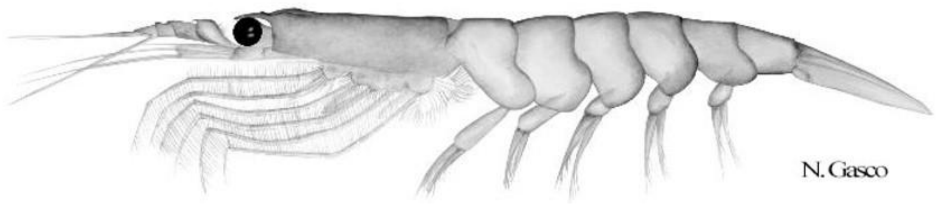
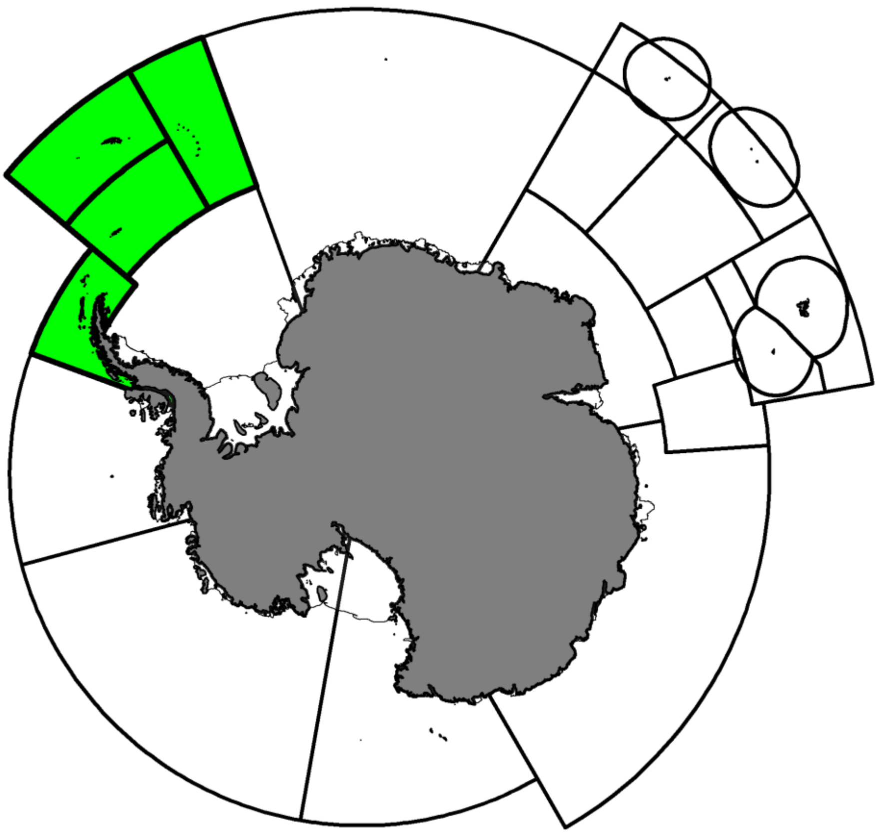
CCAMLR's revised krill fishery management approach in Subareas 48.1 to 48.4 as progressed from 2019 to 2022.

20 March 2024



Antarctic krill, *Euphausia superba* Dana, 1850.



Map of the management areas within the CAMLR Convention Area. Subareas 48.1 to 48.4, the regions discussed in this report are shaded in green. Coastlines and ice shelves: UK Polar Data Centre/BAS and Natural Earth. Projection: EPSG 6932.

CCAMLR

Commission for the Conservation of Antarctic Marine Living Resources
Commission pour la conservation de la faune et la flore marines de l'Antarctique
Комиссия по сохранению морских живых ресурсов Антарктики
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CCAMLR's revised krill fishery management approach in Subareas 48.1 to 48.4 as progressed from 2019 to 2022.

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This document summarizes the current and ongoing development of the revised approach to the management of the Antarctic krill fishery. The revised approach was adopted by CCAMLR in 2019 and integrates three components, namely regular updates of biomass estimates, a population projection model to estimate precautionary harvest rates, and a krill-predator spatial overlap analysis to determine the spatial and seasonal allocation of catch limits.

