Draft Report of the Working Group
on Fish Stock Assessment
(Hobart, Australia, 10 to 20 October 2022)

Agenda Item No. 7

Krill (*Euphausia superba*)

7.1 WG-FSA 22/04 provided an update on issues identified in krill fishery data related to the reporting of by-catch data from Chilean and Ukrainian vessels, green weight estimation parameters reported from the Chilean vessel Betanzos and the Norwegian vessel Juvel, and the allocation of catch amounts to two-hourly trawl periods for continuous trawling vessels.

7.2 For all items considerable progress or resolutions has been made through consultation with Members and vessel operators. The WG agreed with the following recommendations:

(i) The Secretariat undertake data changes for krill green weight estimation parameters for the vessel Juvel for seasons 2015 and 2016, using the ρ value of 1 reported in the paper.

(ii) The use and submission of two-hourly catch reporting form for continuous trawling vessels where a flow meter or flow scale is not installed on the primary inlet hose prior to the distribution of catch into holding tanks. Any such requirement may also require relevant changes to CMs 21-03 and 23-06.

7.3 The WG thanked the Secretariat, Member scientists and the industry for clarifying the way in which catch data were clarified and reported.

7.4 The WG noted that the changes do not impact its advice to Scientific Committee as the corrections impact the checking of green weight calculations only; catch limits are managed using the C1 data, reporting of which is not impacted. The Scientific Committee had previously noted to SCIC (SC40 para 3.5) that there may be issues with catch reporting by the Betanzos and Juvel, but the change to the calculations has resolved these issues.

7.5 The authors of SC 22/19 noted that the revision of CM 51-07 should not start with krill management in Subarea 48.1 followed by Subareas 48.2–48.4 in a staged approach. It should be updated on the basis of a coordinated management framework for krill fisheries across the

whole of Area 48. The authors considered that as Subareas 48.1,2,3 & 4 are connected as a system this process would require the development of a krill stock structure hypothesis and the collection of data on the spatial and temporal distribution patterns of krill. The authors proposed that they design and implement a system of biannual (summer and winter) standardised acoustic surveys, including synoptic and regional krill surveys in Area 48, accompanied by comprehensive environmental data collection and observations of marine mammals and seabirds. In the authors' view, implementing such a system of standardised surveys, throughout Subareas 48.1 to 48.4, would provide the necessary and sufficient scientific support to develop a fisheries management strategy and provide the scientific basis for a comprehensive revision of CM 51-07 and CM 51-01.

7.6 The WG noted that there are short comings in the data that are used for the provision of advice on the krill management, and that there is always room for improvement. The ambition of the Scientific Committee and its working groups is the establishment of a pragmatic data collection and analysis programme that supports regular advice updates to Commission. While there is a need to address shortcomings in the future, the WG noted that the information available can be used to carry out its task to provide advice on the updating of CM 51-07 this year. The WG noted that the work programme concentrating on Subarea 48.1, initially, and then the remaining areas of Subarea 48 has been agreed by both the Scientific Committee and Commission.

7.7 The WG discussed the process that has been agreed in Scientific Committee and Commission for the provision of advice on the revision of 51-07. The working group noted that it had been agreed that Subarea 48.1 would be the first Subarea that the simplified data limited approach would be applied to in order to derive regional catch limits. WG-FSA noted the work to develop the approach, with work plan developed in 2019 and significant progress started in 2021, had continued in ASAM, WG-SAM and WG-EMM who had provided:

(i) further advice on the development and refinement of the management units (strata) in 48.1

(ii) krill acoustic biomass estimates for the agreed strata

(iii) a training workshop on the application of the Grym model

(iv) development of a method for the derivation of improved length weight data for the Grym

(v) further analysis and consideration of appropriate recruitment information

7.8 WG-SAM noted that the development of the Grym methodology still required the refinement and agreement of some parameters, particularly a proportional recruitment time series (WG-SAM 2022 Para 3.8). In the absence of agreed parameter values, WG-SAM recommended that a suitable range of parameter options be used to provide catch estimates on which advice to Scientific Committee from WG-FSA can be based (WG-SAM 2022 Para 3.8).

7.9 WG-EMM revised the biomass estimates for Subarea 48.1 management units (strata) (Table 1, WG-EMM 2022) and noted that a workshop to develop a stock structure hypothesis for the krill stock, similar to that which had been conducted for Area 48 Antarctic toothfish (REF), would progress the discussions on regional links between Subareas particularly the movement of krill, within and between Subareas (flux) (WG-EMM 2022, Para 2.89).

7.10 WG-FSA 22/37 presented proposals to standardise the collection and processing of krill acoustic survey data. The authors noted the Scientific Committee recommendations to develop standardized methods for processing and reporting future acoustic survey results, and that they considered that it is important to streamline the system of krill acoustic surveys carried out in the CCAMLR area. In particular, standardization of acoustic surveys would require:

(i) Clear and transparent definitions and requirements to streamline the system of krill acoustic surveys carried out in the CCAMLR area;

(ii) For each type of survey recommendations for design and timing of the acoustic survey; methodological aspects and standardized procedures for data collection and processing, and reporting results.

(iii) The authors also considered that there is no scientific basis for swarming behaviour in krill which forms the basis of the swarm based analysis approach, highlighting a substantial difference between swarm based and db difference methods derived from their survey data.

