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"MONITORING OF ENVIRONMENTAL IMPACTS FROM SCIENCE AND OPERATIONS IN ANTARCTICA"

A Report

for

The Scientific Committee on Antarctic Research (SCAR)
and
The Council of Managers of National Antarctic Programs (COMNAP)

July 1996

Acknowledgments

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EXECUTIVE SUMMARY

Monitoring is a fundamental element of environmental management and conservation. It is clear that coordinated, standardized approaches to environmental monitoring are essential if temporal and regional trends in the quality of the Antarctic environment are to be effectively determined. Sharing of experiences and findings from environmental monitoring amongst Antarctic operators is essential to maximize return from invested resources. While a number of national programs have conducted localized assessments of the impact of human activities there has been little coordination of methodologies, study designs, or data interpretations. International coordination of monitoring activities will significantly contribute to the management of human activities in Antarctica.

The following points summarize important concepts and approaches that are essential to the meaningful and realistic development of environmental monitoring programs in Antarctica:

- Environmental monitoring of human activities and impacts is only useful when it is firmly tied to an environmental management strategy.

- There are three distinct objectives for monitoring in Antarctica: (1) to protect the scientific value of the Antarctic, (2) to help in the continuous improvement of Antarctic environmental management, and (3) to meet the legal requirements of the Protocol and national legislation.

- Environmental monitoring is precisely targeted measurement of key species, processes or other indicators, carefully selected on the basis of scientifically-sound, predetermined criteria. Environmental monitoring is not the measurement of every constituent and biological population in an attempt to detect change.

- Environmental monitoring of human activities and impacts requires coordination with monitoring of basic meteorologic and hydrologic parameters. Appropriate interpretation of monitoring data can only occur by considering the environmental setting.

- Environmental monitoring programs may include: desk top assessments of inputs and outputs; measurement of outputs; measurement of indicators of change in environmental matrices (air, water, sediments); measurement of indicators in the value or resource of concern; and measurement of biological indicators at the individual, population, or community level.

- A generic hypothesis to cover all environmental monitoring would be *the activity of concern causes no unacceptable deterioration of values or resources*.

- Specific hypotheses appropriate for activities occurring at a location and the values in the area that may be impacted must be developed on a case-by-case basis.

- Actual on-site situations are complex and a prioritization of activities thought to contribute to impact must be developed on a case-by-case basis.

- First order changes in the environment are often most clearly recognized as a physical or chemical change.

- A key principle in considering the importance of anthropogenic impacts is that the scientific value of Antarctica is an important resource to preserve.

- Very low level alterations might be significant from a scientific viewpoint and technologies may not be routinely available to detect these changes.

- Biological monitoring and physicochemical monitoring are required to adequately support management decisions.

- Biological monitoring indicates whether outputs have impacted the adjacent environment as well as serving as a direct measure of change in a value, e.g., the biota.

- Biological monitoring is most valuable for ice-free stations, field camps of a permanent or semi-permanent nature where flora and fauna normally exist, and the marine environment.

- The decision to undertake biological monitoring needs to be assessed on the basis of the proximity of biota to stations or field camps and other human activities, the likelihood of impact, utility of the data produced, logistical practicalities, and cost.

- There are a series of basic tenets for the design of appropriate monitoring programs including: have a clear question, have controls, have a balanced design, have replicates randomly allocated, perform preliminary sampling (pilot study), assess the sampling methods, estimate error variability, determine natural environmental patterns, determine if the statistical analysis assumptions are satisfied, and accept the results.

- Based on the activities known to occur in the Antarctic typical monitoring scenarios include: accidental, chronic, and cumulative impacts.

- Features of Antarctica that should be considered when designing monitoring programs include a lack of background data, the wide separation between sites, the structure of food chains, and growth rates and geographical patterns of organisms.

- The development of recommended monitoring techniques for parameters of relevance in the Antarctic would be useful both in standardizing monitoring and avoiding duplication of effort by providing advice to operators in developing monitoring activities.

- It will not be possible to meet the environmental monitoring requirements of the Treaty without an effective data management system.

- Free access to and wide availability of data are important to national program managers so that locally collected data can be examined in a broader context.

- Long-term preservation of data is important in ensuring that baseline information can be developed against which to measure change.

- Subaliquots of all samples collected during environmental monitoring in Antarctica should be preserved and archived.

- A feedback mechanism is necessary to determine whether monitoring is effective and hence whether it should continue to be supported or how it can be improved.

- Performance of the monitoring program should be judged with reference to the objectives of the monitoring program. These objectives will be set in response to three types of requirements: (1) Protocol; (2) scientific, and (3) practical.

- Environmental monitoring should be periodically reviewed by the individual national programs.

Based on these deliberations a series of recommendations for future action will be provided.

DEFINITION OF TERMS

The field of environmental monitoring contains a wide variety of terms which are often used with conflicting definitions. For the purposes of this report the following definitions will be used.

ACTIVITY - An event or process resulting from the presence of humans in the Antarctic.

EXPOSURE - The process of interaction between the output and a value or resource. Output does not necessarily lead to exposure (e.g., a chemical may not be in a biologically available form, a noise may occur when a breeding site is unoccupied).

IMPACT - Change in the values or resources attributable to a human activity. Impact is the consequence (e.g., reduced plant cover) of an agent of change not the agent itself (e.g., acid rain). Synonym - effect.

MONITORING - Standardized measurement or observation of key variables or outputs over time, their statistical evaluation and reporting on the state of the environment in order to define quality and trends.

OUTPUT - A physical change (e.g., movement of sediments by vehicle passage, noise) or an entity (e.g., emissions, an introduced species) imposed on or released to the environment.

SURVEY - A finite duration, intensive program to measure, evaluate, and report on the state of the environment for a specific purpose.

1.0 INTRODUCTION

Environmental monitoring in Antarctica has a long history that can be broadly classified as global or localized based on the spatial scales of interest. A number of scientific programs have gathered data related to global phenomena. Gaseous constituents of the atmosphere have been continuously monitored since the International Geophysical Year (1957). Baseline measurement of pollutants in Antarctic snow and ice have also been conducted. In the context of global phenomena related to human impact, monitoring of "greenhouse gases" (carbon dioxide, methane, nitrogen oxides, CFCs), baseline assessment of heavy metals and acidification, and the monitoring of ultraviolet radiation related to ozone depletion are best known. Data gathered over long periods of time that investigate the status of global phenomena can provide baselines from which the impact of science and operations on the local environment can be assessed.

A number of national programs have conducted localized assessments of the impact of human activities in Antarctica monitoring specific compounds, organisms, and/or activities. However, there has been little coordination or agreement on standardized methodologies so detecting temporal and/or regional trends in environmental quality is difficult. Nevertheless these data are important. While few summaries or bibliographies of monitoring studies in the Antarctic exist, these programs have produced relevant data on the effects of hydrocarbon pollution, heavy metal accumulation in plants, heavy metal persistence and movement in soils, pesticides, and other organic compounds in animals, the effects of trampling on soils and plants, population trends in flora and fauna, the effects of disturbances on bird populations, the effects of marine litter on birds and seals, lake eutrophication due to human activities, and air pollution generated during the combustion of fossil fuels.

The need for environmental monitoring in Antarctica was succinctly stated in a SCAR/COMNAP discussion document in 1992:

> **"Environmental monitoring is a fundamental element of basic research, environmental management, and conservation. The organized and systematic measurement of selected variables provides for the establishment of baseline data and the identification of both natural and human-induced change in the environment. Monitoring data are important in the development of models of environmental processes, which in turn facilitate progress towards a predictive capability to detect environmental impact or change. The collection and evaluation of monitoring data is essential for the detection of human perturbation within the natural variability of ecosystem processes. Since all environmental monitoring must be based on testable hypotheses it can also contribute to advancement in both basic and applied research."**

2.0 RECOGNITION OF THE REQUIREMENTS

The Protocol on Environmental Protection to the Antarctic Treaty calls for regular and effective monitoring to allow assessment of the impacts of on-going activities on the Antarctic environment and associated ecosystems (Article 3.2d and 3.2e). The goals of monitoring should include, but not be limited to, verification of predicted impacts and early detection of "unforeseen effects." The latter is logically inconsistent by definition and is explicitly dealt with later in this report.

At ATCM XV (1989) environmental monitoring of human impact was discussed under several agenda items, particularly item 9(a). The Meeting adopted Recommendation XV 5 which set out a series of activities that should be monitored (i.e., waste disposal, contamination by oil and hazardous or toxic chemicals, construction and operation of logistic support facilities, conduct of scientific programs, and recreational activities). It was clear that for monitoring programs to be implemented they must be compatible with the realities of Antarctica. It was recommended that a Group of Experts be convened to provide advice on a range of topics essential for meaningful monitoring programs.

ATCM XVI (1991) continued the discussions on environmental monitoring. SCAR and COMNAP provided a discussion paper on the topic which served as the principal source of information. The implications of impacts related to the presence of humans and the lack of agreed principles for monitoring were discussed under several agenda items. It was decided that a specialized meeting would be required to further develop the initiative. Accordingly, the terms of reference for the First Meeting of Experts (as defined in ATCM IV-24) were developed and defined in paragraph 66 of the ATCM XVI report (Table 2.1).

The First Meeting of Experts was convened in June 1992 in Buenos Aires and provided a report to ATCM XVII in November 1992. The report contained nine recommendations. The first eight recommendations concerned the selection of representative facilities for monitoring, development of an international data management system to exchange environmental monitoring data, development of an Antarctic Data Directory, establishment of national scientific advisory boards for guidance on science and data management, development of standards to minimize the impacts of fossil fuel combustion, development of formats for long-term monitoring programs, establishment of a base-line surveillance program for the Southern Oceans, and ensuring the coordination of complementary ecosystem related research and monitoring activities. The ninth recommendation proposed a meeting of technical experts be convened to consider the design of monitoring programs, scientific protocols for monitoring, standardization and quality assurance, applicable technologies, and data management.

At ATCM XVIII in April 1994 SCAR and COMNAP offered to convene and sponsor the follow-on workshops and the Terms of Reference were agreed. It was deemed important to build international consensus and to make optimum use of monitoring expertise outside of the Antarctic community. Details of the workshops were circulated to all SCAR National Committees, to all MNAPs and to all NGOs with an active interest in Antarctica.

Table 2.1. Terms of reference provided by ATCM XVI for the First Meeting of Experts on Environmental Monitoring in Antarctica held in Buenos Aires, Argentina from June 1-4, 1992.

To Consider Monitoring for the following Purposes:

To obtain a regular and verifiable record of activities and environmental data necessary to:

- assess and quantify impacts of activities, including impacts predicted in the course of environmental impact assessments;
- provide early warning of negative impacts;
- identify preventative or remedial measures needed to reduce or eliminate adverse impacts;
- plan similar activities in the future.

Topics to be Considered by a Group of Experts:

- Identification of the nature and possible significance of adverse impacts on the values of Antarctica as set forth in Article 3 of the Protocol on Environmental Protection to the Antarctic Treaty which might require monitoring;
- Identification of activities, environmental and other data required to detect and monitor possible impacts and to distinguish these impacts from natural variability;
- Identification of methodologies and technologies available for monitoring (especially inexpensive and automated systems);
- Identification of steps needed to create national and cooperative data systems which would provide for collection, quality control, archiving, evaluation, exchange and retrieval of environmental data;
- Identification of existing relevant data sets, including baseline data repositories, including programs which generate these data.

The scope and complexity of the subject made it necessary to divide the deliberations into two interconnected workshops. The first workshop was tasked with developing options for monitoring the impacts of human activities associated with scientific research and logistical operations. The second workshop examined the priorities identified by Workshop 1 and assessed methodologies, applicable technologies, study designs and data management practices needed to ensure the implementation of meaningful monitoring programs. A mechanism to judge the success or failure of any program implemented was also discussed.

The workshops served as a forum to bring together Antarctic science and logistics experts and environmental scientists from outside the Antarctic community. The workshops attracted experts from a broad range of disciplines (see Volume 2). The assembled group was charged with developing a consensus on an approach to monitoring that would be practical, scientifically sound, realistic, and cost effective while still meeting the requirements of the Protocol and the Treaty. The results of the workshops are reported here. The recommendations of these workshops will be thoroughly reviewed by SCAR and COMNAP before a report is provided to ATCM XX in 1997.

3.0 TERMS OF REFERENCE

The Terms of Reference as outlined by ATCM XVIII are given in Table 3.1. Due to the complexity of the issues and the overlapping nature of many of the topics, a cross-reference between the Terms of Reference and the applicable sections of this report is also provided in Table 3.1.

4.0 PROTOCOL REQUIREMENTS

In developing guidelines for monitoring, it is essential that the legal requirements under the Treaty system be met (Table 4.1). In most cases these requirements arise from the implementation of the Protocol by national legislation. There are also instances where countries have decided that existing national environmental legislation is applicable to their nationals and programs in Antarctica. This report only considers legal requirements arising from the Protocol itself.

It was considered that references to monitoring in the Protocol could be categorized under the following headings:

(i) global process monitoring,

(ii) record keeping and compliance monitoring,

(iii) monitoring the impacts of activities,

(iv) operational activity monitoring, and

(v) functions of the Committee on Environmental Protection (CEP)

Item (v), the functions of the CEP with regard to environmental monitoring, was considered to be outside the terms of reference and therefore is not considered further.

Table 3.1 Terms of Reference and Related Portions of this Report

Terms of Reference	Applicable Report Section
1. To review the priority of impacts which need monitoring, taking into account the activities and impacts identified by ATCM XVIII namely:	
• station and airstrip logistics operations;	7.0
• waste water and sewage;	4.4, 7.0, 8.2
• incineration of waste;	7.0, 8.1
• power and heat generation;	7.0, 8.7, 9.2
• accidental fuel spills;	7.0, 8.3
• human impact on flora and fauna; and	4.4, 7.0, 9.0
• scientific research	7.0, 8.8, 9.0
2. To develop hypotheses on which to base the design of monitoring programs.	6.0
3. To provide technical advice, including:	
• minimum monitoring needed to meet the requirements of the Protocol (based on a precautionary approach);	4.0
• baseline information;	4.1, 4.3.1
• ecosystem health indices;	9.0
• key variables to be monitored;	5.0
• design of monitoring programs	10.0
• scientific protocols for monitoring;	10.0, 13.0
• measurement methods, including frequency of measurements;	10.0
• standardization and quality assurance of techniques and data;	10.0, 11.0, 13.0
• applicable technology;	13.0
• data management; and	11.0
• criteria for judging whether monitoring program objectives are being met.	12.0

Table 4.1 Antarctic Environmental Protocol References to Monitoring

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1. GENERAL ENVIRONMENTAL PROTECTION AND MONITORING

- **Article 3**. - *The protection of the Antarctic environment and dependent and associated systems and the intrinsic values of Antarctica, including its wilderness and aesthetic value...shall be fundamental considerations in the planning and conduct of all activities in the Antarctic Treaty area.*

- *Activities in the Antarctic Treaty area shall be planned and conducted on the basis of, information sufficient to allow prior assessments of and informed judgments about, the possible impacts on the Antarctic environment.*

2. SPECIFIC REQUIREMENTS RELATED TO HUMAN IMPACT, RESEARCH, AND MONITORING

- **Article 3**. - *Regular and effective monitoring to assess impacts and facilitate early detection.*

- **Article 8 and Annex I**. - *Prior assessment of the impacts of activities on the Antarctic environment.*

- **Annex I** - *Appropriate procedures, including monitoring be put in place to assess and verify the impact of an activity assessed in an IEE or CEE.*

- **Annex V**. - *The parties shall make arrangements for obtaining and exchanging information on and significant change or damage to any ASMA, ASPA, or Historic Site or Monument.*

3. REFERENCES TO MINIMIZING IMPACT

- *Monitoring may be needed to assess impact under Annex II. Taking of or harmful interference with native flora and fauna shall be prohibited except in accordance with a permit.*

- **Annex II**. - *Precautions are to be taken to prevent the introduction of micro-organisms not present in the native flora and fauna.*

- **Annex III**. - *Production and disposal of wastes are to be reduced so as to minimize impact on the Antarctic Environment and interference with the natural values of Antarctica....*

- **Annex V**. - *Management plans for protected areas should include management activities to protect the values for which special protection or management is required.*

4.1 Global Process Monitoring

Global scientific monitoring was considered to fall outside the remit of the workshops. However, it was recognized that global process monitoring contributes both to the establishment of baselines and to an understanding of ecosystem and environmental processes. In particular, global scientific monitoring is seen to contribute specifically to meeting the requirements of Article 3.2(e) of the Protocol. But references to global process monitoring in the preamble and Article 3 of the Protocol are not considered further.

4.2 Record Keeping and Compliance Monitoring

Some implicit references in the Protocol to monitoring were interpreted as operational procedures for record keeping. An example is the need for garbage and sewage record books. In addition, certain other references in the Protocol, which might be construed as monitoring, were in essence a means of ensuring compliance with permitting regulations. One such example is the need to maintain and exchange records of visits to protected areas under Article 10 of Annex V. Again, these issues are not considered further. These records are seen as a vital resource in interpreting any monitoring results as a first order assessment of activities and their potential for impact.

One other approach which relies on record keeping is that of preparing a mass balance for pollutants. In this the difference between the quantity shipped into the Antarctic and the quantity shipped out provides an estimate of the amount and type of materials left within the Treaty area. Existing records of, for example, fuel utilized within the Antarctic would provide a gross estimate of pollutant input to the Treaty area from the burning of hydrocarbons.

4.3 Monitoring the Impacts of Activities

Article 3 of the Protocol sets out the general principles guiding the conduct of activities in the Antarctic. These include:

(i) monitoring of activities where the activity itself is considered to provide an index of impact;

(ii) monitoring environmental change which is believed to be causally related to a particular activity; and

(iii) monitoring environmental change to assess the accuracy of predictions made as part of an Environmental Impact Assessment (EIA).

The following features were noted:

(i) the reference in Article 3.2(c(v)) to the capacity to monitor implies a recognition that baseline information on which to build a subsequent monitoring program may not always be available. Nevertheless, monitoring should still be undertaken when required. But a clear indication needs to be given in such circumstances of the inadequacies of the baseline data on which the prediction of impacts is based;

(ii) the extension of the principles of the Protocol, including monitoring activities, to wilderness and aesthetic values, might be seen by some as posing problems. However, sound environmental management will provide a primary protection for such values although problems may still exist in agreeing on a standard methodology for application to values such as these;

(iii) Article 3.2(d) contains the only specific reference in the Protocol to monitoring for the assessment of the impacts of ongoing, as opposed to proposed activities;

(iv) the references to "effective" monitoring implies that: anthropogenic effects can be differentiated above background noise, feedback to operational management is essential, and that a predictive capability is desirable;

(v) notwithstanding the mandatory obligation set out in Article 3.2(e), the wording is logically inconsistent insofar as it is not possible to define the monitoring requirements for "unforeseen effects"; and

(vi) the general principles of monitoring apply to all governmental and non-governmental activities in Antarctica including scientific research programs, tourism and related logistic activities.

The most explicit requirements for monitoring are detailed in Annex 1 on EIA. With respect to CEEs there is a mandatory obligation to include appropriate monitoring procedures. No opt-out mechanism is provided. But such monitoring is discretionary for IEEs, recognizing that although an operator may not include monitoring procedures, national authorities subsequently assessing an EIA may require monitoring. Monitoring programs are unlikely to be needed for activities attracting only preliminary assessment although some form of environmental surveillance may be recommended. Nevertheless, where the impacts of such activities are likely to be cumulative, monitoring to verify those impacts would be appropriate.

4.4. Operational Activity Monitoring

In certain contexts the Protocol identifies monitoring requirements to address operational activities. Such requirements include, for example, the need to evaluate environmental impacts of wastes emanating from scientific activities and their associated logistic support (see Article 8 (1) and (2) of Annex III).

The application of general principles such as minimization of emissions and discharges, rigorous audit to eliminate unnecessary generation of wastes, and recycling are assumed to be part of the underlying management philosophy of all Antarctic Treaty Consultative Parties (ATCPs). There is always room for improvements in environmental management in the context of cost/benefit and risk analyses.

5.0 THE FRAMEWORK FOR MONITORING

A fundamental concept is that environmental monitoring of human activities and impacts is only useful when it is firmly tied to an environmental management strategy. Monitoring by itself accomplishes nothing. Before undertaking environmental monitoring it is essential to define why monitoring is required and how the results will be used to direct management decisions. This in turn infers that monitoring should be hypothesis driven and that the hypotheses to be tested should be clearly stated at the outset of the monitoring program.

Another key principle in considering the importance of anthropogenic impacts is that the scientific value of Antarctica is an important resource to preserve. This implies that human-risk based monitoring developed in temperate climates may not be directly applicable to Antarctica. Very low level alterations might be significant from a scientific viewpoint. However, technologies may not be routinely available to detect these changes.

There are three distinct objectives for monitoring in Antarctica:

(i) to protect the Antarctic's scientific value,

(ii) to help in the continuous improvement of Antarctic environmental management, and

(iii) to meet the legal requirements of the Protocol and national legislation.

Within these objectives, the goals of Antarctic environmental monitoring in the Antarctic include (Table 5.1):

(i) establishing the present status of key values and resources,

(ii) providing an early warning of deterioration in key values and resources,

(iii) identifying the activities most responsible for such deterioration,

(iv) providing an evaluation of present activities to forecast and forestall deterioration, and

(v) verifying the effectiveness of predicting impacts through the EIA process.

The use of the term “key values and resources” is consistent with the principle that monitoring is not about the measurement of everything in a haphazard approach to detect change but about precisely targeted measurement of a few species, processes, or other indicators, carefully selected on the basis of scientifically-sound, predetermined criteria.

The recommended stages in developing an appropriate monitoring program are illustrated in Figure 5.1. The management objectives of any monitoring program must be defined at an early stage including specifying informational needs and performance criteria. The second major step is to develop a testable hypothesis specific to the site to be monitored and then implement a pilot study to ensure that the proposed design is feasible. The third stage is to organize and implement the full study utilizing the most appropriate technologies, methodologies, statistical designs, and data management techniques. The fourth stage is the assessment of the data on a regular basis and development of specific recommendations for management actions. Corrective action and review of the original objectives will lead to continuous improvement of the program in the context of the overall management strategy.

Environmental monitoring programs may include the following (Table 5.1):

(i) desk top assessment of inputs and outputs - this is an essential precursor to environmental monitoring that can indicate which activities are of potential concern. It may also satisfy some requirements of record keeping and compliance monitoring, but it does not constitute environmental monitoring *per se* because it does not involve direct measurement of environmental attributes;

(ii) measurement of outputs may satisfy some requirements of record keeping and compliance monitoring as well as contributing to direct environmental monitoring;

(iii) measurement of indicators in the environment (e.g., number of people visiting an area or levels of lead in snow where levels of lead are not of direct interest but are indicative of potential exposure of biota);

(iv) levels in the value or resource of concern (e.g., lead levels in biota or lead of local origin in ice cores being used to monitor global lead levels);

(v) indicators at the individual level (e.g., physiological or behavioral change in biota, change of ice crystal structure);

(vi) population level or univariate changes (e.g., changes in population density, reduced area of terrestrial sediment); and

(vii) community level or multivariate changes (e.g., change in the numerical structure of communities, change in the particle size distribution of a terrestrial sediment).

Table 5.1. Assessment of the ability of some generalized elements of monitoring to satisfy the goals of monitoring.

	Goals of Monitoring		
Elements of Monitoring	Establish the present status of values and resources	An early warning of deterioration in the values and resources	Identify the activities mos responsible for observec deterioration
-top assessment of input/outputs	X	?	?
surement of outputs	X	?	?
ls in environment	?		?
ls in biota			?
idual level parameters (e.g., physiological havioral			?
lation level parameters			?
munity level parameters			?

