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Practical Biological Indicators of Human Impacts in Antarctica

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Information Paper submitted by SCAR and COMNAP to CEP IX
under Agenda Item 9 (Environmental Monitoring and Reporting)

Introduction

1. Protection of the environment is a high priority for all nations that conduct science and operate in Antarctica. The Antarctic Treaty System, with its Agreed Measures for the Conservation of Fauna and Flora (1964) and its Protocol on Environmental Protection (1998), prescribes comprehensive protective measures and monitoring activities to assess outcomes. All signatories to the Antarctic Treaty pledge to uphold these principles in accordance with international requirements and domestic legislation regarding protection of the environment.
2. Over the past decade the Scientific Committee on Antarctic Research (SCAR) and the Council of Managers of National Antarctic Programs (COMNAP) have been investigating the most practical and useful monitoring methods and design elements to determine the extent and significance of human impacts on the Antarctic to meet international and national obligations. In the course of this physical, chemical and biological measures have been considered in detail.
3. For the most recent discussions forty-four (44) participants from fourteen (14) countries gathered for two and a half days to discuss the status of biological indicators of human impact in Antarctica. The workshop was held in Bryan/College Station, Texas, USA from 16-18 March, 2005. The US National Science Foundation's Office of Polar Programs, COMNAP, SCAR and Texas A&M University provided financial support to convene the workshop.

Preceding Deliberations and Reports

4. Environmental monitoring in Antarctica has been conducted by a number of National Antarctic Programs for many decades. At the 1994 Antarctic Treaty Consultative Meeting [ATCM XVIII], COMNAP and SCAR offered to convene technical workshops to provide the ATCM with advice on practical, scientifically sound and cost effective monitoring that would meet the requirements of the Protocol on Environmental Protection to the Antarctic Treaty.
5. The July 1996 report, entitled *Monitoring of Environmental Impacts from Science and Operations in Antarctica*, provided extensive guidance on the design and selection of indicators of chemical contamination and physical disturbance. This was followed by a manual of agreed methods for analytical protocols intended to promote standardisation of monitoring efforts and increase inter-comparability across monitoring programs. COMNAP sponsored a review of Environmental Impact Assessment procedures to determine if they were effective. COMNAP compiled a report entitled *Summary of Environmental Monitoring Activities in Antarctica* to ATCM XXI in 1997. In addition there were a series of workshops and reports on various aspects of monitoring programs. These reports culminated with the COMNAP report "*Practical Guidelines for Developing and Designing Environmental Monitoring Programs in Antarctica*" - March 2004. This report provided guidance on how to design and implement a monitoring program.

Workshop Terms of Reference

6. The previous workshops had left the basis for biological monitoring undecided as there was insufficient information available for the participants to make recommendations. SCAR and COMNAP decided to return to this when more data was available. The workshop organised in Texas was intended to address the question again. The Terms of Reference agreed by SCAR and COMNAP for the workshop where:

- To consider the range of biological indicators of human impacts that can be appropriately applied in the Antarctic setting.
- To assess the available history and data on biological indicators from the molecular to the ecosystem level and assess the strengths and weaknesses of these methodologies.
- To consider if the monitoring of "key species" is practical and to assess the limitations of monitoring schemes based on these biological representatives.
- To review existing biological monitoring protocols that have been tested, validated and used in temperate climates and determine how they might be adapted to Antarctica.
- To develop a series of recommendations that will assist National Antarctic Programs in establishing meaningful and practical long-term monitoring programs in Antarctica that provide for comparability across programs and optimise the ability of monitoring program results to inform management decisions.

General Discussions and Key Findings

7. The design of a monitoring program, including the use of biological indicators, must first define the issues of concern and establish which pressures (impacts, practices etc.) may be the cause of these issues. The second step is to establish the state of the system under pressure. Finally, monitoring information should inform management actions through appropriate feedback. Monitoring also provides feedback to management on the efficacy of the actions taken by documenting outcomes.
8. Workshop participants agreed that some practices in other locations were either impractical in Antarctica or required considerable modifications. However, concepts such as marine benthic indicators of biological integrity, sentinel indicators as integrators of contaminant exposure, the sediment quality triad, the use of toxicity assays and transplant experiments, and collection of long term data sets were all seen as potentially useful approaches to be considered when designing monitoring programs in Antarctica.
9. Workshop participants concluded that successful biological monitoring was already taking place and that practitioners should make full use of the lessons learned in these existing programs, including those organised by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR).
10. It was also concluded that many potential biological indicators were not yet viable for the purposes of routine monitoring in the Antarctic. Deficiencies included highly variable results, expensive or complex methodological protocols, unclear cause and effect linkages and relationships, incompatibility with natural population levels, and other problems. However, criteria for the selection of practical biological indicators for use in monitoring programs are well established and applicable to the Antarctic setting .
11. Molecular-level biological indicators of stress or exposure are many and varied. They hold promise for the early detection of impacts which are usually sub-lethal in their effects. However, they are in generally expensive, utilise complex protocols, linkages to higher level effects are unclear, and cause and effect are not always well understood and/or documented. While ecosystem-level indicators are holistic in their integration of multiple effects, they are often complex to measure, cause and effect relationships are not well understood, and measurements protocols are time and resource intensive.
12. It was concluded that a general framework utilising comparable biological indicators was feasible for the detection of local human impacts. The environment can best be observed based on its major components: terrestrial biota, vertebrates and the marine benthos. In the terrestrial setting, aerial photography and visual examination can be used to quantify the community structure and the diversity of vegetation. Vertebrates, such as penguins and other seabirds, can be characterised by population size and breeding success close to and far from Antarctic stations. Vertebrate data and trends must be juxtaposed on long-term decadal baseline datasets that are already being collected at several locations. The response of marine benthic biota to physical disturbance, toxins and organic enrichment is well established and community level responses can be described and predicted using multi-metric approaches. Well tested and proven approaches include indicators of ecosystem integrity or health.