7.11 The WG noted that this was a similar paper to that which had been submitted to WG ASAM (WG ASAM 2022 paragraph 2.3 and 2.4). WG ASAM had noted that both the db difference and swarms-based krill identification methods had been agreed for estimating acoustic biomass. It was noted that the differences between methods were not as apparent in

other comparative studies using the two methods. Many of the issues discussed in the paper, including standardisation, have previously been discussed in ASAM and are being progressed (WG ASAM 2022 Table 1).

7.12 WG-FSA 22/30 presented an evaluation of proposed stratum-scale catch limits for the krill fishery in Subarea 48.1 to assess whether they are likely to be precautionary. The authors compared stratum catch limits for Subarea 48.1, which have been proposed in papers to WG-FSA, WGSAM and WG-EMM, to the times series of stratum survey biomass. The ratio of a proposed stratum catch limit to survey biomass was used to derive an estimate for the exploitation rate that would have occurred, in that year, if the catch limit had been applied. The authors noted that there is sufficient information available to evaluate whether proposed management options for Subarea 48.1 are likely to allow CCAMLR to fulfil its obligations under Article II of the Convention, and to objectively compare alterative management options.

7.13 The WG noted that the method had the potential for development as a diagnostic approach to compare catch limits derived from a range of approaches against the information collected across a time series of acoustic estimates. Uncertainties associated with the approach were noted including the timing and availability of surveys (summer vs winter).

7.14 WG-FSA 22/35 presented alternative proportional recruitment estimates for Subarea 48.1 based on reanalysis of the US AMLR data series. The authors noted that, previously proportional recruitment parameter estimates were based on the entire US AMLR summer survey time series but with data collected in daytime. They noted that it had previously been recommended that data collected at night only be used, to reduce the light-linked net avoidance of krill. In addition, the Joinville Island stratum, which has been recognized as an important area for krill recruits, was not fully covered by the entire US AMLR survey time series. The authors provided alternative proportional recruitment estimates based on re-analysis of the US AMLR data given the above two considerations, resulting in a gamma estimate of 0.0355 based on the 2002-2011 continuous time series and a gamma estimate of 0.0412 based on all surveys (2002-2011 plus 1997) that covered all four US AMLR survey strata using data collected at night only.

7.15 The WG noted that CCAMLR data collection protocols recommend that night-time samples are collected when “open and close” nets are deployed. Where samples are collected using normal nets, day and night-time oblique tows are recommended for collecting length distribution data and as such samples from both day and night could be used.

7.16 The range of proportional recruitment scenarios calculated in WG-FSA-2022/35 were based on the US-AMLR surveys. The Working Group noted that the scenarios presented within WG-FSA-2022/35 did not include the 2020 RV Atlantida data (WG-EMM-2021/12).

7.17 The WG therefore recalculated the Grym scenarios presented in WG-FSA-2022/35 to include both day and night data from all US-AMLR surveys which sampled Joinville Island strata (1997, 2002-2011) as well as the 2020 RV Atlantida survey. 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 are presented in Annex 1. The revised gamma estimate was 0.0338.

7.17.1 The WG agreed to use recruitment series from all trawls (day and night) that include data from Joinville stratum and Russian 48.1 survey to derive recruitment parameter for Grym which resulted in a new value of gamma, 0.0338 (Annex 1).

7.18 The WG recommended that a gamma value of 0.0338 be used in the calculation for the Subarea 48.1 catch limits.

7.19 WG-FSA 22/39 reviewed progress made by SC-CAMLR and its working groups towards an agreed, science-based, krill management approach since 2019. The authors also reviewed progress made by WG-ASAM-2022, WG-SAM-2022 and WG-EMM-2022, and presented updated spatial and seasonal allocation of krill catch limit based on analysis by the Working Group meetings as well a revised harvest rate estimate presented to the WG-FSA-2022 meeting (WG-FSA 22/35).

7.20 The WG also noted that there was a requirement for a simplified approach for the explanation of the revised krill data limited management process to SC and Commission. Annex 2 presents the workflow of the krill data limited management approach that has been in development in Scientific Committee's working groups over the last 3 years. This approach is comprised of three components, namely the biomass estimation, the stock assessment using the GYM model in R (Grym) and the Spatial overlap analysis (formerly called the Risk Assessment, see WG-EMM-2022 para 2.72).

7.24 The framework computes relative overlap within a region and can evaluate overlap associated with different proposals, or scenarios, to subdivide the catch. It is intended that the krill data limited management approach will be improved and progressed as it is applied to

other Subareas in Area 48 individually or in a holistic approach based the experiences and knowledge gained.

7.25 The WG agreed the Grym data and parameters and acoustic biomass estimates to be used for allocating catch limits noting that, the use of the baseline allocation in the overlap analysis should be applied in the spatial overlap analysis as it is considered more precautionary than the fisheries desirability scenario.

7.26 The WG also noted that the data limited approach currently does not consider seasonal movement of krill between summer and winter and that additional surveys would be required to further refine the approach.

7.27 The WG discussed how the workflow of the three components (biomass estimation, Grym & Decision rule, and spatial overlap analysis) can be integrated, and whether gamma should be applied to each biomass estimated for each stratum independently to derive spatial distribution of catch limits or gamma to be applied to the total biomass for Subarea 48.1, and multiply alpha for each stratum estimated from the spatial overlap analysis. The WG agreed that distributing catch simply based on biomass estimates in strata does not take account of uncertainties in predator requirements, and information on critical areas for krill reproduction, as determined in the spatial overlap analysis.

