A preliminary assessment for mackerel icefish (*Champsocephalus gunnari*) in Division 58.5.2, based on results from the 2026 random stratified trawl survey.

Dale Maschette and Philippe Ziegler

Department of Climate Change, Energy, the Environment and Water, Australian Antarctic Division, 203 Channel Highway, Kingston, Tasmania, Australia. 7050

Email contact: dale.maschette@aad.gov.au

Recommendations

We recommend the catch limits in Conservation Measure 42-02 be set at 130 t in the 2026/27 season and 112 t in the 2027/28 season.

Abstract

The annual random stratified trawl survey was undertaken in Division 58.5.2 in the vicinity of Heard Island and McDonald Islands during March 2026. Based on data from this survey, this paper provides a preliminary assessment for mackerel icefish (*Champsocephalus gunnari*) population structure, abundance and yield in Division 58.5.2 using standard CCAMLR methods (CMIX and Grym).

The 2026 survey indicated relatively small abundances of 1 to 3-year old icefish. The 4+ cohort accounted for 69.7% of the population biomass, but is not used in the projections to estimate catch limits. Based on the Grym implementation, catches of 130 t in the 2026/27 season and 112 t in the 2027/28 season satisfy the CCAMLR decision rules.

Introduction

The fishery for mackerel icefish (*Champsocephalus gunnari)* around Heard Island and McDonald Islands in Division 58.5.2 began in 1997 (CCAMLR 2020). A random stratified trawl survey (RSTS) has been undertaken each year on the shallow plateau (<1000 m) in Division 58.5.2 to collect data on the distribution, abundance and population structure of Patagonian toothfish, mackerel icefish and other species.

Prior to 2011, the population of mackerel icefish in Division 58.5.2 generally exhibited one or two cohorts which dominated in abundance and biomass, and these were separated in age by one or two years (Welsford 2010, Welsford 2015, Williams *et al.* 2001). Since the maximum age of mackerel icefish in this region is thought to be around five years, strong cohorts have resulted in large variation of population abundance and the amount of production available to the fishery (SC-CAMLR 2010). However, between 2011 and 2016 at least four and often five cohorts were apparent in the population simultaneously, with no single cohort being overwhelmingly dominant (Maschette & Welsford 2019). Since 2016 there have been at least four cohorts present with normally the 2+ and 3+ being cohorts being the largest (Maschette & Welsford 2019, Appendix A Figure A.3).

This study provides an analysis of data collected in the 2026 survey to estimate the current abundance and cohort structure in the mackerel icefish population in Division 58.5.2 and its implications for yields in the fishery for the 2026/27 and 2027/28 seasons.

Methods

2026 survey

The design of the survey conducted in 2026 used the same principles as previous surveys in Division 58.5.2 (Maschette *et al.* 2026). The three strata where mackerel icefish are abundant (Gunnari Ridge, Plateau West and Plateau Southeast) were surveyed in daylight when icefish are close to the seafloor and most effectively sampled by demersal trawls (van Wijk *et al.* 2001). Survey hauls were allocated at random within each stratum, however a minimum spacing of 5 nautical miles between survey stations was specified to ensure hauls would not overlap. Icefish density estimates per haul ranged from 0 – 15.8 tons per km^2. Survey diagnostic information as outlined in Maschette *et al.* (2018) and endorsed by WG-SAM-18 (para. 3.11) are presented in Appendix A.

Assessment methods

The assessment method followed those agreed by SC-CAMLR (SC-CAMLR-XVI, para 5.70) for assessing yield in mackerel icefish, as published by de la Mare *et al.* (1998), and is identical to that used to estimate yields for mackerel icefish in Division 58.5.2 in previous years. Recent work undertaken as part of the krill management strategy (SC-CAMLR-38 Table 1, para 3.34) re-implementing the Generalized Yield Model (GYM) software in an open source software has resulted in the R package 'Grym' (Wotherspoon & Maschette 2020). Briefly, the Grym implements the same projections as the GYM software but uses an explicit solution with the composite trapezoidal quadrature rule rather than an adaptive Runge Kutta method, resulting in a more accurate projection (Maschette *et al.* 2020).

