State of the environment reporting: an Antarctic case study

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ABSTRACT. The requirement for an Antarctic component to the 2001 Australian State of the environment report initiated the development of a state of the environment system designed to remain current, yet minimize the resources required for maintenance. A series of environmental indicators was developed and refined by a group of experts during a period of 18 months. A simple descriptive template and data for each indicator were incorporated into a web-accessible database system called SIMR (System for Indicator Management and Reporting). The system captures indicator data either dynamically from sensors or by web input by indicator custodians. The system also prompts custodians for regular input of evaluations of indicator status. The system (http://www-aadc.aad.gov.au/soe) has been an effective framework for considering all aspects of state of the environment reporting and a practical tool in research and operational aspects of the Australian Antarctic Division.

Contents

Introduction

Effective state of the environment (SOE) reporting relies on regular, long-term monitoring to examine the current status of, and trends in, environmental and other relevant variables resulting from either natural variability or human-induced (anthropogenic) pressures. The purposes of reporting this information are to place a yardstick on the condition of the environment; to better understand environmental processes; to reduce negative anthropogenic influences; and to increase general awareness about environmental conditions. Gathering environmental information in a systematic, easily accessible, and comprehensible form facilitates SOE reporting.

The rise of SOE reporting internationally has been closely related to increasing awareness of the principle of ecologically sustainable development (ESD), and the implementation of national and international agreements to help achieve this outcome. ESD has been defined as 'using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased' (Commonwealth of Australia 1992). In order to achieve ESD, there is a need for a means of appraising its two integral components: development (an economic–social measure) and ecological sustainability. While there have long been indices to measure economic and social trends (such as gross domestic product or measures of living standards), until relatively recently there has not been a parallel framework for evaluating natural or human-induced trends in the condition of the environment. The need for a comprehensive approach to determining environmental trends has developed into the practice of SOE reporting, which has become an internationally accepted process for the assessment of progress towards ESD.

In the past two decades, the governments of a diverse range of countries have integrated environmental reporting into national economic policy formulation and have published reports on national environmental conditions (for example, http://www-aadc.aad.gov.au/links/soe_links.asp). In 1979, the Organisation for Economic Co-operation and Development (OECD) made a recommendation that member countries develop national SOE reports (OECD 1979). This appears to be the first international requirement for SOE reporting. In 1986, the Canadian government was one of the first to publish a national SOE report (Bird and Rapport 1986), which was followed by passage of legislation (the Canadian Environmental Protection Act 1988) requiring the Canadian government to 'provide information to the people of Canada on the state of the Canadian environment.'

SOE reporting boomed in the mid-1990s, with the production of numerous reports at global (United Nations Environment Programme 1997), regional (for example, Bernes 1993; Hansen and others 1996; Arctic Assessment and Monitoring Programme 1997), national (for example, Lane, 1993; Ministry of Natural Resources 1994; Environment Canada 1996; Reidhead and others 1996; Taylor

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and Smith 1997), and sub-national levels (for example, Ministry of Environment, Lands and Parks 1993; Office of the Commissioner for the Environment 1995; Ohio Comparative Risk Project 1995). This increase was likely due to the requirements for SOE reporting following the inception of international agreements promoting ESD earlier in the decade. For example, Agenda 21 (United Nations Conference on Environment and Development 1992) — the international agreement on sustainable development adopted by more than 178 governments at the 1992 United Nations Conference on Environment and Development in Rio de Janeiro — called for improved environmental information for decision-making and for countries to report on the state of their environments to the United Nations Commission on Sustainable Development. Environmental reporting is also required by other international bodies, including the United Nations Economic and Social Council for Asia and the Pacific, the World Meteorological Organization, and conventions such as the Framework Convention on Climate Change and the Convention on Biological Diversity.

During the past two decades, the OECD has produced regular reports on the state of the environment and continues to review systematically the environmental performance of individual member countries in meeting both domestic and international commitments. A number of other international agencies and non-government organisations, such as the United Nations Environment Program and World Resources Institute, have also begun to produce regular SOE reports, such as the recent *Global environmental outlook 3* (United Nations Environment Programme 2002).

