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# Antarctic Krill Fisheries and Rapid Ecosystem Change: The Need for Adaptive Management

## ***Abstract***

This paper calls for the need for adaptive management of Antarctic krill fisheries in the Scotia Sea/ Antarctic Peninsula region to take account of the combined impacts of recovering populations of predators, future fishing and climate change. This area holds the greatest concentration of krill, has been subject to major depletion of hunted or fished stocks in the past, and is strongly affected by climate change. Therefore, a management system based on feedback procedures (adaptive management) is needed.

CCAMLR's Ecosystem Monitoring Program (CEMP) is a valuable monitoring tool that needs to be expanded and improved in order to meet the needs of adaptive management.

## **1 The impacts of resource extraction on the Scotia Sea/Antarctic Peninsula region**

The Scotia Sea/Antarctic Peninsula region has a long history of extraction of biotic resources, occurring in a sequential pattern (e.g. Hilborn et *al.*

South Georgia (fur seals, black-browed albatrosses, macaroni and gentoo penguins) in relation to annual krill availability, although Ainley & Blight (2009) note that the loss of groundfish, and their juveniles (important top predator prey), confounds the patterns. Ducklow et al. (2007) showed that the decrease in winter sea ice in the western Antarctic Peninsula has significantly contributed to long-term changes in the relative abundance of krill-dependent penguin populations.

In the Western Antarctic Peninsula region, the population trends of Adélie and Chinstrap penguins appear to be affected negatively by a winter krill deficit. This deficit also affects Gentoo penguins and elephant seals in the opposite direction (Ducklow et al., 2007; Siniff et al., 2008). Similar results on population trends at the South Orkneys suggest the loss of buffering against the changing sea ice environment by the more abundant and ice-

scheme for krill, which accounts for interactions between the fishery, krill predator populations and environmental factors, still remains to be developed. In its 2007 meeting, CCAMLR decided that the further development of feedback management approaches will be given priority from 2009 onwards.<sup>3</sup> However, CCAMLR has failed so far to make progress on this issue.

An essential element in the development of a feedback management system for krill fisheries is CCAMLR's Ecosystem Monitoring Program (CEMP), which is discussed in section 4.

#### **4 CCAMLR's Ecosystem Monitoring Program (CEMP)**

CEMP was established in 1985 to monitor the effects of fishing on both harvested species (target species) and dependent species (predators), so as to assist CCAMLR with its task of regulating the commercial harvesting of Antarctic marine living resources in accordance with the "ecosystem approach" embodied in Article II ([www.ccamlr.org](http://www.ccamlr.org)). Based on a feedback management approach, it was expected that such a monitoring program would enable CCAMLR to adjust management measures in response to new information as it became available.

The idea behind the establishment of the CEMP was that krill predators could be good indicators of the availability of krill. The concept of indicator species was thus developed, referring to those dependent or related species that are likely to reflect changes in the species targeted by the fishery, and indicate the state of those parts of the ecosystem that are most impacted by fishing activities.<sup>4</sup>

One of the challenges of the CEMP is to be able to distinguish whether a detected change in an indicator species is due to fishing or to environmental effects, including climate change. Representativeness of the monitoring sites of their respective areas and regions constitutes another challenge.<sup>5</sup> This is mainly because the CEMP is largely dependent on national research programs and priorities. Although management considerations influenced the initial selection of monitoring sites, this selection was also determined by practical considerations such as the presence of pre-established research stations. The continuity of contributions to the CEMP also depends on national priorities, since participation in the program is voluntary. As a result, the program is restricted to monitoring a few selected krill predators and is established in only a few areas. Predator monitoring is currently restricted to land-based species.

The CEMP assessment of the impacts of krill fishing on dependent species still remains to be integrated into long-term management procedures. These procedures enable the continuous adjustment of relevant measures in response to new information obtained, according to the feedback management approach adopted by CCAMLR. At the moment, the nature of CEMP can be described as a "surveillance monitoring" program, where basic ecological data are gathered allowing for *a posteriori* attribution of the causes of change, but there is no direct link between this monitoring program and a specific management objective, and therefore it is not a truly adaptive scheme.

Although CEMP data have provided invaluable insights in the understanding of the key ecological processes in the South Atlantic and some other areas, implementing a feedback management procedure would require moving from current surveillance monitoring to "operational monitoring". The latter is designed to respond to a specific management objective, such as detecting whether a certain trigger level has been reached. The design and implementation of an operational monitoring program require clear definition of the change to be detected. Also, the monitoring should be designed so as to deliver the statistical power required to detect such a change (Reid, 2007). As CCAMLR moves into truly adaptive management procedures, the ability to effectively manage the fishery in those areas where there is no monitoring will be very limited.

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<sup>3</sup> SC-CCAMLR, 2007, para. 3.36.

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CCAMLR has already recognized that in its current configuration, CEMP does not allow distinguishing the impacts of fishing from those associated with environmental change, which was its main objective at the time of its creation. In addition, some CEMP sites have been discontinued in recent years and data submitted to the CEMP has decreased. In some cases, information arising from different CEMP sites with similar geographical and oceanographic features indicate contradictory trends on predator parameters, which are difficult to explain without further investigation.

As was acknowledged by CCAMLR's Working Group on Ecosystem Monitoring and Management (WG-EMM) at its last meeting in 2009, climate change may induce rapid changes within the ecosystem, impacting the way indices generated by CEMP are being used to detect fisheries impacts. According to WG-EMM, in order to distinguish between climate change and fisheries impacts, it may be necessary to establish reference sites (i.e. where no fishing takes place) and/or additional parameters.<sup>6</sup>

At this critical moment in the development of the krill management regime, CCAMLR needs to make progress towards an effective feedback management system. The CEMP must be expanded accordingly to support this system. In this context, decision rules must be developed to allow adaptive management through appropriate data arising from operational monitoring (as opposed to surveillance monitoring). On the basis of these decision rules, an analysis of the CEMP should be undertaken. This analysis can include questions such as location of additional monitoring sites, the need to add new species into the program as necessary, and indices to be measured.<sup>7</sup> The potential use of area closures in the monitoring program in order to evaluate the combined effects of fishing and climate change, using closed (reference) areas as a control should also be considered. Furthermore, the CEMP should be expanded to include monitoring of krill and other prey species, and to include monitoring of the impact of climate change on the ecosystem.

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established with the main goal of detecting changes in predator indicator species as a result of fishing. Therefore, integrating CEMP assessments of the combined impacts of krill fishing and climate change on dependent species into long-term management procedures should be a key element of CCAMLR's adaptive management scheme, as well as an important component of a climate change adaptation plan for Antarctic marine ecosystems. In addition, CEMP, which also monitors a few species in the Southern Indian Ocean, should be integrated into broader monitoring plans for the Southern Ocean.



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