Assessment diagnostic information as outlined in Maschette *et al.* (2018) and endorsed by WG-SAM-18 (para. 3.11) are presented in Appendix B.

Cohort structure

A mixture analysis was undertaken using the CMIX procedure (de la Mare 1994, de la Mare *et al.* 2002) to estimate the density of fish in each age class. The contribution of each age class to the overall biomass was estimated by scaling each age class by its mean weight at length. The survey data were pooled to a single survey data set. As in previous years the sampling effort across strata was un-equal and the data are re-scaled so that the mean of the re-scaled data is the same as the stratified mean of the raw data. For each haul in k strata, the density data are re-scaled by the composite sampling fraction following de la Mare & Williams (1996):

$$D_{i,j} = d_{i,j} \frac{A_i}{\sum_k A_k} \times \frac{\sum_k n_k}{n_i}$$

where $D_{i,j}$ is the re-scaled density for haul i in stratum j, $d_{i,j}$ is the original density estimate for that haul, and A_i and n_i are the area and the number of hauls in stratum i respectively.

Weight-at-length relationship

The parameters of the weight-at-length relationship, a and b were re-estimated using the *nls*() function in R (R Development Core Team 2025) to fit the relationship:

$$W=aL^b$$

where W is the weight (kg) and L is the length (mm) of individual icefish taken during the 2025 survey.

Length-at-age

Maschette *et al*. (2024) evaluated von Bertalanffy growth parameters using survey data. Here we use their estimate for the period 2018-2024 as agreed by WG-FSA-IMAF-2024 (para. 3.7). The growth function estimated $L\infty$ of 559.1 mm, growth rate K of 0.294 and t_0 of 0.066.

Maturity

For the assessment, all fish (aged 1 – 3 years) were assumed to be mature so that the status of the whole stock is taken into account when estimating yield.

Natural mortality

Natural mortality was assumed to be 0.4 (de la Mare 1998).

Survey biomass and preliminary yield estimation

Using the method described in Constable *et al.* (2005, Appendix 1), a bootstrap algorithm was implemented in R to estimate the uncertainty in the total biomass (tonnes) of mackerel icefish over the survey area (Appendix B). The lower one-sided 95% confidence bound of the biomass estimate was then used as the estimate of the standing stock at the start of the projection period.

In combination with the biological parameters and other input settings shown in Appendix B (Table 3), the Grym package in R (Wotherspoon & Maschette 2020) was used to estimate the fishing mortality and corresponding catch that satisfies the short-term decision rule, i.e. that will result in a 75% escapement relative to a two-year projection with zero fishing mortality (Figure 1).

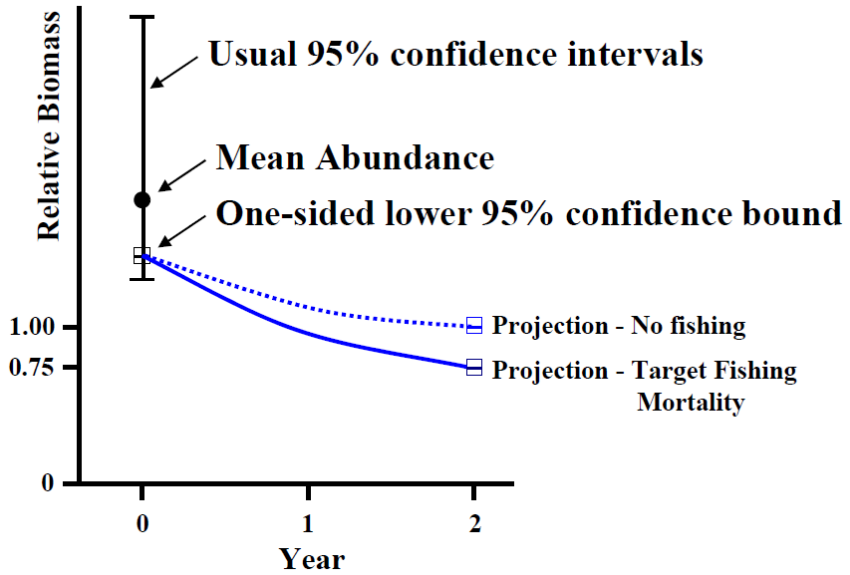


Figure 1. Decision rule for determining yield for mackerel icefish in year 1 and 2 after a survey (from Constable *et al.* 2005).

