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Conservation in the Scotia Sea in light of expiring regulations and disrupted negotiations

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Article Impact Statement: As coarse-scale catch limits for the Antarctic krill fishery expire, conserving krill predators requires higher-resolution regulation.

KEYWORDS
Antarctica, Antarctic krill, CCAMLR, fishery management, krill predators, precaution, risk assessment

INTRODUCTION

If, by 1 December 2022, the total allowable catch of Antarctic krill (*Euphausia superba*) taken from the Scotia Sea (here, waters between 50–70°S and 20–70°W) (Figure 1) is not partitioned in space and time, the objective of an international conservation regime will be jeopardized. The objective of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) is conservation (CCAMLR, 1980), and the management provision that distributes krill catches throughout the Scotia Sea expires in November. This provision mitigates the risk that concentrated fishing will adversely affect krill predators. Unless the 26 members of CCAMLR achieve consensus to extend this provision or establish an alternative that partitions the catch and thereby limits concentrated fishing, some krill predators are likely to be negatively affected. If not for the COVID-19 pandemic, CCAMLR might have already adopted suitable partitioning.

Krill are important prey for numerous predators (Laws, 1985) and provide globally relevant ecosystem services (Cavanagh et al., 2021) (Appendix S2); these facts underpin management of the krill fishery. Climate change and increasing whale populations will likely modulate the production and distribution of krill (Savoca et al., 2021; Sylvester et al., 2021) and thus, its availability to predators and the provision of its ecosystem services. To conserve the marine ecosystem in the face of change, CCAMLR requires a precautionary management strategy for the krill fishery that flexibly adjusts catch limits. The current strategy uses fixed catch limits, and CCAMLR has not updated these limits for over a decade.

CURRENT MANAGEMENT STRATEGY

Two conservation measures (CMs) (i.e., regulations CCAMLR uses to manage fisheries) define the current management strategy for krill in the Scotia Sea. The first, CM 51-01, limits the overall catch. The second, CM 51-07, expires this year and limits catches within four subareas (CCAMLR, 2020). These CMs are often considered precautionary because the catch limits are <10% of krill biomass in the Scotia Sea (Hill et al., 2016).

Conservation Measure 51-01 specifies two annual catch limits: an aspirational limit (5.61 Mt, the "precautionary catch limit") and an interim "trigger limit" (620 kt) (CCAMLR, 1991). The aspirational limit is intended to be precautionary by neither adversely affecting the production of krill nor its availability to krill-dependent predators. However, the aspirational limit applies to 2.1 million km^2, whereas most fishing typically occurs in ≤3% of that area (Figure 2). The CCAMLR adopted the trigger limit given concerns about the ecosystem effects of concentrated fishing if catches rise to aspirational levels. Krill catches cannot exceed the trigger limit until CCAMLR agrees to distribute catches among small-scale management units (SSMUs) (Figure 1).

