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Opportunities for IWC-CCAMLR collaboration to contribute to CCAMLR's Revised Krill Fishery Management Approach

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Development of CCAMLR krill fishery management

Antarctic krill (*Euphausia superba*) is both abundant and broadly distributed in the Southern Ocean, with most of its life history stages considered important prey items for a wide variety of organisms (Trathan and Hill 2016). The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) is responsible for the management of the krill fishery, and, with the exception of whales and seals, all other marine living resources in the Southern Ocean, including targeted, dependent and associated species. (CCAMLR defines the geographical extent over which it has jurisdiction as the region between the Antarctic Polar Front and the continent; see here for more details.)

The Convention is unique in that it has at its core the objective of conservation of marine living resources, where conservation includes rational use (CCAMLR 1982). CCAMLR was established by international convention in 1982 in response to increasing commercial interest in Antarctic krill resources. A summary of the history of the Antarctic krill fishery is given in the krill fishery report. In Subareas 48.1, 48.2, 48.3 and 48.4 (see Figure 1), limits on krill harvesting are described in Conservation Measures 51-01 and 51-07.

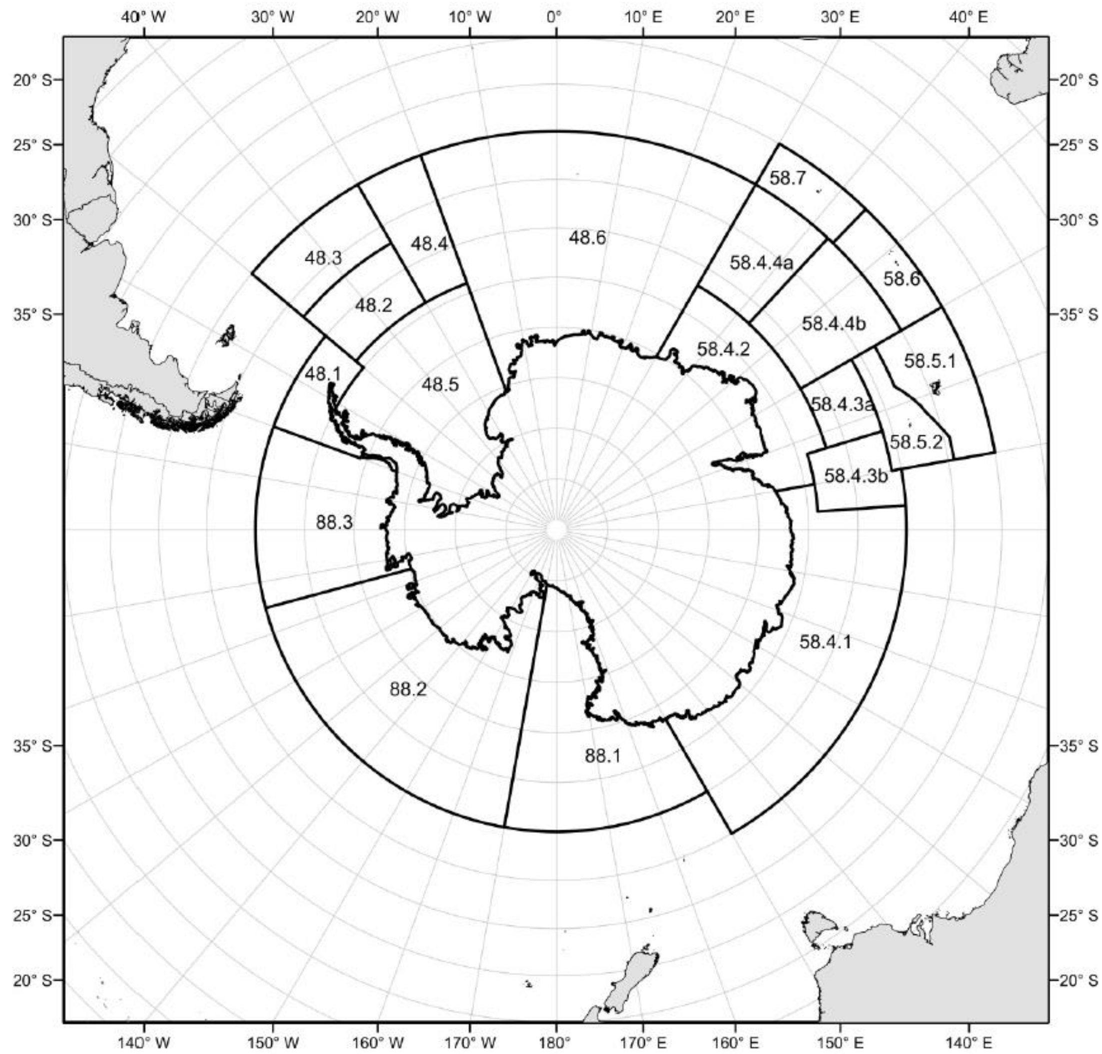

Figure 1 CCAMLR Area with Statistical Subareas and Divisions.

