWS toxic chemical monitoring program in the Strait of Georgia has two main components:

1. SEABIRD MONITORING -The first is part of a long term monitoring project which focuses on eggs and involves other seabird species and locations along the west coast. In the Strait, are collected Double-crested and Pelagic cormorants from Mandarte Island (48 38N 123 17W) every four years dating from 1973. The next sample time will be 1993. Collected are 15 eggs whcih are analyzed as pools of 3 eggs each to reduce vaviance. These egg samples are routinely analyzed for a variety of persistent OC pesticides (DDE, dieldrin, mirex,HCH,HCB, etc.) and for PCBs (41 congeners). PCDD,PCDF and non-ortho PCBs have been done on some samples and will likely be routine for the forseeable future.

2. STRAIT OF GEORGIA MONITORING - This project began by using Great Blue Herons to monitor the Fraser River estuary in 1977. Generally 10 eggs are collected and analyzed individually or as a pool of 10. The project grew with the pulp mill dioxin issue and now includes herons and Double-crested cormorants. A number of colonies of each species around the Strait of Georgia have now been located and identified. The present protocol involves annual egg collections from a core set of colonies each year. For each species, each year all but one of the colonies are analyzed as a pooled sample (one pool of 10 eggs), while one colony receives individual analyses each year (N=10). The colony receiving individual analyses changes on a rotational schedule. The eggs are analyzed for OCS, PCBs, PCDDs, PCDFs.

In addition, for 1988, 1990, 1991 and 1992, incorporated are bioeffects monitoring into the project by collecting paired eggs from that years special colony. One of the pair is incubated,sacrificed at hatching and assayed for MFO activity and other morphological and biochemical markers of exposure and effects.

MARINE MONITORING PROGRAMS - PACIFIC REGION

ENVIRONMENT CANADA - CANADIAN WILDLIFE SERVICE

PROGRAM TITLE: COASTAL ECOSYSTEM MONITORING

PROGRAM HEAD: R.W. ELNER ADDRESS: P.O. BOX 340
DELTA, B.C. V4K 3Y3
TEL: 604 - 946-8546
FAX: 604 - 946-7022

ASSOCIATED MARINE MONITORING PROJECTS:

The mandate of Canadian Wildlife Service, to conserve and manage habitat as well as target wildlife species, necessitates a quantitative appreciation of ecosystem function. Although ecological understanding is a fundamental to wildlife management decisions, present ability to predict the outcome of such decisions is poor. Achievement of an improved predictive ability has been hindered, in part, by paucity of reliable long term data series on wildlife populations and physical environmental variables. Recently, Ecosystems Research Division has started programs to model key wildlife populations and predict their responses to habitat perturbations, including climatic change. Programs involve a multi-disciplinary approach utilizing a combination of monitoring and experimental techniques to sequentially test hypotheses and advance knowledge through strong inference. Resources are being optimized by working, where possible, in collaboration with other agencies. The initial focus is on coastal ecosystems and migratory shorebirds.

There is a critical need for long-term monitoring sites in representative coastal habitats to gather physical (oceanographic and meteorological) and biological data (spatial distribution, size and abundacnce of plants, invertebrate species and population parameters of shorebirds themselves). Analyses of the resultant data series should help identify factors affecting recruitment and survival of shorebirds and provide the quantitative natural history information necessary for formulating testable hypotheses. Such a baseline is particularly important to track the impact of global climate changes.

The following coastal habitat/shorebird monitoring sites have been established in cooperation with DFO (other cooperative monitoring initiatives are being instigated in southern (Mexico) and northern (Alaska) aspects of the migratory range):

1. Boundary Bay
2. Brunswick Point
3. Westham Island

Other coastal monitoring sites are also being established cooperatively with DFO on Vancouuver Island:

soft-bottom	1. Meares Island 2. Baines Sound	hard-bottom	1. Sydney Is. 2. Drumbeg

Opportunities for Networking:

Establishment of statistically sound sampling protocols and standardized techniques/equipment for routine monitoring of soft and hard bottom coastal sites.

Establishment of core expertise/teams for collecting, processing and identifying invertebrates in field samples and stomach contents.

ENVIRONMENT CANADA - ENVIRONMENTAL PROTECTION

PROGRAM TITLE: TOXIC ASSESSMENTS

PROGRAM HEAD: CHRIS GARRETT
ADDRESS: 224 West Esplanade
North Vancouver, B.C.
TEL:
FAX:

1992-1994 projects:

Time has been scheduled on Fisheries research vessel for September of 1993 for sampling in Vancouver Harbour and in Victoria/Esquimalt Harbours. However, our field programs are not definite due to refocusing of priorities and responsibilites within the CCB. The shift is towards evaluation of PSL 2 chemicals. Since the PSL 2 list is still being developed in Ottawa it is hard to know whether this evaluation will involve field programs.

1992-1993 projects:

1.) Title: Levels of chemical contaminants in B.C. harbours

Objective: To determine levels of regional priority chemicals in sediments and biota in B.C. harbours

Output: Samples of sediments and several species of biota (invertebrates and fish) have been collected from Vancouver, Victoria and Esquimalt Harbours between 1988 and 1992. Samples have been analyzed for chlorophenols, chlorinated anisoles, PCBs (Arochlors and congener specific), organotins, phthalate esters, PAHs, organochlorine pesticides and metals. Select samples have been analyzed for chlorinated paraffins and chlorinated diphenyls ethers. In addition, liver samples have been collected from flatfish from select areas for histopathological examination and for MFO analysis. Gallbladders from flatfish were also removed for analysis of PAH metabolites in bile. Results are currently being compiled and evaluated. Some data is still outstanding.

Uses: The data is being used to support the national PSL program. Information on PSL 1 chemicals has been supplied to Task Force leaders. Information on chlorinated diphenyl ethers will be assessed to determine whether these chemicals are good candidates for the PSL 2 list currently being compiled. Studies in Victoria and Esquimalt Harbour were being conducted in consultation with Capital Regional District, Coast Guard, Royal Roads Military College, and the Department of National Defense. Some funds were supplied by DND for the Esquimalt study. Information generated by programs initiated by ourselves and the above agencies will be shared once programs are complete. The data generated in this study will be provided to CWS to support their assessment of contaminant levels in seabirds overwintering in harbours. Data will also be provided to DFO to support there efforts to obtain information on chemicals in commercially important species.

Reports: The data will be published in an Environmental Protection regional report.

Database: The data will be entered on DBase IV in 93/94

2.) Title: Levels of chemical contaminants in the vicinity of B.C. marinas and shipbuilding/repair facilities

Objective: To determine environmental levels of organotins and other priority chemicals in the vicinity of southern coastal marinas and shipbuilding/repair facilities in B.C.

Output: Samples of water, sediment, and mussels were collected from marinas and off shipbuilding/repair facilities in southern coastal B.C. between 1987 and 1991. In addition, other species of biota were obtained in the vicinity of some shipbuilding and repair facilities. Samples have been analyzed for chlorophenols, chlorinated anisoles, PCBs (Arochlors and congeners), organotins (butyltins, phenyltins, cyclohexyltins), phthalate esters, PAHs, organochlorine pesticides and metals. Select samples have been analyzed for chlorinated paraffins and chlorinated diphenyl ethers. Results are currently being compiled and assessed. Some analyses are still outstanding.

Uses: The data is being used to support the national PSL program. Information on PSL 1 chemicals has been supplied to Task Force leaders. Information on chlorinated diphenyl ethers will be assessed to determine whether these chemicals are good candidates for the PSL 2 list currently being compiled.

Organotin data obtained during the early part of this study was used to support the development of regulations by AgCan to restrict the use of butyltins in marine paints used in Canada. The organotin data will also be used to evaluate levels of butyltins in the vicinity of recreational and commercial vessel moorings. The information will be used to evaluate the effectiveness of legislation introduced by AgCan in 1989 to limit the use of butyltins in marine paints in Canada.

The data will be provided to CWS in support of their evaluation of contaminants levels in seabirds.

The data will also be of assistance in the revision of the draft code of good practice for the shipbuilding/repair industry.

Reports: The data will be published in an Environmental Protection regional report.

Database: The data will be entered on dBASE IV in 93/94

Historical:

1.) Between 1987 and 1991 a substantial amount of information on PCB levels in biota and sediments from coastal locations in B.C. was generated. This data is currently being compiled into a data report. The report will be in draft form within the next one to two months and the data will be entered on dBASE IV later in 93/94.

2.) Between 1987 and 1991 a substantial amount of information on metals levels in biota and sediments from coastal locations in B.C. was generated. This data will be entered on dBASE IV later in 93/94. A regional data report will be prepared in late 93/94 or in 94/95.

3.) Between 1987 and 1991 a substantial amount of information on chlorophenol levels in biota and sediments from coastal locations in B.C. was generated. This data will be entered on dBASE IV later in 93/94. A regional data report will be prepared in late 93/94 or in 94/95.

4.) A regional data report on PAH levels in the B.C. environment will be prepared late in 1993/94. The data will be entered on dBASE IV.

5.) In 1987 and 1988 select salmon farms in B.C. were sampled to determine levels of organotins in the vicinity of salmon farms using TBT-treated net pens. Samples of farmed salmon, sediment, water, rockfish, and shellfish were collected and analyzed for butyltins (and other contaminants). This information was supplied to AgCan and Environment Canada in Ottawa and was used to support the ban on the use of TBT at aquaculture sites. Wild salmon were obtained and analyzed for organotins and other contaminants for comparison. The results of this study will be published in a regional report in 93/94 or 94/95. The data will be entered onto dBASE IV in 93/94.

6.) In 1991 juvenile starry flounder and sediment samples were collected off wood preservation sites on the lower Fraser River. The objective was to determine the presence of PAHs in the environment as a result of creosote use at these facilities. Samples were also analyzed for PCBs, chlorophenols, and metals. In addition, livers were taken from the fish for histopathological examination and MFO analysis. Gall bladders were removed for the analysis of PAH metabolites in bile. The results of this study will be published in a regional report in 93/94 or 94/95. The data will be entered onto dBASE IV in 93/94.

MARINE MONITORING PROGRAMS - PACIFIC REGION

ENVIRONMENT CANADA - ENVIRONMENTAL PROTECTION

PROGRAM TITLE - VANCOUVER HARBOUR (BIEAP)

PROGRAM HEAD: JANICE BOYD

ADDRESS: 224 West Esplanade
North Vancouver, B.C.
V7M 3H7
TEL:
FAX:

HISTORY:

- Following a review of existing environmental information on Vancouver Harbour (Waters 1985, 1986) studies began in May 1985 to determine the distribution of specific organic and inorganic contaminants, potential industrial and urban sources, health of the benthic environment, and need for remedial measures.

- May 1985 to October 1987: 8 field surveys sampled 88 stations for surface sediment and 11 trawl stations for biota. Sediment parameters included particle size, sediment volatile residue (SVR), several trace metals, oils & grease, hydrocarbons, polychlorinated biphenyls (PCB), chlorophenols (CP), and polycyclic aromatic hydrocarbons (PAH). Biological parameters included relative abundance, tissue trace metal and PAH levels in benthic species including sole, crab and shrimp, idiopathic liver lesions in flatfish, and length/weight of English sole. Trend assessment possible for 36 of the 88 stations i.e. parameters monitored 2-6 times. Remaining stations provide spatial information. Data reported in Goyette and Thomas (1987), Goyette et al. (1988), and Goyette and Boyd (1989).

- October 1988: 10 surface sediment stations revisited; 4 new stations added. Sediment cores collected 7 of the 10 old stations. Trawling occurred at 5 old stations. Sediment parameters as above, excluding particle size. A few samples analyzed for PAH. Trawl parameters inluded relative abundance and English sole length/weight measurements. Some data reported in text of Goyette and Boyd (1989). Remainder to be reported in 1993-94.

- November 1989: 20 stations selected from past surveys to evaluate the Sediment Quality Triad approach to environmental impact assessment using multivariate statistics (Cross et al., In Press). Sediment toxicity, sediment chemistry and benthic community structure formed the components of the triad. Sediment toxicity tests included amphipod (Rhepoxynius) survival, avoidance and reburial; Neanthes growth and survival, echinoderm larvae, fish cell cytoxicity/genotoxicity, and clam reburial (EVS Consultants, 1990). Sediment chemistry parameters as above excluding PAH (Boyd and Goyette, in prep) and benthic community structure (Cross and Brinkhurst 1990).

- January 1991: Surface sediment sampling for (18 sites) polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzo furans (PCDF) and PAH levels (24 sites); 6 sites from previous surveys (Boyd and Goyette, in prep). PCDD and PCDF data reported in News Release May 1, 1992.

BURRARD INLET ENVIRONMENTAL ACTION PROGRAM (BIEAP)

- On June 21, 1991, the federal departments of Environment (DOE) and Fisheries and Oceans (DFO), the provincial B.C. Ministry of Environment (MOE), Greater Vancouver Sewerage and Drainage District (GVS&DD) and Vancouver Port Corporation (VPC) initiated the Burrard Inlet Environmental Action Program (BIEAP) with the signing of the "Agreement Respecting an Environmental Action Program for Burrard Inlet."

