Australian Government
Australian Fisheries Management Authority

Seventy third meeting of the Sub-Antarctic Resource Assessment Group (SARAG)

FINAL MINUTES
SARAG 73

18-19 AUGUST 2025

SUB- ANTARCTIC RESOURCE ASSESSMENT GROUP (SARAG)

CHAIR: Bruce Wallner

DATE: 18-19 August 2025

VENUE: Hadley's Orient Hotel, Hobart, Tasmania

ATTENDANCE

Members
Philippe Ziegler, AAD
Cara Masere, AAD
Rich Hillary, CSIRO
Tim Ward, IMAS (Day 1)
Brad Milic, Industry (ALF Pty Ltd)
Rhys Arangio, Industry (Austral Fisheries)
Elissa Mastroianni, AFMA

Executive Officer
Rachel Downes, AFMA

Invited Participants
Heather Patterson, ABARES
Pia Bessell-Browne, CSIRO
Dale Maschette, IMAS/AAD

Observers
Selina Stoute, AFMA
Natalie Couchman, AFMA (Day 1)
Steph Brodie, CSIRO, (Agenda items 4 & 5)
Dan Corrie, AFMA (Agenda items 4 & 5)
David Smith, Invited Observer, (Agenda item 7)
Bailey Bourke, AAD
Ryan Leadbetter, AAD

Agenda Item 1: Preliminaries

1.1 Welcome and Apologies

1. The seventy-third meeting of the Sub-Antarctic Resource Assessment Group (SARAG 73) was opened at 9:00am on 18 August 2025 by the Chair, Bruce Wallner.

2. The Chair welcomed members, invited participants and observers to the meeting. The Chair acknowledged the Muwinina people as the Traditional Owners and custodians of the land SARAG 73 met on, including their ongoing connections to Land and Sea Country and paid respects to their Elders past, present and emerging.

3. Members **NOTED** that the meeting was being recorded for the purpose of developing the meeting minutes.

1.2 Declarations of Interest

4. The Chair reminded members and observers of the procedure for declaring and managing conflicts of interest as outlined in the *Fisheries Administration Act 1991* and AFMA Fisheries Administration Paper No. 12, including that all members must declare any actual or perceived conflicts of interest (not limited to pecuniary gain) in the fishery at the commencement of the meeting and as soon as they become evident during the discussion of relevant agenda items.

5. SARAG **NOTED** declarations of interest from members, invited participants and observers at the start of the meeting (detailed at **Attachment A**).
6. The Chair noted that industry has a strong interest in stock assessment and total allowable catch (TAC) advice (Agenda Items 6 and 8). SARAG **AGREED** that while all members would discuss the technical input aspects of these items, industry members would leave the room whilst remaining RAG members finalised the RAG's TAC recommendations.

1.3 Adoption of Agenda

7. The agenda (**Attachment B**) was adopted without change.

Agenda Item 2: Actions Arising

8. SARAG **NOTED** the written update on the status of actions arising from previous SARAG meetings at **Attachment C**.

Agenda Item 3: Member Updates

3.1 AFMA update

9. SARAG **NOTED** the written update as provided by AFMA (**Attachment D**) as well as the update on Endangered, Threatened and Protected (ETP) interactions and gear loss reports from the past season.

10. **RECALLING** their previous (SARAG 69) consideration on seal interactions, SARAG **NOTED** that interaction numbers with seals have returned to low levels this last season. This confirms previous RAG advice that interaction levels are variable and generally low, with no clear geographic hotspots or seasonal patterns evident at present.

3.2 Industry member updates

11. SARAG **NOTED** the following verbal updates from industry members:

Australian Longline Fishing Pty Ltd

- The *FV Antarctic Aurora* has been fishing at HIMI and the *FV Antarctic Discovery* at MITF in the current season. Fishing in both fisheries has been positive during the season.

- Observations at HIMI have shown a higher abundance of smaller fish. A reduction in sea lice has also been observed.

- Although slower at the beginning of the season, catches at MITF improved during the season. Some good catches in area that have not seen effort previously.

- There was one occurrence of sperm whale depredation at MITF. No other sperm whale was reported for either fishery.

Austral Fisheries Pty Ltd

- The *FV Isla Eden* started the season in SIOFA at the South Indian Ridge fishing for a few days. The *FV Cape Arkona* undertook the RSTS as usual. The survey was positive in terms of high abundance of toothfish.

- The RSTS was followed by three weeks of icefish trawling. The icefish market has returned to pre-COVID demand.

- Observations at HIMI have noted an Influx of small toothfish coming into the fishery, similar to observations by Australian Longline Fishing Pty Ltd.

- A voluntary move on rule relating to killer whales has been deployed three times now and appears effective at mitigating depredation by killer whales.

- The catches at HIMI were good early in the season, however they dropped off over June-July.

- The *FV Cape Arkona* and *FV Isla Eden* are currently returning to port to unload. Both vessels will head back to HIMI for one more trip each this season. Austral is on track to catch the quota by early-mid November.

- Austral have implemented a reward system on board the vessels at HIMI to incentivise identifying skate tag recaptures by the crew. This season has shown a higher return of skate tags which is either a function of the area being fished or the reward system encouraging crew to look for tags.

- The winter weather at HIMI has been the worst in many years.

3.3 AAD update

12. SARAG **NOTED** the following updates from AAD:

- The paper 'Quantifying distinctions in the otolith shape of morphologically similar Sub-Antarctic grenadier species (Macrourus) to assess fishery observer identifications' by Connor et al., (2025) has established baseline otolith morphometric data of the four *Macrourus* species at HIMI. This work may be able to assist in differentiating older catch records by species where catch is listed at the genus level.

- The first paper on skate survival, ' Behavioral indicators of post-release survival in a deep-sea skate' by Appert et al., (2025) has been published

Agenda Item 4: Climate and Ecosystem Status Reports

13. SARAG **NOTED** a presentation by CSIRO on the Climate and Ecosystem Status Report Cards on the HIMIF and MITF (**Attachment E**).

14. SARAG **DISCUSSED** the climate report cards and **RECOMMENDED** that EEZ and HIMI Marine Reserve boundaries be included for sea surface and bottom temperature graphs in the reports. CSIRO agreed to include this recommendation in the future reports. SARAG **PROVIDED ADVICE** on observations for each fishery as per Agenda item 3 Industry Update.

15. SARAG **NOTED** that Austral vessels are participating in the Fishing Vessels as Ships of Opportunity Program (FishSOOP) project. Austral has developed and deployed 2000m sensors developed for the HIMI toothfish fishery which have been used to collect environmental data this current season. Austral are working with researchers on how to have data available in real time for meteorological forecasting purposes while maintaining confidentiality. Public availability of data will be deferred until 1 January each year.

ACTION ITEM – CSIRO to add in EEZ and marine park boundaries for sea surface and bottom temperature graphs on the Climate and Ecosystem Status Report Cards for next year.

Agenda Item 5: Climate Risk Framework Trial Draft Report – MITF

16. SARAG **NOTED** two presentations by AFMA on the Climate Risk Framework (CRF) and the CRF Trial Draft Report on the Macquarie Island Toothfish Fishery (MITF). SARAG **NOTED** the following:

    - Patagonian toothfish was selected as a trial species to inform the development of AFMA's CRF. The CRF Working Group met with industry representatives, management and scientific stakeholders at a meeting on 9 October 2024 to consider the trial application of the draft CRF to the MITF.

    - The trial draft assessment high-level outcomes, as provided in Table 1, particularly that the trial draft report assessed Patagonian toothfish in the MITF as 'very low'[1] risk in Step 1 of the trial.

    - Following extensive consultation, the draft CRF has been revised and is currently being considered by the CRF Working Group. The final CRF will be considered by the AFMA Commission in September 2025 with a view to be implemented in early 2026.

Table 1 Summary of draft CRF Species Assessment Report for Patagonian toothfish in the MITF

Risk assessment step	Results

[1] The term 'very low' replaces the term 'none' in the revised draft as a better reflection of overall risk.

Step 1 **Risk Assessment**	'Very low' – reduced from 'low' to 'very low' following incorporation of additional climate-related information
Step 2 **Identify Measures**	Various response measures identified– including robust data collection, spatial closures, and future MSE testing of the stock assessment.
Step 3 **Residual Risk**	The CRF Working Group advised to maintain the overall risk rating of very low, noting there are several measures identified at Step 2 that validate the climate risk score and establish ongoing monitoring that allows for timely and informed changes to management.
Step 4 **Advice to Commission**	The CRF Working Group recommended that no additional measures are required to mitigate the effect of climate change on the Patagonian toothfish in the MITF.

17. SARAG **DISCUSSED** and **PROVIDED ADVICE** on the application of the CRF to the MITF and the results of the Trial Draft Report. SARAG **AGREED** with the trial draft assessment of Patagonian Toothfish and suggested no changes. SARAG supported the CRF as a framework, and despite the 'very low' risk score for Patagonian Toothfish, recognised the benefit of undertaking the assessment, particularly as it informs consideration of potential climate impact scenarios in future MSE testing.

Agenda Item 6: MITF TAC setting

6.1 MITF toothfish stock assessment and TAC recommendation

18. SARAG **NOTED** a presentation by CSIRO on the updated analyses on growth and maturity (**Attachment F**) and noted that results are similar to previous years.

19. SARAG **NOTED** a presentation by CSIRO on the 2025 MITF Patagonian stock assessment (**Attachment G**). SARAG **DISCUSSED** the following:

    - The 2025 assessment estimates a female stock spawning biomass of 66%. While the overall stock status is above target, stock status varies among the two regions in the model (0.83 North vs. 0.36 South). Due to areas closed to fishing and poor fishing grounds, much of the northern region cannot be fished. The southern region dropping below the target reference point was noted; and there was discussion surrounding the single catch limit set for both regions and the potential need to reconsider this approach in the future if current trends continue.

    - It was noted that there is higher uncertainty in the size of the population in the northern region, compared to the southern region and this has been a feature of the assessment for an extended period due to the lower fishing effort in this area resulting in less tag releases and recaptures than in the south.

- The 2025 assessment estimated a lower stock status (66%) than the 2023 assessment (73%), as is expected in a fish down phase moving the stock towards the target reference point (in line with the CCAMLR harvest control rule (HCR)).

- A range of TAC options were presented that represent different catch split scenarios among the regions in the model. The recommended TACs from these options range from 395 to 428 t with an average of 408 t, a 11% decrease from the 2023 average of 459 t. This is driven by a lower stock status estimate compared to that in 2023. This relatively high variability in TAC through time is partly a consequence of the CCAMLR HCR, further highlighting the reason to move away from this rule;

- The work investigating potential alternative harvest control rules through MSE (Agenda Item 9) will address the issues relating to high variability in TACs among assessments and implications of the spatial differences evident in the fishery.

- Industry noted that on water observations show that toothfish in the MITF appear to mix less than toothfish at HIMI.

20. SARAG **ADVISED** that no further work is required prior to adopting the assessment and using it as a scientific basis for calculating a recommended TAC.

21. SARAG **CONSIDERED** the range of potential TACs as shown in Table 2, noting that there was no formal restriction on catches in different areas. SARAG noted advice from CSIRO that an 80:20 split represents actual average recent split in catches and that the actual difference in TAC between different options was very small.

Table 2 MITF TAC options with Aurora Trough TAC set at 150, 200 and 250 t with 10:90, 20:80 and 50:50 split for the North:South split

Aurora Trough	NMRL	SMRL	SNRL %	SMRL %	TAC
150	25	228	10	90	403
200	20	179	10	90	399
250	14	130	10	90	395
150	52	208	20	80	410
200	41	163	20	80	404
250	30	120	20	80	400
150	139	139	50	50	428
200	110	110	50	50	420
250	81	81	50	50	412
Average					**408**

22. SARAG **CONSIDERED** the information available on potential climate change impacts on the fishery, including that presented under Agenda Item 4, and reiterated their previous advice that current data collection, including updated length-weight relationships in stock assessments, and the ability to incorporate climate data in future modelling, along with applying the precautionary approach to the TAC setting process will enable AFMA to respond to changes in the fishery, including those due to climate change.

23. SARAG **CONSIDERED** the annual yields of Patagonian toothfish for 2026/27 and 2027/28 estimated to satisfy the CCAMLR decision rule for the species and for the different catch distribution scenarios across the MITF.

24. To manage conflicts of interest, Industry members left the room while remaining RAG members finalised the RAG's TAC recommendations.

25. On the basis that**:**

    - that even though there is uncertainty in the biomass in different areas, the assessment provides a reliable basis upon which to base management advice; and

    - with no significant changes to the fishery, their selection criteria should mirror the last TAC setting decision, with a TAC selected based on the average recent split (80:20) and assuming 200t taken in the Aurora Trough,

    SARAG **RECOMMENDED** a TAC of 404 t for Patagonian toothfish for the 2026/27 and 2027/28 fishing seasons in the MITF.

6.2 MITF bycatch trends and TAC recommendations

Bycatch trends over time

26. SARAG **CONSIDERED** the presentation provided by CSIRO on bycatch trends analysis over time (action item as listed at **Attachment C**) and **NOTED** the following:

    - Bycatch at MITF has been low and well below the bycatch limits set since 2007;

    - Most bycatch is below 500kg per year per species. The analysis filtered out bycatch per species which was less than 500kg per year; and

    - The analysis showed no concerning trends and that the current 50t bycatch limit per species remains appropriate.

27. SARAG **RECOMMENDED** that CSIRO
    - conduct this analysis biannually to support future TAC recommendations; and
    - include a climate change section in future TAC reports (for bycatch and target species).

Bycatch TAC recommendations

28. SARAG:

- **AGREED** that there had been no significant increase in bycatch for any species, or any trends to indicate current catch limits should be amended;

- **NOTED** that the results of the recent Ecological Risk Assessment showed no high-risk species in the MITF; and

29. Having regard to the above, SARAG **RECOMMENDED** bycatch limits as 50t per species for the 2026/27 and 2027/28 seasons of the MITF.

Agenda Item 7: HIMI toothfish stock assessment workplan and progress

30. SARAG **RECALLED** that SARAG 71 recommended a one-year toothfish TAC for the 2024/25 HIMI fishery season, along with a workplan that covered high and medium priority tasks._SARAG **RECALLED** the goal of the workplan is to provide an update HIMI toothfish stock assessment in 2026.

31. SARAG **NOTED** advice from AFMA and AAD that Australia also committed to specific stock assessment tasks at the 43rd meeting of the CCAMLR Scientific Committee Meeting. The CCAMLR workplan aligns with SARAG 71's recommended work plan.

32. SARAG **NOTED** the following overview of progress to date against the workplan:

    i. a technical working group (TWG) has been established to provide advice to SARAG on the appropriate use of tagging data within the integrated stock assessment;

    ii. CSIRO will be engaged to lead the development of a new spatially explicit stock assessment model working in partnership with AAD; and

    iii. extensive analysis has been undertaken by AAD that will guide the:

        - development of a spatially explicit stock assessment model;
        - move to a sex-based model; and
        - evaluation of the results of the more recently developed, randomised longline survey and potential integration into the stock assessment; and
        - sensitivity testing of data weighting settings in current stock assessment model.

33. SARAG **NOTED** advice from AFMA that given the level of work needed to comprehensively resolve the tagging related issues apparent in the stock assessment, resources are focused on developing a new stock assessment by 2026 rather than in 2025.

7.1 TWG Recommendations

34. SARAG **RECALLED** that the HIMIF Expert Technical Working Group (TWG) has been established to provide advice to SARAG on the appropriate use of tagging data within the integrated stock assessment of Patagonian toothfish at HIMI.

35. SARAG **NOTED** that the TWG has met twice and **CONSIDERED** the recommendations of the TWG (**Attachment H** and **Attachment I**).

36. SARAG **DISCUSSED** the following:

    - The scientific advice of the TWG is that moving to a spatially explicit and sex-based model will be pursuing a best practice approach for the HIMI stock assessment.
    - A bespoke model will build upon work from the MITF, but the differences between these models should be recorded.
    - A bespoke model will be run parallel to the Casal2 model, which will allow clear presentation of the specific limitations of Casal2 to deal with the tagging bias.
    - Under the workplan, the next TWG meeting is scheduled for December 2025. The timing of the next TWG will be revisited once progress has been made.

37. SARAG **ENDORSED** the TWG recommended approach for incorporating the available tagging data into the HIMI toothfish integrated stock assessment (TWG ToR 2), noting that this model will not use Casal2, will be spatially explicit, and will be sex-based.

7.2 Relevant additional work

Randomised longline survey results

38. SARAG **NOTED** a presentation from AAD on the 2024 randomised longline survey (RLS) results at the HIMI fishery.

39. SARAG **RECALLED** that investigating the integration of data from structured (i.e. randomised) longline fishing into the stock assessment is part of the high priority stock assessment workplan (SARAG 71) and was recommended by CCAMLR WG-FSA-IMAF 2024. Explicit guidance for industry on spreading fishing effort over a larger area to implement or approximate a random sampling strategy has been underway since the 2023/24 fishing season.

40. SARAG **DISCUSSED** the results of the 2024 RLS, and **NOTED** the following:

- The Chapman biomass estimate saw a sharp increase in 2024, particularly in the commercial hauls. The RLS has had some influence on skipper behaviour, for example in choosing to fish commercially in areas which coincided with the RLS research haul. However, it is hard to determine to what degree changed behaviour contributed to the biomass estimate, as opposed to actual observed increased fish abundance.

- The RLS is running again this season (2024/25), with slight alteration to spatial distances for vessel choice stations. The long-term goal is to include the RLS in the stock assessment if necessary to deal with the tagging data.

- It is difficult to categorise “atypical” fishing in areas chosen through the RLS. Some areas that are being fished through the RLS may have not been previously fished due to an industry expectation of lower abundance of fish and therefore lower catch per unit effort (CPUE) in that area.

- Over time, in tagging data, there have been different recapture rates across areas that are close to each other. This creates some difficulty in understanding the recapture rates in these areas, and how this relates to the goals of the RLS.

Data pipeline and weighting approach

41. SARAG **NOTED** a presentation by AAD on the work being undertaken by AAD to review the stock assessment workflow. This has been necessitated by the move from CASAL to Casal2 and is included in the HIMI Stock Assessment Workplan.

42. This work focuses on streamlining and improving robustness of the stock assessment in four main areas: the data pipeline, automated model generation, data weighting and diagnostics. SARAG acknowledged the benefits of this work and the efforts of AAD.

Sex-based stock assessment

43. SARAG **NOTED** a presentation by AAD on the current work being undertaken on the initial investigation of a sex-specific stock assessment model for Patagonian toothfish in the HIMI fishery (**Attachment J**). This work is also included in the HIMI stock assessment workplan.

44. SARAG **NOTED** that more work is needed before this model can be implemented, with specific questions on how to estimate growth requiring further consideration. The RAG acknowledged a need to compare methods for estimating growth but suggested more information was needed before committing to lots of additional otolith sampling or ageing.

45. SARAG **AGREED** that the differences between male and female toothfish warrant a sex-based model and **ENDORSED** this approach.

7.3 Papers to WG-FSA-2025 – relevant to HIMI toothfish stock assessment

46. SARAG **NOTED** the following papers proposed to be presented by AAD to the CCAMLR WG_FSA 2025 that relate to the HIMI toothfish stock assessment:

- Sex-based parameter updates;
- Spatial stock assessment analyses and work; and
- Spatial distribution model.

Agenda Item 8: HIMI TAC setting

8.1 HIMI toothfish TAC

47. SARAG **RECALLED** their advice from SARAG 71 (August 2024) including consideration of the available scientific analysis and the HIMI stock assessment workplan in making their TAC recommendation of 2,400t into the 2024-25 fishing year.

48. SARAG **NOTED** that following a lack of consensus during the WG-FSA-IMAF (7-11 October 2024) on a catch limit for Patagonian toothfish in Division 58.5.2 (i.e. HIMI), CCAMLR 44 set a lower catch limit than that recommend by SARAG 71 of 2,120t for the 2024/25 and 2025/6 seasons, for each season (see CM 41-08 (2024)). SARAG **NOTED** that in November 2024, the AFMA Commission also set a Patagonian toothfish TAC of 2,120t for the HIMIF for the 2024/25 season.

49. SARAG **CONSIDERED** the progress against the HIMI toothfish stock assessment workplan for updating the stock assessment, the advice of the Technical Working Group (TWG), and work currently underway on the HIMI toothfish stock assessments, discussed under Agenda Item 7.

50. SARAG **AGREED** that their previous climate change advice (that Toothfish catchability is predicted to increase due to the higher temperatures and body condition of toothfish caught has been above average) still applied this year. SARAG **CONSIDERED** the additional information on potential climate change impacts on the fishery presented under Agenda Item 4 .

51. SARAG **AGREED** that the conclusions drawn in 2024 still hold. If anything, the progress and results of additional work strengthens the RAG's position on the model-based (rather than biological) issues with the stock assessment and supports applying the same approach this year.

52. On the basis that SARAG's advice in 2024 on status of the stock and the likely negative bias in most recent stock assessment (2024) still hold, and in light of the work being undertaken under the HIMI stock assessment workplan, SARAG **RECOMMENDED** the TAC be set at the same level agreed by CCAMLR for Division 58.5.2 of 2,120t for 2025/26 season for Patagonian Toothfish in the HIMI Fishery.

8.2 HIMI bycatch TAC recommendations

53. SARAG **CONSIDERED** the results of the random stratified trawl survey (**Attachment K)** presented by AAD.

54. SARAG **NOTED** that biomass estimates for most of the by-catch species subject to a TAC were similar to the survey averages in recent years. The slightly lower biomass of grey rock cod was likely due a lack of sampling in their preferred areas, noting the patchy distribution of this species.

55. SARAG **NOTED** that there were no updated assessments for the species subject to a TAC. However, updates were planned for the skate bycatch assessment (2026 or 2027), grey rockcod and unicorn icefish (2026 or 2027) and both macrourid species groups (2027). SARAG **AGREED** it was a priority for exact timing on completion of the stock assessments to be confirmed by AAD.

56. Having **CONSIDERED** the relevant results of the RSTS (**Attachment K**), most recent biomass estimates, and information available on potential climate change impacts SARAG **AGREED** there was no evidence to indicate current TACs were no longer appropriate, and **RECOMMENDED** the bycatch limits as listed in Table 3 for the 2025/26 fishing season for the HIMI Fishery. Table 3 SARAG 73 recommended HIMI bycatch limits for the 2025/26 fishing season

ACTION ITEM – AAD to confirm timing of the skate bycatch assessment, grey rockcod, and both *Macrourus* spp at SARAG 75 (scheduled for August 2026)

Species	TAC (tonnes)
Caml grenadier (*Macrourus caml*) and Whitson's grenadier *(M. whitsoni)*	409
Bigeye grenadier (*M. halotrachys*) and Ridge tailed rattail (*M. carinatus*)	360
Unicorn icefish (*Channichthys rhinoceratus*)	1,663
Grey rockcod (*Lepidonotothen squamifrons*)	80
Skates and rays (*Bathyraja* spp.)	120
All other species (each)	50

8.3 HIMI icefish assessment and TAC recommendation

57. SARAG **CONSIDERED** the results of the random stratified trawl survey (**Attachment K**) and the 2025 HIMI mackerel icefish stock assessment (**Attachment L**) presented by AAD. SARAG **NOTED**:
    - The 2025 survey showed a slightly higher icefish mean biomass than 2024, with lengths and weights very similar to 2024.
    - There was no evidence for changes in stock assessment and population parameters or processes that could be due to the effects of environmental variability or climate change detected in the mackerel icefish fishery (see Appendix C of **Attachment L**)

- Stock assessment advice estimates that applying the CCAMLR decision rules results in a TAC for mackerel icefish of 1,429 t in the 2025/26 season and 1,126 t in the 2026/27 season in Division 58.5.2 (HIMI).

58. **CONSIDERING** the biomass estimates, climate change information in Appendix C of the stock assessment (**Attachment L**), and stock assessment advice SARAG **RECOMMENDED** a TAC of 1,429 t for the 2025/26 season and a TAC of 1,126 t for the 2026/27 for mackerel icefish in Division 58.5.2.

Agenda Item 9: MITF MSE project – candidate management procedures

59. SARAG **NOTED** a presentation by CSIRO providing an update on the MSE project (**Attachment M**).

60. SARAG **AGREED** that CSIRO should progress a tag-based model with spatial structuring, with results to be presented in 2026.

61. SARAG provided the following **ADVICE**, as requested by CSIRO, on the management objectives, timeframes, uncertainties required in the operating models (OMs), robustness tests and operational practicalities:

    - there is an industry preference for gradual TAC changes over shorter, sharper ones, and agreement that a 10% maximum annual change variance should be implemented.

    - target reference point should be in line with Commonwealth Harvest Strategy Policy.

    - assessing the economic impacts of different decision rules will be important, if possible. CSIRO advised that it would be possible to include a net present value (NVP) metric, and could involve measures of CPUE and price information. Industry needs to consider and provide advice on what would be most useful and appropriate for inclusion.

    - Spatial differences in biomass and recruitment should be considered, and this process may help tease out the impacts of spatial closures on the fishery and consider the usefulness of an RLS for the MITF.

    - Testing should include:

        - a range of options for frequency of TAC setting (i.e. between 2 and 5 years), and how often to do the assessment, noting the management procedure and stock assessment would be run in different years; and

        - options for overcatch and undercatch scenarios.

62. SARAG **NOTED** that including variability in a range of parameters in MSE testing is the best practice approach to building climate resilience into fisheries management.

Agenda Item 10: CCAMLR MSE for assessed toothfish fisheries

63. SARAG **NOTED** a presentation from AAD on the MSE for CCAMLR toothfish fisheries.

64. SARAG **RECALLED** that SC-CCAMLR 42 recommended an analyses of current and alternative toothfish decision rules, including building on the work of WG-FSA-2019/08, WG-SAM-2021/08, SC-CAMLR-38/15 and WG-FSA2023/28 to investigate alternative rules and assumptions about future recruitment, and addressing the recommendations 6.1 and 6.2 of the report of the independent review (SC-CAMLR-42/02 Rev. 2).

65. SARAG **RECALLED** that the recommendations 6.1 and 6.2 of the independent review are:

- 6.1 MSE should be conducted to investigate alternative periodicity of assessments, length of projection and alternative harvest strategies to achieve CCAMLRs objectives; and

- 6.2 CCAMLR continue to explore alternative methods for robustly estimating requirement used in projections.

66. SARAG **NOTED** that at its meeting in June 2025 ,WG-SAM discussed MSE for the existing and potential new CCAMLR decision rules for assessed toothfish fisheries, and that these discussions will continue at WG-FSA in October 2025.

67. SARAG **CONSIDERED** the recommendations from WG-SAM 2025 as detailed in the WG-SAM-2025 Preliminary Report (paragraphs 5.12, 5.13, 5.15, 5.17 and 5.18).

68. SARAG:

- **ADVISED** that having different operating and estimating models is considered best practice

- **AGREED** that Antarctic toothfish and Patagonia toothfish are different, and so different approaches to MSE may be appropriate.

- **ACKNOWLEDGED** the timing identified by WG-SAM to have MSE results for all assessed CCAMLR toothfish fisheries available by WG-FSA-2026, but **ADVISED** that taking additional time to pursue a best practice approach is preferable.