In 2010, the Scientific Committee agreed that the best estimate of krill biomass from the CCAMLR-2000 Survey in Area 48 (Trathan et al., 2001) was 60.3 million tonnes. Using a krill population projection model - the Generalised Yield Model (GYM, Constable and de la Mare, 1996; Constable et al., 2000) - CCAMLR agreed to the current precautionary catch limit for krill of 5.61 million tonnes per season (1 December to 30 November of the following year) in Subareas 48.1, 48.2, 48.3 and 48.4 combined (SC-CAMLR-XXIX (2010), paragraph 3.30; Conservation Measure 51-01).

Precautionary catch limits for krill were determined using a set of decision rules to estimate what proportion of the stock could be fished while still achieving the objective of the Convention. To do this, a simulated population of krill was projected forward in time using the GYM to simulate the effects of different catch levels. For each projection, a starting point is randomly picked from an initial biomass distribution and the population is projected forward with key parameters, such as recruitment, drawn at random from plausible ranges to account for natural variability and uncertainty.

The revised krill fishery management approach

In 2019, CCAMLR endorsed (CCAMLR-38 (2019), Paragraph 5.17) a three-component (*Figure 2*) revision of the krill fishery management approach (ostensibly for Area 48, but with potential implications for future krill fishing management in Subdivisions 58.4.2 and 58.4.1), comprising:

(i) a stock assessment to estimate precautionary harvest rates (often referred to as '*gamma*'), as estimated using the GYM.
(ii) regular updates of krill biomass estimates, initially at the subarea scale, but potentially at multiple scales,
(iii) a 'risk assessment' framework to inform the spatial allocation of catch.

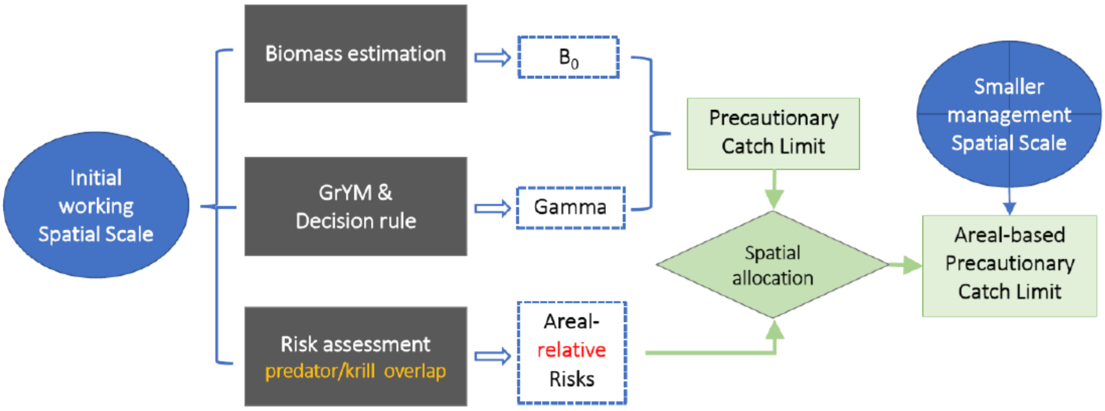

Figure 2 The three components and workflow of the revised krill management approach. Figure taken from SC-CAMLR-40 (2021; Annex 8, Figure 1). The 'risk assessment' component is now known as a Spatial Overlap Analysis.

In 2021, noting the greater availability of data in Subarea 48.1 than in 48.2, 48.3 and 48.4, The Scientific Committee endorsed (SC-CAMLR-40 (2021), paragraph 3.13) the recommendation of WG-EMM-2021 (paragraph 2.66) that the development of management advice for these other Subareas will take longer. Consequently, scientific efforts have focused on Subarea 48.1. It is worth noting that not all CCAMLR scientists agree with such a staged approach due to the connectivity between Subareas, and consider that a coordinated management framework across Area 48 would be preferable. The revision of the krill fishery management approach involves efforts from all working groups of the Scientific Committee, which has developed an ambitious list of tasks (SC-CAMLR-40 (2021), paragraph 3.24).