Few fish in the mackerel icefish population in Division 58.5.2 survive beyond age 4, and typically a drop in abundance between 3+ and 4+ cohorts is observed in consecutive surveys (Welsford 2011, Welsford 2015). Consequently, the assessment scenarios run here only includes the biomass estimated from the 0+ to 3+ cohorts.

Results

Cohort structure

The best CMIX fit to the survey length density data was achieved when the population was assumed to consist of four components, i.e. year classes 1+ through 4+ (Tables 1 and Appendix B). A substantial 4+ cohort dominated the 2026 survey (Figure 2). Overall fish density was estimated to be lower than last year (Table 2).

Table 1. Results of CMIX analysis of mackerel icefish from the 2026 random stratified trawl survey in Division 58.5.2.

	Mixture Components			
	1 (1+)	2 (2+)	3 (3+)	4 (4+)
Mean length (mm)	167	267	335	368
SD (mm)	12.4	14.9	16.6	17.4
Intercept of CV	8.3			
Slope of CV	0.02			
Total density (n.km^{-2})	29	185	273	612
SD (n.km^{-2})	14	37	1467	252
Sum of observed densities	1098			
Sum of expected densities	1099			

Table 2. Comparison of mean density of mackerel icefish (n.km^{-2}), and the CMIX estimate of overall and cohort density in the surveys conducted in 2024, 2025 and 2026 in Division 58.5.2. Note that the age of each year cohort increments by one year after the nominal birthdate of 1 December. For example, the 2+ cohort observed in 2025 is the same as 3+ cohort observed in 2026.

Year	Month	Overall Density		Cohort Density			
		Expected	Observed	1+	2+	3+	4+
2024	March	23155	23221	2331	20339	226	260
2025	March	4121	4156	73	494	3517	37
2026	March	1098	1099	29	185	273	612