	Goals of Monitoring	
Elements of Monitoring	Evaluate present activities to forecast and forestall deterioration	Verify the effectiveness of predicting impacts through the EIA process
Desk-top assessment of input/outputs		X
Measurement of outputs		?
Levels in environment		
Levels in biota		
Individual level parameters (e.g., physiological or behavioral		
Population level parameters		
Community level parameters		

= definitely addresses goal; ? = indicative but not conclusive; X = unlikely to address goal

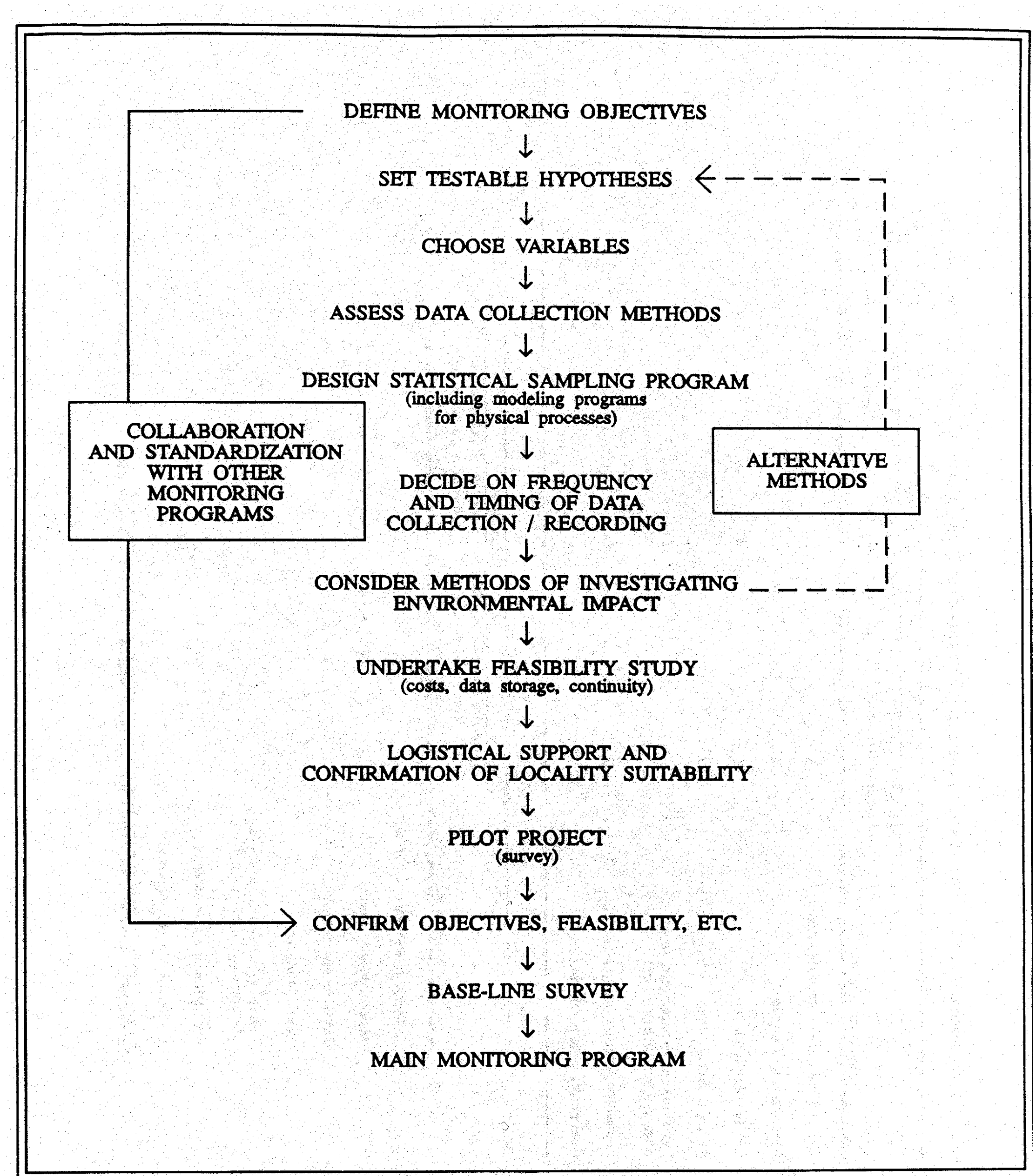

Figure 5.1 Flow diagram for designing an environmental monitoring program for local, regional, or global application (from SCAR/COMNAP Discussion Document, 1992).

Monitoring based on field observations alone generally does not conclusively identify cause and effect relationships. One way to directly address cause and effect issues is through properly designed laboratory and/or manipulative field experiments.

5.1 Criteria for Selecting Parameters for Monitoring

The following criteria were considered essential in selecting variables used for monitoring programs. The variables must:

(i) exhibit changes far in excess of limits of detection,;

(ii) be directly relatable to a testable hypothesis;

(iii) be known or establishable above natural variability (i.e., background);

(iv) give information from which management decisions can be made;

(v) be able to sustain the monitoring activity;

(vi) be able to be sampled within logistical and time constraints;

(vii) be measurable on samples that can be transported without deterioration or be measurable on-site in the field; and

(viii) be amenable to quality assurance procedures including demonstrable precision, accuracy, and reproducibility.

It is also desirable that the variables:

(i) be measurable by cost effective, simple, and standard procedures (if the procedures are non-standard intercalibrations are mandatory);

(ii) be strongly related by what is believed to be a causal link to a particular activity or process;

(iii) be a direct measure of change in a value of concern;

(iv) permit generalizations about causative agents;

(v) be definable in terms of limits beyond which changes are judged to be deleterious; and

(vii) be measurable without conflicting with scientific activities.

6.0 DEVELOPING HYPOTHESES

A generic hypothesis to cover all environmental monitoring would be *the activity of concern causes no unacceptable deterioration of values or resources*. The hypothesis is stated in the negative as it is a null hypothesis and can be refuted. Monitoring should be designed to determine whether the activity causes a deterioration. If an unacceptable deterioration is observed the hypothesis is refuted. It will never be possible to demonstrate conclusively that an activity does not cause deterioration. The generic hypothesis should be used to generate specific hypotheses that are appropriate for particular locations, for the activities occurring at these locations, and the values that may be impacted.

The following examples give some indication of the practical way in which hypothesis framing might work. The focus can be site or impact specific. For example:

(i) output of macerated sewage from a station of 50 people into coastal waters causes no loss in benthic biodiversity from nutrient enrichment,

(ii) accumulation of lead from the burning of hydrocarbons does not impair the growth of Antarctic plants, and

(iii) movement of heavy metal contamination in dry soils is less than 1 m per year.

wide variety of settings represented by Antarctic logistics, science operations, and tourist activities. The intensity, duration, area influenced by the activity, the repetitiveness of the activity, and the potential for cumulative impacts are among the issues that need to be considered on a case-by-case basis. During hypothesis development, each situation must be analyzed, experts conferred with, and a monitoring program designed for each mixture of activities. Fundamental concepts of study design need to be adhered to and appropriate technologies and methodologies to be applied as needed.

7.0 PRIORITIZATION OF ACTIVITIES

To suggest ways in which impacts could be measured one needs to define the activities which could cause impacts. Typical activities practiced in Antarctica were evaluated as to their potential for outputs and impacts (Table 7.1). It is not possible to produce a general prioritization of activities that would be applicable in all situations encountered in the Antarctic. Actual on-site situations are complex and a prioritization of activities thought to contribute to impact is a site specific exercise. The activities of concern need to be assessed on a variety of temporal and spatial scales that are not easily categorized into a general scheme that satisfies the wide variety of settings represented by Antarctic logistics, science operations, and tourist activities. The intensity, duration, area influenced by the activity, the repetitiveness of the activity, and the potential for cumulative impacts are among the issues that need to be considered on a case-by-case basis. During hypothesis development, each situation must be analyzed, experts conferred with, and a monitoring program designed for each mixture of activities. Fundamental concepts of study design need to be adhered to and appropriate technologies and methodologies to be applied as needed.

8.0 MONITORING OF PHYSICAL AND CHEMICAL IMPACTS

First order changes in the environment are often most clearly recognized as a physical or chemical change. The addition of a chemical or the destruction of a physical feature are often the first indication that humans have had an impact on the surrounding environment. Physical and chemical perturbations are also often most directly measurable. In particular, certain anthropogenic chemicals do not naturally occur and thus their presence in the environment can be unambiguously related to human activities. The importance of a variety of physical and chemical inputs to the Antarctic environment are evaluated in Table 8.1.

8.1 Emissions and Dust

Atmospheric emissions from fossil fuel burning (power and heat generation, aircraft, vehicles, etc.), emissions from incineration and other general activities can alter local environments. These activities can result in the introduction of particles as well as specific contaminants to the atmosphere (e.g., polycyclic hydrocarbons probably from exhaust). On a larger scale, they may jeopardize the scientific value of Antarctica for monitoring low-level global changes in atmospheric aerosols. It was considered that particle emission levels on the larger scale were too low for monitoring by conventional means away from stations. It was also noted that monitoring programs must keep abreast of developing technologies especially those using satellite imagery where appropriate.

Local monitoring should include as a minimum a record of the amount of fuel burned and trash (if any) incinerated. This, by itself, will allow first order estimates of mass emissions of particles and of SO_2, NO_X and subsequent modeling of dust and particle plumes. Collection of air samples provides confirmation of estimates. Samples of snow can be used as integrated samples of contaminant deposition. Small scale models using local meteorologic measurements and stack configurations can be used to identify locations for snow sampling. The use of ice cores dated by radiometric or other means could provide a record of contamination as a function of historical station activities just as sediments have been used in temperate climates. The amount of soil deposited in individual layers may be best quantified through microscopic rather than chemical analysis.

8.2 Liquid and Solid Waste

Each station should document the mass emissions (i.e., concentration times flow) of suspended solids, BOD, phosphorus, and nitrogen in its wastewater. For stations with fewer than 20 people this can be estimated with sufficient accuracy on the basis of models based on daily emissions per person. For stations with 20 to 200 people the modeled estimates should be augmented by actual measurements of flow rates each year and analysis of composite samples. For larger stations, monthly measurements may be needed. If actual measurements confirm the modeled estimates they need not be continued.

Table 7.1 Operational Activities: Outputs and Impacts

Activity	Operation	Potential Outpus											
		Air/Exhaust Emissions	Dust	Contaminant	Liquid Waste	Solid Waste	Fuel/Haz Spills	Noise	EMR	Mechanical Actions	Heat	Introductions	Sampling Relocation
Transport	aircraft	x	x	x	-	-	x	x	-	x	x	x	-
	ships/boats	x	-	x	x	-	x	x	-	x	x	x	-
	vehicles	x	x	x	-	-	x	x	-	x	x	x	x
	foot traffic	-	?	-	-	-	-	x	-	-	x	-	-
Station/Camp	power generation	x	-	x	-	-	x	x	-	-	x	-	-
	heating	x	-	x	-	-	x	-	-	-	x	-	-
	water production	x	-	-	x	-	x	-	-	-	x	-	-
	liquid waste disposal	-	-	x	x	-	x	x	-	-	x	x	-
	solid waste incineration	x	-	x	-	-	x	-	-	-	x	-	-
	solid waste disposal	-	-	x	-	x	x	-	-	-	-	x	-
	fuel storage and delivery	-	-	x	-	-	x	-	-	-	-	-	-
	snow dump/runoff mgmt	-	x	x	x	x	-	-	-	x	-	-	x
	warehouse storage	-	-	x	-	-	x	-	-	-	-	x	-
	facility/equip maintenance	-	-	x	x	x	x	x	-	-	-	-	-
	communications	-	-	-	-	-	-	-	x	-	-	-	-
Construction	building (incl. demolition)	-	x	x	-	x	x	x	-	x	-	-	-
	excavation/fill	-	x	-	-	-	-	x	-	x	-	-	-
	airfield	-	x	x	-	-	x	x	-	x	-	-	-
	road	-	x	x	-	-	x	x	-	x	-	-	-
	pier/wharf	-	x	x	-	x	x	x	-	x	-	-	-
	explosives	x	x	x	-	-	-	x	-	x	-	-	-
Science	sampling of flora/fauna	-	-	-	-	-	-	x	-	x	-	x	x
	sampling of rock/sediment/snow/ice	x	x	x	x	x	x	x	-	x	-	x	x
	explosives	x	x	x	-	-	-	x	-	x	-	-	-
	balloons	-	-	x	-	x	-	-	-	-	-	-	-
	field equipment/installations	?	-	x	-	x	x	?	?	x	-	x	-
	chemical release	?	-	x	-	-	x	-	-	-	-	-	-
	EMR generation	-	-	-	-	-	-	-	x	-	-	-	-

x = high potential for outputs
- = low potential for outputs
? = unknown potential for outputs

Table 7.1 Cont.

Activity	Operation	Potential Impacts*: Landscape Alteration	Habitat Destruction	Individual Change	Population Change	Community Change
Transport	aircraft	-	-	x	x	-
	ships/boats	-	-	x	x	-
	vehicles	x	x	x	x	-
	foot traffic	-	-	x	-	-
Station/Camp	power generation	x	x	x	x	-
	heating	x	x	x	x	-
	water production	x	x	x	x	-
	liquid waste disposal	x	x	x	x	-
	solid waste incineration	-	-	x	-	-
	solid waste disposal	x	x	x	x	-
	fuel storage and delivery	x	x	x	x	x
	snow dump/runoff mgmt	x	x	x	x	-
	warehouse storage	-	-	x	-	-
	facility/equip maintenance	-	x	x	-	-
	communications	-	-	x	-	-
Construction	building (incl. demolition)	x	x	x	x	x
	excavation/fill	x	x	x	x	x
	airfield	x	x	x	x	x
	road	x	x	x	x	x
	pier/wharf	x	x	x	x	x
	explosives	x	x	x	x	x
Science	sampling of flora/fauna	-	x	x	x	x
	sampling of rock/sediment/snow/ice	x	x	x	x	x
	explosives	x	x	x	x	x
	balloons					
	field equipment/installations	-	x	x	x	-
	chemical release	-	x	x	x	x
	EMR generation	-	-	x	-	-

*Aesthetic/wilderness disruption and changes to scientific capability are possible impacts that apply to all categories.
x = high potential for impacts
- = low potential for impacts
? = unknown potential for impacts

Table 8.1. Outputs resulting from human activities in Antarctica and principal physical and chemical indicators of their impact.

Outputs	Indicators	Possible Impacts*
Air Emissions	•SO_2, NO_x, CO, PAH, heavy metals, fuel consumed •type, quantity, timing, duration	•landscape, biological change
Dust	•particulates, albedo, water turbidity •type, quantity, timing, duration	•landscape, biological change
Liquid Waste (including brine)	•flow rate, suspended solids, BOD, pH, faecal coliforms, nutrients (PO_4, NO_3, NH_4^+), total Kjaldahl nitrogen •type, quantity, timing, duration	•biological change
Solid Waste (including dumps and debris)	•leachates, foreign materials •type, quantity, timing duration	•landscape, biological change
Fuel/Hazardous Materials (including fuel blowdown)	•PAH (air, water, land/snow), albedo, chemicals, radionuclides, etc. •type, quantity, timing, duration	•landscape, biological change
Noise	•type, quantity, timing, duration	•biological change
Electromagnetic radiation	•type (frequency), quantity (strength) timing, duration	•biological change
Mechanical actions, Constructions, (excavations, fill, explosions, compaction)	•topography, erosion, deposition, vehicle/foot traffic, albedo •type, quantity, timing, duration	•landscape, biological change
Heat	•temperature, thermal regime, timing, duration	•biological change
Introductions, Samplings, Extractions, and Relocations	•alien biota, geological/biological specimens, snow/ice/water levels, •type, quantity, timing, duration	•landscape, biological change

*Biological change covers all changes to individuals, populations, and communities. Habitat disruption is covered under both landscape and biological change. Biological indicators are not included in this table. Aesthetic/wilderness disruption and changes to scientific capability are possible impacts that apply to all categories.

Saline water discharges from desalination operations can be subject to monitoring for their own sake (salt, heat) as well as for the contaminants introduced during the distillation or reverse osmosis process. If distillation is used to produce potable water, chemicals may be introduced through corrosion or added as corrosion inhibitors. These chemicals should be monitored as part of the mass emissions when wastewater is discharged.

Spot sampling of effluents will also detect the discharge of solvents into drains which is in violation of most operating procedures.

The objective of monitoring run-off streams is to quantify the mass emission of suspended solids and petroleum hydrocarbons in snow melt emanating from a station. This requires measuring suspended solids concentrations, total petroleum hydrocarbons, and flow.

The need to monitor receiving water quality depends on the mass emission of contaminants and the rate of water renewal in the receiving stream. Rates of oceanic water renewal can be measured primarily by extracting residual current data from current meter records. Dissolved oxygen, water clarity, and nutrients can be measured near and away from wastewater outfalls. Small inputs into swift currents will leave no trace, while emissions into stagnant waters can induce large changes.

It is recommended that dissolved oxygen, water clarity, and nutrients be measured near and away from wastewater outfalls.

Under the Environmental Protocol each nation is required to remove solid waste after each season. Past waste is to be removed or contained and a survey should be conducted to document the effectiveness of the containment if removal is not feasible.

The Environmental Protocol prohibits dispersal of solid waste so, in principle, there should be no debris in the vicinity of stations. However, what debris there is should be cleaned up and, in the process, monitored. CCAMLR has published guidelines for conducting surveys of beach debris that could be followed at scientific stations and field sites. Underwater debris is not so readily removed. Seafloor observations by divers or by remotely operated vehicles can quantify the extent of submarine debris near scientific stations. Trawling for this purpose can cause a significant disruption of seafloor biota and potentially redistribute debris over a wider area.

Sediments in the receiving waters serve as integrators of contaminant inputs. Sediment analyses can be used to indicate the extent of change caused by scientific stations. A major proviso, however, is that sand as opposed to silt and clay has too low a specific surface area to adsorb contaminants in other than very low amounts. Therefore, prior to monitoring sediments, grain size should be determined. Sediments with more than 80% sand should be analyzed for hydrocarbons (because freshly added oil will remain in the interstices of sand) but not analyzed for other chemicals. Sediment containing at least 20% fine-grained material are suitable for the analysis of total organic carbon (TOC) and total trace elements (Cu, Zn, Ni, Pb, Hg, Cd, and Ag) as tracers of human activity in addition to organic contaminants.

It may also be appropriate to measure contaminants in benthic marine organisms. Two species of bivalve mollusks are ubiquitous in Antarctic waters, the clam (*Laternula elliptica*) and the scallop (*Admussium colbecki*). Annual collections of one or the other can provide tissues whose concentrations of chemicals will change in response to changes in discharges. The utility of the "Mussel Watch" approach to temporal monitoring should be considered at selected sites.

8.3 Fuel and Hazardous Material Spills

The Standing Committee on Antarctic Logistics and Operations Programs (SCALOP) has requirements for reporting accidental spills. These require that records be kept of the type, amount, and estimated recovery of spilled material. Such records should be extended to historical spills, if the information is available. Chemical measurements can delineate the extent of contamination around stations due to chronic discharge of various hydrocarbon based fluids.

Some engines, in particular helicopter engines, are designed to emit raw fuel (mostly in gaseous form) through their exhaust pipes when turned on and off. This blowdown amounts to a controlled spill and is apparently avoidable. It would be difficult to monitor contamination related to blowdowns.

8.4 Noise

The problem of aircraft noise is recognized as a disturbance to bird rookeries. There are guidelines already in place to limit this disturbance. Information is extremely limited on the interaction of Antarctic systems and noise.

8.5 Electromagnetic Radiation

Electromagnetic radiation is being addressed under other auspices.

8.6 Mechanical Actions and Construction

Physical changes in the landscape around the stations could be monitored through systematic and periodic photography and updating of maps. High resolution satellite imagery would be useful in addition to ground based measurements. Survey benchmarks can be installed for future reference to monitor vertical changes from subsidence or other landscape changes resulting from human activities.

8.7 Introductions, Samplings, Extractions, and Relocations

The introduction of alien biota is clearly prohibited by the Protocol. Scientific activities themselves can result in impacts due to sampling, extraction, and relocation of materials from the site of origin. These impacts can be minimized by requiring collection and disposal of any by-products produced as a result of sample collection or extraction.

9.0 MONITORING LOCAL IMPACTS ON BIOTA

Biological monitoring indicates whether outputs have impacted the environment as well as serving as a direct measure of a value, i.e., the biota. The range of biological methods available is wide and there is considerable variation in the ease with which these methods can be used and the extent to which inferences can be drawn.

One method for the selection of organisms and indicators is presented as a decision tree in which the first choice is identification of the activity type at a particular site as permanent, semi-permanent, or transient (Figure 9.1). This is followed by a description of the site in terms of the environmental setting namely ice-free, perennial ice cover, or open ocean. Next the geographic setting is defined as land or nearshore and then as terrestrial, freshwater, or marine. For all activities on perennial ice or on the ocean it was considered impractical to use biological indicators for monitoring. Next, significant biological impact may be associated with contamination, sedimentation, enrichment, and disturbances as produced by various outputs, such as noise, mechanical actions, sampling, and so forth.

Based on the outputs and activity types a range of biological organisms can be chosen as indicators of change or impact. The most useful biological variables are summarized in Table 9.1 based on habitat. Having followed the decision tree, organisms which are candidates for monitoring are identified.

While the use of biological indicators of change is a complex issue, careful consideration of the current understanding of the interactions between biological organisms and human activities is needed in order to produce useful information for managers. The strength of biological monitoring lies in its capacity to detect secondary and tertiary impacts of physical and chemical outputs. Biological organisms are often the most immediate and visible resource of concern. To illustrate how biological monitoring can assist in the formulation of management policy, the suitability of various species as indicators of impact was evaluated at three levels: the individual, the population, and the community (Table 9.1). A four-point scale was used to evaluate whether the indicator species was highly recommended or not recommended. Evaluations were based on variable selection criteria outlined in Section 5.1. For practical reasons, it was not possible to evaluate every parameter for every species by every criterion (e.g., simplicity, cost, feasibility, effectiveness, availability of suitable techniques). Specialist biology groups are needed to undertake further more detailed evaluations of the suitability of various indicators. Table 9.1 is only indicative of the approach and is not meant to be comprehensive or exhaustive.

Indicators based on population structure, species abundance, and spatial and temporal distributions were considered most suitable for biological monitoring. Often the most noticeable change, as far as the public is concerned, is in the populations of highly visible species (i.e., penguins, seals, birds). However, the time scales over which changes occur (years) and the extent of natural variability may make monitoring of these animals unsuitable for the purposes of management decision-making. Certain species are more suitable as indicator species of specific outputs (e.g. lichens for evaluating the presence of trace elements in the environment).

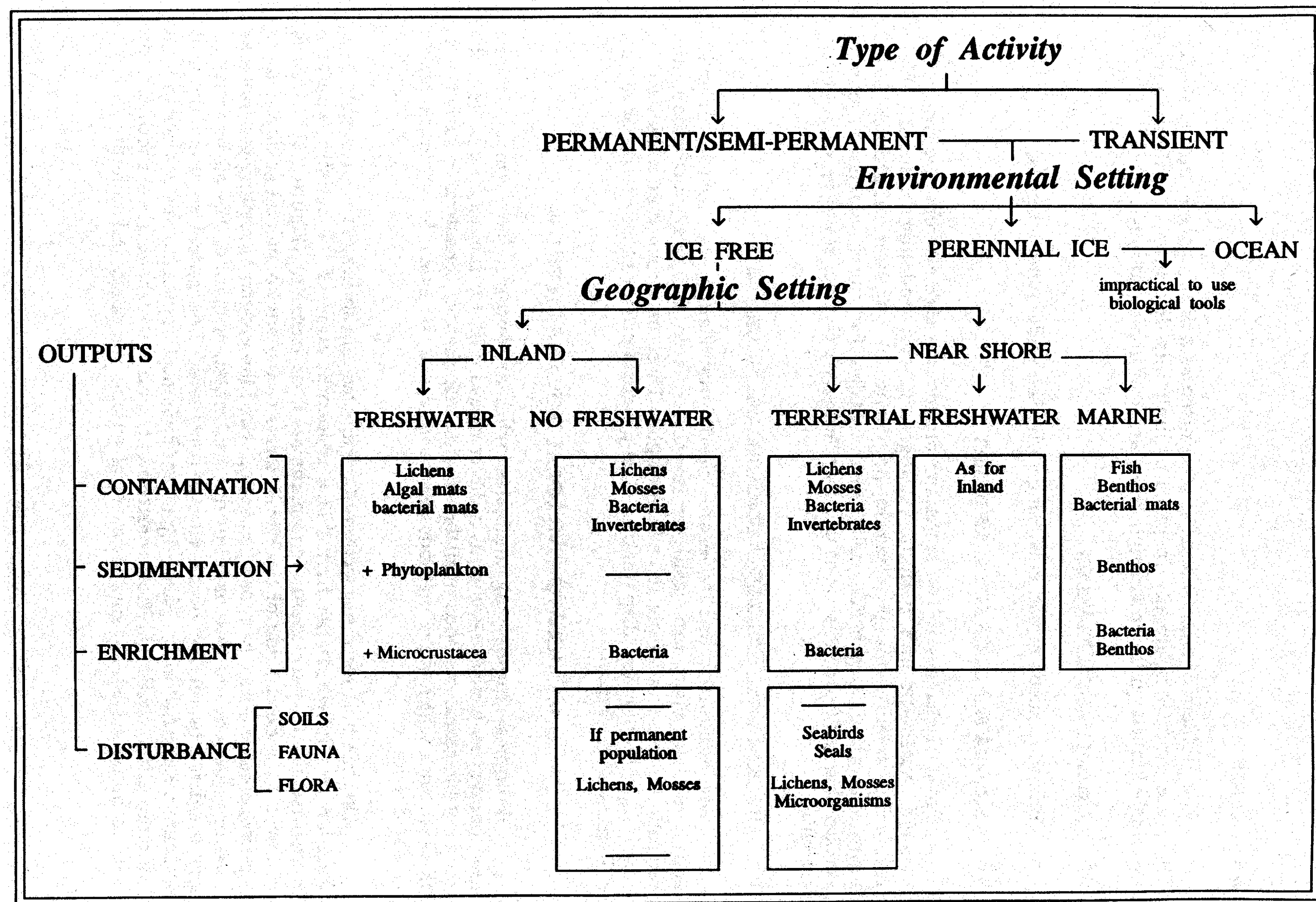

Figure 9.1. Decision tree for selection of biological parameters to monitor.