A central element to the revision of the management of the krill fishery in Subarea 48.1 is its subdivision into smaller areas (*i.e.*, management units). While considering data availability (in particular active acoustic biomass data), distribution of fishing effort and scenarios tested within the spatial overall analysis (previously, risk assessment) framework, SC-CAMLR considered candidate management units in 2022, as outlined in *Figure 3*.

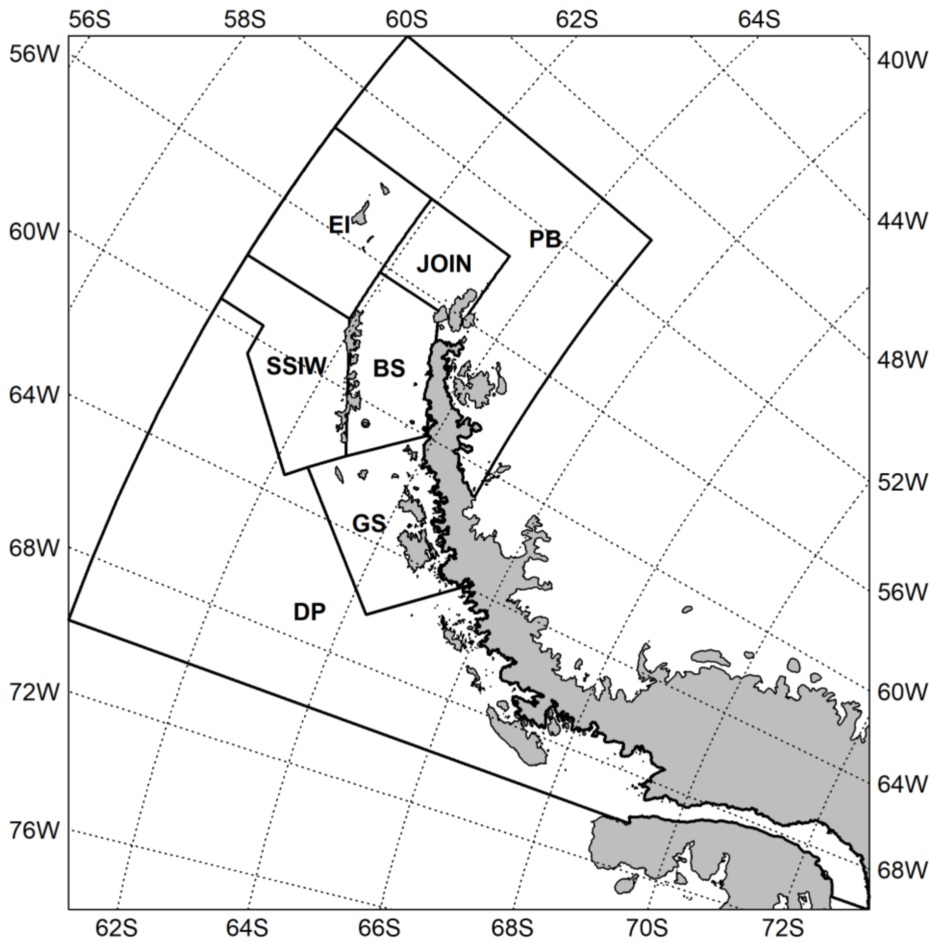

Figure 3 Krill fishery management units in Subarea 48.1. EI - Elephant Island, JOIN - Joinville, BS - Bransfield Strait, SSIW - South Shetland Islands West, GS - Gerlache Strait, DP - Drake Passage, PB - Powell Basin. Taken from SC-CAMLR-41 (Figure 1).

Development of the three components on the revised krill management approach have each taken several years, the combined effort of SC-CAMLR and its Working Groups. Below is brief summary of the biomass estimates and estimation of the precautionary harvest rates, and a more in-depth look at the risk assessment (spatial overlap) approach to inform the spatial allocation of catch, as it directly considers the needs of krill predators, such as baleen whales.

Krill biomass estimates

The latest krill biomass estimates for each proposed management unit outlined in *Figure 3* (SC-CAMLR-41 (2022), Table 3) were developed based on the density estimates and uncertainty collated in WG-EMM-2021/05 Rev. 1, and scaled to the updated management units following methods agreed by SC-CAMLR's Working Group on Acoustic Survey and Analysis Methods (WG-ASAM-2022, paragraphs 3.19-3.22, Table 9).