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Background

The Commission for the Conservation of Antarctic Marine Living Resources (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, limits on krill harvesting are described in Conservation Measures 51-01 and 51-07.

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 fishing 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, 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 biomass 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 (Fig. 1A) 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 precautionary catch limit for krill is set on the basis of a precautionary constant harvest rate (*gamma*). Using the GYM outputs, the following rules (Butterworth et al., 1992; Constable et al., 2000) are applied to determine a precautionary harvest rate (Fig. 1):

1. Choose a harvest rate, *gamma*1, so that the probability of the spawning biomass dropping below 20% of its median pre-exploitation level over a 20-year harvesting period is 10%.

2. Choose a harvest rate, *gamma*2, so that the median escapement at the end of a 20-year period is 75% of the median pre-exploitation level.

3. Select the lower of *gamma*1 and *gamma*2 as the precautionary harvest rate.

The actual precautionary catch limit is the precautionary harvest rate selected in step 3 multiplied by the estimate of biomass from surveys of that stock, intended to represent B_0, the unexploited biomass.

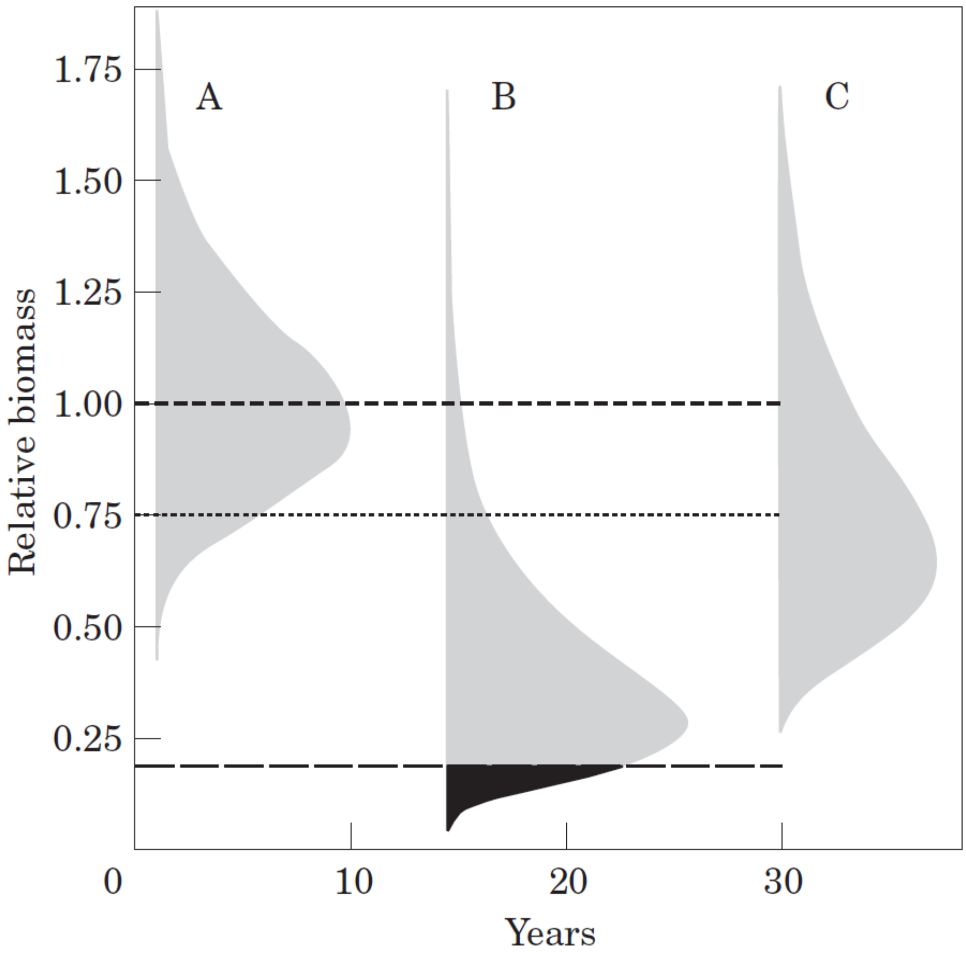

Figure 1: Statistical distributions of krill spawning biomass obtained by 'Monte Carlo' projections of a population model that takes into account the effects of uncertainties in krill demography and unexploited biomass: Distribution A represents the potential unexploited biomasses (dash line: median); B is the statistical distribution of lowest population biomasses under a constant catch limit selected so that the