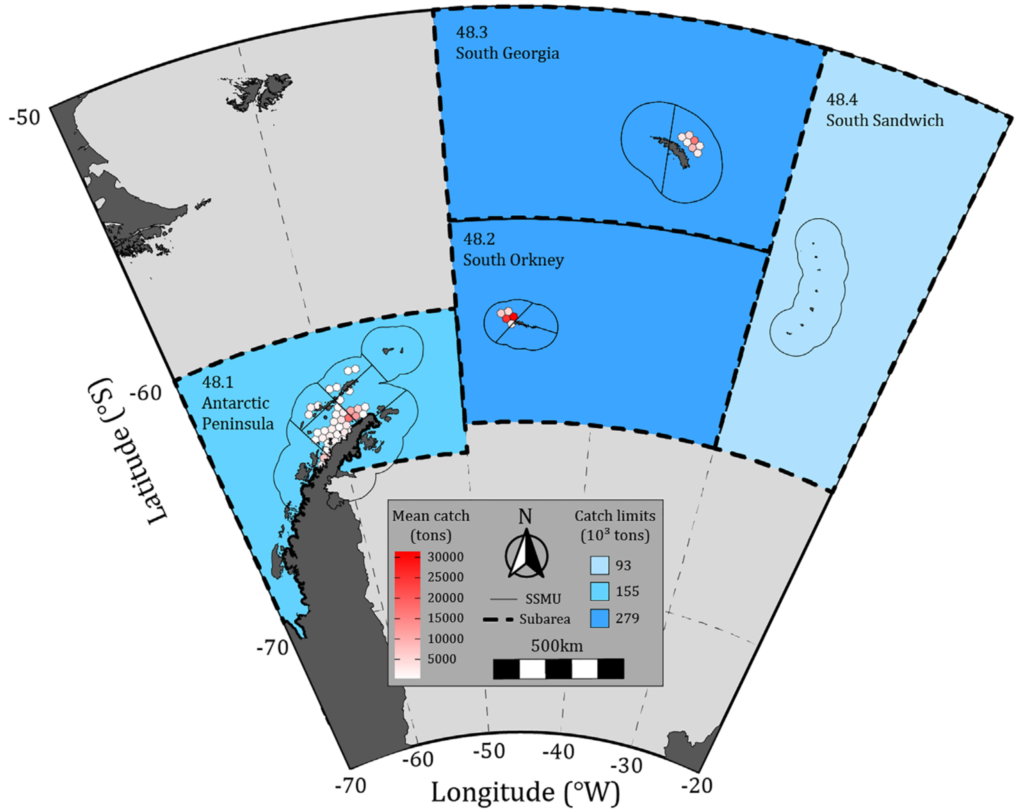

FIGURE 1 Spatial footprint and mean annual catches in small-scale hexagons that identify locations, where 90% of the total krill catch was taken from the Scotia Sea since 2009. Hexagons are centered 30 km apart to approximate the daily foraging range of Adélie penguins (*Pygoscelis adeliae*), which depend on krill during the austral summer. Shading highlights concentrated krill catches in small areas near the Antarctic Peninsula, South Orkney Islands, and South Georgia (Subareas 48.1, 48.2, and 48.3, respectively). Krill fishing is permitted, but does not occur, near the South Sandwich Islands (subarea 48.4). Details on the spatial analyses are given in Appendix S1

The Scientific Committee (SC) that advises CCAMLR first articulated concerns about the ecosystem effects of concentrated fishing in 1986, questioning whether high catches near the South Orkney Islands "had any demonstrable effect on local krill-dependent predators" (SC-CAMLR, 1986). The SC subsequently advised that a spatial distribution of catch was desirable to "ensure that the catch is not entirely concentrated in the foraging range of vulnerable land-breeding predators" (CCAMLR, 1991), but CCAMLR did not partition catch limits. For nearly two decades after the adoption of CM 51-01, slow development of the fishery and no evidence for plausible effects of fishing on krill predators reduced the urgency to distribute catches among SSMUs.

After nearly 20 years of work to consider alternatives for distributing catches among SSMUs (e.g., Hewitt et al., 2004), the SC advised that catch limits should be applied at scales that match the operational footprint of the fishery. Notably, the SC agreed that a harvest rate consistent with the trigger limit was "not as cautious as might have been thought" and that status quo management may reduce CCAMLR's ability to achieve its objective (SC-CAMLR, 2009). The CCAMLR still could not agree on catch limits for SSMUs, but, in 2009, they adopted CM 51-07 as a precautionary stopgap to distribute catches, up to the trigger limit, across four subareas.

Trends in the fishery since adoption of CM 51-07 indicate an increasingly concentrated fishery (Watters et al., 2020) (Figure 2). This is evidenced near the Antarctic Peninsula by decreases in the spatial footprint of the fishery and the time required to take the catch limit (Figure 2). Across all subareas, the mean catch within each footprint has risen in the last decade. In the absence of purposeful management to partition catch limits at scales finer than subarea and annual scales, we expect fishing effort and catches to increase and further concentrate. Technological advances, including continuous fishing methods and construction of high-capacity krill-fishing vessels, and investment in infrastructure to facilitate efficient capture and processing of krill incentivizes fishing in predictable hotspots to recoup capital costs (Appendix S3). Furthermore, expansion of new krill-based products and markets fuels the development and implementation of national strategies, including subsidies, to increase participation in the krill fishery (Appendix S3).