7.28 The WG agreed to apply the gamma value to the total survey biomass agreed for Subarea 48.1 by WG ASAM and WG-EMM and to then subdivide the total area catch using the baseline strata alpha values derived from the spatial overlap analysis (Table 7.1).

7.30 During the WG-FSA meeting the catch limits by strata were recalculated using the baseline scenario in the spatial overlap analysis and with a gamma value of 0.0338. Table 1 shows the re-calculated catch limit for the seven candidate management units (strata).

Table 1: Precautionary catch limits allocated for the candidate management strata in Subarea 48.1 based on the 'alpha' from the baseline scenario and gamma 0.0338.

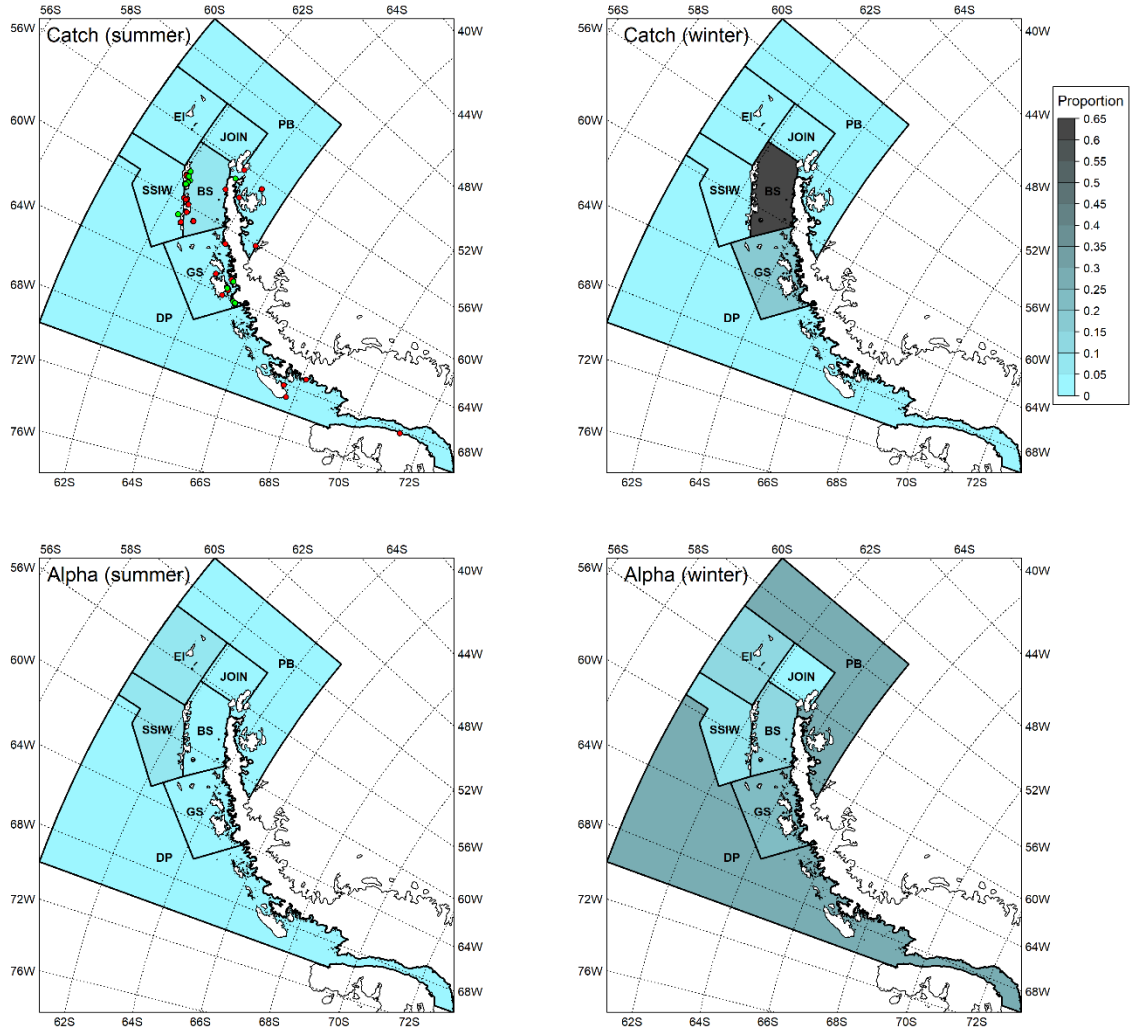
Management unit	Baseline (risk value, 0.46)				
	alpha		Catch Limit (t)		
	Summer	Winter	Summer	Winter	Sum
Joinville (JI)	0.0008	0.0178	525	11 860	12 385
Elphant (EI)	0.0662	0.1097	44 253	73 298	117 552
Bransfield (BS)	0.0061	0.1094	4 075	73 112	77 187
South Shetland Islands West (SSIW)	0.0549	0.0731	36 694	48 857	85 551
Gerlache Strait (GS)	0.0238	0.2116	15 921	141 378	157 300
Powell Basin (PB) +Drake passage (DP)	0.0450	0.2815	30 046	188 079	218 125
Total	**0.1968**	**0.8032**	131 515	536 585	668 101

7.31 The Working Group agreed that a total catch limit for E. superba in Subarea 48.1 set at 668 101 tonnes for 2022/23 would be consistent with the precautionary yield estimated using the CCAMLR decision rules for krill and that subdividing this total catch limit among management units and seasons as presented in Table 1 would be consistent with the process agreed for setting krill catch limits (SC2019 3.30). The Working Group further agreed that the catch limits presented in Table 1 are based on use of the best available science.7.32 The WG reviewed distribution of mean catch for each stratum during summer and winter periods in the last 5 years. The noted that the majority of the catch was taken from the Bransfield Strait stratum during winter period, followed by Gerlache Strait stratum (Figure 3 upper maps).