SOE reporting in Antarctica has lagged behind other areas of the world. Harris (1995) submitted a paper to the Scientific Committee on Antarctic Research (SCAR) suggesting the need for an Antarctic SOE report. Discussions on the possible development of a State of the Antarctic environment report were initiated at the Twentieth Antarctic Treaty Consultative Meeting (ATCPs 1996). The issue has been raised at all subsequent ATCMs or associated meetings of the Committee for Environmental Protection (CEP: the committee tasked with supporting the Protocol on Environmental Protection to the Antarctic Treaty), with several papers being presented on the need for such a report and options for developing an Antarctic SOE report (see, for example, ATCPs 1997). SCAR provided a scoping study to CEP III in 2000 (SCAR 2000), which addressed these points as well as describing the key environmental variables, present and future threats to that environment, and links with SOE reports for other parts of the world. Despite the papers, discussions during the meetings, and inter-sessional discussion by specifically tasked groups, agreement has yet to be reached on the appropriate scope, focus, target audience, resources, and timeframe for an Antarctic SOE report.

Some type of systematic environmental reporting on the Antarctic would seem to be expedient given the CEP's obligation under the Protocol on Environmental Protection to provide advice and formulate recommendations to the Treaty Parties on the 'state of the Antarctic environment' (Article 12.1(j)). Other articles directly related to SOE reporting, such as 'the collection, archiving, exchange and evaluation of information related to environmental protection' (Article 12.1(i)) and 'the need for scientific research, including environmental monitoring, related to the implementation of [the] Protocol' (Article 12.1(k)) are included in the Protocol.

The United Nations General Assembly has also acknowledged the significant role played by the Antarctic in the world environment and has consequently called for information concerning the state of the Antarctic environment (for example, the United Nations General Assembly 1993). A brief summary of Antarctic environmental issues was presented at the 51st session of the General Assembly (United Nations General Assembly 1996). At that meeting, it was noted that much of the data of 'global concern' requiring 'enhanced access' under Agenda 21 is directly related to the state of the Antarctic environment. The General Assembly also indicated its support for continued efforts to produce a comprehensive Antarctic-wide SOE report within the Antarctic Treaty System, noting that such a report would have practical benefits to both the Treaty nations and the global community in terms of drawing together widely dispersed data into an accessible and easily interpretable form.

Many of the signatories to the Antarctic Treaty are already producing national SOE reports or are involved in reports for specific regions such as the Arctic (Nilsson 1997), European Arctic (Hansen and others 1996), Baltic (Baltic Environmental Forum 2000, see http://www.bef.lv/baltic/baltic2/content.htm), and Asia–Pacific (Awaji and Teranishi 2000). New Zealand has published a SOE report for the Ross Sea region of Antarctica (Waterhouse 2001), clearly signifying its intentions irrespective of the production of an SOE report for the whole of Antarctica.

More recently, a web-based SOE reporting system covering the area of the Antarctic claimed by Australia and Australia's sub-Antarctic islands has been developed. This paper discusses the development of this automated reporting system, as well as the characteristics that suggest it could be a model for future SOE reporting.

Australian and Australia–Antarctic SOE reporting

The first national Australian SOE report was produced in 1986 (Department of Arts, Heritage and Environment 1987), which was followed by a more comprehensive report in 1996 (State of the Environment Advisory Council 1996). However, these volumes did not consider areas of Australian interest in the Antarctic. In 1999, the Environment Protection and Biodiversity Conservation Act (EPBC) was passed, requiring 'a report on the environment in the Australian jurisdiction to be prepared . . . every 5 years.' Therefore, specific assessment of the state of the environment in the Australian Antarctic Territory (an external territory within the scope of the

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EPBC) is now required every five years within the framework of the national SOE report. As administrators of Australia's Antarctic program, the responsibility for environmental reporting falls to the Australian Antarctic Division.

One of the key outcomes of the 1996 Australian SOE report was the recognition that the 2001 report should be based on environmental indicators that accurately and cost-effectively reflected the state of the environment. Conacher (1998) summarised the importance of indicator-based SOE reporting, stating: 'It has become apparent that for these reports to provide accurate data both on the current state of the environment and on trends over time, there needs to be an agreed set of quantifiable indicators of environmental (or land) quality. Only in this way can temporal trends or spatial comparisons be identified objectively.'