Agenda item 11: Ecological Risk Management Strategy – MITF and HIMIF

69. SARAG **NOTED** the advice from AFMA on the application of AFMA's Approach to Ecological Risk Assessment and Management policy to the MITF and HIMIF (Fisheries Management Paper 14 (FMP 14)). AFMA advised that in line with its policy, it had drafted a Sub-Antarctic Bycatch Strategy 2025 (the Bycatch Strategy), to replace the currently outdated Sub-Antarctic Bycatch and Discarding Workplan 2013.

70. SARAG **NOTED** that the most recent HIMI ERA was published in 2018. The MITF ERA is currently being finalised, but the required comments and corrections will not change the outcomes of risk ratings.

71. SARAG **RECALLED** that no species were identified as high risk in the ERA for either fishery. The Bycatch Strategy therefore focuses on monitoring bycatch species, ensuring continued effectiveness of current mitigation and identifying information gaps, and skates and rays (as an area of current interest).

72. SARAG **CONSIDERED** the draft Bycatch Strategy, in particular Section 6 'Bycatch workplan action items' and **RECOMMENDED** the addition of the following actions:

    a. Ongoing data collection by industry and observers and to consider observer training as needs arise for general bycatch species
    b. The stock assessment for skates and rays to be presented in 2027, or as available. Once results are available, AFMA, with the advice of SARAG and SouthMAC, to consider and incorporate results in bycatch limits.
    c. Post release survival research from AAD and UTAS to be presented in 2026

73. With the inclusion to the actions above, SARAG **AGREED** to the bycatch workplan action items as shown in **Attachment N.**

Agenda Item 12: HIMI offal discharge area

74. SARAG **NOTED** and considered and industry proposal for the creation of three new additional offal discharge zones (**Figure 1**).

75. The RAG reviewed the distribution of reported seabird bycatch and fishing effort with longline gear from 2014-2025 (combined). Over that period there were a total of 35 bycaught seabirds dead and 14 alive. No interactions or fishing effort was reported in the proposed new offal areas.

76. In considering the matter SARAG recalled the recommendation of SARAG 59 (May 2019) to create an offal discharge zone away from fishing grounds, in deep water, with offal discharged while steaming and below the waterline. The purpose of offal discharge zone was to mitigate wildlife

interactions, particularly with seabirds, whilst allowing the necessary operational activity to occur. In considering the proposal SARAG:

a. **NOTED** the offal discharge area has not changed since its first introduction in 2019 however since the expansion of the Heard Island and McDonald Islands Marine Reserve on 25 January 2025, industry can no longer discharge offal in most of the area. Industry advised that in some cases vessels may now have to expend up to two days of steaming to the remaining available offal discharge zone. The industry proposal advised that steaming time could be reduced by around 10 days across a season (across all vessels) with the introduction of the three new additional zones, thereby improving efficiency and reducing associated costs.

b. **AGREED** that the proposed three new offal areas meet the same criteria used by SARAG in 2019 to advise on whether the offal discharge areas and supporting arrangements would be effective in minimising wildlife interactions during offal discharge operations (**Table 1**). SARAG did not identify any other criteria or factors upon which to evaluate the proposal.

77. SARAG **RECOMMENDED** the addition of the three new additional small areas for offal discharge on the basis that:

a. the proposed three new offal discharge areas would likely be just as effective as the current offal discharge area in minimising wildlife interactions with longline fishing during offal discharge operations as:

i. all of the areas are in deep water and away from main fishing grounds;

ii. operational protocols around offal discharge remained the same: industry only discharge while steaming (i.e. not setting or hauling) and offal is always macerated and released below the waterline;

b. SARAG did not identify any additional environmental risks from included the three additional offal discharge areas; and

c. the proposed changes pursue economic efficiency.

Table 2. Factors considered under offal discharge zone proposals in 2019 and 2025

Factor	SARAG 59 (2019) Proposal	SARAG 73 (2025) Proposal
Area is in deep water, within HIMI EEZ. SARAG 73 confirmed that discharging in deeper water means the offal will more likely	✓	✓ water 2,000-3,000m deep

be diluted more quickly and dispersed.		
Area is away from fishing grounds	✓	✓ see Fig. 1 below
Offal only dumped while steaming	✓ Not an SFR condition, but industry practice	✓ Not an SFR condition, but industry practice
Offal always macerated and discharged below the waterline	✓ Not an SFR condition, but industry practice	✓ Not an SFR condition, but industry practice

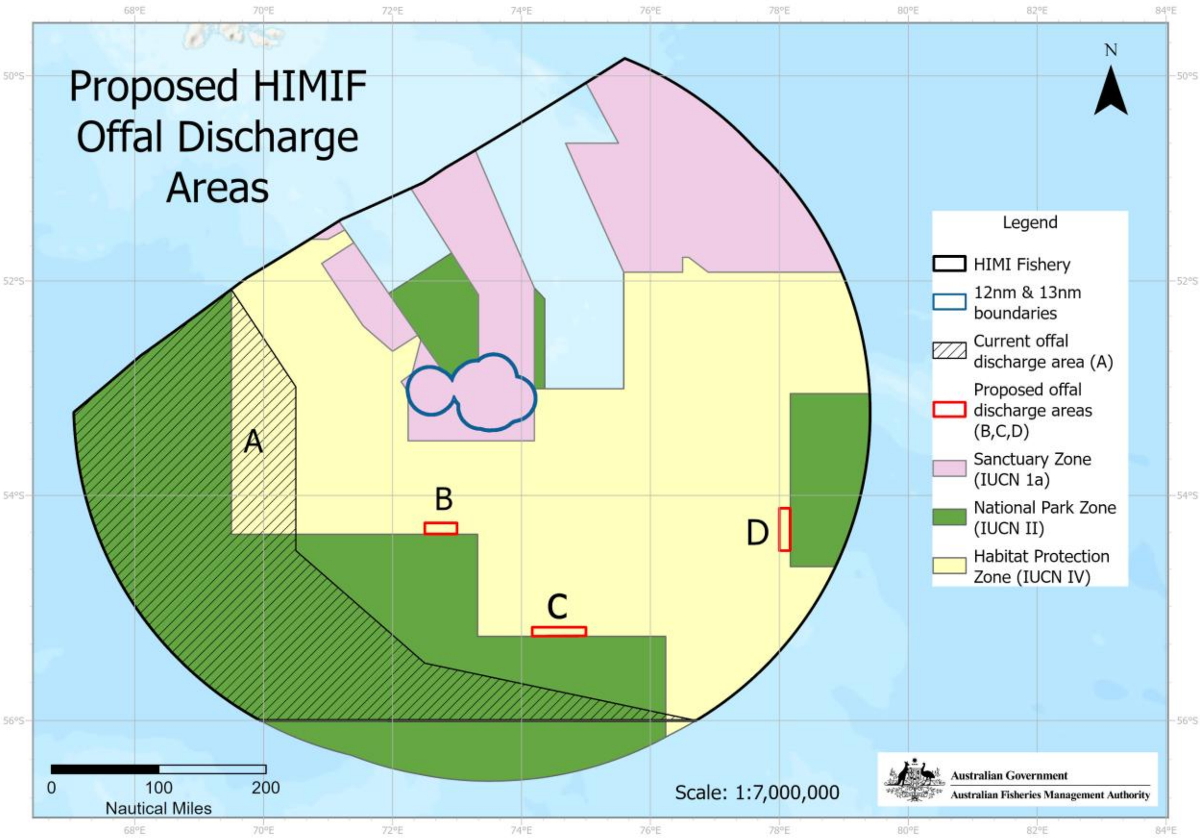


Figure 1. Map showing 2025 industry proposed offal discharge areas and HIMI Marine Reserve boundaries.

Agenda Item 13: Additional CCAMLR papers

78. SARAG **RECALLED** the proposed papers to be submitted by AAD to CCAMLR relevant to the HIMI toothfish stock assessment under Agenda Item 7.3

79. SARAG **NOTED** that the following additional papers would be submitted by AAD to the CCAMLR Working Group on Fish Stock Assessments 2025 (WG-FSA) including:

    a) 2025 HIMI Random Stratified Trawl Survey Report

    b) 2025 HIMI Icefish stock assessment

c) HIMI Macrourids - Otolith morphology

d) East Antarctic Season Report

e) East Antarctic Research plan

Agenda Item 14: Annual research statement and 5 year strategic research plan

80. SARAG **CONSIDERED** and **DISCUSSED** the current and potential research priorities for Sub-Antarctic fisheries. The RAG noted that the only currently funded research outside the Industry/FRDC Southern Ocean Industry Partnership Agreement was the MITF MSE work. SARAG also noted interest from industry in including the survey cost component (but not design or analysis) of the RSTS in the AFMA call for research.

81. SARAG **PROVIDED ADVICE** on the five-year strategic research plan as agreed in **Attachment O**

82. **SARAG DISCUSSED** and **PROVIDE ADVICE** on the revised annual research statement for 2026-27, in line with the 5-year strategic research plan, as agreed in **Attachment P**.

Agenda Item 15: Other business and next meeting

83. SARAG **NOTED** the value of holding an annual AAD/AFMA/Industry meeting and **AGREED** to hold one next year before SARAG 75 to be held in August 2026.

84. SARAG **AGREED** that SARAG 74 would take place between 26-28 May 2026.

85. The Chair closed the meeting at 2:05pm.

Attachment A

Table 4. Member, invited participant and observer declarations of interest as advised to date.

Name	Membership	Declared interests
Bruce Wallner	Chair	No pecuniary or other potential interests in sub-Antarctic fisheries.
Dr Philippe Ziegler	Scientific member	Employed by AAD and is the Fishery scientist responsible for Heard Island and McDonald Islands Fishery (HIMIF) work, including the HIMI stock assessments. Dr Ziegler has no pecuniary interest in the sub-Antarctic and his salary is not connected to any research grants noting that he is a principle and co-investigator on current FRDC projects. Dr Ziegler is also the scientific member of SouthMAC, and the Scientific Representative for Australia to CCAMLR.
Cara Masere	Scientific member	Member of the Fisheries team within the Southern Ocean Ecosystems Program at the AAD and has no pecuniary or other interests in the sub-Antarctic fisheries.
Rich Hillary	Scientific member	Employed by CSIRO and is the Principal Investigator of the Macquarie Island Toothfish Fishery (MITF) stock assessment. He is a member of AFMA's Southern Bluefin Tuna Management Advisory Committee (SBTMAC) and Tropical Tuna RAG. Dr Hillary advised that he has no pecuniary interests in the sub-Antarctic fisheries.
Tim Ward	Scientific member	Associate Professor in Fisheries Science, Institute Marine and Antarctic Studies, University of Tasmania Scientific Member, AFMA Small Pelagic Fishery Resource Assessment Group (SPFRAG) Principal Investigator (PI) on AFMA and FRDC research projects on SPF (e.g. Blue Mackerel DEPM) and other fisheries (Bass Strait Central Zone Scallop Fishery) Conservation Member, AFMA Great Australian Bight Management Advisory Committee (GABMAC) PI and Scientific Advisor, Department of Natural Resources and Environment Tasmania (Tasmanian Sardine Fishery) Conservation Member, South Australian Marine Scalefish Fishery Management Advisory Committee (MSFMAC) Member, MSFMAC Science Subcommittee Chair, AFMA Tropical Rock Lobster RAG

Name	Membership	Declared interests
Brad Milic	Industry member	Senior Manager of Policy and Resource at ALFPL which holds various fishing rights in, and operates vessels in, the sub-Antarctic fisheries and New and Exploratory fisheries under the jurisdiction of CCAMLR. Mr Milic owns a consultancy business that currently has a contract with Atlantis Fisheries Consultancy Group, involved with their clients' interests in the BSCZSF, and their fishery and chain of custody MSC accreditation.
Rhys Arangio	Industry member	Employed by Austral Fisheries P/L (Austral Fisheries) as the General Manager of Science and Policy. Austral Fisheries owns Statutory Fishing Rights (SFRs) in the Australian sub-Antarctic fisheries, which include waters under the jurisdiction of CCAMLR. Noting no changes since the last meeting, Mr Arangio is the Executive Officer of COLTO, as well as being a member of SouthMAC. He was not aware of any investigation or prosecution action by AFMA against his Company, nor of any legal action taken by his Company against AFMA, and has an interest in all agenda items.
Elissa Mastroianni	AFMA member	AFMA employee, no interests pecuniary or otherwise.
Rachel Downes	Executive officer	AFMA employee, no interests pecuniary or otherwise.
Heather Patterson	Invited participant	Employed by the Department of Agriculture, Fisheries and Forestry and is the author of the chapters relevant to SARAG in the Australian Bureau of Agricultural Resource Economics and Sciences (ABARES) Fishery Status Reports. Dr Patterson noted that she has no pecuniary interest in the sub-Antarctic fisheries.
Pia Bessell-Browne	Invited participant	Employed by CSIRO as an assessment scientist. Dr Bessell-Brown advised they are the principal investigator on the FRDC project 'Developing a harvest control rule to use in situations where depletion can no longer be calculated relative to unfished levels.' Dr Bessell-Browne noted she has no pecuniary interests in the sub-Antarctic fisheries.
Dale Maschette	Invited participant	Employed by IMAS and is a fishery scientist responsible for HIMI work including the HIMI icefish stock assessments. They hold no pecuniary interest in the subantarctic fisheries. Their salary is connected to two FRDC research grants related to Southern Ocean fisheries, one that they are the primary investigator on, another that they are a co-investigator on.
Selina Stoute	AFMA Observer	AFMA employee, no interests pecuniary or otherwise.
Dan Corrie	AFMA	AFMA employee, no interests pecuniary or otherwise.

Name	Membership	Declared interests
Nat Couchman	AFMA	AFMA employee, no interests pecuniary or otherwise.
David Smith	AFMA	Dr Smith consults on the fisheries and marine resources research and assessment. Dr Smith is an observer of the AFMA Research Committee, AFMA Climate Risk Framework Working Group and Commonwealth Research Advisory Committee. Dr Smith is an Adjunct Professor at IMAS, University of Tasmania and an Independent Fisheries Scientist for the SA Marine Scalefish Fishery Management Advisory Committee (MSFMAC). Dr Smith is also the chair of the MSFMAC Science Subcommittee and a coinvestigator to the FRDC Project 2021-042 Impacts of COVID19 on the Australian Seafood Industry: Extending the assessment to prepare for uncertain futures and FRDC Project 2021-077 Development of "guidance" for conducting stock assessments in Australia.
Bailey Bourke	AAD	AAD employee, no interests pecuniary or otherwise.
Ryan Leadbetter	AAD	AAD employee, no interests pecuniary or otherwise.

Attachment B

73rd Meeting of the Sub-Antarctic Resource Assessment Group (SARAG)

Hadley's Orient Hotel, 18-19 August 2024

Draft Agenda

Chair: Bruce Wallner

Approx time	Item	Purpose	Presenter
	Day 1 –		
9:00 (30 mins)	**1. Preliminaries**		
	1.1 Welcome and apologies	For noting	Chair
	1.2 Declaration of interests	For action	Chair
	1.3 Adoption of agenda	For action	Chair
	2. Actions Arising	For noting	AFMA
	3. Member updates	For noting	All
9:30 (30 mins)	**4. Climate and Ecosystem Status Reports – HIMI & MITF**	For discussion	AFMA/CSIRO
10:00 (45 mins)	**5. Climate Risk Framework trial draft report – MITF toothfish**	For advice	AFMA
10:45 (15 mins)	**Morning Tea**		
11:00 (2 hours)	**6. MITF TAC setting** **6.1.** MITF stock assessment and toothfish TAC recommendation **6.2.** **a)** Bycatch trends over time **b)** Bycatch TAC recommendations	For advice	CSIRO/AFMA
13:00 (45 mins)	**Lunch**		
13:45 (1 hour 30 mins)	**7. HIMI toothfish stock assessment workplan and progress** **7.1** TWG updates and recommendations **7.2** Relevant additional work **a)** Randomised longline survey results **b)** Data pipeline and weighting approach **c)** Sex-based stock assessment **7.3** Papers to WG_FSA 2025 – relevant to HIMI toothfish stock assessment	For advice	AAD/AFMA

Approx time	Item	Purpose	Presenter
15:15 (15 mins)	**Afternoon Tea**		
15:30 (2 hours)	**8. HIMI TAC Setting** **8.1** HIMI Toothfish TAC **8.2** HIMI Bycatch TAC recommendations **8.3** HIMI Icefish assessment and TAC recommendation	For advice	AAD/AFMA
17:30	**Day 1 Meeting Close**		

Approx time	Item	Purpose	Presenter
	Day 2 –		
9:00 (1 hour 30 mins)	**9. MITF MSE project – candidate management procedures**	For advice	CSIRO
10:30 (15 mins)	**Morning Tea**		
10:45 (1 hour 30 mins)	**10. CCAMLR MSE for assessed toothfish fisheries**	For advice	AAD
12:15 (45 mins)	**Lunch**		
13:00 (1 hour)	**11. Ecological Risk Management Strategy – MITF and HIMIF**	For advice	AFMA
14:00 (1 hour)	**12. HIMI offal discharge area**	For advice	Industry/AFMA
15:00 (15 mins)	**Afternoon Tea**		
15:15 (1 hour)	**13. Additional CCAMLR papers –** not relevant to the HIMI toothfish stock assessment		
16:15 (1 hour)	**14. Annual research statement and 5 year strategic research plan**	For advice	AFMA
17:15 (15 mins)	**15. Any other business and next meeting**	For advice	All
17:30	**Day 2 Meeting close**		

Attachment C

Item	Action arising	Status as at SARAG 71
1	**HIMI Data Collection Approaches** AAD to work with CSIRO, industry and AFMA to provide a paper to the next SARAG meeting outlining the broad scientific and resource costs and benefits associated with the implementation of different surveys and research proposals: Random Stratified Trawl Survey (RSTS review, including variations to the periodicity), continued refinement of the longline research hauls (RLH) and development of a time series of fishery independent longline hauls & Close Kin Mark Recapture (CKMR) (SARAG 66 – Agenda Item 5.4)	**Ongoing** No change since SARAG 71. SARAG 70 advised that it still considers this work as an ongoing priority for the HIMI Fishery. SARAG suggested revising the wording of the action item to reflect the development and continued refinement of the longline research hauls at HIMI which has been completed.
2	**Domestic Decision Rule HIMI** Development of a domestic decision rule for HIMI Toothfish TAC setting be explored going forward, noting this may require specific funding (SARAG 69 – Agenda Item 6).	**Ongoing** No change since SARAG 71. SARAG 70 noted that the progress of this action item is to some extent dependent on other work that is currently underway such as the MSE project for MITF and the exploration of different decision rules at CCAMLR.
3	**MITF Bycatch Analysis** Analysis of bycatch trends over time to be provided as part of the stock assessment to inform future SARAG considerations of bycatch limits for the MITF (SARAG 69 – Agenda Item 6).	**Complete** Analysis to be presented by CSIRO at SARAG 73 under agenda item 6.2
4	**Observer Data** Observer data to be analysed for gaps in observation (time of day) and develop paper on species specific diurnal patterns and risk for SARAG 70 (SARAG 69 – Agenda Item 7).	**Ongoing** No change since SARAG 70. SARAG 70 noted that the additional analysis required to further evaluate the risk of daylight setting to seabirds in MITF has not been undertaken due to lack of resourcing, further noting AFMA's advice that if such work remains a priority a scope needs to be developed for a discrete project. Such work may also include the scientific analysis of observer seabird data to support SARAG's ongoing risk-assessment of the season extension trail.
5	**Climate and Ecosystem Report Cards** CSIRO to revise the bottom temperature graphs in the next iteration of the Climate Ecosystem Status Reports for HIMIF and MITF to include three different upper and midwater column observations at 0-400m, 400-1000m and 1000-2000m depth (SARAG 71 – Agenda Item 4).	**Complete** This was completed by CSIRO after SARAG 71. The climate reports cards were updated as per the action item and can be found on the AFMA website. Climate-and-Ecosystem-Report-2024.pdf

6	**Resourcing of the HIMI toothfish stock assessment workplan** AAD to consider the required resourcing to complete the workplan following the CCAMLR 43 meeting and to discuss with SARAG in November (SARAG 71 – Agenda Item 5).	**Complete** A consolidated stock assessment work plan with some costings, together with a proposal to establish a Technical Working Group were provided to SARAG for comment in December 2024.
7	**Sub Antarctic Fisheries 5-Year SRP** AFMA to circulate the revised draft Sub Antarctic Fisheries 5-Year SRP (2025-2029) for comment out of session (SARAG 69 – Agenda Item 11).	**Ongoing** The draft strategic research plan was circulated to SARAG members for comment on 11 October 2023 with a response received from one member, however was not finalised. The draft annual research statement for 2026-27 and draft five-year research plan will be discussed at this meeting at Agenda Item 14.
8	**Observer Reports** AFMA to re-include a field for gear type reporting in the observer reports (SARAG 71 – Agenda Item 7).	**Complete** This issue was raised at SARAG 71 with regards to the RSTS, noting that 'gear type is no longer captured in the AFMA observer report and the CCAMLR observer report has ceased collecting this data, therefore gear type and mesh size data is not being captured.' The AFMA Observer team have advised that CCAMLR released a new observer report template last year. In section 3.1 of the new CCAMLR report template instructions ask the observer to compare the vessel's fishing gear with the gear described in the CCAMLR vessel notification details and provide details in the comments section if they differ, or if any non-standard gear is deployed by the vessel.
9	**RSTS Instructions** AAD to update the RSTS instructions to instruct skippers to provide reasoning when a reserve station is used and additional species sampling guidance (SARAG 71 – Agenda Item 7).	**Complete** This was actioned in the most recent RSTS instructions
10	**Draft MITF ERA** SARAG member comments on the draft MITF ERA to be compiled out of session and provided to CSIRO. The final draft MITF ERA to be recirculated to SARAG for finalisation (SARAG 71 – Agenda Item 8.1).	**Ongoing** Comments on the MITF draft ERA were received from members following SARAG 71. The comments are currently being reviewed and incorporated by CSIRO and AFMA. The ERA will be finalised in the coming months and will be recirculated to SARAG for finalisation.
11	**Live Release of Small Toothfish** The AAD and CSIRO undertake an analysis of historical data for HIMIF and MITF, respectively, of small fish under 1kg to better understand the proportion of catch that they make up and inform any changes required to sampling protocol (SARAG 71 – Agenda Item 12).	**Ongoing** Due to competing priorities and limited resources at both the AAD and CSIRO this has not progress since SARAG 71.

Australian Government
Australian Fisheries Management Authority

Attachment D

Sub-Antarctic Resource Assessment Group (SARAG)

Meeting 73 18-19 August 2025

Agenda item 3 Member Updates

AFMA update

Sub-Antarctic Fisheries Electronic Monitoring trial

86. The Southern Ocean Fisheries Electronic Monitoring Trial is now underway. The aim of the project is to undertake a comprehensive trial to understand the feasibility and applications of using EM as an independent data collection and logbook data validation tool in the SOF. The objectives of the project include:

    i. To deploy electronic monitoring systems on three commercial fishing vessels operating in the SOF to collect required fishing data for a period of up to one year.

    ii. To determine to what extent EM can be used to collect and verify current data requirements as previously identified by the fishery/SARAG.

    iii. To undertake a cost analysis for the use of EM and supplementing data collection programs to collect required fishery data in the SOF

    iv. To determine the potential of artificial intelligence machine learning (AIML) applications in the SOF.

87. A Southern Ocean Fisheries (SOF) Business Reference Group (SOFBRG) has been established by AFMA to provide advice and guidance to the project. The SOFBRG includes AFMA, industry, and science representatives. The Trial is scheduled to end 30 June 2026.

88. The project has successfully installed the EM systems on the three trial vessels within the SOF Fishery and AFMA has successfully received EM data from two vessels and undertaken a preliminary review of the footage to validate system functionality and that camera angles are optimal. Footage is high standard with good camera views of critical operational areas.

89. Further updates will be provided as the project progresses.

Longline fishing season extension trial MITF

90. SARAG will recall that at its meeting on 9-10 July 2024, the AFMA Commission approved a trial of a longline fishing season extension from 1 September to no later than 21 September in the MITF subject to specific arrangements. Fishing is yet to occur under the current iteration of the trial. AFMA management will advise when fishing does occur, and report of relevant data collected.

CCAMLR Exploratory Fishing Applications

91. Consistent with previous years, one Australian proposal was received for CCAMLR New and Exploratory fisheries was received. Notification of this proposal has been made to CCAMLR and will be considered at the coming CCAMLR meetings.

Amendment of gear specifications is the *Fisheries Management (Heard Island and McDonald Islands Fishery) Regulations 2002*.

92. AFMA is continuing to work with the Department of Agriculture, Fisheries, and Forestry to repeal the gear specifications contained in Part 4 of the *Fisheries Management (Heard Island and McDonald Islands Fishery) Regulations 2002*. It is intended for gear specifications to then be implemented through Statutory Fishing Right (SFR) conditions.

93. Current expectations are that the regulations will be considered by the Executive Council in early September 2025.

94. SARAG will recall that at its meeting in August 2024 (SARAG 71), SARAG
    i. deemed the HIMI Trawl gear modification that commenced in 2020 to be complete on the basis of the results showing that the new trawl gear had a reduced skate bycatch rate and reduced overall environmental impact compared to using the currently permitted trawl gear; and
    ii. recommended that AFMA progress the implementation of the new trawl gear, including consultation with SouthMAC, noting that AFMA needs to progress legislative amendments for the change to take effect.

95. SouthMAC, noting the advice from SARAG 71 (in 26(b) above), supported the use of the new trawl gear on an ongoing basis. Specifically, to allow the use of the following ground gear:
    a) bobbins that are 400 mm in diameter to be used. Current regulation prohibits the use of bobbins that are less than 520 mm in diameter; and
    b) rock hopper rubber discs that are 200 mm in diameter. Current regulation prohibits the use of rock hopper rubber discs that are less than 400 mm in diameter.

96. For the 2024/25 fishing season AFMA approved a further scientific permit to trial the modified gear to support ongoing investigations by industry to undertake further testing of the gear for the purpose of determining its benefits with regard to fuel efficiency compared to the old gear.

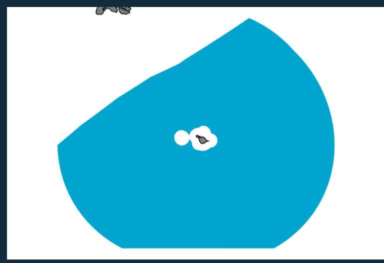
Export approval under the EPBC Act

97. On 26 June 2025 AFMA Management submitted an application to the Department of Climate Change, Energy, the Environment and Water (DCCEEW) for the assessment of the CCAMLR New and Exploratory Fisheries under the EPBC Act. The application is used by DCCEEW to assess the management arrangements for Australia's participation in the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) New and Exploratory Fisheries against the Guidelines for the Ecologically Sustainable Management of Fisheries – 2nd Edition and the requirements set out in relevant sections of the EPBC Act.

98. The CCAMLR New and Exploratory Fisheries was declared an approved Wildlife Trade Operation (WTO) under the EPBC Act on 24 December 2015 and has been re-approved two times. The current WTO accreditation expires on 27 November 2025.