Background ecological information on many species is often limited. Identification of some organisms may prove difficult. Natural variability of indicators based on species such as seals and penguins may make meaningful inferences from population dynamics difficult to interpret due to a variety of confounding natural influences. Many major food chains in Antarctica are marine driven and the larger species are not dependent on the *in situ* prey.

Therefore, accumulation of toxic substances through food chains are more likely to reflect inputs of regional origin rather than local emissions. These constraints are considered further during study design discussions (Section 10.2).

Cause and effect relationships are difficult to discern in relation to changes in populations and/or species and caution is needed in inferring such linkages without considerable supporting evidence. It is also required that biological, as well as physical and chemical, monitoring be coordinated with basic meteorological and hydrologic monitoring in order to interpret the patterns observed. It was clear that many of the sought after integrative indicators of ecosystem health are not well understood. Much remains to be done in developing an understanding of the fundamental processes, controls, interactions, and responses of Antarctic organisms to environmental and human perturbations.

Table 9.1 Monitoring Options for Local Biological Impacts: Methodologies, Applicable Technologies, and Experimental Design

Indicator Species	Existing Monitoring Program	Change at the Individual Level: Levels of Contamination in Biota	Physiology	Behavior
Terrestrial Site				
Birds	CEMP[a]	3+	1	1-3
Plants		-		
Lichens	BIOTAS	1		-
Mosses		2	4	-
Microorganisms	BIOTAS	4	1	-
Invertebrates	BIOTAS	4	-	-
Freshwater Site				
Streams				
Algal mats		1	4	-
Bacteria		-	3	-
Invertebrates		3	-	-
Lake/Pond				
Algal Mats		1	4	-
Phytoplankton		4	4	-
Microcrustacea		4	4	4
Bacteria		1	2	-
Marine Sites				
Seals	APIS[b]	?	?	4
Fish	FSA[c]	1	1	3
Zooplankton		4	4	4
Phytoplankton		3	4	-
Benthos				
Infauna		1	3	4
Epifauna		1	3	4
Bacterial mats		-	-	-

1-Highly recommended
2-Moderately useful
3-Possibly useful
4-Not recommended
- Not Applicable
?-Unknown
[a]CEMP - CCMLAR Environmental Monitoring Program
[b]APIS - Antarctic Pack Ice Seals
[c]FSA - Fish Stock Assessment Program

Table 9.1. Cont.

Indicator Species	Change at Population Level: Abundance	Distribution	Reproductive Success	Change at the Community Level: Structure	Diversity (composition and structure)
Terrestrial Site					
Birds	1	1	1-2	3	-
Plants					
Lichens	1	1	-	-	2
Mosses	1	1	4	-	3
Microorganisms	3	1	-	-	4
Invertebrates	2	1	3+	3+	1
Freshwater Site					
Streams					
Algal mats	1	1	4	-	3
Bacteria	1	2	4	-	4
Invertebrates	-	-	-	-	-
Lake/Pond					
Algal Mats	1	3	4	-	4
Phytoplankton	2	4	-	-	2
Microcrustacea	2	4	4	4	3
Bacteria	1	3	4	-	4
Marine Sites					
Seals	3	3	2	4	-
Fish	3	3	3	4	3
Zooplankton	4	4	4	4	4
Phytoplankton	4	4	4	4	4
Benthos					
Infauna	1	2	3	3	4
Epifauna	1	2	3	3	1
Bacterial mats	1	1	-	-	-

1-Highly recommended
2-Moderately useful
3-Possibly useful
4-Not recommended
- Not Applicable

10.0 DESIGN OF MONITORING PROGRAMS

There are a series of basic tenets for the design of monitoring programs (see Figure 5.1):

(i) **Have a clear question**. The thought process should be: question=>hypothesis=>variables=>model=>statistics and tests of hypotheses=>interpretation.

(ii) **Have controls**, both spatial and temporal where appropriate.

(iii) **Have a balanced design**, e.g. similar sampling effort at each impact level and time.

(iv) **Have replicates**, **randomly allocated**.

(v) **Conduct preliminary sampling (pilot study)** in order to do the following (vi-ix):

(vi) **Assess the sampling methods** to ensure they are efficient and do not introduce bias into the study. Adequate quality assurance must be applied from initial sample collection, through transport to the laboratory, and during the analysis.

(vii) **Estimate error variability** and necessary sampling effort to achieve the desired power.

(viii) **Determine natural environmental patterns** to be incorporated into the study design (e.g., stratification).

(ix) **If statistical analysis assumptions are not satisfied** (they probably won't be) then transform variables before analysis, use nonparametric methods, or use simulation or randomization methods.

(x) **Accept the results**. It is acceptable to set multiple criteria (e.g., Type I and II error levels) *a priori*. It is acceptable to conduct a new study to check on results you do not believe. It is acceptable to change the sampling design during a study if you do it in a way that preserves compatibility of post-change data with pre-change data for statistical analysis purposes. But don't try to find statistical methods that give you the result you want.

10.1 Typical Antarctic Impact Scenarios

Based on the activities known to occur in the Antarctic, typical monitoring scenarios were defined and the design elements outlined above were discussed for each scenario.

10.1.1 Accidental Impacts

The design of a program to monitor an accident (e.g., a spill) based on the above 10 steps, should include the following:

(i) **Have a clear question.** The hypothesis is likely to be formatted in terms of the spatial extent of detectable change and time to recovery.

(ii) **Have controls.** Optimum spatial or temporal controls may not be available because the site of the accident will not have been chosen. Spatial controls are more likely to be available. Pre-accident (temporal control) data may be serendipitously available.

(iii) **Have a balanced design.** Sampling should be balanced within the limitations of suitable controls.

(iv) **Have replicates randomly allocated.** Yes, however it is unlikely you will be able to replicate the spill and so should consider the limits of generalizations that are possible with replication only at the sampling level.

(v) **Conduct preliminary sampling (pilot study).** Yes, however there may be considerable pressure to get on with the "real" sampling program and the luxury of commencing sampling in the fullness of time may not be available.

(vi) **Assess the sampling methods.** Yes - see (v) above.

(vii) **Estimate error variability.** Yes - see (v) above.

(viii) **Determine natural environmental patterns.** If stratification is identified, it may be more efficient to concentrate only on a single stratum. Sampling of all strata may spread resources too thinly and limit the rigorousness of the study. Stratified sampling may be used to reduce the effects of background variability.

(ix) **If statistical analysis assumptions are not satisfied,** bring in a statistician at the planning stage rather than after the samples have been taken.

(x) **Accept the results.** Establish a single statistical test criterion or, alternatively, establish multiple criteria *a priori*.

10.1.2 Chronic Impacts

Monitoring of chronic impacts from point sources (e.g., sewage discharges) should include these essential elements:

(i) **Have a clear question.** Such studies will be most valuable if the hypotheses address cause-effect relationships. This can be done by selecting a series of sampling sites representative of a range of operational processes with each category of process replicated. For example, to determine the effect of sewage effluent disposal on the benthos, factors may include the number of people on station and the type of sewage treatment. Select a number of stations representative of each size or treatment type, and replicate the sampling as well.

(ii) **Have controls.** Temporal control may not be available; however, spatial controls probably will be and should be included in the design.

(iii) **Have a balanced design.** It might not be possible to sample adequately throughout the year.

(iv) **Have replicates randomly allocated.** As generalizations about the effect of different types of operations are the prime objective, there should be replication at the highest level, i.e., replicate stations using the same process.

(v) **Conduct preliminary sampling (pilot study).** Yes.

(vi) **Assess the sampling methods.** Yes.

(vii) **Estimate error variability.** Yes.

(viii) **Determine natural environmental patterns.** Stratification may be apparent.

(ix) **If statistical analysis assumptions are not satisfied,** bring in a statistician at the planning stage rather than after the samples have been taken.

(x) **Accept the results.** Establish a single statistical test criterion or alternatively establish multiple criteria *a priori*.

10.1.3 Cumulative Impacts

Monitoring of cumulative impacts from non-point sources should include these essential elements:

(i) **Have a clear question.** The hypothesis here will relate to detectable change without reference to a particular cause/effect relationship. The variables monitored should be those of generic concern rather than merely indicators of change.

(ii) **Have controls.** Recognize that temporal controls may not start at time zero.

(iii) **Have a balanced design.** Yes.

(iv) **Have replicates randomly allocated.** Yes, however it may be possible to conduct complete censuses for some variables, e.g., the maximum number of elephant seals on a beach during a summer. To estimate the average number of visitors to a site over summer may require a complete census on several randomly chosen days during the summer.

(v) **Conduct preliminary sampling (pilot study).** Yes.

(vi) **Assess the sampling method.** Yes.

(vii) **Estimate error variability.** Yes.

(viii) **Determine natural environmental patterns.** Stratification by site types is a possible strategy. Temporal information may demonstrate wide natural variability in biological parameters.

(ix) **If statistical analysis assumptions are not satisfied,** bring in a statistician at the planning stage rather than after the samples have been taken.

(x) **Accept the results.** The prime reason for this type of monitoring will be to provide an early warning of change. To be useful there should be a level of concern which triggers a management activity or response, or a series of limits - stated as a magnitude of change that is considered significant with a probability that the change is real. Establish multiple criteria *a priori*, i.e., a small change with a high probability of being real or a large change with a smaller probability of being real.

10.2 Other Considerations

Features of Antarctica that should be considered when designing monitoring programs include a lack of background data, the wide separation between sites, the structure of food chains, and growth rates and geographical patterns of organisms.

10.2.1 Lack of Background Data

Many Antarctic environments and their component species are understudied. Therefore, background data on life histories, distribution patterns and relative abundances are either lacking or poorly known. Data on physical characteristics such as ocean currents, nutrients, weather patterns, etc., are only available for limited regions. Antarctic monitoring programs will often have to be designed with little or no background data.

10.2.2 Sites of Potential Environmental Impacts are Widely Separated

In the Antarctic the sites of potential impacts are focused mostly on the permanent stations which are usually far apart. There are only a few places within the Antarctic Treaty area where bases are clustered into relatively small areas, e.g., King George Island, McMurdo Sound. Therefore monitoring programs must be designed for very short gradients of impact-related variables from station operations. For example, petroleum spills usually occur only at station sites, and their effects can be expected to diminish quickly with distance away from the site. Also, the effects of sewage outfalls will typically be apparent over relatively short distances.

10.2.3 Antarctic Food Chains

One imagines Antarctic food chains as having few links and involving few species. This is sometimes true but because of a lack of understanding of interactions and energy flow, such an assumption must only be made with caution. It is known that physical characteristics such as ice cover and ocean current patterns are often different from one annual cycle to the next. Changes in such features can greatly influence food chain dynamics, e.g., Weddell seal diets vary greatly from one year to the next probably because of changes in currents and/or ice and reproductive success of prey species. Such variation is likely to be characteristic of many other species' feeding and movement patterns, and this must be considered in making monitoring program design decisions.

10.2.4 Turnover Rates, Species Growth Patterns

At all levels of organization, turnover rates tend to be slow in the Antarctic. For example many species are very long lived, have relatively low reproductive rates, and grow slowly. Therefore, recovery from disturbance is a slow process. One must be careful about using study designs that include destructive sampling or collection of specimens for analysis of contaminants because the monitoring itself could cause significant damage to the community. Also natural temporal environmental patterns can cause changes in ecosystem attributes, e.g. changes in abundance may persist for a long time.

10.3 General Considerations

Principles of study design are universal, but some apply with greater force than others and in particular ways to environmental monitoring in Antarctica. This is so because certain types of impacts are more likely than others and also because of unique features of the Antarctic environment. The lack of background data must be addressed. Baseline studies of important organisms in representative habitats and an inventory of real and perceived environmental impacts are needed for the entire Antarctic continent. Identified impacts need to be prioritized in terms of environmental significance, using criteria such as geographical coverage, community/ecosystem structure and function, food web dependence, cumulative effects, impact on reproduction, and reversibility. Of the three types of studies, responses to unpredictable accidents, e.g., spills, are the most difficult to design well in Antarctica as is the case elsewhere. However, baseline studies could be conducted in habitats at locations where spills are most likely to occur such as along shorelines where supply ships operate. These could provide pre-impact data in the event of a spill.

11.0 DATA MANAGEMENT AND DATA QUALITY ASSURANCE

It will not be possible to meet the environmental monitoring requirements of the Antarctic Treaty System without an effective data management system. A properly designed and implemented data management system is the mechanism through which effective use of the information collected by environmental monitoring programs can be made to fulfill obligations under the Environmental Protocol and other Antarctic Treaty System provisions.

Data management in the context of a national and international network will promote the efficient and effective use of data arising from monitoring and other related activities. Data comparability will be facilitated through the establishment of such a data protocol. Free access to and wide availability of data are important to national program managers so that locally collected data can be examined in a broader context. Easily available and understandable data will also allow problems to be identified and appropriate preventative or remedial measures to be taken. Finally, the system will promote the long term preservation of data which is important in ensuring that baseline information can be developed against which change is measured.

11.1 Goals of a Data Management System

The most fundamental objective of data management is to promote the goals of all environmental monitoring programs through the efficient and effective management of data arising from monitoring and other related activities.

This objective will be achieved by the following:

(i) establishment of a data format protocol to ensure comparability of data;

(ii) avoid duplication of monitoring efforts;

(iii) ensure the long-term preservation of data;

(iv) facilitate the availability of and access to data;

(v) enable National Programs to make better use of environmental data by being able to make comparisons with adjacent monitoring programs providing a broader perspective for data interpretation; and

(vi) maximize the utility of data and consequently the conclusions that arise from their analysis.

In essence, data management allows information collected in environmental monitoring programs to be used to make decisions in a timely and cost-effective manner that provide for the preservation of the Antarctic environment. It will also facilitate fulfillment of the requirements of the Environmental Protocol and other Treaty System provisions. The educational and training components of this process, in turn, will be valuable in encouraging preventative rather than reactive actions and helping to ensure that the natural and scientific value of Antarctica is preserved.

11.2 Quality Assurance[1] and Data Management

Appropriate and cost-effective management of data collected by national environmental monitoring programs in the Antarctic is not possible unless the data are reliable and can be compared both within and between programs: in other words, unless their quality can be assured. From this standpoint, quality control (QC) and quality assurance (QA) must be a fundamental component of the design and implementation of any environmental monitoring program. The high cost associated with scientific activities in Antarctica means that questionable data waste valuable and limited resources. This is even more important with environmental monitoring data, which are intended to promote the preservation of the Antarctic environment and provide decision-makers with information that allows them to take corrective actions when necessary. In this context, poor quality data can be even worse than an absence of data because they could be misleading and result in the diversion of resources from real needs to false targets.

The importance of quality assurance and quality control activities was dearly set forth in the report on the First Meeting of Experts on Environmental Monitoring in Antarctica (Buenos Aires, June 1-4, 1992) which stated

> "...it is essential that measurements are referenced to standards accepted by all the laboratories undertaking a particular type of measurement, and that these laboratories undertake regular intercalibration studies ... Accuracy and repeatability should be covered by quality assurance requirements..." (Paragraph 56)

[1] Quality Control is the compliance with criteria adopted by the experimentalist in performing determinations in order to guarantee that reliable data are generated (e.g., the proper use of certified materials). Quality Assurance is a system put in operation by an external party to verify whether data provided by the experimentalist are self-consistent and can be traced back to a minimum set of requirements supporting their validity.

To ensure high quality data that will allow comparison between data collected by different National Programs, intercomparison exercises are strongly recommended and should be conducted on a regular basis, both at the national and international level. It is further recommended that certified reference materials be developed for chemical and physical properties of soil, water, biota and other matrices from Antarctica. Such certified reference materials are extremely valuable in assuring the quality of data collected in environmental monitoring programs. Reference materials provide verification of the performance of laboratories and assists laboratories in ensuring internal quality control is working.

11.3 Interaction With Other Programs

Interaction and cooperation with other national and international groups tasked with collecting environmental measurements and dealing with issues of data management and quality assurance should be promoted. An example of such a group is the SCAR-COMNAP initiative of the Antarctic Data Directory System (ADDS). This approach will result in: 1) proper exploitation of existing expertise in fields closely related to or overlapping with Antarctic environmental monitoring; 2) optimization of available instrumental facilities in a harmonized fashion; and 3) avoidance of any possible discrepancies in the approach taken and pattern followed by monitoring and research units that would impair their reliability.

11.4 Structure and Components of a Data Management System

There are several options for the design of a data management system, ranging from a completely distributed system to a completely centralized system. Each has different costs and benefits. A networked structure, with centralized management, can be implemented at reasonable cost while meeting the goals set out previously in paragraph 11.1;. The structure of the proposed data management system is shown in Figure 11.1.

Data would be gathered by National Programs and then processed and held by National Antarctic Data Centers (NADC's), which could then choose to distribute the data amongst a number of national specialist centers, laboratories, etc. rather than hold it themselves. The NADC's would, however, be responsible for ensuring that data conformed to agreed guidelines. Thus all data originating in NADC's should exist in a specified format.

The NADC's would be linked to a common Interface Site (e.g., a World Wide Web Home Page), which in turn would be linked to National Programs, individual scientists and other users, via the Internet. Such a system would allow rapid access to all available data.

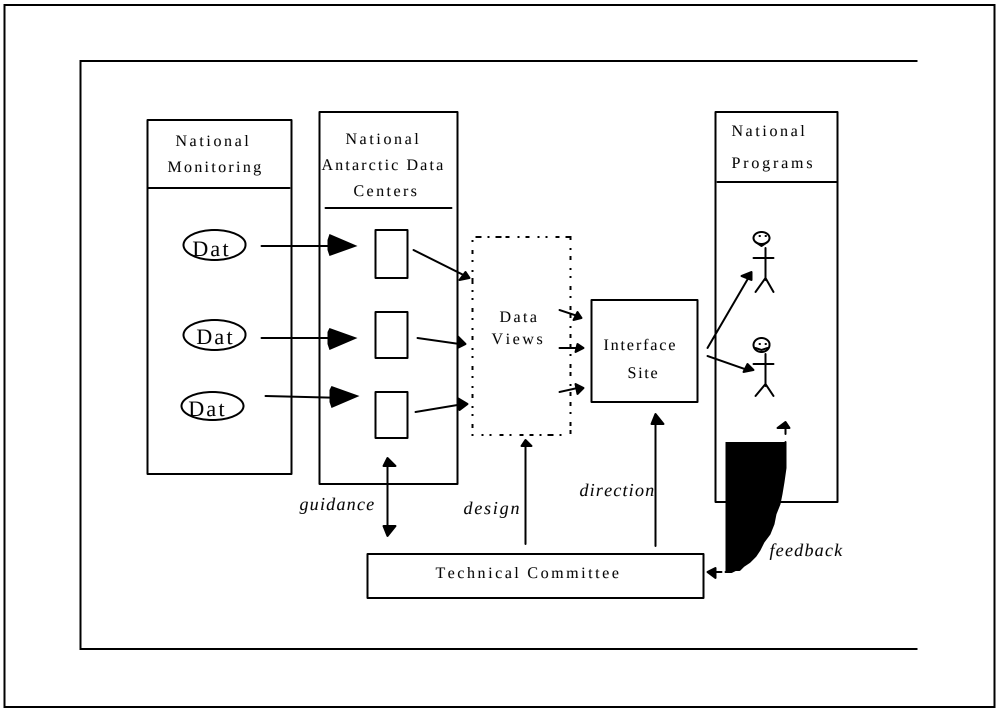

Figure 11.1. Proposed Data Management System

11.5 Data

In this context the word "data" is defined as numerical or textual information measuring or reporting the values of specific monitoring programs together with any other information that may be necessary for the appropriate interpretation of those data.

Data originating from NADC's will not necessarily be of the same resolution. However, there will be a minimum resolution requirement for participation in the system. A filter, called a Data View (DV), will create a common interface to all datasets of a certain type, so that inter/intra-site and inter-program comparisons may be made with ease.

All data should be associated with "meta-data", i.e. information describing the data in question. Amongst other information, this will provide details of the investigators, content, range and resolution of the data and quality assurance information. This meta-data should be intimately linked to the data so that it is impossible to access a dataset without also receiving information about that dataset. Thus data of different origins (e.g. data collected as part of scientific research or as part of a monitoring program) and quality will be easily identifiable. Furthermore, meta-data are likely to be those first seen when accessing the Interface Site, making the searching and retrieval of datasets a simple operation.

It is anticipated that two types of data will be collected by National Monitoring Programs and held at the NADC's. These include: (1) data collected using methodologies that conform to internationally agreed monitoring standards which should therefore be comparable between sites; and (2) data that are collected according to site specific methodologies. Both types of data would be available through the Interface Site. If data are released by the NADC, identification of the type of data would be clearly indicated in the associated meta-data.

11.6 Administration

The system described is a distributed one, since data would be held on individual national or institutional databases. However, management of the system should be centralized as with the SCAR-COMNAP ADDS. The Interface Site would provide centralized access to the system and would be responsible for providing much of the infrastructure to enable the system to operate. The system should be overseen by a technical committee that will provide appropriate advice and direction as required. This technical committee will provide guidance on the types and formats of data to be held at NADCs, their minimum resolution requirements, the design of the Data Views and the level, statistical robustness and appropriateness of the summaries of data, if any, provided by the Data Views. In addition, the Technical Committee should:

(i) provide administrative direction to the Interface Site;

(ii) guide both the NADCs and the National Programs with respect to data matters;

(iii) address aspects of data access and control;

(iv) provide appropriate instruction to end-users; and

(v) enter into dialogue with the National Programs, especially regarding feedback on the system and its operation.

It is recognized that a number of National Programs may take some time to develop the technical and administrative infrastructure needed to participate in this system. In the interim, it is suggested that these programs consider bilateral or regional agreements to deposit data on the NADCs of programs that have the requisite infrastructure. Alternatively, the Interface Site could provide the facility for management of such data until the National Program in question is in a position to develop its own NADC. It is not anticipated that the Interface Site will provide such facilities in the long term. As a minimum, Treaty Parties should exchange information on their monitoring programs in accordance with existing Treaty provisions.

11.7 Environmental Sample Archive

Subaliquots of all samples collected during environmental monitoring in Antarctica should be preserved and archived. Such "archived" samples would allow for verification and confirmation of data previously collected whenever a significant improvement in methodologies takes place and/or if doubts are raised regarding the validity of the original data. In addition, trace components of the sample that are not now measured or taken into account could be investigated and quantified at some future date should the need or interest arise. This requires that parallel samples are taken and stored under conditions that ensure the integrity of both inorganic and organic species.

12.0 PERFORMANCE CRITERIA

A feedback mechanism is necessary to determine whether monitoring is effective and hence whether it should continue to be supported or how it can be improved.

Performance of the monitoring program should be judged with reference to the objectives of the monitoring program. These objectives will be set in response to three types of requirements (1) protocol; (2) scientific; and (3) practical:

(i) **Protocol requirements** are specified by the Environmental Protocol to the Antarctic Treaty (see Section 2.0). Special emphasis should be placed on monitoring the impact of ongoing activities, but the evaluation process should also consider the specific requirements relating to IEE's and CEE's of new activities.

(ii) **Scientific requirements** were proposed by GOSEAC and further developed at these workshops (see Section 6.0). Two important elements are the need for a hypothesis-oriented approach and the need for integration via interdisciplinary synthesis.

(iii) **Practical requirements** fall within three categories: cost, feasibility, and utility (see Section 5.0). Cost includes the question of the cost-effectiveness of monitoring operations. Feasibility relates to the availability of expertise and equipment as well as logistical requirements of a monitoring operation. Utility refers to whether the monitoring program is generating information that can be used for management decisions to reduce the impact of human activities on the Antarctic environment.

Any proposed monitoring program should be systematically evaluated relative to the key requirements. This evaluation should take into account the general principles as outlined in Section 5.0.

12.1 Evaluation of Monitoring Programs for Continuous Improvement

Environmental monitoring should be periodically reviewed by individual national programs, and the results of such reviews shared amongst programs for mutual benefit. It is recommended that review and critical evaluation focus on each of three phases of the monitoring activity: data collection, data analysis, and use of results in management decisions.

The sampling program's activities should be reviewed to ascertain that:

(i) the original design of locations, times, replications and measured variables is being followed consistently. If costs, operational difficulties, changing technologies, etc. are limiting the intended design, appropriate changes must be put in place;

(ii) the quality of the data is as originally specified;

(iii) once analysis has begun, data collection should also be reviewed to determine if the design is inadequate or excessive based on the objectives; and

(iv) changes in the hypothesis may be required as new insights or new activities and/or technologies occur.