probability of the biomass dropping below 20% of the pre-exploited median level over a 20-year harvesting period is 10% (large-dashed line); C is the statistical distribution of biomass at the end of 20 years of exploitation under a constant catch limit selected so that median escapement at the end is 75% (dotted line) of the pre-exploited median level. Figure taken from Constable et al., 2000.

In setting a precautionary catch limit over an area comprised of several Subareas, CCAMLR recognised in the early 1990s that the fishery could become spatially concentrated, which could have localised ecosystem impacts. In recognition of this risk, CCAMLR introduced in 1991 a trigger catch level of 620,000 tonnes which the fishery cannot exceed until there is an agreed mechanism to distribute catches geographically such that localised impacts are avoided or minimised. The trigger level value was selected as it represented the sum of the maximum historic catches reported at that time from each Subarea (*N.B.*: the historical catch figures have been updated to 676,303 tonnes since the trigger level was introduced; see Table 1 in Hill et al., 2016). In 2009, the trigger level was explicitly subdivided into Subareas such that no more than 25% (155,000 t) could be taken from Subarea 48.1, no more than 45% (279,000 t) could be taken from Subarea 48.2 and Subarea 48.3 and no more than 15% (93,000 t) could be taken from Subarea 48.4 (Conservation Measure 51-07; Fig. 2). These percentages deliberately sum to more than 100% to provide some flexibility to the fishery in each Subarea while the total catch is capped at the trigger level of 620,000 tonnes to achieve the objective of distributing fishing effort.

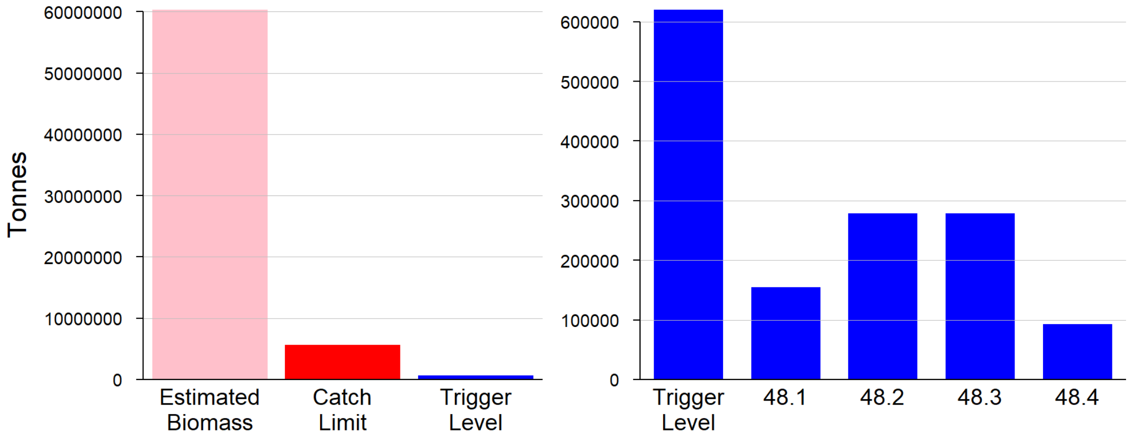

Figure 2: Estimated biomass from the CCAMLR-2000 survey in Area 48, catch limit and trigger levels in Subareas 48.1–48.4 (Conservation Measures 51-01 and 51-07).