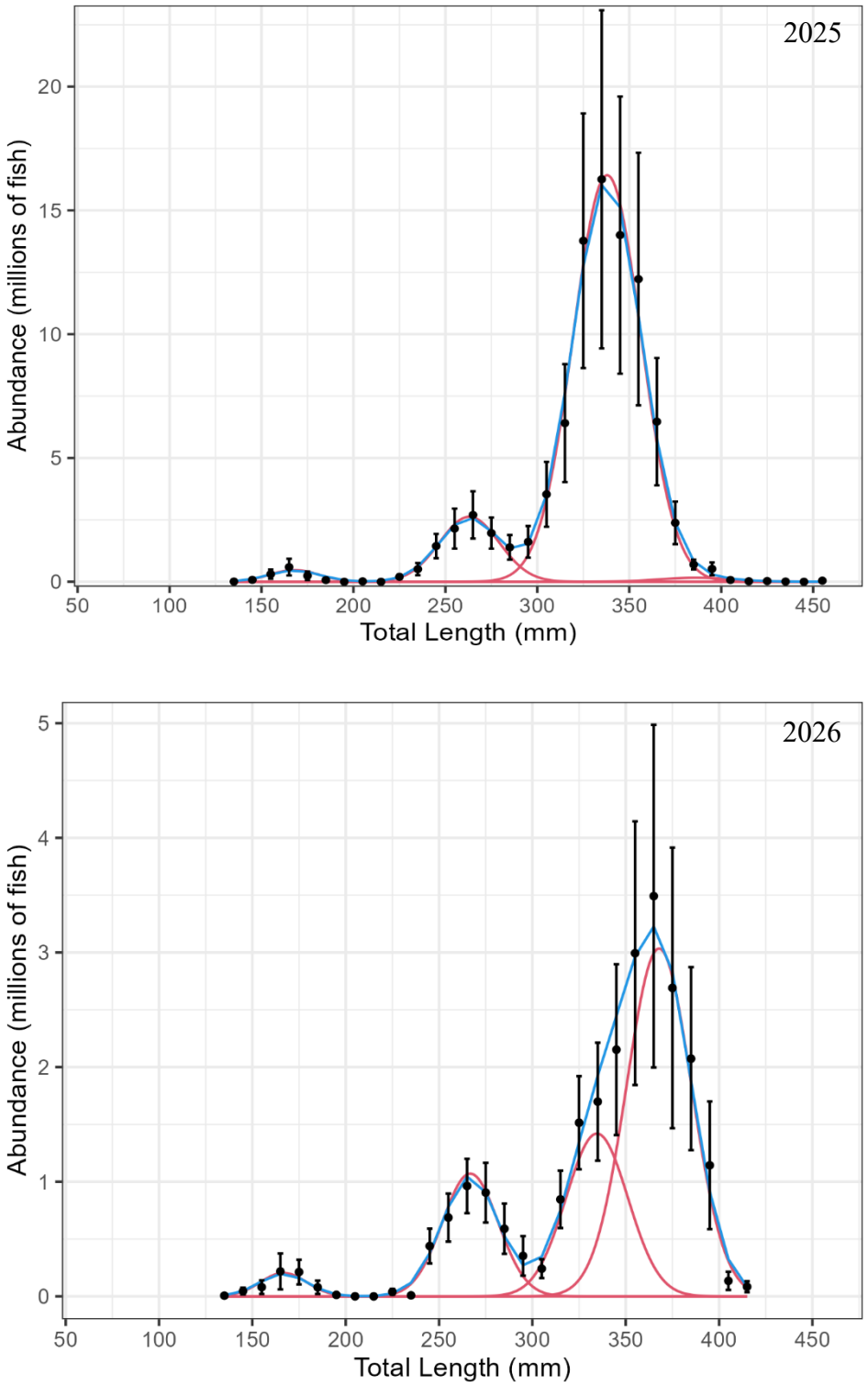


Figure 2. Observed and estimated length densities using CMIX for mackerel icefish in the surveys from March 2025 (upper panel) and March 2026 (lower panel). Shown are observed mean abundances at length (black circles, ± SE), fitted total abundances at length (blue lines), and fitted abundances at length for the different components (red lines).

Weight-at-length relationship

The weight-at-length relationship was re-estimated based on 2 748 icefish measured during the survey. The re-estimated weight-at-length relationship closely followed that of last year (Table 3, Figure 3).

Table 3. Estimates of the weight-at-length parameters of mackerel icefish fitted to data from each survey conducted in 2025 and 2026 in Division 58.5.2.