99. DCCEEW released AFMA application for public comment between 7 July and 6 August 2025 (refer to DCCEEW's website: Australian export from New and Exploratory Fisheries in the CCAMLR Statistical Divisions 58.4.1 and 58.4.2 - DCCEEW). DCCEEW will consider any submissions received and where necessary seek further information from AFMA prior to finalising their assessment.

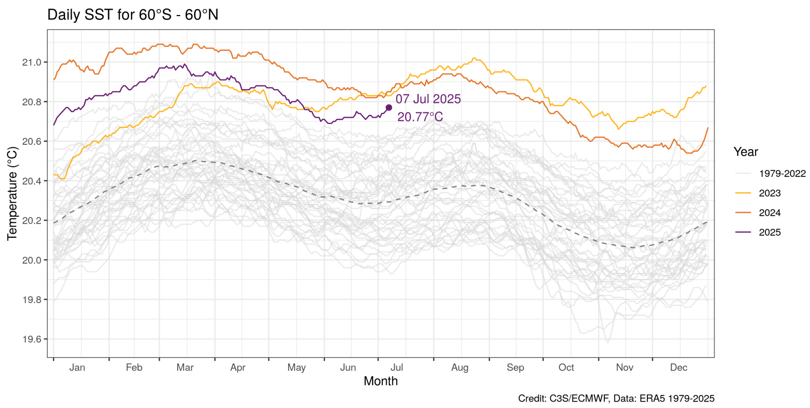
Heard Island and McDonald Islands Fishery



July 17, 2025

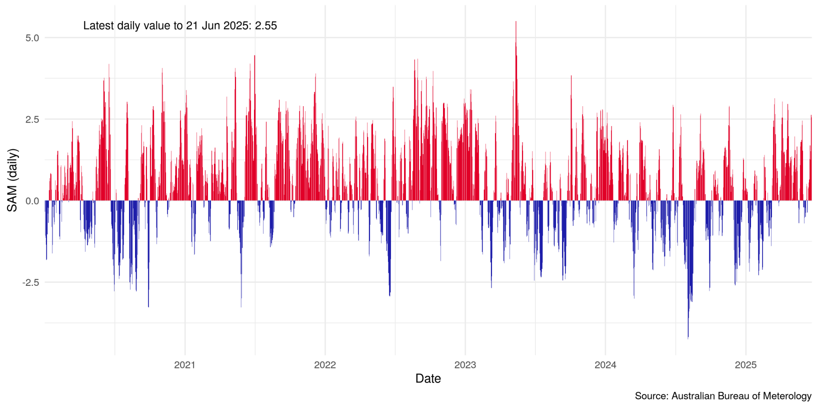
Historical Period

Climate Drivers: Sea Surface Temperature (SST)



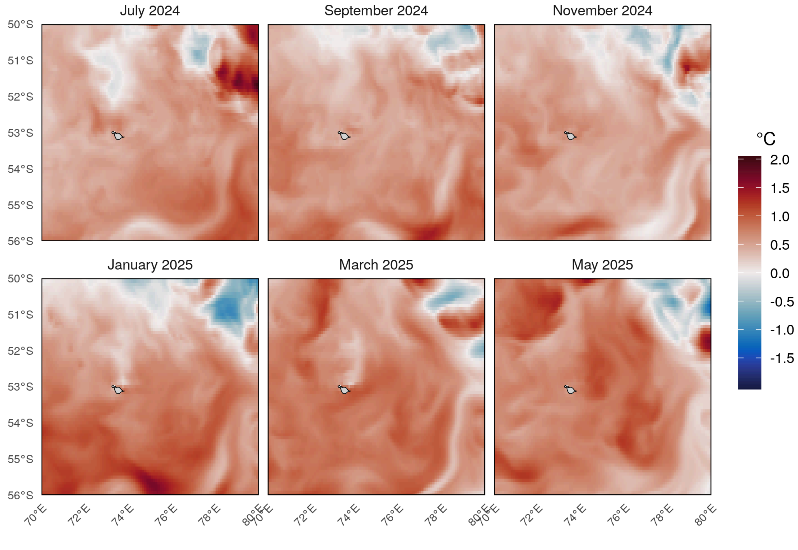
Global Sea Surface Temperatures (SST) have remained at record highs in 2025 (*Copernicus*)[2].

Climate Drivers: Southern Annular Mode (SAM)



Southern Annular Mode (SAM) indicates the N-S movement of westerly winds in the mid-high latitudes. Positive SAM (westerlies move south) have become more common over time and are associated with increased sea ice extent[1]. (*BOM SAM*).

Regional Dynamics: SST Anomaly

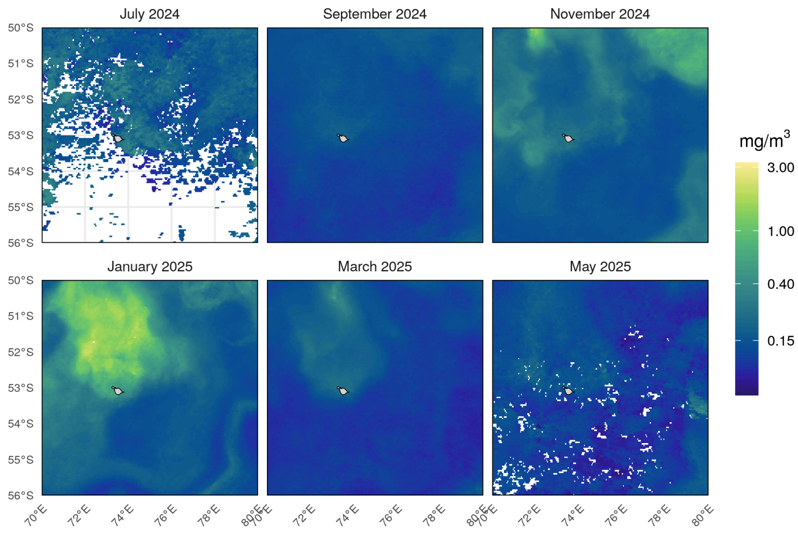


Source: CMEMS

Bi-monthly maps of SST anomalies show the HIMI region has largely been anomalously warm for the last year[3]. Anomalies are relative to 1993-2016. Patches of anomalously cool water can be seen in the north-east corner of the domain.

Marine heatwaves (MHW), regions of anomalously warm water, occurred across most of the region over the past year (*MHWtracker*)[5]. The impacts to the fishery are unknown.

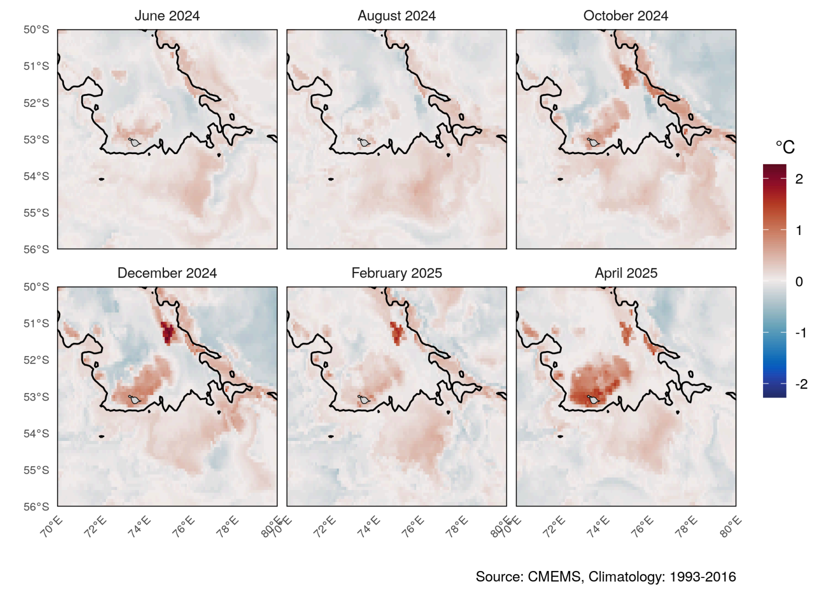
Regional Dynamics: Chlorophyll-a



Source: CMEMS

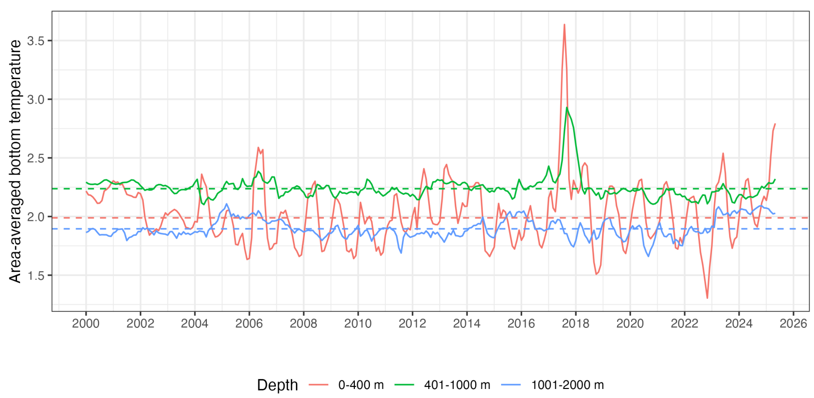
Bi-monthly maps of surface chlorophyll-a (log scale; mg/m3)[3]. Surface chl-a is a proxy for ecosystem productivity. Elevated surface chl-a persists in the north of the HIMI region throughout the year. Peaks in surface chl-a are notable during spring and summer months. White values indicate cloud cover.

Regional Dynamics: Bottom Temperature Anomaly



Bi-monthly maps of bottom temperature anomalies, with the 1000 m contour shown in black. The HIMI region has seen anomalously warm waters along the 1000 m contour in the north-east, in shallower waters around Heard Island, and in the southern part of the domain[3]. Anomalies are relative to 1993-2016. Patches of anomalously cool water can be seen on the plateau north of Heard Island. Low (high) temperatures can decrease (increase) toothfish catchability at a lag of ~6 months[4].

Regional Dynamics: Bottom Temperature Time-series



Area averaged monthly bottom temperature of three depth bins from Jan-2000 to May-2025[3]. The past year has been warmer than the longterm average (solid line) across both depth bins, but most notable at shallow (0-400 m) and deeper depths (1001-2000 m). 2℃ is the lower preferred temperature of Patagonian toothfish.

Observations

2025 observations

To be sourced from RAG.

2024 observations

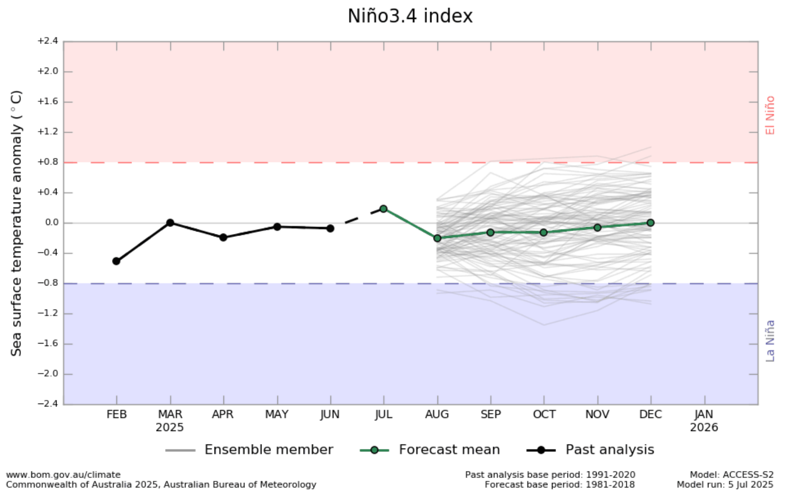
- Trips and catch rates have been standard.
- Catch sizes have been average, ranging 5-7 kh depending on the area.
- No Orcas seen; Minkes sighted; Sperm whale depredation occurred.

2023 observations

- Catches have been unremarkable, but in line with the past few years.
- Two size classes of toothfish in catches.
- Small increases in fish size compared to last year.
- Increaseased interferance from sea lice (depredation or eating bait).
- Orcas observed and the 90-mile move-on rule worked effectively.
- Sea ice observed to clear faster this year. No obvious signed of the impact of low sea ice extent.

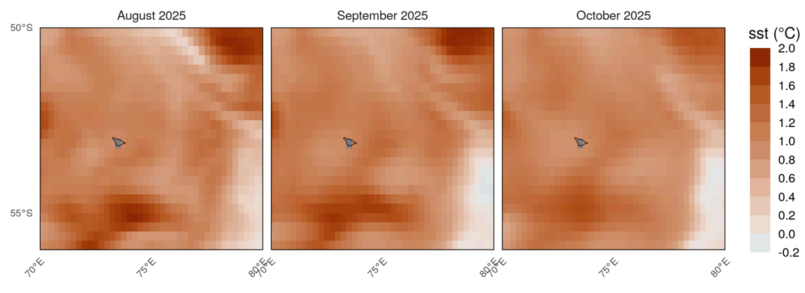
Future Outlook

Climate Drivers: Nino3.4



ENSO is forecast to remain neutral until December. During La Niña, the Southern Annular Mode tends to shift to positive phases, where westerly winds move south and result in strong circumpolar westerlies (BOM OceanT)[6].

Regional Dynamics: SST Anomaly



Model: ACCESS-S (sourced from the Bureau of Metereology)

Forecasts of SST anomalies for the next three months indicate anomalously warm conditions across most of the region (BOM)[7]. Forecasts are updated regularly.

Sources:

(1) http://www.bom.gov.au/climate/sam/

(2) https://pulse.climate.copernicus.eu/.

(3) Copernicus Marine Service.

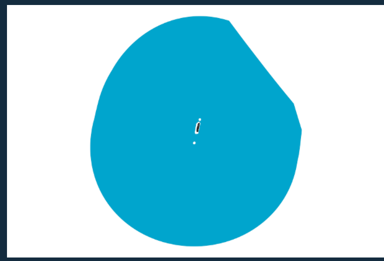
(4) https://www.frdc.com.au/project/2019-169

(5) https://www.marineheatwaves.org/tracker.html.

(6) http://www.bom.gov.au/climate/ocean/outlooks/?index=nino34

(7) https://access-s.clide.cloud/

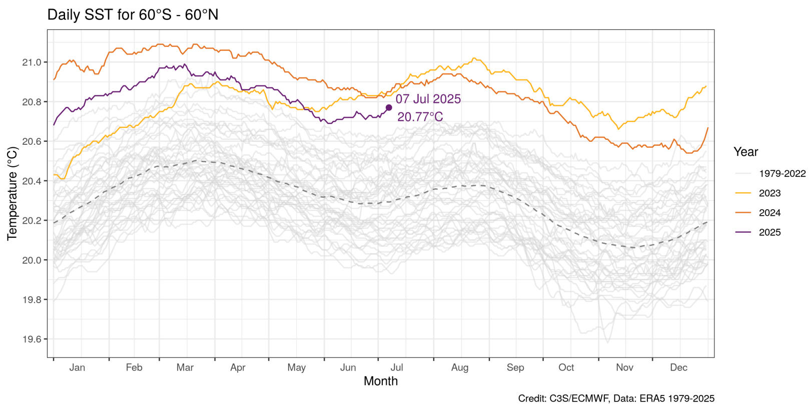
Macquarie Island Toothfish Fishery



July 17, 2025

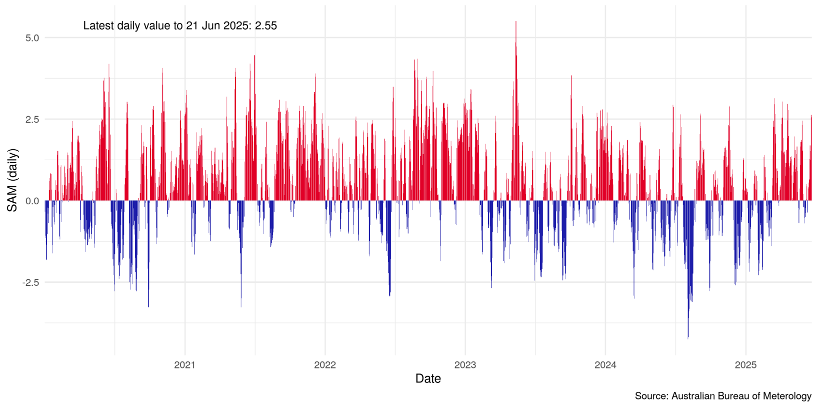
Historical Period

Climate Drivers: Sea Surface Temperature (SST)



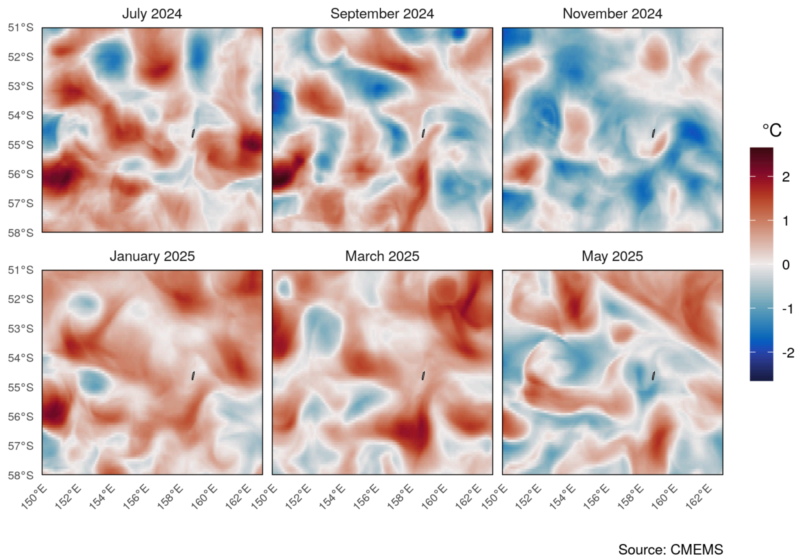
Global Sea Surface Temperatures (SST) have remained at record highs in 2025 (*Copernicus*)[2].

Climate Drivers: Southern Annular Mode (SAM)



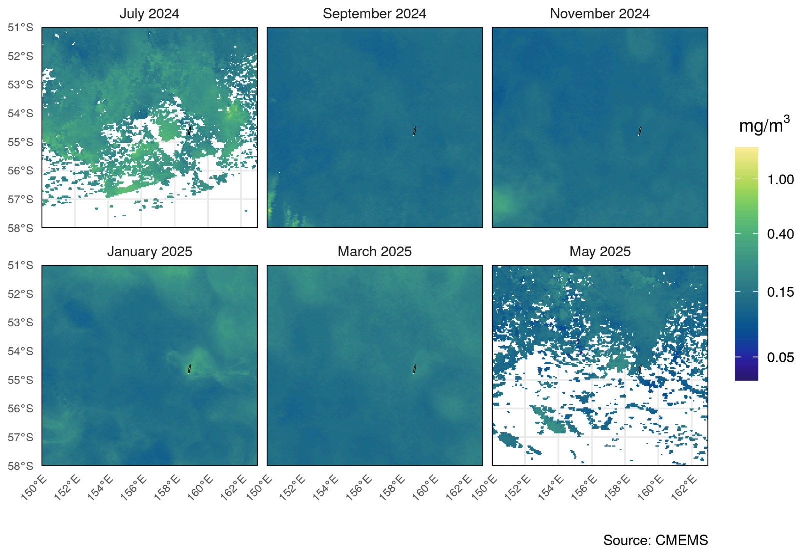
Southern Annular Mode (SAM) indicates the N-S movement of westerly winds in the mid-high latitudes. Positive SAM (westerlies move south) have become more common over time and are associated with increased sea ice extent[1]. (*BOM SAM*).

Regional Dynamics: SST Anomaly



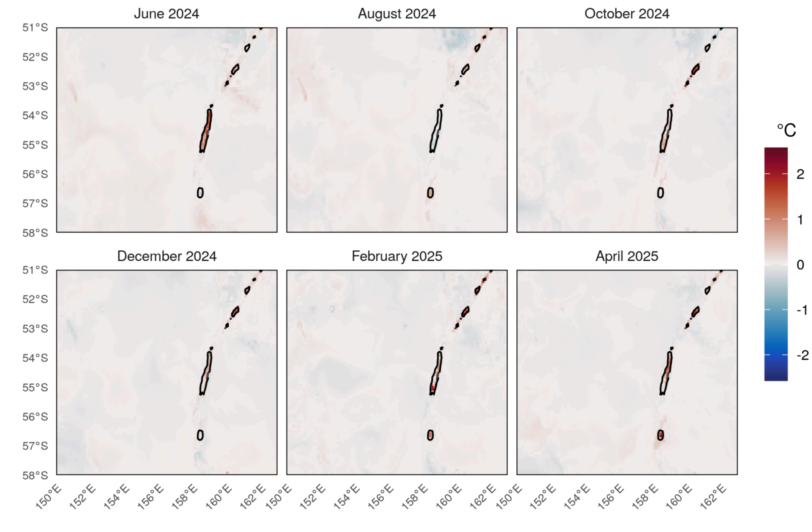
Bi-monthly maps of SST anomalies show the MACA region has seen a series of both anomalously cool and warm waters over the last year[3]. Anomalies are relative to 1993-2016.

Regional Dynamics: Chlorophyll-a



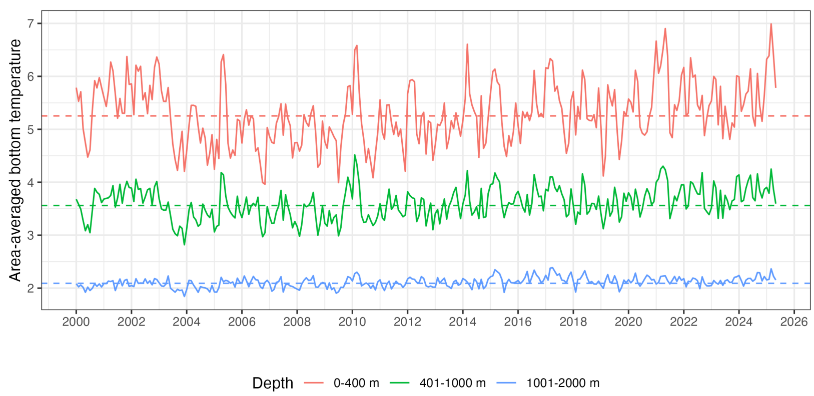
Bi-monthly maps of surface chlorophyll-a (log scale; mg/m3)[3]. Surface chl-a is a proxy for ecosystem productivity. Elevated surface chl-a is patchy, with higher values seen in summer and around the island. White values indicate cloud cover.

Regional Dynamics: Bottom Temperature Anomaly



Bi-monthly maps of bottom temperature anomalies, with the 1000 m contour shown in black. Bottom temperatures of the broader MACA region have been, in general, slightly warmer than average. More intense anomalies are seen in waters shallower than 100 m, with this region often anomalously warm over the past year[3]. Anomalies are relative to 1993-2016. Low (high) temperatures can decrease (increase) toothfish catchability at a lag of ~6 months[4].

Regional Dynamics: Bottom Temperature Time-series



Area-averaged monthly bottom temperature at three depth bins from Jan-2000 to May-2025[3]. The past year has been warmer than the longterm average (solid line) across all depth bins. 2℃ is the lower preferred temperature of Patagonian toothfish.

Observations

2025 observations

To be sourced from RAG.

2024 observations

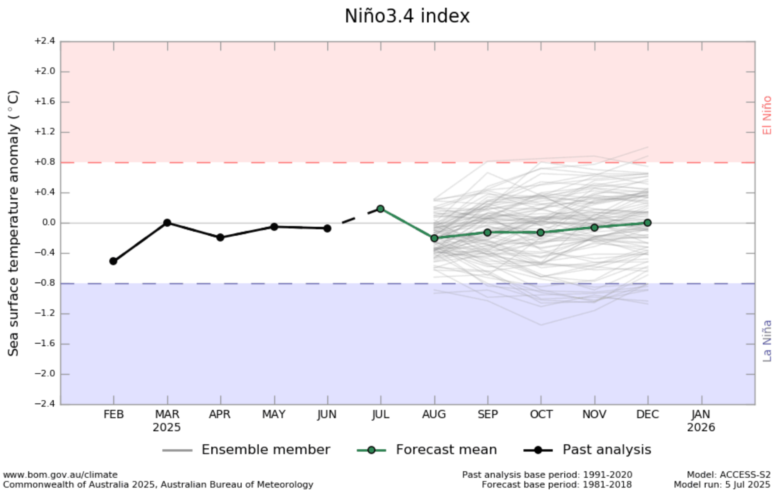
- None recorded.

2023 observations

- Initial fishing efforts finding good sized fish.
- No obvious signs of the impact of low sea ice extent.
- The interaction and location of currents in this region are of interest, and a better indicator of ecosystem and fishing conditions compared to sea ice extent.

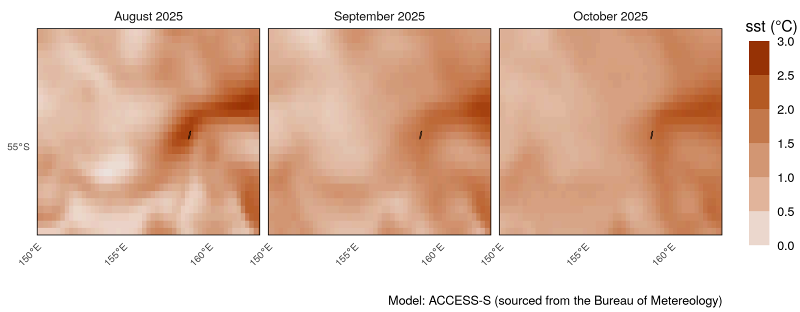
Future Outlook

Climate Drivers: Nino3.4



ENSO is forecast to remain neutral until December. During La Niña, the Southern Annular Mode tends to shift to positive phases, where westerly winds move south and result in strong circumpolar westerlies (*BOM*)[5].

Regional Dynamics: SST Anomaly



Forecasts of SST anomalies for the next three months indicate anomalously warm conditions across most of the region (*BOM*)[6]. Forecasts are updated regularly.

Sources:

(1) http://www.bom.gov.au/climate/sam/

(2) https://pulse.climate.copernicus.eu/.

(3) Copernicus Marine Service.

(4) https://www.frdc.com.au/project/2019-169

(5) http://www.bom.gov.au/climate/ocean/outlooks/?index=nino34

(6) https://access-s.clide.cloud/

Attachment F

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Updated biological relationships for the 2025 stock assessment of Macquarie Island Patagonian toothfish

P. Bessell-Browne & R. Hillary

19 June 2025

Citation

Bessell-Browne, P. & Hillary, R. (2025) Updated biological relationships for 2023 stock assessment of Macquarie Island Patagonian toothfish. Technical paper presented to the SARAG, 18-19 August 2025, Hobart, Australia.

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Contents

1 Background

In this paper we detail updates to two key biological relationships that are essential for the Macquarie Island (MI) toothfish stock assessment: growth and maturity. For growth, we have ageing data up to and including 2023; for maturity we have data up to and including 2024.

2 Growth relationships

We now have ageing data from 1996 up to and including 2023 and so we are in a position to update the male and female growth relationships required for the stock assessment. There are 4,534 female and 2,934 male length-age measurements. That is an additional 450 female and 255 male measurements compared to the previous growth update in 2023.