12.2 Use of Results in Management Decisions

Data collection and analyses are intended to provide decision-makers with a sound scientific information from which environmental management decisions are made. Therefore, review every few years should consider these aspects:

(i) do the data and the results of the monitoring provide managers with the information envisioned in original designs? If not, adjustments must be made;

(ii) has management's use of the data resulted in a measurable decrease in human impact?; and

(iii) the management value of long-term information may be much greater than short-term. (Program modification for short-term benefit must be considered with caution.)

12.3 Review Mechanism

Assessment within each country should be conducted by external peer review. Appropriate models can be found in several nations in which environmental management is reviewed by a panel or department that is independent of the national Antarctic program. The panel should include a range of Antarctic and non-Antarctic scientists and personnel with operational experience in Antarctica. Other representation may include non-governmental technical experts as well as organizations with direct oversight responsibility or policy-making authority. A mechanism needs to be found to ensure the effectiveness of the program review procedures.

13.0 OUTSTANDING ISSUES

It was considered that certain parts of the Terms of Reference would be more effectively addressed during future deliberations. It was established that there was no generic monitoring program that would be appropriate at all locations at all times. However, it was clear that the employment of standard methods and ensuring the intercomparability of monitoring data were obtainable goals. Monitoring programs can be designed that would be appropriate at some locations for certain periods of time. It was equally clear that the indicators of impact were diverse and dependent on the setting at the site studied. Therefore issues related to applicable technologies and protocols would best be considered on a case-by-case basis. A direct consequence of this reasoning is that the methods and the associated quality assurance are dependent on the design of the program and thus are not easily addressed in ways that would provide guidance for all situations that might be encountered. The determination of applicable technologies and methodologies are desirable goals that are attainable through consultation with groups of experts.

Standard protocols and quality assurance practices have been extensively developed in temperate and arctic climates. The fundamentals of these approaches are applicable to monitoring programs in Antarctica. It was also realized that health indices and other generic attributes of ecosystems that one might wish to assess, were not at a stage of understanding where they could be routinely used as tools for practical environmental monitoring. Broader questions related to ecosystem health, while laudable, were thought to remain in the realm of basic research.

14.0 CONCLUSIONS

This report summarizes the results of two workshops of technical experts that were convened by SCAR and COMNAP in response to a request by ATCM XVIII to provide advice to Treaty Parties on environmental monitoring. The conclusions with respect to the Terms of Reference are:

TOR-1. To review the priority of impacts which need monitoring taking into account the activities and impacts identified by the Meeting of Experts on Environmental Monitoring.

<u>It was concluded that</u>:

- No generic or general prioritization of the activities which need monitoring is possible in terms of the categories defined in the TOR.
- Prioritization of activities for monitoring must be site specific and be based on such features as intensity, frequency, duration, areal extent, seasonal timing, geographic location, and the resources in the area that might be impacted.
- Each situation must be analyzed, experts conferred with and a monitoring program designed for each mix of activities at a given location.

TOR-2. To develop hypotheses on which to base the design of monitoring programs.

<u>It was concluded that</u>:

- Environmental monitoring is only useful when it is firmly tied to an environmental management strategy.
- Monitoring is not the measurement of everything in a haphazard approach to detect change.
- Monitoring should be the precisely targeted measurement of a few key species, processes or other indicators, carefully selected on the basis of scientifically-sound, predetermined criteria.
- A generic hypothesis to cover all environmental monitoring would be “the activity of concern causes no unacceptable deterioration of values or resources”.
- Specific hypotheses appropriate to particular locations, the activities occurring at the location, and the values that might be impacted must be generated on a case-by-case basis.

TOR-3. To provide technical advice including:

- *Minimum monitoring needed to meet the requirements of the protocol.*

  It was concluded that:

  - Monitoring has three objectives: (1) to protect the scientific value of the Antarctic; (2) to help with continuous improvement of Antarctic environmental management, and (3) to meet the legal requirements of the protocol and national legislation;

  - The definition of minimum requirements under the Protocol were subjective and related to terms such as "resource", "value", "minor", and "transitory" which have no agreed upon definitions.

- *Baseline Information*

  It was concluded that:

  - Baseline information for the Antarctic is minimal and that long-term databases were needed to establish change related to human impacts.

  - Due to the high level of natural variability, baselines may be difficult if not impossible to establish in the time-frames needed for management decision.

  - Alternative approaches such as control sites, comparable studies, time series, and manipulative experiments may be more appropriate to assess impact.

- *Ecosystem Health Indices*

  It was concluded that:

  - Biological monitoring and physicochemical monitoring are required to adequately support management decisions.

  - The decision to undertake biological monitoring needs to be assessed on the basis of proximity of biota to stations or field camps and other human activities, the likelihood of impact, the utility of the data produced, logistical practicalities, and cost.

  - Ecosystem health indicators are not at a stage where cause and effect can be easily determined.

  - SCAR Working Groups of biological experts should be conferred with to determine if, and what, ecosystem health indices are appropriate for monitoring.

- *Key Variables to be Monitored*

  It was concluded that:

  - A series of mandatory and desired criteria are useful in selecting variables to be monitored.

  - Key chemical and physical variables can be related to specific activities (see Table 8.1).

  - Biological variables are useful but more problematic in assisting management decisions due to a lack of unambiguous cause and effect interpretations.

  - Some biological indicators can provide specific information for management decisions (see Table 9.1).

- *Design of Monitoring Programs*

  It was concluded that:

  - Antarctic environmental monitoring programs should implement design elements proven to be successful in temperate and arctic environments.

  - A series of basic tenets for the design of monitoring programs include: (1) have a clear question, (2) have controls, (3) have replicates randomly allocated, (4) do preliminary sampling, (5) assess the sampling methods, (6) estimate error variability, (7) determine natural environmental patterns, (8) determine if the statistical assumptions are satisfied, and (9) accept the results.

  - Statistical design considerations in the context of the hypothesis to be tested must be considered before any resources are invested or field activities are initiated.

- *Scientific Protocols for Monitoring*

  It was concluded that:

  - Appropriate expertise be assembled to develop a technical handbook as a guide to scientific protocols to be used in monitoring programs (this was judged to be beyond the mandate and expertise of these workshops).

- *Measurement Methods, Including Frequency of Measurement*

  It was concluded that:

  - The most appropriate methods and the details of the study design can only be addressed on a case-by-case basis based on the fundamental principles outlined in the report.

- *Standardization and Quality Assurance of Techniques and Data;*

  It was concluded that:

  - A set of recommended techniques and parameters of relevance to Antarctica should be developed to standardize monitoring and to provide advice to operators in developing monitoring activities.

  - Standards and procedures developed in temperate and arctic climates should be applicable, and should be adopted for use in Antarctic monitoring programs with appropriate modifications.

  - Unique characteristics of Antarctica that need to be considered when developing monitoring programs include a lack of background data, the wide separation between sites, the structure of food chains, and the growth rates and geographic patterns of organisms.

  - Standard QA/QC practices must be a cornerstone of Antarctic environmental monitoring to ensure maximum return on resource investment in monitoring activities.

- *Applicable Technology;*

  It was concluded that:

  - Guidelines on applicable techniques and QA/QC procedures should be addressed on a case-by-base basis in the context of the fundamental principles outlined in the report.

- *Data Management;*

  It was concluded that:

  - Free access and wide availability of data is important so that national program managers that collect local data can put their results in a broader, regional context.

  - Effective international data management is crucial to the fulfillment of Protocol requirements for monitoring.

  - Long-term preservation and standardization of data is important in ensuring that baseline information can be developed against which change is measured;

- *Criteria for Judging Whether Monitoring Objectives are Being Met;*

  <u>It was concluded that</u>:

  - A feedback mechanism is necessary to determine whether monitoring is effective and hence whether it should be supported and how it can be improved.
  - The performance of a monitoring program should be judged with reference to protocol, scientific and practical objectives.
  - Environmental monitoring should be periodically reviewed by individual national programs preferably with the assistance of an objective, third party organization.

Agendas of the meetings, a list of attendees, and short summaries of workshop presentations are provided as supporting information in the attached annexes.

ANNEX 1

WORKSHOP PROGRAMS

WORKSHOP 1
PRIORITISATION OF IMPACTS AND THE
DEVELOPMENT OF MONITORING OPTIONS

October 17-20, 1996
Oslo, Norway

TUESDAY, 17 OCTOBER 1995

0800-0900 Registration

0900-0905 Welcome Address

0905-0915 Opening Address: Goals of the Workshop
Workshop Chairman: *O .Rogne (IASC, Norway)*

0915-1000 Science in Antarctica - its importance and impacts
O .Orheim (SCAR, Norway)

1000-1030 Role of Environmental Monitoring
A. Karlqvist (COMNAP, Sweden)

1030-1100 Coffee Break

1100-1145 Principles of Environmental Monitoring
W.P. Williams (University of London, United Kingdom)

1145-1215 The Arctic Monitoring and Assessment Programme
L.-O. Reierson (AMAP Secretariat, Norway)

1215-1245 Monitoring Human Impacts in the Arctic
C. Herlugson (British Petroleum, USA)

1245-1345 Lunch Break

1345-1730 Working Group Sessions

WG1: Key Impacts of Operational Activities
Chairman: E. Chiang (NSF, USA)
Rapporteur: G.M. Wratt (NZAP, New Zealand)

WG2: Key Impacts related to Science Activities and Ecosystems
Chairman: M. Tilzer (Alfred-Wegener-Institut, Germany)
Rapporteur: J.R. Shears (British Antarctic Survey, United Kingdom)

WG3: Design of Monitoring Frameworks
Chairman: M. Riddle (Antarctic Division, Australia)
Rapporteur: R. Schorno (Geosciences Foundation, Netherlands)

WG4: Interpretation of Protocol Requirements on Monitoring
Chairman: M. G. Richardson (FCO, United Kingdom)
Rapporteur: R. Hansson (Norsk Polarinstitutt, Norway)

WEDNESDAY, 18 OCTOBER 1995

0900-0945	Types of Pollution - Hydrocarbons *I. Venkatesan (University of California, USA)*
0945-1030	Types of Pollution - Sewage *G. McFeters (Montana State University, USA)*
1030-1100	*Coffee Break*
1100-1145	Types of Pollution - Atmospheric *E.W. Wolff (British Antarctic Survey, United Kingdom)*
1145-1230	Antarctic Case Study - Environmental Monitoring of Impacts at Terra Nova Bay Station *P. Giuliani (ENEA, Italy)*
1230-1330	*Lunch Break*
1330-1730	Working Group Sessions

THURSDAY, 19 OCTOBER 1995

0900-0930	Report of WG4
9030-1000	Question Time
1000-1230	Working Group Sessions
1230-1330	*Lunch Break*
1330-1730	Working Group Sessions

FRIDAY, 20 OCTOBER 1995

0900-0930	Report of WG1
0930-1000	Report of WG2

1000-1030 Report of WG3

1030-1100 *Coffee Break*

1100-1230 Workshop Conclusions and Recommendations

1230 *Lunch* and Close of Workshop

WORKSHOP 2
PRACTICAL DESIGN AND IMPLEMENTATION OF ENVIRONMENTAL MONITORING PROGRAMS

March 25-29, 1996
Texas A&M University
College Station, Texas, USA

MONDAY, 25 MARCH 1996

1300-1700	Registration *Rudder Tower, 2nd Floor*
1830-1930	Reception at the home of Dr. Ray Bowen, President of Texas A&M University
*2000-2100	The History of Texas A&M University in the Antarctic: Four Decades of Science and Discovery on the Ice *Sayed El-Sayed, Texas A&M University (USA)* *Rudder Tower Theater*

TUESDAY 26 MARCH 1996

0800-0900	Registration *Rudder Tower, 2nd Floor*
	*<u>Plenary Session I - Rudder Theater</u>
0900-0910	Welcome *Dr. Ronald G. Douglas, Executive Vice President and Provost of Texas A&M University*
0910-0945	Keynote Address: History of Environmental Monitoring *Robert Huggett, U.S. Environmental Protection Agency (USA)*
0945-1015	The Framework of Environmental Concerns and Response in Antarctica *Robert Rutford, University of Texas at Dallas (USA)* *Robert Hofman, Marine Mammal Commission (USA)*
1015-1045	*Coffee Break*
1045-1115	Report of the Oslo Workshop - Prioritisation of Impacts and the Development of Monitoring Options *David Walton, British Antarctic Survey (United Kingdom)*
1115-1200	Fundamentals of Environmental Study Design *Roger Green, University of Western Ontario (Canada)*

1200-1300 *Lunch*- Rudder Tower Dining Room

1300-1530 Working Group Sessions

WG1: Monitoring Options for Physical and Chemical Impacts: Methodologies, Applicable Technologies, and Experimental Design
Chair: Tom O'Connor, National Oceanic and Atmospheric Administration (USA); Rapporteur: Indira Venkatesan, University of California-Los Angeles (USA); Rudder Tower Room 402

WG2A: Monitoring Options for Biological Impacts: Methodologies, Applicable Technologies, and Experimental Design
Chair: Jose Valencia, Universidad de Chile (Chile); Rapporteur: Robert Spies, Applied Marine Sciences (USA); Rudder Tower Room 504

WG2B: Monitoring Options for Biological Impacts: Methodologies, Applicable Technologies, and Experimental Design
Chair: Peter Williams, Kings College (UK); Rapporteur: Colin Harris, International Centre for Antarctic Information and Research (NZ); Rudder Tower Room 510

WG3: The Role of Data Management and Quality Assurance in Monitoring Programs
Chair: Steve Smith, International Centre for Antarctic Information and Research (NZ); Rapporteur: David Agnew, Commission for the Conservation of Antarctic Marine Living Resources (Australia); Rudder Tower Room 404

WG4: Performance Criteria: How Do We Judge Whether Monitoring is Effective?
Chair: Warwick Vincent, University of Laval (Canada); Rapporteur: Robert Carney, Louisiana State University (USA); Rudder Tower Room 502

1500-1530 *Coffee Break*

1530-1700 Working Group Session
Rudder Tower

WEDNESDAY 27 MARCH 1996

*Plenary Session II - Rudder Theater

0900-930 The Tools Available for Data Management and Data Accessibility Issues
Steve Smith, International Centre for Antarctic Information and Research (New Zealand)

930-1000	How Do We Ensure the Quality and Intercomparability of Data Produced in Monitoring Programs? *Michael A. Champ, Texas Engineering Experiment Station (USA)*
1000-1030	Marine Debris, An Antarctic Concern? *Ed Goldberg, Scripps Institute of Oceanography (USA)*
1030-1100	*Coffee Break*
1100-1130	Environmental Monitoring in the Antarctic: The CCAMLR Experience *David Agnew, Commission for the Conservation of Antarctic Marine Living Resources (Australia)*
1130-1200	Experiences in Large Complex Monitoring Programs: Are There Lessons to be Learned? *Tom O'Connor, National Oceanic and Atmospheric Administration (USA)*
1200-1300	*Lunch - Rudder Tower Dining Room*
1300-1500	Working Group Sessions *Rudder Tower*
1500-1530	*Coffee Break*
1530-1700	Working Group Sessions *Rudder Tower*

THURSDAY 28 MARCH 1996

0900-1030	Working Group Sessions *Rudder Tower*
1030-1100	*Coffee Break*
1100-1230	Working Group Sessions *Rudder Tower*
1230-1330	*Lunch- Rudder Tower Dining Room*
1330-1500	Working Group Sessions *Rudder Tower*
1500-1530	*Coffee Break*

1530-1700 Working Group Sessions
Rudder Tower

1830 Dinner and Social Event

FRIDAY 29 MARCH 1996

Plenary Session III - Memorial Student Center, Rm. 201

0900-0945 Presentation of WG1 Findings
Tom O'Connor, National Oceanic and Atmospheric Administration (USA); Indira Venkatesan, University of California-Los Angeles (USA)

0945-1030 Presentation of WG2 Findings
Jose Valencia, Universidad de Chile (Chile); Robert Spies, Applied Marine Sciences (USA); Peter Williams, Kings College (UK); Colin Harris, International Centre for Antarctic Information and Research (NZ)

1030-1115 Presentation of WG3 Findings
Steve Smith, International Centre for Antarctic Information and Research (New Zealand); David Agnew, Commission for the Conservation of Antarctic Marine Living Resources (Australia)

1115-1200 Presentation of WG4 Findings
Warwick Vincent, University of Laval (Canada); Robert Carney, Louisiana State University (USA)

1200-1330 *Lunch*

1330-1530 Forum: Implementation of Environmental Monitoring in the Antarctic
Panel: Working Group Chairs and Organizing Committee

1530 Adjourn

ANNEX 2

SUMMARIES OF PRESENTATIONS

WORKSHOP 1

Opening Address

O. Rogne
IASC Secretariat, PO Box 5072, Majorstua, 0301 Oslo, Norway

It is a pleasure to welcome you to Oslo, and to this Antarctic Environmental Monitoring Workshop. As you have seen from the documentation you have received, this issue has been discussed earlier both within COMNAP and SCAR, and by a Meeting of Experts in Buenos Aires, Argentina, in June, 1992.

In 1994 the XIX Antarctic Treaty Consultative Meeting (ATCM) requested that SCAR and COMNAP jointly convene workshops to provide expert advice on the design and implementation of environmental monitoring programmes in the Antarctic. The terms of reference for the workshops are defined by the ATCM.

There will be two linked workshops. The first one starts today and is concerned with Prioritisation of Impacts and the Development of Monitoring Options. The second workshop is entitled Practical Design and implementation of Environmental Monitoring Programmes and will be held at College Station, Texas, USA, in March 1996.

The underlying aims of the workshops are:

- to identify approaches to monitoring that are simple to implement, practical, realistic and cost effective;
- to take into account the realities of resources, logistical constraints and the limitations of present technologies;
- to develop a hierarchy of options that can be progressively implemented as required; and
- to meet obligations arising out of the Madrid Protocol.

I mentioned that the terms of reference for these workshops were defined by the ATCM, and they are included in the documentation. However, as terms of reference provide the main guidelines for our work, I would like to remind you about the three main elements:

1. To review the priority of impacts which need monitoring (taking into account the activities and impacts identified by the 1990 Antarctic Treaty Meeting of Experts on Environmental Monitoring).
2. To develop hypothesis on which to base the design of monitoring programmes.
3. To provide technical advice.

The Importance of Environmental Monitoring

Man has seriously damaged or changed the natural environment and the balance in nature in many parts of our globe. There are international agreements that we should do better in the Antarctic. I believe all those concerned in Antarctica have an interest in seeing her valued attributes and resources conserved. Conservation must have a long-range view, and monitoring is our tool to assess the present status, trends, and attainment of goals in support of the conservation of valued attributes and resources.

The goals of environmental monitoring in Antarctica could be summarised as:

To provide an early warning of deterioration in the valued attributes or resources, through:

- identifying the activities most responsible for such deterioration;
- establishing the present status of the values and resources;
- providing an evaluation of present activities to forecast and forestall future deterioration; and
- verifying the effectiveness of predicted impacts through an EIA process.

There is a need to emphasise that we at this workshop should only be concerned with essential monitoring as required under the Protocol for activities undertaken in the Antarctic and not with long-term research projects such as carbon dioxide monitoring, i.e., projects that contribute to the global picture.

The output of this first workshop is intended to be:

1. Summary papers to be included in a combined proceedings volume.
2. Recommendations to ATCM on the framework, focus and design of monitoring programmes.
3. Key input to the second workshop in 1996.

The output of both workshops will be combined and considered by SCAR and COMNAP at their meetings in Cambridge in August, 1996. After agreement and endorsement of both sponsoring bodies, the workshop results will be presented at XXI ATCM in New Zealand in 1997.

The output from our workshop is the basis on which the next workshop will have to develop. In this work, we must be realistic and keep in mind a balance between a good scientific basis for monitoring and the expense of the programmes.

The Role of Monitoring - Some Introductory Remarks

A. Karlqvist
Swedish Polar Secretariat, Stockholm, Sweden

According to a standard definition the basic objective of environmental monitoring is to detect and measure changes in the environment by collecting time series of data for defined purposes and for observing trends in the selected variables . In the context of this workshop, and in line with the remit from the ATCM, the focus is on monitoring of impacts of human activities from research and its associated logistic operations. Hence scientific monitoring, such as measurements of greenhouse gases or stratospheric ozone, is outside the scope of our concern here. However, there is common understanding that monitoring should be done in a scientific way and that all monitoring programmes need to be based on testable scientific hypotheses. Although this is a sound principle it is not unproblematic to apply for operational purposes. It should be recognized that there are distinctive differences between science and operational monitoring and sometimes real conflicts of interests.

First of all the purpose of operational monitoring is different from scientific investigations. The raison d'etre is to provide a basis for decision making. (Not decision making in general but specific decisions, e.g. regarding human health, damages to the ecosystem, disturbance to science programs etc.). Monitoring which is irrelevant for decision making or does not improve the ability to make decisions has no operational value, regardless of how interesting it might be from a scientific point of view. On the other hand it might sometimes be sufficient to make quite simple and unscientific observations and still have enough information to guide decision making. Certain types of impacts are obvious, others (especially cumulative) impacts are not.

It is evident that monitoring in Antarctica is a resource demanding task. Cost-effectiveness must be a priority. It is not only of concern for managers but for the scientists as well. For most national Antarctic programmes the total amount of resources is fixed. Monitoring will compete with other activities. It is a zero-sum game!

In addition to the direct costs in the form of trained people, time, scheduling constraints, equipment and analysis work, monitoring also demands a long-term commitment and discipline. The involvement of scientists poses a dilemma. Monitoring work is not viewed as a qualification in a scientific career and skilled people are a scarce resource. Although in most cases the actual field work might be handled by technicians, analyses and interpretations of results usually demand specific scientific expertise. In practice, the levels of pollution are often such that the analyses are done at low levels close to the detection limits, sometimes requiring advanced instruments and careful handling to avoid contamination.

It might be useful to illustrate these ideas with a couple of examples. The snow fields in the vicinity of the Swedish station Wasa have been monitored with respect to emissions from the station. Elemental carbon as well as SO_4 and other ions have been measured during two different seasons (Dec 91 -Feb 92 and Dec 93 - Feb 94). The analytical procedures applied were ion chromatography and optical methods (for elemental carbon). In summary the results showed that there were no measurable effects from the station except within ca 300 metres downwind from the station. The variability was high and it was difficult to separate the anthropogenic influence from natural variation. In a scientific context these rather inconclusive results might serve as an argument for more research. But how should a prudent manager react? Should the sampling be continued, extended or aborted? Where does it make sense to monitor? Should the analytical techniques be changed and perhaps other variables being measured? Or should decisions be made to change the procedures and energy production at the station and to invest in new equipment?

These are very real management decisions. We must be able to defend why we select certain key variables to monitor and (even more important) why we ignore others. And we must be able to design our monitor programmes so there are natural stopping rules. It does not make sense and no one would be interested in running programs which go on for ever. It is important that the collective wisdom of this workshop in Oslo and the following one in Texas in March next year should provide guidance in how to handle such practical issues of resource allocation.

The direct costs of this monitoring exercise at Wasa have been limited, although some rather expensive laboratory work was involved. But there are other costs to the expeditions which are more indirect. Wasa is a summer station situated ca 120 km inland. The snow sampling was undertaken as the first thing before the station opened in the season and as the last thing when leaving. This procedure puts logistic constraints on the movement of people.

Another case which illustrates the logistical aspects even more clearly is the proposal to make a CCAMLR Environmental Monitoring Program Site at Bouvet Island. (This is being evaluated by our Norwegian colleagues at the moment). The idea is to make regular counts of seals and penguins as top predators in order to assess the productivity of the marine ecosystem in the Southern Ocean. Landing at Bouvet Island is difficult. Even if the island is en route for the nordic expeditions to Antarctica, a stop at Bouvet Island and deployment of personnel would probably mean a couple of days - maybe more - of the expedition’s time, i.e., a delay for 30-40 scientists to do their work. These are very real costs even if they do not show up explicitly in budget calculations.

These examples should not be regarded as an argument for less monitoring but rather as a reminder of reality of operations. The scientific background of environmental monitoring is well recognised and the existing documentation gives a very good input to our discussions here. We know what could be done; now we should agree upon what must be done, which

- meets legal requirements
- makes scientific sense
- is operationally feasible
- is useful for decision making.

Principles of Environmental Monitoring

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Introduction

Monitoring is a fundamental aspect of research, environmental management and conservation. The organized and systematic measurement of selected variables provides for the establishment of baseline data and the identification of both natural and human induced change in the environment. Monitoring data are important in the development of models of environmental processes which, in turn, facilitate progress towards a predictive capability to detect environmental impact or change. The collection and evaluation of monitoring data is essential for the detection of human perturbation within the natural variability of ecosystem processes (1).

It is important to recognise that monitoring is only part of the environmental management process and that any monitoring programme must be developed in accordance with management objectives. It is also important that there is a clear understanding of what is meant by monitoring, which can be used as an all-embracing term to cover long-term trend monitoring and compliance monitoring.