Work began in May 2000 on the Antarctic component of the 2001 Australian SOE report. It soon became evident, however, that this component of the report would be comprised of a range of Antarctic 'cameos' (for example, a paragraph on Antarctic tourism) rather than systematic input using an indicator framework. Furthermore, many of the indicators on which future Australian SOE reports would be based have little relevance to Antarctica. In order to redress these problems, and to facilitate Antarctic input into future Australian SOE reports, it was decided to develop an SOE reporting system specifically designed to monitor the state of the Antarctic environment in areas in which Australia had direct interest. In order to do this, a suite of indicators relevant to Australia's involvement in Antarctica was developed. A structure was produced in which data relevant to these indicators would be placed in a digital database that could be updated regularly and accessed whenever necessary. The system was envisaged to a) be administered via the web; b) be accessible from the web; c) be framed around a consistent template; and (d) store all indicator data and evaluations of the status of the indicator. In addition to fulfilling requirements for future national SOE reports, this system (named SIMR: a System for Indicator Management and Reporting) was intended to provide information to scientists, environmental managers within the Australian Antarctic program, and, importantly, the general public.

The Condition-Pressure-Response (CPR) indicator-based system was considered an effective method for developing and classifying indicators. This system was originally proposed under the term Pressure-State-Response (PSR) by the Organisation for Economic Co-operation and Development (OECD 1993). The PSR/CPR models have been increasingly applied elsewhere, including all Australian SOE reports. The CPR approach has been chosen because of its useful analogy to human health where one first enquires to 'how are you?' (your condition) and if that condition is not satisfactory, what *pressures* may be affecting your well-being or condition. Finally, 'given the pressures, what are you doing to reduce those pressures?' that is, what is your response?

The PSR/CPR model defines a series of key indicator-types that reflect attributes that are important to the state of the environment. *Condition* indicators provide insight into the status of an environmental quality (for example, air quality at Antarctic bases). *Pressure* indicators include those anthropogenic pressures or stresses that are applied to environment quality (for example, fuel usage at Antarctic stations, which directly relates to emissions to the atmosphere and therefore air quality). *Response* indicators usually detail what we are doing to mitigate environmental pressures (for example, expenditure on emission controls).

The development of the Antarctic indicators involved initial consideration of 443 indicators (Alexandra and others 1998; Fairweather and Napier 1998; Hamblin 1998; Manton and Jasper 1998; Newton and others 1998; Pearson and others 1998; Saunders and others 1998; Ward and others 1998; Australian and New Zealand Environment and Conservation Council 2000) covering seven general theme areas of the 2001 Australian SOE report (Australian State of the Environment Committee 2001). Most of these indicators were discarded as unsuitable for Antarctic application, while others either could be used directly in an Antarctic context or could be readily adapted to the Antarctic environment. This process resulted in the selection of a suite of 57 indicators (Table 1). A workshop attended by Antarctic experts including engineers, managers, and scientists, judged each of the indicators against the 15 criteria listed in Table 2 (Pearson and others 1998), providing a basis for refinement. All proposed indicators met at least five of the 15 listed criteria and most exceeded 10. A few indicators with scores less than 10 were included to provide necessary coverage of important environmental issues (see http://www-aadc.aad.gov.au/soe for indicator reports including criteria satisfied). New indicators not directly related to Australian indicators were proposed at this workshop. Subsequently, indicators were refined in extensive consultation with the group of experts through a period of more than 18 months. Potential indicators were typically eliminated because they were impractical to measure on a regular and long-term basis due to logistical and economic constraints of operating in the Antarctic.

The suite of indicators listed in Table 1 will evolve. Experience with the system to date has resulted in some indicators being dropped and also hinted at other indicators that may be developed in the future to provide better coverage of particular Antarctic issues; to provide a better balance between conditions, pressures, and responses; or to address emergent issues. While the authors see the need for standardizing a suite of indicators, new environmental issues will arise and more effective indicators may depose others. Sufficient experience is building to enable us to designate a subset of the indicators listed in Table 1 as core indicators, where resources are committed to their long-term maintenance.