Precautionary harvest rates

In 2019, the GYM was recoded in R (Maschette et al. 2020; SC-CAMLR-39/BG/19) and named Grym (Generalised R Yield Model). The Grym reproduces the GYM software core functionalities and presents a series of advantages compared to GYM: it provides more flexibility in parameters and functionality, uses a new method for solving differential equations, includes more possibilities for recruitment formulations, works on any platform that can run R (Windows, Mac, Linux), and, its code is easier to read and is publicly available. The SC-CAMLR endorsed the value of *gamma* (the precautionary exploitation rate) for Subarea 48.1 generated using the Grym of 0.0338 (SC-CAMLR-

41 (2022), paragraphs 3.33). It noted that it was the first revision to this parameter for several decades and that it was based on the best available science.

Spatial allocation of catch (via Spatial Overlap Analysis)

Given that feedback management methods were not being advanced and adopted as quickly as was anticipated, a 'spatial overlap' approach was developed reduce catch in times and areas important for krill predators (particularly land-based central-place foragers) or for krill population renewal. This approach was endorsed by CCAMLR in 2016 (CCAMLR 2016, paragraph 5.16).

The spatial overlap analysis computes relative spatial and seasonal overlap between krill and its predators within a region and can evaluate overlap associated with different proposals, or scenarios, to subdivide the catch (WG-FSA-2022, paragraph 7.23). It produces "*alpha*" values for each management unit and each season within a given scenario (which sum to one), which index the level of overlap, with lower *alphas* where the overlap is greater. Catch limits would then be allocated by multiplying the precautionary overall catch limit by the *alpha* of each management unit, in each season (if using a temporal/seasonal component), effectively decreasing catch in some areas and increasing catch in other areas to move the fishery away from areas and seasons important for krill predators.

To date, an initial spatial overlap analysis of krill fishing has been completed for Area 48 (Constable 2016), with a revision also being completed for Subarea 48.1 (Warwick-Evans et al. 2022a). A spatial overlap analysis has also been completed for Subdivisions 58.4.1 and 58.4.2 in East Antarctica (Kelly et al. 2017, Kelly et al. 2018).

While noting the existing data deficiencies, especially from winter, SC-CAMLR applied the spatial overlap analysis (based on the *alphas* from the 'AMLR strata new5' baseline scenario (i.e., where space was divided similar to *Figure 3* of this document) given in Warwick-Evans and Trathan (2021; WG-FSA-2021/16), as reported in WG-FSA-2022 (Table 10)) to the new management units, and determined precautionary catch limits (SC-CAMLR-41 (2022), paragraph 3.45) in each management unit, in winter and summer (SC-CAMLR-41 (2022), Table 2). Members had, however, diverging views on the required changes to Conservation Measures (SC-CAMLR-41 (2022), paragraphs 3.59-3.61) and were not able to provide consensus advice to the Commission (SC-CAMLR-41 (2022), paragraphs 3.67-3.69). This work is ongoing.

Future considerations

Apart from the three foundational elements of the revision of the krill fishery management approach, several other topics are considered by the Scientific Committee and the Commission, including (CCAMLR-41 (2022), paragraph 4.17):

- (i) the monitoring of catch limits at smaller spatial scales,
- (ii) the harmonisation and/or integration of different spatial management initiatives within Subarea 48.1, including the ARK voluntary restricted zones and the D1MPA proposal (a proposed Marine Protected Area, encompassing region within the Western Antarctic Peninsula and South Scotia Arc)
- (iii) future monitoring of krill biomass and other components of the ecosystem, including fish by-catch, krill dependent predator species, especially in data-limited areas such as the Gerlache Strait, and the assessment of the potential impacts of the increased fishery on the ecosystem.

In 2022, noting that as a proportion of the krill stock is transported from Subarea 48.1 to Subareas 48.2 and 48.3, the SC-CAMLR indicated that a holistic approach to all Subarea catch limits is required when fully implementing the new management strategy (SC-CAMLR-41 (2022), paragraph 3.26). The Commission noted (CCAMLR-41 (2022) paragraph 4.12) the Scientific Committee's consideration of the management implications of applying these new catch limits, in particular the need to acquire new monitoring data as catch limits increase, and the integration of krill management approaches in Subarea 48.1 with the D1MPA proposal (SC-CAMLR-41 (2022), paragraphs 3.43 to

3.66) to coordinate efforts and further develop the management approach for the conservation and rational use of marine living resources. This would be supported by a revised data collection plan (SC-CAMLR-41 (2022), Table 1), an enhanced CCAMLR Ecosystem Monitoring Programme (CEMP; SC-CAMLR-41 (2022), paragraph 3.8, 3.41, 3.48), and the development of a krill stock hypothesis (SC-CAMLR-41 (2022), paragraph 3.28; also the subject of a recent SCAR Krill Expert Group (SKEG) virtual workshop).

