12

Climate Change and Management of Antarctic Krill Fisheries

Olav Schram Stokke

Introduction

What challenges does climate change pose to effective management of fisheries for Antarctic krill – and is the international management regime dimensioned to meet those challenges?[1] The combination of rising levels of sea temperature, acidification and ultraviolet radiation in the Southern Ocean is expected to induce a poleward shift in the distribution of the world's biggest marine stock: Antarctic krill (see Ch. 11). Some reports indicate that such a shift is already underway (Atkinson et al. 2009; Hill et al. 2019), although these findings have been disputed (Cox et al. 2018, 2019). From what we know about krill biology, inter-species interaction and oceanographic conditions in the Southern Ocean, a poleward shift would most probably imply significant reduction of habitats suitable for krill spawning, hatching, larval survival and juvenile growth (McBride et al. 2021).

Such potentially cumulative impacts of climate change further compound a management challenge that the regional regime, centred on the Commission for Conservation of Antarctic Marine Living Resources (CCAMLR), has not fully met thus far. In contrast to the agility shown in developing responses to steep increases in illegal, unreported and unregulated (IUU) fishing for valuable deep-sea species like Patagonian toothfish in the late 1990s and early 2000s (Miller et al. 2010), CCAMLR's management of the krill fisheries has not evolved according to the Commission's own aspirations. Monitoring and research of the stock and associated species have been irregular and spatially limited; and the existing harvest-control rule is not linked to the best available information on the status of Antarctic krill and krill-dependent stocks.

This chapter briefly reviews the institutional framework for managing krill fisheries, outlining how climate change has been addressed within CCAMLR, and examining the prospects for further advances toward ecosystem risk assessment and a more adaptive management system. Thereby it contributes to answering the second and the third overarching research questions addressed in this volume (see Ch. 1): management challenges deriving from stock-shifts and the extent to which those operating the regime are able to modify it, if that is necessary for maintaining high performance.

CCAMLR and climate change

Adopting and revising conservation and management measures in response to changes in the status of harvested stocks is a core task of any institution responsible for fisheries management. CCAMLR's ecosystem management objective entails the obligation to consider also the impacts on krill-dependent species – which include penguins and other sea birds as well as fish, seals and whales (Hill et al. 2016). The institutional framework for pursuing this objective consists of the decision-making Commission and the advisory Scientific Committee (SC-CAMLR), both with subsidiary bodies, as well as a secretariat. CCAMLR's attention to the impacts of climate change has been rising steadily during the past fifteen years.

Institutional framework

The Convention on the Conservation of Antarctic Marine Living Resources (CAMLR Convention) was adopted in 1980 amidst concerns that expanding krill fisheries could have substantial and negative impacts on the Southern Ocean ecosystem. Commercial harvesting of krill had begun in 1961/2; by the late 1970s, there was a multinational fishery operating in the Atlantic sector (FAO Statistical Area 48) as well as in the Indian Ocean sector (Divisions 58.4.1 and 58.4.2) – and annual catches rose from less than 100,000 tonnes to nearly 500,000 tonnes by the late 1980s (CCAMLR 2018: 3–4). The dissolution of the Soviet Union, which had dominated the krill fishery, resulted in considerably reduced effort; today's catch levels (around 450,000 tonnes) are taken largely by Norway, South Korea and China (CCAMLR 2018: 4); Ukraine, Chile and in some years Russia also participate in an 'Olympic'-style fishery (no national or vessel quotas). Since the early 1990s, harvesting has been mostly confined to Area 48, which covers the Scotia Sea and the western Antarctic Peninsula (CCAMLR 2018: 4; see Ch. 11).

The Commission is to give effect to the three-pronged precautionary ecosystem management objective set forth in Article II of the CAMLR Convention: 1) prevent a targeted stock from falling below levels 'which ensure its stable recruitment'; 2) maintain the 'ecological relationships between harvested, dependent, and related populations … and the restoration of depleted populations'; and 3) minimize 'the risk of changes in the marine ecosystem which are not potentially reversible after two or three decades'. Meeting annually, the Commission adopts, by consensus (Art. XII), conservation measures that become legally binding on members unless they opt out within ninety days (Art. IX).

For krill, the Commission has adopted a series of conservation measures which set the maximum amount that can be taken in each of the sub-areas where the fishery occurs. Other measures oblige members to notify the secretariat of vessels planning to participate in the krill fishery well ahead of the season; to report regularly on catch and effort; to ensure that their vessels adhere to all krill-specific regulations and adhere to general regulations on matters such as vessel marking, gear restrictions and bycatch mitigation.

The Scientific Committee is charged with promoting cooperation on research with respect to Antarctic marine living resources. It is to advise the Commission on measures to implement the objectives of the Convention, including by establishing assessment criteria and methods, analysing direct and indirect effects of harvesting, and evaluating the effects of proposed conservation measures (Art. XV). This advice derives from assessments conducted by five working groups, including those on Ecosystem Management and Monitoring (EMM, responsible for krill, including predator–prey interactions and how they relate to environmental features) and Fish Stock Assessment (FSA, responsible for targeted finfish resources, mostly toothfish). Other working groups and sub-groups evaluate new assessment methods and models.

The Standing Committee on Inspection and Compliance (SCIC) advises the Commission on ways to improve adherence to conservation measures. Important compliance mechanisms include the System of Inspection, which ensures access for inspectors designated by non-flag states to fishing vessels and logbooks at sea as well as in port, and the System of International Scientific Observations. The latter was established primarily for scientific monitoring purposes, but now also provides information on the compliance of specific vessels; the required observer coverage in the krill fishery has increased gradually, achieving full coverage by 2020 (CCAMLR 2018a: 8).