Environmental monitoring, environmental surveys and environmental surveillance are terms that have been used widely in the literature and can be loosely regarded as any activity involved in the measurement of environmental parameters. However, although the activities involved in these programmes may overlap, it is probably useful to define the terms more precisely (2).

Monitoring

Long-term standardized measurement, observation, evaluation and reporting of the environment in order to define status and trends.

Survey

A finite duration, intensive programme to measure evaluate and report the quality of the environment for a specific purpose.

Surveillance

Continuous, specific measurement, observation and reporting for the purpose of environmental management and operational activities.

Monitoring Data and Information Needs

The most critical step in developing a successful and cost-effective monitoring programme is the clear definition of information needs and monitoring objectives, which should be derived from an integrated assessment of management and policy objectives. The information needs must be clearly identified by policy makers and the monitoring programme must respond to those information needs.

The clear specification of monitoring objectives ensures that only the necessary data are collected and that proper information is gained from the monitoring programme, promoting effective and efficient monitoring at lower cost.

The ultimate goal of monitoring is to provide information, not data. In the past, many monitoring programmes have been characterized by the 'data rich, information poor' syndrome, i.e., the focus has been primarily on data collection aspects. There should now be more attention on the analysis and further use of collected data so that the end product of monitoring is information. Data that do not contribute to identified information needs, or whose use cannot be stated explicitly, should not be collected.

A key element to the development of effective environmental management is to establish at a very early stage a monitoring framework for designing an appropriate environmental information system. The monitoring framework covers all aspects of a monitoring programme to ensure that the information will be generated to meet the monitoring objectives (3). A monitoring framework should consist of at least the following five steps:

1. Define information needs for management;
2. Define information that can be produced by monitoring;
3. Design monitoring network;
4. Document data collection procedure;
5. Document information generating and reporting procedures.

Such a framework helps contribute to efficient monitoring, as all monitoring activities are anticipated, and the costs for the entire programme can be reviewed.

Monitoring Objectives

In order to assess the information needs for management it is essential to have clearly defined management objectives which in turn will enable environmental monitoring objectives to be formulated. Environmental monitoring objectives can be classified into two broad categories which can be combined in practical terms to varying degrees. These are basic environmental protection and the evaluation of impact and risk (4).

Basic Environmental Protection - The majority of monitoring programmes fall into this category and are designed to provide baseline or background levels of pollutants; assessment of pollutant levels at impacted sites; estimation of pollutant loads and budgets; and detection of trends.

Evaluation of Impact and Risk - An extension of monitoring for basic environmental protection is to incorporate an evaluation of impact and risk and to provide data for prediction of future impacts. The first stage in such an extended remit involves the monitoring and assessment of pollutant pathways, transformations, and accumulation through water, sediments and biota leading to an assessment of exposure of the biota and humans.

In order to incorporate aspects of risk assessment to ecosystems and human populations more detailed monitoring will be required on the impact of contaminants on biota by monitoring and assessing the effects on individuals, species, ecosystems, and the exposure of humans and the risk to human health. The purpose of such monitoring is to engage in risk assessment and risk management. Risk assessment is usually used in the context of human health but it is increasingly realised that with a fragile ecosystem an element of risk assessment needs to be used to manage environments for conservation - to retain biodiversity and ecosystem integrity and to enable sustainable development of unique resources.

Design of Monitoring Programmes

The design of sampling programmes to monitor the environment therefore involves a number of important decisions once the objectives of the programme have been defined.

These include:

What determinants to measure;
How many samples are required in a given time interval;
Where to sample or locate monitors;
How to sample;
How the data obtained will be transformed into useful information.

These decisions must be taken against an understanding of the precision required of the results, the nature and variability of the system being monitored, and the availability of resources.

An essential feature of an environmental data base is that the data are verified both for method and precision. Harmonized methodology is essential and can be incorporated into monitoring design protocols. Harmonization of techniques and inter-laboratory calibrations can in the long term save money being spent on inaccurate or inappropriate methodologies being used. An alternative option for inter-laboratory quality control procedures is the Performance Based Analytical System (PBAS). This permits choice of methodology but there must be proof of the methods adequacy and the method must provide results that can be calibrated against standard methods. It is important to stress that the Quality Assurance procedures of an environmental monitoring programme must ensure that all aspects of the programme receive appropriate attention. The data are no better than the weakest link and therefore all elements must provide quality assurance.

It is frequently suggested that the availability of resources is outside the field of sampling theory and that statistically based sampling programmes cannot be modified by such considerations. Whilst the 'ideal' programme may be of interest, the statistical and practical aspects of a programme cannot be separated and statistical sampling theory can still be validly used to allocate resources within a limited overall budget. Ultimately if the objectives of a given programme cannot be met within the available resources, a radical re-think may be necessary. It is better, however, to recognize this by giving due attention to the sampling exercise before effort is wasted in collecting data which subsequently turns out to be inadequate.

Data Requirements for Monitoring and Assessment

If we consider the attributes of monitoring data required for different management objectives we can see that for basic environmental protection monitoring data will include physicochemical monitoring of key parameters with estimates of means, range and variance plus details of spatial and temporal variation. Before recommending embarking on extensions to the basic environmental protection programme one needs to be aware of the information needs of this approach and hence the resource implications. We can consider the possible types of environmental data that may be required:

- biological monitoring
- measurement of bioaccumulation and biomagnification.
- measurement of ecosystem stress - use of biological indicator organisms.
- measurement of ecosystem processes.
- measurement of ecosystem integrity.
- human health monitoring (measurement of exposure and risk assessment.)
- integrated human and ecosystem monitoring
- development of models to enable prediction of future environmental impacts and risks.
- integrated pollution monitoring to provide holistic assessment of best management options.
- early warning systems

A useful concept is that monitoring programmes should be designed to provide early warning signals of problems. In this context early warning can be defined as the detection of signals indicating a future environmental problem with a sufficient lead time to initiate corrective or mitigatory actions. The principle is thus to monitor one or more parameters to predict a future state of the system in time to allow appropriate corrective management procedures (5).

The key components of an effective early warning system need to comprise: i) Problem awareness, ii) Signal detection, iii) A forecasting or model component, iv) Communication system. v) Mitigation system) vi) A learning component.

Integrated Environmental Management Systems

Nationally and internationally, the emphasis in environmental protection is moving steadily away from just achieving compliance with statutory release limits. Emphasis is now being given on the need for industry to take the initiative to prevent pollution in the first place and to conserve resources. Industry is being encouraged to implement a formalized and systematic approach to environmental management leading to standard specifications for environmental management systems such as BS7750, the Ecomanagement and Audit Scheme (EMAS) and ISO 4001 (6). This is clearly a very important strategy to be encouraged for all activities taking place in Antarctica. These standards can be applied to any activity, large or small, ranging from camp site to cruise ship, from refueling post to mining exploration station.

The standard specifications for environmental management systems essentially represent common sense and best environmental practice. These practices need to be applied to the entire operation and thus will consider the following basic elements of an organizations actions which should be

examined from an environmental perspective so that the environmental impact of each element of an operation can be identified and, as far as possible, eliminated.
Important aspects of these systems is that they explicitly require an organization to make a commitment to continual improvement in environmental performance and to specify objectives for improvement over a specified time scale. BS7750 requires that objectives are publicly available for scrutiny. Organizations are also required to identify and evaluate all direct and indirect environmental impacts particularly those over which the company has or may be expected to exert some control. Organizations are required to maintain an internal register of significant environmental effects. BS7750 requires that monitoring procedures including methodology and quality control should be clearly specified. The EMAS is less specific but also refers to monitoring procedures. Records must be kept by organizations of all appropriate environmental legislation and regulations.

In the context of Antarctica it would seem appropriate that all companies, research groups and tourist facilities, etc. should be required to adopt best environmental practice and that this could be achieved through a registered environmental accreditation system leading to an integrated environmental management system which operated prior to any pollution release through to the management of pollution and abatement measures.

Conclusions

Monitoring is an expensive activity. It is estimated that current costs of all water quality monitoring in the European Union is approximately 350-500 million ECU. Despite this sum of money, there is still insufficient information being collected to meet all the water management needs. At the same time the funds for monitoring are often limited due to budget constraints. Thus there is always a need for better information at lower cost. The cost effectiveness and efficiency of monitoring can be improved in part by monitoring strategy, i.e., by having clearly defined monitoring goals and data gathering needs and an established monitoring framework.

In the Antarctic, with the various international players operating separately in many respects, it is vital that issues of comparability and availability of data from different countries or monitoring programmes are dealt with at the formative stage. Reliability and comparability of data can be ensured by quality assurance and quality control in all activities of monitoring.

Availability of data can be facilitated if agreements on the procedures for data handling, reporting, storage and exchange are established as part of the Monitoring Framework developed at the outset of the monitoring programme. As far as possible data should be collected, recorded and reported in standard, preferably digital and electronic, formats. Data archiving is a most important aspect of data handling and needs to incorporate the local recording and storage of monitoring data which will permit local assessments of current status and trends, together with the development of a centralized database which can be reliably accessed to provide wide ranging State of the Environment Reporting.

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Arctic Monitoring and Assessment Programme

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The polar regions of the world, once considered as places far from any trace of civilization and thus also of its less desirable consequences, are gaining attention as regions with non-negligible concentrations of man-made contaminants. This is particularly true for the Arctic, which, because of its different geographical setting, seems to be increasingly affected by numerous inorganic, organic and radioactive trace elements. This fact is of concern for at last two reasons. On the one hand, the Arctic and its southern counterpart are sensitive indicators for specific types of contaminants and their various transport paths. Because of a lack of any considerable industrial activity in the high Arctic and even more so in the Antarctic, the polar regions represent an ideal laboratory for the detection of trace substances and the unravelling of their interactions with different environmental compartments. On the other hand, due to the delicate nature of polar ecosystems, these contaminants present serious threats for Arctic nature and its inhabitants, including humans.

It was this concern that led the Environmental Ministers of the eight Arctic countries (Canada, Denmark/Greenland, Finland, Iceland, Norway, Russia, Sweden, USA) to consider effective ways of safeguarding the circumpolar environment. In response to an initiative by the State of Finland, the ministers met in Rovaneimi, Finland. After thorough discussions, they drafted an **Arctic E**nvironmental **S**trategy (AEPS) which was passed on June 14 1991. As one of the direct items under AEPS it was decided to initiate an effort directed at assessing the present state and monitoring any future changes of the Arctic environment, the **Arctic M**onitoring and **A**ssessment **P**rogramme (AMAP). AMAP not only strives to measure the levels of anthropogenic contamination but also to assess their effects on relevant components of the Arctic environment.

In order to pursue this task, AMAP through its Task Force, its secretariat in Oslo and various national committees, drafted a first overall implementation plan as well as individual national implementation plans for the initial phase of the programme. This phase will be completed by a **State of the Arctic Environment Report** due to be delivered to a ministerial meeting in the near future.

AMAP has four key objectives:

- to monitor, assess and report the status of the Arctic environment
- to document and assess the effects of anthropogenic pollution
- to recognize the importance of and the use of the Arctic flora and fauna to the indigenous peoples
- to document levels and trends of contaminants

AMAP is directed by the AMAP Task Force which consists of representative s of the eight Arctic countries as voting members, as well as representatives of international Arctic indigenous organizations, international organizations involved in monitoring and regulatory activities, assessment and research and observers from a number of countries with significant research activities in the Arctic.

There is no common fund or budget available for AMAP. The monitoring and assessment activities are solely financed by participating countries or though bilateral or international agreements or programmes. This is a critical factor for the success of AMAP.

In order to achieve some coordination of activities “lead countries” were agreed for major compartments:

1. The atmosphere - Canada
2. The marine environment - Norway
3. The terrestrial environment - Sweden
4. The freshwater and rivers - Finland
5. Human health - Denmark

Out of a substantial list of important parameters to be monitored in each compartment priority was given to three : persistent organic pollutants, selected heavy metals, radionuclides. Considerable progress has been made in all these three classes, both in synthesizing existing data and collecting new data within a framework of agreed protocols and with inter-laboratory cross-calibrations.

Techniques for Protection of the Arctic Environment

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At BP Exploration (Alaska) our main environmental objectives are to minimize and eliminate environmental liability and risk, maintain our license to operate and conduct corrective action for past practices.

To help protect the Arctic environment in which we operate, we focus on production practices, including facility design and construction, pipeline design and construction, and operations. The goal is to eliminate or reduce impacts, including air emissions, releases to water, releases to land, spills and loss of habitat. For example, we site facilities to avoid sensitive areas. Buildings are elevated to protect the permafrost. Construction is timed to reduce interference with wildlife. Roads and pipelines are separated to facilitate wildlife movements. We use ice roads and ice pads. We have achieved a 70% reduction in surface impacts by eliminating reserve pits for surface storage of drilling muds and cuttings, using directional drilling and reducing wellhead spacing. By centralising support functions and sharing or consolidating facilities we have further reduced our footprint on the Arctic tundra and facilitated development of peripheral fields. Prior to development, we conduct environmental assessments to establish baseline data on habitat types, and wildlife distribution, abundance and movements.

Waste management is another area in which we can reduce or eliminate impacts. Waste handling facilities are centralised. We have an aggressive recycling programme and comprehensive employee training to increase environmental awareness and we conduct audits of our facilities and operations.

Spill prevention is the third major area in which we can reduce pollution and environmental impacts. We use secondary containment to reduce the chance of spills reaching the tundra, we have implemented strict fluid transfer procedures and we use surface liners. We pre-deploy equipment at sensitive sites and provide comprehensive training for employees and on-site contractors. There are scheduled and surprise drills to maintain readiness.

All of these efforts provide experience with tools useful to those who have to address issues relating to development in areas beyond Alaska, such as the Antarctic. The lessons BP have learned over more than three decades in Alaska can be applied elsewhere. We understand the processes occurring in the Arctic environment and how our facilities affect those processes. We can now focus on advance planning and eliminating environmental liabilities. We have learned the value of working cooperatively with agencies and national representatives and with environmental organisations (NGOs and government). We are constantly looking for ways to improve our operations and apply innovative technologies to prevent future deterioration.

Pollutants in Antarctica: Hydrocarbons, Metals and Synthetic Chemicals

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Major Focus of the Presentation

The intention is to present an overview of the chemicals potentially released in Antarctica by humans and of the present knowledge of contaminant distributions. Station and airstrip logistics operations, station maintenance and scientific research, accidental fuel spills and surface run-off all contribute to hydrocarbons, metals and synthetic chemicals in the region. Natural inputs of the former two components have also been adequately documented in the literature.

Introduction

In general, anthropogenic input is very low, representing global background signal and below the thresholds of harmful effects. Pollution is limited to few locations and events. The extent of halo of contaminants is limited to hundreds of metres from the point source. The sphere of influence of human activity depends on the intensity of contamination and the local oceanographic setting i.e., high energy environments help disperse while low energy environments tend to accumulate the contaminants.

Long distance atmospheric transport is indicated by the similarity of contaminant pattern or fingerprint of chemicals i.e. PCBs in Antarctica, to that observed in the entire southern hemisphere. However, the available data demonstrate that on a continent-wide basis local inputs far outweigh global inputs. At the present time local inputs are probably the only ones with potential to accumulate to levels that might induce biological responses.

Literature survey also clearly shows that spatial coverage for contaminants is patchy and relevant time-series data are sparse. Most of the early work has been confined to coastal regions mainly because of the easy accessibility from research stations. The available data are, therefore, not representative of the marine ecosystems in the Southern Ocean.

Fossil fuel spills are the most unpredictable and potentially most catastrophic contaminating events in the Antarctic region.

Practicalities of Monitoring Hydrocarbons and Other Components

The utility of monitoring depends on how well the anthropogenic signature can be differentiated from natural inputs e.g.,. for hydrocarbons from seepage and shale erosion, or for metals from weathering of basaltic debris. Hydrocarbon distribution patterns rather than indices i.e., odd/even ratios, appear to be more suited to understand the region. Monitoring of synthetic chemicals i.e., PCBs, DDTs, alkylbenzenes etc. is valuable because of their unambiguous origins. However, the general occurrence of the chlorinated hydrocarbons in the region at very low levels challenges the sample handling and analytical techniques.

Alkylbenzenes, indicators of laundry detergents, have been reported in only one study and this could be extended both to other locations as well as being applied more intensively at some sites to follow the sewage plume. Faecal sterols are also indicators of sewage inputs in the vicinity of settlements. These compounds could be measured wherever hydrocarbon monitoring is planned.

Recommendations

Spatial and temporal baselines of selected compounds or indices should be established by planned spatial coverage, identifying reference stations, repeat visits to reference stations and seasonal coverage for variability. It is against this baseline data that the local perturbations must be measured.

Complete inventories of chemicals and other commodities transported in and out of Antarctica should be undertaken. Information, particularly on chemicals which are transported to Antarctica, their volume, contaminants or byproducts generated from their various uses should be gathered.

Types, frequency and intensity of activities carried out in Antarctica should be listed.

A mass balance should then be possible from the rate and type of contaminants produced and the activities in the region. This will help estimate or predict the environmental levels of pollutants and thus their potential for effects.

Environmental Monitoring in Antarctica: Atmospheric Pollution

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The Antarctic atmosphere has been subject to changes in recent decades due to global pollution, long-range transport from other continents, and local pollution from stations and other sources.

Globally distributed pollutants, seen also in the Antarctic, include chlorofluorocarbons (CFCs, responsible for Antarctic ozone depletion), and radiatively-important trace gases (such as carbon dioxide and methane).
Antarctic stations participate in global programmes to monitor levels of these pollutants, and ice core data are used to trace changes over periods before instrumental records began.

For long-range transport, the Antarctic is in very different position from the Arctic, being much more isolated from potential sources. Thus, the major concerns of Arctic monitoring schemes, such as input of pesticides and metals from mid-latitude sources, are of little environmental concern in Antarctica, although of interest for understanding transport. Sampling of snow and ice cores has been used to show significant changes over recent decades in atmospheric levels of radionuclides (from atmospheric nuclear testing) and lead (from mining activities and leaded fuels). On the other hand, nitrate and sulphate, indicators of acid precipitation, remain more or less unchanged in concentration.

The main sources of pollution within Antarctica are Antarctic stations, and vehicles (including ships and aircraft) away from stations. Field camps are very minor contributors. Fuel combustion (and evaporation), waste combustion, and construction, are expected to be the main contributors to atmospheric emissions. Emissions from aircraft, ships and stations are likely to be of similar importance to the Antarctic atmosphere as a whole. However, in considering local concentrated effects, only the static source (stations) should be of concern.

A whole host of pollutants will be emitted - CO, CO_2, SO_x, NO_x, soot, hydrocarbons, polycyclic aromatic hydrocarbons, heavy metals, dioxins, dust, heat, noise and electromagnetic radiation might all be of concern if emitted in large quantities. Pesticides, PCBs, radionuclides, and microbiota have also been mentioned in documents, although we could expect that there are no significant atmospheric emissions of these species in Antarctica.

In designing a suitable monitoring programme, it is necessary to decide what is being protected. Concerns could be for human health, for flora and fauna, for stability of snow cover, for science programs, or a general desire to keep the Antarctic pristine. Different criteria would apply to the protection of each of these. A programme would also need to take account of the different types of station. At one end of the spectrum is the inland ice station, with a strong temperature inversion and less strong winds, making dispersion less efficient, but with no local wildlife to protect. At the other end are coastal stations with strong katabatic winds driving pollutants away, but which may have wildlife very near the station.

A few examples can be given where monitoring around a station has already been carried out. Measurements of lead in surface snow (as a surrogate for air) around Halley station showed levels approximately 3 times background at 1 km from the station. No effect was discernible at 10 km distance. Emissions of lead from leaded aviation gasoline used in some aircraft could also have had a widespread effect on concentrations. Although these findings suggest possible limitations on scientific studies of long-range transport of lead pollution from outside Antarctica, levels even 1 km from the station are about 1000 times lower than typical levels in populated areas.

Soot from generators can increase the levels of black carbon measured a few hundred metres away by factors of 100 above background. However, surveys carried out around South Pole and Vostok stations suggest that the levels even 1 km downwind of the stations are too low to influence snow albedo.

Another combustion product, polycyclic aromatic hydrocarbons (PAHs) was measured around Terra Nova Bay station. Although slightly elevated levels were seen at about 200 m from the source in the downwind direction, values were still in a similar range to the lowest detected in other remote regions.

It appears that, where measurements have been made, most pollutants are undetectable above background even a few hundred metres from the source. The implication is that monitoring at km distances from stations will yield values below detection limits, while sampling in generator chimneys will clearly show raised levels. What questions, yielding answers in between these two extremes, should monitoring be asking?

For monitoring to be worthwhile, results must be accurate and meaningful. In fact, for many species of concern, background levels may be measurable only by expert analysts using research instruments or very expensive devices, and taking great precautions. There is a significant likelihood of contamination from oily clothes, cigarette smoke, passing vehicles and other causes if sampling programmes are poorly designed. For most species, only within tens to hundreds of metres from the source is measurement likely to be more routine. Collection on filters or in flasks for subsequent analyses in home laboratories may be possible if stringent instructions and precautions are used by well-motivated collecting personnel. Analysis will still be expensive in these cases, and there are concerns over sample stability (volatility) during several month transport to home laboratories for many organic species. Measurement of emissions in incinerator stacks, etc., is of course possible, though probably most protocols are designed for larger sources.

A hypothesis on which to base atmospheric monitoring might be:

a. that there is an area around each station beyond which there is no possibility of ecological damage, and that there are no ecosystems within this area;

b. that there is a larger area within which raised concentrations can be seen, but that this is an acceptably small part of the area of Antarctica.

Any assessment is then aimed at defining the size of these areas, and this might be done in a number of ways.

Possible monitoring strategies can be considered:

1. Routine, year-round monitoring of many species at many sites at all stations would be very expensive, and would likely yield many incorrect and meaningless data.

2. A paper study of emission inventories, backed by plume modelling, could identify potential problem species and stations, particularly those where ecosystems are in the downwind direction. Monitoring could them be concentrated in these problem areas. An add-on to this approach would be to monitor stacks to validate the inventories.

3. An intensive study of a few "typical" stations could be used to validate the modelling approach for other stations.

4. An expert group, with state-of-the-art knowledge and instruments could be commissioned to monitor at stations on SCAR's behalf, ensuring consistency of data between stations.

There is probably some scope for reducing emissions of some species (e.g., use of unleaded fuel, avoidance of Cl-containing species in incinerators), but some pollution is inevitable as long as combustion takes place.

In summary, existing data show that atmospheric pollution from Antarctic sources is extremely localised (to within a few hundred metres of source emissions), and likely to have an ecological effect only where stations are very close to biota. There are also areas close to stations where some science programmes cannot be carried out because of atmospheric pollution.

A monitoring programme would be most useful if it concentrated on areas where real threats might exist. It must avoid producing a lot of incorrect or meaningless data.

Environmental Monitoring at the Terra Nova Bay Station

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Introduction

Italy signed the Antarctic Treaty in 1981. In 1985 the National Programme of Research in Antarctica (PNRA) was established with funding for five years. In 1991 a second five-year programme was approved and a new five-year programme is at present in preparation.

The PNRA foresees a wide range of research projects within five major groupings:

- Geological evolution of the Antarctic continent and of the Southern Ocean
- Global Change
- Observatories and geographical information
- Methodologies for environmental conservation
- Technological research

In the Act of Parliament instituting the PNRA it is also stated that international cooperation must be encouraged. In particular, at least 20% of the funding must be used for joint ventures with other national programmes. Italian researchers are active in a number of the large international programmes promoted by SCAR.

Italy became a Consultative Party to the Antarctic Treaty in Oct. 1987 and a member of SCAR in September 1988.

The summer research station Baia Terra Nova was established in the 1985/86 season in the Ross Sea area, on a rocky, ice-free coastal site at 74° 41'42" S and 164° 7'23" E. The site had been selected in the previous years by Italian scientists, in cooperation with the New Zealand Antarctic Programme.

The site presents a number of desirable characteristics, both from the scientific and the logistic points of view. Ten years of operation of the station have confirmed fully the original decision to choose the site from where a full range of interesting and important scientific research activities can be performed. From the logistic point of view, the bathymetry of the area allows easy access by ship. The position of the station near the tip of a small peninsula which protects the sea ice in a small bay has allowed the use of a sea ice runway, which can be used from mid October to the beginning of December by C-130 aircraft. This development permits an earlier opening of the activities at TNB than can be achieved with only ship support. Another advantage of TNB is its comparative proximity to the US and NZ bases at McMurdo Sound, about 350 km to the south.

The first Italian expedition went to Antarctica in the 1985-86 season. A detailed survey of the local area was performed, to study the site and to select the actual positions of the base buildings. The expedition used tents and non-permanent accommodation and some material and equipment was left on site for the following campaigns. The construction of the station began with the second expedition in 1986-87. During this expedition the implementation of the scientific programmes and of the environmental monitoring activities began.