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Table 1. Australian Antarctic environmental indicators (as of September2002). Indicator types = condition, pressure, response.

SIMR indicator number	Indicator title	Indicator type	Theme area	Indicator criteria satisfied (Table 2)
1	Monthly mean air temperatures at Australian Antarctic stations	C	Atmosphere	12
2	Highest monthly air temperatures at Australian Antarctic stations	C	Atmosphere	11
3	Lowest monthly air temperatures at Australian Antarctic stations	C	Atmosphere	11
4	Monthly mean lower stratospheric temps above Aus. Ant. stations	C	Atmosphere	11
5	Monthly mean mid-tropospheric temperatures above Australian Antarctic stations	C	Atmosphere	11
8	Monthly mean atmospheric pressure at Australian Antarctic stations	C	Atmosphere	11
10	Daily broad-band ultraviolet radiation observations using biologically effective UVR detectors	C	Atmosphere	11
11	Atmospheric concentrations of greenhouse gas species	C, P	Atmosphere	13
12	Noctilucent cloud observations at Davis	C	Atmosphere	8
13	Polar stratospheric cloud observations at Davis	C	Atmosphere	8
14	Midwinter atmospheric temperature at altitude 87 km	C	Atmosphere	12
15	Stratopause region parameters for Davis	C	Atmosphere	9
27	The annual population of Adélie penguins at colonies in the vicinity of Casey, Davis, and Mawson and on Shirley Island and Whitney Point	C	Biodiversity	13
28	Standard demographic parameters for Adélie penguins at Mawson	C	Biodiversity	13
29	Breeding population of the southern giant petrel at Heard Island, the McDonald Islands, and within the AAT	C	Biodiversity	13
30	Breeding population of king penguins at Heard Island	C	Biodiversity	13
31	Annual population estimates of southern elephant seals at Macquarie Island	C	Biodiversity	14
33	Annual catch in tonnes of marine species harvested in Australian Antarctic and sub-Antarctic waters	P, R	Biodiversity	12
35	Number of permits issued for entry into Specially Protected Areas and Sites of Special Scientific Interest in the Australian Antarctic Territory	P	Land	14
36	Numbers of species protected at various levels of conservation status	R	Biodiversity	13
37	Species and numbers of species killed, taken or interfered with, or disturbed in the Antarctic and the sub-Antarctic for scientific research	C	Biodiversity	12
38	Mean sea level for the Antarctic region	C	Coasts and oceans	13
39	Average chlorophyll concentrations for the Southern Ocean across latitude bands 40–50°S, 50–60°S, 60°S–continent	C	Coasts and oceans	6
40	Average sea-surface temperatures in latitude bands 40–50°S, 50–60°S, 60°S–continent	C	Coasts and oceans	11
41	Average sea-surface salinity in latitude bands: 40–50°S, 50–60°S, 60°S–continent	C	Coasts and oceans	11
43	Fast-ice thickness at Davis and Mawson	C	Coasts and oceans	9
46	Annual tourist ship visits and tourist numbers	P	Coasts and oceans	9
48	Station and ship person days	P	Human settlements	14
49	Medical consultations per 1000 person years	C	Human settlements	10
50	Volume of waste water discharged from Australian Antarctic stations	P	Human settlements	13
51	Biological oxygen demand of waste water discharged, Australian Antarctic stations	P	Human settlements	11
52	Suspended solids content of waste water discharged, Australian Antarctic stations	P	Human settlements	11
54	Amount of waste incinerated at Australian Antarctic stations	P, R	Human settlements	15
56	Monthly fuel usage of the generator sets and boilers	P	Human settlements	14
57	Monthly incinerator fuel usage of Australian Antarctic stations	P	Human settlements	14
58	Monthly total of fuel used by vehicles at Australian Antarctic stations	P	Human settlements	14
59	Monthly electricity usage at Australian Antarctic stations	P	Human settlements	14
60	Total helicopter hours	P	Human settlements	13

