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Monitoring and management in the Antarctic - making the link between science and policy

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Abstract: Management of human impacts in the Antarctic requires an effective system of monitoring to provide information about the process being managed and the effectiveness of management actions. Human impacts arise as a result of processes that originate in the region (endogenous) and those that originate outside the region (exogenous). A number of monitoring programmes have been established in both terrestrial and marine systems to measure impacts that arise as a result of endogenous process such as fishing, tourism and research. However, most of this monitoring is surveillance monitoring, which is not linked to a specific management objective, and does not produce quantitative metrics that can be assessed and compared to agreed targets. However, defining such target levels for the Antarctic, where the aim is to minimise human impacts, is a complex process. Although potential analogues for target setting exist in other parts of the world these are generally insufficiently precautionary to be applied in the Antarctic. The challenge for scientists and policymakers working in the Antarctic is to provide quantitative measures, with agreed trigger levels, and to develop appropriate monitoring schemes to manage human impacts in the future.

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Monitoring and management

Management has many definitions but may generally be considered as the process of measuring a quantity on a regular basis and making appropriate adjustments in order to reach a predefined goal. Any successful management approach, whether of people, resources or ecosystems, requires information on the operation of the system that is to be managed. This information is necessary both in order for management action to be devised and also to allow the effectiveness of such management to be evaluated. The repeated gathering of such information on a process in order to determine how it changes over time, and hence whether management action is required, is referred to as monitoring. In the context of this paper the 'process' that we are seeking to manage is the impact of humans on the ecological systems of the Antarctic. Therefore, in situations where such impacts might arise an appropriate system of monitoring is required.

Human impacts in the Antarctic

Although the Antarctic is often described as the last unspoilt wilderness on Earth it has not escaped the impacts of man. These impacts, in both the terrestrial and marine environments (Kock 1991, Walton & Shears 1994), can appropriately be considered as those that are the manifestation of processes that originate outside the region (exogenous forces), such as climate change and ozone depletion, and those that arise as a result of the direct impact of man in the region (endogenous forces) such as tourism, fishing and the operation of research stations. Clearly it is essential to understand both the role and response of the Antarctic to global, exogenous processes and in particular how the sensitivity to change of the polar regions act as an indicator of them.

In considering an approach to managing the processes that produce impacts in the region it may be pragmatic to restrict the consideration to how we detect the effects of, and respond to, the endogenous forces. However, although the focus may be on the impact of endogenous forces it is important to recognise that the exogenous forces highlighted above often provide a essential context for the interpretation of more small-scale impacts. For example any attempt to interpret the impact of humans on a regularly visited penguin colony may be flawed if no account was taken of regional trends in penguin numbers that may be arising as a results of climate variability.

The impact of fishing in the Antarctic

There is evidence of the impact of man on both the terrestrial and the marine environment of the Antarctic. However, it is in the ocean that surrounds the continent, where the exploitation of seals, whales, fish and krill may have fundamentally altered the marine ecosystem in parts of the Southern Ocean (Croxall & Nicol 2004), that the greatest impact has occurred. Furthermore, it is in the marine environment that the greatest threats to the Antarctic

may still exist (Clarke & Harris 2003). Following the sequential, unsustainable, exploitation of seals, whales and fish the initiation of a fishery for Antarctic krill *Euphausia superba* Dana in the early 1970s prompted concern that the over-exploitation of krill could have considerable ecological consequences. Antarctic krill is a keystone species in the marine foodweb and natural fluctuations in its abundance have well documented impacts on a range of upper trophic level species (e.g. Croxall *et al*. 1999, Reid *et al*. 2005). Thus with the development of a commercial fishery for krill came the potential for widespread ecological effects. This led to the establishment of the Commission for the Conservation of Marine Living Resources (CCAMLR, www.ccamlr.org) to manage fisheries in the Southern Ocean in a way that considered the consequences of fisheries on both target and non-target components of the ecosystem (Constable *et al*. 2000). As part of this ecosystem-based approach to fisheries management CCAMLR sets a catch limit for krill that takes account of the intrinsic population demographics of krill as well as the requirements of dependent species such as penguins and seals (Constable & de la Mare 1996). An important component of the approach of CCAMLR is the CCAMLR Ecosystem Monitoring Programme (CEMP), which was established in 1989. CEMP has two aims, the first of which is to detect changes in the krill based ecosystem, particularly with respect to krill dependent predators, the second is to evaluate whether such changes are due to harvesting or due to natural changes in the marine environment (Agnew 1997).

What is monitored and how does it meet the initial objectives?

Antarctica plays host to a number of long-term monitoring studies of the population size and breeding success of krill predators that provide the potential to separate the direct impacts of man from the natural variability that characterizes the region. Many of these studies were originally established to address questions relating to the fundamental ecology of individual species rather than as part of monitoring *per se*. Nevertheless many of these long-term studies in the Antarctic, as elsewhere, are now delivering ecological insights that were not part of the aims at their inception and their potential to deliver data that is of great importance to management is increasingly being recognized.

Time-series of data collected, as forerunners to and then part of CEMP, have already indicated a range of variability, primarily linked to changes in food availability at scales from years to decades. These studies have provided insights into the ecosystem consequences of large-scale environmental variability (Murphy *et al*. 2007). At South Georgia for example long-term monitoring of Antarctic fur seals, gentoo and macaroni penguins, and black-browed albatrosses has provided evidence of concordant changes in breeding success linked to krill availability (Reid & Croxall 2001). There are also time series of diet data that not only reveal changes in prey composition but also provide data on the size of prey consumed. Although the collection of data on the size of krill taken is not part of the requirement for CEMP these data have allowed detailed comparisons of the sizes of krill taken by predators, scientific nets as well as commercial fisheries (Reid *et al*. 1999, 2004).