2.1 Data & Methods

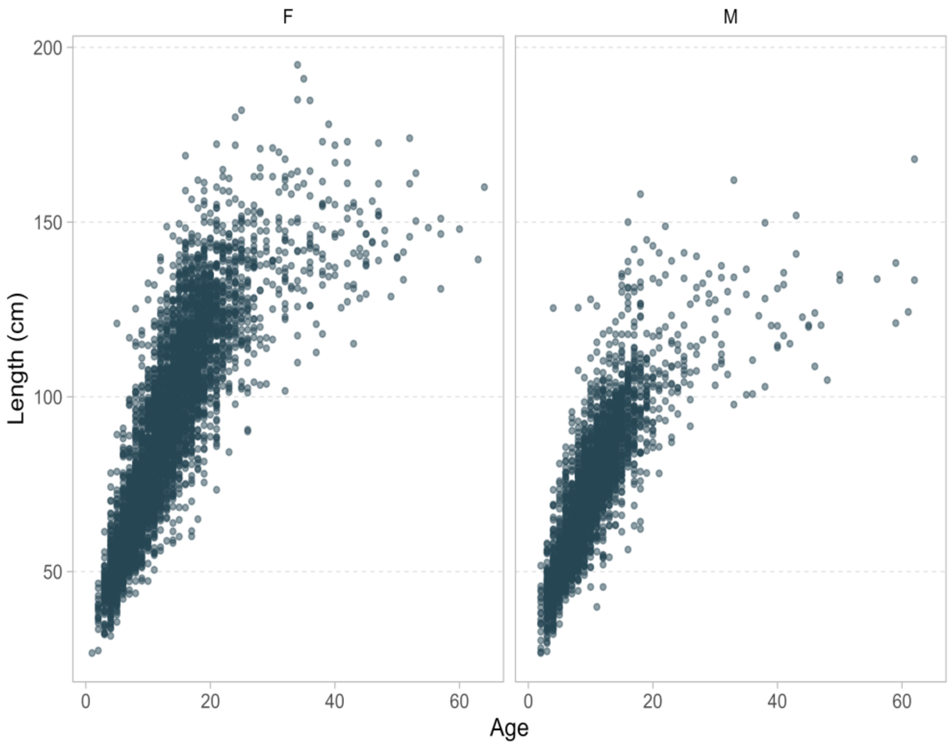

Figure 1 Length-at-age summary for the female (left) and male (right) aged animals.

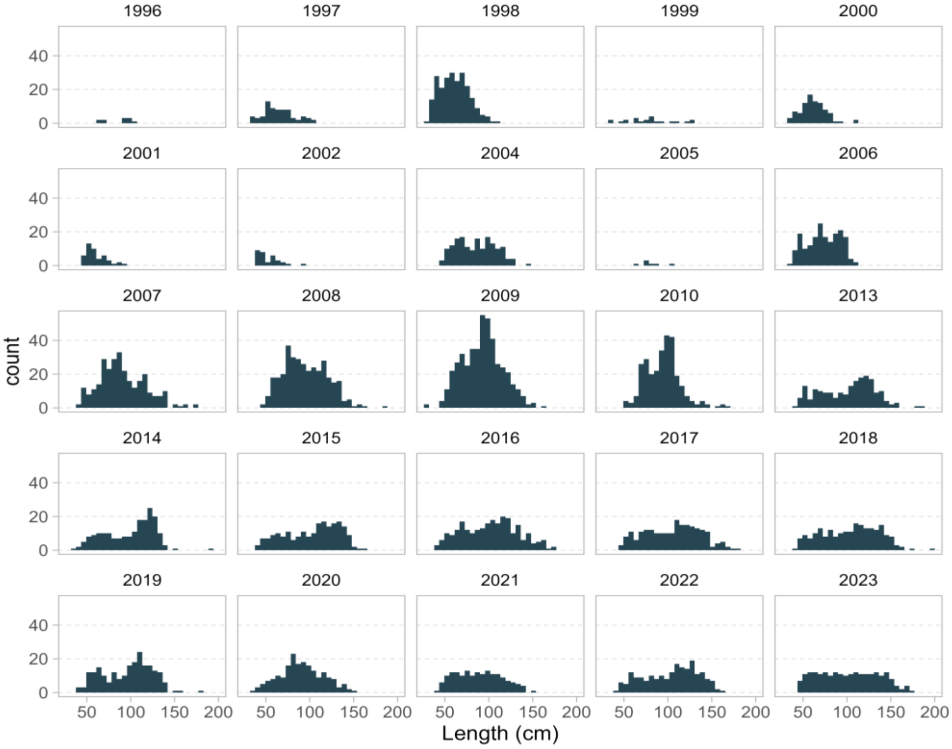

Figure 2 Length frequency summary for the female aged animals.

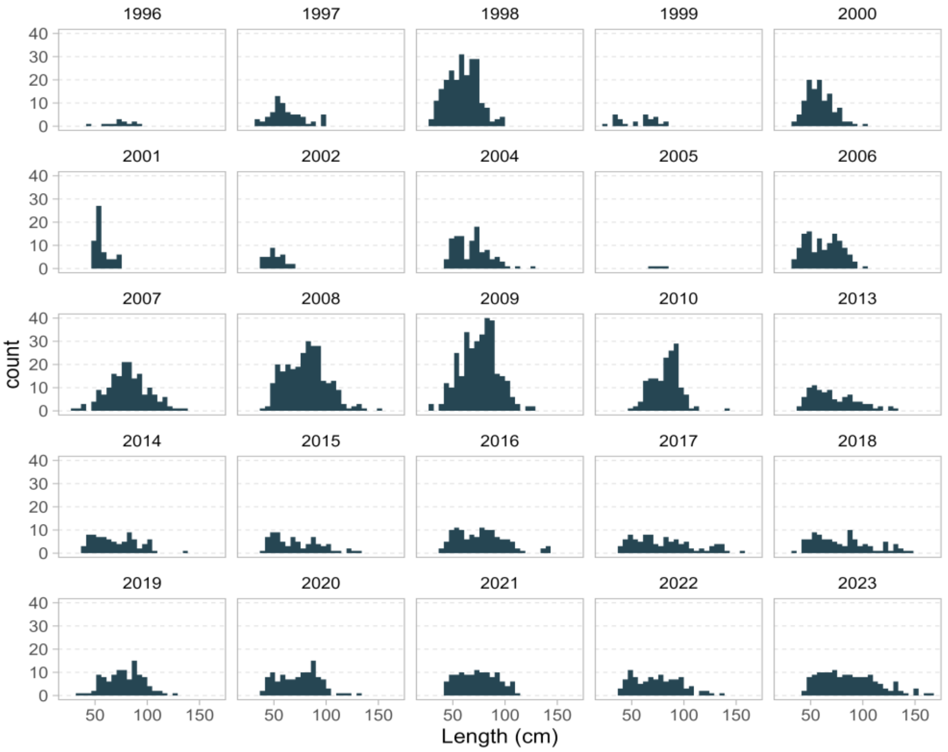

Figure 3 Length frequency summary for the male aged animals.

The distribution of length-at-age is simply defined from the growth relationship. The mean length-at-age is defined via the Schnute parameterisation of the von Bertalanffy growth curve:

$$\mathbb{E}\big(l(a)\big) = l_1 + (l_2 - l_1)\frac{1 - \exp\big(-k(a - a_1)\big)}{1 - \exp\big(-k(a_2 - a_1)\big)},$$

where l_1 and l_2 are the lengths at reference ages a_1 and a_2 ($a_2 > a_l$), and k is the growth rate.

To generate the distribution of length-at-age we assume a lognormal distribution (with a given standard deviation σ_l) around this mean length-at-age. This gives us a sex-specific distribution of length-at-age, $\pi_{l\,|\,a,s}$.

To get to the "true" distribution of age-given-length we use Bayes' rule:

$$\tilde{\pi}_{a\,|\,y,l,s} = \frac{\pi_{l\,|\,a,s}\pi_{a\,|\,y,s}}{\pi_{l\,|\,y,s}},$$

where $\pi_{y\,|\,a,s}$ is the prior age distribution, and $\pi_{l\,|\,y,s}$ is the length distribution in the fishery:

$$\pi_{l\,|\,y,s} = \sum_a \pi_{l\,|\,a,s}\,\pi_{a\,|\,y,s},$$

and the prior age distribution is defined as follows:

$$\pi_{a\,|\,y,s} \propto \mathrm{LogN}\big(\mu_{y,s}, \sigma^2_{y,s}\big)$$

For a given ageing error matrix, $A_{a,a'}$ where $\sum_a A_{a,a'} = 1$ and a' is the ``true'' age in this sense, the adjusted distribution of age-given-length (that we use to compare to the observations) is defined as

$$\pi_{a\,|\,y,l,s} = \sum_{a'} \tilde{\pi}_{a'\,|\,y,l,s}\,A_{a,a'}.$$

For the length frequency data of the aged fish (note: different to the length frequency data per fishery used in the assessment) we assume a Dirichlet-multinomial distribution:

$$\Lambda^l_{y,s} = \frac{\big(n_{y,s}!\big)\Gamma\big(\omega_{y,s}\big)}{\Gamma\big(n_{y,s} + \omega_{y,s}\big)} \prod_l \frac{\Gamma\big(n_{y,l,s} + \omega_{y,s}\pi_{l\,|\,y,s}\big)}{n_{y,l,s}!\,\Gamma\big(\omega_{y,s}\pi_{l\,|\,y,s}\big)}$$

where n is the number of individuals in each length bin, $n_{y,s} = \sum_l n_{y,l,s}$, Γ is the gamma function, and the over-dispersion parameter, $\omega_{y,s}$, is defined as follows:

$$\omega_{y,s} = \frac{n_{y,s} - \varphi_{l,s}}{\varphi_{l,s} - 1},$$

and $\varphi_{l,s} > 1$ is the over-dispersion *factor*: the degree to which the multinomial variance is inflated due to correlation between the length classes. The point of going to the trouble of using the D-M formulation is that $\varphi_{l,s}$ is an estimable parameter (as opposed to tuning to get the right value of $n_{y,s}$).

We assume a multinomial distribution for this likelihood as the default, primarily because we assume size dictates selectivity, so we would then expect that the distribution of age *within a given length class* would be random (i.e. multinomial in this case). So, the likelihood of the age-given-length data is as follows:

$$\Lambda^{a|l}_{y,l,s} = \prod_a \big(\pi_{a\,|\,y,l,s}\big)^{n_{y,a,l,s}}$$

For the Schnute model reference ages we assume $a_1 = 5$ and $a_2 = 20$ as assumed in the revised assessment model. Length bins are in 10 cm blocks from 20 cm at the minimum to a maximum that ensures the largest length bin includes the largest animal observed in the data (for each sex). The parameters estimated in the full model (using both length and age-given-length data) are:

- Mean length-at-age parameters: l_1, l_2, and k
- Standard deviation in mean length-at-age: σ_l
- Prior mean μ_y and standard deviation σ_y of the prior age distribution
- Over-dispersion factor in the length data φ_l

The overall (sex-specific) joint log-likelihood is defined as follows:

$$\ln\Lambda_s^{tot} = \sum_y \left(\ln\Lambda_{y,s}^{l} + \sum_l \ln \Lambda_{y,l,s}^{a\,|\,l} \right).$$

We use the TMB package (Kristensen et al., 2016) to find the parameters which maximise the joint likelihood of the length and age-given-length data, as well as give us approximate standard errors for each of the parameters and process variables.

2.2 Results

Fits to the female and male size data can be seen in Figures 4-5, and the summary of the mean age-given-length can be found in Figures 6-7. Table 1 summarises the key parameter estimates. Compared to previous estimates, there have been some changes in estimated parameters. This is most apparent in the estimate of L_∞ for females, and less so for males. Estimates of k were slighly lower than in 2021, while l_1, l_2 and σ_l were similar and well estimated. As seen in previous analyses, males seem to grow faster initially, but to a smaller asymptotic length; as a result, size-at-age (and weight) of females is greater than males from around age 5 years onwards.

Table 1 Maximum likelihood estimates (and approximate standard errors in brackets) of key estimated parameters and process variables for each sex. The * for each of the over-dispersion coefficients indicate that the estimates hit the lower bound and, as such, we cannot produce sensible standard errors. The 2023 estimates are included for comparison.

VARIABLE	k	l_1	l_2	L_∞	t_0	σ_l	φ_l
Female	0.041 (0.002)	50.54 (0.38)	116.45 (0.49)	194.18 (6.38)	-2.37 (0.20)	0.146 (0.013)	6.89 (0.31)
Male	0.057 (0.004)	49.38 (0.33)	103.99 (0.68)	144.42 (4.51)	-2.34 (0.23)	0.141 (0.017)	6.34 (0.24)
Female (2023)	0.055 (0.002)	49.58 (0.003)	115.74 (0.004)	166.75 (0.03)	-1.37 (0.15)	0.15 (0.008)	1.05 (NA*)
Male (2023)	0.069 (0.002)	49.12 (0.002)	101.67 (0.006)	130.58 (0.03)	-1.83 (0.16)	0.144 (0.012)	1.05 (NA*)

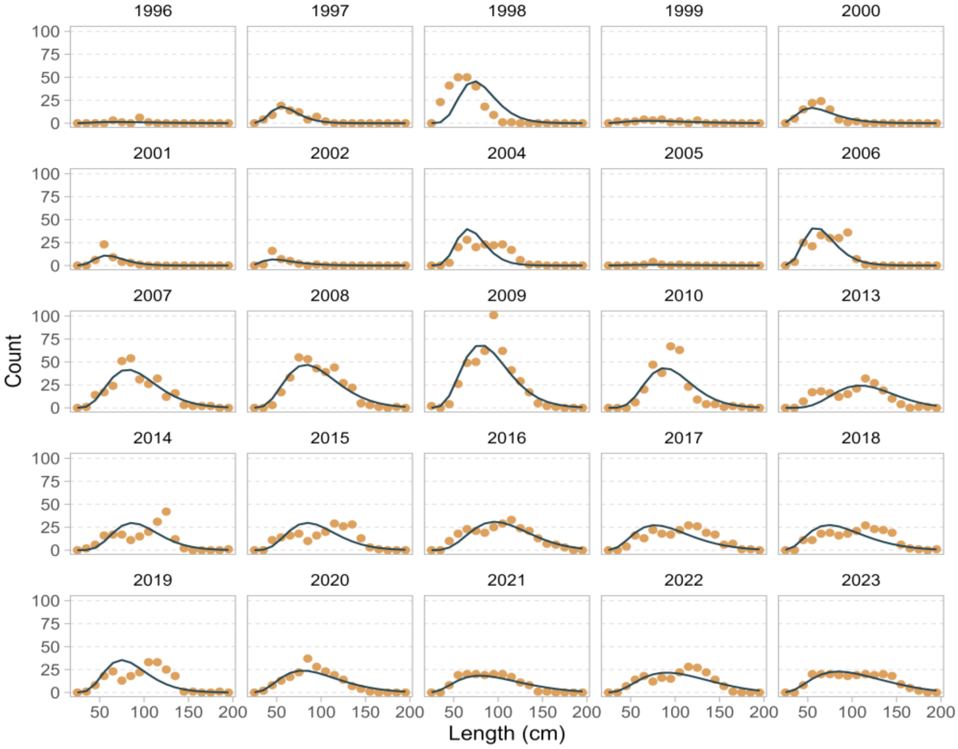

Figure 4 Observed (circles) and predicted (lines) length frequency summary for the female aged animals.

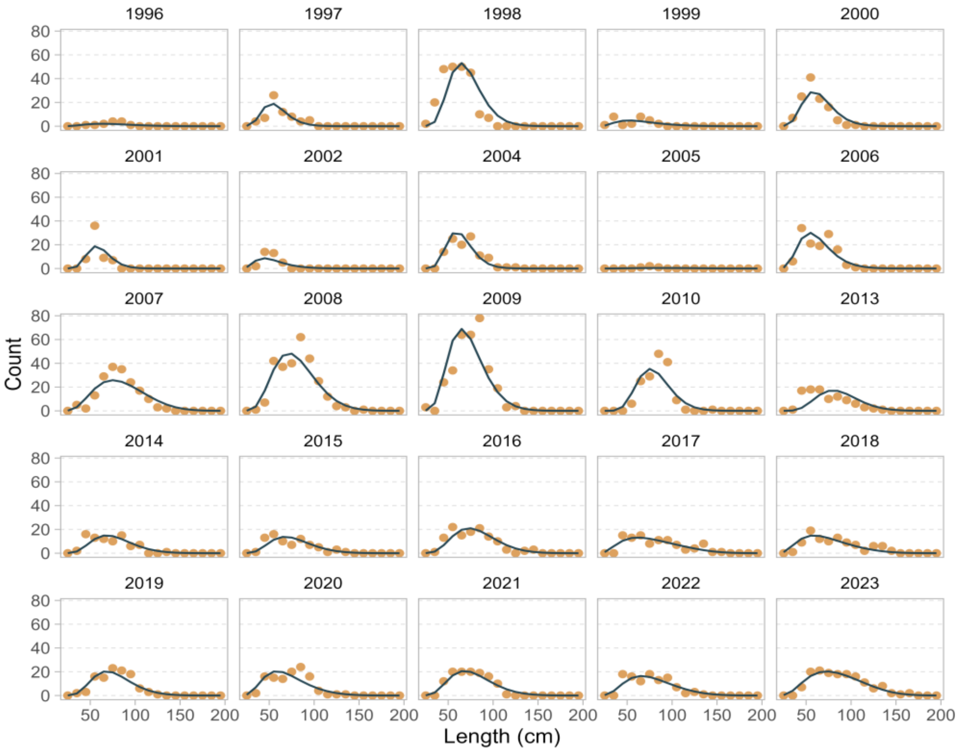

Figure 5 Observed (circles) and predicted (lines) length frequency summary for the male aged animals.

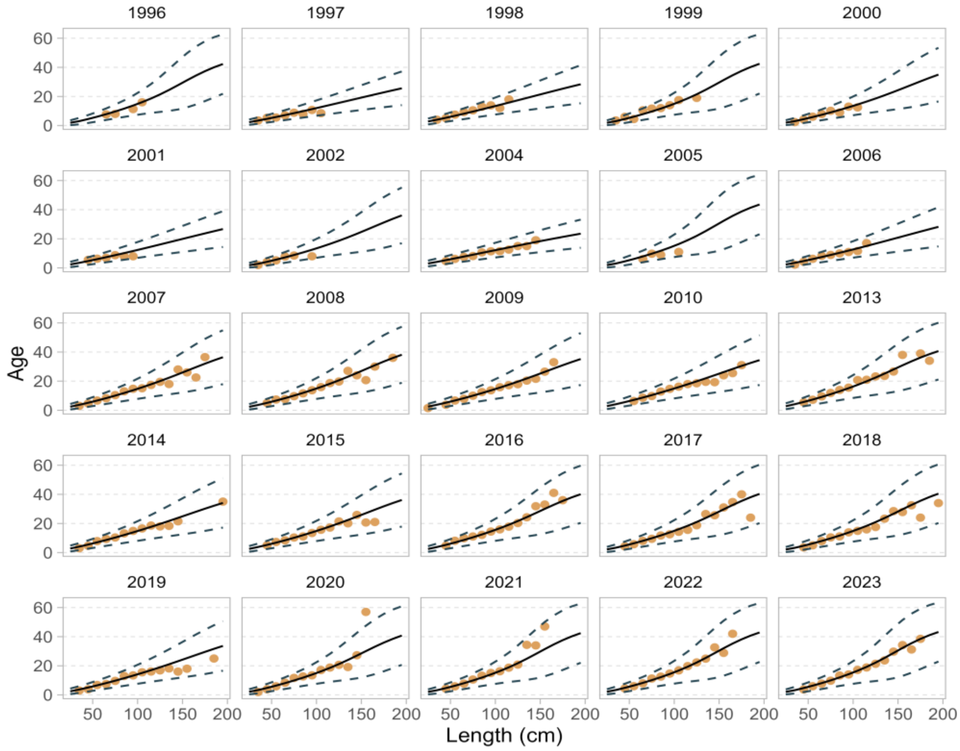

Figure 6 Observed (circles) and predicted median (solid line) and 95% CI (dotted lines) mean age-given-length summary for the female aged animals.

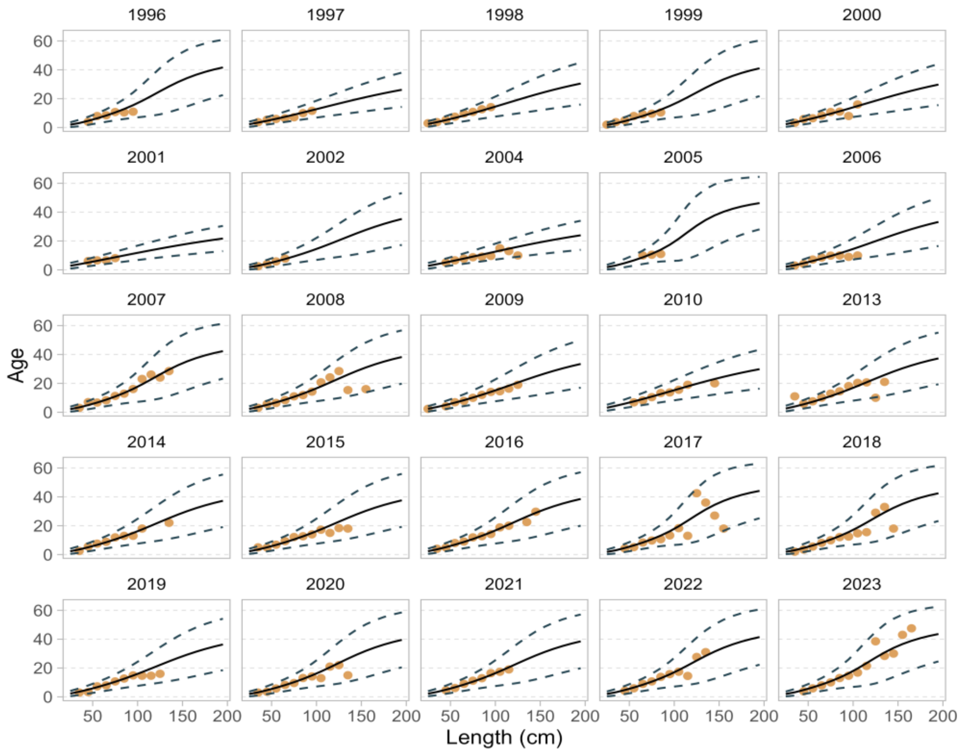

Figure 7 Observed (circles) and predicted median (solid line) and 95% CI (dotted lines) mean age-given-length summary for the male aged animals.

When summarising the fits to the length data, fits are generally fairly good for both sexes, with no apparent systematic issues in fit over time. For both sexes, the estimates of the over-dispersion factor were around 6, which is higher than previous estimates and suggests some over-dispersion in the size data of aged animals (Table 1). However, it appears that the multinomial distribution used is still appropriate. Fits to the mean age-given-length data are good for both sexes and across years (Figures 6-7). Importantly, almost all the estimates sit within the approximate 95% CI. Analyses of the standardised residuals for these data show that the variance clusters around 0.9 for both sexes and specifically they do not appear consistently over one, further supporting the use of a multinomial distribution. The estimated growth curves are shown in Figure 8.

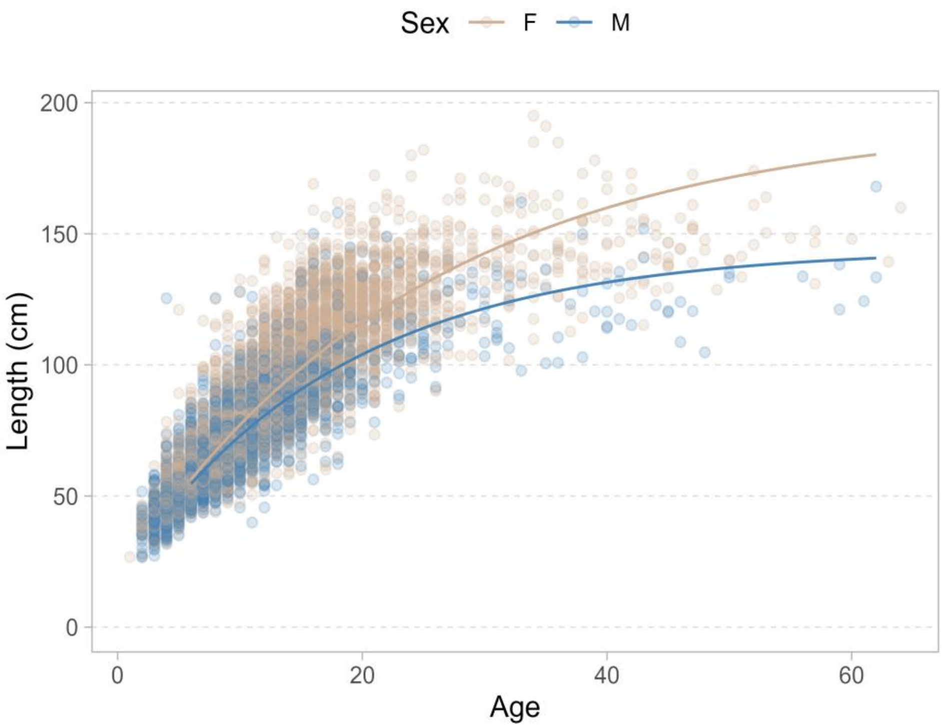

Figure 8 Estimated growth curve for females and males (lines) with data used to estimate parameters (points).

3 Maturity relationships

Maturity is a key life-history characteristic used as input to age- and size-structured integrated assessment models. For the Macquarie Island toothfish stock assessment maturity-at-length is the key relationship (Hillary, 2019a), used with the distribution of length-at-age to get an expected maturity-at-age relationship, which is used to define the female spawning population abundance and age structure. The method used to estimate these key parameters was updated in 2019 (Hillary, 2019b) to better account for established maturity definitions (Kock and Kellermann, 1991), and agreed by the SARAG to be used in an update to the stock assessment to calculate the recommended TACs later that year. The method is continued here for the 2025 assessment.

3.1 Data & Methods

Figure 9 summarises the current data (by sex and length) for MI toothfish. The MI assessment uses maturity-at-length as the fundamental input, so extra analysis is required to account for the differential treatment of animals that are stage two and those that are stage three and above. This is done as follows: within a given length-class, a given proportion of the animals will have maturity stage two; whatever the expected length class those animals would be in two years hence would be the reference length at which the relative maturity of those animals applies. For the animals of maturity stage three and above their length-at-sampling is the reference length. The overall reference length for a given length class is simply the sum of the reference lengths for stages two and three and above animals weighted by the relative number of animals in those two maturity stage classifications.

The reference length in a given length class is calculated as follows:

$$w_{l,m} = \frac{k_{l,m}}{\sum_{j\in\{2,3+\}} k_{l,j}},$$

$$g(l) = \sum_{j\in\{2,3+\}} \gamma\,(l,j) w_{l,j},$$

$$\gamma(l,2) = l + (L_\infty - l) \times (1 - e^{-k\tau}),$$

$$\gamma(l,3\,+) \equiv l,$$

where $\tau = 2$ (to represent the length of the animal 2 years hence) and $k_{l,m}$ is the number of animals of maturity stage m in length class l. The likelihood of having maturity stage 2–6, given the parameters μ and ν, is assumed to be binomial:

$$\ell(\mathbf{k}\,|\,\mu,\nu) \propto \prod_{l\in\mathcal{L}} \pi_l^{k_l}\,(1-\pi_l)^{n_l-k_l},$$

which is maximised to obtain the MLE estimates of μ and ν. In the equation above, $\mathbf{k}$ is the vector containing the number of animals in a given length-class at maturity stage 2–6 and $\mathcal{L}$ the length partition.