- Purpose of the Agreement: to establish a management framework to facilitate the coordination of activities intended to protect and improve the Environmental Quality. Primary objectives of BIEAP: reduce existing contaminant discharges to Burrard Inlet, control future discharges to limit the potential for future impacts, control habitat degradation, and provide, where appropriate, remedial measures for existing impacts.

- BIEAP is a 5 year program (1991-1996). DOE, DFO, MOE, GVS&DD and VPC each contribute $80k per year to support the primary objectives. The federal portion of the Agreement is funded under Green Plan through FRAP.

- Each partner in BIEAP undertakes some environmental monitoring in Burrard Inlet; a coordinated program is being built on what exists. For example, GVRD conducts ongoing water quality monitoring as required under their permits to discharge municipal effluent; B.C. Environment conducts ongoing Water Quality Objectives and impact assessment monitoring with respect to the industrial and municipal discharges they permit. DOE and DFO measure various contaminant and biological response parameters in support of ambient quality monitoring. VPC provides the GIS and database support for management of the environmental data.

- September 1991 to November 1992: Environment Canada and B.C. Environment proposed a 2-year study to assess biological responses of benthic fish exposed to urban and industrial discharges. Three biochemical indices: prevalence of idiopathic liver lesions, aromatic hydrocarbon (AH) metabolites in bile, and mixed function oxygenase - ethoxyresorufin-o-deethylase (MFO-EROD) activity in liver of English sole compared to sediment contaminant levels. Sediment parameters as per above including PAH, PCDD and PCDF.

  Environment Canada initiated the study in September 1991. In year one, B.C. Environment provided funding for the MFO analyses. BIEAP funded the MFO and liver lesions analyses in the second year. The results will be reported in the 1993-94 fiscal year and used to support the recommended monitoring program.

1993-94 WORK PLANS RELATED TO MONITORING:

MAIN OBJECTIVE: To develop a coordinated and focussed monitoring program to measure environmental quality changes in the Inlet following remedial actions.

OUTPUTS: Complete outstanding data reports idenified above (DOE).

Produce database containing all Vancouver Harbour environmental data from above studies using DBASEIV or FOXPRO (DOE).

Integrated monitoring program based on existing knowledge and programs of all BIEAP partners (BIEAP).

REFERENCES:

Boyd, J.M. and D.E. Goyette. In Prep. Development and Application of a Sediment Quality Triad Approach to Determine Pollution-Induced Environmental Degradation. Phase 2: Sediment Chemistry. Environment Canada, Environmental Protection, Regional Data Report DR90-11.

Boyd, J. and D. Goyette. In Prep. Polycyclic Aromatic Hydrocarbon (PAH) and Dioxin/Furan Concentrations in Vancouver Harbour Sediments, January 1991. Environment Canada, Environmental Protection, Regional Data Report DR91-07.

Cross, S.F. and R.O. Brinkhurst. 1991. Spatial Distribution of Macrobenthic Infauna in Burrard Inlet: November 1989. Fisheries and Oceans, Canadian Data Report of Hydrography and Ocean Sciences No. 92. 35 pp.

Cross, S.F., J.M. Boyd, P.M. Chapman, and R.O. Brinkhurst. Submitted. A multivariate approach to assessing the spatial extent of benthic impacts established using the sediment quality triad. Archiv. Environm. Contam. Toxicol.

E.V.S. Consultants. 1990. Development and Application of a Sediment Quality Triad Approach to Determine Pollution-Induced Environmental Degradation. Phase 1: Sediment Toxicity Testing. Environment Canada, Environmental Protection, Regional Manuscript Report MS91-01. 22 pp. + appendices.

Goyette, D. and J. Boyd. 1989. Distribution and Environmental Impact of Selected Benthic Contaminants in Vancouver Harbour, B.C. 1985 to 1987. Environment Canada, Environmental Protection, Pacific and Yukon Region. Regional Program Report 89-02. 99 pp. + appendices (separate volume, inludes 7 data reports).

Goyette, D. and M. Thomas. 1987. Vancouver Harbour Benthic Environmental Quality Studies May 1985 to September 1986. Relative Species Abundance and Distribution - Trawl Catch. Environment Canada, Environmental Protection, Pacific and Yukon Region. Regional Data Report DR 87-03. 63 pp.

Goyette, D., D.Brand, and M. Thomas. 1988. Prevalence of Idiopathic Liver Lesions in Engish Sole and Epidermal Abnormalities in Flatfish from Vancouver Harbour, B.C. 1986. Environment Canada, Environmental Protection, Pacific and Yukon Region. Regional Program Report 87-09. 48 pp.

MARINE MONITORING PROGRAMS - PACIFIC REGION

FISHERIES AND OCEANS CANADA

PACIFIC BIOLOGICAL STATION - NANAIMO

PROGRAM TITLE: LA PEROUSE PROJECT

PROGRAM HEAD: D.M. WARE

ADDRESS: PBS
NANAIMO, B.C.
V9R 5K6
TEL: 604 - 756-7199
FAX: 604 - 756 7053

The La Perouse/MASS Project is a multi-disciplinary, multi-species investigation conducted by the Pacific Biological Station and the Institute of Ocean Sciences in support of long-term management of the major fish stocks off the west coast of Vancouver Island. Initiated in 1985 following the major 1982/1983 El Nino event in the Pacific Ocean, the primary focus of the La/Perouse/Mass program has been directed toward describing and understanding the causes of annual and interannual variability of the fish and zooplankton stocks over La Perouse Bank on the southwest portion of the Vancouver Island shelf.

The principal objectives of the La Perouse/MASS project are:

-To determine the key physical and biological factors that affect commercial fish population distributions, abundance and natural mortality rates;

-To determine the dominant predatory-prey relationships in this productive upwelling system and to use measurements of spatial and temporal distributions of predator and prey stocks to model the principal interactions in the system;

-To use the emerging scientific results from the program to develop and verify sophisticated bio-physical models that can be used as operational tools in the long-term planning and management of the multi-species fisheries off the west coast of Vancouver Island.

The three main component of the program are:

1. The Physical Oceanography Program - headed by Rick Thomson

2. The Biological Oceanography Program - headed by Dave Mackas

3. The Fisheries Oceanography Program - headed by Dan Ware and Sandy McFarlane.

.. refer to La Perouse Project Annual Progress Reports

MARINE MONITORING PROGRAMS - PACIFIC REGION

FISHERIES AND OCEANS CANADA

INSTITUTE OF OCEAN SCIENCES

PROGRAM TITLE: SEA SURFACE TEMPERATURE & SALINITY

PROGRAM HEAD: DR. HOWARD FREELAND

Lighthouse Sea Surface Temperature(SST) and Salinity data sets phoned daily.
Longest record: Departure Bay, since 1912; Race Rocks, 1926. Most others since 1934-36. These are among the best, high-quality, long term data sets available in the world to answer questions and validate models on effects of global climate change. It is crucial that they be maintained.

Monthly reports are in the West Coast Fisherman. Automation of the lighthouses and weather stations destroys continuity of these tremendously important data sets. When the Amphitrite Point lighthouse was automated IOS hired a local contractor to continue the SST/Salinity sampling. An AES weather station at Cape St. James, currently manned (3 people), will be closed Sept. '92. Unlesss some provisions can be made these data sets will be lost, and it is the only one for a large and critical portion of the coast.

MINUTES

FEDERAL MARINE ENVIRONMENTAL QUALITY MONITORING

IN THE PACIFIC REGION

June 9, 1992

<u>Present</u>:

Bob Wilson	DFO(IOS) (Chair)
Hal Nelson	DOE(EP)
Howard Freeland	DFO(IOS)
Rob Waters	DOE(Consultant)
Lee Harding	DOE(IW)
Loyd Snowdon	EM&R(Inst. Sed. & Petrol. Geol., Calgary)
Ian Moul	DOE(CWS)
John Elliott	DOE(CWS)
Bob Elner	DOE(CWS)
Robin Brown	DFO(IOS)
Glen Jamieson	DFO(PBS)
Mel Best	EM&R(PGC)
Julie Shrimpton	DOE(EP)
Janice Boyd	DOE(EP)
Fred Stephenson	DFO(CHS)
Duane Brothers	DOE(EP)
Norman Crewe	DFO(IOS)
Jeff Fargo	DFO(PBS)
Dan Ware	DFO(PBS)
Don Noakes	DFO(PBS)
Bill Shaw	DFO(PBS)
Ian Williams	DFO(PBS)

<u>Purpose</u>:
The purposes of the meeting were to (1) prepare an initial inventory of long term federal monitoring programs as a preliminary step in developing a regional integrated monitoring network for the marine environment, and (2) explore opportunities for collaboration, including funding for new, long term monitoring.

<u>Inventory of Federal Programs</u>:

Howard Freeland
-Lighthouse Sea Surface Temperature (SST) and salinity data set phoned daily
-Longest record: Departure Bay, since 1912; Race Rocks, 1926. Most others since 1934-36-These are among the best, high-quality, long term data sets available in the world to answer questions and validate models on effects of global climate change. It is

crucial that they be maintained.
-Monthly Report in West Coast Fisherman
-concern: It's unfortunate that no one from AES was invited. Automation of the lighthouses and weather stations destroys continuity of these tremendously important data sets. When the Amphitrite Point lighthouse was automated IOS hired a local contractor to continue the SST/Salinity sampling. An AES weather station at Cape St. James, currently manned (3 people), will be closed in September '92. Unless some provision can be made to sampling of SST/Salinity, this data set will be lost, and it is the only one for a large and critical portion of the coast (see map in handout). One solution would be to have AES construct a structure from which an automated sampler can be deployed.
ACTION: Lee to contact AES to see what can be done.

Robin Brown
-Oceanographic data (CTD) since 1956 at Ocean Station P ("Papa") and transect (see map) by ship. Since 1981, 4-5 cruises/year. Will be continued for at least the next 5 years.
-Weather station buoy observations: SST, air temp., wind speed and direction, wave height and direction. Ties into US network; stations well placed. Highly reliable instruments.
-Shore-based weather stations operated by AES. IOS manages (analyses, interprets, archives) data, CCG services stations. Most in place since 1986; one since 1976.

Fred Sepheneson
-Tide stations, 40 year time series. There are 14 stations on the south coast, 3 on north coast. Data in hourly heights. DOE(IW) operates stations; IOS provides funds for construction and data management/interpretation. Data have to be interpreted in terms of crustal motion, also monitored (see PGC program below).

Mel Best
-4 Global Positioning System (GPS) tracker stations for long term interferometry network. Measures absolute motions between different points to monitor vertical and horizontal crustal motions. Also setting up an offshore program using acoustic transponders on the seafloor to measure relative plate motion. Perhaps Geodetic Survey should have been to this meeting.
-Earthquake monitoring since 1890s, more accurately since 1940s.
-Sediments often collected and archived; not always analyzed, but have been useful for environmental work, for example, the long term geochemical database in Halifax Harbour. Samples archived for Fraser delta, Howe Sound. Some are dried out, some frozen. Map of stations available. Lack of fixed stations prevents time series analyses, but cores can provide historical record.
-Ocean Drilling Program (ODP) measures temperature and pressure versus time down holes for geological analysis. Location of samples and GPS stations are available on request.

Loyd Snowdon
-2 billion year time series, in down to 1 million year

increments. Sediments are analyzed for anthropogenic and petrogenic hydrocarbons.
-Example of study: measurement of plume from Creosote injected into a drilled hole in Ontario to monitor plume movement and degradation.
-Has lab capability; would like to get a baseline of HC data for BC.
-Can use ^{137}Ce to data cores in recent sediments. Inorganic lab: ICP mass spec/laser ablation system for parts per trillion measurements (Dave Buckley).

Dan Ware (see handout)
-La Perouse Banks - 5 current moorings, each monitoring a discrete water mass
-CTD grid off Barkley Sound since 1985. 6/year every two months depending on ship time. Data have been tremendously useful for assessing water characteristics in relation to survival of salmon. A1 and C1 are longest time series current meter moorings in waters off B.C.. CTD data goes into World Data Bank and into scientific literature.
-La Perouse biological studies: This is the most biologically productive marine region on the west coast of North America. Seasonal variability is now well known and they are starting to examine inter-annual variability. There is a 8 year record of trophic structures, including trophic relationships of herring, salmon, dogfish and hake. Data include lengths, weights, diets, etc.. Sampling is done at least once per year, 2-3 times in some years.

Norm Crew (for Hal Rogers)
-organochlorine data for salmon and other organisms in Georgia Strait, Fraser River by GCMS. Derek Muir also doing dioxins and co-planar PCBs in marine mammals. Plans to survey pulp mill sites and analyze for history of contamination. Extracts are archived after analysis, and are available for further work.
-A Green Plan initiative to begin monitoring contaminants in fish has been approved, including a tissue bank and a data management system.
-L. Harding also mentioned that the results of industry sampling of sediments and tissues for dioxins & furans at closed fishing areas are available in dBASE/QuikMap format. New data from ongoing monitoring are added regularly.