Terra Nova Bay Station

The station is for summer use only, being active from mid-October to the end of February. The initial decision of the PNRA was that the construction and operation of a year-round base was not justifiable on the basis of the scientific programmes proposed at that time. However, the option to transform TNB into a year-round station remains open. The temperatures at TNB during spring and summer are not extreme, with minima around -10° C to -15° C and maxima around 0° C.

The station has been built gradually. In the 1986-87 season one main building and two auxiliary building were assembled, using standard ISO 20 containers with extra thermal insulation. These buildings are mounted on steel columns raised above the granitic rock of the site, in order to avoid the accumulation of wind-driven snow. The main building of 630 sqm is composed of 34 container-modules in two rows of 17 with an aisle in between. It houses sleeping quarters, shower and toilet facilities, kitchen, surgery, radio room, office space and some laboratories. In the same season a reverse osmosis desalination plant (7 cu m/day), two diesel generators (175 kVA each), and workshops were also installed. At the end of the 1986/87 season the base was fully operational with a capacity of 48 persons.

More buildings and facilities were added in the following seasons. In particular: two more powerful diesel generators (375 kVA each), while the two older ones were put in reserve; bigger reverse osmosis plant, with a production of 28 cu m/day; a sewage treatment plant and an incinerator were installed in 1987/88; ten containers housing laboratories; in 1988-89, new modules were added for 7 new laboratories, a computer room, offices, one meeting room, radio room, operations room, 4 sleeping rooms with facilities; six containers were installed near the main building to house an aquarium, scuba dressing room and two geology laboratories. A major addition during the 1988-89 season was the construction of two large hangars to be used as workshops, warehouses and vehicle storage. The fifth campaign, 1989-90, saw the establishment, at 400 m from the main building, of a sub-millimetric infrared laboratory.

In addition to the buildings mentioned there have been other infra structural developments. The station has two helipads with local fuel storage. The main fuel storage is in two steel, double skinned cylindrical tanks, each having a 600.000 l capacity.; additional fuel storage has been provided near the diesel generators in order to avoid too frequent fuel transfers, which could lead to spills.

Environmental Considerations

The Terra Nova Bay station has been built and is operated in such a way as to keep the environmental impact to the minimum. It is however a rather large station with a major and diverse scientific programme. In order to minimise the use of fuel, a co-generation system is installed on the diesel generators to recover waste heat which is used for heating the station. A strict waste management plan is enforced and most wastes are retrograded out of the Antarctic Treaty area.

From the 1991-92 campaign the base has standardised JP8 as fuel for practically all uses, from the diesel generators to the refuelling of the helicopters and the C-130 that is used for logistic support. This has cut to the absolute minimum the use of leaded fuels.

An environmental monitoring programme was begun very early in the life of the station as will be described later and many activities have been modified by the results of this monitoring.

Environmental Monitoring

The main purpose of the applied monitoring is the detection of local and regional environmental effects caused by specific human activities. In the case of an Antarctic station the specific human activities are those performed during the operation of the station. Thus, both logistic and scientific activities are included In selecting what to monitor, factors such as the following must be considered:

- type of environment
- equipment and personnel available
- cost of monitoring and its duration
- interference between monitoring and other activities
- relevance of the monitored variables

Both the Recommendation XV-5 and the Protocol on Environmental Protection to the Antarctic Treaty call for national programmes to establish environmental monitoring programmes for activities that include:

1. waste disposal
2. contamination by oil and other noxious substances
3. construction and operation of stations, field camps, ships, aircraft and logistic support
4. implementation of field programmes
5. recreational activities
6. activities related to protected areas.

The Protocol, in particular, requires, in its Art. 3.2 (d) and (e), “regular and effective monitoring to allow assessment of the impacts of ongoing activities, including the verification of predicted impacts” and “to facilitate early detection of the possible unforeseen effects of activities”.

Several of the research projects carried out under the PNRA deal with environmental monitoring for basic research purposes. The applied environmental monitoring which has been implemented at TNB since the beginning of the operation of the station in the 1986-87 season has borrowed ideas and methodologies from these scientific projects. Scientific monitoring has been concerned with sea water, freshwater, soils, particulates, sediments, air, etc, as well as different biota. The applied environmental monitoring has concentrated its attention on only some of these.

TNB is a very active station and the range of its logistic and scientific activities is quite broad for a summer-only station. Consequently, in the selection of what to monitor, a certain number of decisions had to be taken. The programme has been developed as activities developed, in the sense that with the installation of new equipment, such as the incinerator, or with increase in the number and types of vehicles, changes were made in the monitoring programme. The availability of different means of sample analysis has sometimes changed the type or the frequency of sampling.

The Environmental Monitoring Programme at TNB

The first expedition (1985-86) did not perform any environmental monitoring. There was yet no permanent accommodation or installation and most efforts were concentrated on a survey of the area, some bathymetric work, the determination of the point sites for the future station.

Airborne Particulates Monitoring

1986-87 The programme of monitoring was initiated and the collection of samples began. This was done before the actual start of construction of the station buildings and before the start of activities, in order to collect background values. This initial monitoring was centered on airborne particulate matter and freshwater. The collection of samples was performed with a low-volume air sampler about 1200 m from the centre of the station, taking good care not to sample the diesel generator exhausts. This first set of samples was aimed at the measurement of 44 elements including Na, K, Mg (marine origin), La, Sc, Al, Si (crustal origin), and V, Hg, Cd (anthropogenic origin). Analyses used an Instrumental Neutron Activation Analysis (INAA) in the TRIGA research reactor of the Casaccia Research Centre. The extremely low concentrations of the elements, very close to or below the sensitivity of the instrumentation, was a significant problem. Because of this, the sampling periods of the samplers was gradually increased.

1987-88 Sampling for airborne particulates was performed in the vicinity of the station buildings. Two new automatic low volume samplers were used, set at about 100 m NE and at 600 m SW. This monitoring was performed in order to assess the effects of station activities.

1988-89 The monitoring programme was focused on the impacts from station activities. Four automatic samplers were in action, the two installed the year before and two new ones, one 100 E of the station and another well away from the station at Skua Lake. One interesting fact emerged: with the increased activity of the station, there was no significant increase in the values of the pollutants measured. After this campaign, on the basis of the results obtained so far and because of the lack of a good correlation with meteorological data, it was decided to carry on with the multi-elemental characterization of the environment, in order to obtain enough data to perform statistical analyses and to obtain a reliable set of background values.

1989-90 Two Andersen high volume samplers were put into operation at 120 m S and at 700 m WSW. They have an air flow of 1130 l/min, with a sampling period of 3 days. Logistics and local land morphology had a part in the selection of the sampling sites. The filters were analysed both by INAA techniques for the determination of the most important minor and trace elements and for PAH (Polycyclic Aromatic Hydrocarbons) determination. This latter determination is important because PAH is characteristic of combustion products. Biotic accumulation of PAH was investigated in the marine bivalve *Laternula elliptica*, an organism selected because of its local abundance and low mobility. In this campaign the PAH methodology was adjusted to Antarctic conditions and from the next campaign onwards we have a regular set of data on PAH. This determination was made necessary by the increased power rating of the new diesel generators, by the entry into operation of the incinerator, and by the general increase of the logistic activity.

1990-91 Two additional high volume samplers were installed, thus completing the circle of monitoring points around the station. This allowed the determination of the main directions of airborne transport of pollutants and confirmed the very low levels of contamination from the most important sources, i.e., diesel engines and vehicles. We had to review the programme of analyses, because of difficulties in the utilization of the TRIGA reactor used for the neutron activation analyses. We also considered the use of the Atomic Absorption Spectrometry applied for the detection of Pb. As a consequence and also to simplify matters somewhat, it was decided to reduce the elements for analysis to seven. The attention was then directed to anthropogenic elements and to a few crustal and marine elements. In the PAH determinations, only 11 compounds were selected (phenanthrene, anthracene, pyrene, etc). All of these analyses were repeated in later campaigns and the raw data from the first campaigns was elaborated.

1991-92 This campaign was a small one and only one person dedicated to the monitoring programme was present at TNB. The four high volume samplers were in operation around the station, while the low volume sampler at Skua Lake was not in operation. The weather was awful most of the time and the concentrations of all monitored elements, including those of PAH, were extremely low.

1992-93 Very reduced campaign, practically only for station maintenance. The only data collected were those of airborne particulates and PAH; the latter were also very low, because of a very reduced activity.

1993-94 This was a large campaign. The four high volume samplers were in operation and a fifth one was installed at Skua Lake. This sampler was also used for some spot sampling in order to verify filter efficiency as a function of sampling time. We also performed the characterization of single sources. The spectrum of PAH investigation was broadened to include a number of compounds derived specifically from diesel engine operation (coronene, cyclop cd, etc); the spectrum of PAH compounds was now at 23. The elaboration of data from this and the next expedition is in progress.

1994-95 It was decided to add another high volume sampler at Campo Icaro, 2 km S from the station. This decision was taken because station logistics were extending out towards the Skua Lake site. The PAH sampling was continued along the lines established in the previous campaign, in order to create a meaningful data set and to correlate these measurements with those of concentrations in the bivalve *Laternula*. Slight changes were made to the programme for the determination of inorganic compounds.

Sewage Treatment Plant

A biological sewage treatment plant was installed in the 1987-88 season. No monitoring of the effluent was performed in that season and the first trial measurements of BOD (Biological Oxygen Demand) were made in 1988-89. Systematic monitoring was started in 1989-90 and in 1990-91 a full monitoring programme was implemented. This programme included the measurement of BOD, COD (Chemical Oxygen Demand), surface active agents, nitrites, oils. This monitoring indicated that the plant was not large enough for the load and plans were made to install a new physico-chemical plant in the next season.

The new plant was installed in the 1991/92 season. A certain amount of adjustment was necessary in the monitoring. This now comprised: COD, nitrites, nitrates, free ammonium, free oxygen, turbidity, Fe. Most samples were also subjected to microbiological analyses. Sampling was performed daily and the results were used continuously for plant adjustments.

Apart from this monitoring programme, at the beginning, in mid-campaign and at the end three sets of samples were collected along two transects to determine faecal coliforms in the discharge area.

In the 1992-93 season also the old plant was put in operation, but no effluent monitoring was performed. In 1993-94, the effluent of the old plant was again monitored and because of high bacterial load, it was decided to add to the effluent sodium hypochlorite. In the 1994-95 the monitoring programme was carried out until January 1995: after that, the two systems, the biological and the physico-chemical were connected in series, because of the excessive load. It has been decided to install a completely new plant, designed for the higher loads of the recent expeditions. This will be done in the 1995-96 campaign.

Incinerator

The incinerator was installed at TNB in the 1987-88 season. It is a two-stage machine, has a capacity of 50 kg/h with a limit of 200 kg/day. and it is designed for the following typical waste composition: food scraps 40%, paper 20%, glass 15%, packing material 15%, tins 10%. At TNB it is used mainly for burning paper, untreated wood and food scraps.

Some particulate matter samplings have been performed and analyses were done in order to characterise the emissions. But this sampling and monitoring have been always difficult because of the discontinuous use of the apparatus which makes isokinetic sampling difficult. Furthermore, the stack is narrow and fumes are very concentrated, sending gauges off scale.

Therefore, the monitoring of the incinerator emissions is not undertaken at source but as part of the TNB monitoring programme.

Use of the data

The monitoring of airborne particulates over seven seasons has produced a large amount of data. The data on PAH cover only three austral summers and provide a basis for only qualitative conclusions.

The airborne particulates data show that in the 1987-88 the levels were quite high, compared to the other seasons; indeed, during that campaign there was a lot of ground movements because of the construction of considerable station infrastructure. There was an increase in rare elements content (LA, Ce), in Th, from intrusive rocks, and in elements such as Fe, Al, Cr, Zn. This last elements seem to have a crustal origin, rather than an anthropogenic one.

Another interesting observation can be made about lead; Pb determinations were performed during the 1989-90 campaign because of the increase in the number of vehicles using leaded fuel. Significant lead levels were detected, in comparison with literature values. Some of these values can also be attributed to the operation of the incinerator. This origin was also confirmed by some results obtained during the 90/91 campaign.

The 1991-92 campaign was characterised by very bad weather, with very abundant snow; this weather minimised the environmental impact. During the same season a low level of Hg was measured which we have been unable to explain.

A constant difficulty that our monitoring programme has had and still has is that the majority of the analyses on samples are performed out of Antarctica, in Italian laboratories and usually in laboratories which are not part of the National Antarctic Programme. This produces a delay in obtaining the data because the laboratories are not dedicated to Antarctic research. Some of the simpler analyses are performed in TNB itself: an example are those related to the sewage plant monitoring. In that case it is possible immediately to apply the results to the actual running of the plant, with considerable operational and environmental benefits.

During these years of Antarctic experience we have felt the need for having sampling and analyses protocols, in order to carry out comparisons among all countries active in Antarctica. It would be also very useful to establish standard reference levels for key monitoring parameters and for the desirable frequency of monitoring. These workshops are now addressing this need. Finally, we believe that applied monitoring data from all Antarctic stations should be gathered in one data base and accessed through a GIS.

Conclusions

The environmental monitoring programme at TNB has been a long one. It was started at the right time and it has been useful because it has led to a good understanding of the Antarctic environment and its relationship with human activities. Many improvements could be made to it, in terms of better and more rational sampling, better elaboration of the collected data, more rational use of the results. A problem that exists with monitoring programmes is their high cost, in terms of equipment, manpower, laboratory utilization, materials, logistics, interference with scientific and logistic activities etc.

Also, these are programmes which should last the whole lifetime of a station and therefore it is necessary, actually indispensable, to have a good “record” of activities and samples. The organization of a large monitoring programme, even in an environment as “clean” as Antarctica is not an easy task, if one desires to do it well. With the Antarctic adding its own peculiarly difficult characteristics to the complexity of any programme effective sharing of information among the people active in this “applied science” subject can go a long way to making a difficult but useful job a little easier and better.

WORKSHOP 2

The Framework of Environmental Concerns and Response in Antarctica

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Concern regarding the environmental impacts of human activities in Antarctica is not new. The Antarctic Treaty, for example, prohibited nuclear explosions and disposal of radioactive waste in Antarctica. It also provided all contracting parties with the Treaty. It specified that representatives of the contracting parties were to meet periodically to exchange information, to consult on matters of common interest, and to formulate and recommend to their governments measures to further the principles and objectives of the Treaty, including measures to preserve and conserve living resources.

Since the Treaty entered into force in 1961, there have been 19 regular consultative meetings and 11 special consultative meetings. The Treaty did not address resource issues. Most of the special consultative meetings have dealth with resource issues. They have produced a number of free-standing agreements which, along with the Antarctic Treaty, form what is known as the Antarctic Treaty System. These include the Convention for the Conservation of Antarctic Seals, the Convention for the Conservation of Antarctic Marine Living Resources, the Convention on the Regulation of Antarctic Mineral Resource Activities, and the Protocol on Environmental Protection to the Antarctic Treaty.

The Scientific Committee on Antarctic Research (SCAR), which was established to plan and coordinate scientific investigations in the Antarctic during the 1956/57 International Geophysical Year, has served as an unofficial scientific advisory body to the Antarctic Treaty Consultative parties. in 1960, SCAR developed General Rules of Conduct for the Preservation and Conservation of Living Resources in Antarctica. At the first ATCM in 1961, the consultative party representatives recommended to their governments that they recognized the urgent need for measures to conserve living resources in Antarctica and, as an interim measure, that they promulgate general rules of conduct along the lines of those developed by SCAR (Recommendation I-8).

At the ATCM held in Brussels in 1964, the Treaty parties adopted Agreed Measures for the Conservation of Antarctic Fauna and Flora. The Agreed Measures refer to the Antarctic Treaty Area as a Special Conservation Area. They require each participating government to prohibit the killing, wounding, capturing, or molesting of any native mammal or bird within the Treaty Area, except in accordance with a permit. In addition, they require each participating government to take steps necessary to minimize “harmful” interference” with the living conditions of any native mammal or bird, except in accordance with a permit. They provide for designating Specially Protected Areas (SPAs) to protect areas of outstanding scientific interest, and prohibit entry into those areas except in accordance with a permit issued for a compelling scientific purpose. The Agreed Measures established the precedent for using permits to regulate and restrict activities that could adversely affect native flora, fauna, and their habitats in Antarctica.

At the VIIth ATCM in 1972, the Consultative Parties representatives adopted Recommendation VII-3, which provides for designating and affording special protection to Sites of Special Scientific Interest (SSSIs). The recommendation invites SCAR, through national committees, to propose sites for designation as SSSIs, and to propose management plans for those sites. This recommendation set the precedent for establishing agreed management plans for certain areas in Antarctica.

The presence, and need to develop agreed measures to govern exploitation, of both living and non-living resources in Antarctica was recognized by the mid-1960s. The Convention for the conservation of Antarctic Seals, concluded in 1972, set the precedent for developing free-standing agreements to deal with resource issues. It was followed in 1980 by the Convention for Conservation of Antarctic Marine Living Resources (CCAMLR), in 1988 by the Convention on the Regulation of Antarctic Mineral Resource Activities (CRAMRA), and in 1991 by the Protocol in Environmental Protection to the Antarctic Treaty (Environmental Protocol).

Each of the agreements were precipitated or accompanied by corresponding advice from SCAR. The ecosystem-approach embodied in CCAMLR, for example, had its roots in the 1976 SCAR Conference on Living Resources of the Southern Ocean. Also in 1976, SCAR formed a group of specialists to provide advice to the Treaty parties on the environmental implications of possible mineral exploration and exploitation in the Antarctic. The work of that group, combined with the work of a Group of Experts formed during the IXth ATCM in London in 1977, provided the technical basis for the negotiations that lead to CRAMRA. A 1984 report by SCAR -- "Man's Impact on the Antarctic Environment: A Procedure for Evaluating Impacts from Scientific and Logistic Activities" -- provided the technical basis for the environmental impact assessment and monitoring provisions in both CRAMRA and the Environmental Protocol.

CCAMLR is unique in that is objectives are to maintain the ecological relationships between harvested, dependent, and related populations and to prevent or minimize the risk of long-term or irreversible changes in the Antarctic marine ecosystem, as well as to prevent depletion of populations subject to commercial exploitation. The CCAMLR Scientific Committee has developed and begun implementing an Ecosystem Monitoring Program as one of the means for meeting these objectives. The program has three components: (1) monitoring of representative land-breeding krill predators at a network of sites throughout the Antarctica; (2) comprehensive studies of krill, krill predators, and related environmental variables in three "integrated study areas"; and (3) directed studies of crabeater seals in one or more pack-ice areas. Additional information concerning this and other aspects of CCAMLR will be provided in a paper to be presented later by David Agnew, the CCAMLR Data Manager. The CCAMLR Ecosystem Monitoring Program, and the thinking that led to its three-prong structure, may help to identify the most cost-effective way for determining and monitoring the environmental impacts of research and related operations in the Antarctic.

As noted earlier, the negotiation of the Convention on the Regulation of Antarctic Mineral Resource Activities was concluded in 1988. At the XVth ATCM in Paris in 1989, Australia and France indicated that they would be unable to ratify the Convention, and proposed instead development of a comprehensive Convention for the Protection of the Antarctic Environment. The other parties agreed and adopted Recommendation XV-1, calling for a special consultative meeting to be held in 1990 to discuss elaboration of a comprehensive system for the protection of the Antarctic environment. These discussions led to the Protocol on Environmental Protection to the Antarctic Treaty, concluded in 1991.

Many aspects of the Environmental Protocol were derived directly from the CRAMRA. The basic environmental principles set forth in Article 3 of the Environmental Protocol, for example, are patterned after article 4 of the CRAMRA.

With respect to this workshop, Articles 3, 8, 11, 12, and Annex 1 of the Protocols are of particular relevance. Article 3 specifies that activities conducted in the Antarctic Treaty Areas are to be planned and conducted so as to accord priority to scientific research and to preserve the value of Antarctica as an area for the conduct of such research, including research essential to understanding the global environment. It requires that monitoring be done, as and when necessary, to verify the predicted impacts, and to facilitate the early detection of the possible unforeseen impacts of activities, both within and outside the Antarctic Treaty Area on the Antarctic environment and dependent and associated ecosystems. Article 8 and Annex 1 prescribe requirements for environmental impact assessment. Article 11 establishes an expert advisory committee -- the Committee for Environmental Protection. Article 12, describes the functions of the committee.

At the XVIth ATCM in Bonn in 1991, it was agreed that a meeting of experts should be held to consider and provide advice on environmental monitoring needed to implement the Protocol. The meeting was held in Buenos Aires, Argentina, in June 1992. That meeting concluded that the activities most likely to have environmental impacts of possible concern were (1) station and airstrip construction and logistic operations; (2) waste water and sewage disposal; 93) incineration of waste; (4) power and heat generation; (5) activities involving or affecting native flora and fauna; (6) scientific research; and (7) accidents resulting in fuel spills or other types of environmental contamination. Among other things, the participants recommended that a meeting of technical experts be convened to examine in greater detail such things as program design, available technology, and means for standardizing data collection and assuring data quality. This and the companion workshop held in Oslo in November are the response to that recommendation.

The Tools Available for Data Management and Data Accessibility Issues

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Abstract

Management of data includes the collection, storage, manipulation and transfer of data and the output of information. A data management system employs a suite of tools to carry out these functions. Before the tools appropriate to a particular application are selected issues such as data redundancy, standards, access and sharing must be addressed. Database management systems (DBMS) are effective for managing large data sets. Geographic information systems (GIS) are more appropriate data management tools for spatially referenced data and may be more useful in a long term environmental monitoring program. WAIS the Wide Area Information Search system and the World Wide Web (WWW) represent two tools currently available for accessing and querying a distributed database.

1. Introduction

Establishment of an effective data management program requires identification of an information strategy (Harrison, 1992). This strategy should encompass firstly user needs and priorities, and secondly data issues such as collected, manipulation, storage, maintenance, access and transfer of information. The chief objective of an environmental monitoring program is to identify and measure changes in the environment through the collection of temporal data. In order to achieve this goal an appropriate information or data management system (DMS) must be designed. Such a system should allow *information* of utility to decision makers to be produced from these *data*. A DMS consists of several distinct but connected sub-components; data management issues such as collection, processing and access protocols, a data management tool kit, a user interface and the end users (Figure 1). In this synopsis, the issues involved in the collection and assimilation of data into a useful information resource are discussed. This is followed by an investigation into the available technologies which allow this system to function, i.e., the data management tools. Finally, the broader issues of data accessibility are reviewed and present day access utilities relevant to a distributed user base described.

2. Data Management

A data management system is an information storage and retrieval system designed to permit file update and inquiry, produce data summaries, generate and process new data organizations and allow rapid and easy access by a user group. The utilities which provide this functionality represent the data management tools. An example of a DMS are file management systems or database management systems (DBMS). Before the appropriate data management tools can be determined certain key issues must be addressed. In this section issues integral to the design of a DMS implemented as part of an environmental monitoring program in the Antarctic are discussed.

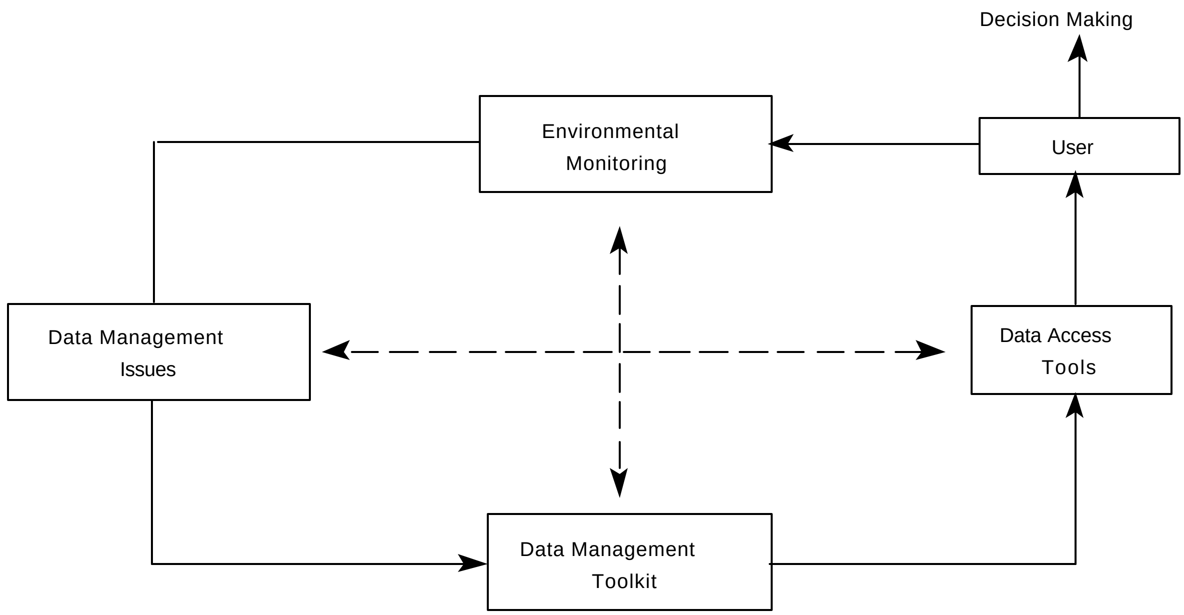

Figure 1. A data management system (DMS).