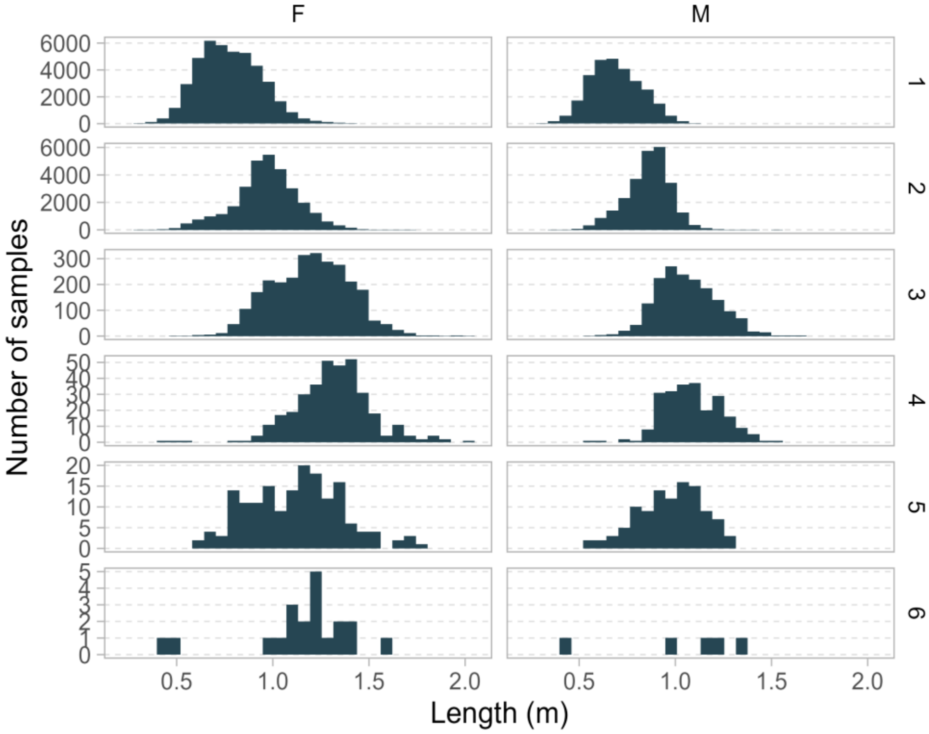

Figure 9 Measured maturity stage (1–6) data (vertical panels) given length (x-axis) in metres and for both sexes.

The data are organised in terms of specific and not necessarily equal size length classes, l. For each nominal length class l, the data are n_l (number of animals measured for maturity stage, and k_l the number of animals found to be at maturity stage 2–6). Within a given length-class this can be modelled as a binomial process, with associated probability π_l:

$$\pi_l = \frac{g(l)^\nu}{\mu^\nu + g(l)^\nu},$$

where:

- $g(l)$ is the reference length-class given an animal is within length class l when measured, accounting for the relative number of maturity stage 2 and 3–6 animals in the sample (see below for details).
- μ is the length at 50% maturity.
- ν is a shape parameter.

3.2 Results

For females there were 67,792 measurements with both maturity state and length, for males there were 49,067. For females $\mu = 89.96$ and $\nu = 5.98$; for males $\mu = 77.49$ and $\nu = 7.81$. In 2023 for females we estimated that $\mu = 90.48$ and $\nu = 5.59$; for males $\mu = 78.31$ and $\nu = 7.49$ (Bessell-Browne and Hillary, 2023). In both cases, given the quality of the fits to the data (see Figures 10-11), and the number of data points, the CVs are around 1% or less. The maturity-at-length relationship for both females and males is shown in Figure 12.

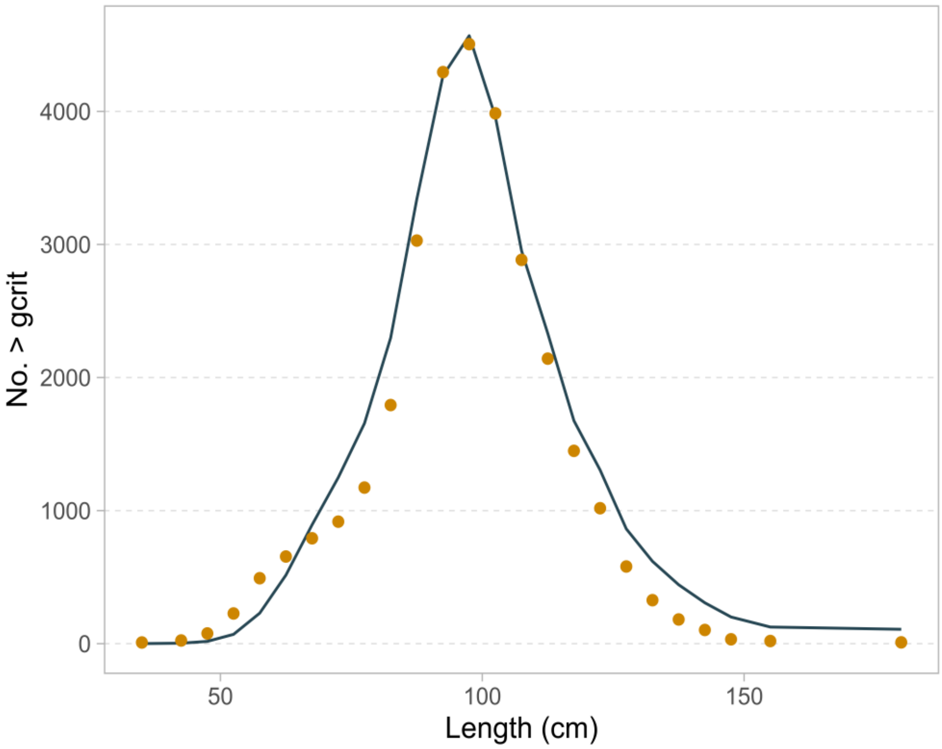

Figure 10 Fits to female maturity data, when grouped into the numbers (per length bin) with maturity state of 2 or greater.

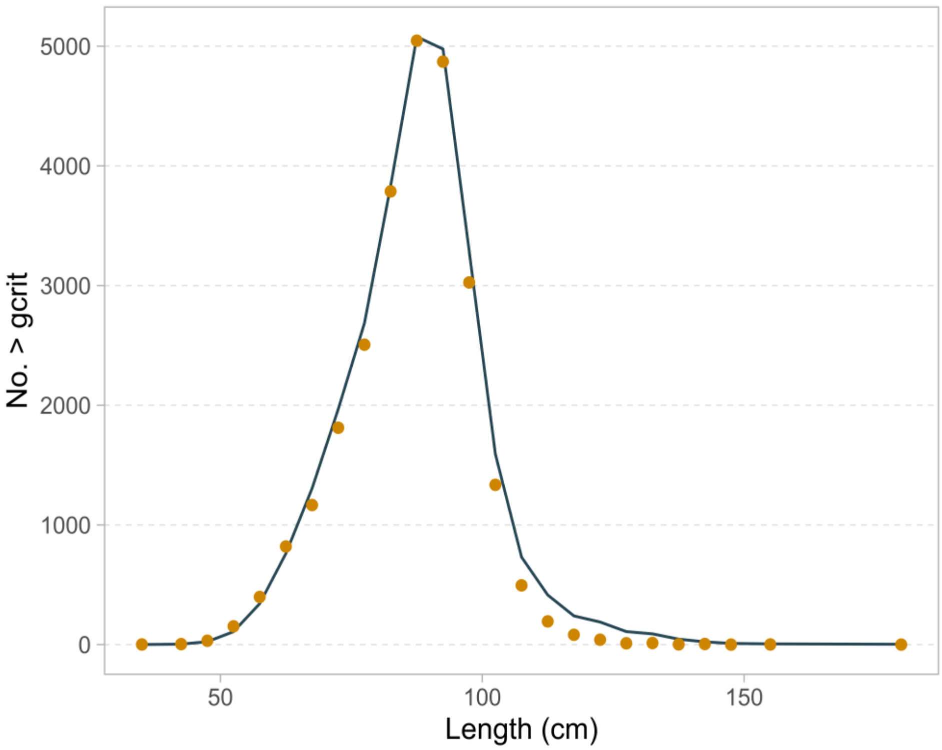

Figure 11 Fits to male maturity data, when grouped into the numbers (per length bin) with maturity state of 2 or greater.

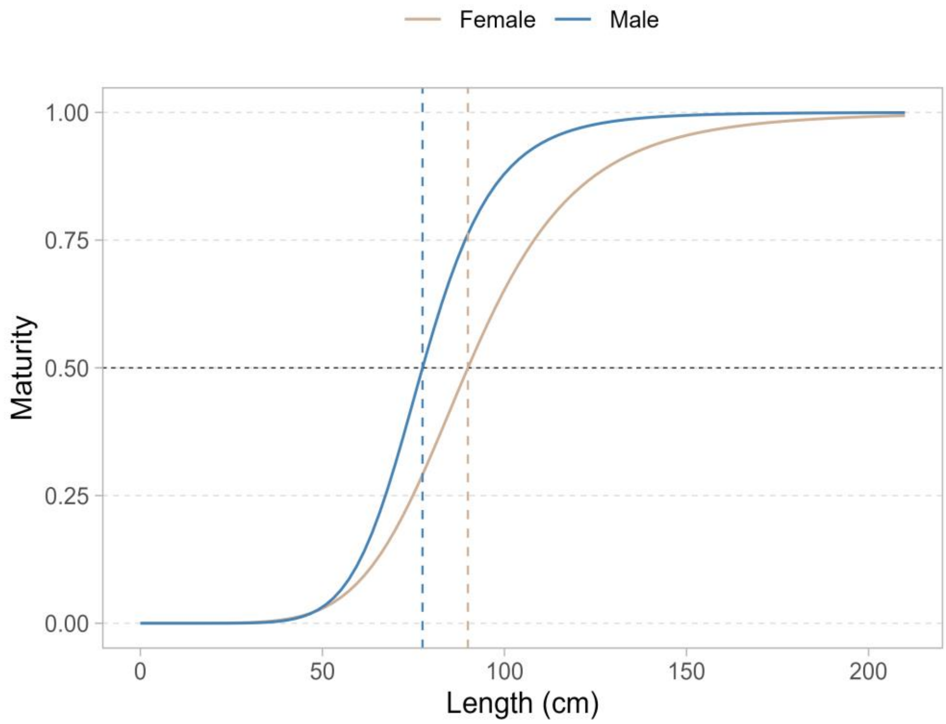

Figure 12 Estimated maturity-at-length relationships for both males and females.

4 Discussion

Using a conditional age-at-length statistical framework first outlined in Hillary et al. (2015) we estimated the key growth parameters and distributions for both sexes. Data from 1996 and up to and including 2023 are included. The growth parameters are accurately estimated for both sexes with females generally being longer-at-age than males from age 5 onwards. Estimates of L_∞ have increased compared to previous estimates, particularly for females (Bessell-Browne and Hillary, 2023; Hillary, 2021). This change appears to have been driven by the most recent two years of age-at-length data, where additional longer, but younger fish have been observed compared to previous years. There also appears to be an increased number of large fish in the length frequencies. This has influenced the overdispersion parameter estimate, which is now larger (and not on a lower bound), suggesting some conflict between the length data and age data, with the lengths pulling the estimate of L_∞ higher. Variability in length-at-age is estimated to be essentially the same for both sexes. Fits to both the length data and the mean age-at-length data are good, and the multinomial distribution appears appropriate for the age-given-length data. Given the accuracy of the estimates, it is appropriate to continue to use these updated estimates as pre-specified inputs to the revised stock assessment model in 2025.

Using the agreed updated method for estimating maturity-at-length (Hillary, 2019b) a revised maturity relationship for both males and females has been estimated. For females the size at 50% maturity was 90.0 cm and for males it was 77.5 cm (given the growth dimorphism this difference is actually far less pronounced when translating to maturity-at-age). These estimates are almost identical to those in 2023 (Bessell-Browne and Hillary, 2023). As with the growth estimates, given the accuracy of these estimates and no evidence of model misspecification, these updated estimates will be used as pre-specified inputs to the updated stock assessment in 2025.

5 References

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Attachment G

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Integrated stock assessment for Macquarie Island Patagonian toothfish using data up to and including 2024

For discussion at SARAG, 18–19th August 2025, Hobart, Tasmania.

P. Bessell-Browne & R. Hillary

4th August 2025

Citation

Bessell-Browne, P. and Hillary, R. (2025) Integrated stock assessment for Macquarie Island Patagonian toothfish using data up to and including 2024. Technical paper presented to the SARAG, 18-19 August 2025, Hobart, Australia

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Contents

1 Acknowledgments

Many thanks to AFMA, CSIRO and industry for funding and assistance, and to Tim Lamb and the AAD for providing the data.

This document was internally reviewed by Dr Ashley Williams and Kristin Privitera-Johnson.

2 Executive Summary

This paper presents results from an integrated stock assessment of Patagonian toothfish (*Dissostichus eleginoides*) at Macquarie Island using data collected from 1994 up until and including August 2024, but only including conditional age-at-length data until August 2023. The assessment uses a spatial model that fits to data from the entire Macquarie Island toothfish fishery, and assumes a single reproductive stock, but takes into account spatial structuring of the population within the region. Two areas, northern and southern, are incorporated into the model, with movement of fish between areas, and recruitment to both areas. A single Total Allowable Catch (TAC) for the entire Macquarie Island region is calculated using the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) harvest control rule.

This assessment uses Template Model Builder (TMB) and fits to data obtained from the tag-recapture program since 1995, to length composition information from 1994–2022, and to age-at-length data obtained from aged otoliths (1997–2021). It is an update of the 2023 assessment (Bessell-Browne and Hillary, 2023a). The assessments are based on a length-age structured population dynamics model, with maximum likelihood and Bayesian methods used to fit the available data.

The model designates five fleets: Aurora Trough trawl (ATT); Northern Valley trawl (NVT); Aurora Trough longline (ATL); Northern Macquarie Ridge longline (NMRL); and Southern Macquarie Ridge longline (SMRL). Fits to the length composition data are acceptable and the fits to the age at- length data are good. The model fits the tag-recapture data well, with good accord between the total number of expected recaptures from both the release and recapture year perspective. There is some spatial divergence in the most recent years (over-predicting returns in the North and under-predicting them in the South) that may be linked to spatial recruitment trends but nothing outside the predictive distribution. The assessment presented here estimates a lower female spawning stock biomass (SSB) stock status of 0.66 relative to unfished levels (0.60–0.73 95% credible intervals) than the 2023 assessment (median of 0.73 with 0.66–0.81 95% credible intervals). Average recruitment is almost identical to the previous assessment and the most recent recruitment estimates remain above average, albeit highly uncertain.

The two new years of length frequency data include an additional 5,856 fish in 79 hauls for Aurora Trough Longline, 2,619 fish in 81 hauls for Northern Macquarie Ridge Longline and 8,368 fish in 244 hauls for Southern Macquarie Ridge Longline. The remaining length frequency data were amended to ensure that no lengths from tagged fish were included as these may bias length frequency distributions since they were not randomly sampled. New conditional age-at-length data were also available for 2022/23 and 2023/24, with an additional 44 ages in the north and 266 ages in the south in 2022/23 and 95 ages in the north and 271 ages in the south in 2023/24. Age data from 2024/25 were not available for inclusion in this assessment.

New tag recaptures from the 2021/22, and 2022/23 data included 220, 26 and 196 recaptures respectively by the Aurora Trough, North Macquarie Ridge and South Macquarie Ridge Longline fleets. This makes a total of 442 tag recaptures. In addition, there were 599, 73 and 246 new tag releases in 2022/23 in the Aurora Trough, North Macquarie Ridge and South Macquarie Ridge respectively, and 398, 145 and 440 new tag releases in 2024/25 in those same regions.

The recommended TACs range from 395 to 428 t with an average of 408 t, a 11% decrease from the 2023 average of 459 t. This is driven by a lower stock status estimate compared to that in 2023.

3 Introduction

3.1 The Fishery

The Patagonian toothfish (*Dissostichus eleginoides*) is a large, long-lived, bottom-dwelling species inhabiting the continental shelf waters of sub-Antarctic islands, oceanic ridges and the southern South American continent. Patagonian toothfish is a highly prized table fish with significant imports to Japanese, North American and European Union markets.

Patagonian toothfish have been known to grow to over 2 m in length and may live to more than 50 years of age. They inhabit depths from approximately 300 m to 2,400 m, with juveniles generally found in shallower water. They feed on small fish and squid in the mid-water and various fish and crustaceans on the bottom. Patagonian toothfish are believed to reach sexual maturity at around 10 years of age, and possibly older for Macquarie Island fish (Constable and Morrison, 2001; Goldsworthy and Lamb, 2001).

Patagonian toothfish lack swim-bladders so often reach the surface in good condition even though they may have been caught from depths of 2,400 m. This has allowed the development of an extensive tagging program at both Macquarie Island and the Heard Island and McDonald Islands (HIMI). Tagging studies have increased knowledge of the species movement, growth and available abundance (Tuck and Constable, 2003; Williams, 2001).

3.2 The fishery

Bottom-set longline and trawl fisheries for the Patagonian toothfish developed in the waters of several of the Southern Ocean’s sub-Antarctic islands during the late 1980s and early 1990s. At this time trawl fisheries for toothfish were established within Australian Commonwealth waters around HIMI and Macquarie Island, however longline has become the predominant fishing methods since around 2009.

Macquarie Island lies approximately 1,500 km to the southeast of Tasmania (Figure 1). The fishery off Macquarie Island began in November 1994. Two major trawl fishing grounds have been discovered: Aurora Trough and the Macquarie Ridge Northern Grounds region. A tagging experiment began in 1995/96 within the Aurora Trough and the following season within the Macquarie Ridge region.

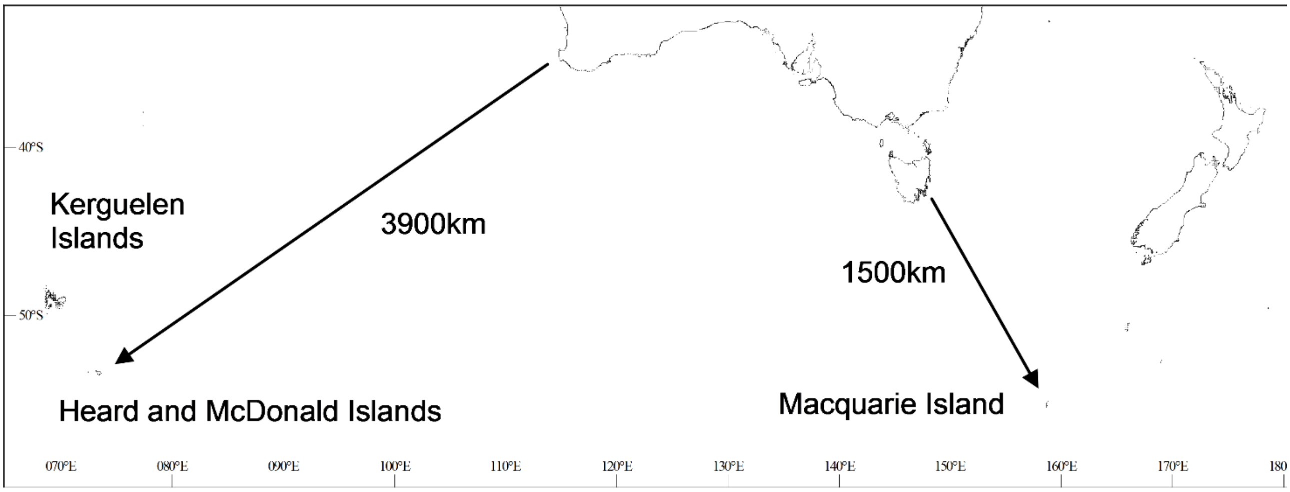

Figure 1 The location of Macquarie Island (54°30'S, 158°57'E) and Heard Island and McDonald Islands (53°06'S, 73°30'E) relative to New Zealand and Australia.

A Total Allowable Catch (TAC) for the fishery was first introduced in the 1996/97 fishing season (Table 1, Figure 2). The TAC for the 1996/97 fishing season was based on the catches of the first two fishing seasons and the tagging experiment in the 1995/96 fishing season. The setting of TACs after the 1996/97 fishing season was then based on results from a tagging-based stock assessment model. For the Aurora Trough region, commercial TACs for the trawl fishery were 750 and 200 t for the 1996/97 and 1997/98 fishing seasons respectively, and were zero after the 1997/98 fishing season (but with a 40 t research TAC to continue the tagging experiment and monitoring). In 2003/04, following indications of improved stock status from the assessment, Aurora Trough was re-opened to commercial fishing with a 354 t TAC. However, the assessment in the following year suggested that the stock had fallen marginally below the threshold for a commercial fishery so once again, the commercial fishery closed and a research quota was instigated. Since then, a commercial fishery has existed in every season except for 2009/10 (Table 1).

For the Macquarie Ridge sector, the annual trawl TAC reduced steadily in the years following the 1,500 t TAC of 1998. However, the TACs between 1998/99 and 2006/07 were allowed to increase within the fishing season if the catch rates exceeded 10 t/km^2 over three consecutive fishing days. If this catch rate dropped below the trigger level, then the TAC fell to the lower TAC. If the lower TAC had been reached, then fishing ceased.

In July 2007 the AFMA Board agreed to the commencement of longline fishing for Patagonian toothfish in the Macquarie Ridge sector of the Macquarie Island Toothfish Fishery (MITF) for a trial period of three years, with annual reviews, and subject to conditions and specific limits for incidental mortality of seabirds. In 2009, the Aurora Trough quota was also taken by longline. Longline fishing continued for the 2010/11 season, with continued high catch rates in both the Aurora Trough and Macquarie Ridge Sectors. Tagging rates have been high, and there have been longline recaptures of fish tagged in the trawl fishery. Since 2009/10 the catch has been taken entirely by longline.

Since 2012/13, a single TAC has been set for the whole of the Macquarie Island region. The 2018/19 and 2019/20 TAC was set at 450 t, with a recommendation to catch a little more than half of this total TAC in Aurora Trough (250 t), and 60% of the remainder taken from North Macquarie Ridge (120 t) and the rest from South Macquarie Ridge (80 t). The actual catch in 2017 was around 90 t below the TAC, with around 145 t more than the recommendation of the catch taken from South Macquarie Ridge, but with much less than the recommended catch taken in the other two regions (Table 1).

In 2018, the actual catch was within two tonnes of the TAC, with the regional spread of catches close to that recommended in the 2017 assessment (Table 1). This was the second largest catch by longline in North Macquarie Ridge up until 2018, indicating that considerable effort was made to match the recommended spatial distribution of catches, particularly in the north (Table 1). In both 2019/20 and 2020/21, the actual catches were close to the TAC, and the catches in North Macquarie Ridge were even higher than the 2018/19 North Macquarie Ridge catch in both years, ensuring good representation of the catch between northern and southern regions. In 2021/22 catches were below the combined TAC and this divergence increased in 2022/23, where the catch was around 200 t below the TAC. In these two years the proportion of catch taken in North Macquarie Ridge have also fallen substantially (Table 1). In 2023/24 catches were again below the TAC, however, remained stable in 2024/25 and were similar to the TAC, which had declined (Table 1).

3.3 Previous assessments

Prior to 2010, TAC determination for the Macquarie Island Patagonian toothfish stock had been based on stock assessments using the tag-recapture model developed initially by de la Mare and Williams (1997), and modifications described in Tuck et. al., (2003). This tag-recapture model estimated pre-tagging available abundance and annual net changes in available abundance between fishing seasons for the major fishing grounds of Macquarie Island (Tuck and Lamb, 2009). In 2004, a new model that expanded upon the traditional tag-based model was introduced (Tuck and Lamb, 2006). This “integrated” assessment included information on length-frequency and tagging data in an age-structured model that allowed estimation of annual spawning biomass and cohort strength. In 2008/09 work commenced on using the integrated assessment platform of Stock Synthesis for the assessment of Aurora Trough Patagonian toothfish (Fay and Lamb, 2009; Tuck and Methot, 2008). This model development continued and the Stock Synthesis assessment was used to set the TAC for the Aurora Trough component of the fishery for the 2010/11 fishing season (Fay and Tuck, 2010).

Table 1 Time series of Patagonian toothfish TAC (t) by fishing year.

Fishing season	Administrative period	TAC Aurora Trough	TAC Macquarie Ridge	TAC Entire Region
1994/95	none			
1995/96	none			
1996/97	1 Sept 1996 - 31 Aug 1997	750	1,000	
1997/98	1 Sept 1996 - 31 Aug 1997	200	1,500	
1998/99	1 Jan 1999 - 31 Dec 1999	40	600	
1999/00	1 Jan 2000 - 31 Dec 2000	40	510	
2000/01	1 Jan 2001 - 31 Dec 2001	40	420	
2001/02	1 Jan 2002 - 31 Dec 2002	40	242	
2002/03	1 Jan 2003 - 30 Jun 2003	40	205	
2003/04	1 Jul 2003 - 30 Jun 2004	354	174	
2004/05	1 Jul 2004 - 30 Jun 2005	60	148	
2005/06	1 Jul 2005 - 30 Jun 2006	255	125	
2006/07	1 Jul 2006 - 30 Jun 2007	241	100	
2007/08	1 Jul 2007 - 30 Jun 2008	390	86	
2008/09	1 Jul 2008 - 30 Jun 2009	312	150	
2009/10	1 Jan 2009 -14 Apr 2010	60	150	
2010/11	15 Apr 2010 - 14 Apr 2011	140	150	
2011/12	15 Apr 2011 - 14 Apr 2012	150	360	
2012/13	15 Apr 2012 - 30 Apr 2013			455
2013/14	1 May 2013 - 30 Apr 2014			415
2014/15	1 May 2014 - 14 Apr 2014			410
2015/16	15 Apr 2015 - 14 Apr 2016			460
2016/17	16 Apr 2016 - 14 Apr 2017			450
2017/18	15 Apr 2017 - 14 Apr 2018			450
2018/19	16 Apr 2018 - 14 Apr 2019			450
2019/20	15 Apr 2019 - 14 Apr 2020			450
2020/21	16 Apr 2020 - 14 Apr 2021			555
2021/22	15 Apr 2021 - 14 Apr 2022			555
2022/23	16 Apr 2022 - 14 Apr 2023			635
2023/24	17 Apr 2023 - 14 Apr 2024			635
2024/25	18 Apr 2024 - 14 Apr 2025			468

The 2010 Aurora Trough assessment base case model estimated the 2010/11 female spawning stock biomass (SSB) to be 2,004 t or 54% of unfished spawning biomass (Fay and Tuck, 2010). Trawl available biomass was estimated to be well above 66.5% pre-tagging (1995) levels, which had previously been used as the limit reference point for the Aurora Trough toothfish fishery. The

2010/11 TAC for Aurora Trough was set to 140 t, based on projections under the CCAMLR harvest control rule. The TAC for 2010/11 season for the Macquarie Ridge sector was set at 150 t, as for the previous season, given the absence of an assessment.