As the krill fishery continued to develop, the SC consistently advised that the risks of concentrated fishing were increasing, and CCAMLR regularly renewed CM 51-07. In 2016, CCAMLR renewed the measure for 5 years because "concentration was occurring at scales smaller than SSMUs and… repeatedly in some areas" (SC-CAMLR, 2016). This 5-year extension granted the SC time to develop further advice. Meanwhile, catches in the

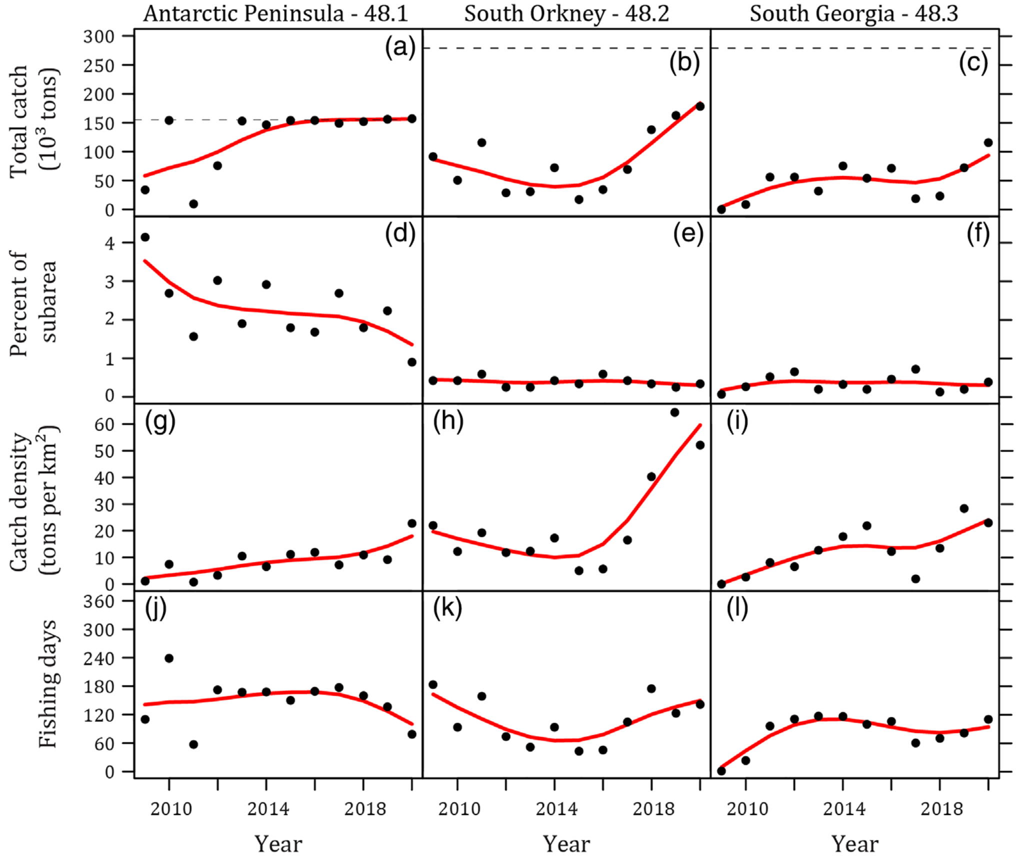

FIGURE 2 Krill fishery indices in the Antarctic Peninsula (Subarea 48.1, left column), South Orkney Islands (Subarea 48.2, middle column), and South Georgia (Subarea 48.3, right column) for 2009–2020: (a–c) total annual krill catches (dashed line, catch limits); (d–f) annual spatial footprints of the krill fishery estimated as the percentage of each subarea covered by small-scale hexagons from which 90% of the annual catch is taken; (g–i) mean annual krill catches in the small-scale hexagons comprising the annual spatial footprint; and (j–l) duration of the krill fishing season based on the number of days with reported catch from each subarea (red curves which suggest trends, smoothing splines, are fitted with 4 equivalent degrees of freedom). Catches in Subarea 48.1 consistently reached the limit specified in CM 51-07 and subsequently concentrated in space and time. Catches in Subareas 48.2 and 48.3 have not reached the limits under CM 51-07, but have increased within the small footprint of the fishery. See Appendix S1 for details on the spatial analyses