The CAMLR Convention applies south of a line that approximates the Antarctic Polar Front (Art. I), a natural and dynamic boundary for the regional marine ecosystem (see Ch. 11), and forms part of a larger institutional complex (Oberthür and Stokke 2011) that includes the Antarctic Treaty System (ATS) (Stokke and Vidas 1996). The centrepiece of that system is the 1959 Antarctic Treaty with its annual Consultative Meeting (ATCM), advised by the Scientific Committee for Antarctic Research (SCAR) and, after the adoption of the 1991 Environmental Protocol, by the Committee for Environmental Protection (CEP). Other major components of the ATS are the 1972 Convention on the Conservation of Antarctic Seals, as well as all measures in force under these various agreements, such as the Agreed Measures for Conservation of Antarctic Fauna and Flora (including birds and mammals) (Vidas 1996). The CAMLR Convention's spatial ambit and placement in a larger institutional complex are conducive to ecosystem-based management: among the major krill predators, only whales are managed by an institution that is not a formal part of the ATS – the International Whaling Commission. CCAMLR cooperates with that institution through regular exchange of scientific information, as it also does with the Commission for the Conservation of Southern Bluefin Tuna, which manages a stock with some occurrence in northern parts of the CCAMLR area.

Rising attention to climate change

A recent review of responses to climate change by regional fisheries management bodies (Rayfuse 2019) found that CCAMLR has been more explicit than other organizations on the need to take climate change into consideration, adding, however, that none of the organizations studied had advanced substantially toward integrating climate impacts into their research and regulatory activities. References to climate change and its potential impacts on the Southern Ocean ecosystem can be found in Scientific Committee reports since 1989 (SC-CAMLR 1989: Annex 2) but their frequency and prominence remained low, well into the early 2000s.

As with other fisheries management bodies (Sumby et al. 2021), a turning point occurred in 2007, coinciding with the publication of the IPCC Fourth Assessment Report as well as the International Polar Year (2007–8) with its many climate-related projects. That year, the Commission 'urged Members to develop and maintain long-term scientific monitoring programmes studying the krill-based ecosystem as these will allow the Scientific Committee to investigate the effects of climate change as well as the effects of the fishery' (CCAMLR 2007: 14). The Commission also noted that climate-change impacts could be upgraded to a separate agenda item for the Scientific Committee (CCAMLR 2007: 70–3), thereby reinforcing expectations of concrete advice on the matter. The year after, it endorsed three work-areas designated by the Scientific Committee with a view to examining: 1) the robustness of stock assessments and scientific advice to the rising uncertainty accompanying climate change; 2) the need for improved monitoring programmes of harvested and associated species to provide robust and timely indicators of climate change impacts; and 3) whether climate-change uncertainty calls for modification of management objectives or performance indicators (CCAMLR 2008).

Subsequent progress in these three work-areas has been uneven. Within the first two areas, on robustness and monitoring, the Scientific Committee soon advised that climate change might induce rapid change within ecosystems, and that distinguishing climate impacts from fisheries impacts would probably require that existing CCAMLR Ecosystem Monitoring Programme (CEMP) sites for ecosystem monitoring be supported by data collection in reference areas with no fishing (SC-CAMLR 2009). The Commission responded promptly: it adopted Resolution 30/XXVIII, urging members and others to increase their consideration of the impacts of climate change in the Southern Ocean to better inform CCAMLR management decisions, and endorsed a review of CEMP (CCAMLR 2009). More than a decade later, however, that CEMP review is still forthcoming, awaiting consensus within the Commission on a new krill management procedure (SC-CAMLR 2018) – which in practice will require successful completion of the third designated work-area, on possible modifications of management objectives and performance indicators.

Since 2015, the Commission has examined climate-change impacts on conservation as a separate agenda item, involving controversy over two issues in particular: a proposed addition to Resolution 30/XXVIII, requesting that all papers submitted to the Scientific Committee or the Commission include a climate-change implications statement; and a proposed Climate Change Response Work Programme (CCRWP) modelled on one implemented by the Committee for Environmental Protection under the Antarctic Treaty's Environmental Protocol (CCAMLR 2017). The controversy over climate-change statements has revolved around the scientific value of requiring such statements also in CCAMLR papers that do not examine time-series of climate data (CCAMLR 2018b). Critics of the CCRWP have focused on its proposed mechanism for identifying and revising climate-change responsive goals and actions by the Commission and the Scientific Committee, arguing that it might duplicate activities in other forums and bypass assessments by the Scientific Committee and its working groups (CCAMLR 2018b).

Although climate change has received growing attention in CCAMLR, the agreed approach has been to deal with its implications not through climate-specific requirements or structures, but by seeking to improve the general institutional capacity to detect and respond to any detrimental impacts of harvesting. With respect to the krill fisheries, as the remainder of this chapter will show, those efforts have revolved around risk-assessment procedures and the Commission's longstanding aspiration to move closer to 'feedback management, which involves the continuous adjustment of management measures in response to information' (CCAMLR 1991a: 15).

Ecosystem risk assessment: progress and limitations

The harvesting pressure on Antarctic krill in the Southwest Atlantic sector, where the fishery is concentrated, has never exceeded one per cent of the estimated spawning-stock biomass in this area. Assessments of risk have therefore focused less on replenishment of the krill stock than on any impacts that reduced abundance may have on krill-dependent predators in the local areas where fisheries occur.

Catch reports from the commercial krill fisheries, required by CCAMLR on a haul-by-haul basis at gradually finer spatio-temporal scales, are the main sources of data on the distribution of harvesting operations. Several factors – including the patchiness of these operations compared to the distribution of the stock, and the scarce knowledge held on the mechanisms and patterns of krill flux (movement) – limit the use of catches per unit effort for stock-assessment purposes (Santa Cruz et al. 2018), so abundance estimates derive mostly from standardized net and acoustic surveys (Meyer et al. 2020). For cost reasons, large, area-scale surveys have been rare – for the Southwest Atlantic sector, they have been conducted only in 2000 and 2019.

In contrast, regional biomass estimates, as part of local monitoring programmes in the main fishing areas, have been sufficiently regular to provide time-series data that reveal very wide fluctuations in local abundance, as in the Bransfield Strait and north of the South Shetland Islands, where inter-annual differences can be as large as two to three orders of magnitude (Reiss 2008). Knowledge of such fluctuating abundance in fisheries hotspots has made the question underlying most of the krill management discussions in CCAMLR even more pressing: to what extent do krill fisheries put local predators at risk?