The current trigger level is not linked to the assessment of krill biomass. In 2010, although the precautionary catch limit was amended from 3.47 million tonnes to 5.61 million tonnes, the trigger level (set when the precautionary catch limit was 1.5 million tonnes) was not changed. However, modelling studies completed after the precautionary catch limit was increased suggest that the risks of not achieving the three principles of conservation articulated in Article II of the Convention may increase substantially as catches increase from the trigger level to the precautionary catch limit (Plagányi and Butterworth, 2012; Watters et al., 2013). Additionally, in discussions related to the use of the GYM, the Working Group on Ecosystem Monitoring and Management (WG-EMM) considered the application of the decision rules used by CCAMLR to determine the precautionary catch limit for krill and noted that for stocks such as krill that experience high interannual variability in abundance, the probability with which the biomass may fall below 20% of the initial biomass may be greater than 0.1 even in the absence of fishing (WG-EMM-10, paragraph 2.78). Given the potential impact of climate change on recruitment variability, the Working Group agreed that both the recruitment variability and the specification of the current decision rule relating to the maintenance of stable recruitment should be investigated.

Fishing effort has become more spatially concentrated since the mid-2000s (Fig. 3). In discussing the revision of the management of the krill fishery, the Scientific Committee expressed concern over the potential implications of the rapid expansion of the krill fishery into data-limited areas such as the Gerlache Strait and noted that the impact of increased krill catches and their spatial and temporal concentration had yet to be evaluated (SC-CAMLR-41, paragraph 3.50), and, that it was a factor driving the need for spatial and temporal management of the krill fishery, which had consequences on the scale of future management units (SC-CAMLR-40, paragraphs 3.6 and 3.12).

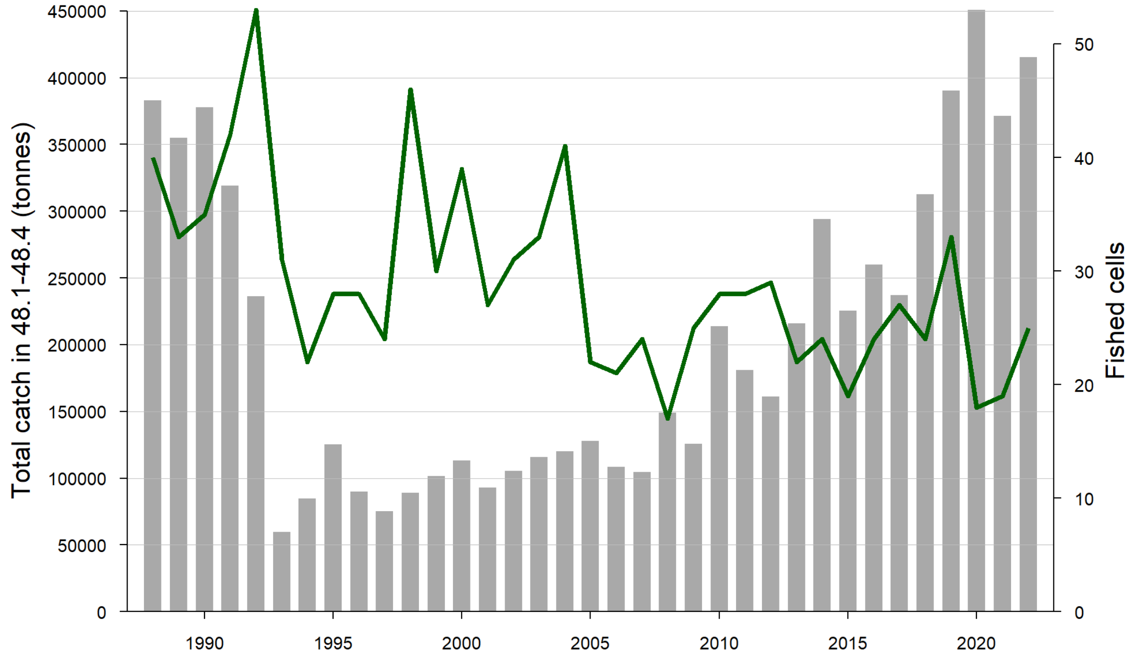

Figure 3: Total krill catch reported in Subareas 48.1–48.4 since 1988 (grey, left axis) and count of spatial cells in which catch has been reported (green, right axis) after aggregation of the data using equal area (100 km x 100 km) cells (see Krill fishery report, Fig. 3).