The increasing role of whale science in krill management discussions

Although the estimated status of Southern Hemisphere baleen whale populations was instrumental in the establishment and focus of CCAMLR in the early 1980s (Hofman 2019), discussion of the use of cetacean science/data in the ecosystem approach to managing the krill fishery has waxed and waned over the subsequent decades. For example, Antarctic minke whale was originally listed as a CEMP indicator species at the inception of that programme in the 1980s. However, this species was removed from the CEMP programme in 1991 due to an inability to collect data on the key parameters for the species (SC-CAMLR 1991, paragraph 6.5). An attempt was made to reinstate Antarctic minke whale as a CEMP indicator species in 1997, but the request could not be agreed upon as again there was no evidence to suggest performance data of the species could be collected to the CEMP standard, and that 'non-invasive techniques' would be required (SC-CAMLR 1997, paragraphs 6.19-6.21).

Recently, however, there has been a notable increase in the presentation of cetacean research to SC-CAMLR and its working groups, and the application of such data to various initiatives developed to inform krill management. This increase is largely due to recognition that the most heavily exploited baleen whale populations of the Southern Hemisphere are showing signs of recovery (Leaper and Miller 2011; Zerbini et al. 2019; Jackson et al. 2020; Calderan et al. 2020; Herr et al 2022), and preliminary modelling suggesting that krill consumption by whales may be substantially larger than that of other krill predators in some regions (Baines et al. 2021, Savoca et al. 2021; Warwick-Evans et al. 2022b; Kelly et al. 2018). Additionally, there is evidence for spatio-temporal overlap of whale feeding areas and krill fishing (Reisinger et al. 2022; Ryan et al. 2023) and even recent recorded incidents of humpback whale entrapment in krill trawl nets for the first time (Welsford et al. 2022; SC-CAMLR 2022).

Cetacean science could broadly assist CCAMLR with management of the krill fishery, in addition to contributing to the IWC's management goals in the Southern Hemisphere. Cetacean-related data/results that would be immediately useful to CCAMLR in their pursuit of precautionary and ecosystem-based management of the krill fishery fall into two categories. First, they would be useful in setting spatially and temporally defined catch limits using the revised krill management approach. Second, the development of methods to minimise/eliminate risk of whale incidental mortality in the krill fishery. These data needs are complementary to longer-term efforts to model ecosystem function, including the role of climate change, to inform feedback management.

Consumption rates

A key parameter in estimating importance of krill in space and time is krill consumption by the various krill-dependent predators. In the spatial overlap analysis, krill consumption needs of predators are considered explicitly—and consumption rates are either modelled or empirically measured. Roughly speaking, estimated consumption rates for a given region or time period is a product of the individual consumption (typically either daily or over a season), residency times and an absolute abundance estimate. As demonstrated by Reilly *et al*. (2004), estimating individual consumption rates can be difficult, but this is an active field of research (e.g., Savoca et al. 2021, Skern-Mauritzen et al. 2022). Using alternative approaches, some authors have attempted to estimate ecosystem-level energetics, via mass-balance ecosystem modelling (e.g., Surma *et al.* 2014, Tulloch *et al.* 2018). Bringing together these two approaches would be helpful for estimating whale consumption rates, both for CCAMLR's needs and broader ecosystem modelling outputs. Such efforts would also greatly benefit from the availability of more recent whale distribution and abundance information.

Spatial distributions of cetaceans

Although Area 48 has already been subdivided into Small Scale Management Units (SSMUs in 2002; CCAMLR (2002; paragraph 4.5)), and again during the most recent biomass estimation analyses (see *Figure 3*), these spatial subdivisions were not made with any specific consideration of cetacean foraging. Whilst it is true that cetaceans are not central-place foragers, and are likely to be much less sensitive to localised depletion of krill through fishing activity, the degree to which animals are returning to the same foraging areas each season is not well known, and the ability to track individuals over a single feeding season (and beyond) has developed greatly since the early 2000s. SSMUs (or something similar) for Subdivisions 58.4.1 and 58.4.2 remain to be delineated; cetacean distribution and abundance, in addition to satellite tracking studies, would be highly informative in that process.