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Table 1. Continued

SIMR indicator number	Indicator title	Indicator type	Theme area	Indicator criteria satisfied (Table 2)
61	Total potable water consumption at Australian Antarctic stations	P	Human settlements	5
62	Water levels of Deep Lake, Vestfold Hills.	C	Inland waters	7
63	Number and area of protected areas in the Australian Antarctic and sub-Antarctic jurisdiction	R	Land	14
65	Station footprint for Australian Antarctic stations	P	Land	8
67	Resources committed to heritage expertise	R	Natural and cultural heritage	12
69	Resources committed to environmental issues	R	Human settlements	13
70	The presence or absence of vascular plant species in two defined areas of Heard Island	C	Biodiversity	11
71	The distribution and extent of sphagnum moss on Macquarie Island	C	Biodiversity	13
72	Windmill Islands terrestrial vegetation dynamics	C	Biodiversity	14

The model of the management and reporting system

Once the list of indicators had been determined, a mechanism had to be designed by which the information for the indicators could be collated, analysed, and made available to managers, scientists, and the public. Accessibility from the web was seen as an efficient and flexible mechanism to capture and disseminate information and to link to other extensive databases.

Traditional SOE reports, many of which are prepared to support legislation, tend to be either paper-based or, recently, web-based reports that follow a book structure (see, for example, the United Nations Environment Programme's SOE report for Azerbaijan at http://www.grida.no/enrin/htmls/azer/soe/ecology/index.html; or Environment Canada's SOE Infobase at http://www.ec.gc.ca/soer-ree/). Such reports are useful, narrative in approach, but usually require considerable resources in their production. With the usual publication process, preparation time often leads to information and data being outdated by the time of release. This is just as true of the commonly appearing web-based reports (which are usually paper-based reports placed onto the web with minimal change) as it is of paper-based reports. Web-based reports clearly have an advantage of accessibility and do permit the possibility of free-text search facilities and dynamic on-line analysis that is impossible with paper-based reports.

SIMR's database links to the information held in the metadata, biodiversity, bibliographic, and research project databases. A key component of the system has been the use of a standard template for the description of the indicators (Table 3). This template provides the systematic framework for the detailed descriptions of the indicators, demonstrates to the indicator custodians the terms of

Table 2. Criteria for evaluating indicator effectiveness (after Pearson and others 1998).

An effective environmental indicator should:	
1	Serve as a robust indicator of environmental change
2	Reflect a fundamental or highly valued aspect of the environment
3	Be either national in scope or applicable to regional environmental issues of national significance
4	Provide an early warning of potential problems
5	Be capable of being monitored to provide statistically verifiable and reproducible data that show trends over time and, preferably, apply to a broad range of environmental regions
6	Be scientifically credible
7	Be easy to understand
8	Be monitored regularly with relative ease
9	Be cost-effective
10	Have relevance to policy and management needs
11	Contribute to monitoring of progress towards implementing commitments in nationally significant environmental policies.
12	Where possible and appropriate, facilitate community involvement
13	Contribute to the fulfilment of reporting obligations under international agreements
14	Where possible and appropriate, use existing commercial and managerial indicators
15	Where possible and appropriate, be consistent and comparable with other countries' and State and Territory indicators

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Table 3. Template for describing environmental indicators. SIMR stores information against each of the items in the table below for each indicator. Items marked with an asterisk are for administrative purposes and are not used when a standard report is requested. In addition to the evaluations for each indicator, there are theme-based evaluations.