7.33 Based on the spatial overlap model alpha values, which allocates a low alpha to the Bransfield Strait, due to the higher relative overlap with predators, the catch in this stratum is reduced. Higher alphas, and therefore associated catch limits, are allocated to strata where the current fishery does not concentrate (Figure 3 lower maps). The recommended catch limit allocation will reduce the current concentration of catch occurring in Bransfield Strait and distribute fishing effort across to the strata that are currently not intensively fished.

7.34 The WG also noted that the concentration of research stations and CEMP sites in certain strata, and that there are some strata that do not have any CEMP site and/or Stations (Figure 3 top left).

Figure 3. Distribution of krill catch (top) and alphas (bottom) in summer (left) and winter (right) in subarea 48.1. Catch is shown here as a proportion of the total catch over the last 5 years (2018-2022), alphas correspond to proportions of the total catch limit for Subarea 48.1. CEMP sites (green) and Comnap-listed infrastructure (red) are shown in the top-left panel. EI – Elephant Island, JOIN – Joinville, BS – Bransfield Strait, SSIW – South Shetland Islands West, GS – Gerlache Strait, DP – Drake Passage, PB – Powell Basin.



7.35 The Working Group noted that substantial scientific progress had again been made this year, despite the restrictions on time available due to the requirement for virtual intersessional meetings. The development of a revised krill fishery management approach over the last three years, and following reviews and comments on the approach and information contributing to it, during 2022, by WG-ASAM, WG-SAM and WG-EMM can form the basis for SC advice on the revision to CM 51-07.

7.36 The considerations and progress achieved in each WG are summarised in Figure 2.

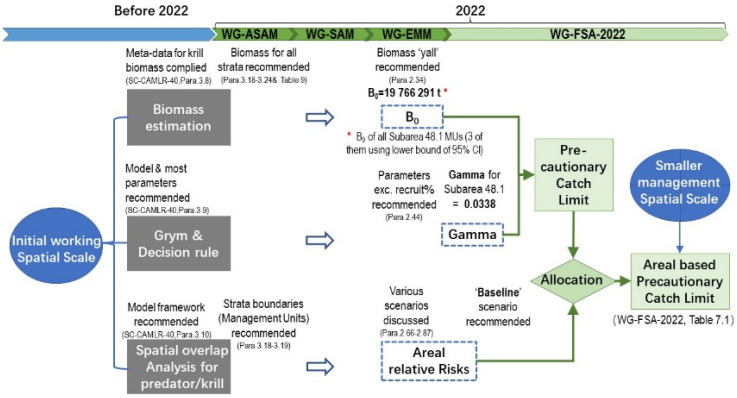


Figure 2. The three components and workflow of the revised krill management approach, as agreed at SC-CAMLR-40, Annex 8 (paragraph 3.25) and subsequent recommendations leading to the FSA agreed strata catch limits by each Working Group.

Implementation of the agreed catch limits for the management of the Subarea 48.1 strata

7.37 Dr Kasatkina noted that it is important to consider that the management process is currently working on one area, Subarea 48.1, and not yet including 48.2,3 & 4. The approach could be considered to be treating Subarea 48.1 as a single population unit rather than its actual status as a component of a larger complex. In a changing climate there is a need for new information rather than relying on historic data and that a new synoptic survey should be considered.

7.38 Dr Kasatkina noted that a schedule of work should be agreed in SC in order to progress the other Subareas as soon as practicable, identifying the information that is needed, a programme for collecting it and a time table for provision of advice for the other Subareas as soon as is possible.

7.39 The WG noted that while the data limited approach has resulted in the allocation of catch limits to the Subarea 48.1 strata using a precautionary approach that interactions between the Subareas due to the flow of krill between areas (flux), needs to be considered.

7.40 The WG discussed the revised catch limits allocated to the strata using the data limited approach, as set out in Table 1. It was noted that the data / information available for the setting of catch limits in some of the Subarea 48.1 strata was very limited particularly Elephant Island, Joinville, Gerlache Strait, Drake Passage and Powell Basin.

7.41 Table 2 provides information to support understanding how the revised catch limits stand and relation to fishing activities since 1988. The WG discussed the various implications of the revised catch limits in the context of the information provided within the Table. The WG noted that in several of these areas, Elephant Island, Gerlache Strait, Drake Passage and Powell Basin a substantial increase in catch limits is proposed for areas with limited data when applying the spatial overlap algorithm. In the case of Bransfield Strait stratum, the catch limit will be reduced from recent values.