The development of stock assessment models that fitted to data from both the Aurora Trough and Macquarie Ridge was presented to SARAG in November 2009 (Fay et. al., 2010). Several versions of the models were developed which primarily differed in the model structure in terms of accounting for the spatial nature of the fishery. These analyses included: a single area model which designated different fleets to capture the spatial and gear-dependent differences in availability but assumed a homogeneous resource, and two- and three-area models which accounted for heterogeneity in toothfish availability between the northern, southern, and ridge areas of operation of the fishery, with movement among areas. All models were able to fit the length data and age-at-length data equally well, however the models differed in their ability to mimic the patterns of tag recaptures by fleet. The single area models indicated that current SSB was around 64% of unfished conditions, with the spatial models suggesting a slightly less depleted stock, with 2010/11 SSB being 67% and 72% of unfished equilibrium respectively. The time series of SSB showed a steady decline over the duration of the fishery for all models. Models which used multiple areas in addition to multiple fleets estimated larger stock sizes, and larger current stock size relative to those in unfished conditions. Uncertainty in the estimation of movement rates in the spatial models reflected the low numbers of tag recaptures outside the area of release, and also the generally low numbers of recaptures of fish released in the Northern Valleys Macquarie Ridge trawl grounds.

The 2011 assessment used the same models as in 2010, but the base case assessment assumed alternative model parameters (Fay, 2011; Fay and Haddon, 2011). The Aurora Trough assessment estimated 2011/12 female SSB to be 58% of unfished conditions, while the two-area model estimated the 2011/12 SSB for the whole of Macquarie Island to be 72% of unfished. The projected catches that met the CCAMLR harvest control rule were 150 t from Aurora Trough and 360 t from Macquarie Ridge (assuming a 70:30 split between the southern and northern Macquarie Ridge).

From 2012/13 a single TAC was set for the whole of Macquarie Island, and the two-area model used as the base case. The 2012 assessment estimated the 2012/13 female SSB for the whole of Macquarie Island to be 70% of unfished SSB (Wayte and Fay, 2012), the 2013 assessment estimated the 2013/14 female SSB for the whole of Macquarie Island to be 69% of unfished (Wayte and Fay, 2013), with further estimates of 68% for the 2014 assessment (Day and Hillary, 2014), 69% for the 2015 assessment (Day and Hillary, 2015), 67% for the 2016 assessment (Day and Hillary, 2016) and 69% for the 2017 assessment (Day and Hillary, 2017).

The 2019 assessment initially estimated the 2019/20 female SSB for the whole of Macquarie Island to be 70% of unfished (Hillary and Day, 2019a) using the same model structure as Day and Hillary (2017), but with the assessment in TMB rather that Stock Synthesis. However, this estimate for 2019/20 female SSB was subsequently revised to 85% using an updated maturity curve (Hillary and Day, 2019b), prior to setting the TAC. The change from Stock Synthesis to TMB was made to allow for improved incorporation of tag data in the assessment. The 2021 assessment again performed the assessment using TMB and estimated the 2021/22 female SSB to be 85%, the same as the 2019 assessment.

The 2023 assessment initially estimated the 2023/24 female SSB for the whole of Macquarie Island to be 73% of unfished (Bessell-Browne and Hillary, 2023a) using the same model structure as the

2021 assessment. The larger decline than anticipated was due to a large number of tag returns in the northern region of the model, which allowed biomass in this region to be more accuracy estimated at a lower level.

3.4 Modifications to the previous assessment

The following data have been added to the current assessment:

1. 2023 and 2024 catches
2. 2023 and 2024 length compositions
3. 2023 and 2023 tag recaptures
4. 2022 and 2023 age-at-length compositions

Ageing data from 2024 were not made available in time for inclusion in this assessment.

4 Methods

4.1 Data

The four primary data inputs to the model are:

1. **Catch**: in tonnes, per fleet, (1994–2024).
2. **Length frequency**: for each fleet, and using the number of hauls (not fish sampled) as the initial sample size, (1994–2024).
3. **Conditional age-at-length**: for each fleet and sex, we have the number of fish of a given age conditional on the length class samples came from, (1996–2000, 2002, 2003, 2005–2010, 2013–2023).
4. **Tagging**: release events are now characterised by a length class and area of release, with recapture data being subsequent total recaptures (across all recapture lengths) in each of the spatial regions of the model, from the tag-release-recapture program, begun during the 1995/96 season.

4.1.1 Catch data

This stock assessment treats the annual catches as known and exact. These data are therefore directly input into the model and are not fitted. The catch history by fishing year is distributed across two fishing methods, trawl and longline, within the five fleets considered by the stock assessment model: Aurora Trough trawl (ATT), Northern Valley trawl (NVT), Aurora Trough longline (ATL), northern Macquarie Ridge longline (NMRL), and southern Macquarie Ridge longline (SMRL) (Table 2, Figure 2).

Annual catch data used in earlier assessments comprised the total catch, which included a small proportion of fish that were caught and released (including fish released with tags) as well as fish that were retained. Since the 2017 assessment, the catch data were adjusted to exclude any released fish.

TAC history is listed in Table 1 with catches by fleet and area are shown in Table 2.

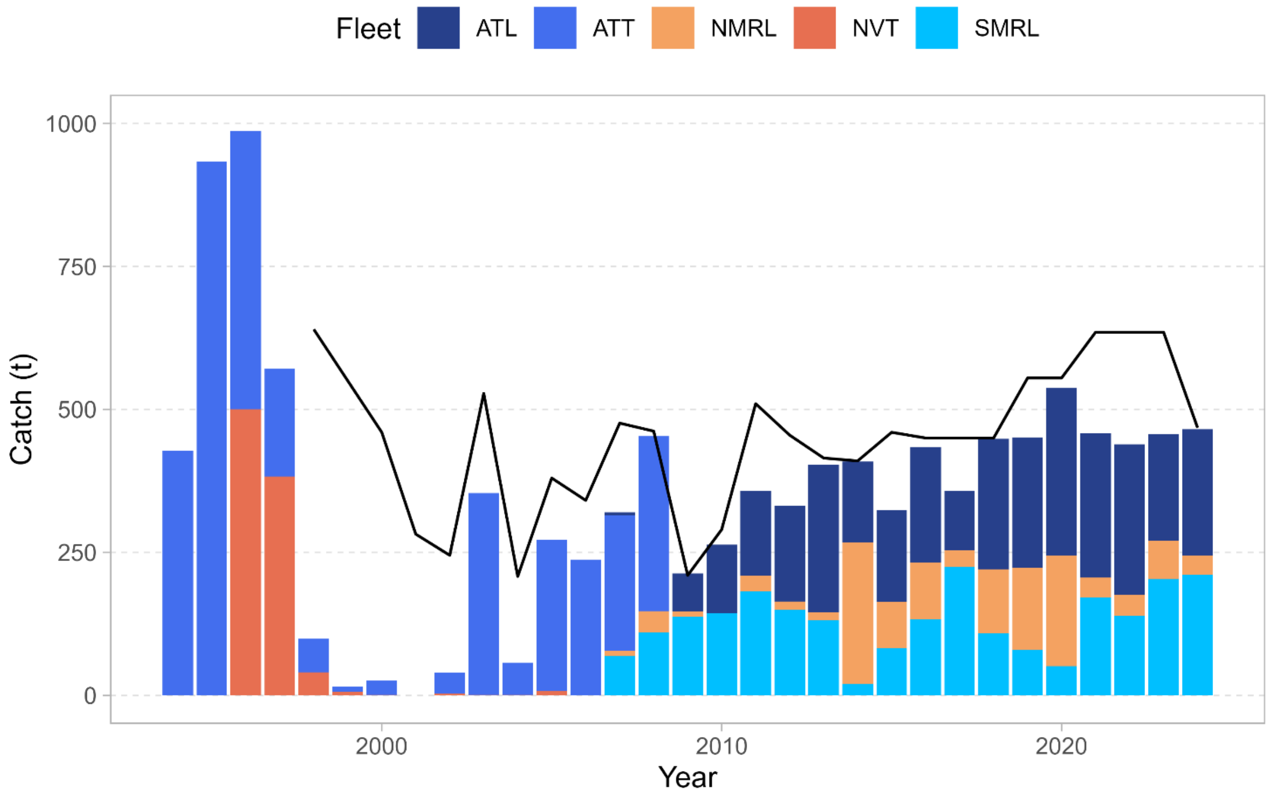

Figure 2 Catch history and total TAC by fishing year, with catches stacked by fleet and the black line representing the combined TAC (with TACs summed for Aurora Trough and Macquarie Ridge from 1996–2011). Fleets in blue colours operate in the southern region and those in oranges operate in the northern region. There was a small research quota in the Aurora Trough from 1998–2002 and in 2004.

Table 2 Time series of Patagonian toothfish catches (t) by fishing year and fleet, including total catch (removals only) over all fleets and combined TAC (combined over both regions up to 2011/12).

Fishing season	Trawl AT	Trawl NV	Longline AT	Longline NMR	Longline SMR	Total Catch (t)	Combined TAC (t)
1994/95	427.3	0.0				427	
1995/96	932.9	0.0				933	
1996/97	486.3	500.3				987	1,750
1997/98	188.2	382.8				571	1,700
1998/99	58.5	40.5				99	640
1999/00	9.0	6.6				16	550
2000/01	25.4	0.6				26	460
2001/02	0.0	0.0				0	282
2002/03	36.4	3.3				40	245
2003/04	352.8	0.7				353	528
2004/05	56.8	0.6				57	208
2005/06	264.5	7.9				272	380
2006/07	237.3	0.0				237	341
2007/08	236.8	0.0	5.4	9.0	69.2	320	476
2008/09	306.1	0.0	0.0	37.1	109.8	453	462
2009/10			66.6	8.7	138.2	214	210
2010/11			120.2	0.0	143.6	264	290
2011/12			148.2	27.4	181.9	358	510
2012/13			167.3	14.5	149.7	332	455
2013/14			258.5	13.8	131.3	404	415
2014/15			141.2	248.0	19.6	409	410
2015/16			160.8	81.1	82.6	324	460
2016/17			202.4	98.9	133.0	434	450
2017/18			104.1	28.5	225.0	358	450
2018/19			227.8	111.7	108.7	448	450
2019/20			227.9	143.5	79.7	451	450
2020/21			292.8	192.9	51.6	537	555
2021/22			252.1	34.6	171.4	458	555
2022/23			262.9	37.2	139.2	439	635
2023/24			186.0	66.4	204.1	457	635
2024/25			221.5	32.4	211.5	465	468

4.1.2 Length frequency data

Samples of the length composition of the catch were available for all fishing seasons (1994/95 to 2024/25). Each annual length composition is based on the measurement of several hundreds (or thousands) of fish (Tables 3 and 4). However, it is unlikely that the number of fish measured in each year is an appropriate metric of the effective sample size, due to expected high correlations among fish lengths within individual hauls/shots. Thus, input assessment sample sizes for the individual length compositions are set at the number of hauls sampled for the trawl data, and the number of shots for the longline data. For all fleets the over-dispersion factor (that scales the initial sample sizes to the correct value) is estimated within the model.

Table 3 Number of length samples by fleet and season for the trawl fleets, both in terms of number of shots from which samples were taken, and the total number of fish measured.

Fleet	Season	Number of shots	Number of fish	Mean number per shot
AT trawl	1994/95	126	3,414	27
	1995/96	257	6,721	26
	1996/97	103	2,725	26
	1997/98	81	1,409	17
	1998/99	54	3,354	62
	1999/00	38	831	22
	2000/01	20	1,415	71
	2001/02	2	1	1
	2002/03	19	733	39
	2003/04	96	4,580	48
	2004/05	19	702	37
	2005/06	124	3,368	27
	2006/07	72	765	11
	2007/08	94	1,461	15
	2008/09	131	2,199	17
NV trawl	1994/95	3	18	6
	1995/96	43	2,250	52
	1996/97	139	2,393	17
	1997/98	78	2,031	26
	1998/99	42	638	15
	1999/00	13	350	27
	2000/01	2	1	1
	2001/02	24	390	16
	2002/03	6	83	14
	2003/04	13	274	21
	2004/05	27	548	20
	2005/06	3	14	5

Table 4 Number of length samples by fleet and season for the longline fleets, both in terms of number of shots from which samples were taken, and the total number of fish measured.

Fleet	Season	Number shots	Number fish	Mean number per shot	Fleet	Season	Number shots	Number fish	Mean number per shot
AT	2007/08	2	200	100	**SMR**	2007/08	28	1,589	57
	2009/10	9	548	61		2008/09	44	1,750	40
	2010/11	18	1,066	59		2009/10	50	1,886	38
	2011/12	45	1,779	40		2010/11	34	1,546	45
	2012/13	52	1,916	37		2011/12	96	3,388	35
	2013/14	79	3,046	39		2012/13	126	4,080	32
	2014/15	62	2,216	36		2013/14	94	3,107	33
	2015/16	84	2,950	35		2014/15	18	561	31
	2016/17	94	3,376	36		2015/16	76	2,404	32
	2017/18	66	2,254	34		2016/17	123	3,865	31
	2018/19	93	3,335	36		2017/18	174	5,527	32
	2019/20	93	3,245	35		2018/19	76	2,464	32
	2020/21	98	3,583	37		2019/20	35	1,260	36
	2021/22	96	3,186	33		2020/21	32	1,021	32
	2022/23	129	4,518	35		2021/22	75	2,381	32
	2023/24	82	3,035	37		2022/23	97	3,059	32
	2024/25	74	2,821	38		2023/24	127	4,353	34
NMR	2007/08	5	160	32		2024/25	117	4,015	34
	2008/09	13	406	31					
	2009/10	7	246	35					
	2011/12	26	829	32					
	2012/13	31	838	27					
	2013/14	11	340	31					
	2014/15	70	2,570	37					
	2015/16	96	2,739	29					
	2016/17	128	3,337	26					
	2017/18	57	1,368	24					
	2018/19	104	3,045	29					
	2019/20	141	4,075	29					
	2020/21	159	4,748	30					
	2021/22	50	1,240	25					
	2022/23	42	1,165	28					
	2023/24	52	1,765	34					
	2024/25	29	854	29					

Disaggregation of the length data by sex is possible, and the model could allow for the inclusion of composition data from both sexed data and data for which the sex is unknown, with the expectation that the latter is a random sample from the catch and is a combination of the individual compositions by sex. The percentage of the seasonal length samples that were sexed has varied considerably over the duration of the fishery. Additionally, inspection of the data suggests that the unsexed fish sampled for length are quite different from the male and female portions of the length composition for some years (Fay, 2010). Consequently, length data were aggregated by sex for all years. Length bin structure is at 10 cm intervals between 0 and 30 cm, 5 cm intervals between 35–150 cm, and at 10 cm intervals above this range up to 190 cm.

4.1.3 Age data

Age-at-length samples are available from aged fish that were captured in 1996–2000, 2002, 2003, 2005–2010 and 2013–2021 (Table 5. New ageing data from 2022 and 2023 were added this year, but the 2024 conditional age-at-length data were not available.

Table 5 Sample sizes of aged fish from the southern and northern areas of the fishery by year and gender. Tag recaptured fish not included.

Year	Sex	North	South	Total
1997/98	F	19	52	71
	M	21	47	68
1998/99	F	80	179	259
	M	103	155	258
1999/00	F	13	7	20
	M	16	11	27
2000/01	F	87	1	88
	M	118	2	120
2001/02	F	3	42	45
	M	7	53	60
2002/03	F	31	1	32
	M	32	2	34
2003/04	F	0	0	0
	M	0	0	0
2004/05	F	0	165	165
	M	2	108	110
2005/06	F	0	7	7
	M	0	4	4
2006/07	F	28	159	187
	M	38	91	129
2007/08	F	7	261	268
	M	3	167	170
2008/09	F	23	300	323
	M	1	258	259
2009/10	F	51	388	439

Year	Sex	North	South	Total
	M	32	294	326
2010/11	F	0	285	285
	M	0	161	161
2013/14	F	15	185	200
	M	9	88	97
2014/15	F	85	107	192
	M	23	59	82
2015/16	F	76	129	205
	M	19	57	76
2016/17	F	67	185	252
	M	32	90	122
2017/18	F	20	196	216
	M	12	85	97
2018/19	F	49	166	215
	M	26	70	96
2019/20	F	92	123	215
	M	14	94	108
2020/21	F	53	141	194
	M	17	92	109
2021/22	F	22	142	164
	M	22	96	118
2022/23	F	34	170	204
	M	10	96	106
2023/24	F	57	160	217
	M	38	111	149
Total		1,507	5,842	7,349

4.1.4 Tag recapture data

Between the 1995/96 and 2024/25 fishing seasons, 22,555 Patagonian toothfish were tagged at Macquarie Island, of which 3,687 have been recaptured (Table 6, Table 11, Table 12, Table 13). Fish are still being recaptured from releases in the early years of the fishery. The recapture rates by region in 2021/22 and 2022/23 follow similar patterns to those seen in earlier years, with the number of recaptures of fish released in the north much lower than the number of recaptures of fish released in the south.

Table 6 Total numbers of tag recaptures by fleet of release (rows) and recapture (columns), for fish at liberty for greater than 180 days. These releases and recaptures are aggregated over all years.

Released by	AT - trawl	NV - trawl	AT - longline	NMR - longline	SMR - longline
AT trawl	851	1	170	2	41
NV trawl	8	72	1	7	6
AT longline	0	0	1,112	4	163
NMR longline	0	0	6	103	37
SMR longline	0	0	207	18	878

To allow for mixing of tagged fish with the untagged population, and to prevent the loss of too many tag recapture events in the early data-limited assessments for all stock assessments up until 2015, recaptures within the year of release were removed from previous assessment release data if the recapture occurred within 10 days of release (c.f. Tuck and Lamb (2009)). Given the quantity of tag data now available to the assessment and to ensure full mixing of tagged and untagged fish for all stock assessments after 2016, recaptures were removed from the release data if the recapture occurred within 180 days of release. This effectively removes recaptures of any fish tagged within the same fishing season. The same 180 day mixing period, as first applied to the 2016 assessment, was continued in this current assessment. As with the length data, the over-dispersion factor for the tag data is internally estimated within the assessment to account for spatiotemporal release and recapture correlation.

Tag-recapture experiments rely on the tags being discovered and reported when the fish are captured. This may not occur if tags are lost from the fish, or if tagged fish are not reported. From the recapture of multiple tagged fish in this fishery, estimates of tag loss rates indicate that the probability of losing both tags is negligible. Likewise, many individual fish have been recaptured several times. The rates of tag loss and tagging mortality were assumed to be zero. This is consistent with previous assessments of toothfish at Aurora Trough and Macquarie Island. A sensitivity to this assumption is included.

The non-detection of tagged toothfish has been a problem, especially with electronic tags. The detection of visible tags also relies upon the vigilance of the crew and observers. Estimates of the tag detection rate by season are available for the trawl fishery (Figure 3, data from Tuck and Lamb Tuck and Lamb (2009)), and were input to the model in order to implement a time-varying detection rate. In the absence of additional information, the tag detection rate for the longline fleet was assumed to be 0.94 (the average of the calculated annual values from the trawl fishery) for all years.

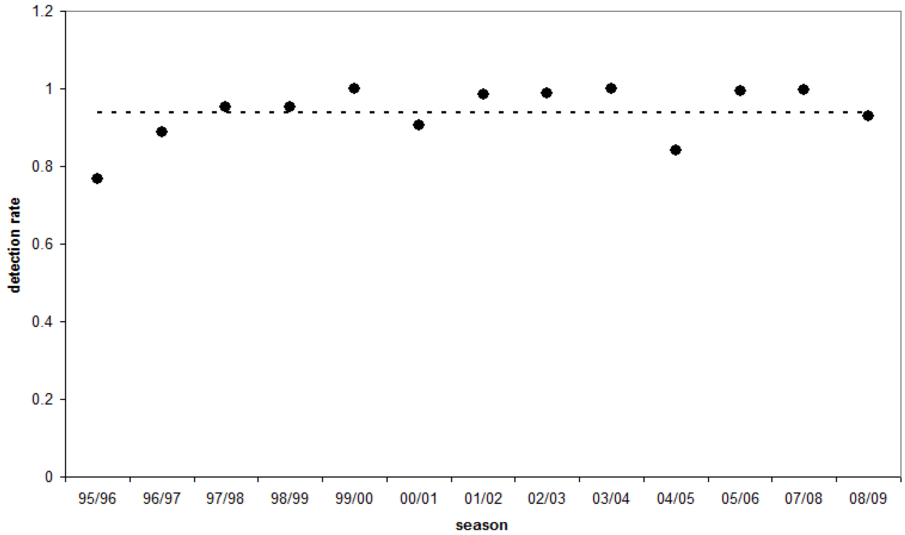

Figure 3 Estimated tag detection rate (points) by fishing season (Tuck and Lamb 2009). Dotted line corresponds to the mean detection rate (0.938) over the time series.

4.2 Biology

There have been a number of updates to the growth and maturity relationships for this stock over the years. Growth is now estimated externally to the assessment using a conditional age-at-length approach (Hillary, 2021). Updated growth estimates had higher estimates of L_∞ than in the previous assessment (Bessell-Browne and Hillary, 2025). In 2019 the maturity-at-length relationships for males and females was also revised (Hillary, 2021), resulting in a significant decrease in the length at 50% and 95% maturity for females. These estimates were calculated using updated data for this assessment (Bessell-Browne and Hillary, 2025). The updated estimate of 89.96 cm and 77.5 cm are almost identical to the 2021 estimates of 90.48 cm and 78.31 cm, respectively (Bessell-Browne and Hillary, 2023b).

The length-weight relationship is the same as previously employed:

$$w_l = al^b$$

where $a = 4.4 \times 10^{-6}$ and $b = 3.14$ and weight is measured in tonnes, with length measured in centimeters. The age-independent value of natural mortality is $M = 0.13$, with the $M = 0.155$, the value assumed in the HIMI assessment, explored as a sensitivity. For the steepness parameter of the stock-recruitment relationship (the key resilience parameter with respect to recruitment overfishing) the default value assumed is $h = 0.75$ with values of 0.6 and 0.9 explored as sensitivity scenarios.

4.3 Population dynamics model

The assessment framework uses the Template Model Builder (TMB) package in R (Kristensen et al., 2016). This is, at present, the most efficient and flexible statistical modelling package available. It allows for highly complex statistical models (including the use of random effects) to be efficiently and robustly estimated. The *tmbstan* R package is used for the MCMC runs used to generate the key probabilistic summaries of the assessment variables (Monnahan and Kristensen, 2018). This links models written in TMB to the currently accepted most efficient MCMC sampler (the No U-turns or NUTS algorithm) and, for the models explored, runs in just over 90 minutes.

The full details of the assessment method can be found in Hillary and Day (2019a).

4.3.1 Length related variables

All the key data series used in the assessment involve size-specific predicted quantities: length distributions in the catch, age-given-length, and length-specific recapture probabilities. As the population dynamics model is primarily age-based we need to translate a number of age-based quantities into length, these include:

1. Predicted length frequency (aggregated across sexes) for each fishery.
2. Predicted distribution of age-given-length, accounting for ageing error, in each of the fisheries and for both sexes.
3. Predicted sex ratio-at-length for each region.
4. Predicted spatial recapture probability-at-length, derived from length-based harvest rates and the growth transition matrices for each sex.

For the tagging likelihood we need to calculate a sex-specific growth transition matrix given the length-based nature of this part of the model. This is done following the method outlined in Hillary (2011) that deals with both the differing size of the length bins, and the stochastic uncertainty in the expected growth increments of the fish, given the growth curve. The transition matrix, $G_{l,l',s}$, is the probability that a fish in length bin l after a given time τ (taken to be one year here) will be in length bin l' (and $\sum_{l'} G_{l,l',s} = 1$).

4.3.2 Candidate selectivity functions

Selectivity is assumed to be inherently length-based and not sexually dimorphic, even though differences in selectivity-at-age by sex are possible given the different growth curves for males and females. We explored three potential selectivity functions:

- **Double-logistic**: a fully smooth function that encompasses the features of the double-normal and double-normal plateau functions.
- **Generalised gamma**: uses a modified gamma distribution-type kernel that is a reduced parameter dome-shaped distribution to avoid over-parameterisation and convergence issues of the double-logistic function when the plateau-type dynamics are absent.
- **Logistic**: conventional logistic function that has no potential for dome-shaped dynamics.

4.4 Likelihood functions

4.4.1 Length frequency data

The underlying distribution we assume is a Dirichlet-multinomial for the sex-combined length frequencies, where the over-dispersion factor φ_f by fishery f is estimated with all the other parameters.

4.4.2 Conditional age-at-length data

The underlying distribution assumed for the age data are multinomial for a given length bin - i.e. the distribution of age within a given length bin is assumed to be random and, therefore, no over-dispersion factors are required.

4.4.3 Tagging data

For the tag recapture model, we derive fits within what would be considered a *multi-state mark-recapture model*. This assumes there are a number of probabilistic states a tagged fish can inhabit over the recapture period of a given release event, including: which length class it is in, what spatial region it is in, what sex it is, and whether it has been recaptured or not. The release covariates are year, length class and region; the recapture covariates are year and region of recapture. Both size at recapture and sex-at-release are integrated over within the tagging model (we do not use the sexed tag recapture information).

The base likelihood for the tagging data is essentially the multinomial distribution, which is known loosely as the Brownie model (size and spatially structured in this case, Hillary and Eveson, 2015). This follows the recapture history of a given release event and has been shown to be more informative on both abundance and migration, relative to the previous two-stage likelihood (Hillary and Day, 2017). Tagging data are, however, well known to be often over-dispersed (i.e. more variable than the underlying base distribution would predict). To accommodate this process, we again use the Dirichlet multinomial (D-M) distribution to model the likelihood of a given tagging event's recapture history.

4.4.4 Overall likelihood and objective function

The overall log-likelihood of the data is simply the sum of all three log-likelihoods of the data sources:

$$\ln\Lambda^{tot} = \ln\Lambda^{l} + \ln\Lambda^{a|l} + \ln\Lambda^{tag}$$

The full objective function to be maximised includes the recruitment prior and additional penalties to prevent harvest rates and tag recapture probabilities exceeding pre-specified maximum levels.