Title	Description	Example
Status*	Administrative status	Approved, preliminary, in review, obsolete
Custodian	Person responsible for maintaining the information on the indicator	More than one person can be associated with each indicator if data entry and associated information duties are split
Monitoring location	Latitude, longitude, or place-name where indicator is measured	Indicators may be measured at a point or cover substantial areas
Theme area	Indicators fall into one of the themes as defined within the 1996 Australian State of the Environment Report	Atmosphere, biodiversity, coasts and oceans, human settlement, inland waters, land, natural and cultural heritage
Organisation	The organisation to which the custodian belongs	Could be government departments, universities, or private companies
Indicator type	The classification of the indicator	Condition, pressure, or response
Rationale for indicator selection	Why is this indicator useful for SOE reporting?	An indicator may be used to detect anthropogenic impacts
Criteria satisfied	A list of 15 criteria that indicators should mostly satisfy	Indicators should be scientifically credible
Analysis of indicator data	How are the data analysed to detect utility as an environmental indicator?	Data may be transformed to better detect change, for example, temperature anomaly
Research issues	Answers to: 'if you had more resources, how would you use them to improve the utility of this indicator?'	Better ways to measure parameters, automation, better methods of standardisation, address unknown aspects
Data update frequency	In what time period are new data expected?	Daily, monthly, annually
Notification for data*	Date when custodian is e-mailed for new data	Date
Notification for evaluation*	Date when custodian is e-mailed for an evaluation	Date
Data quality	Description of the quality of the data	Plus or minus 0.05°C
Data usage constraints	What constraint does the custodian place on the public use of the data?	Copyright for any data is held by the Commonwealth of Australia; users shall acknowledge the source in reference to the data
Data entry format*	How the indicator data are captured	Web form, direct from instrument, or bulk load
Data display format*	How the data are displayed in report	Plot, table, or specialised
Visibility*	Can the public see this indicator?	Public or private
Photograph	An image that portrays some aspect of the indicator	A GIF or JPEG image with acknowledgement
Data distribution	The contact details where the data may be downloaded or obtained	An organisation name and web address
Evaluation	A concise summary of the implications to SOE reporting, given current data	Usage of Antarctic blend fuel increases with the number of people on-station
Related resources	Links to other indicators, metadata, and bibliography	This indicator is related to indicators 3,5,6, and 8
Parameters	The specific measurements that are monitored by the indicator	Temperature in °C

reference of their involvement, and enables the indicators to be readily compared and reported on. The indicator custodians are the knowledge of the system. They have been selected because of the extensive expertise in the area that their indicator covers. SIMR effectively delegates most of the responsibility for environmental reporting to the custodians.

Another key component of the strategy was to use metadata as a framework to store the template content of each indicator. Metadata enables the indicators and associated data to be discovered using the web and fully described using template information. For example, all of the indicators and associated data are discoverable (and downloadable) via NASA's Global Change Master Directory (http://gcmd.gsfc.nasa.gov/).

It was reasoned that our system would be successful if the custodians found it easy to load data and to use a reporting style that facilitated their analysis and evaluation. The custodians have three responsibilities: to provide one-off answers to questions in the template (Table 3), to gather and enter indicator data, and to provide regular evaluations against that indicator. All this information is stored in the database, including any interactions with custodians. In addition to evaluations of

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Table 4. Australian organisations with Antarctic environmental indicator custodial responsibilities.

Australian Antarctic Division
Australian Radiation Protection and Nuclear Safety Authority
Bureau of Meteorology, Department of the Environment and Heritage
Bureau of Rural Sciences
Commonwealth Scientific and Industrial Research Organisation
Curtin University of Technology
Institute of Antarctic and Southern Ocean Studies, University of Tasmania
La Trobe University
National Tidal Facility
Tasmanian Department of Primary Industries, Water and Environment
University of Wollongong

each indicator by its custodian, separate theme custodians are currently being recruited to provide an evaluation of all indicators within each theme.

The custodian can enter the required data or an evaluation report for that indicator using the web. For example, an indicator may be measured every three months and the data entered into the database and evaluated formally each year. Dynamic web-entry forms enable updates to be made in minutes. Data that cannot be easily loaded by the custodian on the web are bulk-loaded into the database by a system administrator using a standard template. Where possible, data are automatically acquired, for example, sea-surface temperature and salinity data from the Southern Ocean recorded on voyages of *Aurora Australis* (Australia's primary Antarctic research and re-supply vessel).

A report detailing all known aspects of any or all of the environmental indicators can be produced on the web 24 hours a day. The report includes graphed or tabular data and the most recent status report by the indicator custodian: the evaluation. Where possible, indicators are displayed in a graph where the x-axis represents time and the y-axis represents the indicator value. (See http://purl.oclc.org/NET/belbin/soe_paper_figure for an example; this URL is a persistent URL or PURL (see www.purl.oclc.org), where the quoted URL above will never change but the lookup or final URL may change over time to track the page location.) Ready access to all the indicator data in the database system can assist custodians to analyse their data. For example, histograms can be generated and trend lines can be added to graphs or the location of indicator monitoring points displayed.