In 2021, Conservation Measure 51-07 (as agreed by CCAMLR-XXXV, paragraph 5.19) expired. In 2022 (CCAMLR-40, paragraph 6.12) and 2023 (CCAMLR-41, paragraph 4.21) the Commission agreed to 1-year extensions to enable further progress on the revision of the krill fishery management approach.

The revised krill fishery management approach

In 2019, the Commission endorsed (CCAMLR-38, Paragraph 5.17) a three-component (Fig. 4) revision of the krill fishery management approach, comprising:

(i) a stock assessment to estimate precautionary harvest rates,

(ii) regular updates of biomass estimates, initially at the subarea scale, but potentially at multiple scales,

(iii) a risk assessment framework to inform the spatial allocation of catch.

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, 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. However, 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 has involved efforts from all Working Groups of the Scientific Committee, which has developed an ambitious list of tasks (SC-CAMLR-40, paragraph 3.24).

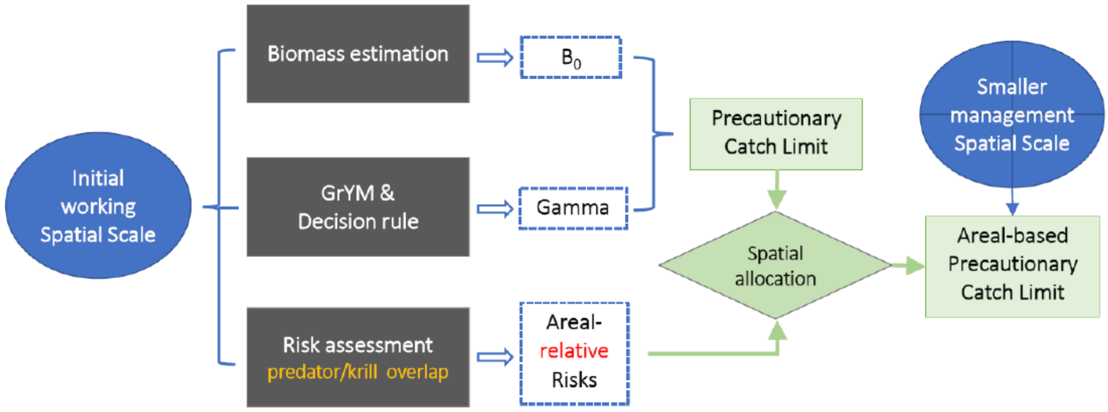

Figure 4: The three components and workflow of the revised krill management approach. Figure taken from SC-CAMLR-40 (Annex 8, Figure 1).

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 acoustic data), distribution of fishing effort and scenarios tested within the risk assessment framework, the Scientific Committee considered candidate management units in 2022 (Fig. 5).