The initial aims of the CEMP programme were to detect changes in the krill-centric components of the ecosystem and there is little doubt that the data collected on the reproductive performance of krill predators has indicated changes associated with variability the abundance of Antarctic krill. The second aim, to attribute causality with respect to fishing or the environment is far more challenging. However, as the levels of krill fishery have been generally very low since CEMP began (Nicol & Endo 1997, CCAMLR 2006) this has yet to be fully tested. Nevertheless, the considerable advances that have been made in detecting the effects of large-scale environmental signals in data on the performance of predators (Forcada *et al*. 2005, 2006) provides considerable encouragement that the second aim is realistic and attainable.

It is apparent that there are a range of definitions and interpretation of what actually constitutes ‘monitoring’, particularly with respect to its ability to detect specific changes in an ecosystem. In order to provide a framework within which to interpret monitoring data it may be useful to consider a hierarchical approach that is dependent upon the level of specification of the aims of the monitoring programme. Such a division of monitoring, according to different levels of intensity and specification, follows the guidance on monitoring under the European Union Water Framework Directive (EU 2000), wherein there are three such levels:

1. Surveillance Monitoring – is based on best available knowledge of the system being monitored, where the emphasis is on collecting basic ecological data that allows the *a posteriori* attribution of the causes of change. The aims of a surveillance monitoring programme include the provision of information for the assessment of long-term changes under ‘natural’ conditions as well as the appropriate design of future monitoring programmes.

2. Operational Monitoring - is put in place in response to a specific management objective, to detect, for example, whether a trigger level has been reached. The design and implementation of an operational monitoring programme require clear definition of the change to be detected and an evaluation of the monitoring design required to deliver the statistical power required to detect such a change.

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3. Compliance or Investigative Monitoring - is implemented with respect to a particular location/process in order to identify if the implemented management action is achieving the desired aim. This is the direct monitoring of a process that arises as a result of the detection of a secondary effect by an operational monitoring programme.

The majority of current monitoring programmes in the Antarctic region, both in the terrestrial and marine environment (including those of CEMP), would probably be best described as Surveillance Monitoring as their primary role is not linked to a specific management objective. Nevertheless data from CEMP and other monitoring programmes have provided the means to develop an understanding of the causes and consequences of ecosystem variability, including the relationship between biotic and abiotic drivers, at a range of spatial scales. Thus, whilst there can be little doubt that the data arising from surveillance monitoring can be of tremendous value in understanding the key ecological processes, it is important to be realistic about the potential power to detect specific changes that such programmes are likely to deliver.

Moving from surveillance to operational monitoring in the Antarctic

In order to progress from surveillance to operational monitoring it is essential to provide a clear articulation of specific management objectives. Developing an effective system of management requires a translation of qualitative objectives such as to 'detect the effects of fishing' or 'to minimise human impacts' into quantitative metrics that can be assessed against agreed targets. There are examples from many regions of specific legislation that define critical levels for perturbations or pollutants in aquatic and terrestrial systems (WHO 2004).

From these well specified objectives it is possible to implement operational monitoring programmes in order to provide advice on when limits are exceeded. In the Antarctic, whilst there is a great deal of monitoring effort, there are very few examples of specific legislation that detail the requirement of those monitoring programme. In essence there are a range of potential ways of answering a questions, should such a question be defined in sufficient detail.

One possibility may be to translate relevant legislation from other regions to the Antarctic in order to specify effect/contamination level thresholds. However, many such levels elsewhere in the world are defined with the aim of maintaining an environment that is not prejudicial to the health of humans or other organisms. In the Antarctic, where the aim is to maintain a 'pristine' environment the use of such levels would be inappropriately high in many (if not all) cases. It is necessary to determine what levels of perturbations/contamination arising from human activity in the Antarctic are acceptable and to articulate these in such a way that appropriate operational monitoring programmes can be implemented. The assessment of these levels, and the design of the appropriate monitoring schemes, is likely, in many cases, to be based on information from existing surveillance monitoring; underlining the importance of the link between science and policy in the Antarctic. For example, it would be unhelpful to define a limit for a particular perturbation, whether a pollutant or the effect of a fishery, that was lower than the minimum level discernable from background levels of natural variability given current monitoring capability. Equally however, it is essential that potentially damaging processes are not allowed to continue simply because of limitation in monitoring capacity or capability.

The reasons why monitoring programmes in the Antarctic, including CEMP, have not been translated into operational monitoring reflect the lack of a decisions about what, on the continuum between 'pristine' and 'safe', is an acceptable level of impact. This decision lies with those charged with the governance and protection of the Antarctic, both within CCAMLR and the broader Antarctic Treaty System. Therefore, the ultimate decision as to the level of an impact that is acceptable will be a political decision, but hopefully one that is guided by scientific advice. The challenge for the Antarctic science community is for the scientists involved to deliver this science in a policy-relevant form, that is amenable to managers and decision makers, such that it does have the capacity to influence policy decisions about impact levels. Furthermore where specific impact levels are agreed in advice should be provided on the type and amount of monitoring required to detect those levels. In doing so the interaction between science and policy in the Antarctic should provide a framework by which the impact of man on the Antarctic can be effectively managed.

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