7.42 The WG noted that such substantial increase in these areas could outpace the ability to monitor catches, by-catch and the impact on the wider ecosystem and that a staged increase in catch limits, in line with increased survey frequency, CEMP monitoring sites and data collection should be considered by the SC in order to ensure that increases in fishery exploitation are concomitant with increased collection of data to ensure that CCAMLR meets its objectives for management of the krill fishery and related species under Article 2.

7.43 The WG discussed the types of information that would be required to be collected, as well as a staged approach in Elephant Island, Gerlache Strait, Drake Passage and Powell Basin to monitor the various ecosystem components while krill catch limit is increased. This included:

(i) Krill biomass, recruitment and demography, and its distribution in relation to the fishery, especially during winter season where most catch is allocated;

(ii) Monitoring of fish bycatch and regular collation of information, analysis and reporting of trends, stock status and seasonal distribution of those species;

(iii) Monitoring of the status of dependent predator species through e.g. the CEMP program, including cetaceans

(iv) The development and assessment to the potential impact of the increased fishery to the ecosystem in general.

7.44 In addition the WG noted that SC should consider the impact on monitoring of the fishery, including:

(i) The ability of the Secretariat to implement monitoring in the new management approach;

(ii) Revision of reporting requirements including more frequent catch reporting to enable management of smaller catch limits; e.g. the C1 form and the observer logbook may need revision to accommodate the refined Management Unit;

(iii) The fishery closure forecasting procedure may need some refinement to adapt to the small catch limit allocated in some Management Unit.

(iv) Increases in SISO observer coverage, and refinement of sampling and reporting protocols.

7.45 The WG also noted that there will also need to be consideration of how the changed catch limits interact with alternative proposed management measures such as the D1MPA.

7.46 Many members noted that a staged approach to the increasing catch limits, while fishery and predator monitoring and reporting are established and information analysed and reported would provide a mechanism for feedback management.

7.47 The WG reiterated its advice that the current management approach as outlined in CM51-07 is considered precautionary and that if future monitoring and reporting does not conform to the requirements to provide regular updates to the data limited approach used in Subarea 48.1, the catch limit currently outlined in CM 51-07 could provide a fall back position.

Table 2. Proposed catch limit for each stratum as well as local biomass estimates, information related to fishing activities, research efforts and future research required in each stratum. EI – Elephant Island, JOIN – Joinville, BS – Bransfield Strait, SSIW – South Shetland Islands West, GS – Gerlache Strait, DP – Drake Passage, PB – Powell Basin.

Strata	**JOIN#**	**EI#**	**BS**	**SSIW**	**GS#**	**PB & DP#**
Catch limit tonnes (Summer/Winter)	12,385 (525/11,860)	117,552 (44,253/73,298)	77,187 (4,074/73,112)	85,551 (36,694/48,857)	157,300 (15,921/141,378)	218,125 (30,046/188,079)
Biomass(tonnes) and CV%	860697 49.15	3382428 26.92	1187487 42.83	2515678 36.27	703327* NA	11116674* NA
Local area harvest rate	1.44%	3.48%	6.5%	3.4%	22.37%	1.90%
Maximum catch since 1988 (Year)	32015 (2022)	51521 (1989)	120453 (2020)	64872 (1992)	52909 (2017)	2600 (1998)
Maximum catch since 2018 (Year)	32015 (2022)	2040 (2019)	120453 (2020)	8159 (2018)	42642 (2018)	1500 (2021)
Ratio of proposed catch limit to historical maximum catch?	0.39	2.28	0.64	1.32	2.97	83.89
Current and past Fishing activities	Very limited	Moderate in the past, currently limited	Currently active	Active in the past, currently limited	Moderate to Active since 2010	Very limited
Number of surveys used in biomass estimates	11	27	30	29	1	1
Number of CEMP sites available	0	0	5	1	1	1
Monitoring and science required in the future?	• Recruitment Surveys. • Biomass Surveys • krill population connectivity with neighbouring Strata • Further predator monitoring					

*Note these biomass estimates were the lower one-sided 95th estimate due to only having a single survey.

Some members note these areas should have a stepwise increase towards the proposed limits (see para. XX)

Annex 1

Stock assessment modelling for *Euphausia superba.*

Dale Maschette

WG-FSA-2022/35 calculated a range of proportional recruitment scenarios based on the US-AMLR surveys. The values tested were based on 1) whether they included: daytime only, night time only, or all data, as well as 2) whether all years of data were used, only those years with Joinville Island strata sampled (1997, 2002-2011), or those years with Joinville Island strata sampled continuously (2002-2011). The Working Group noted that all data should be used, and that the scenarios presented within WG-FSA-2022/35 did not include the 2020 *RV Atlantida* data (WG-EMM-2021/12).

Here an addition to the Grym scenarios is presented in WG-FSA-2022/35 which includes both day and night data from all US-AMLR surveys which sampled Joinville Island strata (1997, 2002-2011) as well as the 2020 *RV Atlantida* survey. 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 (Table 1).

Table 1. Grym parameters and their initial values from WG-FSA-2021/39 Scenario 18. Note, natural mortality is calculated within the model as a function of proportional recruitment. It is included here to provide an expected range for comparing to those calculated for proportional recruitment values.