Model	Parameter	
	a	*b*
2025	2.842E-09	3.123
2026	1.002E-09	3.302

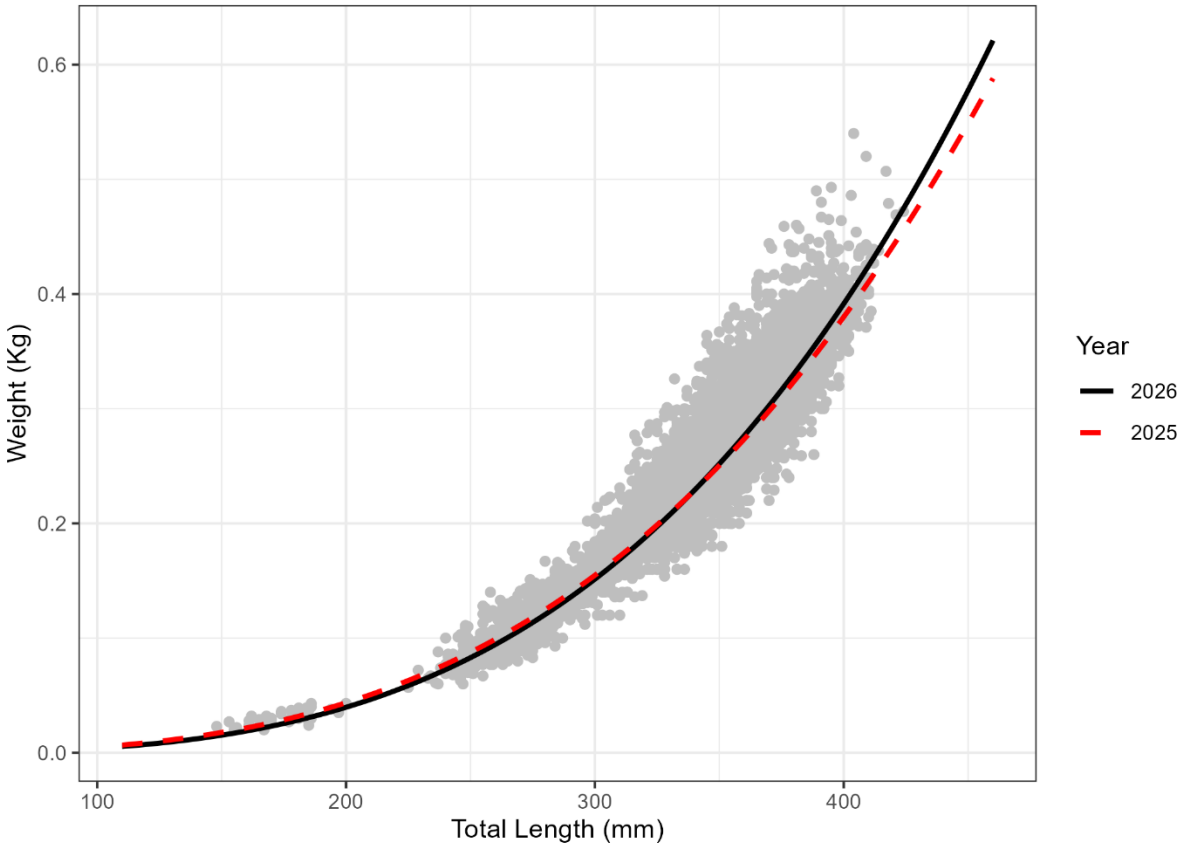


Figure 3. Weight-at-length data for mackerel icefish sampled during the 2026 random stratified trawl survey in Division 58.5.2 (grey dots) with fitted non-linear least squares regression (solid black line) and fitted regression to the 2026 survey. The 2025 survey fit is shown as a dashed red line.

Using the estimated weight-at-length relationship for 2026, the contribution of each age class to the overall biomass present during the survey was estimated, indicating that fish up to 3+ only constituted around 30.33% of the biomass present across the three icefish strata (Table 4).

Table 4. Proportion of mackerel icefish biomass at age in the 2026 random stratified trawl survey in Division 58.5.2.

Age class	Mean length (mm)	Density ($n.km^{-2}$)	Mean weight (kg)	Proportion of biomass (%)
1+	167	29	0.022	0.25
2+	267	185	0.103	7.30
3+	335	273	0.218	22.78
4+	368	612	0.297	69.67

Survey biomass and preliminary yield estimation

The biomass estimates with bootstrapped uncertainty for each icefish survey stratum and overall are shown in Table 5. The 2026 survey showed a much lower mean biomass, and lower one-sided 95% confidence interval biomass compared to 2025 (Appendix 1, Figure B.2).

Table 5. Abundance (tonnes) of mackerel icefish in Division 58.5.2 estimated by bootstrapping hauls from the 2026 random stratified trawl survey. SE = standard error; Lower CI & Upper CI = lower and upper confidence intervals respectively; LOS 95% CI = lower one-sided 95% confidence interval.