4.5 Estimated parameter options

The core set of estimated parameters are:

- Unfished total recruitment, R_0

- Selectivity parameters for each fleet
- Recruitment deviations for a pre-specified subset of years
- Spatial recruitment parameters, η_r
- Overall recruitment deviation SD, σ_r
- Parameters of the migration matrix, Φ
- Over-dispersion parameters φ_f and φ^{tag}

4.6 Model dimensions

This section deals with some high-level summaries of the input data, as well as the relevant dimensions of the model (years, ages, size classes etc.) and settings of the different parameterisations for the various model processes. The model runs from 1985 to 2025 (i.e. 10 years before fishing began) and includes fish aged 1 to 52. Size-classes range from 0 to 190 cm: 0 to 30 in 10 cm bins, 30 to 150 cm in 5 cm bins, and from 160 to 190 cm in 10 cm bins. The model is run as a two region model with a Northern and Southern region (with the same latitudinal separator for these regions as used in previous assessments). There are five fleets:

1. Aurora Trough trawl (ATT): assumed in region 2 (Southern region) and with an assumed time-invariant double-logistic selectivity
2. Northern Valley trawl (NVT): assumed in region 1 (Northern region) and with an assumed time-invariant generalised gamma selectivity
3. Aurora Trough longline (ATL): assumed in region 2 (Southern region) and with two possible selectivity options: generalised gamma or logistic
4. North Macquarie ridge longline (NMRL): assumed in region 1 (Northern region) and with two possible selectivity options: generalised gamma or logistic
5. South Macquarie ridge longline (SMRL): assumed in region 2 (Southern region) and with two possible selectivity options: generalised gamma or logistic

5 Results

This section summarises:

- Bridging from the previous assessment with incremental inclusion of new data
- Reference model configuration and fits to the various data sets
- Population dynamic summaries from the MCMC runs for the reference model
- Impact of the outlined sensitivity scenarios

5.1 Bridging

A bridging exercise was undertaken to sequentially include new data since the 2023 assessment to determine the impact of the different data sources on the resulting stock assessment outcomes. The order of bridging was:

1. 2023 basecase
2. update growth
3. update maturity
4. add catches
5. add lengths
6. add ages
7. add tags

Results of this analysis demonstrate that there is variation in estimates of female SSB with the addition of data, however, including the updated tagging data brings estimates back inline with estimates from the 2023 assessment, albeit with a slightly higher estimate of female SSB_0 (Figure 4).

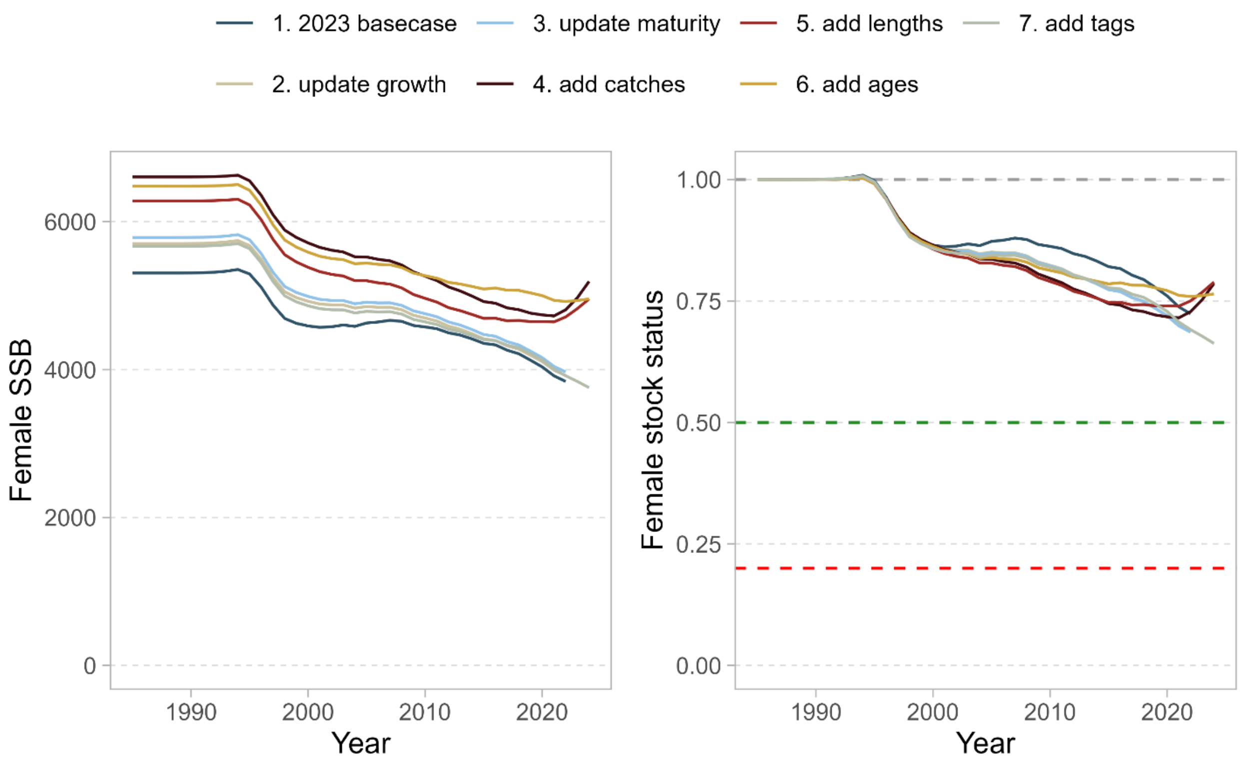

Figure 4 Impacts of bridging the updated growth and maturity parameters and data inputs from the 2023 assessment on female SSB and stock status estimates.

5.2 Reference assessment model

For the base case, or reference, assessment model, we assume that the reference ages for the Schnute parameterisation of the von Bertalanffy growth function to be $a_1 = 5$ and $a_2 = 20$. This ensures that they are (a) are within the observed data range, and (b) are not too close or too far apart, relative to the data range. For the reference model we keep the growth parameters *fixed*, estimating them using the conditional age-at-length method detailed in Hillary (2021). Therefore, these data are used to inform the model on population size and age structure (including recruitment), not growth. The input growth parameters are detailed in Table 7.

Table 7 Maximum likelihood estimates (and approximate standard errors in brackets) of the growth parameters used in the reference model. The values used in 2023 are included below the most recent estimates for comparison purposes.

Variable	k	l_1	l_2	L_∞	t_0	σ_l	ϕ_l
Female	0.041 (0.002)	50.54 (0.38)	116.45 (0.49)	194.18 (6.38)	-2.37 (0.20)	0.146 (0.013)	6.89 (0.31)
Male	0.057 (0.004)	49.38 (0.33)	103.99 (0.68)	144.42 (4.51)	-2.34 (0.23)	0.141 (0.017)	6.34 (0.24)
Female (2023)	0.055 (0.002)	49.58 (0.003)	115.74 (0.004)	166.75 (0.03)	-1.37 (0.15)	0.15 (0.008)	1.05 (NA*)
Male (2023)	0.069 (0.002)	49.12 (0.002)	101.67 (0.006)	130.58 (0.03)	-1.83 (0.16)	0.144 (0.012)	1.05 (NA*)

A detailed summary of the estimation of the growth parameters can be found in Bessell-Browne and Hillary (2025), but Table 7 shows the estimate used as model inputs in the reference case. As seen in previous analyses, males grow faster initially, but to a smaller asymptotic length; as a result, size-at-age (and weight) of females is greater than males from about age five onwards. The key parameters (k, l_1, and l_2) are all very accurately estimated (Table 7). Variability in mean length-at-age is very well estimated in both cases and is the same for both sexes. The standard errors are informative and suggest that uncertainty in growth is smaller than in all the other parameters used as inputs to the model or estimated therein (see later). For the female maturity-at-length relationship estimated in Bessell-Browne and Hillary (2025) the associated lengths at 50% maturity were 90.0 cm for females and 77.5 cm for males. As with the key growth parameters, the estimated accuracy of these parameters is high enough that considering them effectively fixed inputs to the model is highly unlikely to cause underestimation of the overall level of uncertainty in the key stock status outputs.

5.3 Fitting summary for reference model

The fits to the length frequency data for the two trawl fleets are in Figure 5, and for the three longline fleets in Figure 6, Figure 7 and Figure 8. Due to variability among years, particularly for the trawl fleets, some of the fits are poor, however, this is to be expected given the level of variability and overall fits to the length data are good.

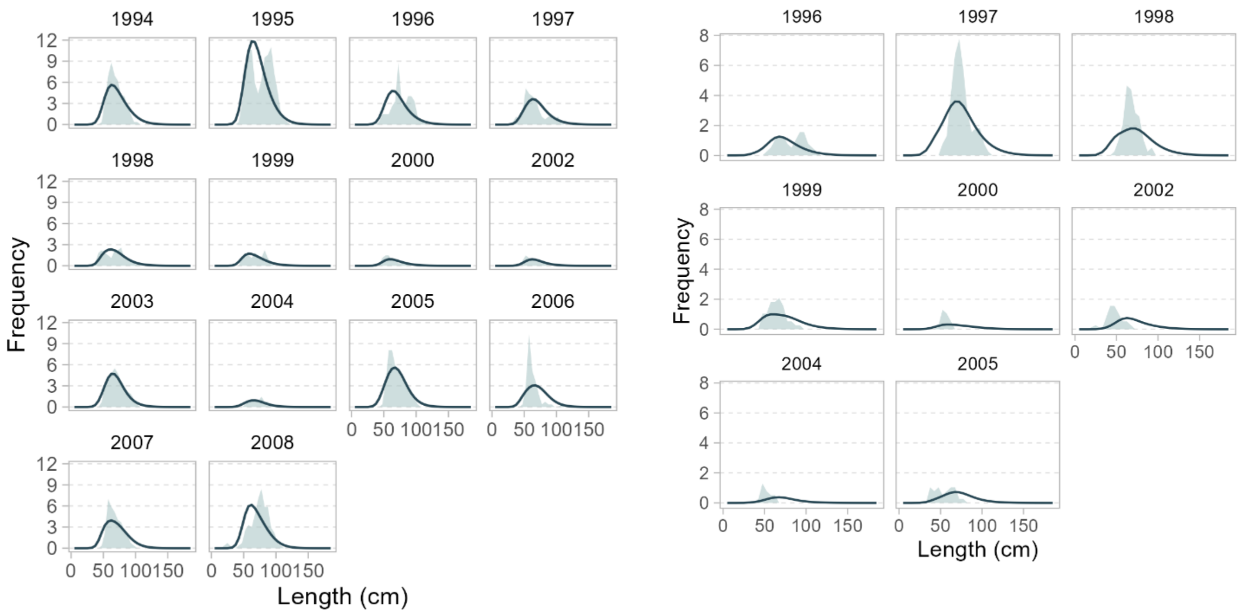

Figure 5 Fits to the ATT (left) and NVT (right) trawl fisheries length data. Shaded area is the observed data, and the lines the predictions.

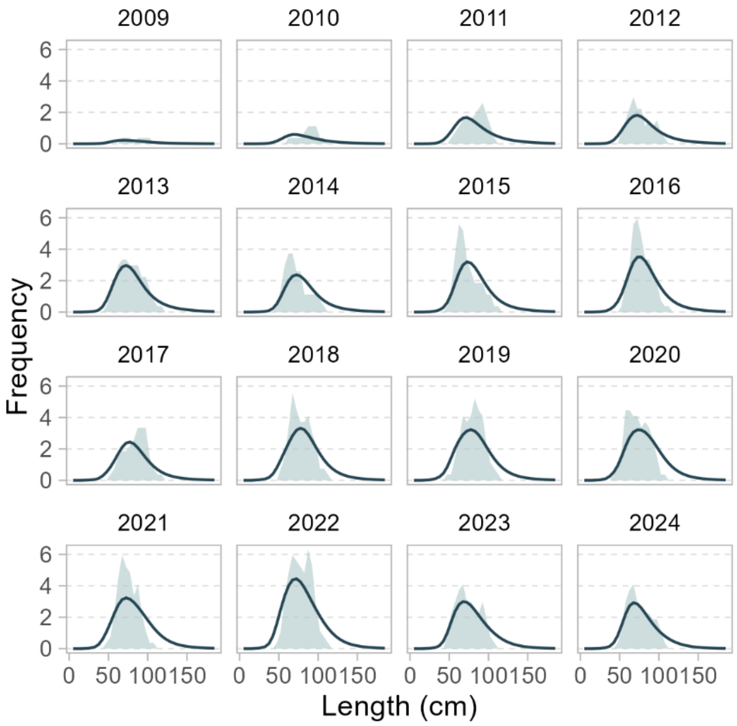

Figure 6 Fits to the ATL longline fisheries length data. Shaded area is the observed data, and the lines are the predictions.

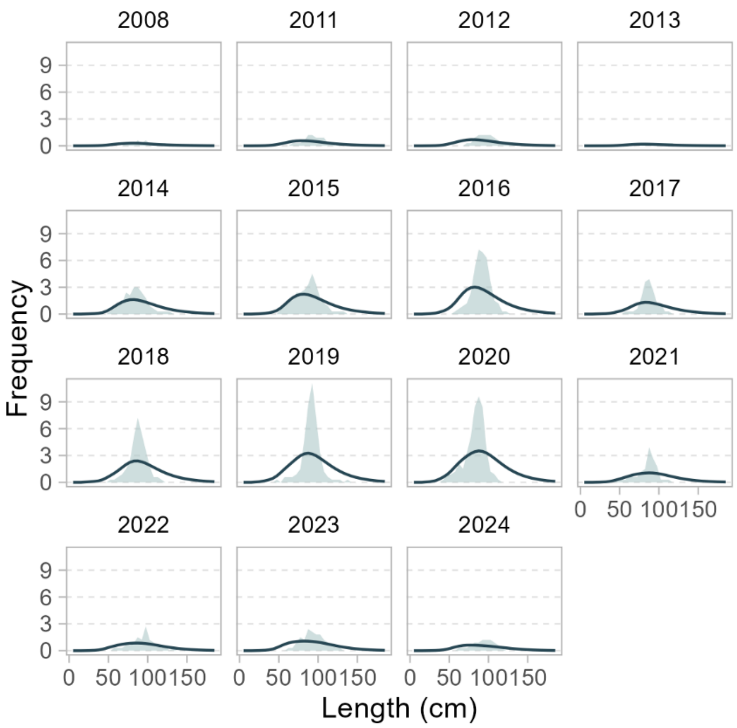

Figure 7 Fits to the NMRL longline fisheries length data. Shaded area is the observed data, and the lines are the predictions.

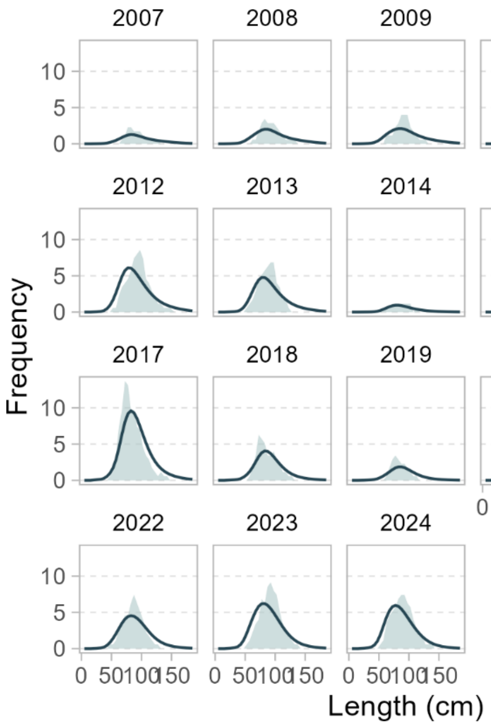

Figure 8 Fits to the SMRL longline fisheries length data. Shaded area is the observed data, and the lines are the predictions.

Figures 9 and 10 show the fits to the female conditional age at length data for the Aurora Trough trawl fleet for males and females and Figure 11 and 12 show the same for Northern Valley Trawl fleet. Figure 13 and 14 show the fits to the female conditional age at length data for the Aurora Trough longline fishery, Figure 15 and 16 show the same for Northern Macquarie Ridge longline fishery, and Figure 17 and 18 show the Southern Macquarie Ridge longline fits.

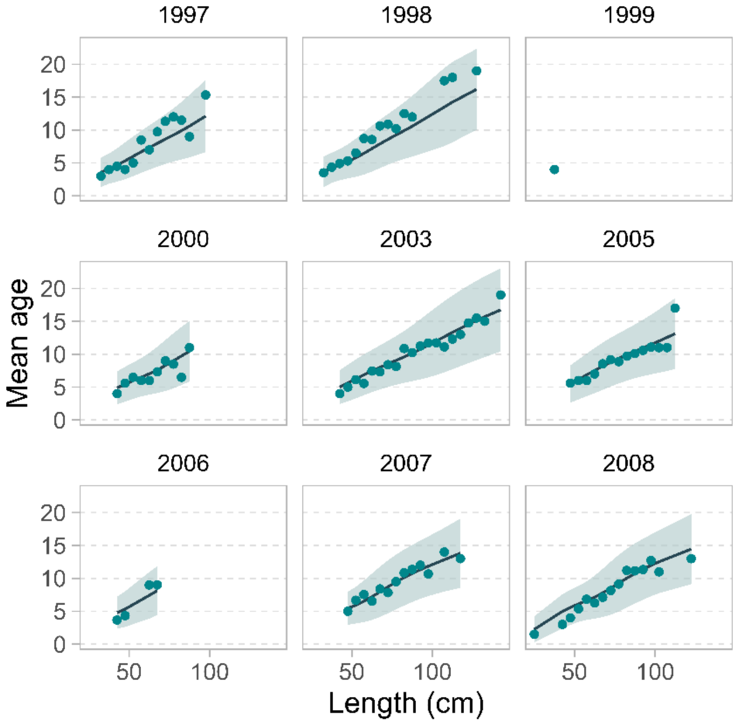

Figure 9 Fits to the ATT trawl fisheries age-given-length data for females. Points are the observed mean age, and the lines and shaded area are the predicted median and 95th percentile.

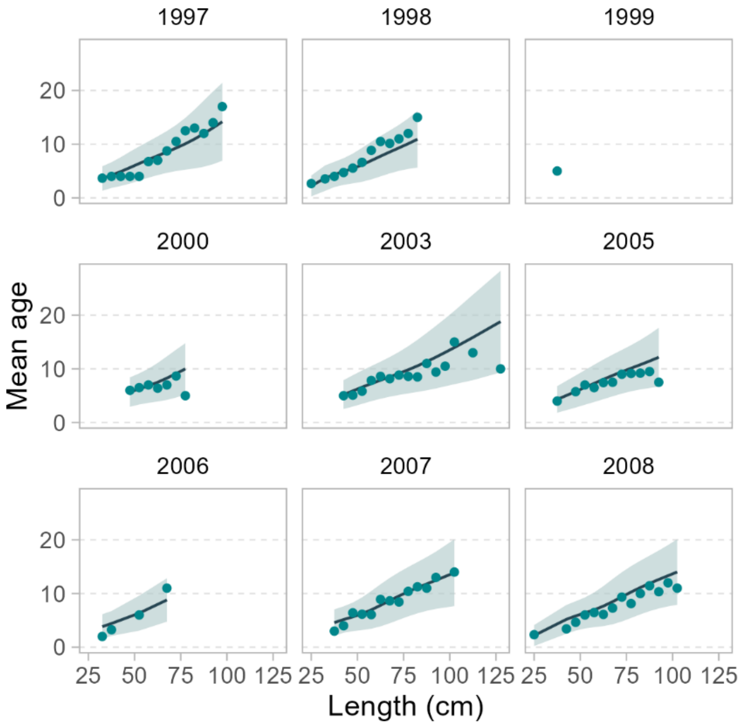

Figure 10 Fits to the ATT trawl fisheries age-given-length data for males. Points are the observed mean age, and the lines and shaded area are the predicted median and 95th percentile.

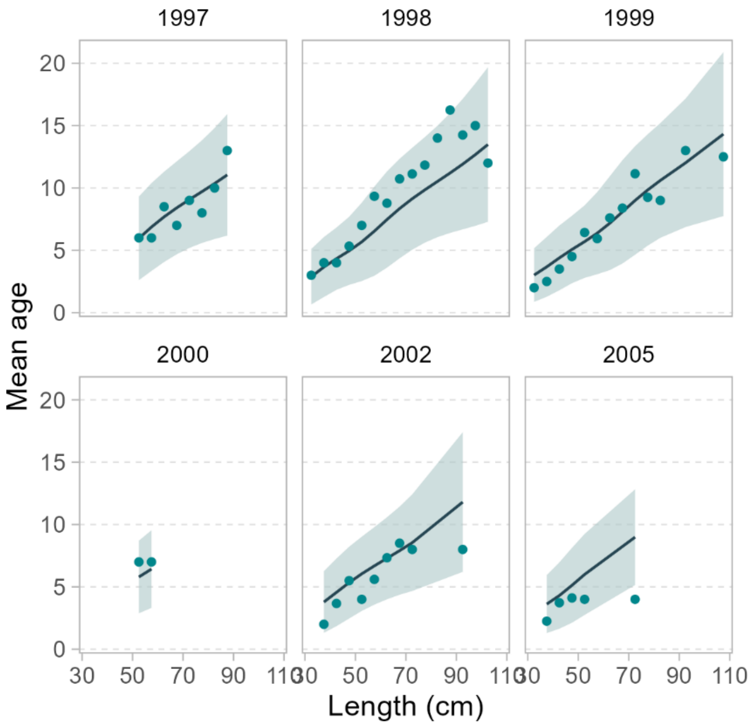

Figure 11 Fits to the NVT trawl fisheries age-given-length data for females. Points are the observed mean age, and the lines and shaded area are the predicted median and 95th percentile.

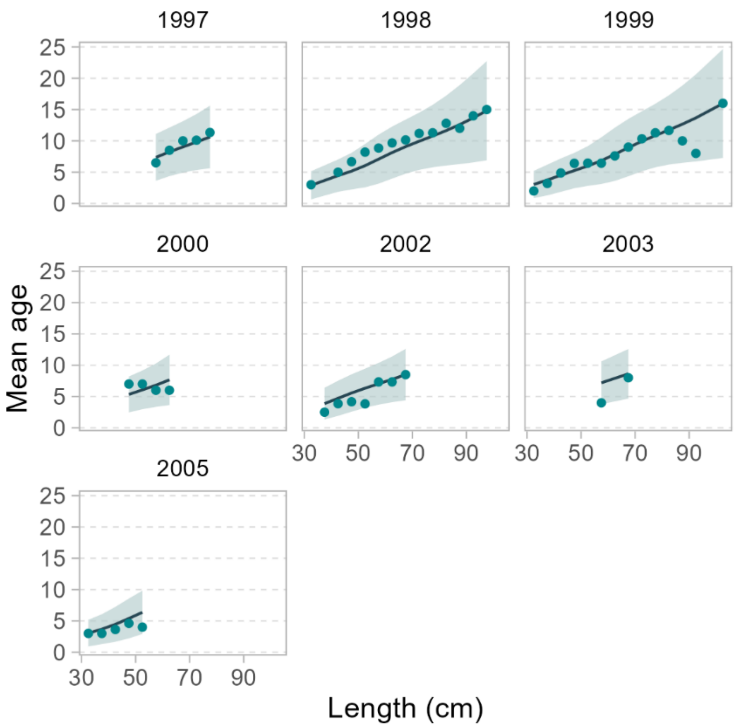

Figure 12 Fits to the NVT trawl fisheries age-given-length data for males. Points are the observed mean age, and the lines and shaded area are the predicted median and 95th percentile.

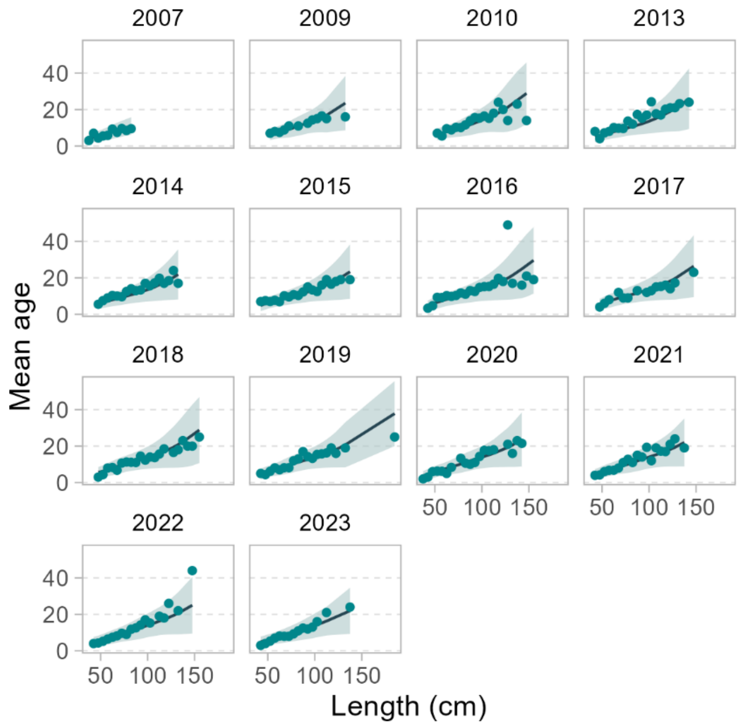

Figure 13 Fits to the ATL longline fisheries age-given-length data for females. Points are the observed mean age, and the lines and shaded area are the predicted median and 95th percentile.

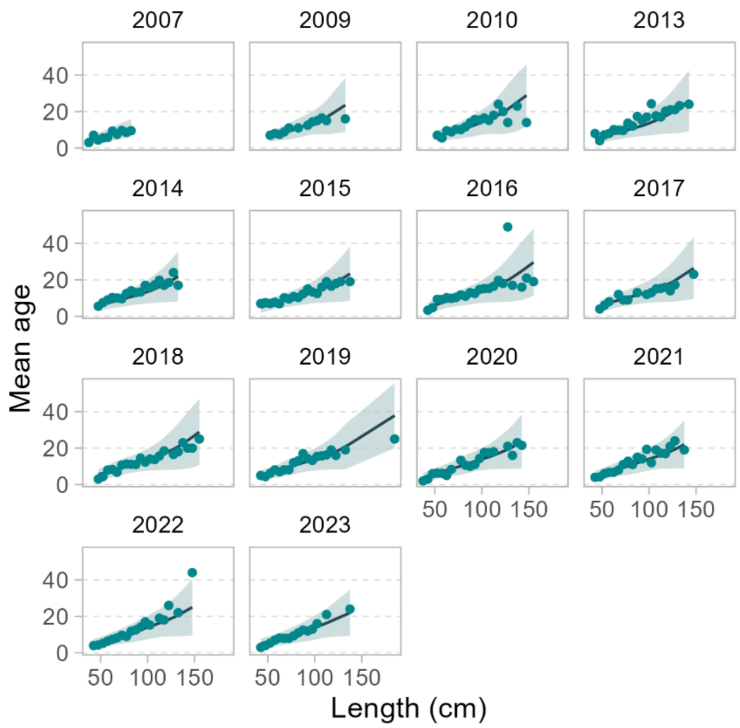

Figure 14 Fits to the ATL longline fisheries age-given-length data for males. Points are the observed mean age, and the lines and shaded area are the predicted median and 95th percentile.