A major response to this question came in 1985, with the establishment of CEMP, focused on selected life-history stages of land-based seals, penguins and several other seabird species with restricted mobility during the foraging season (Agnew 1997; Kock et al. 2007). However, a review of that programme, nearly two decades later, found it 'unlikely that the existing design of CEMP, with the data available to it, would be sufficient to distinguish between ecosystem changes due to harvesting of commercial species and changes due to environmental variability, whether physical or biological' (SC-CAMLR 2003: 8).

Ecosystem-based risk assessment of the krill fisheries requires data on fisheries, on krill abundance at various scales (to account for flux), and on local predator requirements in fisheries hotspots (Krafft et. al 2015) – all collected and analysed in ways that allow evaluation of functional relationships (Kawaguchi and Nicol 2020; Meyer et al. 2020). When examining advances in the ecosystem risk assessment underlying Scientific Committee advice on krill, it is instructive to focus on a few particularly important regulatory decisions by the Commission:

1. The advice to set a first precautionary catch limit on krill in the Southwest Atlantic sector (CCAMLR 1991b)) was motivated by concerns that localized overfishing might negatively affect predator populations, fuelled by fine-scaled fisher reports indicating concentration near colonies of foraging penguins and seals (SC-CAMLR 1991). The basis for setting this catch limit was data on krill abundance derived from surveys conducted in the pre-CCAMLR era; the first and second international BIOMASS experiments.
2. A second important krill Conservation Measure (CCAMLR 1992) subdivided the catch limit among sub-areas of the Southwest Atlantic, largely proportional to distribution estimates from the pre-CCAMLR area survey (SC-CAMLR 1992). Implementing that subdivision, however, would be required only if total catch in heavily fished sub-areas reached a 'trigger level' of 620,000 tonnes, corresponding to the highest recorded annual catch in each sub-area. Whereas predator demand formed the basic rationale for the catch limit as well as the trigger, the report from the scientific deliberations made only a single reference to CEMP predator monitoring, which by then had been underway for seven years – namely, that despite such monitoring, 'it is currently impossible to estimate total consumption for all krill predators in the subareas' (SC-CAMLR 1992: 15).
3. The next major step in krill conservation (CCAMLR 2000a) was taken immediately after the CCAMLR 2000 synoptic krill survey of the Southwest Atlantic sector: on the basis of improved acoustic analysis methods, greater knowledge on krill life history and a concomitant improvement in stock-assessment methods, the Commission raised the precautionary catch limit for the area and spatially allocated it at the sub-area level based on survey estimates of the stock distribution. Importantly, the Commission also upgraded the trigger level, from a threshold obliging further subdivision to an area-level interim catch limit, applicable until a subdivision of the much higher precautionary catch limit (currently at 5.61 MT) is agreed (CCAMLR 2000b).
4. To facilitate more high-resolution risk assessment and conservation measures, the Scientific Committee two years later proposed several small-scale management units (SSMUs) – distinguishing in each sub-area between one pelagic area and one or more land-based predator areas (SC-CAMLR 2002). However, disagreement on the feasibility and scientific merit of various options for subdividing the krill catch limit among them has prevented consensual advice on the matter thus far. Static or dynamic options under longstanding evaluation by the Scientific Committee require fine-scaled distribution estimates of historical catches; krill biomass, as used already at the sub-area level; predator demand; krill biomass minus predator demand; dynamic predator-based indices of krill availability; and ecosystem

responses to structured fishing, with harvesting effort rotating among SSMUs (e.g. SC-CAMLR 2004; see also Hewitt 2004).

5. The most recent substantive update of conservation measures related to krill fishing (CCAMLR 2009a) allocated the trigger level among four sub-areas (48.1–4) in the Southwest Atlantic, again based largely on survey-derived estimates of the standing krill stock (CCAMLR 2009b). Driving the subdivision was advice by the Scientific Committee, based on improved modelling of functional relationships among fisheries, krill and spatially restricted predators which indicated that even the relatively low trigger-based catch limit might not suffice to protect predators if the fishery should become more concentrated near foraging areas (SC-CAMLR 2009; Meyer et al. 2020). The conservation measure subdividing the trigger level was time-limited and has been renewed several times: the one currently in force expires in November 2022 (CCAMLR 2021).

This brief review of major decisions on krill thus far brings out the progress and limitations in CCAMLR's risk assessment. The 2009 decision to subdivide the trigger level drew upon multispecies modelling parameterized in accordance with the best available knowledge at that time on processes linking fisheries and ecosystem response, using spatially resolved data on variations in krill and predator abundance (Watters et al. 2013). The limitations are equally evident, however: neither the catch limit (based on historical fishing maxima) nor its subdivision (based on estimates of krill distribution from the 2000 survey) reflects updated information from ongoing krill surveys and monitoring of predator abundance and reproductive performance. Important advances in understanding the krill-centric ecosystem had driven the decision to subdivide the trigger-based catch limit, but not the substance of that decision.

A dynamic, whole-ecosystem, data-driven risk-assessment procedure that can support adaptive management of krill is still a work in progress (Kawaguchi and Nicol 2020; Meyer et al. 2020); however, three moves by the Scientific Committee since the latest regulatory update deserve attention. In 2013, the Committee consolidated a staged approach envisaging catch limits above the trigger level based on information that incorporates a steadily broader range of observation series, including multiple-scaled krill surveys and CEMP-based quantification of predator demand (SC-CAMLR 2013). A second move was to develop a risk assessment framework for providing advice on how to distribute future catch levels spatially, in order to spread and moderate the risks to predators (SC-CAMLR 2016). The most recent advance was agreed immediately after the 2019 Area 48 Survey had demonstrated that commercial fishing vessels could effectively collect large-scale scientific data on krill (SC-CAMLR 2019a; see also Ch. 5). The Scientific Committee adopted a detailed work plan to collate data layers and analyses from a wide range of past, ongoing and enhanced monitoring and research activities – including the two large-scale area surveys, annual regional krill surveys and predator monitoring, and tracking of land-based and pelagic predators (SC-CAMLR 2019b).