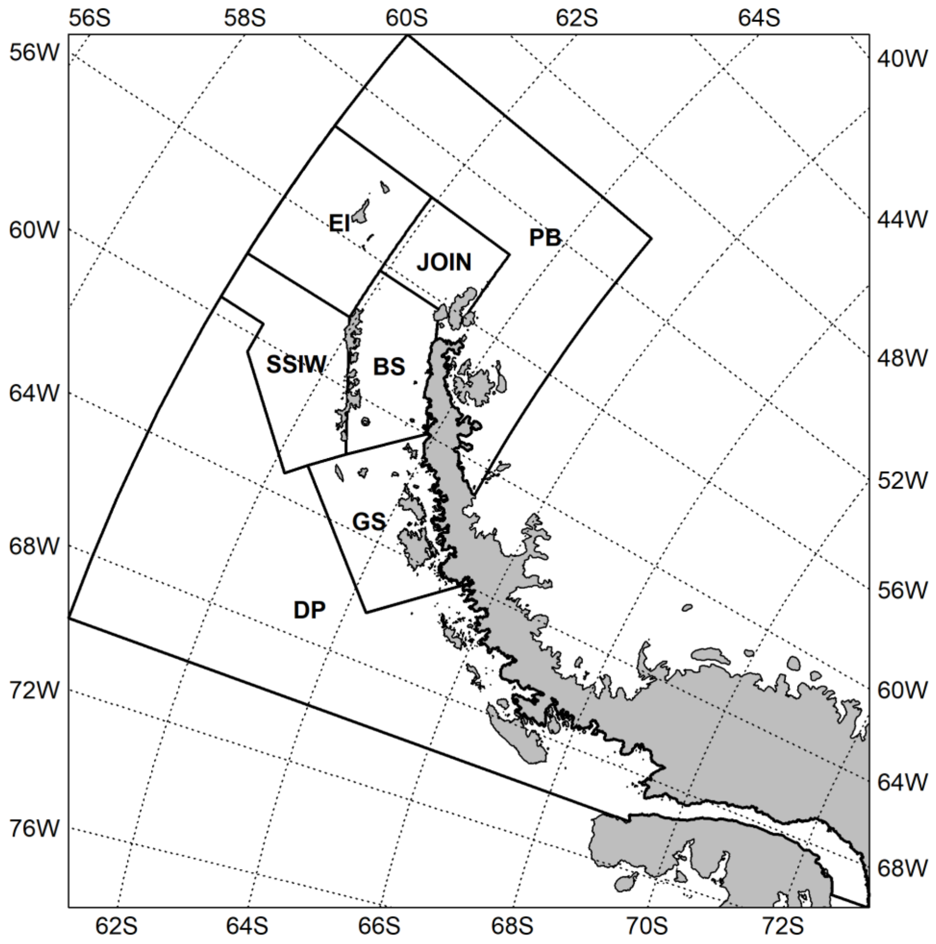

Figure 5: Krill fishery management units in Subarea 48.1. EI – Elephant Island, JOIN – Joinville, BS – Bransfield Strait, SSIW – South Shetland Islands West, GS – Gerlache Strait, DP – Drake Passage, PB – Powell Basin. Taken from SC-CAMLR-41 (Figure 1).

The sections below provide details on the three components of the revised krill fishery management approach as progressed from 2020 to 2022, as well as additional elements under consideration. Although these were considered by all Working Groups and the Scientific Committee, each was a focus topic for a particular Working Group:

- Working Group on Acoustic Survey and Analysis Methods (WG-ASAM): biomass estimates based on acoustic surveys,
- Working Group on Statistics, Assessments and Modelling (WG-SAM): krill population projection model configuration,
- Working Group on Ecosystem Monitoring and Management (WG-EMM): recruitment modelling, projection model parameter values and spatial overlap analysis,
- Working Group on Fish Stock Assessment (WG-FSA): Synthesis and provision of resulting advice to the Scientific Committee.

Biomass estimates

Within Subarea 48.1 both recent (Kasatkina et al., 2021; Krafft et. al, 2021; Wang et al., 2021) and historic (*e.g.*, Reiss et. al, 2008) data from acoustic surveys are available. In 2022, discussions in WG-ASAM and WG-EMM resulted in an agreement on the use of the available acoustic data (WG-EMM-2022, paragraphs 2.34 and 2.35); the best contemporary estimate would, for the purpose of an initial revision to catch limits in Subarea 48.1, be obtained by computing the long-term average of historic data for strata with several surveys, and, using the lower bound of the one-sided 95% confidence interval (assuming a lognormal distribution) for strata with a single survey. Should strata surveys occur annually in the future, the Working Group considered that a five-year window to average acoustic biomass estimates may become appropriate.

While noting these discussions (SC-CAMLR-41, paragraphs 3.16–3.22), the Scientific Committee recommended that given the periodic and dynamic nature of krill population dynamics, future catch limits should be revised frequently to ensure a precautionary management of the krill fishery (SC-CAMLR-41, paragraph 3.24), and it noted that the use of fishing vessels to undertake regular acoustic surveys within management strata will be essential in order to obtain regular biomass estimates (SC-CAMLR-41, paragraph 3.25).

The latest biomass estimates for each management unit (Table 3 in SC-CAMLR-41) were developed based on the density estimates and CVs collated in WG-EMM-2021/05 Rev. 1 with the methods described above, and scaled to the updated management units following WG-ASAM-2022 methodology (paragraphs 3.19–3.22, Table 9 in WG-ASAM-2022).