Hal Nelson
-Shellfish Growing Water Quality bacteriological monitoring pursuant to 1948 Bilateral Agreement with US since 1972 at 2400 marine stations and 1000 freshwater stations. 8,000 fecal coliform and salinity analyses/year, mostly on east side of Vancouver Island (Baynes Sound area). Each growing area is surveyed a minimum of once every 3 years; random key stations are sampled annually at each approved growing area. Remote areas, where sampling is less frequent, are being added to network:

Bella Bella area in 1991 and 1992 and possibly Prince Rupert area south to Bella Bella in 1993 and Queen Charlotte Islands in 1994.
-Some sediments and shellstock (tissues) also analyzed for organic/inorganic contaminants.
-Planned "Mussel Watch" monitoring for contaminants in shellfish. Pilot study on East Coast, workshop in a few months.
-PSP data collected by Fish Inspection (L. Harding also noted that this data is available in LOTUS 123 format, and new data are now added to database regularly).

Duane Brothers
-some 30 Ocean Dump sites monitored irregularly. Data prior to 1985 suspect. Samples are archived. Trace metal data has been reported; some samples collected since 1987 are archived for analysis for organics. A list and marine charts showing sample location are available. A bibliography of all reports containing dumpsite monitoring data will be compiled and submitted.
-Under the Green Plan, funds have been dedicated to dumpsite monitoring for the duration of the Plan. Protocols are to be developed this year for a more consistent dump site monitoring program.
-Under the Green Plan, research funds have been dedicated. These could possibly be used to complement monitoring.
-core samples are archived from a 1988 survey of some 30 unpolluted reference sites. Trace metal results have been reported.

Glen Jamieson
-Currently working on Geoduck, long-lived ((150 years) bivalves. Growth rates can be ascertained by analyzing annuli of shells. For example, growth decreased commensurate with establishment of log booming in Ladysmith Harbour (this is published).
-Long term monitoring sites in intertidal zone started last year at Baynes Sound, Meares Island, Gabriola Island, Sidney Spit and Clayquot Sound. Submersible temperature recorders have been installed. Data set includes growth rate, survival of geoduck, measurements on predators including crabs and starfish.
-Data for crabs off Tofino since 1985 and off the Fraser Riverquarterly since 1987. Interpretation includes recruitment and population dynamics in relation to ocean variables.
- Experimental plots for geoduck recruitment at Gabriola Island and Clayquot Sound. Also has samples available from Boundary Bay, Roberts Bank and Sturgeon Bank.
-Shrimp: Ian White and Jim Boutillier have analyzed shells for trace elements for stock identification.

Bill Shaw
-Long Term Plankton Research initiated in 1990 (see map of stations). Acronym for the plankton project is COPRA. Some sites date back to 1985. Sampling is opportunistic: need to piggyback on other research. Strait of Georgia and La Perouse Bank are areas sampled most frequently. Samples are preserved in formalin, then analyzed for species composition, biomass. CTD also sampled at each station (same format as IOS uses). There is

an opportunity to collect samples for seabird food chain studies.

Jim Gower (not present; discussion led by H. Freeland)
-archives satellite imagery back to 1970s: visible and IR bands. Data are collected from every pass during working hours. Plan to automate reception to include data at all hours. Problem: how long to archive data. Difficulties of extracting/analyzing image data, particularly from older images. Is this information potentially useful for long term monitoring, and hence worth keeping?

Don Noakes and Ian Williams
-Stock assessment of salmon. Scales and otoliths have been collected and archived by the International Salmon Commission for sockeye since 1937 and for pinks since the late 1950's.
-Water temperature, turbidity and zooplankton abundance for selected rivers and lakes (Chilko, Shuswap, Quesnel), as well as escapement data, have been collected for about 40 years.
-John Stockner (not present) is initiating long term monitoring of Quesnel Lake, at a site that will be part of the Globel Exchange Monitoring Network.
-Carnation Creek monitored since early 1970s: effects of logging on salmon in a coastal watershed. Records include temperature, discharge, turbidity and paramenters related to fish populations. A similar study is being started in an interior watershed (Stewart/Takla).

Jeff Fargo
-Trawls for fish epibenthic community in Hecate Strait, Stations A-D. Parameters include weight/unit effort, size & age structure of populations, stomach contents. Sediments analyzed for benthic community assemblages and linked to fish food sources & trophic linkages. Expandable Bathy-Thermograph (XBT) casts at 100 sites, soon to be replaced with CTD. Plankton tows are done at a few of these stations. This is ongoing for the foreseeable future; the Ricker is committed. Room for other researchers is available.

John Elliott
-CWS collects seabird eggs at selected colonies every 4-5 years and analyses for organic contaminants. Extra eggs are archived in a tissue bank, some samples as far back as 1968.
-Strait of Georgia is monitored for contaminants in herons and cormorants yearly; some work also now being done on eagles. See Handout.

Bob Elner
New marine ecosystem monitoring study (3 sites on the lower mainland) being established to examine food chain relationships that support migratory shorebirds and waterfowl. PBS (Jamieson) is cooperating. Heads and livers beinggg kept for toxicological analysis, guts for parasite work. See handout.

Julie Shrimpton

-2 programs started in 1988: Contaminants in sediments and tissues from Vancouver and Victoria Harbours, and organics in relation to sawmills and wood treatment facilities. Programs are not repetitive or long term. Data are in DECalc on the VAX; plan to transfer them to dBASE to provide access to other researchers. See handout.

Janice Boyd
-Burrard Inlet Environment Improvement Plan, a component of the Fraser River Action Plan: long term monitoring program being developed, based on 1985-87 study.

DISCUSSION
Participants agreed that there are four marine regions on the west coast that have a long history of data, and are important to monitor for reasons of biological productivity and/or representation of west coast water masses: La Perouse Banks, Hecate Strait, the Strait of Georgia/Fraser River delta, and Ocean Station P. It is absolutely crucial for reasons of global climate change, for long term management of fisheries, and for environmental management, to continue and enhance long term data sets. It was unclear how a coordinated monitoring network can be established; however, it was agreed that several initiatives could contribute to such coordination: formalized data interchange formats, standard sampling and analytical protocols, and central data management for some types of data (i.e., those used in several disciplines, or by different agencies). It was also agreed that formal agreements between (or among) agencies can held secure long term commitments to monitoring. Bob Wilson and Lee Harding agreed to pursue such agreements through their respective line managements. Several opportunities for collaboration were identified; researchers will contact each other directly. Samples archived by several groups were seen as an important resource. DFO (Rogers) plans to establish a new tissue bank, and looks forward to cooperation of other agencies in contributing samples, and in jointly determining a regular sample archiving plan. There are also opportunities for joint design of new programs funded by the Green Plan to serve multiple objectives of participating agencies, for example, by linking ocean dump site monitoring with contaminants in fish monitoring. Other agencies, such as the province, also have important roles in future monitoring, and should be involved in future meetings. Another meeting of this group plus these other players was suggested, possibly in 3-6 months. Lee Harding and Bob Wilson agreed to work together to develop a regional network for marine environmental monitoring. The discussion was unfortunately cut short due to the time commitments of some participants.

APPENDIX D: Arctic Databases of Relevance to the MEQ monitoring network.

Arctic Monitoring and Assessment Programme - AMAP
Project Directory

CANADA

Reference no.: PD-67

Project title: Temporal Variation of Organochlorines in Ringed Seal from the Canadian Western Arctic.

Project responsible: Addison, R.F.
Bedford Institute of Oceanography (BIO)

Dartmouth, Nova Scotia, B2Y 4A2
P.O.Box 1006

Telephone: 902 426-3279 / 902 423-0757
Facsimile: 902 426-2256
Telex: 01931552
E-Mail address: BEDFORD.INST

Associated research programmes:

Lead institution:
Marine Chemistry Division, BIO

Information reported to other International programmes?: No

Start year: 1972 **Termination year:** Cont

Project objectives:
Detection of long-term changes in Organochlorine concentrations in Arctic ringed seals.

Summary:
Between 1970's, 1980's, PCB concentrations have declined but DDT-group concentrations have remained constant.

Keywords:
Ringed Seal, Phoca Hispida, Organochlorine, temporal change, DDT, PCB.

Project type:
- **Monitoring:** X
- **Modelling:**
- **Research:** X

Project output:
- **Databases:**
- **Datasets:**
- **Maps:**
- **Text:**
- **Graphics:**

Arctic Monitoring and Assessment Programme - AMAP
Project Directory

Stations:
Mackenzie Delta, NWT, Canada.

Parameters:
Organochlorine concentration in seal blubber. Age, sex, condition and size of seal.

Methods:
Blubber frozen <0%; subsequently extracted with chloroform methanol, cleaned up on Florisil and subjected to capillary GC with ECD.

Sampling frequency: Every 5-10 years. **Reporting frequency:** As results accumulate.

Quality assurance:
[redacted] Intercalibrations for OC analysis.

Registration date: 12-04-91

Comments:

Arctic Monitoring and Assessment Programme - AMAP
Project Directory

Reference no.: PD-68 **CANADA**

Project title: Organochlorine pesticides and PCBs in Arctic Ocean Marine Food Webs.

Project responsible: Hargrave, B.T.
Bedford Institute of Oceanography (BIO)

Dartmouth, Nova Scotia, B2Y 4A2
P.O.Box 1006

Telephone: 902 426-3188 / 902 426-2504
Facsimile: 902 426-7827
Telex: 019-31552
E-Mail address: (SCIENCENET) BEDFORD.INST

Associated research programmes:

Lead institution:
DFO, Biological Sciences Branch, Habitat Ecology Division.

Information reported to other international programmes?: No

Start year: 1986 **Termination year:** Cont

Project objectives:
Measurements of bioaccumulation and mass valances of organochlorines pesticides and PCBs in the marine food web and Arctic Ocean Basin.

Summary:
Most particle reactive organochlorines are biomagnified by epontic ice algae and plankton. More water soluble compounds are not bioaccumulated and show a lower rate of vertical transfer through the water column of the Arctic Ocean.

Keywords:
Arctic Ocean, organochlorines, food-web biomagnification.

Project type:	**Monitoring:**	
	Modelling:	X
	Research:	X
Project output:	**Databases:**	
	Datasets:	
	Maps:	
	Text:	X

Arctic Monitoring and Assessment Programme - AMAP
Project Directory

Graphics:

Stations:
Canadian Ice Island used as sampling platform. Off Ellef Ringnes Island (1986) in Peary Channel (1989).

Parameters:
Organochlorines in dissolved and particular form in snow, ice, seawater; tissue analyses of planktonic and benthic crustaceans; vertical deposition of settling particles.

Methods:
Standard tissue extractions. Water OCs concentrated on XAD-Z resin using submersible pumps in-situ to filter 100-200 liter samples.

Sampling frequency: 2-3 weeks intervals during 1-2 months between May-Sept 1986-1990**Reporting frequency:** Annually, biannually as data is analyzed.

Quality assurance:
DFO internal intercalibration (3 laboratories) carried out in 1989.

Registration date: 12-04-91

Comments:

Arctic Monitoring and Assessment Programme - AMAP
Project Directory

Reference no.: PD-73 **CANADA**

Project title: Hydrocarbons in Arctic Freshwater and Marine biota.

Project responsible: Lockhart, L.W.
DFO, Freshwater Institute (FWI)
501 University Crescent
Winnipeg, Manitoba, R3T 2N6

Telephone: 204 983-7113 /
Facsimile: 204 983-6285
Telex: 075-7491
E-Mail address:

Associated research programmes:
See Muir, Wagemann (FWI)MacDonald/Carmack (IOS)

Lead institution:
FWI

Information reported to other international programmes?: No

Start year: 1980 **Termination year:** Cont

Project objectives:
To define distribution of PAH in Arctic fish.

Summary:
Fish sampled from Arctic rivers and analysed for PAH.

Keywords:
Fish and PAH.

Project type:
- **Monitoring:**
- **Modelling:**
- **Research:**

Project output:
- **Databases:**
- **Datasets:**
- **Maps:**
- **Text:**
- **Graphics:**

Stations:

Arctic Monitoring and Assessment Programme - AMAP
Project Directory

Various points North of 60●.

Parameters:
PAH distribution plus relevant biological data for samples.

Methods:
Samples frozen, extracted, analysed for PAH by HPLC or cap-column GC.

Sampling frequency: As required. **Reporting frequency:** As data accumulates.

Quality assurance:

Registration date: 15-04-91

Comments:

Arctic Monitoring and Assessment Programme - AMAP
Project Directory

Reference no.: PD-74

CANADA

Project title: MFO enzyme activities in arctic fish (and marine mammals).