Parameter	48.1	Reference
First Age Class	1	Thanassekos (2021)
Last Age Class	7	Constable and de la Mare (1996)
t0	0	Constable and de la Mare (1996)
L∞	60mm	Constable and de la Mare (1996)
K	0.48	Thanassekos (2021)
Start growth period (dd/mm)	21/10	Thanassekos (2021)
End growth period (dd/mm)	12/02	Thanassekos (2021)

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Weight-length parameter - A (g)	0.000004	Maschette et al., (2021)
Weight-length parameter – B	3.204	Maschette et al., (2021)
Min length, 50% mature	37.6 mm	Maschette et al., (2021)
Max length, 50% mature	44.3 mm	Maschette et al., (2021)
Range over which maturity occurs	8mm	Maschette et al., (2021)
Start of spawning season (dd/mm)	15/12	Kawaguchi (2016)
End of spawning season (dd/mm)	15/02	Kawaguchi (2016)
Monitoring interval (dd/mm)	01/01 to 15/01	Thanassekos (2021)
Recruitment function	*Proportional*	
Mean proportional recruitment	0.5047205	This study
SD of proportional recruitment	0.2406113	This study
Natural Mortality range	0.5-1.1	Pakhomov (1995)
Min length, 50% Selected	30mm	Thanassekos (2021)
Max length, 50% Selected	35mm	Thanassekos (2021)
Range over which selection occurs	11mm	Thanassekos (2021)
Fishing Season (dd/mm)	01/12 to 30/11	Thanassekos (2021)
Reference Date (dd/mm)	01/10	Thanassekos (2021)
Reasonable upper bound for Annual F	1.5	Constable and de la Mare (1996)
B0logSD	0.361	Kinzley (2021)
Target Escapement	75%	Constable and de la Mare (1996)

Two gamma values are calculated to meet the requirements of the decision rules. The first, that the probability of the spawning biomass dropping below 20% of its pre-exploitation median level over a 20-year harvesting period is 10%; the second, that the median krill escapement in the spawning biomass over a 20-year period is 75% of the pre-exploitation median level. The final step of the decision rules is to select the lower of the two as the level for calculation of krill yield. The yields that satisfy the two rules are 3.38% and 6.8% respectively, choosing the lower of the two results in a precautionary yield of 3.38% for Subarea 48.1. Diagnostic and projection plots are shown in Figures 1-3, Table 2.

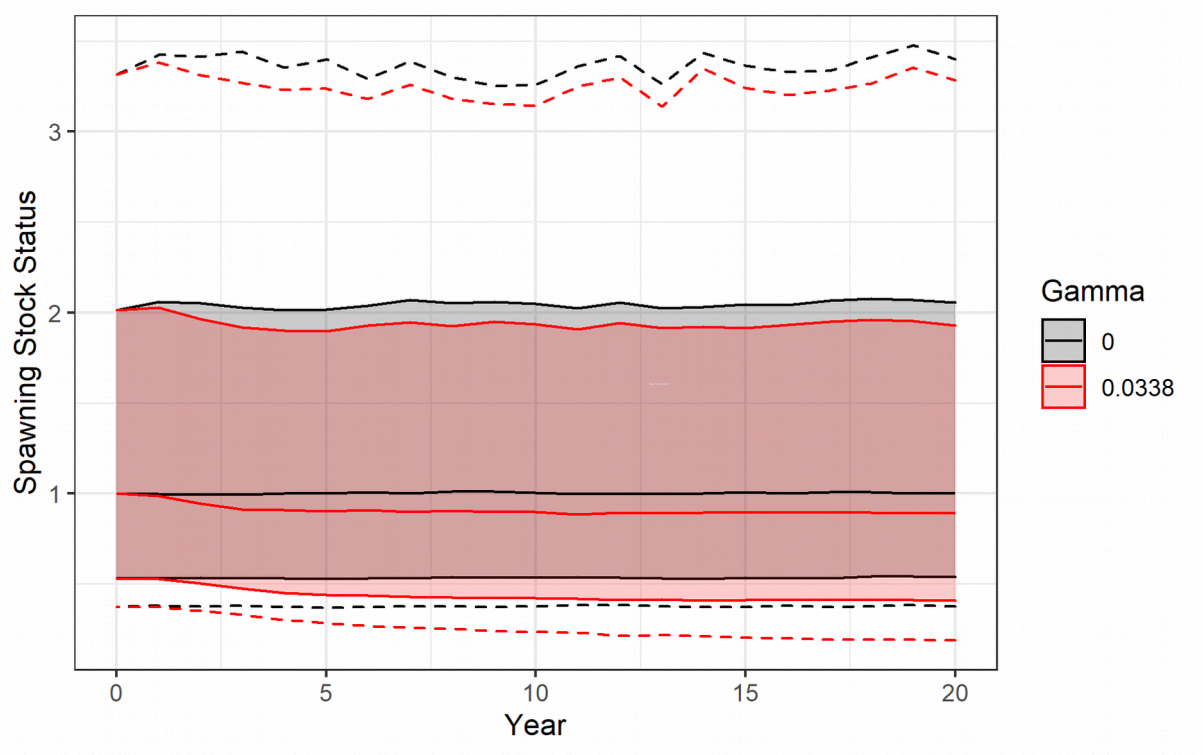

Figure 1: Spawning Stock Status for 20-year simulated krill population in Subarea 48.1 based on fished and unfished projection, showing median with 90% (shaded) and 97.5% confidence intervals (dashed).

Table 2: Summary statistics of mortality based on mean and standard deviation for proportional recruitment using an inverse-beta distribution.