2.1 Data Redundancy

Data Redundancy can be discussed at two levels, within a database and between databases. The former refers to the duplication of data sets within a database while the latter refers to duplication of effort, i.e., collection of similar data by different organizations. Nondatabase systems require a separate file for each application. One of the principal reasons for establishing an integrated database is to reduce data redundancy. While redundancy cannot be completely removed it is able to be controlled, the level of control depending on the type of database.

The situation whereby information is maintained in multiple data repositories (i.e., national programs) has the potential to lead to substantial redundancy and/or duplication of effort. Data collection programmes should be coordinated with and contribute to data collected by other national and international programs (Abbott and Benninghoff 1990).

2.2 Data Standards

Standardization in collection of environmental data is fundamental for inter-site comparisons in an international monitoring program. An important characteristic of an environmental database is verification of data method and precision. Clearly, data can only be used in accordance with its integrity. Poor decision making through analysis of low integrity data is to be avoided. Monitoring in Antarctica is resource demanding and inaccurate or inappropriate techniques can prove expensive to remedy. Consistency in collection technique is necessary to assure data comparability. There will however almost always be subtle or even substantial differences in technique and therefore data quality simply due to human and environmental variance. A necessary feature of an environmental monitoring program should therefore be routine reporting of data method and precision. Each data set should include a metadata description, i.e., data about the content, quality, condition, and other characteristics of the data.

Standards for data models, structures and documentation are also necessary and must be adhered to if these data are to be used as a resource for decision making. Even with absolute consistency in data collection, discrepancies in processing and modeling can reduce comparability. Where data are transformed into new data sets, and ultimately *information*, the procedures used should be documented and standardized where possible. The tools employed by participating data centres should undergo "*inter-laboratory calibration*" (Williams 1995). As an international environmental monitoring program will more than likely contain several data repositories maintenance of protocols must be the responsibility of each data centre.

Standards should also be used in the transfer of information. Standardizing stored data formats is particularly desirable as an aid to *data interchange* or migration between systems. Where at all possible, data should be collected, stored and transferred in standard, preferably digital format.

2.3 Data Access

With respect to the collection and storage of environmental data in the international context, ensuring access to the data repository or repositories is critical. Access to digital databases from an international user base is now feasible through several avenues; e.g., electronic mail, file transfer protocol (ftp), telnet, World Wide Web. An operational system should enable query and retrieval of data from a database. Recent technologies such as the World Wide Web and the Wide Area Information Search (WAIS) system provide such functionality. These are discussed in more detail later.

2.4 Data Sharing

The Antarctic Treaty states that "*scientific observations and results from Antarctica shall be exchanged and made freely available*". For an environmental monitoring program to succeed data must be shared between participating programs. The information strategy must have as a goal the routine reporting of information. The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) program has found that a high degree of coordination and cooperation is required by all members to ensure monitoring remains balanced (Agnew pers. comm. 1996). The level of abstraction at which data are shared is an important issue. Generally, it is processed information rather than raw or intermediary data which is required by decision makers. However, during the processing phase, intermediary data may be transferred between data centres. Confidentiality issues need to be addressed where such data sharing is occurring. Where necessary, authorization checks should be carried out whenever access to particularly sensitive data is attempted. Flexibility can be achieved by specifying different checks for each type of access, e.g., retrieve, modify, delete, etc. Without such checks the security of the data may in fact be more at risk in a sophisticated database system than in a traditional filing system (Date 1982).

3. Data Management Tools

The development of database applications involves two main levels: abstract and physical. Abstract constructs (i.e., objects and their associations) are usually close to the way users describe their applications. Physical constructs (e.g., relations, indexes) are part of DBMSs and tend to involve a large number of technical details. To interact directly with the DBMS requires considerable technical expertise. It is preferable for users to interact with databases only at the abstract level, as a result being insulated from the technical details at the physical level. To achieve this situation requires the existence of database tools which are able to accept requests expressed in abstract terms and convert them to procedures of the underlying DBMS.

3.1 GIS

The choice of which DBMS to use is an important one requiring firstly, examination of the underlying data including its variability and secondly, the user needs. Observations of indicator variables in appropriate time series can enable determination of cause and/or effect in ecosystems (Cairns et al. 1979). A useful tool for managing spatial time series data are geographic information systems (GIS). A GIS contains all the components of an information system, including an underlying relational DBMS, but with the additional facility to perform spatial analysis. John Antenucci, President of PlanGraphics (1993) states "*GIS will lead as a form of data management in the decade upon us*". Data may be corrected for incompatibilities in dimension or projection, multi-thematic spatial data can be overlaid and evaluated for spatial co-registration, modeling may be carried out and new data sets created. Information is readily accessed, updated, manipulated, and exported.

GIS can be viewed as an almost self-supporting processing and manipulation tool in a management system which deals primarily with spatial data. Such a viewpoint however undermines it's data assimilation, access and presentation capabilities. GIS may be used to integrate remote sensing data of environmental properties such as sea surface temperature, sea ice concentration, glacier dynamics, land and ocean topography, etc. These data form an already standardized set of digital information able to be utilized in not only change detection also scenario modeling. GIS is also compatible with advances made in navigation technology, particularly the Global Positioning System (GPS). GPS data may be collected in the field, transferred to a data centre and incorporated into a GIS quickly and seamlessly. These data thus provide an additional layer of information able to be used in the monitoring process. GIS is a beneficial tool in long-term monitoring as it graphically compares and displays temporal data sets. In this respect it provides a useful data access tool able to illustrate information in a form more in tune with our image of the environment.

As the volume and complexity of information increases, system performance must keep pace. In less than 30 years GIS technology has evolved from basic computer mapping to sophisticated management of spatial data. The scalability of this technology is assured with the development of knowledge based GIS a logical next step (Emery 1993).

3.2 Data Directories

A useful component within a tool kit to facilitate management of widely distributed environmental data is the *data directory*. A data directly is effectively a database in its own right-a database that contains "data about data". A comprehensive directly may include information about data location, model, project details, contacts, etc. These *metadata* descriptions should be made accessible to the user base via a query interface just like any other database. The information required by decision makers is likely to be highly processed and not that native to a DMBS or GIS. With a searchable data directory users can quickly determine which information exists and avoid any duplication while similarly such a directly will also identify existing redundancies. This philosophy is being implemented as part of the Antarctic Data Directory System (ADDS), a SCAR-COMNAP initiative to make information about scientific data readily available.

4. Data Access Tools

In general, decision makers will only interact with the DBMS or GIS at an abstract level. Information will be queried and retrieved from a front end or user interface. The tools available to develop such a front end or access to the data repositories are now discussed.

WAIS, the Wide Area Information Search system is a distributed information search and retrieval system, offering connection to multiple databases through one access point (Cronin et al. 1994). WAIS is a query-oriented rather than a navigational system. Queries are typically Boolean combinations of string patterns which are matched against content words, and can be relayed to a designated set of servers. By default WAIS looks for complete exact matches. For example, if you search for lab, only objects that contain the work lab will be returned. An object containing the word laboratory will not be detected. Partial word matching is provided by adding an asterisk "*" at the end. WAIS has been replaced by the World Wide Web to provide full-text search for documents set on a single Web server.

The World Wide Web (WWW) is the fastest growing application on the internet enabling routine transmission of graphs, imagery, video and audio. The WWW has revolutionized the internet making it accessible to a wider audience through its higher level of abstraction. The WWW is not simply an enormous array of hyperlinked documents; it contains embedded database gateways, and the objectives retrieved from these databases may contain pointers to other objects in the same or other databases. Using this functionality, a browseable federation of databases may be constructed. A browseable federation is a hybrid of hypertext and database capabilities. Data are maintained in topic-oriented databases connected through hyperlinked documents. Queries can be posed to individual databases located on the basis of keyword searches. Application gateways are also feasible with the WWW providing direct interaction with specific application software located on a distant server.

The WWW makes the *distributed database*, required in an Antarctic environmental monitoring program, a feasible alternative to an integrated but centralized database. A distributed database is a database that is not stored in its entirety at one physical location, but instead distributed across a network of geographically dispersed computers connected through a communications link. Such a system would allow links to be made between individual databases effectively making the combined system look like a centralized system to the user (Date 1982). From a user standpoint such a system is extremely user friendly with full access to every data repository available from a single interface.

The WWW has tremendous potential as an interface for a distributed database although some infrastructural inadequacies related to network bandwidth have been identified. These problems are testimony to the growing popularity and acceptance of the WWW and solutions, in the form of load-balancing protocols and network privatization leading to increasing bandwidth are already underway.

5. Summary

- An information strategy should address issues such as data redundancy within a database and between databases, standards in data quality, processing and transfer, data access protocols and data sharing.

- GIS provides complete data management functionality and a suite of spatial analysis tools useful for managing and investigating spatial data.

- GIS is compatible with GPS and remote sensing data and represents a useful data access utility through sophisticated presentation capability.

- WAIS and WWW are two tools which enable access to a *distributed database* by putting a higher level of abstraction on the network protocols.

- A useful tool to facilitate management of distributed data is the *data directory*.

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Marine Debris, An Antarctic Concern?

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Introduction

About twenty-five years ago I convened a symposium on the resources and pollution in the North Sea. About this time Dayton and Robilliard examined the contamination of the McMurdo Sound benthos in the Antarctic. In neither case were there observable cases of pollution, if one defines it as the loss of or limited use of resources as a consequence of the introduction of materials by the activities of human societies. Two decades later there was clear-cut evidence for eutrophication of some North Sea coastal areas from the entry of industrial and domestic wastes. There is pollution in parts of the North Sea. Now in 1996, following extensive studies of potential pollutants in the Antarctic coastal zone over this time period, do the resources of public health, ecosystem integrity or aesthetics appear threatened? Has there been any serious environmental damage? Polluting materials identified in lower latitudes will be the springboard of this presentation. Typical examples of their penetration into the Antarctic marine environment will be given. With this background, what monitoring activities are called for?

Sources

There are three sources of anthropogenic materials to the Antarctic coastal zone: (1) human activities on the Antarctic continent; (2) ships at sea in the area: and (3) human activities in both the northern and southern hemispheres.

Potential Pollutants

Pollutants identified at lower latitudes, primarily in the northern hemisphere include:

Litter in the benthos: Perhaps the most serious problem in the Antarctic. The plastic component can constitute 90% or more of the litter, is not easily biodegradable, and can persist for centuries. The solids can inhibit gaseous exchange between the overlying waters and the sedimentary pore waters. Anoxia and hypoxia can develop. The make-up of the ecosystem can be radically altered and thus a natural resources is lost. At McMurdo Station around Winters Quarter Bay, the areal coverage of the seafloor can reach a value of 15%. In the Mediterranean the values range between 0.0001 and 0.01%. The plastics also provide shelter for opportunistic organisms.

Halogenated hydrocarbons: These compounds have been used as biocides and industrial chemicals for over three decades. Tanabe and his co-workers carried out extensive analyses of air, water, ice and snow samples collected around Japanese research stations in the Antarctic and the adjacent marine environments. They assumed the compounds had sources in higher latitudes and were transported atmospherically. The compositions of the PCBs, DDT compounds, and HCH isomers were uniformly maintained in the transport process. A recent investigation of animals from Nova Bay in the Ross Sea indicated a clear relation between trophic level and total PCB concentration: fish < penguin < skua. The toxic potentials of these xenobiotics were an order of magnitude less than those of bird and mammal populations from lower latitudes.

Recently, this collectives of compounds have been identified as endocrine imitators, causing reproductive and behavioral disfunctions in some organisms. The issues are contentious although in the marine environment two clear-cut problems have been well defined: DDT and its degradation products and tributyltin upon the reproductive successes of organisms.

Anthropogenic hydrocarbons: They can arise from any of the three sources. For example, Cripps and Priddle used the bivalve *Yoldia eightsi* to monitor n-alkanes and polycyclic aromatic hydrocarbons following the establishment of a British Research Station at Signy Island. The n-alkane concentrations were highest in organisms close to the settlement, in agreement with an anthropogenic origin whereas the primarily biogenic PAHs reached maxima 250 m from the station. No biological impacts were reported.

Artificial Radionuclides: There have been extensive measurements of three radionuclides, Zr-95, Cs-137, and Ce-144 at five sampling sites by the U.S. Environmental Measurements Laboratory. In no cases where there any indications of measurable contamination, although occasionally an outlier appeared. There is no concern with regards to these materials.

Metals: There are large numbers of measurements of a variety of metals in organisms, sediments, and waters. Such measurements are extremely easy to make and thus attractive. Only three metals have been involved in pollution episodes in lower latitude areas: tin as tributyltin in the unacceptable morbidity's and mortalities of gastropods and other organisms; mercury as methyl mercury in the Minimata Bay Disease in which hundreds of Japanese citizens lost their lives and many more suffered illnesses; and copper as an organic complex which impacted upon oyster populations in Taiwan. There are no unusually high values of metals in components of the marine environment that might cause impacts upon organisms or public health.

Overview

Many substances alien to the Antarctic are in measurable amounts and some may be increasing. Others, through regulatory actions are decreasing. With the sense that measurements everywhere and all of the time of these contaminants cannot be made, what are the priorities with limited funds and personnel? I submit that two collectives of materials are worthy of assessment for monitoring programs: litter on the seafloor and halogenated hydrocarbons.

Seafloor litter may continue to build-up in certain areas although discharges from ships and from shore facilities to the marine environment are prohibited. But what of the litter already in place as in McMurdo Bay sediment? What is the extent of the litter in areal coverage per unit area? Can this be measured by photography, by trawling or by radar? Is the impact of anoxia increasing? Can it be measured by sentinel organisms such as the areal abundance of Capitella -- the Capitella Watch?

The second problem involves the halogenated hydrocarbons entering both atmospherically and from the facilities on shore. Are the levels in birds, such as the skua increasing? Are there any population decreases or changes in behavior of these or other birds? Are the body burdens of these creatures increasing with time?

The Role of Quality Assurance in Monitoring and Research in Polar Environments

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ABSTRACT

During the 70s and 80s, it became obvious that the data and information collected by many environmental programs were not comparable within some projects and comparisons across environmental studies were also difficult. These projects generally did not quantify the reliability of analytical results for a given protocol or methodology, from simple field sampling to complex chemical extraction and analyses. This became a crisis as national surveys were implemented which required multiple and regional laboratories to collect and analyze data on a national basis. The approach developed here assess intra- and inter-laboratory laboratory precision; the relevance by using "real" samples with typical analyte concentrations for intercalibration exercises; and feedback and education to laboratories. The value of this approach has been demonstrated in about 20 domestic and international studies.

POLAR MONITORING AND RESEARCH

The need for environmental monitoring in polar regions was identified at scientific and political levels. On 14 June 1981, the eight Arctic circumpolar countries (USA, Canada, Denmark, Iceland, norway, Sweden, Finland, and the former Soviet Union) signed an Arctic Environmental Protection Strategy which among other requirements commits each country to assess on a continuing basis the threats to the Arctic environment, and to monitor the levels of, and to assess the effects of, anthropogenic pollution in all components of the Arctic environment. The current focus of this strategy is on persistent organics, heavy metals and radionulcides (Champ *et al.*, 1992).

The recently completed Protocol to the Antarctic Treaty on environmental Protection (26 countries) is a comparable document that recognizes the unique opportunities in Antarctica for scientific monitoring of and research on processes of global as well as regional importance. It also states that regular and effective monitoring shall take place to allow assessment of the impacts of ongoing activities, including the verification of predicted impact. The Antarctic Treaty Consultative Parties have long recognized the need to protect the Antarctic environment and have requested support from the Scientific Committee on Antarctic Research (SCAR) to provide necessary expert scientific advice: and the Scientific Committee established by the 1980 Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) to begin to implement a plan to monitor key components of antarctic ecosystems. A quality assurance plan is the first step in implementing a monitoring program.

QUALITY ASSURANCE

Quality assurance must be an integral part of any multinational multi-year monitoring effort from the inception of any environmental program. It cannot be done retroactively. The quality of the data must be stated in Data Quality Objectives that will meet the needs of the program. Therefore, the purpose of the monitoring program must be known before sample collection and analysis begins. If this is not the case, then the data produced may not be precise enough for the differences over space or time that the monitoring program intends to detect. Cost is also an important factor since production of data of higher quality than needed to answer the program objectives is an unnecessary financial burden. The Management/Coordinators of an environmental program must take an active lead in and provide support to QA/QC efforts. Otherwise data of limited use will result.

QA/QC in an Ongoing Monitoring Program

The National Ocean and Atmospheric Administration (NOAA) National Status and Trends (NS&T) Program is a large scale multi-year monitoring program that determines the current status of, and changes over time in the environmental health of US estuarine and coastal waters. This long-term monitoring program (1984 to the present) is an example of an environmental program that uses numerous aspects of quality assurance and can serve as an example for environmental monitoring program managers.

In the NS&T Program, concentrations of organic and inorganic contaminants are determined in bivalves, bottom-dwelling fish (through 1992) and sediments. The analytes include 24 polycyclic aromatic hydrocarbons, 20 polychlorinated biphenyl congeners, DDT and its metabolites, 9 other chlorinated pesticides, organotins, 5 major elements, and 12 trace elements. The quality of the analytical data generated by the NS&T Program is overseen by the performance-based Quality Assurance (QA) Project (Cantillo and Lauenstein, 1993). This Project has been in operation since 1985 and is designed to document sampling protocols, analytical procedures and laboratory performance, and to reduce intralaboratory and interlaboratory variation. In addition, the QA Project facilitates comparisons among different monitoring programs with similar QA activities and thus extend the temporal and spatial scale of such programs. It is necessary that sampling sites, sampling protocols and analytical procedures be described in detail, and this has been done for the NS&T Program Lauenstein *et al.* (1993) and Lauenstein and Cantillo (1993). The NS&T Program does not prescribe specific analytical methods but encourages the use of state-of-the-art procedures. This allows the use of new or improved analytical methodology or instrumentation without compromising the quality of the data sets. It also encourages the contractor laboratories to use the most cost-effective methodology while generating data of documented quality. The analysis of reference materials, such as the National Research Council (NRC) of Canada Certified Reference Materials (CRMs) and National Institute of Standards and Technology (NIST) Standard Reference Materials (SRMs), and of control materials generated for use by NS&T labs as part of the sample stream, is required. A minimum of 8% of the organic analytical sample string consists of blanks, reference or control materials, duplicates, and spike matrix samples. The use of control materials does not entirely replace the use of duplicates and spiked matrix samples. A minimum of 2% of the standard inorganic sample string consists of calibration materials and reference or control materials. Analytical data from all control materials and all matrix reference materials are reported to the NS&T Program office. These data are stored in the NS&T Program office.

Method Detection Limits (MDLs) are calculated and reported annually on a matrix and analyte basis. Since 1989, the method used for calculating MDLs is that used by EPA and is described in detail in the 7/1/88 edition of the Federal Register (Definition and Procedure for the Determination of the Methods Detection Limits - Revision 1.11). If the EPA method is not used or is modified, the procedure used for MDL calculation is described in detail. Acceptable limits of precision for organic control materials are ±30% on average for all analytes, and ±35% for individual analytes. These limits apply to those materials where the concentrations of the compounds of interest are at least 10 times greater than the MDLs. The application of these guidelines in determining the acceptability of the results of the analysis of a sample is a matter of professional judgment on the part of the analyst, especially in cases where the analyte level(s) are near the limit of detection. All NS&T laboratories are required to participate in a continuing series of intercomparison exercises utilizing a variety of solutions and natural matrix materials. The organic analytical intercomparison exercises are coordinated by NIST and the inorganic exercises by NRC. Results of these exercises have been described in Valette-Silver (1992), Cantillo (1995a), Cantillo and Parris (1993), and Willie and Berman (1995a, 1995b, 1995c, 1995d and 1995e).

In has been shown that the performance of laboratories improves with time, as the result of experience gained through participation in intercomparison exercises (Cantillo, 1995a; Willie and Berman 1995a, 1995b, 1995c, 1995d and 1995e). This improvement can only be demonstrated through the continued analysis of a material, such as a CRM, SRM or a control material with known analyte concentrations. The NOAA intercomparison exercises for trace metals for 1991 through 1993 used BCSS-1 as part of the exercise materials. Typical results reported by a laboratory joining the exercise program in 1991 are presented in Figure 1. The accuracy of the Cr, Zn and Se determinations improved with time, as did the precision of the Se analysis.

No CRMs or SRMs are analyzed specifically as part of the trace organic intercomparison exercises, so an evaluation similar to the one done for the trace metal exercises using changes in CRM and SRM results over time is not possible. A measure of improvement of laboratory performance can be made, however, by comparing the performance of a laboratory joining the exercises for the first time and that of a laboratory that has participated for several years (Figure 2). Laboratories newly joining the exercises usually have larger percent errors than the veteran laboratories. Within a year or two, however, the performance of the new laboratories typically improves and equals those of the veteran laboratories.

To ensure high quality environmental data are derived from monitoring programs, QA must begin even before a contract is awarded. Organizations proposing to perform analyses of large quantities of environmental samples should be required to perform analyses of representative matrix samples provided to them as part of the laboratory selection process. Since this requires considerable expense, the testing should not be required of otherwise unqualified laboratories or in cases where the contract itself is relatively small. Laboratories competing to analyze bivalve mollusks under contract to the NS&T Mussel Watch Project were required to undergo analytical tests of their ability to quantify environmental contaminants as part of the contract evaluation process. In 1994, competing laboratories were tested but using matrix materials for the quantitation of both trace elements and organic contaminants. Three laboratory groups participated in the exercises. All laboratories were within the acceptance criteria for the quantitation of trace elements and all laboratories performed reasonably well for the quantitation of organic contaminants. The laboratories' successes may be the result of the fact that all laboratories participating in the analytical testing had been long-term participants in the NS&T QA project.

QA/QC in a Monitoring Program

One of the basic components of a monitoring program is a rigorous QA/QC system that encompasses sampling and analytical processes, and data management. Such a QA/QC system must be inplace before sampling and data gathering activities start and must continue through the life of the monitoring program. Whenever possible, intercomparisons exercises should be done to compare and document laboratory/equipment performance, and thus extend the range of comparability. The QA/QC program must be supported by top management and resources must be allocated for it. This is not an area to reduce or exclude for lack of funds.

Standards and Reference Materials

The use of reference materials (RMs) is part of good quality assurance practices that insure analytical data of documented quality. An RM is a material or substance one or more properties of which are sufficiently well established to be used for the calibration of an apparatus, the assessment of a measurement method, or for the assignment of values to materials. A Certified Reference Material (CRM) is an RM one or more of whose property values are certified by a technically valid procedure accompanied by or traceable to a certificate or other documentation which is issued by a certifying body such as NRC, NIST or others. A Standard Reference Material (SRM) is a CRM produced and certified by NIST. A compendium of RMs for use in environmental science can be found in Cantillo (1995).

During the last few years, there has been an increase in the number and type of RMs of environmental origin, and their use in the environmental analytical community is increasing. At the request of the Intergovernmental Oceanographic Commission/United Nations Environment Programme Group of Experts on Standards and References Materials (GESREM), NOAA has periodically prepared a publication that assembles and updates all information available on RMs for use in marine chemistry and marine pollution research and monitoring (Cantillo, 1995). This publication was recently expanded it to include all aspects of environmental science. The current edition lists more than 1200 reference materials from 28 producers and contains information about their proper use, sources, availability, and analyte concentrations. RM types included are: ashes, gases, oils, rocks, sediments,sludges, soils, tissues and waters; instrumental performance evaluation RMs; and physical properties RMs. Indices are included for elements, isotopes, and organic compounds. An excellent discussion of various aspects of quality assurance and of the use of reference materials can be found in Taylor (1985b).

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APPENDIX

There are several concepts and terms that are essential to discussions about quality assurance, even that concept itself. While at a very detailed level any definition can be challenged as being too narrow or too broads, these defintions, extracted from Taylor (1985b) are very useful.

Quality Assurance is a system of activities whose purpose is to provide to the data user the assurance that the data meets defined standard of quality. It consists of quality control and quality assessment. QA applies to field and laboratory practices including collection, identification, storage, preservation, shipment and analysis of samples.

Quality Control is the over all system of activities whose purpose is to control the quality of the data to meet the needs of the user in a satisfactory, adequate, dependable and economic way.

Quality Assessment is the system of activities whose purpose is to provide assurance that the quality control activities are being done effectively.

Sensitivity is a measurements of the capability of methodology or instrumentation to discriminate between samples having different concentrations of analytes.

The Detection Limit is the smallest concentration/amount of some component of interest that can be measured by a single measurement with a stated level of confidence. This subject is discussed in detail in Keith *et al.* (1983).