Project responsible: Lockhart, Lyle.
Freshwater Institute (FWI)
501 University Crescent
Winnipeg, Manitoba, R3T 2N6

Telephone: 204 983-7113 / 204 832-2978 (res)
Facsimile: 204 -983-6285
Telex: 07-57419
E-Mail address: DFO NET OMNET AS MCMULLEN

Associated research programmes:

Lead institution:
FWI

Information reported to other international programmes?: No

Start year: 1984 Termination year: Cont

Project objectives:
To define and map levels of MFO activities (EROD, AHH) in arctic species of fish and marine mammals.

Summary:
Collections of fish from a number of locations have been made and MFO enzyme activities determined. These have served both to identify and to rule out suspected cases of pollution.

Keywords:
MFO, P450,induction, burbot (Lota lota), whitefish (Coregonus), char, trout (Salvelinus), walleye (Styzostedian).

Project type:	Monitoring:	X
	Modelling:	
	Research:	X
Project output:	Databases:	
	Datasets:	
	Maps:	X
	Text:	X
	Graphics:	

Arctic Monitoring and Assessment Programme - AMAP
Project Directory

Stations:
Several in lower Mackenzie drainage (71. Good Hope, Arctic Red., Ft. McPherson, Tuktoyaktuk), Slave River (71.Smith), Gordon Lake, Hazen Lake, Lakes on Cornwallis Island.

Parameters:
Fish MFO and organochlorines (sometimes) (Muir) and metals (sometimes) and PAH (sometimes).

Methods:
Livers take in dry ice and maintained frozen until analyzed. Methodology adapted from published references for EROD (spectrofluorometric) and AHH (14-C - BaPUC - BaP) and <<<<p-450.

Sampling frequency: As opportunities arise. **Reporting frequency:** As data are generated and warrant reporting.

Quality assurance:
Inter laboratory sample exchanges (among three labs so far).

Registration date: 15-04-91

Comments:

Arctic Monitoring and Assessment Programme - AMAP
Project Directory

CANADA

Reference no.: PD-78

Project title: Baseline levels of heavy metals in Baffin Bay.

Project responsible: Lorin, D.H.
Bedford Institute of Oceanography (BIO)

Dartmouth, Nova Scotia B2Y 4A2
P.O.B_ox 1006

Telephone: 902 426-3565 /
Facsimile:
Telex: 019-31552
E-Mail address: (SCI.NET) Bedford .Inst

Associated research programmes:

Lead institution:
BIO, Marine Chemistry Division

Information reported to other international programmes?: No

Start year: 1980 **Termination year:** 1984

Project objectives:
Determine baseline levels of heavy metals (Cr, Cu, Pb, Zn, V, Co and Ni) in sediments from Baffin Bay and adjacent sounds.

Summary:
No anomalous levels of heavy metals were found in Arctic sediments. All were or near natural expected levels.

Keywords:
Heavy metals, sediments, Baffin Bay, Lancaster Sound, Smith Sound, Jones Sound.

Project type:
- Monitoring: X
- Modelling:
- Research: X

Project output:
- Databases:
- Datasets:
- Maps:
- Text: X
- Graphics:

Arctic Monitoring and Assessment Programme - AMAP
Project Directory

Stations:
Baffin Bay, Lancaster Sound, Jones Sound and Smith Sound.

Parameters:
Heavy metals (Cr, Cu, Pb, V, CO, Ni, Zn) Major Elements (Al, Fe, Mn, Ca, Mg, K). Organic Carbon, Grain size.

Methods:
Sediments frozen <0●C dried, digested in HF Metals determined by FAAS and GFAAS methods.

Sampling frequency: Every 10 years. **Reporting frequency:** As results are available.

Quality assurance:
Certified sediment reference materials. ICES/IOC intercalibration exercises.

Registration date: 15-04-91

Comments:

Arctic Monitoring and Assessment Programme - AMAP
Project Directory

Reference no.: PD-79

CANADA

Project title: Baselines levels of heavy metals on the Greenland Shelf.

Project responsible: Lorin,D.H.
Bedford Institute of Oceanography (BIO)

Dartmouth, Nova Scotia B2Y 4A2
P.O.Box 1006

Telephone: 902 426-3565 /
Facsimile: 902 426-2256
Telex: 019-31552
E-Mail address: (Sci.net) Bedford.Inst

Associated research programmes:
Environmental Monitoring

Lead institution:
Bedford Institute, Marine Chemistry Division

Information reported to other international programmes?: Yes
Greenland Environmental Research Institute, Copenhagen, DK.

Start year: 1985 **Termination year:** —

Project objectives:
Determine baseline levels of heavy metals on the Greenland Shelf and detect anthropogenic inputs if any.

Summary:
Sediment samples have been obtained from the east and west Greenland Shelves. Heavy metals and major elements have been determined in most of the samples.

Keywords:
Heavy metals, Greenland Contamination and Sediments.

Project type:	**Monitoring:**	X
	Modelling:	
	Research:	X
Project output:	**Databases:**	
	Datasets:	
	Maps:	
	Text:	X
	Graphics:	

Arctic Monitoring and Assessment Programme - AMAP
Project Directory

Stations:
At selected intervals along the east and west coastal of Greenland.

Parameters:
Heavy metals : Cr, Cu, Pb, Co, Ni, V, Zn Major elements : Al, Si, Fe, Mn,Ca, Mg, K

Methods:
Core samples, frozen (<0●C) thawed, dried, digested in HF. Metals determine by FAAS and GFAAS.

Sampling frequency: Every 20 - 5 km along the coast. **Reporting frequency:** As results accumulate.

Quality assurance:
Certified sediments reference materials. ICES/IOC intercalibrations.

Registration date: 15-04-91

Comments:

Arctic Monitoring and Assessment Programme - AMAP
Project Directory

Reference no.: PD-70 — CANADA

Project title: Organochlorines in Arctic marine mammals.

Project responsible: Muir, D.C.
DFO, Freshwater Institute (FWI)
501 University Crescent
Winnipeg, Manitoba R3T 2N6

Telephone: 204 983-5168 /
Facsimile: 204 983-6285
Telex: 075-7491
E-Mail address:

Associated research programmes:
See Addison (BIO), Lockhart (FWI), Wagemann (FWI)

Lead institution:
DFO, FWI

Information reported to other international programmes?: No

Start year: 1975 **Termination year:** Cont

Project objectives:
Define spatial temorak trends of OC residues in marine mammals and arctic food webs.

Summary:
Marine mammals and other components of Arctic marine food webs sampled at annual intervals and at spatial intervals of ± 1000 km for organochlorines analysis.

Keywords:
Organochlorine, mammal, trend and food web.

Project type:
- Monitoring:
- Modelling:
- Research: X

Project output:
- Databases:
- Datasets: X
- Maps:
- Text: X
- Graphics:

Arctic Monitoring and Assessment Programme - AMAP
Project Directory

Stations:
Various points in Canadian Arctic (North of 60●).

Parameters:
Organochlorine residues in blubber. Age, sex, condition of animal sampled.

Methods:
Standard organochlorine analysis in marine mammal blubber, using capillary column with ECD or MS detection.

Sampling frequency: Temporally, ± annually, spatially, ± 1000 km. **Reporting frequency:** As data accumulates.

Quality assurance:
National and international.

Registration date: 15-04-91

Comments:

Arctic Monitoring and Assessment Programme - AMAP
Project Directory

Reference no.: PD-69 **CANADA**

Project title: Spatial and temporal trends in contaminants in marine and freshwater biota.

Project responsible: Muir, D.C.
Freshwater Institute
501 University Crescent
Winnipeg, Manitoba, R3T 2N6

Telephone: 204 983-5168 / 204 983-5041
Facsimile: 204 983-6285
Telex:
E-Mail address:

Associated research programmes:

Lead institution:
Freshwater Institute, DFO

Information reported to other international programmes?: No

Start year: 1988 **Termination year:** Cont

Project objectives:
1- Measurement of trends in organochlorines (OCs) in ringed seals, 2- circumpolar survey of organochlorines in beluga, 3- spatial and temporal trends in OCs in freshwater fish, 4- lead and other metals in ringed seal and walrus (see Wagemann)

Summary:
This project consists of four sub projects identified in DIAND - DFO funded arctic contaminants studies over the past few years. It seeks to characterize contaminant levels spatially and temporally in the Canadian arctic, and in cooperation with other agencies, on an international basis.

Keywords:
Organochlorines (PCBs, PCC, DDT). Marine mammals, whales, seals, freshwater fish (lake trout, arctic char)

Project type:

	Monitoring:	X
	Modelling:	
	Research:	X

Project output:

	Databases:	X
	Datasets:	
	Maps:	

Arctic Monitoring and Assessment Programme - AMAP
Project Directory

Text: X
Graphics: X

Stations:
Hudson Bay, Davis Strait, Ungava Bay and various inland lakes.

Parameters:
Organochlorines <pcbs, <pc (toxaphene) DDT group, age, sex, etc.

Methods:
For methods on organochlorines see Muir et al. Arct. Environmental Contaminants Toxicology pages 17, 613, 1989 or 19, 530, 1990.

Sampling frequency: Various, some sites every 3 to 5 years. **Reporting frequency:** As results accumulate.

Quality assurance:
Through ICES, and other Canadian programs.

Registration date: 12-04-91

Comments:

APPENDIX E: Other National Monitoring Programs.

National Ocean Dumpsite Monitoring

Ocean dumping proponents are responsible for providing the baseline information required in permit application, whereas Environment Canada is responsible for CEPA compliance monitoring. The Marine Environment Division of Environment Canada has recently developed interim guidelines to be applied to compliance monitoring at ocean dumpsites, i.e. to verify that permit conditions have been met and that impacts observed at the dumpsite do not exceed those expected and accepted by the permit terms and conditions (Environment Canada 1993b). The guidelines will be used at ocean dumpsites beginning in 1993-94, and it is anticipated that biological monitoring guidelines will be incorporated into the interim guidelines by the end of 1994-94.

The guidelines recommend that monitoring objectives be formulated into testable hypotheses, and that monitoring plans be permit- and site-specific. Recommended measurements of relevance to the National Marine Status and Trends Monitoring Network are (1) contaminant concentrations in the sediments, and (2) contaminant uptake by selected species and ensuing effects on those species. The core monitoring program includes measurements of cadmium, mercury, PCBs, total PAHs, low molecular weight PAHs, high molecular weight PAHs, and total organic carbon. If chemical concentrations are of concern, bioassays could be employed to assess toxicity. If there is evidence of sediment contamination and toxicity, further biological monitoring could be triggered; examples mentioned are bioaccumulation studies, evidence of diseases in key species, and population and community responses in the field. Details are being addressed in 1993-94 and core biological monitoring will be incorporated into the interim guidelines for 1994-95 dumpsite monitoring.

Monitoring will be conducted both at dumpsites and (if transport is occurring) at nearby areas of concern (natural beauty, cultural or historic importance, special scientific or biological importance, migration routes of living marine resources, spawning and nursery areas, sport and commercial fishing areas, and mariculture areas). Furthermore, the guidelines recommend that for most monitoring objectives, there should be a spatial control (reference site).

The guidelines also recommend that there be a temporal control (baseline information from the dumpsite). Presumably, that information is collected by the proponent during the process of dumpsite selection, also the guidelines caution that "...care should be taken in supplementing the available information should the study design require." There is no specific mention of collecting baseline information at the reference site. Such information would be an important characteristic of the ocean dumpsite monitoring program in terms of its value to the National Marine Status and Trends Monitoring Network.

The guidelines contain a number of sound recommendations about sampling design and QC/QA. Final dumpsite monitoring reports are to be prepared within the calendar year following the field survey and submitted to the Chief, MED, for distribution to each EP regional office responsible for the implementation of ocean dumpsite monitoring. Also, MED will produce national reports annually. The National Marine Status and Trends Monitoring Network would profit from receiving data from dumpsite surveys before the reports are prepared, assuming that the data have been checked and verified.

Aquatic EEM Requirements under the Pulp and Paper Effluent Regulations

As regulated under the amended Pulp and Paper Effluent Regulations (PPER) of the federal *Fisheries Act* (1992), the adequacy of national effluent regulations for protecting fish, fish habitat, and the use of fisheries resources will be assessed by undertaking aquatic EEM studies at all locations where effluent is discharged to the aquatic receiving environment. The EEM program will be "evolutionary" in that requirements of subsequent EEM cycles will be determined following an evaluation of the first cycle. Results of the first EEM cycle will be reported before 1 April 1996.

"For the purposes of EEM, effects may include, but are not limited to," the following:

- changes in the health of fish
- distortion of fish population structure or life cycles
- "deterioration of habitat essential for growth and sustenance of fish," and
- "accumulation of substances in fish to levels prejudicial to human health and/or the marketability of fish."

The requirements specify that there will always be at least one reference area to which exposure areas will be compared; the reference areas should have zero mill effluent exposure, and a separate reference area should represent each habitat type for mills where there are several major habitat types in the exposure area.