Moving toward feedback management

Important as it is to ensure that decision-makers obtain updated information on the status of krill stocks and stocks of krill-dependent species in harvesting areas, an effective feedback management system also requires that the decision-making body can agree on regulatory measures that respond to changing indices (Trathan and Agnew 2010). During the past ten years, CCAMLR's ability to reach consensus on proposed conservation measures has been on a downward slope.

Scientific uncertainty concerning the impacts of krill harvesting on local ecosystems has contributed to longstanding disagreement among CCAMLR members on whether to subdivide catch limits among smaller management units in the Southwest Atlantic. Finer subdivision is controversial because small management units imply less flexibility for fishing vessels to deploy their harvesting capacities efficiently. Even with the current much larger management units (four sub-areas in the Southwest Atlantic sector), subdivision of the trigger-based catch limit regularly results in closures in parts of the operational area well before the season ends. Critics of smaller management units also argue that static management measures where modification requires consensus are unlikely to keep pace with dynamic changes to the marine ecosystem and may thus hamper rather than promote the ability to react adaptively.

Thus, subdivision of krill catch limits links up to a larger debate within CCAMLR concerning the balance between environmental protection and rational resource use (see, e.g. Press et al. 2019). In the context of krill management, debates on that balance have revolved around achieving a scientific basis for allocating the trigger level in a way that can be both responsive to changes in the status of the krill stock and its predators *and* attentive to the cost effectiveness of fishing operations and the comparative importance of various marine areas for the economics of the fishery (see, e.g. CCAMLR 2016a: 12–15). As noted above, the spatial allocation of the trigger level comes with an expiry date because the current conservation measure will remain in force only until November 2022. Accordingly, maintaining or increasing the present spatial resolution of krill catch limits to protect krill-dependent predators will require that a new conservation measure be adopted through consensus – and, as discussed below, failure to obtain consensus has become increasingly frequent in CCAMLR decision-making.

Consensus in CCAMLR

As in some other international environmental institutions, legally binding decisions by CCAMLR require consensus (Art. XII), a slightly softer requirement than unanimity, as it suffices that no member *objects* to a proposed conservation measure (see also Ch. 3 by Young and Stokke). The consensus requirement derives in part from disagreement among those who negotiated the Convention regarding the status of seven partially overlapping sovereignty claims to Antarctic territory. Specifically, the consensus rule provides procedural reinforcement of Article IV, which is aimed at ensuring that the general 'freeze' of the sovereignty issue established by the Antarctic Treaty will be upheld also in situations where members regularly engage in fisheries regulation and enforcement that might otherwise be interpreted as deriving from territorial jurisdiction (Stokke 1996). The veto right, ensured by the consensus rule, means that acceptance of CCAMLR regulations and enforcement actions by other states can always be construed as deriving from nationality-based jurisdiction, thus neither strengthening nor undermining claims to territorial jurisdiction. This embeddedness of the consensus requirement in the larger sovereignty issue in Antarctic governance means that strengthening the decision rule to some variety of majority decision is even less likely than for other resource management regimes in which each member has the right of veto.

From a governance point of view, the consensus rule has the obvious disadvantage that decisions can easily be blocked – but the accompanying advantage is that it compels members to search for solutions that can accommodate the most strongly-held concerns of others. In CCAMLR, the consensus-seeking approach typically begins informally at the working-group level; by the time an issue reaches the Commission, any disagreements should have been aired and noted prior to the formal deliberations (Everson 2017: 148). Although this procedure holds no guarantee of consensus, it does allow those who put forward a proposed conservation measure to adjust it in ways that may make it more acceptable to opponents. Conversely, the Rules of Procedure of the Scientific Committee require that its reports to the Commission 'shall reflect all the views expressed at the Committee on the matters discussed' (Rule 3, based in the Convention's Art. XVI); this ensures a high degree of transparency regarding positions taken by various members on controversial matters. Such transparency typically raises the political costs of opposing proposals that enjoy the support of a clear majority of Scientific Committee members.

Controversy on the balancing of protection and rational use

During the past ten years, instances of opposition to proposed conservation measures within CCAMLR have become more frequent, especially on matters concerning marine protected areas (MPAs) (see Brooks et al. 2019; Sykora-Bodie and Morrison 2019). Although not impinging directly on the process of revising the krill management system, MPA controversies have highlighted the balance between the protection and utilization components of CCAMLR's objective, laid out in the provision that '[f]or the purposes of this Convention, the term "conservation" includes rational use' (Art. II).

In line with UN Convention on Biological Diversity, the Commission has pledged to establish a representative network of MPAs in the Convention area (Everson 2017). Building on earlier measures to protect CEMP sites and areas accorded special management or protection status under the Environmental Protocol, in 2009 the Commission designated the South Orkney Islands Southern Shelf MPA (CCAMLR 2009a). Commercial fishing was prohibited, but the MPA boundaries had been drawn to exclude from the original proposal the area where actual harvesting occurred (CCAMLR 2009b: 21). Soon thereafter, the Commission agreed on a general framework for establishing MPAs (CCAMLR 2011), largely consistent with MPA best practices established elsewhere (Brooks et al. 2019: 3); and in 2016 it designated the world's largest MPA, in the Ross Sea region (CCAMLR 2016b).

Notwithstanding this string of regulatory achievements on MPAs, CCAMLR deliberations on the matter had become increasingly polarized, and many proposals failed to obtain consensus. Since around 2012, a subset of fishing-state members have expressed rising concern that MPA proposals might have the effect of undermining the rational-use part of the objective, and have questioned the scientific basis for introducing restrictions on fishing operations beyond the framework already in place (see CCAMLR 2015: 54, 58; CCAMLR 2016a: 58–60; CCAMLR 2018b: 25, 28). On the other side of this debate, a group of members with little or no engagement in Antarctic fisheries have expressed frustration at the lack of progress, emphasizing the CCAMLR commitment to create a representative system of MPAs, and the role of this instrument in providing scientific reference areas for monitoring natural variability, long-term change, and the effects of human activities (see CCAMLR 2012: 23–39; CCAMLR 2017: 46–53; CCAMLR 2018b: 33).