Precision is the degree of mutual agreement characteristic of independent measurements as the result of repeated applications of the process. Precision is a measure of the level of reproducibility of a given methodology or instrumentation under optimum conditions. Accuracy is the degree of agreement of a measured value with the true or expected value of the quantity under concern.

Data Quality Objectives are the stated precision and accuracy ranges that are deemed acceptable for a given measurement. If, for example, data need to have an accuracy of ±1%, then data resulting from a measurement system with an accuracy of ±20 would not meet the DQOs. If, however, only the determination of the presence or absence of a substance is needed, then data with an accuracy of ±20% may be more than adequate for this purpose.

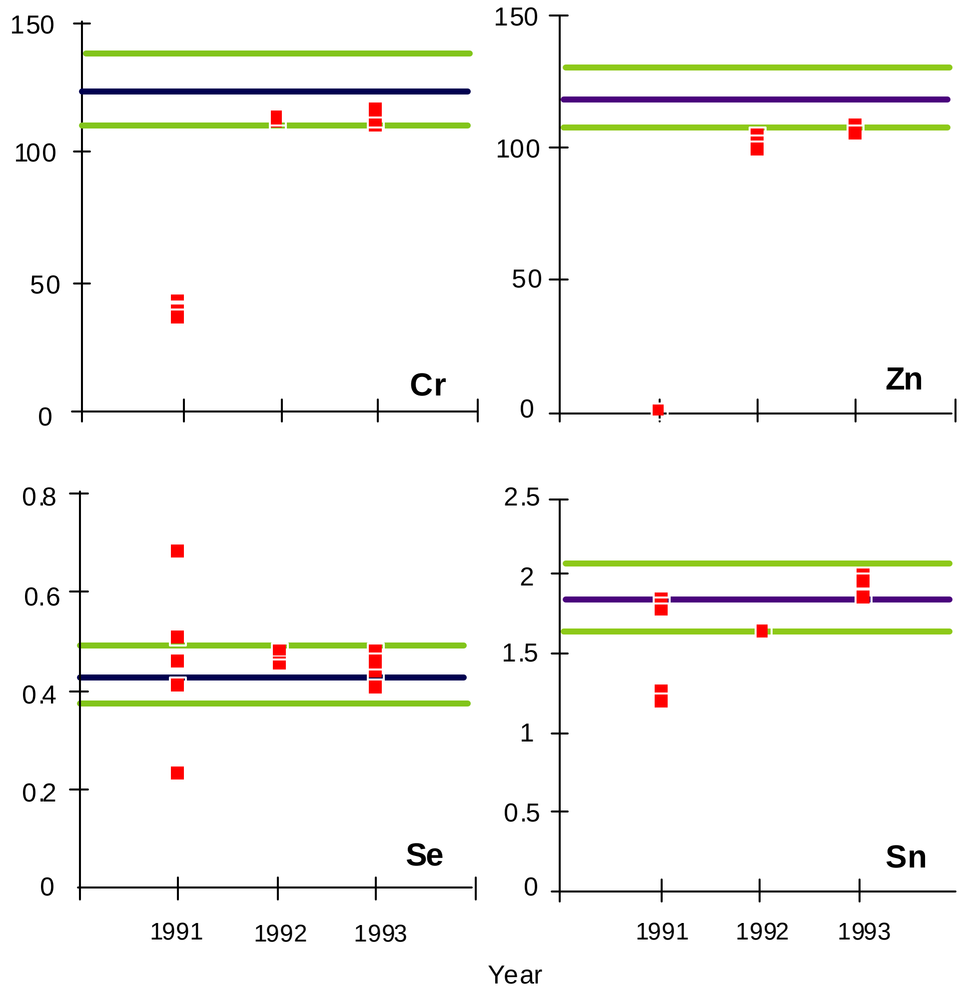

Figure 1. 1991 through 1993 Cr, Zn, Se and Sn intercomparison exercise results of five replicates of BCSS-1 reported by a laboratory participating in the exercises for the first time in 1991 (Solid line is the certified value. Dashed lines are   uncertainty.). (µg/g dry wt.)

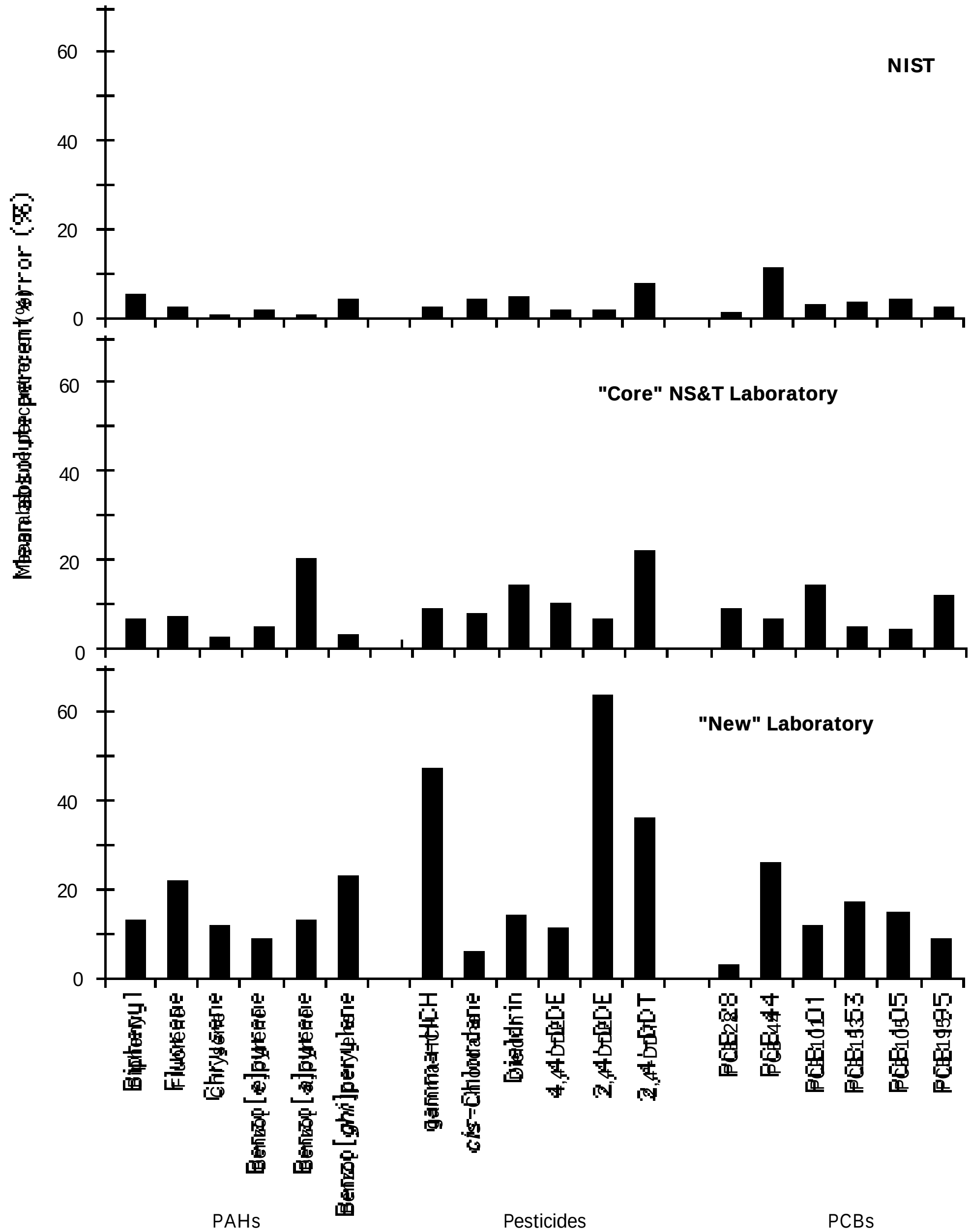

Figure 2. 1990 Enriched bivalve tissue extract intercomparison exercise results mean absolute percent errors of PAHs, pesticides and PCB congeners analyses by NIST, an NS&T laboratory, and a non-NS&T laboratory participating in the intercomparison exercise for the first time.

Environmental Monitoring in the Antarctic - the CCAMLR Experience

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Introduction

CCAMLR's requirement for monitoring arises from Article II of the Convention which states CCAMLR's management objectives:

- prevention of decrease in harvested populations to levels below those which ensure stable recruitment
- maintenance of ecological relationships
- prevention of changes in the ecosystem which are not potentially reversible in 20-30 years.

These imply that, within a time-frame of 20-30 years,

- we know what defines the current ecosystem;
- we can detect human-induced changes in it and assess their deleteriousness;
- we have sufficient understanding that we can predict ecosystem responses to various changes

These are typical expectations of a monitoring system. CCAMLR has responded with the elaboration of a complex ecosystem monitoring program, and a number of simpler monitoring initiatives.

The design of the CCAMLR Ecosystem Monitoring Program (CEMP)

Initiation and Aims

The stated **aim** of the program was:

1. to detect and record significant changes in critical components of the ecosystem, to serve as a basis for the Conservation of Antarctic Marine Living Resources;

2. to distinguish between changes due to the harvesting of commercial species and changes due to environmental variability, both physical and biological.

To manage the monitoring program, CCAMLR set up an Ad Hoc working group on Ecosystem Monitoring in 1984, which was established as a permanent working group in 1985, 3 years after CCAMLR came into existence in 1982:

- **coordination**: to plan, recommend, coordinate and ensure the continutiy of a multinational CCAMLR ecosystem monitoring program;

- **design**: to identify and recommend research including theoretical investigations aimed at facilitating design and evaluation of the monitoring program;

- **data collection**: to develop and recommend methods for collection, storage and analysis of data including formats for submission to CCAMLR

- **data interpretation**: to facilitate the analysis and interpretation of data and

- **decision making**: to identify the resulting management implications

Scope and historical development

The design of the ecosystem monitoring program evolved over several years commencing prior to the time that CCAMLR came into force (1982). The first step was a number of papers summarising the current status of the Antarctic ecosystem, suggesting ways in which Article II could be implemented and setting out the objectives of a monitoring program were treated by a number of authors .

It was realised very early on that management of the Antarctic ecosystem as a whole was impractical. Instead, CCAMLR aims at management of harvesting of Antarctic marine living resources with reference to the impact that harvesting has on the ecosystem. It was also realised that since even monitoring the population status of krill on an annual basis, for instance, would be highly impractical (Bengtson 1984), monitoring the entire ecosystem would be impossible. For its ecosystem monitoring program CCAMLR has therefore adopted the concept of indicator species - dependent or related species that are likely to reflect changes in the availability of harvested species, especially krill, and therefore 'indicate' the state of those parts of the ecosystem which are most impacted by the activities regulated by CCAMLR.

Species: Species were identified according to a set of criteria for their importance as indicators (Sabourenkov, 1989). Firstly a set of critical prey items were identified, selected for their key positions in Antarctic sub-ecosystems and their potential as harvestable resources. These were krill, *Euphausia superba*, the antarctic silverfish *Pleuragramma antarcticum*, early life stages of fish and *Euphausia crystallorophias*. Secondly, a number of predators were selected as indicators to monitor changes in food availability, with the criteria that they should be specialist predators on the prey items identified, have a wide geographical distribution, be important ecosystem components, and that sufficient be known of their biology and sufficient baseline data exist to construct a scientific monitoring program. The present list contains Crabeater and Antarctic fur seals, Adelie, chinstrap, gentoo and macaroni penguins, Antarctic and cape petrels and black browed albatross.

Sites: A core set of sites were chosen from within three defined Integrated Study Regions (ISRs: regions for the intensive study of predators, prey and environmental interactions), and a wide network of additional sites was proposed to complement the research within these Regions. Within the Regions sites were chosen so that distinctions between broad scale and local scale changes, and changes occuring in fished areas versus non-fished areas could be detected, but their position was also limited by practical considerations and the presence of established bases.

Monitored parameters: Several parameters are monitored for each predator species. The scales over which these parameters are expected to integrate changes in the status of the ecosystem varies from several weeks, close to monitoring sites (eg the quality of chick diets) to annual/semi annual, Region wide (the weight of birds arriving to breed). Parameters for monitoring environmental condition and prey species condition are being developed to assist with the separation of harvesting and environmental effects on predators.

Data management: it was recognised early on that the strength of the program would be in standardisation of methodologies and central collation of data which would enable the intense analysis and cross-comparison of sites, species, and parameters required to identify anthropogenic changes. Standard Methods for monitoring predator parameters were agreed in 1987 (CCAMLR 1988) and have been revised several times since then. Data collected using these parameters has been submitted since 1991, and now covers the period 1976 - 1995 for some parameters. Standard methods for monitoring prey and environmental parameters are currently under development.

Field work and data acquisition for the program is carried out voluntarily by CCAMLR member parties. The data they collect are submitted to the CCAMLR Secretariat, who carry out specified standard analyses for consideration by the Working Group on Ecosystem Monitoring and Management. CCAMLR now holds a dataset containing nearly 50 combinations of site, species and monitored parameter for predator species alone. The Secretariat also collect and archive data used by the program which are acquired from remote sensing programs, for example, satellite sea-ice data. Theoretical and modelling contributions to the program are made both by CCAMLR members and by the Secretariat.

Interpreting monitoring results: There are two parts to interpreting monitoring results: a review of trends, and an assessment of future ecosystem responses. CCAMLR has conducted an annual review of predator status based on its monitoring results since 1992. Because of the statistical complexity of the process this has so far been simply a qualitative review, but development of the analytical process has now reached the point where a full quantitative review is now possible (Agnew, 1995).

Basic research is an extremely important part of the interpretation process. From its inception, the program has encouraged parallel programs of research and monitoring (Sabourenkov 1989), always understanding that interpretation of monitoring results is dependent in part on independent research. Interpretation of ecosystem responses has stimulated research on a number of models of interactions between components of the krill dominated ecosystem.

Integration into the decision structure: CCAMLR has a fairly well defined idea of what management entails - regulation of fishing activity through conservation measures. It has also incorporated the “ecosystem approach” into its conservation measures for some time. However, a direct feedback link between the results of the monitoring system and management decisions leading to conservation measures regulating fishing has been harder to develop. This was mostly because the scientific problem of detecting changes in ecological relationships, distinguishing between natural fluctuations and those induced by fisheries, and then developing appropriate management advice was perceived to be so large that there was a reluctance to tackle it, even theoretically, despite it being the stated aim of the program. This lead to a feeling amongst some CCAMLR scientists that the program was unlikely to contribute to CCAMLR’s management of Antarctic resources. Substantial progress has now been made to define this link, in particular by the Working Group on Ecosystem Monitoring and Management.

Review of the program: In 1995 CCAMLR initiated an extensive review of the monitoring program to establish whether the parameters which are being measured are yielding data which reflect changes in the ecosystem adequately. Of primary concern is whether Type 1 and Type 2 errors are being successfully controlled. The results of this review, which will take several years, could be the modification, addition or removal of methods.

Scheme for a monitoring program

The CCAMLR experience has shown that a successful environmental monitoring program requires a number of critical parts. Each of these parts should be addressed before the monitoring program is initiated, as clear definition of goals and methods early on in the program will assist greatly with later work.

Initial design: This must define the goals of the program, formulate testable hypotheses, and select monitoring variables. Establishment of standard procedures to ensure standard data quality and inter-comparability is essential at the start of the program.

Monitoring data gathering: This includes the commitment to long term data collection, and standardised data storage and quality control procedures. CCAMLR has found this most conveniently performed by a centralised agency.

Monitoring data interpretation: This includes the elaboration of routine analyses which can be applied across species, sites and years. It also includes a substantial component of investigative analysis and modelling in order that changes due to natural and human induced causes may be separated, and that the consequences of ecosystem changes and management measures can be effectively predicted.

System review: The review of whether the program is able to meet its aims is most conveniently done at intervals of several years. A balance must be obtained between the consistency of monitored parameters and monitoring methods which is required by a long term ecological monitoring system, and the necessary review of these methods. This component is also essential to ensure that the program maintains enough flexibility to respond to changing requirements.

Decision making: The results of the program must feed back into a decision pathway, so that actions can be modified on the basis of results from the monitoring program. The objectives of this decision path must be agreed at the outset of the monitoring program.

Independent research: Modelling and empirical research is an integral part of the initial design of the program, system review and data interpretation. For the Ecosystem monitoring program, for instance, research is critical to the separation of environmental and fisheries-induced causes for predator parameter variation.

This scheme follows Abbott & Benninghoff (1990) fairly closely, except for the specific inclusion of decision making into the general scheme. As CCAMLR has learnt, it is extremely important to include this section from the outset during program design, and to agree mechanisms for arriving at corrective decisions. Without this step a monitoring program is merely a long term data collection exercise.

Other CCAMLR monitoring initiatives

In 1984 the Commission agreed that members would periodically survey beaches, seal and penguin colonies in the vicinity of their coastal stations and other areas to determine the types quantities and sources of any fishing gear or other debris accumulating there. The first reports on debris surveys were submitted in 1987 and from 1988 periodic surveys of marine debris on beaches in the Convention Area have been carried out. CCAMLR did not at the outset agree common guidelines for carrying out such surveys. This lack of standardisation began to seriously affect Commission's ability to summarise and statistically compare data from different surveys and lead to the adoption of standards in 1993 (Secretariat, 1993).

Specific Antarctic problems

CCAMLR has met a number of problems in implementing its monitoring program which could be described as specifically Antarctic in nature. The shear size of the Southern ocean, and even of the ISRs is a major problem - the smallest, the South Georgia ISR is slightly larger than Lake Superior, and the largest, around Prydz bay, is the size of the eastern Mediterranean or the Gulf of Mexico. This creates difficulties in designing representative monitoring and in deciding the scale for management action. The oceanographic features of the region are on a gross scale fairly simple - a relatively homogeneous body of water contained by the Antarctic convergence, with a strong eastward current offshore and a westerly counter-current inshore - but this in itself gives rise to difficulties in assigning appropriate management zones. The strong current system gives rise to considerations of flux between one area and another, which creates difficulties when separating trends in adjacent areas.

The strong seasonality in the Antarctic has given rise to problems of ensuring consistent monitoring from year to year. In some years, heavy pack ice has prevented researchers from arriving at monitoring sites in time to weigh penguins as they come ashore, for instance. The rugged terrain has meant that choice of sites is not always ideal. The remoteness of the region also meant that there was a paucity of existing data on some species in some areas. The inclusion of this requirement has meant that monitoring at some sites has taken longer to initiate than at others. In fact, most monitoring is done near sites of prior occupation, around existing bases.

The international legal status of the Antarctic, and the numbers of research staff and tourists, meant that some sites needed to be protected to ensure that monitoring was unhindered or disrupted by outside influences. This lead to the development of CCAMLR's Conservation Measure 18/XIII, agreed in 1990, which allows for the development of management plans for CEMP sites which restrict entry into and activities within the site. The international nature of CCAMLR has meant that its decisions are required to meet a balance of interests, and must be mutually agreed in an international forum. Prior agreement on the roles of monitoring programs was therefore an essential part of the preparatory work for the monitoring program.

Conclusions

Monitoring is a combined discipline activity, which requires rigorous goals and objectives to be agreed at the outset. Consideration must be given to the design of the program, the relationship between monitoring and research, standardisation and centralisation of data collection, storage and analysis, and the integration of monitoring results into management decisions. The program should be reviewed regularly in terms of its objectives, and long term (15-20 years) commitments to ensure continuity of both data acquisition and analysis should be made.

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Monitoring the Status and Trends of Chemical Contamination by the NOAA Mussel Watch Project

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Introduction

Since 1986, the National Oceanic and Atmospheric Administration (NOAA) Mussel Watch Project has been chemically analyzing sediments and mussel and oyster tissues collected at sites throughout the coastal United States. Sediment data describe the status, or spatial distribution, of contamination on a national scale. The molluscan data, on the other hand, are used primarily to describe and follow temporal trends in contaminant concentrations. Results, published in a number of reports[1-5], indicate that high levels of chemical contamination are generally limited to relatively small areas near urban centers, that concentrations are decreasing for chemicals whose use has been banned or severely curtailed, and that no measured chemicals exhibit increasing trends. Experience gained as the Project has evolved, has led to alterations in the frequencies of sample collection, the level of replication and the chemicals measured.

Chemical Selection

The program began with a list of major and minor elements, chlorinated pesticides, polychlorinated biphenyls, and polycyclic aromatic hydrocarbons to be measured in both sediments and mollusks. The list has been slightly shortened by eliminating some of the major elements (e.g. Si and Al) whose concentrations in mollusks were not being correctly quantified by the analytical methods appropriate for tissues. For the most part, though, chemicals have been added. The original list of pesticides contained many compounds whose use has been banned (e.g. DDT and PCBs). They remain among the measured chemicals but chemicals have been added that are still in use (e.g. endosulfan and chlorpyrifos). It has been particularly interesting to have added tributyltin whose use in U.S. coastal waters was banned in 1988, except on vessels longer than 25 m. The molluscan data for this compound and its breakdown products show that its concentration is decreasing. Alpha-HCH has begun to be monitored because it is isomeric with the already measured pesticide Lindane (gamma-HCH) and is commonly found in areas of the world where technical Lindane (not isomerically pure) is used. The list of polycyclic aromatic hydrocarbons has been expanded to include a series of alkylated compounds whose presence should be diagnostic of oil as opposed to combustion products characterized by the parent, non-alkylated, PAH compounds.

Frequency

When the project began, it was planned to annually sample surface sediment at each site. However, after two years, sediment sampling ceased except a newly visited sites. The reason was simply that without sediment dating there was no way to assign a time scale to the upper 2 cm of sediment+the sampled depth. In quiet areas with little deposition the upper 2 cm might represent several of years. If sediments are undergoing active biological mixing, as they usually are except under anoxic conditions, the upper 10 cm may be homogenized and represent many decades. Under turbulent conditions only recently deposited sediment might be found. However, in this latter case, the sediment is usually winnowed of fine grained material leaving only sand. It was determined in the Project not to use data from sandy sediments when making overall assessments. Because of its low specific surface area relative to mud (clay and silt), sand almost always carries lower concentrations of chemical contaminants.

There is an ancillary program to the Mussel Watch Project whereby sediment cores are collected in areas where it is thought they may provide a sequence of temporally independent sections. If radiodating confirms that the depths in the core do represent distinct years or short sequences of years, chemical analysis then proceeds to reconstruct the long-term chronology of contaminant loading to the area.

The original plan with mollusks also called for annual collections. In this case, as opposed to sediment, there was good reason to believe that chemical concentrations in mussel and oysters can change within a year if the concentrations in their environment change. However, after the first seven years of the program (1986-1992) collections have been biennial (there are collections every year but not at every site). The central reason for this is that a trend is a statistically significant correlation between concentration and year and the "n" which determines the significance of the correlation coefficient is the number of years. As "n' becomes large, the fiscal advantage of halving its rate of increases has little statistical consequence. Replication

Initially, triplicate composites of 20 oysters, or 30 mussels, or 3 surface sediment grabs were collected, homogenized and analyzed. That did allow estimates of variance and statistical comparisons among samples. However, for the most part, data are used for trend detection or in an aggregate fashion where the variance about any individual concentration does not come into play. While logistic costs do not change whether one of three composites are collected, there are savings in performing analysis on only one, rather than three composites. Since that saving has little statistical consequence, only single composites began being analyzed in 1993.

Conclusion

Any monitoring program should remain flexible. Original design is important but as time passes it should be reexamined. The NOAA Mussel Watch Project, for example, has added chemicals and decreased sample frequency and replication. While not discussed, sites have been added and some sites dropped and chemical analytical techniques have changed. It is important not to have chemical data tied to a particular technique. As more efficient methods evolve they should be tried and if they produce comparable results to existing techniques they can be adopted.

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ANNEX 4

LIST OF ACRONYMS AND ABBREVIATIONS

AMAP	Arctic Monitoring and Assessment Programme
ATCM	Antarctic Treaty Consultative Meeting
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CEE	Comprehensive Environmental Evaluation
CEMP	CCAMLR Ecosystem Monitoring Programme
CEP	Committee for Environmental Protection
CFC	Chlorofluorocarbon
Cl	Chlorine
CO	Carbon monoxide
CO_2	Carbon dioxide
COMNAP	Council of Managers of National Antarctic Programmes
DDT	Dichloro-diphenyl-trichlorethane
EIA	Environmental Impact Assessment
ENEA	Energia Nucleare e delle Energie Alternative
EPA	Environmental Protection Agency
FCO	Foreign and Commonwealth Office
IASC	International Arctic Science Committee
IEE	Initial Environmental Evaluation
NO_x	Nitrogen oxide
NSF	National Science Foundation
NZAP	New Zealand Antarctic Programme
PAH	Polycyclic Aromatic Hydrocarbon
Pb	Lead
PCB	Polychlorinated biphenyl
SCAR	Scientific Committee on Antarctic Research
SO_x	Sulphur oxide
WG	Working Group