A fundamental component of aggregated krill consumption estimates is abundance of the krill predator. IWC's IDCR/SOWER sighting series has been hugely informative for assessing status and trends in cetaceans in the Southern Ocean over the past decades. Other national programmes supported smaller-scale multidisciplinary surveys throughout the circumpolar region, but such surveys are often not able to be configured for optimal cetacean sighting protocols. IDCR/SOWER usually involved two ships conducting line-transect surveys between the Antarctic ice-edge and 60ºS. There were three circumpolar surveys (CPI (1978/79-1983/84), CPII (1985/86-1990/91) and CPIII (1991/92-2003/04)) that were completed in 2004, although further regional surveys went on until 2010. As such, broad-scale cetacean distribution and abundance data for the Southern Ocean is aging; our ability to judge population status and trends in the coming decades is therefore highly uncertain.

Krill swarm dynamics

A final type of cetacean data that would greatly assist in CCAMLR's ecosystem approach to managing the krill fishery would be an understanding of the densities, demographics and types of krill swarms that cetacean species target. As an extension of the consumption question, an ecosystem approach would not just try to ensure that enough krill was available for predators, but that enough krill of the right sort, and in the right place, was available. Examples of this type of research include Hazen et al. (2015) or Miller *et al*. (2019).

Whilst the above provides four of the more focused data needs for CCAMLR in its endeavour to manage the krill fishery using the ecosystem-based approach, there are many other topics of cetacean science that would be useful. We encourage broader interaction between the IWC and CCAMLR science communities to better understand and manage the Antarctic marine ecosystem.

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References

Baines, M., Kelly, N., Reichelt, M., Lacey, C., Pinder, S., Fielding, S., Murphy, E., Trathan, P., Biuw, M., Lindstrøm, U., Krafft, B. A., & Jackson, J. A. (2021). Population abundance of recovering humpback whales Megaptera novaeangliae and other baleen whales in the Scotia Arc, South Atlantic. *Marine Ecology Progress Series*, *676*, 77-94.

Calderan, S. V., Black, A., Branch, T. A., Collins, M. A., Kelly, N., Leaper, R., Lurcock, S., Miller, B. S., Moore, M., Olson, P. A., Širović, A., Wood, A. G., & Jackson, J. A. (2020). South Georgia blue whales five decades after the end of whaling. *Endangered Species Research*, *43*, 359-373.

CCAMLR 1982. Text of the Convention on the Conservation of Antarctic Marine Living Resources. Basic Documents, Part 1. Article II. CCAMLR, Hobart, Australia.

CCAMLR (2002). Report of the Twenty-first meeting of the Commission. CCAMLR. Hobart, Australia

CCAMLR (2016). Report of the Thirty-fifth Meeting of the Commission (CCAMLR-XXXV). CCAMLR, Hobart, Australia.

CCAMLR (2019). Report of the Thirty-eighth Meeting of the Commission (CCAMLR-38). CCAMLR, Hobart, Australia.

CCAMLR (2022). Report of the Forty-first Meeting of the Commission (CCAMLR-41). CCAMLR, Hobart, Australia.

Constable, A. and de la Mare, W.K. (1996). A generalized yield model for evaluating yield and the long-term status of fish stocks under conditions of uncertainty. CCAMLR Science 3: 31-54.

Constable, A.J., de la Mare, W.K., Agnew, D.J., Everson, I. and Miller, D. (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(3): 778-791.

Constable, A. et al. (2016). Scientific contribution to the 2016 review of Conservation Measure 51-07: Part 2—outcomes from the application of the risk assessment framework for distributing the krill trigger level in Area 48. WG-FSA-16/48 Rev. 1. 11 pp.

Hazen, E. L., Friedlaender, A. S., & Goldbogen, J. A. (2015). Blue whales (Balaenoptera musculus) optimize foraging efficiency by balancing oxygen use and energy gain as a function of prey density. *Science Advances, 1*(9), e1500469. doi:10.1126/sciadv.1500469

Herr, H., Viquerat, S., Devas, F., Lees, A., Wells, L., Gregory, B., Giffords, T., Beecham, D., & Meyer, B. (2022). Return of large fin whale feeding aggregations to historical whaling grounds in the Southern Ocean. *Scientific Reports, 12*(1), 9458. doi:10.1038/s41598-022-13798-7

Hofman, R.J. (2019). Stopping overexploitation of living resources on the high seas. Marine Policy 103: 91-100.