R.mean	R.sd	M mean	M min	M max	M prop in range
0.5047	0. 2406	0.821	0.265	1.643	0.919

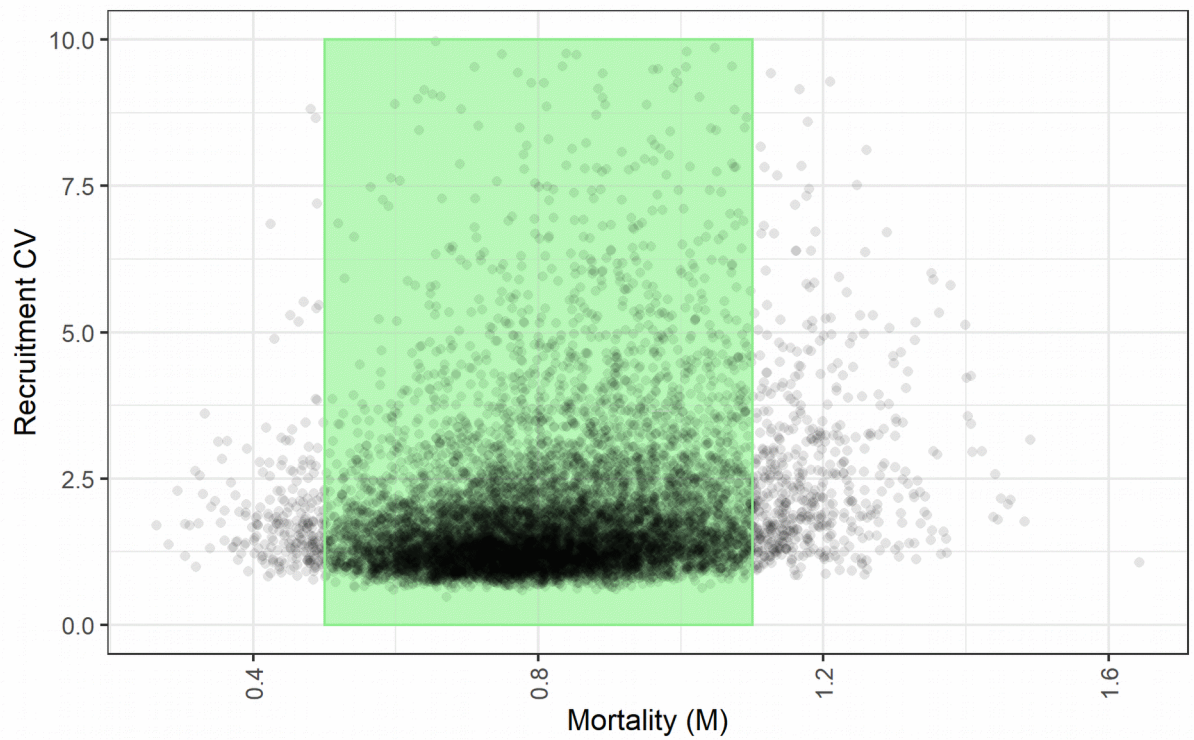

Figure 2: Comparison of Mortality and recruitment CV for mean and standard deviation of proportional recruitment using an inverse-beta distribution. Mortality range 0.5-1.1 in green.