Measurements specified in the requirements include

- adult fish: length, weight, age, gonad weight, egg size, weight of liver or hepatopancreas, external condition
- quantitative benthic community analysis
- contaminants: specified chlorinated dioxin and furan digeners in fish tissue (for mills which have used or continue to use chlorine bleaching)

A national EEM office will be set up within EC to coordinate assessment of results on a national basis and to coordinate data management. For each EEM study, the study design, interpretative report and supporting data are submitted to the Authorization Officer, who is the Regional Director of Environmental Protection, Conservation and Protection, Environment Canada. The Authorization Officer is advised by an Advisory Panel that consists of representatives of Environment Canada, DFO, and the provincial government(s).

Green Plan Toxic Chemicals Programme

This is a DFO proposal for a national monitoring programme for contamination of fisheries and habitats that is scheduled to begin in 1993-94.

National Shellfish Growing Area Contaminant Surveillance Programme

A draft protocol for this programme has been prepared by EC's Shellfish Water Quality Protection Program in 1993. It had been decided in a panel discussion held in conjunction with the Aquatic Toxicity Workshop in November 1990 that a mussel watch program would serve both a human health protection monitoring strategy and environmental (status and trends) monitoring strategy. If a pilot program to be conducted in approved shellfish growing areas was successful, consideration would be given to expanding the monitoring network to include other areas as a part of a more complete status and trends program (EC 7 May 1993).

Parameters to be measured will include metals, PAHs, PCBs (18 congeners), dioxins, hexachlorobenzene, DDT, and other selected pesticides. Ancillary data to be collected will include condition indices of the mussels, and (as a minimum) temperature, salinity, and tide level. Selected growing area sites will be commercially important and will have the potential to receive significant inorganic and/or organic contaminants. Also, "... key continuing reference stations should be identified in each region. These sites can be used to establish or continue to identify regional baselines in each marine ecozone or subzone." The draft protocol (EC 1993) also suggests that "...collection of mussel contaminant data should be integrated at these sites with collection of contaminant data from other portions of the food chain (preferably existing programs)."

Detailed field, laboratory, and data entry methods are described in the draft protocol document. The database structure will follow the departmental ENVIRODAT/NAQUADAT data standard, and the ultimate data repository will be ENVIRODAT.

Phytoplankton Monitoring Programs

During the Third Canadian Workshop on Harmful Marine Algae (DFO 1992), Working Group 6 ("Monitoring Toward the Year 2000") recommended that a study group be appointed to manage the databases that are coming out of the ongoing work on phycotoxins in Canada. The WG also suggested that harmful algal blooms may serve as indicators of coastal habitat degradation, and pointed out that it had been suggested at meetings of DFO's Phycotoxins WG that "... a number of long-term monitoring stations should be set up to identify trends in physicochemical and biological variables over a span of at least several decades."

In 1987, DFO initiated a phytoplankton monitoring program on the east coast. Sampling has been conducted over 3- or 4-year periods at 10, up to 40, 9, and 2 stations in DFO's Quebec, Gulf, Scotia-Fundy, and Newfoundland regions, respectively. Included at all stations were data on phytoplankton identification and counts, temperature, and salinity; at some stations, data on chlorophyll and nutrients were also collected. No attempts have been made to exchange data between regions.

Following the initial 3-year program, a number of phytoplankton watch projects have been established which involve DFO Science and Inspection Services branches, provincial agencies, and industry. Those projects focus on the few species that are potentially dangerous and provide information on the day of sampling. Projects are ongoing in the Pacific, Quebec, Gulf, and Scotia-Fundy regions. Regional plans for continuing phytoplankton monitoring projects are as follows:

- in the Pacific Region, DFO is initiating a research project at 3-4 sites in the Strait of Georgia and on the west coast of Vancouver Island
- in the Quebec Region, the initial 10 stations will continue, and a long-term trend monitoring station will be established at Sainte Flavie

- in the Gulf Region, the establishment of long-term stations is being considered, and the phytoplankton watch project will be continued by Inspection Branch at 30 stations
- in Scotia-Fundy Region, four long-term trend monitoring stations are being established

APPENDIX F: Monitoring Programs Conducted by CWS.

From: Bird Trends 1992, Number 2.

Monitoring studies of marine birds in Canada

— A.J. Gaston, CWS, Hull, PQ

Population monitoring can be done a variety of ways: it may be a complete enumeration of breeding birds, or it may depend on sub-sampling smaller areas of a colony. Some indices of population trends are based on counts of birds (e.g., murres and puffins on their colonies), and others stem from counts of active nests (e.g., gulls, terns). Even a whole-colony count does not include young, pre-breeding birds, which may not all attend the colony. Similarly, adverse environmental conditions may result in a failure to breed in some years. Hence, it is best to treat all forms of count as indices of abundance, rather than total population censuses.

Generally, small colonies are easier to count than large ones, and surface nesting species (such as gulls and gannets) are easier than burrow- (storm-petrels and auklets) or crevice-nesters (guillemots). Most surface nesters can be censused by photographing the colonies, but this approach cannot be used for the others. For the nocturnal burrow-nesters there is little recourse but the time-consuming task of examining each hole in the ground to see whether it is an occupied seabird burrow. In the case of the Ancient Murrelet, young birds can be trapped at departure from the colony as they make their way to the sea, providing an estimate of successful breeders. Some people have attempted to use counts of calling birds to get an index of nocturnal burrow-nesting seabirds, but this technique is very inaccurate.

For terns and gulls, the use of fixed monitoring sites is less appropriate than for other species, because they tend to shift their breeding sites more frequently than most seabirds. For terns especially it may be more appropriate to monitor populations by periodic intensive surveys covering all likely breeding sites. Such surveys are, however, expensive. Consequently, our information on population trends in terns is far from ideal.

Monitoring seabird populations by standardized repeated counts has been carried out in Canada since 1925. At that time, Harrison F. Lewis began counts of the seabird colonies in the migratory bird sanctuaries on the North Shore of the Gulf of St. Lawrence. Those counts

Figure 1. Locations of major seabird monitoring sites in Canada where comprehensive baseline studies have been performed, 1972-1992. Species populations examined are given in Table 1.

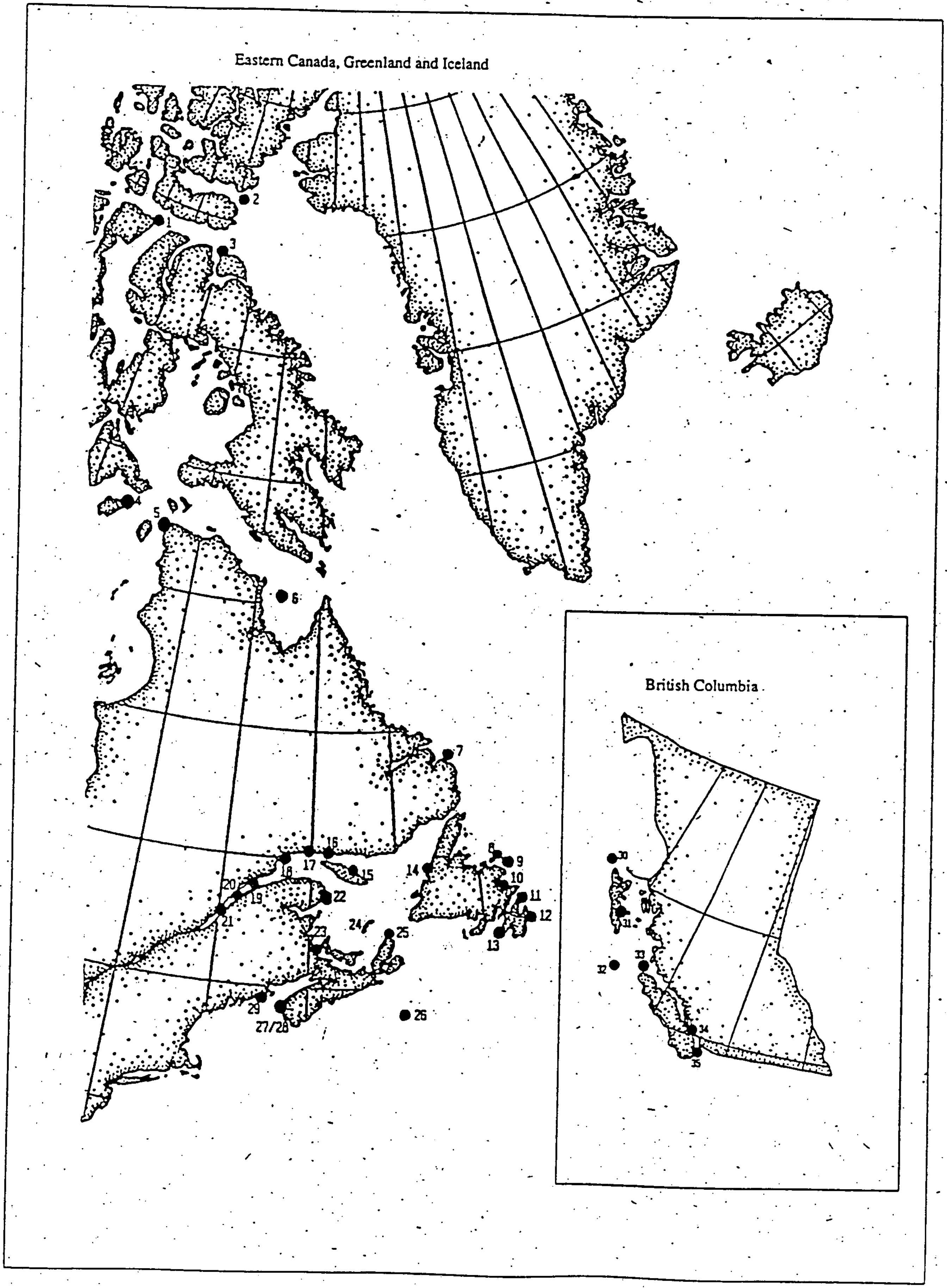


Table 1: Principal monitoring studies of marine birds in Canada.

Locality	Species	Count[1] (D/P)	Year begun	Schedule[1]	Trend[1]	Agency[1]
High Arctic						
1. Prince Leopold I., NWT*	Northern Fulmar	D	1975	8x	?	1
	Glaucous Gull	D	1975	8x	–	1
	Black Guillemot	D	1976	4x	?	1
	Black-legged Kittiwake	D	1975	8x	?	1
	Thick-billed Murre	D	1975(72)	8x	?+	1
2. Coburg I., NWT*	Black-legged Kittiwake	D/P	1973	5x	?	1
	Thick-billed Murre	P	1973	5x	?	1
3. Cape Hay, Bylot I., NWT*	Black-legged Kittiwake	D/P	1972	5x	?	1
	Thick-billed Murre	P	1972	5x	–	1
Low Arctic						
4. Coats I., NWT*	Glaucous Gull	D	1984(81)	Ann	=	1
	Thick-billed Murre	D/P	1981(72)	Ann	+	1
5. E. Digges I., NWT*	Thick-billed Murre	D	1980	5x	?–	1
6. Akpatok I., NWT*	Thick-billed Murre	D	1982	3x	?	1
7. Gannet Is., Labrador*	Common Murre	D	1979	6x	?	1
	Thick-billed Murre	D	1979	6x	?	1
	Razorbill	D	1979	6x	?	1
	Atlantic Puffin	D	1979	6x	?	1
8. Wadham Is. & S. Cabot I., Nfld.	Common Murre	D	1969	4x	?	1
	Atlantic Puffin	D	1969	4x	?	1
9. Funk I., Nfld.*	Northern Gannet	P/D	1972	Fre	+	1
	Common Murre	P	1972	5x	?	1
	Atlantic Puffin	D	1969	3x	=	1
10. Terra Nova, Nfld.	Common/Arctic Tern	D	1975	Ann	–	8
	Common Tern	D	1975	Ann	–	8
11. Baccalieu I., Nfld.*	Leach's Storm-Petrel	D	1976	3x	?	1
	Northern Gannet	P/D	1972	4x	+	1
	Atlantic Puffin	D	1976	4x	?+	1,3
12. Witless Bay Is., Nfld.*	Leach's Storm-Petrel	D	1973	3x	?	1
	Great Black-backed Gull	D	1968	Fre	+	1,3
	Herring Gull	D	1968	Fre	+	1,3
	Black-legged Kittiwake	D	1973	4x	+	1,3
	Common Murre	P	1972	5x	+	1
	Atlantic Puffin	D	1967	Fre	–	1
	Black Guillemot	D	1968	Fre	?	1
13. Cape St. Mary's, Nfld.*	Northern Gannet	P/D	1972	4x	+	1
	Common Murre	D	1980	Ann	–	4
14. Gros Morne, Nfld.	Common/Arctic Tern	D	1975	Ann	=	8
	Common Tern	D	1975	Ann	=	8
15. Anticosti I.	Northern Gannet	P	1969	4x	+	1
16. Mingan I.*	Common Tern	D	1972	3x	+	1,8
	Arctic Tern	D	1978	3x	+	1,8
17. Carrousel I.*	Black-legged Kittiwake	D,P	1940	10x	+	1
18. Lower North Shore	Great Cormorant	D	1925	5yr	–	1
	Double-crested Cormorant	D	1925	5yr	+	1
	Common Eider	D	1925	5yr	–	1
	Great Black-backed Gull	D	1925	5yr	+	1
	Herring Gull	D	1925	5yr	+/–	1
	Ring-billed Gull	D	1925	5yr	–	1
	Caspian Tern	D	1925	5yr	–	1
	Common/Arctic Tern	D	1925	5yr	1	
	Common Murre	D	1925	5yr	+	1
	Razorbill	D	1925	5yr	+/–	1
	Black Guillemot	D	1925	5yr	=	1
	Atlantic Puffin	D	1925	5yr	–	1
19. Pilgrim Is.*	Razorbill	D	1971	4x	+	1,5
20. St. Lawrence estuary	Common Eider	D	1963	Fre	=	1
	Great Black-backed Gull	D	1963	Fre	+	1
	Herring Gull	D	1940	Fre	+/–	1
	Black Guillemot	D	1971	3x	–	1,6
21. Quebec City	Ring-billed Gull	D	1983	3x	+	1
22. Bonaventure I.*	Northern Gannet	D	1969	Fre	+	1
	Black-legged Kittiwake	P	1974	3x	+	1
	Common Murre	D	(1914)	6x	+	1