Jackson, J. A., Kennedy, A., Moore, M., Andriolo, A., Bamford, C. C. G., Calderan, S., Cheeseman, T., Gittins, G., Groch, K., Kelly, N., Leaper, R., Leslie, M. S., Lurcock, S., Miller, B. S., Richardson, J., Rowntree, V., Smith, P., Stepien, E., Stowasser, G., Trathan, P., Vermeulen, E., Zerbini, A. N., & Carroll, E. L. (2020). Have whales returned to a historical hotspot of industrial whaling? The pattern of southern right whale *Eubalaena australis* recovery at South Georgia. *Endangered Species Research*, *43*, 323-339.

Kelly, N., Cox, M.J., Emmerson, L., Kawaguchi, S., Raymond, B., Southwell, C. and Welsford, D. (2017). Towards an ecological risk assessment of krill fishing in East Antarctica (CCAMLR Divisions 58.4.1 and 58.4.2). Paper presented to the Working Group on Ecosystem Monitoring and Management.

Kelly, N., Emmerson, L., Kawaguchi, S., Southwell, C. and Welsford, D. (2018). An ecological risk assessment of current conservation measures for krill fishing in East Antarctica (CCAMLR Divisions 58.4.1 and 58.4.2). Paper presented to the Working Group on Ecosystem Monitoring and Management.

Leaper, R. and Miller, C. (2011). Management of Antarctic baleen whales amid past exploitation, current threats and complex marine ecosystems. Antarctic Science 23(6): 503-529.

Maschette, D.**,** Wotherspoon, S., Pavez, C., Ziegler, P., Thanassekos, S., Reid, K., Kawaguchi, S., Welsford, D., Constable, A. (2020). Generalised R Yield Model (Grym). Document SC-CAMLR-2019/BG/10, CCAMLR, Hobart, Australia

Miller, E. J., Potts, J. M., Cox, M. J., Miller, B. S., Calderan, S., Leaper, R., Olson, P. A., O'Driscoll, R. L., & Double, M. C. (2019). The characteristics of krill swarms in relation to aggregating Antarctic blue whales. *Scientific Reports, 9*(1), 16487. doi:10.1038/s41598-019-52792-4

Reisinger, R. R., Trathan, P. N., Johnson, C. M., Joyce, T. W., Durban, J. W., Pitman, R. L., & Friedlaender, A. S. (2022). Spatiotemporal Overlap of Baleen Whales and Krill Fisheries in the Western Antarctic Peninsula Region. *Frontiers in Marine Science, 9*.

Reilly, S., Hedley, S., Borberg, J., Hewitt, R., Thiele, D., Watkins, J. and Naganobu, M. (2004). Biomass and energy transfer to baleen whales in the South Atlantic sector of the Southern Ocean. Deep-Sea Research Part II-Topical Studies in Oceanography 51(12-13): 1397-1409.

Ryan, C., Santangelo, M., Stephenson, B., Branch, T. A., Wilson, E. A., & Savoca, M. S. (2023). Commercial krill fishing within a foraging supergroup of fin whales in the Southern Ocean. *Ecology, 104*(4), e4002. doi:https://doi.org/10.1002/ecy.4002

Savoca, M. S., Czapanskiy, M. F., Kahane-Rapport, S. R., Gough, W. T., Fahlbusch, J. A., Bierlich, K. C., Segre, P. S., Di Clemente, J., Penry, G. S., Wiley, D. N., Calambokidis, J., Nowacek, D. P., Johnston, D. W., Pyenson, N. D., Friedlaender, A. S., Hazen, E. L., & Goldbogen, J. A. (2021). Baleen whale prey consumption based on high-resolution foraging measurements. *Nature, 599*(7883), 85-90. doi:10.1038/s41586-021-03991-5

SC-CAMLR (1991). Report of the tenth meeting of the Scientific Committee of CCAMLR (SC-CAMLR X). Hobart, Australia

SC-CAMLR (1997). Report of the sixteenth meeting of the Scientific Committee of CCAMLR (SC-CAMLR XVI). Hobart, Australia

SC-CAMLR (2010). Report of the Working Group on Ecosystem Monitoring and Management (WG-EMM-10). In: Report of the Twenty-ninth Meeting of the Scientific Committee (SC-CAMLR-XXIX), Annex 6. CCAMLR, Hobart, Australia.

SC-CAMLR (2010). Report of the Twenty-ninth Meeting of the Scientific Committee (SC-CAMLR-XXIX). CCAMLR, Hobart, Australia.