The rising controversy among CCAMLR members over the MPA instrument is also evident in the contrast between the swift adoption of the South Orkney Islands Southern Shelf MPA in 2009 (Brooks et al. 2019: 3) and the protracted deliberations that have marked subsequent proposals. Variants of the Ross Sea region proposal had been submitted four times without obtaining consensus, and the proposal finally adopted had been tailored to accommodate various objections – notably with its thirty-five-year 'sunset clause' and the large Krill Research Area where directed krill fishing will be permitted, even though no significant krill harvesting has occurred in that region for decades. Proposals for new MPAs in the East Antarctic (variants proposed annually since 2012), the Weddell Sea (since 2016) and the Antarctic Peninsula region (since 2018) have failed to obtain consensus, in most cases despite revisions aimed at accommodating criticisms of previous versions (see overview in Sykora-Bodie and Morrison 2019). Even the two MPAs in existence are subject to considerable controversy, as the Commission has not been able to adopt research and monitoring plans for either of them – in the case of the Ross Sea region, despite the endorsement of the Scientific Committee (CCAMLR 2019: 27–39).

Prospects for progress on feedback management

In view of the rising controversy over the MPA instrument, it is clearly in line with CCAMLR's consensus-seeking tradition that neither the Scientific Committee nor the Commission made any reference to MPAs when, respectively, endorsing and adopting the scientific work plan to support a feedback management approach for the krill fisheries (see above) – beyond noting that the planning group for the Antarctic Peninsula MPA proposal has compiled certain data layers of relevance (SC-CAMLR 2019a: 11–16 and tables 1–4; CCAMLR 2019: 13–14). Similarly, sponsors of a revised version of the MPA proposal for the Antarctic Peninsula region, where krill harvesting is currently concentrated, emphasized that regulation of the fishing activity in the MPA would occur within the regular framework of catch limits spatially allocated by the Commission, primarily through the existing conservation measure on spatial allocation (CCAMLR 2021) or measures replacing or revising it (CCAMLR 2019: 33); one of the sponsors, Chile, is a krill-fishing state.

Indeed, several leading fishing-state members have sought to build bridges between the competing positions regarding the balance between protection and resource use. Drawing on numerous in-depth interviews with CCAMLR delegates and observers in 2017, Sykora-Bodie and Morrison (2019: 9) reported that three states actively engaged in Southern Ocean fisheries – Japan, Korea, Norway – were seen by both sides of the MPA controversy as promoting the kind of constructive dialogue needed to obtain consensus, notably by their insistence on a clear scientific rationale for protective measures and their preparedness to contribute to such research.

The subset of fishing states that have sought to build bridges among the parties to the MPA controversy in CCAMLR has also been central in the development of the scientific work plan in support of a feedback management system for the krill fisheries. Only the UK and the USA are mentioned more frequently than Japan and Norway in the listing of coordinators and data providers for various activities planned to make risk assessment more sensitive to changes in the abundance and distribution of krill and its predators (SC-CAMLR 2019a: 11 and associated tables). Further, Norway coordinated the multinational 2019 Area 48 Survey, and in the same year, Japan conducted a krill biomass survey in Division 58.4.1, aimed at updating a biomass estimate from the mid-1990s (SC-CAMLR 2019a: 7–8).

Active engagement by the leading krill-fishing states in the development of the scientific work plan in support of a feedback management system for the krill fisheries is conducive for obtaining consensus on a feedback management system, because these states can hardly be suspected of seeking to dilute the rational-use part of CCAMLR's conservation objective.

A related and similarly conducive circumstance is the positive attitude expressed by important segments of the krill-fishing industry. Members of the Association of Responsible Krill Harvesting Companies (ARK) take more than 80 per cent of the krill catch in the CCAMLR area; their support to advancing feedback management includes active engagement in scientific workshops and stakeholder meetings on the matter as well as provision of vessel hours, free of charge, for the 2019 Area 48 Survey (SC-CAMLR 2018). This association, which holds observer status within CCAMLR, harvesting activities by enacting voluntary restriction zones seasonally near breeding colonies of krill predators (CCAMLR 2016a). Among the drivers for these supportive activities is that major krill-fishing companies have obtained certification from a leading private governance institution, the Marine Stewardship Council (MSC), which now certifies more than 10 per cent of the world's capture fisheries (see Ch. 5). MSC certification improves access to major markets for some of the most lucrative krill applications, such as nutrients and pharmaceuticals. Measures required or recommended by the MSC to renew existing certificates align well with the feedback management agenda: reduction of bycatch and localized harvesting pressure, and better knowledge of the effects of the krill fisheries on the ecosystem (see, e.g. Hønneland et al. 2020; Roel and Ríos 2020; also Nicol et al. 2012: 35–6).

Another circumstance favouring progress toward feedback management is the substantial increase in krill catches since 2017. This stems from the gradually stronger markets for an expanding range of krill-based products, and possibly also from more efficient gear – notably, deployment of continuous pumping technology in part of the fishing fleet (Nicol and Foster 2016). The recent rise in catches is steeper than expected: industry sources cited by Kawaguchi and Nicol (2020) found it unlikely that catches would exceed 350,000 tonnes in the Southwest Atlantic, and yet a catch close to 450,000 tonnes was reported already in the 2019/20 season (CCAMLR 2020). This development makes it more probable that commercially viable krill harvesting could exceed the trigger level for the Southwest Atlantic sector. Lifting that trigger level will require consensus within the Commission on a mechanism for spatially allocating the higher precautionary catch limit among smaller management units (CCAMLR 2010) – or on some other adaptive solution acceptable to all CCAMLR members.

In summary, the combination of institutional, political and economic considerations gives rise to some optimism regarding the ongoing efforts to move closer to a feedback management system for krill. Members that emphasize the protection part of CCAMLR's conservation objective have strong incentives to accommodate those who favour 'rational use' – because, without a new consensus decision, even the existing level of spatial distribution of fisheries will expire. Conversely, fishing states envisaging a continued rise in capacity and demand know that the catch limit will stay at 620,000 tonnes unless all members agree otherwise. Whatever the exact location of one's preferred balance between protection and rational use, simply retaining the status quo is becoming less and less attractive as a long-term option.