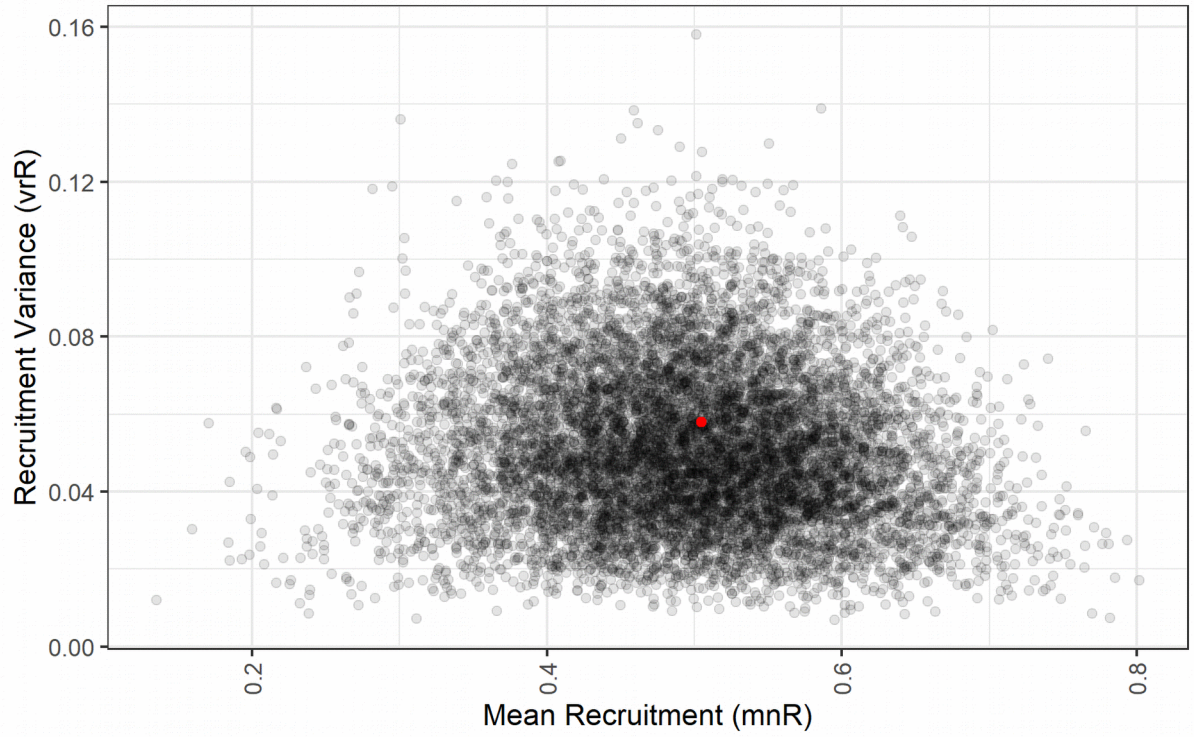

Figure 3: Estimated mean recruitment and recruitment variance for starting mean and standard deviation values for proportional recruitment using an inverse-beta distribution. Starting values for model indicated in red.

Annex 2

Yi-Ping Ying

The krill data limited management approach.

Working Group FSA noted that there was a requirement for a simplified explanation of the revised krill data limited management process used to provide advice to Scientific Committee and Commission. This Annex presents the workflow of the krill data limited management approach that has been in development in Scientific Working Groups and agreed by Scientific Committee.

The approach is comprised of three components, namely the biomass estimation, the stock assessment using the GYM model in R (Grym) and the Spatial overlap analysis (formerly called the Risk Assessment).

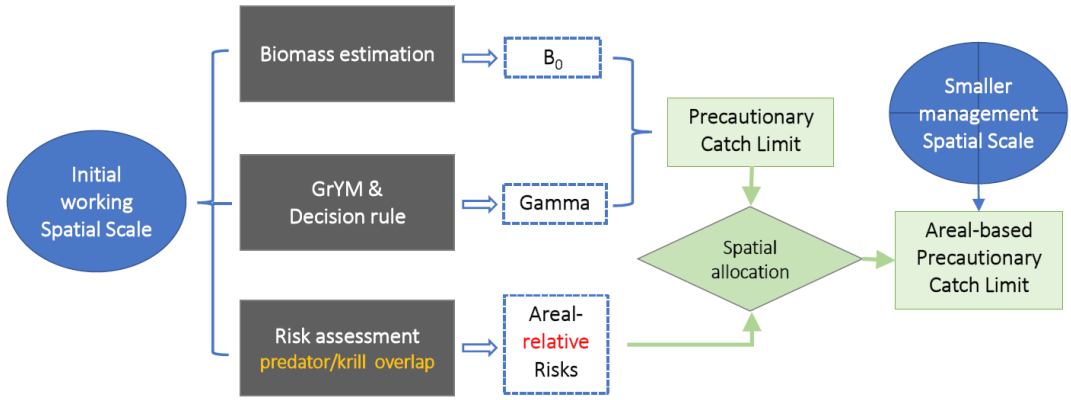

Figure 1. The three components and workflow of the revised krill management approach, as agreed at SC-CAMLR-40, Annex 8 (paragraph 3.25).

Biomass estimation

The first component of the data limited framework is biomass estimation, which is to estimate the standing stock biomass (B0) of the area-specific Antarctic krill stock in question. The B0 estimate for Subarea 48.1 used in the present krill management approach is an aggregated outcome.

The biomass for the adjusted 4 US AMLR strata (Elephant Island, Joinville Island, Bransfield Strait and South Shetland Islands West) is averaged over multi-year survey data to address the dynamic (periodical) nature of krill recruitment; the biomass for the remaining 3 strata (Drake passage, Powell Basin and Gerlache Strait) is the lower one sided 95% CI of the corresponding acoustic estimate based on one single survey.

Grym model assessment

The second component of the framework is the Grym (WG-SAM-2021) model assessment, which is used to estimate the precautionary harvest rate (Gamma) used in the 3-step CCAMLR decision rules developed to operationalize for krill management Paragraph 3 of Article II of the Convention (SC-CAMLR, 1990, Annex 4).

The rules as set out in Butterworth et al. (1992) and Constable et al. (2000):

- achieve a median (spawning) biomass of at least 75% of the pre-exploitation median (spawning) biomass over a 20-year period
- achieve a less than 10% possibility that the spawning biomass falls below 20% of its pre-exploitation median level over a 20-year period
- select the lower of the two values as the precautionary harvest rate of the specific krill stock

When the precautionary harvest rate or Gamma is derived, the Precautionary Catch Limit can simply be obtained by multiplying the B0 with Gamma.

Spatial Overlap Analysis framework (formerly called Risk assessment)

The third component of the framework is the Spatial Overlap Analysis framework which was originally developed by Constable et al. (WG-FSA-2016/47) and extended by Kelly et al. (WG-EMM-2018/37) in the East Antarctica.

The framework used for advice, as implemented and described by Warwick-Evans et al. (WG-EMM-2021/27), can assess the relative overlap of the localised impacts of fishing on both predators and krill, apportioning catch levels in space and time to account for the inverse of the overlap index. Areas with lower overlap are allocated higher proportions of the catch limit, and areas with higher overlap will have lower catch proportions.

The framework does not reduce, or increase, the overall catch limit in a region, but only alters the spatial (between strata) and temporal (between summer and winter) distribution of catch limits.