cont'd

Table 1: continued

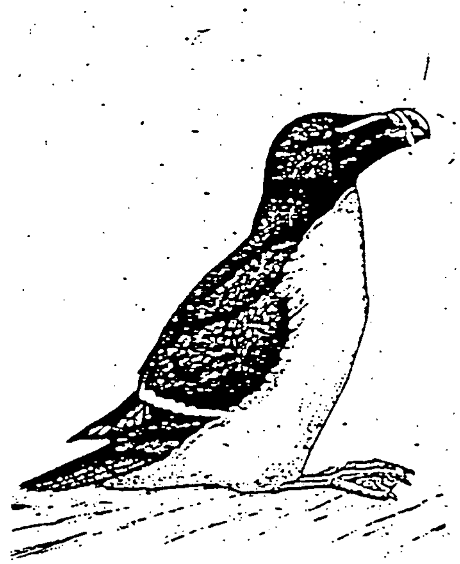
Locality	Species	Count[1] (D/P)	Year begun	Schedule[1]	Trend[1]	Agency[1]
Boreal						
23. Kouchibouguac Park, NB	Common Tern	D	1970	Fre	+	8
24. Magdalene Is.	Northern Gannet	P	1969	6x	+	1
	Common Tern	D	1972	3x	+	1,6,7
	Arctic Tern	D	1972	3x	?	1,7
25. Cape Breton Highlands, NS	Common/Arctic Tern	D	1975	Fre	–	8
26. Sable I., NS*	Common/Arctic Tern	D	1971	5x	–	1
	Roseate Tern	D	1971	5x	–	1
	Herring Gull	D	1970	6x	?	1
	Great Black-backed Gull	D	1970	6x	?	1
27. The Brothers, NS	Roseate Tern	D	1987	Ann	?	10
28. Peters I., NS	Common/Arctic Tern	D	1980	Fre	–	9
29. Machias Seal I., NB*	Common/Arctic Tern	D	1940	Fre	=	1
	Atlantic Puffin	D	1972	Fre	?	1
Pacific						
30. Lucy I.	Rhinoceros Auklet		1983	5x	?	1
31. Laskeek Bay	Pelagic Cormorant	D	1985	Ann	–	1,9
	Glaucous-winged Gull	D	1985	Ann	?	1,11
	Ancient Murrelet	D	1984	Ann	–	1,11
32. Triangle I.	Rhinoceros Auklet		1976	10x	?	1
	Tufted Puffin		1976	10x	?	1
33. Pine I.	Rhinoceros Auklet		1983	3x	?	1
34. Strait of Georgia	Double-crested Cormorant	D	1959	3x	+	1,2
	Pelagic Cormorant	D	1959	3x	+	1,2
	Glaucous-winged Gull	D	1959	3x	+	1
35. Mandarte I.	Double-crested Cormorant	D	1915	8x	+	1,2
	Pelagic Cormorant	D	1959	7x	+	1,2
	Glaucous-winged Gull	D	1915	8x	+	1
	Pigeon Guillemot	D	1961	3x	+	1,2

[1]Abbreviations: * Biological Monitoring System (BMS) site. **Count** D=Direct, P=Photographic. **Schedule** Ann=Annual, Fre=Not annual, but 50% of years, Nx=N times between starting and 1991. **Trend codes** ? unknown; – declining; +increasing; = stable; ?+ unknown, possibly increasing; ?– unknown, possibly declining; +/– increasing in some areas, declining in others. **Agency** 1=CWS, 2=BC Provincial Mus. 3=Memorial University, 4=Newfoundland Fish and Wildlife Division, 5=Societé Duvetnor, 6=MLCP Quebec, 7=Centre de Recherche Ecologique, Montreal, 8=Canadian Parks Service, 9=Nova Scotia Bird Society, 10=Roseate Tern Recovery Team, 11=Laskeek Bay Conservation Society.

have continued at five year intervals ever since and are probably the longest running series of marine bird monitoring data in the world. Prior to 1925, there is some useable information from the accounts of competent naturalists, although it rarely allows more than a qualitative estimate of trends. For instance, it is evident that the huge numbers of auks described by Audubon on his visit to the Gulf of St. Lawrence in the early 19th century had been greatly reduced by Lewis' time, but we shall never know just how large the colonies were in Audubon's day.

Table 1 summarizes the ongoing population monitoring programs for seabirds in Canada. The studies listed have been underway since at least 1985, have included at least three monitoring visits up to 1991, and are likely to be continued by the monitoring agency.

Most of the programs listed in Table 1 are being carried out by CWS. However, there is an increasing trend for such activities to be undertaken by other agencies, especially where they have permanent staff located near the monitoring site. Several provincial departments of environment and the Canadian Parks Service are involved. A few sites are being monitored by local amateurs. We would like to expand the involvement of these groups, both to improve the efficiency of monitoring operations and to increase public interest in seabirds and their role in marine ecosystems.



Razorbill

Noble and Elliott (1986) CWS Contaminants Program

1. INTRODUCTION

Synthetic organochlorine compounds and heavy metals have been reported in wildlife, including seabirds, since the mid 1960's. By 1970, there was an alarming increase in reports of wildlife mortality due to chemical poisoning, and some fish-eating species were found to be laying eggs so thin-shelled that productivity was essentially zero (Ohlendorf et al, 1978). The persistence of organochlorines in the ecosystem was confirmed by their discovery in biota in regions as remote as the Antarctic (Ballschmiter et al, 1981).

Eventually, enough conclusive evidence was accumulated to force legislative action. Use of DDT, PCBs, dieldrin and heptachlor was restricted in North America and most of Europe, around 1970. Use in most other parts of the world, particularly tropical developing countries, has not yet been restricted, and in fact has probably increased since the early 1970's.

Growing public concern about use and disposal of hazardous substances and the health of the environment, provided the impetus for environmental contaminant monitoring programs. For example, the Herring Gull (Larus argentatus) has been used successfully to monitor pollution in the Great Lakes (Mineau et al, 1984).

Since the oceans are the ultimate sink of most manmade persistent substances, there is concern about the health of the marine environment and the impact of contaminants on its denizens. Seabirds, as top predators in the marine food chain, can accumulate significant amounts of these chemicals, and are likely to be the most affected. The DDE-induced crash of American Brown Pelican (Pelecanus occidentalis) populations fifteen years ago (Blus et al, 1971), is evidence that the effects can be very serious.

This report results from a project by the Canadian Wildlife Service (CWS) to review its data on environmental contaminants in Canadian seabirds. Available data on organochlorine and heavy metal levels were examined in order to:

1) determine if toxic chemicals have affected or are continuing to affect the health of Canadian seabird individuals or populations

2) consider the utility of seabird species as indicators of contamination of marine ecosystems by persistent environmental pollutants

3) determine what future monitoring and surveillance of environmental contaminants in Canadian seabirds is necessary.

Table 1 is a summary of organochlorine analyses conducted on seabirds by CWS. The number of analyses for each tissue and species is provided on a yearly basis according to geographic regions. Publications containing some of the data for each species are noted.

Certain sections of this report are organized geographically into east coast, arctic and west coast regions. Maps of collection locations are provided in Appendix 2. A detailed summary of all organochlorine and mercury residue data is available in Appendix 6.

2. METHODS

2.1 General Approach:

Seabirds included in this report are those species which breed on the coasts of Canada and spend their time outside the breeding season in the marine environment. Species such as loons, grebes and phalaropes which breed in freshwater and winter in marine areas were excluded. A search for data on the selected species was made on the CWS National Registry of Toxic Chemical Residues (Elliott et al, 1985), a computerized repository for information on environmental contaminants in Canadian wildlife. Data was available on twenty-four species, as listed in Table 1.

All data on these species were retrieved and a separate data

Table 1

Summary of Canadian Wildlife Service data on organochlorine chemicals in seabirds.
The number of samples analyzed each year is given, according to tissue and area of collection.
Publications including at least part of the data for each species are noted.

SPECIES	TISSUE	GEOGRAPHICAL REGION	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	TOTALS Eggs	TOTALS Tissues	PUBLICATIONS
Northern Fulmar	Whole body	Atlantic				19																38	Peakall and Nettleship, in press
	Liver	Arctic								10	9												
Leach's Storm-petrel	Eggs	Atlantic	19				10				10				10				10		80	22	Pearce et al, 1979
		Pacific			1	5												6		9			Ohlendorf et al, 1978
	Whole body	Atlantic					9				5												Pearce et al, in prep.
	Miscellaneous	Pacific				8																	Elliott et al, in prep. b
Fork-tailed Storm-petrel	Eggs	Pacific			2													3			5		Ohlendorf et al, 1978 Elliott et al, in prep. b
Northern Gannet	Eggs	Atlantic	9	20	6			10	30		6								6		87	44	Keith and Gruchy, 1972 Elliott et al, in prep. a
	Miscellaneous	Atlantic	40		2		2																Chapdelaine et al, in prep.
Double-crested Cormorant	Eggs	Atlantic			15		40	15		14	25			11	10				10		163	6	Pearce et al, 1978
		Pacific			3									10						10			Ohlendorf et al, 1978
	Liver	Atlantic		4						2													Pearce et al, in prep. Elliott et al, in prep.
Pelagic Cormorant	Eggs	Pacific			20			6												11	37	5	Ohlendorf et al, 1978 Elliott et al, in prep. b
	Liver	Pacific	5																				
Common Eider	Eggs	Atlantic					24														24	1	Pearce et al, 1979
	Muscle	Atlantic			1																		

Table 1 (continued)

SPECIES	TISSUE	GEOGRAPHICAL REGION	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	TOTALS Eggs	TOTALS Tissues	PUBLICATIONS
King Eider	Eggs	Arctic									1										1		
Glaucous-winged Gull	Eggs	Pacific			63							10						35			108	20	Ohlendorf et al, 1978
	Miscellaneous	Pacific	20																				Elliott et al, in prep. b
Ivory Gull	Eggs	Arctic									10										10		
Black-legged Kittiwake	Eggs	Arctic									6										6	20	Peakall and Nettleship, in press
	Liver	Arctic								10	10												
Common Tern	Eggs	Atlantic		4	10	3	10	25		10											62	4	Pearce et al, 1979
	Liver	Atlantic		4																			
Razorbill	Eggs	Atlantic					10	3					20								33	2	Pearce et al, 1979 Chapdelaine and Laporte, 1982
	Muscle	Atlantic			2																		
Common Murre	Eggs	Atlantic	10			4															14	7	Pearce et al, 1979
	Miscellaneous	Atlantic Pacific			2 5																		
Thick-billed Murre	Eggs	Arctic								12	10	10									32	42	Peakall and Nettleship, in press
	Liver	Arctic								10	22	20											

Table 1 (continued)

SPECIES	TISSUE	GEOGRAPHICAL REGION	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	TOTALS Eggs	TOTALS Tissues	PUBLICATIONS
Dovekie	Muscle	Atlantic	9																			9	
Black Guillemot	Eggs	Atlantic						3													3	1	Pearce et al, 1979
	Muscle	Atlantic			1																		
Pigeon Guillemot	Eggs	Pacific			13																13		Ohlendorf et al, 1978 Elliott et al, in prep. b
Marbled Murrelet	Miscellaneous	Pacific	6	12																		18	Ohlendorf et al, 1978 Elliott et al, in prep. b
Ancient Murrelet	Eggs	Pacific	5																		5	72	Ohlendorf et al, 1978 Elliott et al, in prep. b
	Miscellaneous	Pacific	28	2	2	4	36																
Cassin's Auklet	Eggs	Pacific			4																4	4	Ohlendorf et al, 1978 Elliott et al, in prep. b
	Miscellaneous	Pacific			2	2																	
Rhinoceros Auklet	Eggs	Pacific			11															6	17	10	Ohlendorf et al, 1978 Elliott et al, in prep. b
	Miscellaneous	Pacific		8	2																		
Atlantic Puffin	Eggs	Atlantic	20				36	1			10				10				10		87	12	Pearce et al, 1979 Pearce et al, in prep.
	Miscellaneous	Atlantic	5		2		5																
Tufted Puffin	Eggs	Pacific			1																1	2	Ohlendorf et al, 1978 Elliott et al, in prep. b
	Whole body	Pacific			2																		

file was created. A hardcopy of the contents was produced and the whole dataset verified by hand against the original documents, such as field collection sheets, laboratory notebooks and analysis reports. The incidence of errors was very low (<0.01%). The few detected errors were corrected and the data declared ready for use. Results of recent analyses and re-analyses were added to the file.