Stratum	Mean	SE	Lower CI	Upper CI	LOS 95% CI
Gunnari Ridge	2 808	799	1 364	4 381	1 577
Plateau SE	945	317	422	1 629	483
Plateau W	1 044	247	605	1 517	670
Pooled	4 797	994	2 998	6 845	3 254

The stock projection used the proportion of overall biomass made up by the 1+, 2+ and 3+ cohorts (30.33%, Table 4). This means that 987 t of the overall 3 254 t lower 95% CI (Table 5) was used in the Grym projection. A total of 419 t of icefish was caught after the survey was conducted, of which 210 t consisted of the 1+, 2+ and 3+ cohorts of the catch and was used in the forward projections. The Grym projection indicated that catches of 130 t in the 2025/26 season and 112 t in the 2026/27 season satisfy the CCAMLR decision rules (Table 6).

Table 6. Target fishing mortality rate and annual yields of mackerel icefish in Division 58.5.2, estimated to ensure 75% escapement over a 2-year projection period for the 1+, 2+ and 3+ cohorts using the Grym package, based on the parameters shown in Table B.2.

Initial biomass estimate (t)	**Target fishing mortality rate (yr^{-1})**	**Catch after survey**	**Yield (tonnes)**	
			2026/27	**2027/28**
987	0.1467	210	130	112

Discussion

Robustness of harvest strategy

Mackerel icefish are known to be a highly plastic species with differing population parameters across its geographic range (Kock 2005). Recent stock assessments indicate that population parameters vary through time within the same population (Maschette & Welsford 2019), which can pose a challenge for stock assessments (SC-CAMLR 2001). However, the current harvest strategy appears sufficiently conservative to avoid harvesting that would be inconsistent with the CCAMLRs objectives (Appendix Figure B.4). Estimating biological parameters regularly (such as Maschette *et al*. 2024) for this assessment also ensures that long-term environmental changes, such as those which are predicted to occur due to global climate change and may impact population characteristics, are accounted for.

Management Advice

The 2026 survey showed a large 4+ cohort in the mackerel icefish population in Division 58.5.2. This was to be expected given that the same cohort was present in the 2025 assessment as a strong 3+ cohort. As in previous years, this assessment assumes that the 4+ cohort is unlikely to be available to the fishery in the coming years, and therefore only uses the 1+ to 3+ cohorts in the forward projections. The 2026 survey also showed a large reduction in overall biomass, and such a large fluctuation in biomass is not uncommon in mackerel icefish (Maschette & Welsford, 2019).

Following the previous advice of CCAMLR, given the plasticity of this species and the differences seen in growth between time periods presented in Maschette *et al*. (2024), we estimated the catch limits using the most recent period of estimated growth (2018-2024).

The projections of the Grym indicated that catches of 130 t in the 2026/27 season and 112 t in the 2027/28 season satisfy the CCAMLR decision rules. We recommend that catch limits be set for these seasons based on this assessment, and a revised assessment be conducted based on survey data collected in 2027 since cohorts younger than age 3+ are not well selected by the survey gear.

Acknowledgements

We would like to express our thanks to the members of the Australian Sub-Antarctic Resource Assessment Group for helpful comments on the analyses and text in this manuscript. We would

also like to thank Tim Lamb for assistance with the data, as well as Austral Fisheries Pty Ltd, and the crew, observers aboard the FV *Cape Arkona* for conducting the survey hauls and collecting the data upon which this paper was based.

References

Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). 2020. Fishery Report 2020: *Champsocephalus gunnari* Heard Island (Division 58.5.2). CCAMLR Fisheries Report, CCAMLR, Hobart, Australia

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

Constable, A.J., A.T. Williamson, de la Mare W.K. 2002. *Generalised Yield Model: User's manual and specifications*. Australian Antarctic Division, Kingston, Australia.