Conclusions

Ongoing and expected climate-related environmental changes, as well as the likelihood of a continued rise in krill catches, have made it increasingly important to overcome the longstanding impasse among CCAMLR members on the development of an adaptive management system for the krill fisheries: one in which regularly updated information on krill and krill-dependent species forms the basis for risk assessment and, if necessary, adjustment of conservation measures. Progress towards such a system has been constrained by inadequate monitoring activities and lack of consensus on how to allocate catch levels spatially in order to spread and moderate the risks to predators.

Recent developments reviewed here seem promising in both regards. In 2016, the Scientific Committee endorsed a conceptual model for the risk-assessment framework. Three years later, the large-scale Area 48 Krill Survey enabled an updated stock assessment for the Southwest Atlantic sector where krill fishing is concentrated; and also in 2019, the Scientific Committee specified a comprehensive work plan to enable advice on the spatial distribution of future catch limits based on a range of past, present and future monitoring activities.

Adoption of krill regulations with finer spatial resolution than found in current conservation measures requires consensus among CCAMLR members – which in turn calls for mutual accommodation among the parties to a decade-long debate over how to balance the protection and the rational-use parts of CCAMLR's conservation objective. We have noted several grounds for optimism regarding the prospects for such accommodation and for further progress toward adaptive krill management.

First, the upcoming expiry of the conservation measure that distributes the trigger level among sub-areas in the Southwest Atlantic sector renders the status quo less attractive to all parties to the protection–rational use debate. Members concerned that greater concentration of the fishery would undermine the protection of local predator stocks now have firm incentives to seek solutions that are palatable also to those emphasizing rational use. Conversely, members concerned that the interim catch limit of 620,000 tonnes will soon become a real constraint on harvesting operations have more compelling reasons than before to develop or endorse a procedure for spatial distribution – without it, they cannot hope to lift that limit. Secondly, leading fishing states and the companies responsible for most of the krill catch have actively promoted the advances recently made in monitoring and risk-assessment procedures, thereby helping to reduce concerns among some members that a revised and adaptive procedure for krill management might undermine the rational-use objective of CCAMLR.

Note

1 This chapter draws on parts of the author's contribution to Margaret M. McBride et al. (2021) as well as previously unpublished material.

References

Agnew D. J. (1997), 'The CCAMLR Ecosystem Monitoring Programme', *Antarctic Science*, 9 (3): 235–42.

Atkinson, A., V. Siegel, E. A. Pakhomov, M. J. Jessopp and V. Loeb (2009), 'A Re-appraisal of the Total Biomass and Annual Production of Antarctic Krill', *Deep Sea Research Part I: Oceanographic Research Papers*, 56 (5): 727–40. https://doi.org/10.1016/j.dsr.2008.12.007.

Brooks, C. M., L. B. Crowder, H. Österblom and A. L. Strong (2019), 'Reaching Consensus for Conserving the Global Commons: The Case of the Ross Sea, Antarctica', *Conservation Letters*. doi: 10.1111/conl.12676.

CAMLR Convention (Convention on the Conservation of Antarctic Marine Living Resources) (1980), Canberra, 20 May, *UnitedNations Treaty Series*, vol. 1329, no. 22301. https://treaties.un.org/doc/Publication/UNTS/Volume%201329/v1329.pdf.

CCAMLR (1991a), 'Report of the Tenth Meeting of the Commission'. https://www.ccamlr.org/en/system/files/e-cc-x.pdf.

CCAMLR (1991b), Conservation Measure 32/X (1991) Precautionary Catch Limitations on Euphausia Superba in Statistical Area 48. https://www.ccamlr.org/en/measure-32/x-1991.

CCAMLR (1992), Conservation Measure 46/XI (1992) Allocation of Precautionary Catch Limit on Euphausia Superba in Statistical Area 48 (Conservation Measure 32/X) to Statistical Subareas. https://www.ccamlr.org/en/measure-46/xi-1992.

CCAMLR (2000a), Conservation Measure 32/XIX (2000) Precautionary catch limitations on Euphausia superba in Statistical Area 48. https://www.ccamlr.org/en/measure-32/xix-2000.