Precautionary harvest rate (*gamma*)

In 2019, the GYM was recoded in R (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 value for *gamma* depends, among other things, on the recruitment variability used in the projections. In 2022, the Scientific Committee endorsed (SC-CAMLR-41, paragraph 3.31) the recommendations by WG-FSA-2022 (paragraphs 7.18 and 7.19) to use the US AMLR survey recruitment series from all trawls (day and night) from years which cover all four strata, including data from the Joinville stratum, as well as the Russian Subarea 48.1 survey to derive recruitment parameters for the Grym. The mean and standard deviation of the proportional recruitment from the 12 surveys were 0.5047 and 0.2406 respectively. All other model parameters were chosen from scenario 18 of WG-FSA-2021/39 to be consistent with the models presented in WG-FSA-2022/39. The inputs to the model and the results were presented in Appendix G of WG-FSA-2022.

The Scientific Committee endorsed the value of *gamma* for Subarea 48.1 generated using the Grym of 0.0338 (SC-CAMLR-41, paragraph 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.

The Scientific Committee noted that it would be useful to record the sources of uncertainty in the estimation of *gamma* and noted that the parameter should be revised based on updated Grym models as new sources of data become available (SC-CAMLR-41, paragraph 3.32).

Spatial allocation of catch limits

The Spatial Overlap Analysis (previously termed the Risk Assessment Framework; SC-CAMLR-41, paragraph 3.36) was introduced in 2016 (WG-FSA-16, paragraph 8.3) and aims to minimise the risk of predator populations, in particular land-based predators, being inadvertently or disproportionally affected by the krill fishery. It was endorsed by the Scientific Committee and Commission in 2019 as part of the three-component (Fig. 4) revision of the krill fishery management approach, has been extensively developed over the years and was implemented within Subarea 48.1 (WG-EMM-2022/17).

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 (a proportion of catch allowed) for each management unit and each season which quantify that overlap, with lower *alphas* for where the overlap is greater. *Alpha* values sum to 1 across all of the spatio-temporal units included in an analysis. Catch limits are then allocated by multiplying the overall Subarea 48.1 catch limit (product of biomass multiplied by precautionary harvest rate *gamma*) by the *alpha* of each management unit, in each season. For example, a low alpha value allocated to the Bransfield Strait in summer due to the higher relative overlap with predators, would result in a low catch limit (WG-FSA-2022 paragraph 7.30 and Table 10 in WG-FSA-2022).

While noting the existing data deficiencies, especially in winter, the Scientific Committee applied the spatial overlap analysis (based on the *alphas* from the 'AMLR strata new5' baseline scenario given in WG-FSA-2021/16, as reported in Table 10 in WG-FSA-2022) to the new management units, and determined precautionary catch limits (SC-CAMLR-41, paragraph 3.45) in each management unit, in winter and summer (Table 2 in SC-CAMLR-41).

Members had, however, diverging views on the required changes to Conservation Measures (SC-CAMLR-41, paragraphs 3.59–3.61) and were not able to provide consensus advice to the Commission (SC-CAMLR-41, paragraphs 3.67–3.69).

Additional elements under consideration

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, paragraph 4.17):

(i) the monitoring of catch and fishery closure forecasting 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,

(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, based on the current understanding that a proportion of the krill stock is transported from Subarea 48.1 to Subareas 48.2 and 48.3, the Scientific Committee indicated that a holistic approach to all Subarea catch limits is required when fully implementing the new management strategy (SC-CAMLR-41, paragraph 3.26). The Commission noted (CCAMLR-41 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, paragraphs 3.43–3.66) to coordinate efforts and develop a coherent approach for the conservation and rational use of marine living resources. This would be supported by a revised data collection plan (Table 1 in SC-CAMLR-41), an enhanced CEMP (SC-CAMLR-41, paragraph 3.8, 3.41, 3.48), and the development of a krill stock hypothesis (SC-CAMLR-41, paragraph 3.28).

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