Constable, A.J., T. Lamb, Williams R. 2005. Preliminary assessment of mackerel icefish (*Champsocephalus gunnari*) for the Heard Island Plateau region (Division 58.5.2) based on a survey in June 2005. *CCAMLR Document WG-FSA-05/39*

de la Mare, W.K. 1994. Estimating krill recruitment and its variability. *CCAMLR Science* 1: 55-70

de la Mare, W.K., Williams R. 1996. Estimates of absolute recruitment for Patagonian Toothfish (*Dissostichus eleginoides*) around Heard Island. Document *WG-FSA-96/38.* CCAMLR, Hobart, Australia

de la Mare, W.K., R. Williams, A.J. Constable. 1998. An assessment of the mackerel icefish (*Champsocephalus gunnari*) off Heard Island. *CCAMLR Science* 5: 79-101

de la Mare, W.K., A. Constable, E. van Wijk, T. Lamb, D. Hayes, Ronai B. 2002. *CMIX: Users manual and specifications*. Australian Antarctic Division, Kingston, Australia.

Kock, K-H. 2005. Antarctic icefishes (Channichthyidae): a unique family of fishes. A review, Part I. *Polar Biology 28:* 862–895

Maschette, D., Welsford D. 2019. Population dynamics and life-history plasticity of mackerel icefish (*Champsocephalus gunnari*) within the vicinity of Heard Island and the McDonald Islands. In: Welsford, D., J. Dell and G. Duhamel (Eds). The Kerguelen Plateau: marine ecosystem and fisheries. Proceedings of the Second Symposium. Australian Antarctic Division, Kingston, Tasmania, Australia. ISBN: 978-1-876934-30-9.

Maschette, D., Burch, P., Yates, P., Welsford, D.C. 2017. A preliminary assessment and revised growth model of mackerel icefish (*Champsocephalus gunnari*) in Division 58.5.2, based on results from the 2017 random stratified trawl survey. Document *WG-FSA-17/22.* CCAMLR, Hobart, Australia

Maschette, D., Earl, T., Sinègre, R. 2018. Diagnostic tools for *Champsocephalus gunnari* stock assessments. Document *WG-SAM-18/34.* CCAMLR, Norwich, United Kingdom.

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

Maschette, D. 2023. A preliminary assessment of mackerel icefish (*Champsocephalus gunnari*) in Division 58.5.2, based on results from the 2023 Random Stratified Trawl Survey. Document *WG-FSA-2023/10.* CCAMLR, Hobart, Australia

Maschette, D., Ziegler, P., Kelly, N., Wotherspoon, S., Welsford, D. 2024. A review of biological parameter estimates for mackerel icefish (*Champsocephalus gunnari*) in the vicinity of Heard Island and the McDonald Islands. Document *WG-FSA-2024/XX.* CCAMLR, Hobart, Australia

Maschette, D., Lamb, T., C., Ziegler P. 2026. Results from the 2026 random stratified trawl survey in the waters surrounding Heard Island in Division 58.5.2. Document *WG-FSA-2026/xx.* CCAMLR, Hobart, Australia

R Development Core Team. 2025. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Version 4.4.1

SC-CAMLR, 2001. Report of the Twentieth Meeting of the Scientific Committee (SC-CAMLR-XX), Annex D: Report of the workshop on approaches to the management of icefish. CCAMLR, Hobart, Australia.

SC-CAMLR, 2010. Fishery Report: *Champsocephalus gunnari* Heard Island (Division 58.5.2). Report of the Twenty-Eighth Meeting of the Scientific Committee (SC-CAMLR-XXVIII), Annex 8, Appendix T. CCAMLR, Hobart, Australia, p. www.ccamlr.org/pu/e/e_pubs/fr/10/appT.pdf.

van Wijk, E., T. Pauly, A. Constable, Williams R. 2001. Acoustic assessment of potential bias in abundance estimates of mackerel icefish from trawl surveys. Document *WAMI-01/5.* CCAMLR, Hobart, Australia

Welsford, D.C. 2010. Preliminary assessment of mackerel icefish (*Champsocephalus gunnari*) in the vicinity of Heard Island and the McDonald Islands (Division 58.5.2), based on a survey in March–April 2010, including a revised growth model. Document *WG-FSA-10/12.* CCAMLR, Hobart, Australia

Welsford, D.C. 2011. Data from recent trawl surveys in the vicinity of Heard Island and the McDonald Islands (Division 58.5.2), reveal an unusual cohort structure in the mackerel icefish (*Champsocephalus gunnari*) population. Document *WG-FSA-11/22.* CCAMLR, Hobart, Australia