SC-CAMLR (2021). Report of the Working Group on Ecosystem Monitoring and Management (WG-EMM-2021). In: Report of the Fortieth Meeting of the Scientific Committee (SC-CAMLR-40), Annex 6. CCAMLR, Hobart, Australia.

SC-CAMLR (2021). Report of the Fortieth Meeting of the Scientific Committee (SC-CAMLR-40). CCAMLR, Hobart, Australia.

SC-CAMLR (2022). Report of the Working Group on Acoustic Survey and Analysis Methods (WG-ASAM-2022). In: Report of the Forty-first Meeting of the Scientific Committee (SC-CAMLR-41), Annex 5. CCAMLR, Hobart, Australia.

SC-CAMLR (2022). Report of the Working Group on Fish Stock Assessment (WG-FSA-2022). In: Report of the Forty-first Meeting of the Scientific Committee (SC-CAMLR-41), Annex 7. CCAMLR, Hobart, Australia.

SC-CAMLR (2022). Report of the Forty-first Meeting of the Scientific Committee (SC-CAMLR-41). CCAMLR, Hobart, Australia.

Skern-Mauritzen, M., Lindstrøm, U., Biuw, M., Elvarsson, B., Gunnlaugsson, T., Haug, T., Kovacs, K. M., Lydersen, C., McBride, M. M., Mikkelsen, B., Øien, N., & Víkingsson, G. (2022). Marine mammal consumption and fisheries removals in the Nordic and Barents Seas. *ICES Journal of Marine Science, 79*(5), 1583-1603. doi:10.1093/icesjms/fsac096

Surma, S., Pakhomov, E.A. and Pitcher, T.J. (2014). Effects of Whaling on the Structure of the Southern Ocean Food Web: Insights on the "Krill Surplus" from Ecosystem Modelling. PLoS ONE 9(12).

Trathan, P. N., Watkins, J. L., Murray, A. W. A., Brierley, A. S., Everson, I., Goss, C., Priddle, J., Reid, K., Ward, P., Hewitt, R., Demer, D., Naganobu, M., Kawaguchi, S., Sushin, V., Kasatkina, S. M., Hedley, S., Kim, S., & Pauly, T. (2001). The CCAMLR-2000 Krill Synoptic Survey: A description of the rationale and design. *CCAMLR Science, 8*, 1-23.

Trathan, P.N. and Hill, S.L. (2016). The Importance of Krill Predation in the Southern Ocean. Biology and Ecology of Antarctic Krill. V., S., Springer: pp. 321-350.

Tulloch, V.J.D., Plagányi, É.E., Matear, R., Brown, C.J. and Richardson, A.J. (2018). Ecosystem modelling to quantify the impact of historical whaling on Southern Hemisphere baleen whales. Fish and Fisheries 19(1): 117-137.

Warwick-Evans, V. and Trathan, P.N. (2021). Using the Risk Assessment Framework to spread the catch limit in Subarea 48.1. Paper presented to the Working Group on Ecosystem Monitoring and Management, 95pp.

Warwick-Evans, V., Constable, A., Dalla Rosa, L., Secchi, E. R., Seyboth, E., & Trathan, P. N. (2022a). Using a risk assessment framework to spatially and temporally spread the fishery catch limit for Antarctic krill in the west Antarctic Peninsula: A template for krill fisheries elsewhere. *Frontiers in Marine Science, 9*.

Warwick-Evans, V., Kelly, N., Dalla Rosa, L., Friedlaender, A., Hinke, J. T., Kim, J. H., Kokubun, N., Santora, J. A., Secchi, E. R., Seyboth, E., & Trathan, P. N. (2022b). Using seabird and whale distribution models to estimate spatial consumption of krill to inform fishery management. *Ecosphere, 13*(6), e4083. doi:https://doi.org/10.1002/ecs2.4083

Welsford, D., N. Walker, M. Favero, B. Krafft, C. Darby and S. Parker (2022). CCAMLR-IWC coordination: incidents of whale by-catch in the Antarctic krill fishery. Paper SC/68D/HIM/04 presented to the Scientific Committee of the International Whaling Commission, 48 pp.

Zerbini, A. N., Adams, G., Best, J., Clapham, P. J., Jackson, J. A., & Punt, A. E. (2019). Assessing the recovery of an Antarctic predator from historical exploitation. *Royal Society Open Science, 6*(10), 190368. doi:10.1098/rsos.190368