2.2 Sample Collection:

Field collection procedures varied. The report covers eighteen years of work during which, collectors, reasons for collecting and methodologies changed. Egg collections were the most standardized. Fresh eggs were collected early in the nesting season at most sites. For species such as terns and cormorants which lay a multiple egg clutch, a single egg was removed from the first clutch. Nests to be sampled were selected at random from the central area of the colony. Late season collecting of unhatched eggs was more opportunistic and involved collection of whatever eggs were available. Eggs for pesticide analysis were removed by hand and refrigerated temporarily. As soon as possible, egg contents were removed and placed into chemically cleaned (acetone and hexane) glass jars with a chemically cleaned foil liner between the lid and the jar. Egg contents were then frozen at -20 C or colder until time of analysis. The collection of Ivory Gull (Pagophila eburnea) eggs from Seymour Island, North West Territories diverged from this general method. Due to the isolated circumstances, egg contents were placed into chemically cleaned glass jars containing formalin as a preservative agent. Collection of adult and juvenile birds was normally by shooting or netting. Carcasses were wrapped in solvent rinsed aluminum foil and/or placed into polyethylene bags then frozen at -20 C.

Appendix G: Canadian Toxic Phytoplantkon Monitoring Programs.

From Therriault and Levasseur (1992).

OVERVIEW OF CANADIAN PHYTOPLANKTON MONITORING PROGRAMS

by

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INTRODUCTION

At the present time, approximately fifteen species of marine algae occurring in Canadian marine waters have the potential to cause harmful effects on both marine organisms and human consumers. This list continues to grow as scientific information increases. Many of these harmful algae can cause serious problems to the fishing industry, both wild and aquaculture. Three major groups of phycotoxins can affect shellfish: paralytic shellfish poisoning (PSP), amnesic shellfish poisoning (ASP), and diarrhetic shellfish poisoning (DSP); and these are endemic on both east and west coasts. In addition, certain species of diatoms and chloromonads on the west coast have caused direct salmonid mortalities, but not thus far on the east coast.

To manage Canadian fisheries, it is essential to develop a sound understanding of the factors that influence the species composition of phytoplankton communities, especially the toxigenic species. Therefore, in 1987 the Department of Fisheries and Oceans (DFO) initiated a phytoplankton monitoring program on the Atlantic Coast.

This brief overview, written from a national perspective, describes the various projects that have been conducted, presents a few results, and outlines future plans. The focus is on the DFO's Science Sector program, but reference is also made to complementary programs in DFO's Inspection Services Branch, as well as industry.

DESIGN OF INITIAL PROGRAM

The first phytoplankton-monitoring project began in the Quoddy region of the Bay of Fundy in 1987, an area with a growing salmonid mariculture industry (Wildish et al. 1988). As a result of the domoic acid crisis in eastern Prince Edward Island (PEI) in late 1987, it was decided to establish an expanded monitoring program which covered the entire Atlantic Zone. A working group, with members from the Scotia Fundy, Gulf, and Québec Regions was convened in the spring of 1988 to develop objectives and protocols for sampling and analysis. It was agreed to undertake a 3-year program with the following objectives:

- Determine what areas and times are favourable or unfavourable for shellfish or finfish aquaculture with regards to the presence of toxins.

- Indicate times when screening for toxins should be more or less frequent if a consistent species succession can be established.

- The program would also provide background information for gauging whether observed phytoplankton events are normal or whether changes in biomass and species diversity may be related to exceptional meteorological events or anthropogenic activity.

On the order of 24 coastal stations were initially selected, most of which were very near to existing mariculture facilities. Sampling frequency was monthly in the winter, fortnightly in the spring and fall, and weekly in the summer. It was recommended that variables measured should include: phytoplankton species enumeration, taxonomy and quantitative abundance, chlorophyll, temperature, salinity, and inorganic nutrients. Attention was also given to developing common database management methods. A summary of the program was presented at the First Canadian Workshop on Harmful Marine Algae (Gordon 1989). As is clear in the above objectives, this initial program was designed to improve scientific understanding of phytoplankton ecology, not to provide an operational early-warning system. In the Gulf Region an early-warning system for the presence of harmful algae was a component of their initial phycotoxin program.

ACCOMPLISHMENTS OF THE ORIGINAL PROGRAM

Stations sampled as part of the core program are identified in Figure 1. Accomplishments vary somewhat by region, depending on the resources and expertise available. Some modifications were also made to program design as results were obtained and evaluated.

Québec Region - Phytoplankton identification and counts, temperature, and salinity data were collected over a 3-year period at ten stations. No nutrient data were collected. Results of 1989 sampling have been published (Larocque and Cembella 1991a; 1991b). Further reports will be published.

Gulf Region - Phytoplankton identification and counts, chlorophyll, temperature, salinity, and nutrient data were collected over a 4-year period at up to 40 stations in collaboration with Inspection Services Branch and others. In addition to this basic information, a number of other variables have been measured including irradiance and extinction, *in vivo* fluorescence, seston, particulate protein and amino acids, ^{15}N uptake rates, and ^{14}C photosynthesis. Offshore samples are obtained when opportunity permits (e.g. from Scotia-Fundy Region ice forecast cruises or from Gulf Region groundfish and herring surveys). Data reports and primary publications describing this work will be published in the near future.

Scotia-Fundy Region - Phytoplankton identification and counts, chlorophyll, temperature, salinity, and nutrient data were collected over a 4-year period at four stations by the St. Andrews Biological Station. Data collected through to 1989 have been published (Wildish et al. 1988; Wildish et al. 1989). Further reports will be

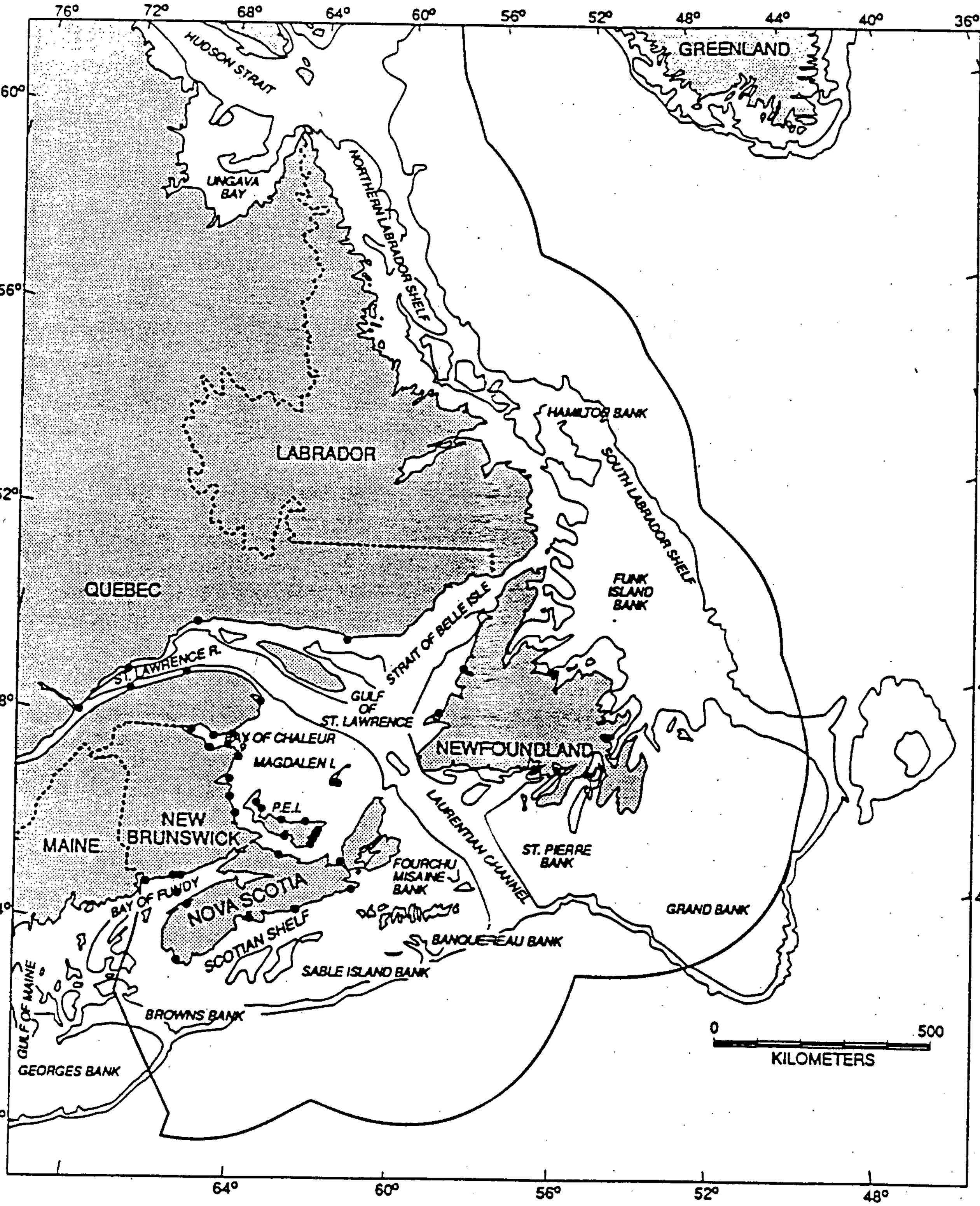

Figure 1. Stations sampled as part of the core phytoplankton monitoring program.

published. Taxonomy, cell counts, chlorophyll, nutrient, suspended particulate matter and light data, as well as profiles of in situ fluorescence, temperature and salinity, were collected over a 3-year period at five stations by the Bedford Institute of Oceanography (BIO). Photocopied interim reports (Keizer 1991a; 1991b; 1991c; 1991d; 1991e) have been prepared as well as a summary for the "Science Review" (Bugden et al. in press). A technical report should be available in 1992 covering the 3-year study.

Newfoundland Region - Taxonomy, cell counts, temperature, and salinity were collected over a 3-year period (1989-92) at two stations: one at Charles Arm in Notre Dame Bay on the northeastern coast of the island, and the second at Pools Cove in Fortune Bay on the island's southern coast. Suspended particulate matter data are also collected at the Charles Arm site. Both sites are active shellfish farms. Data collected in 1989 have been included in two reports (McKenzie et al. 1990a; 1990b). Further reports and publications are pending for the 1990-92 data.

BRIEF SUMMARY OF THE RESULTS OBTAINED IN THE ATLANTIC ZONE PROGRAM

Phytoplankton Taxonomy - Species which have been shown to produce phycotoxins under certain conditions or to damage the gills of salmonids are listed in Table 1. ASP-producing species include *Nitzschia pungens* f. *multiseries*, *N. delicatissima*, and *N. pseudodelicatissima*; PSP-producing species include *Alexandrium funyense*, *A. excavatum*, and *A. tamarense*; DSP-producing species include *Dinophysis norvegica*, other *Dinophysis* species, and *Prorocentrum lima*. Species which are known to be harmful to finfish include *Gyrodinium aureolum* and *Chaetoceros concavicornis*, which is capable of damaging the gills of salmonids. While usually present in low numbers, it is clear that potentially toxigenic species are found at each station and that most are widespread in the Atlantic region. Therefore, there is the potential that toxic events could occur almost anywhere if the environmental conditions are right.

Physical Oceanography - The five stations sampled by BIO represent a wide variety of conditions with respect to their geography, tidal range, freshwater run-off, and aquaculture activity. For example, Woods Harbour and Annapolis Basin have the largest ratios of tidal to non-tidal volume, suggesting that tidal exchange is important at these sites. Annapolis Basin, Ship Harbour, and Tor Bay have comparable, relatively large, ratios of freshwater discharge to non-tidal volume, suggesting the potential importance of this driving force. The annual range of temperature was greater at Tor Bay, Ship Harbour, and St. Margaret's Bay resulting in winter ice formation. Summer temperatures at these three inlets were also higher than at Woods Harbour and Annapolis Basin. This suggests that the larger tidal exchange with the ocean moderates the temperature throughout the year at these two sites. At the stations sampled by BIO, increased vertical resolution of physical variables was achieved

Table 1. Listing of potentially toxic or harmful phytoplankton species which were detected at the monitoring stations. Most species were found in very low numbers.