CCAMLR (2000b), 'Report of the Nineteenth Meeting of the Commission'. https://www.ccamlr.org/en/system/files/e-cc-xix.pdf.
CCAMLR (2007), 'Report of the Twenty-Sixth Meeting of the Commission'. https://www.ccamlr.org/en/system/files/e-cc-xxvi.pdf.
CCAMLR (2008), 'Report of the Twenty-Seventh Meeting of the Commission'. https://www.ccamlr.org/en/ccamlr-xxvii.
CCAMLR (2009a), Conservation Measure 91-03 (2009) Protection of the South Orkney Islands Southern Shelf. https://cm.ccamlr.org/en/measure-91-03-2009.
CCAMLR (2009b), 'Report of the Twenty-Eighth Meeting of the Commission'. https://www.ccamlr.org/en/system/files/e-cc-xxviii.pdf.
CCAMLR (2010), Conservation Measure 51-01 (2010) Precautionary catch limitations on Euphausia superba in Statistical Subareas 48.1, 48.2, 48.3 and 48.4. https://www.ccamlr.org/en/measure-51-01-2010.
CCAMLR (2011), CCAMLR (2011), Conservation Measure 91-04 (2011) General framework for the establishment of CCAMLR Marine Protected Areas. https://cm.ccamlr.org/en/measure-91-04-2011.
CCAMLR (2012), 'Report of the Thirty-First Meeting of the Commission'. https://www.ccamlr.org/en/system/files/e-cc-xxxi.pdf.
CCAMLR (2015), 'Report of the Thirty-Fourth Meeting of the Commission'. https://www.ccamlr.org/en/system/files/e-cc-xxxiv_4.pdf.
CCAMLR (2016a), 'Report of the Thirty-Fifth Meeting of the Commission'. https://www.ccamlr.org/en/ccamlr-xxxv.
CCAMLR (2016b), Conservation Measure 91-05 (2016) Ross Sea Region Marine Protected Area. https://cm.ccamlr.org/en/measure-91-05-2016.
CCAMLR (2017), 'Report of the Thirty-Sixth Meeting of the Commission'. https://www.ccamlr.org/en/system/files/e-cc-xxxvi_0.pdf.
CCAMLR (2018a), 'Krill Fishery Report 2018'. https://www.ccamlr.org/en/system/files/00%20KRI48%202018.pdf.
CCAMLR (2018b), 'Report of the Thirty-Seventh Meeting of the Commission'. https://www.ccamlr.org/en/ccamlr-xxxvii.
CCAMLR (2019), 'Report of the Thirty-Eighth Meeting of the Commission'. https://www.ccamlr.org/en/ccamlr-38.
CCAMLR (2020), 'Report of the Thirty-Ninth Meeting of the Commission'. https://www.ccamlr.org/en/ccamlr-39.
CCAMLR (2021), Conservation Measure 51-07 (2021) Interim distribution of the trigger level in the fishery for Euphausia superba in Statistical Subareas 48.1, 48.2, 48.3 and 48.4. https://cm.ccamlr.org/en/measure-51-07-2021.
Constable A. J., W. K. de la Mare, D. J. Agnew, I. Everson and D. Millet (2000), 'Managing Fisheries to Conserve the Antarctic Marine Ecosystem: Practical Implementation of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR)', *ICES Journal of Marine Science*, 57: 778–91.
Cox, M. J., S. Candy, W. K. de la Mare, S. Kawaguchi, S. Nicol and N. Gales (2018), 'No Evidence for a Decline in the Density of Antarctic Krill *Euphausia superba* Dana, 1850, in the Southwest Atlantic Sector between 1976 and 2016', *Journal of Crustacean Biology*, 38 (6): 656–61. doi: 10.1093/jcbiol/ruy072%.
Cox, M. J., S. Candy, W. K. de la Mare, S. Nicol, S. Kawaguchi and N. Gales (2019), 'Clarifying Trends in the Density of Antarctic Krill *Euphausia superba* Dana, 1850, in the South Atlantic: A Response to Hill et al.', *Journal of Crustacean Biology*, 39 (3): 323–27. doi: 10.1093/jcbiol/ruz010.

Everson I. (2017), 'Designation and Management of Large-scale MPAs Drawing on the Experiences of CCAMLR', *Fish and Fisheries*, 18 (1): 145–59
Hewitt, R., G. Watters, P. Trathan and J. Croxall (2004), 'Options for Allocating the Precautionary Catch Limit of Krill among Small-Scale Management Units in the Scotia Sea', *CCAMLR Science*, 11: 81–97.
Hill, S. L., A. Atkinson, C. Darby, S. Fielding, B. A. Krafft, O. R. Godø, G. Skaret, P. Trathan and J. Watkins (2016), 'Is Current Management of the Antarctic Krill Fishery in the Atlantic Sector of the Southern Ocean Precautionary?', *CCAMLR Science*, 23: 31–51. https://www.ccamlr.org/en/publications/science_journal/ccamlr-science-volume-23/31%E2%80%9351.
Hill, S. L., A. Atkinson, E. A. Pakhomov and V. Siegel (2019), 'Evidence for a Decline in the Population Density of Antarctic Krill Euphausia superba Dana, 1850 still Stands: A Comment on Cox et al.', *Journal of Crustacean Biology*, 39 (3): 316–22. doi: 10.1093/jcbiol/ruz004.
Hønneland G., L. Revenga and J. Addison (2020), 'Aker Biomarine Antarctic Krill: Final Draft Report Conformity Assessment Body: Lloyd's Register', London: Marine Stewardship Council.
Kawaguchi, S. and S. Nicol (2020), 'Krill Fishery', in L. G and T. M (eds), *The Natural History of the Crustacea: Fisheries and Aquaculture*, 137–58, New York, NY: Oxford University Press.
Kock, K.-H., K. Reid, J. Croxall and S. Nicol (2007), 'Fisheries in the Southern Ocean: An Ecosystem Approach', *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, 362 (1488): 2333–49.
Krafft, B. A., G. Skaret and T. Knutsen (2015), 'An Antarctic Krill (Euphausia superba) Hotspot: Population Characteristics, Abundance and Vertical Structure Explored from a Krill Fishing Vessel'. https://doi.org/10.1007/s00300-015-1735-7.
McBride, M. M., O. S. Stokke, A. H. H. Renner, B. A. Krafft, A. D. Lowther, O. A. Bergstad, M. Biuw and J. E. Stiansen (2021), 'Antarctic Krill (*Euphausia superba*): Spatial Distribution, Abundance, and Management of Fisheries in a Changing Climate', *Marine Ecology Progress Series*, 668: 185–214.
Meyer, B., A. Atkinson, K. S. Bernard, A. S. Brierley, R. Driscoll, S. L. Hill, E. Marschoff, D. Maschette, F. A. Perry, C. S. Reiss, E. Rombolá, G. A. Tarling, S. E. Thorpe, P. N. Trathan, G. Zhu and S. Kawaguchi (2020), 'Successful Ecosystem-based Management of Antarctic Krill Should Address Uncertainties in Krill Recruitment, Behaviour and Ecological Adaptation', *Communications earth & environment*, 1: 1–12. doi: 10.1038/s43247-020-00026-1.
Miller, D. G. M., N. Slicer and E. N. Sabourenkov (2010), 'IUU Fishing in Antarctic Waters: CCAMLR Actions and Regulations', in D. Vidas (ed.), *Law, Technology and Science for Oceans in Globalisation: IUU Fishing, Oil Pollution, Bioprospecting, Outer Continental Shelf*, 175–96, Leiden: Brill Nijhoff.
Molenaar, E. J. (2020), 'Integrating Climate Change in International Fisheries Law', in I. U. Jakobsen, E. Johansen and S. Busch (eds), *The Law of the Sea and Climate Change: Part of the Solution or the Problem?*, 263–88, Cambridge: Cambridge University Press.
Nicol, S. and J. Foster (2016), 'The Fishery for Antarctic Krill: Its Current Status and Management Regime', in V. Siegel (ed.), *Biology and Ecology of Antarctic Krill*, 387–421, Cham: Springer International Publishing.
Nicol, S., J. Foster and S. Kawaguchi (2012), 'The Fishery for Antarctic Krill – Recent Developments', *Fish and Fisheries*, 13: 30–40.