The system has entry points on the web for the public, custodians, and administrators. The latter two are password-protected. Each entry point displays an appropriate range of services. For example, a custodial report can include technical details not required in a report to environmental managers. Similarly, administrators can produce reports on the status of indicators, lists of custodians and custodial organisations (Table 4), indicator monitoring locations, evaluation criteria, research issues, or bibliographic references.

SIMR links to other databases allow users to browse related resources. For example, the 'Breeding population of southern giant petrels' indicator has a link to the petrel's taxonomic profile in an Antarctic biodiversity database, making it possible to request all locations where the petrel has been sighted.

The system has helped to create a useful framework for environmental management within the Australian Antarctic Division. Explicit identification of indicator custodians, their roles and responsibilities, and the relevant data were some of the obvious early benefits. This information was directly relevant to two of the four government goals for the Australian Antarctic Division: protecting the Antarctic environment and understanding the role of the Antarctic in global climate change. While much of this information existed, it was dissipated across dozens of people and information sources in a form not easily located, systematised, or tapped. This aspect aligned well with knowledge management initiatives within the Australian Antarctic Division and its parent, Environment Australia. The environment reporting system makes more explicit the tacit knowledge held by indicator custodians about environmental issues, largely by using the template (Table 3).

Forty of the 57 environmental indicators listed in Table 1 relate to active scientific research projects within the Australian Antarctic program. The development of 15 of these 40 indicators (37%) involved the measurement of new parameters. For example, even though vegetation studies were active on sub-Antarctic islands, the process of developing the state of the environment reporting system made it explicit that plant introductions needed to be quantified for the SOE reporting system to be effective. Examination of the research issues associated with each indicator suggests that SOE reporting provides an alternate perspective with which to view Antarctic environmental research. For research issues within the template, the authors asked each custodian 'given your current knowledge of the indicator, what environmental research would you advocate if greater support funding was available?' In a number of cases (for example, indicators 27 and 62 in Table 1), the SOE system elevated the significance of the associated research project

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by placing it into a broader systematic environmental monitoring framework.

Effective communication with indicator custodians and environmental managers was vital for a successful outcome. As with any new paradigm, any initial skepticism had to be overcome by a clear presentation of the context and the benefits. For example, custodians usually became enthusiastic once they recognised that the profile of their work would be raised, that their level of input resourcing was clear up-front via the template, and that disparate environmental data would be put into a highly accessible form. Ironically, in many cases, the system was creating ready access for the custodian to their data for the first time.

While the emphasis of this paper is on an innovative response to SOE reporting, the project has been focused on knowledge of Antarctic region environmental issues. It was recognised at the outset of the project that any emergent system could only be as good as the quality of data that it contained: the indicators, associated data and template descriptions. Most of the work within the project has been on the development of the indicators. The large majority of those within this SOE reporting system were being measured in some form prior to the project and clearly useful against the criteria in Table 2. The system did, however, prove itself as an effective vehicle to capture a mass of highly disseminated tacit environmental knowledge.

It is planned to release a free, stand-alone version of SIMR from http://www-aadc.aad.gov.au/soe.

Conclusions

SIMR is the outcome of placing a suite of environmental indicators (Table 1) and a template (Table 3) into a web-enabled database management system. While it has taken approximately 18 months work to develop the indicators and the system, maintaining currency of the information and reporting on environmental conditions and trends now require minimal resources. The system remains current. There is no publication date. Responsibility for the maintenance of indicator data and environmental status has been delegated to indicator custodians. The data management and display functions are augmented by automatic notification to custodians of required input to the system.

The system is, however, only as good as the information it contains. A range of scientific and operational expertise was recruited in the development of the indicators and refinement of the associated data. The system, including the template, provided a holistic framework that was instrumental in establishing the terms of reference and levels of resourcing required for the peace of mind of custodians and administrators. The structure of the system imposes a high level of internal consistency enabling comparability across indicators, ease of use and administration, and simple extensibility.

It is hoped that this strategy will provide a simple and cost-effective mechanism for the Antarctic Treaty to overcome its caution in the progressing of Antarctic SOE reporting.

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