Scotia Sea rose to their highest levels while being taken from a small footprint (Figure 2). The COVID-19 pandemic does not appear to have affected these trends.

Conservation does not require undetectable ecosystem effects of fishing, but CCAMLR intended to manage the krill fishery so that any such effect would be minor. Results of modeling studies suggest that risks to krill-dependent predators can be minimized if krill catches are spread more broadly across the Scotia Sea than is typical of the current fishery (Plagányi & Butterworth, 2012; Watters et al., 2013). Empirical observations indicate that the ecosystem risks of concentrated krill catches are plausible (Krüger et al., 2021; Watters et al., 2020). A precautionary harvest rate for the krill fishery was estimated for the entire Scotia Sea, but concentrated fishing can lead to local harvest rates that belie precaution because standing stocks of krill are locally variable (Watters et al., 2020). Together, modeling results and empirical observations legitimize CCAMLR's long-standing concern that concentrated krill catches jeopardize conservation and highlight that CM 51-07 represents the bare minimum strategy for distributing future catches. The SC recently advised CCAMLR that CM 51-07 is precautionary (SC-CAMLR, 2021). We believe that CM 51-07 is imperfect but good enough because, to our knowledge, the marginal effects of krill fishing on the population dynamics of krill-dependent predators remain minor.

FUTURE OPTIONS

Several members of CCAMLR wish to increase the allowable catch of krill. To spread the risks of concentrated krill fishing, CCAMLR can distribute catch limits across a greater number of smaller spatiotemporal partitions. The SC is currently working to develop a replacement for CM 51-07 that stipulates, on a seasonal basis, increased catch limits applied to areas smaller than subareas (SC-CAMLR, 2019). This replacement derives from data and models that characterize season-specific spatial overlays of krill density and predator consumption. This replacement is intended to increase catches while improving the likelihood that CCAMLR will achieve its conservation objective (SC-CAMLR, 2019) without being riskier than CM 51-07 itself.

Long-standing concerns about concentrated catches have guided krill-fishery management for over three decades, and history demonstrates that these concerns are valid. Ironically, the presumed precautionary approach to manage the krill fishery failed to prevent the very concentration of fishing CCAMLR intended to avoid, but the relatively low catch limits specified in CM 51-07 have mitigated impacts. Any change to the management of the krill fishery should explicitly account for concentrated fishing, particularly if allowable catches are increased. If CM 51-07 lapses without replacement, CCAMLR will take an extraordinary step backward toward an insufficiently regulated fishery that jeopardizes its considerable achievements toward conservation. We emphasize that, in its own right, CM 51-01 is not sufficient to limit concentrated fishing (620 kt of krill could be taken anywhere).

The COVID-19 pandemic has severely limited the scientific and diplomatic engagement required to adopt an alternative to CM 51-07. Two annual cycles of CCAMLR meetings have passed during the pandemic, and all meetings (usually 8 per year) have been virtual. The time to conduct business during virtual meetings has essentially been half that of in-person meetings. After-hours discussions have been constrained because CCAMLR delegates participate from 13 time zones. Members of CCAMLR and the SC are working hard to design an alternative to CM 51-07, but resolving policy and scientific differences in this complex situation takes time. We cannot predict how the pandemic will shape future meetings, and we emphasize that CM 51-07 remains a reasonable fallback.

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DATA AVAILABILITY STATEMENT

All fishery catch and effort data displayed here are proprietary and held by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). The data are available upon reasonable request from the CCAMLR Secretariat (ccamlr@ccamlr.org).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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