Oberthür, S. and O. S. Stokke (2011), *Managing Institutional Complexity: Regime Interplay and Global Environmental Change*, Cambridge, MA: MIT Press.

Press, A. J., I. Hodgson-Johnston and A. J. Constable (2019), 'The Principles of the Convention on the Conservation of Antarctic Marine Living Resources: Why Its Commission Is Not a Regional Fisheries Management Organisation', in N. Liu, C. M. Brooks and T. Qin (eds), *Governing Marine Living Resources in the Polar Regions*, 9–29, Cheltenham: Edward Elgar Publishing.

Rayfuse, R. (2019), 'Addressing Climate Change Impacts in Regional Fisheries Management Organizations', in R. Caddell and E. J. Molenaar (eds), *Strengthening International Fisheries Law in an Era of Changing Oceans*, 400–33, Oxford: Hart.

Reiss, C. S., A. M. Cossio, V. Loeb and D. A. Demer (2008), 'Variations in the Biomass of Antarctic Krill (Euphausia Superba) around the South Shetland Islands, 1996–2006', *ICES Journal of Marine Science*, 65: 497–508. doi: 10.1093/icesjms/fsn033.

Roel, B. and J. Ríos (2020), 'DERIS, S.A. Pesca Chile: Antarctic Krill Fishery. First Surveillance Audit Report' (Conformity Assessment Body: Bureau Veritas), London: Marine Stewardship Council.

Ruckelshaus, M., T. Klinger, N. Knowlton and D. P. DeMaster (2008), 'Marine Ecosystem-based Management in Practice: Scientific and Governance Challenges', *BioScience*, 58 (1): 53–63.

Santa Cruz, F., B. Ernst, J. A. Arata and C. Parada (2018), 'Spatial and Temporal Dynamics of the Antarctic Krill Fishery in Fishing Hotspots in the Bransfield Strait and South Shetland Islands', *Fisheries Research*, 208: 157–66. doi: 10.1016/j.fishres.2018.07.020.

SC-CAMLR (1989), 'Report of the Eighth Meeting of the Scientific Committee'. https://www.ccamlr.org/en/system/files/e-sc-viii.pdf.

SC-CAMLR (1991), 'Report of the Tenth Meeting of the Scientific Committee'. https://www.ccamlr.org/en/system/files/e-sc-x.pdf.

SC-CAMLR (1992), 'Report of the Eleventh Meeting of the Scientific Committee'. https://www.ccamlr.org/en/system/files/e-sc-xi.pdf.

SC-CAMLR (2002), 'Report of the Twenty-First Meeting of the Scientific Committee'. https://www.ccamlr.org/en/system/files/e-sc-xxi.pdf.

SC-CAMLR (2003), 'Report of the Twenty-Second Meeting of the Scientific Committee'. https://www.ccamlr.org/en/system/files/e-sc-xxii.pdf.

SC-CAMLR (2004), 'Report of the Twenty-Third Meeting of the Scientific Committee'. https://www.ccamlr.org/en/system/files/e-sc-xxiii.pdf.

SC-CAMLR (2009), 'Report of the Twenty-Eighth Meeting of the Scientific Committee'. https://www.ccamlr.org/en/system/files/e-sc-xxviii.pdf.

SC-CAMLR (2013), 'Report of the Thirty-Second Meeting of the Scientific Committee'. https://www.ccamlr.org/en/sc-camlr-xxxii.

SC-CAMLR (2016), 'Report of the Thirty-Fifth Meeting of the Scientific Committee'. https://www.ccamlr.org/en/sc-camlr-xxxv.

SC-CAMLR (2018), 'Report of the Thirty-Seventh Meeting of the Scientific Committee'. https://www.ccamlr.org/en/sc-camlr-xxxvii.

SC-CAMLR (2019a), 'Report of the Thirty-Eighth Meeting of the Scientific Committee'. https://www.ccamlr.org/en/sc-camlr-38.

SC-CAMLR (2019b), 'Report of the Working Group on Ecosystem Monitoring and Management (Concarneau, France, 24 June to 5 July 2019)'. https://www.ccamlr.org/en/sc-camlr-38/03.

Stokke, O. S. (1996), 'The Effectiveness of CCAMLR', in O. S. Stokke and D. Vidas (eds), *Governing the Antarctic: The Effectiveness and Legitimacy of the Antarctic Treaty System*, 120–51, Cambridge: Cambridge University Press.

Sumby, J., M. Haward, E. A. Fulton and G. T. Pecl (2021), 'Hot Fish: The Response to Climate Change by Regional Fisheries Bodies', *Marine Policy*, 123: 104284. https://doi.org/10.1016/j.marpol.2020.104284.

Sykora-Bodie, S. T. and T. H. Morrison (2019), 'Drivers of Consensus-based Decision-making in International Environmental Regimes: Lessons from the Southern Ocean', *Aquatic Conservation: Marine and Freshwater Ecosystems*, 29 (12): 2147–61.

Trathan, P. N. and D. Agnew (2010), 'Climate Change and the Antarctic Marine Ecosystem: An Essay on Management Implications', *Antarctic Science*, 22: 387–98. doi: 10.1017/S0954102010000222.

Vidas, D. (1996), 'The Antarctic Treaty System in the International Community: An Overview', in O. S. Stokke and D. Vidas (eds), *Governing the Antarctic: The Effectiveness and Legitimacy of the Antarctic Treaty System*, 35–60, Cambridge: Cambridge University Press.

Watters, G. M., S. L. Hill, J. T. Hinke, J. Matthews and K. Reid (2013), 'Decision-making for Ecosystem-based Management: Evaluating Options for a Krill Fishery with an Ecosystem Dynamics Model', *Ecological Applications*, 23: 710–25. doi: 10.1890/12-1371.1.