13. The concept of "characteristic fauna" was seen as more applicable to the Antarctic setting rather than "keystone species" which has a specific ecological meaning that is not well defined in Antarctic food webs. It was concluded that it was highly unlikely that single species or even a simple suite of species would adequately provide the full spectrum of information needed to detect the multi-faceted impacts of humans in Antarctica. While single species may have a role in monitoring programs, it was generally believed that multi-metric approaches were more robust and powerful as monitoring tools in addressing the complex disturbance scenarios usually associated with human activities in Antarctica.

14. Workshop participants concluded that long-term datasets were fundamental for establishing the "normal range" of biological attributes and for understanding and determining the extent of natural variability. Long-term datasets are essential for establishing historical trends in biological indicators and for generating models to predict future responses to changes. Long-term data sets are available in selected locations for sea birds, terrestrial plants, mammals and the marine benthos.

15. Single species may be appropriate when stressors are known, the species characteristics are well understood, and when natural variability has been or can be established. Examples of potential target species include: penguins, seals, krill, lichen, and mollusks, depending on the management objectives being addressed through monitoring.

16. To be an effective management tool, monitoring needs to be kept simple and information needs to be provided in a non-technical format to operators. Standard methods are not considered sufficient to ensure high quality data production. Data quality objectives must be stipulated based on management objectives in order to produce results that are method and analyst independent.

Recommendations

17. Biological monitoring is inherently more complicated than either chemical or physical monitoring and its results more difficult to apply. Biological data normally cannot be used on their own but must be interpreted within the context of the physical and chemical environment. Confounding changes in the natural environment must be incorporated when interpreting changes in biological indicators.

18. Quality controlled long-term biological data sets are fundamental to establishing the natural ranges of biological indicators of change and the continuation of long-term datasets should be supported. Quantification of the extent and trends in natural variability is crucial to determining the effect of humans on observed changes in biological indicators.

19. Whilst it is recognised that monitoring approaches from elsewhere can be applied in the Antarctic further work is necessary to determine which of the temperate protocols for monitoring human impacts at the community, population, species and cellular levels are going to be practically useful in the Antarctic.

20. Data quality objectives rather than standard methods should inform the choice of biological indicators for monitoring programs. Current best practice relies on data quality objectives allowing the adoption of methods that can meet data acceptance criteria.

21. Monitoring programs require an unambiguous definition of a "natural", control or original state to identify change(s) due to human intervention and to account for natural variability in biological systems.

22. Operators of National Antarctic Programs should agree on a common set of comparable monitoring parameters to measure the potential biological impacts of station operations while producing comparable and compatible data. The diversity of station surroundings and activities is such that it will be impossible to identify a single biological indicator for use at all sites but it is recommended that the following biological indicators be considered: biodiversity of terrestrial flora, diversity of sea bird species, breeding success of surface nesting species, and marine benthic measurements of biotic integrity.

23. More robust numerical and quantitative models of natural systems are needed for reliable predictions of future biological changes and linkages with their causes. The development of such mechanistic models based on an improved understanding of animal behaviour, food web connectedness and ecosystem resilience is needed to improve risk assessments and to inform the design of mitigation measures.

24. All monitoring data should be made widely available through existing National Data Centres. National Data Centres have been nominated in 16 Antarctic countries and the Joint Committee on Antarctic Data Management (JCADM) is working to extend this. The metadata entries in these Data Centres may not yet reflect the extent and diversity of the data available. Renewed efforts are required to ensure that individual scientists, environmental officers and operators catalogue their data and make it freely available.

25. The coordination and exchange of information on monitoring among COMNAP, SCAR, and CCAMLR should be improved through existing organisational structures. SCAR and COMNAP should consider how to improve information exchange from on-going and future environmental monitoring. The COMNAP Environmental Coordination Group (ECG) and the COMNAP Antarctic Environmental Officers Network (AEON) should explore ways to more effectively interact with the CCAMLR Ecosystem Monitoring Program (CEMP) Subcommittee.

26. To improve scientific communication and information exchange in this field, "Monitoring Practice and Science" oral and poster sessions should be organised at the biennial SCAR Science Conference. Every fourth year a monitoring workshop should be held during the SCAR/COMNAP joint meetings. A forum is needed to link scientific knowledge and advances with environmental monitoring requirements and protocols. The existing biennial SCAR/COMNAP meeting offers such a forum where experiences, challenges, and common issues can be explored and data and information exchanged.

27. The monitoring of human impacts is a fundamental part of Antarctic logistics and must become a routine part of Antarctic station operations. Adequate resources must be provided to ensure that these activities are performed at appropriate frequency and intensity. In order to meet the requirements of Article 3 of the Protocol on Environmental Protection to the Antarctic Treaty, all Antarctic operators should establish monitoring programs capable of assessing the impacts of human activities in Antarctica.