Welsford, D.C. 2015. Preliminary assessment of mackerel icefish (*Champsocephalus gunnari*) in Division 58.5.2, based on results from the 2015 random stratified trawl survey. Document *WG-FSA-15/12.* CCAMLR, Hobart, Australia

Wotherspoon, S., Maschette D. 2020. Grym: R Implementation of the Generalized Yield Model. R package version 0.1.0.9000. github.com/AustralianAntarcticDivision/Grym

Appendix C changes in stock assessment parameters

Table C1: Table summarising evidence for changes in stock assessment and population parameters or processes that could be due to the effects of environmental variability or climate change in the mackerel icefish fishery in Division 58.5.2.

Parameter or process	Population	Stock assessment
<u>Recruitment:</u> Mean recruitment, Recruitment variability (σ_R and autocorrelation)	Icefish surveys show high interannual variability in year class strength. The drivers for interannual changes in recruitment have not been fully explored. Maschette & Welsford (2019) provided and initial hypothesis for the apparent shift in recruitment which occurred between 2008-2011.	Stock assessments for icefish assume no future recruitment in the two-year projection period. The stock assessments are based on the most recent estimate of recruitment from an annual trawl survey and therefore account for interannual variability in recruitment.
Biomass	As a result of highly fluctuating recruitment the population has show highly variable biomass through time showing up to three-fold increases or decreases from one year to another (See appendix B2).	The lower one-sided 95th confidence interval from a bootstrapped biomass estimate from the most recent trawl survey is used as the initial biomass in the stock assessment. This is done to account for the large interannual variability in observed in biomass estimates.
Length at maturity	Length at maturity has been investigated as part of Maschette *et al*., (2024) and has shown fluctuation in the size of maturity through time for both males and females with a generally increasing size of 50% maturity since 2008.	There is no maturity component in the stock assessment.
Stock-recruit relationship	The relationship between spawning stock and recruitment has not been thoroughly investigated.	Due to the stock assessment having no recruitment component there is no stock-recruitment relationship in the stock assessment.
Natural mortality	Natural mortality is uncertain. De la Mare (1998) estimated M to be around 0.30 for age 2 and above, and 0.64 for age 3 and above based on a Heincke estimate for survivorship from age a to all older ages but acknowledge that these estimates were highly uncertain due to recruitment and sampling variability.	Within the stock assessment M is fixed at 0.4.

Growth rates	Growth rates appear to have changed through time, with an increasing asymptotic average length (L∞) and a decreasing growth rate coefficient (K) (Maschette *et al*., 2024).	Within the time series of assessments growth has been estimated four times, as part of the 1997, 2010, 2017 stock assessments and in Maschette *et al.*, (2024)
Length-weight relationship	Annual Length-Weight relationships have shown some fluctuation through time although this is likely due to the presence or absence of size classes in the population (Maschette *et al.*, 2024).	In the stock assessment, estimates from the most recent trawl survey are used.
Sex ratio changes	No evidence of changes in sex ratio in the survey data through time (Maschette *et al.,* 2024).	The stock assessment is an unsexed model.
Spatial distribution	No evidence in the change of spatial distribution through time has been observed (Maschette *et al.,* 2024).	The stock assessment has no spatial components in the model.
Stock structure	Within Division 58.5.2 there have historically been three populations hypothesised. One on Shell Bank to the east of the plateau, one on Pike Bank to the north-west of the plateau and one on the southern part of the plateau centred on Gunnari Ridge. The Pike bank population was heavily over fished prior to the establishment of the Australian and French EEZs and shows little signs of recovery. The fishery is limited to the population on the southern part of the plateau. Gunnari Ridge consistently shows the largest aggregations of adult icefish with Plateau Southeast and Platea West showing a patchier distribution with all age classes present.	
Locations of spawning and site fidelity	Gunnari Ridge is the primary area for spawning mackerel icefish. Icefish seem to move in and out of this area throughout the year.	