Station Number	Location	Potentially Toxic/Harmful Species
1	Sainte-Flavie	*Alexandrium* spp., *Dinophysis* spp.
2	Baie-Comeau	*Alexandrium* spp., *Dinophysis* spp.
3	Gaspé	*Alexandrium* spp., *Dinophysis* spp.
4	Gascons	*Alexandrium* spp., *Diniphysis* spp.
5	Sept-Iles	*Alexandrium* spp., *Dinophysis* spp.
6	Port-Daniel	*Alexandrium* spp., *Dinophysis* spp.
7	Carleton	*Alexandrium* spp., *Dinophysis* spp.
8	Grande-Entrée	*Alexandrium* spp., *Dinophysis* spp.
9	Baie-des-Capucins	*Alexandrium* spp., *Dinophysis* spp.
10	Tadoussac	*Alexandrium* spp., *Dinophysis* spp.
11	SE Gulf St. Lawrence	*Alexandrium excavatum, Nitzschia pungens* f. *multiseries, N. delicatissima, Prorocentrum* spp., *Chaetoceros concavicornis, Dictyocha speculum, Gyrodinium* spp.
12	Lime Kiln Bay	*Alexandrium fundyense, Nitschia pseudodelicatissma*
13	Deadman Harbour	
14	Brandy Cove	
15	The Wolves	
16	Digby	*Alexandrium* spp., *Dinophysis* spp., *Prorocentrum* spp., *Nitzschia pungens* f. *multiseries, Nitzschia pseudodelicatissima*
17	Woods Harbour	*Alexandrium* spp., *Dinophysis* spp., *Prorocentrum* spp., *Nitzschia pungens* f. *multiseries*
18	St. Margaret's Bay	*Alexandrium* spp., *Dinophysis* spp., *Prorocentrum* spp., *Nitzschia pungens* f. *multiseries, Nitzschia pseudodelicatissma, Chaetoceros concavicornis*
19	Ship Harbour	*Dinophysis* spp., *Prorocentrum* spp., *Nitzschia pungens* f. *multiseries, Nitzschia pseudodelicatissma*
20	Tor Bay	*Dinophysis* spp., *Prorocentrum* spp., *Nitzschia pungens* f. *multiseries, Nitzschia pseudodelicatissma*
21	Notre Dame Bay	
22	Fortune Bay	

through the use of a portable CTD. Increased temporal resolution of temperature, which may be used to indicate exchange with offshore waters, was obtained from thermographs moored at each sampling site. This enhanced physical data set is being used to characterize interaction with offshore waters at each site. In the Québec Region, results obtained at ten stations sampled by the Maurice Lamontagne Institute (MLI) during the monitoring program (3 years of data) support the hypothesis that the distribution of *Alexandrium* sp. is largely confined to the plumes of the Manicouagan and Aux-Outardes Rivers in the lower St. Lawrence Estuary and to the Gaspé Current in the Gulf.

Chemical Oceanography - The nutrient distributions at the five sites sampled by BIO varied in a manner that is typical of temperate coastal waters. Concentrations of silicate, nitrate, and phosphate were high during the winter months with substantial and rapid reductions in concentrations occurring in the spring as the phytoplankton populations increased. The initial spring depletion of nutrients was generally followed by increased concentrations in the late spring/early summer, and then very low levels were observed for periods of variable duration. In the late fall, a return to the elevated wintertime concentrations was seen. The observed pattern was similar for silicate, nitrate, and phosphate, but essentially complete removal occurred only for nitrate. The nutrient concentrations were generally uniform from surface to bottom at these rather shallow sampling sites. The exception was Ship Harbour where marked vertical gradients and extremely high concentrations in the bottom waters were found for phosphate, silicate, and ammonia in summer and fall.

Database Management - In the initial stages of the program, several meetings were held to discuss database management and to agree on common approaches wherever possible. The St. Andrews Biological Station developed a master list of phytoplankton species with code numbers to which other regions have contributed. The Québec Region developed a data-entry program which they made available to other Regions. Each Region subsequently developed their own database and assumed the responsibility for maintaining it. BIO has put its data into a FoxPro database management system and is pleased with the ease of access. No attempts have yet been made to exchange data between Regions; but, because of the initial coordination steps taken and the compatibility of new software, this should be a relatively straightforward task.

Publications - A number of publications based on data collected have been released and are listed in the "References" section in this report. These are mostly in the form of interim reports, abstracts, and technical reports.

Pacific Region - In British Columbia coastal waters, there are 13 confirmed and one probable harmful/toxic species present (Table 2).

Table 2. Toxic and harmful species in British Columbia waters.

Confirmed Present	Effect
Dinophysis acuminata	DSP
Alexandrium tamarensi	PSP
Alexandrium catenella	PSP
Alexandrium acatenell	PSP
Cochlodinium citron	PSP?
Nitzschia pungens f. *multiseries*	ASP
Nitzschia pseudodelicatissima	ASP
Heterosigma akashiwo	Fish kill
Undescribed *Chloromonad* species	Fish kill
Chaetoceros convolutum	Fish kill
Chaetoceros concavicorne	Fish kill
Gymnodinium flavum	Fish kill
Prorocentrum minimum	Liver damage (in clams and oysters)

ESTABLISHMENT OF PHYTOPLANKTON WATCH PROGRAMS

As described above, the initial 3-year program had rather broad objectives to improve our scientific understanding of the occurrence of harmful phytoplankton species. It did not address the needs of DFO Inspection Services Branch and the aquaculture industry to have an early warning of blooms of potentially toxic species. Therefore, a number of phytoplankton watch projects have been established which involve DFO Science, DFO Inspection Services Branch, provincial agencies, and industry. These are reviewed below, by Region. These projects focus on those few species which are potentially dangerous and provide information on the day of sampling.

Pacific Region - A phytoplankton watch project was established in the summer of 1986 after a massive bloom of *Heterosigma akashiwo*, which caused heavy fish mortality. It has been operated and funded jointly by the aquaculture industry and the provincial government. The project focuses on education, data gathering, communication, and standards. Until this year, a project coordinator has, among other duties, alerted fish farms of impending harmful bloom situations. A toll-free 1-800 telephone line and direct telephone calls to each farm were the main communication links. The project is being reorganized this year, being decentralized to areas where fish farms are congregated, such as northern Vancouver Island and the west coast of Vancouver Island. The new structure has not yet been finalized.

Québec Region - DFO Science immediately screens samples collected as part of its regular program for potentially dangerous species and reports any evidence of developing blooms to DFO Inspection Services Branch.

Gulf Region - Starting in 1988, DFO Science first operated and then helped the Inspection Services Branch set up its own phytoplankton watch project. Samples are collected on a regular basis at over 30 locations. Phytoplankton monitoring is also conducted by the PEI Department of Fisheries and Aquaculture at 16 sites throughout the province (Bernard 1991).

Scotia-Fundy Region - The St. Andrews Biological Station immediately screens samples collected as part of its regular program for potentially dangerous species and reports any evidence of developing blooms to DFO Inspection Services Branch in Blacks Harbour. Inspection Services Branch in Halifax has recently initiated a phytoplankton watch project along the Atlantic coast of Nova Scotia which is conducted under contract through the Aquaculture Association of Nova Scotia using Economic Regional Development Agreement (ERDA) funding arranged by the Nova Scotia Department of Fisheries (up to October 1992).

To improve the exchange of information on phycotoxin events, a bloom alert network has been established in the Atlantic Zone. Members include DFO Science, Inspection Services Branch, National Research Council, provincial agencies, and the aquaculture industry. Members transmit information of interest by way of fax.

PLANS FOR THE FUTURE

An inventory of all available Canadian databases, including phytoplankton taxonomy, is being compiled by R. Forbes of the Institute of Ocean Sciences. A progress report has been presented at the Mont-Joli workshop.

After 5 years of experience in monitoring phytoplankton, DFO has identified four different kinds of phytoplankton-monitoring projects which are defined as follows.

Long-Term Trend Monitoring - The objective of long-term trend monitoring is to seek and explain gradual changes in species composition and abundance over decadal time scales. They require a long-term commitment at the outset. These stations should be limited in number, selected with care, and institutionalized so that their continuance is not dependent on specific individuals.

Monitoring in Support of Research Programs - These projects will be somewhat flexible and change in design with time depending on results. The initial 3-year DFO Science program falls under this category.

Samples Opportunity - Despite the numerous projects undertaken in recent years, there are many areas important to fisheries for which we have very little information on phytoplankton taxonomy. For example, all stations sampled to date are coastal, and there are none on offshore fishing banks. It is, therefore, important to collect samples on an opportunistic basis whenever conditions allow, even if only once each year.

Phytoplankton Watch Monitoring - As defined above, this type of monitoring provides an early warning of potential problems to regulatory agencies and industry. This can also be a valuable source of biogeographic and floristic data.

Regional plans for continuing phytoplankton monitoring projects are reviewed below.

Pacific Region - DFO is initiating a research project at three to four sites in the Strait of Georgia and on the west coast of Vancouver Island. The major objective is to improve our understanding of the physical and chemical processes leading to monospecific blooms of harmful species in the Region. The nature of the sampling program will also allow the data to be used for monitoring purposes. The sites are chosen so that they may later be incorporated into a long-term trend monitoring project. In addition, sampling kits have been placed on DFO patrol and science vessels, which, with coordinated reports from Fisheries Branch aerial patrols, allows for comprehensive monitoring of opportunity along the coast (Forbes 1991). The industry-supported phytoplankton watch program will continue in a new format, including links to a companion program in Washington State (Horner et al. 1991).

Central and Arctic Region - Tentative Regional plans for phytoplankton monitoring for the coming year will include: 1) Monitoring the phytoplankton, both pelagic and benthic if possible, from the mussel sampling sites on the Yellowknife and Cameron Rivers in the Northwest Territories. It is hoped to be able to get phytoplankton samples to Winnipeg every 3 weeks through the open-water season and enumerate species and biomass. Culturing and isolation of specific species will be attempted if and when a bloom appears to be developing. 2) Monitor acidified lake-302 South at ELA for blooms of the dinoflagellates *Gymnodinium* and *Peridinium*, concentrate by selective filtration, and analyze for toxic compounds. Also attempt to get one or both of these algae into culture. Neither of the above are long-term projects and will be assessed at the end of the year to see if they are worth continuing given the fact that costs will have to be covered by other projects. Not being planned for the coming year is any further research on the east coast. Sufficient data have been gathered, and analysis is underway.

Québec Region - The current 10 stations will continue. A long-term trend-monitoring station will be established at Sainte-Flavie (MLI). Nutrient concentrations (nitrate, nitrite, silicate, phosphate, ammonium, and urea) will be determined weekly at this station. An additional two to three stations will be sampled in the Magdalen Islands and in the Baie-des-Chaleurs in support of research projects. DFO Science will continue to screen samples and pass along to Inspection Services Branch any information on pending blooms.

Gulf Region - The establishment and location of long-term trend monitoring stations are being considered. Monitoring in support of research projects will continue at New London Bay, Cardigan, Brudenell, Murray, and Miramichi Rivers. DFO Inspection Services Branch will continue to operate the phytoplankton watch project at about 30 stations.

Scotia-Fundy Region - Four long-term trend monitoring stations are being established. Three of these stations were established as part of the initial DFO program (Lime Kiln Bay, The Wolves, and St. Margaret's Bay). The fourth will be established at Sambro Head at the mouth of Halifax Harbour near Chebucto Head. Monitoring at Annapolis Basin and Ship Harbour will continue, although with altered sampling schedules, for at least 1 year in support of ongoing process-oriented studies. Monitoring will also be done on an opportunistic basis on Georges Bank, Western Bank, and in the Bras d'Or Lakes. St. Andrews will continue to screen samples collected in the Quoddy region for problem species and alert Inspection Services Branch if necessary. The Aquaculture Association of Nova Scotia will continue to conduct the phytoplankton watch project until at least October 1992 (when current funding expires).

Newfoundland Region - The phytoplankton project at two shellfish farms was completed as of March 1992. No further plans for phytoplankton monitoring have been finalized as yet.

It is very important that the data collected in all phytoplankton monitoring projects are properly managed, analyzed, reported, and made available to interested parties. As discussed above, each Region has the responsibility of constructing and maintaining its own database. A good start has already been made with data analysis, and several technical publications have appeared. It is anticipated that scientific papers will soon be forthcoming. At some stage in the near future, it would be interesting to compare the data from different regions and prepare a zonal overview. The total database provides a wealth of information for comparing the environmental properties and dynamics of coastal inlets, estuaries, and bays - especially in the Atlantic region.

REFERENCES

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