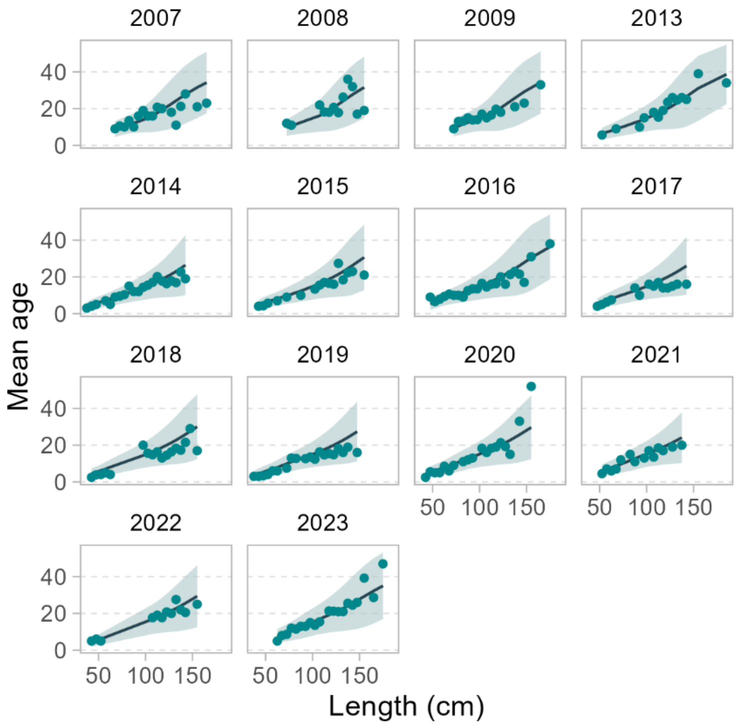

Figure 15 Fits to the NMRL longline fisheries age-given-length data for females. Points are the observed mean age, and the lines and shaded area are the predicted median and 95th percentile.

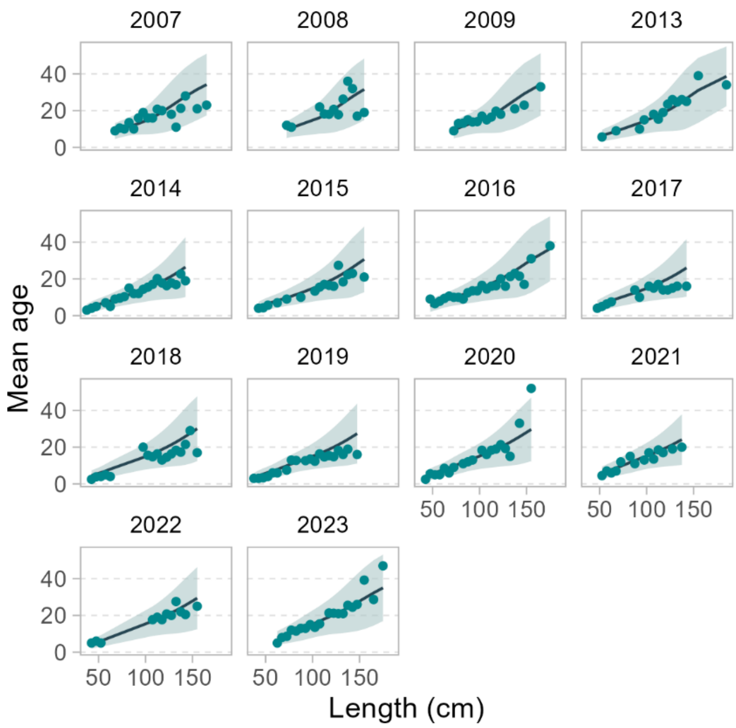

Figure 16 Fits to the NMRL longline fisheries age-given-length data for males. Points are the observed mean age, and the lines and shaded area are the predicted median and 95th percentile.

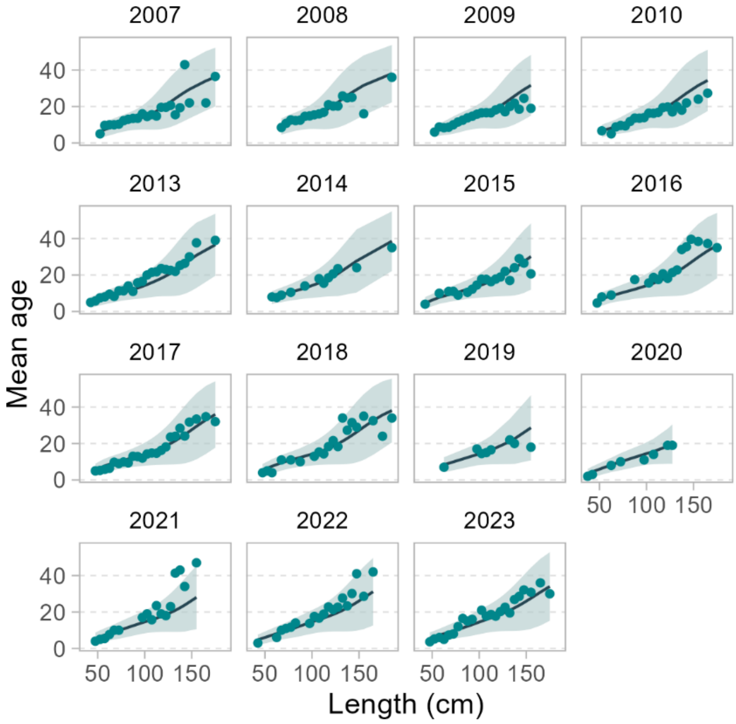

Figure 17 Fits to the SMRL longline fisheries age-given-length data for females. Points are the observed mean age, and the lines and shaded area are the predicted median and 95th percentile.

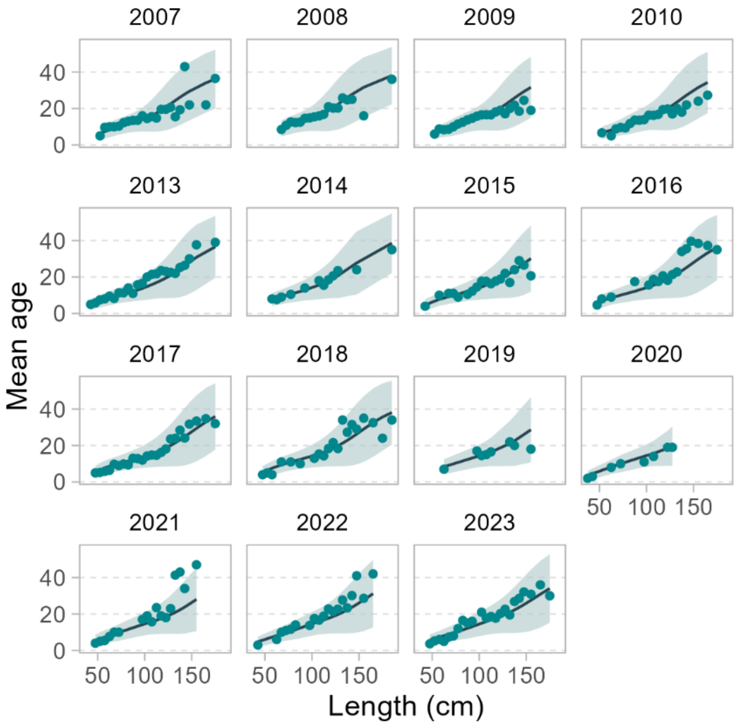

Figure 18 Fits to the SMRL longline fisheries age-given-length data for males. Points are the observed mean age, and the lines and shaded area are the predicted median and 95th percentile.

The fits to the tagging data (Figure 19–Figure 22) are summarised in four key ways:

1. successive recaptures for each year of releases
2. total recaptures for each year of release
3. total recaptures for each year of recapture
4. total recaptures for each year and region of recapture

All these summaries aggregate across the size spectrum of releases and recaptures for visual brevity, and also because size-at-recapture is not an explicit part of the tagging likelihood.

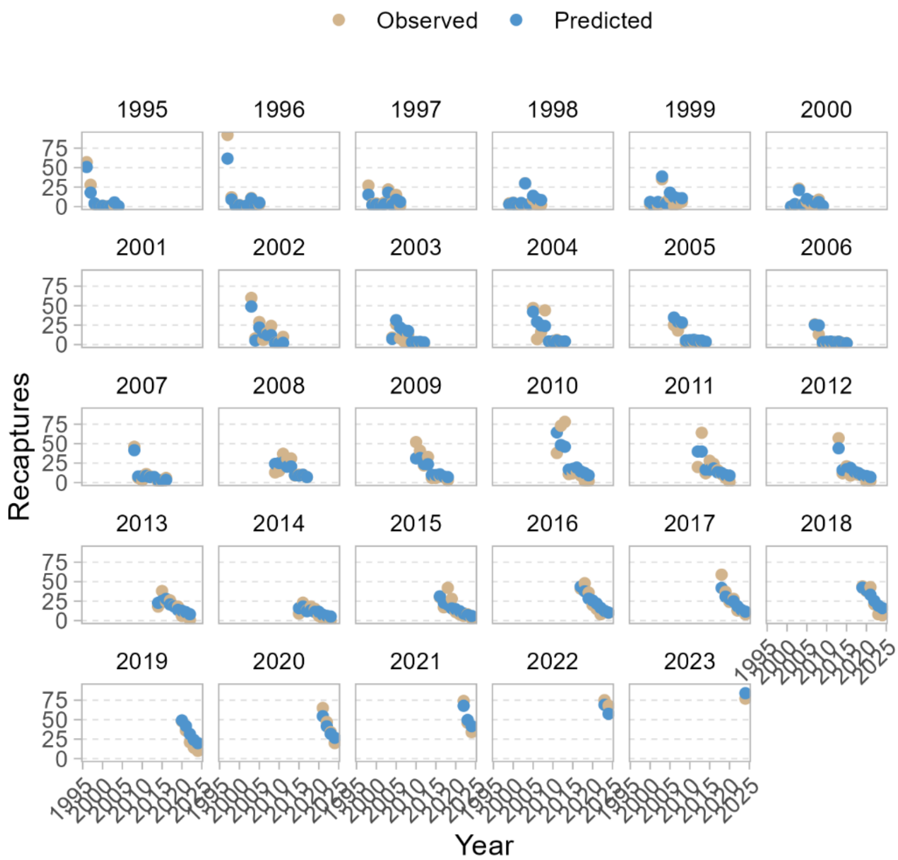

Figure 19 Fits to the tagging data for recaptures following year of release. Observed and predicted recaptures are shown in tan and blue, respectively.

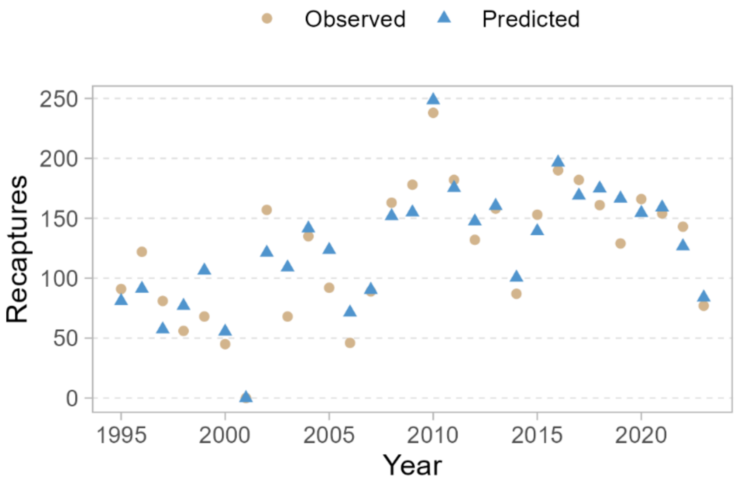

Figure 20 Fits to the total recaptures for each year of release. Observed and predicted recaptures are shown in tan and blue, respectively.

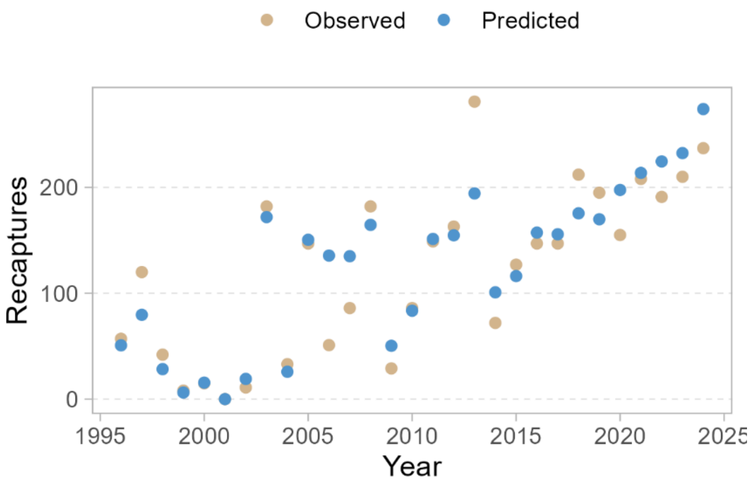

Figure 21 Fits to the total recaptures for each year of release. Observed and predicted recaptures are shown in tan and blue, respectively.

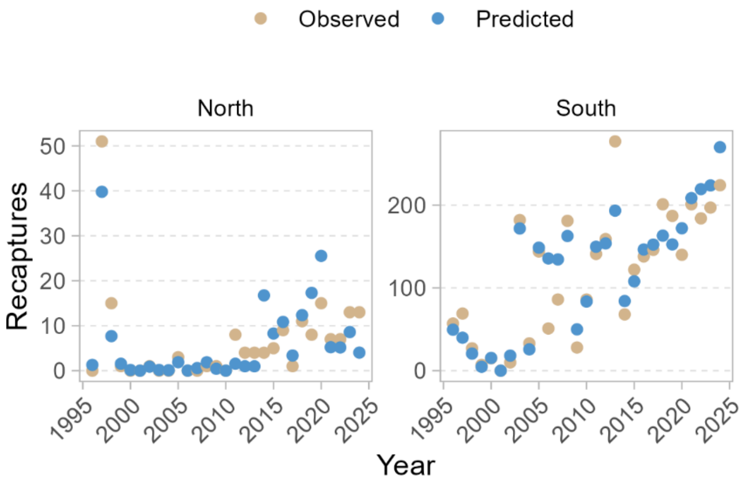

Figure 22 Fits to the recaptures for each year and region of recapture. Observed and predicted recaptures are shown in tan and blue, respectively.

Residuals of the fits to the tagging data are presented in the Appendix, in Figures 32–33.

5.4 Relative data “weighting” estimates

A key feature of the assessment model is that data weighting is achieved via internally estimated parameters, not an ad hoc tuning approach, as is often used in integrated assessments. The results of this model weighting process show that for the ATT and NVT fleets there is clear down-weighting of the haul data - more so for the NVT fleet. For the longline fleets, SMRL is down-weighted very little, but the ATL and NMRL fleet are clearly down-weighted (Table 28). For the ATT data this appears to result from random variation whereas the downweighting for the NVT data appears driven by a systematic lack of fit (cf. clear decrease in mean length over time coupled with the assumption of time-invariant selectivity). For the NMRL data by convention we assume logistic selectivity for this and the SMRL fleet to avoid the appearance of cryptic spawner biomass in the population. While logistic selectivity is the mode of choice for the ATL, and would be for SMRL if permitted the choice, the right-hand limb of the length frequency curve is consistently over-estimated in the last five years of data for the NMRL fleet.

Table 8 Estimates of the over-dispersion factors for the size data for each fleet, and the tagging data, φ^{tag}.

Variable	ATT	NVT	ATL	NMRL	SMRL	φ^{tag}
Estimate	2.79	3.95	2.58	3.41	1.52	1.45

For the tagging data, the estimate of $\varphi^{tag} = 1.45$ clearly suggests that the tagging data are over-dispersed, relative to the assumption of a straight multinomial recapture likelihood. For the conditional age-at-length data, we assumed a multinomial distribution, given the assumption that age data from within a given length class would be random. The reality of whether this is true can only be determined once the model has been fitted to the data. Examining the fits to the data for each sex and fishery (Figure 10–Figure 18) it is apparent that, barring a few isolated examples, the observed mean length-at-age sits within the predicted 95% interval and does not systematically appear above or below the predicted mean. When examining the standardised residuals for over-dispersion (e.g. do they systematically appear greater than 1) there is no evidence that a move to the over-dispersion model (Dirichlet-multinomial) is required. This suggests that:

- the multinomial distribution assumed for these data appears valid
- the model's predictions of age-given-length are clearly statistically consistent with the data and the assumed growth model
- at least for these data, the model has enough freedom to adequately explain the observations
- it would seem to validate the underlying assumption that size (not age) is the right underlying variable to parameterise selectivity

5.5 Population dynamic summaries from MCMC

For the reference assessment base case, we used the *tmbstan* R-based MCMC package Monnahan and Kristensen (2018) to sample from the posterior distribution. The package uses the Hamiltonian MCMC algorithm, designed to solve common problems with traditional MCMC algorithms relating to sampling from complex high-dimensional posterior surfaces. As a result, a convergent MCMC sample from the posterior (1,000 iterations) can be obtained in about 90 minutes. The key female SSB summaries can be found in Figure 26; total recruitment and the key spatial parameters (recruitment fraction to North, η_1, and migration rates between regions) can be found in Figure 27 and Figure 28.

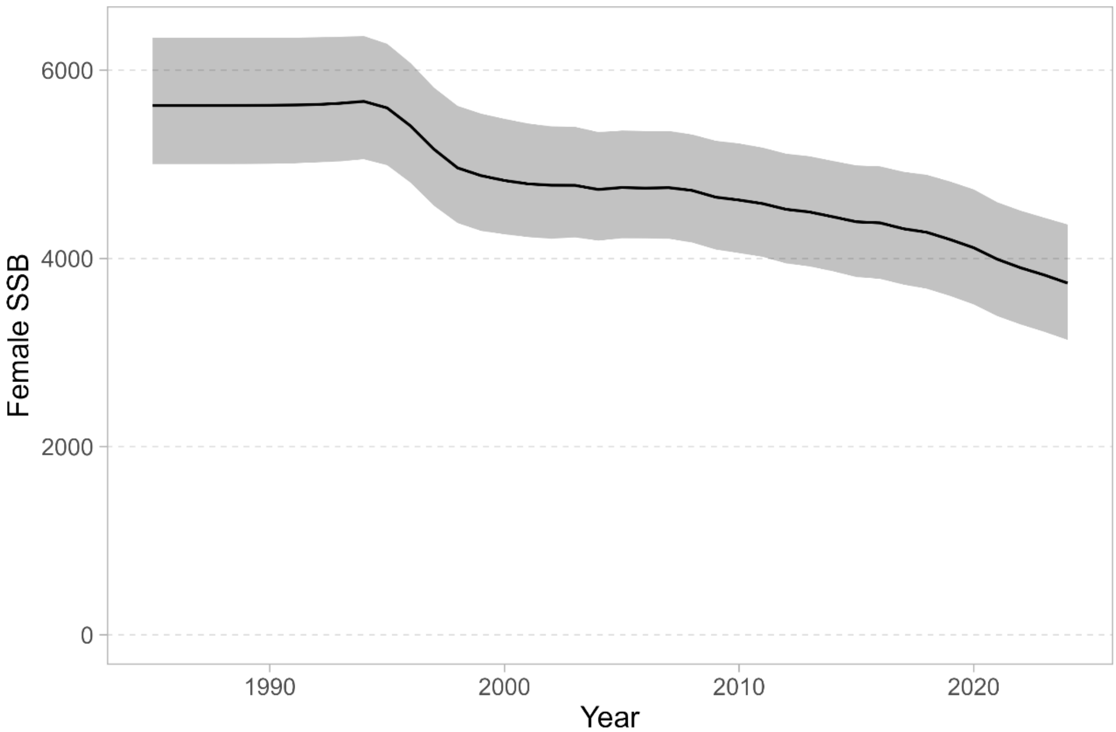

Figure 23 Posterior median and 95% credible intervals for total female SSB.

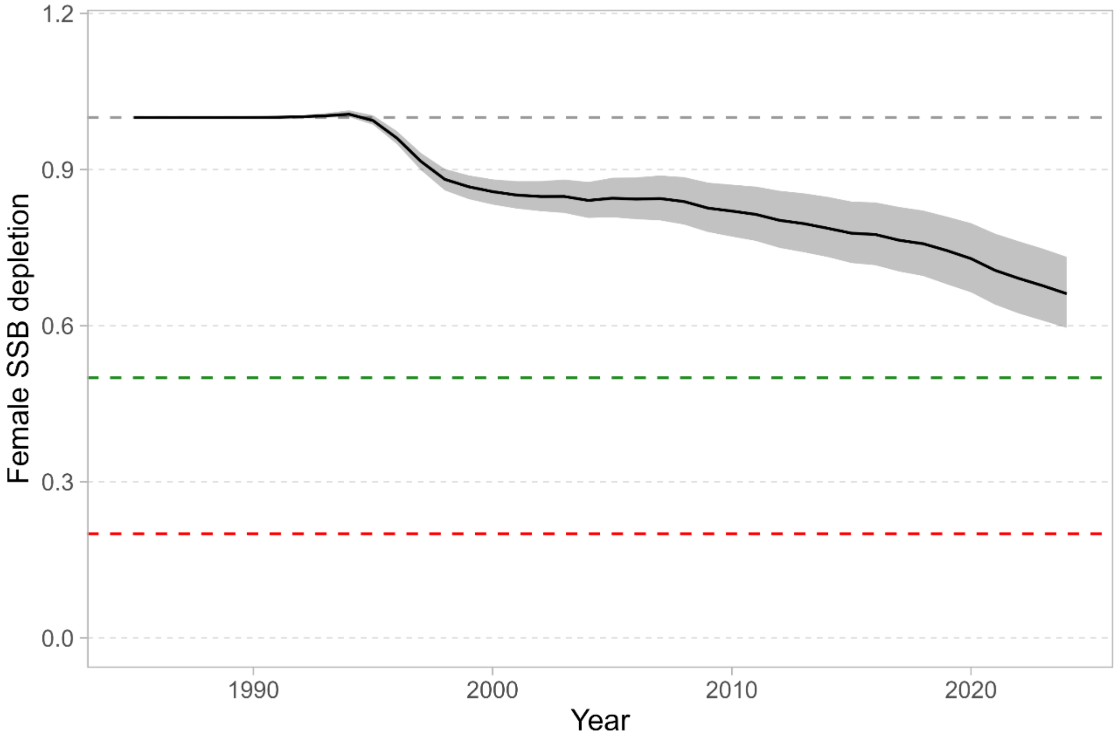

Figure 24 Posterior median and 95% credible intervals for female SSB relative stock status.

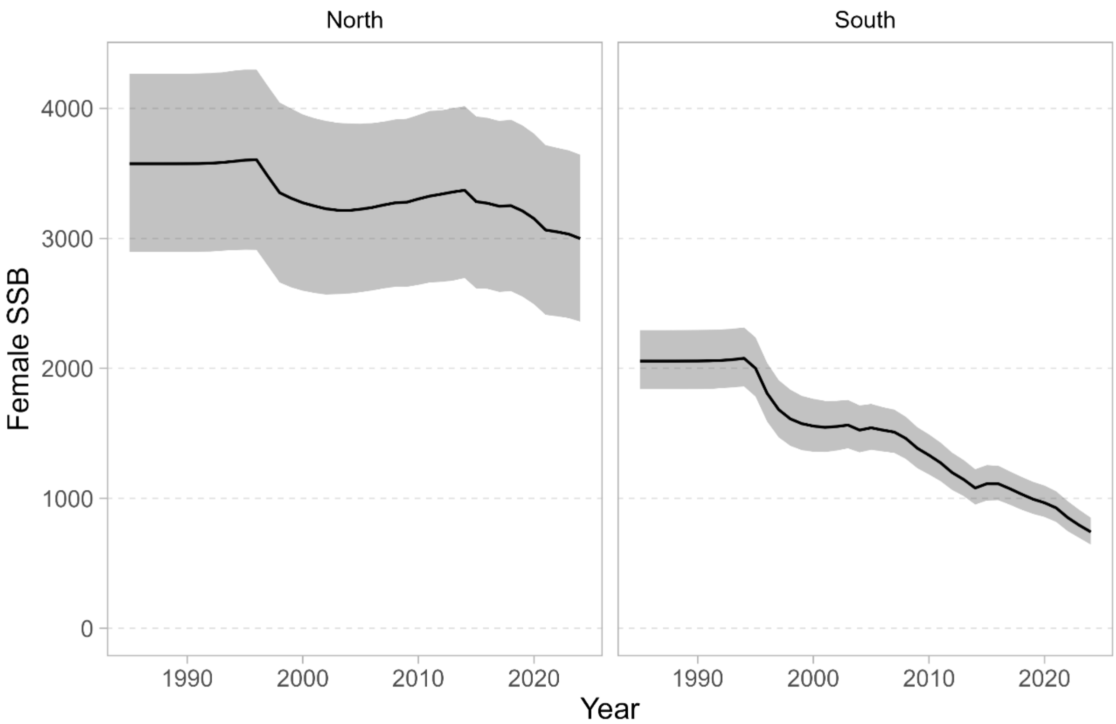

Figure 25 Posterior median and 95% credible intervals for spatial female SSB.

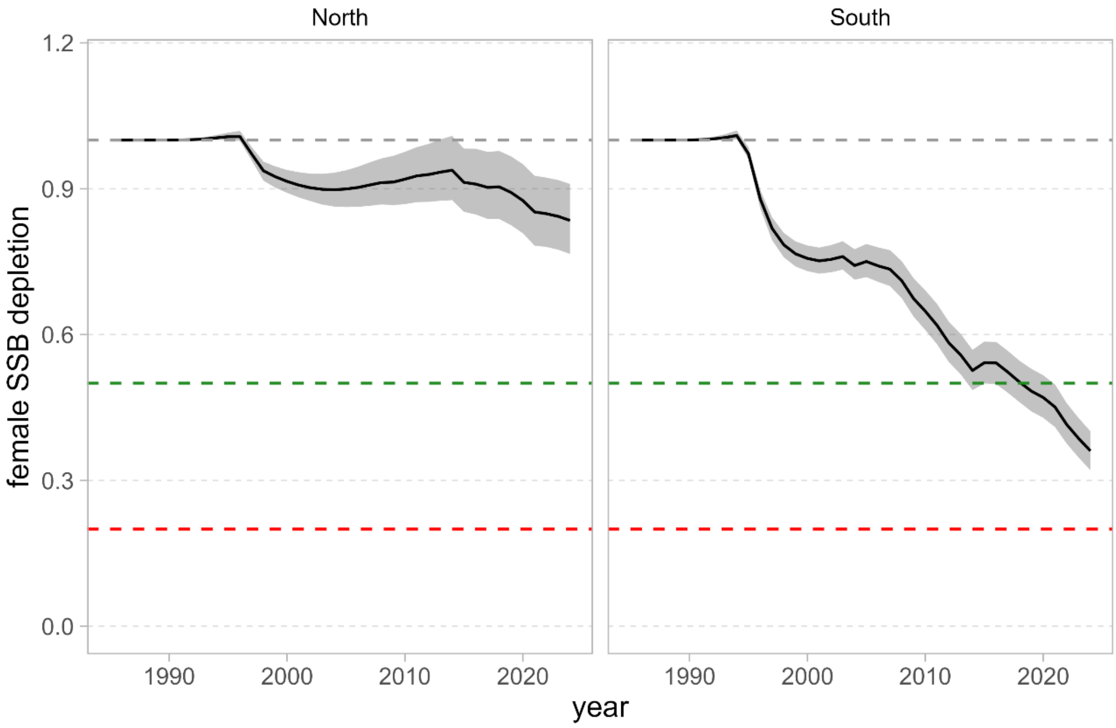

Figure 26 Posterior median and 95% credible intervals for spatial female SSB relative stock status.

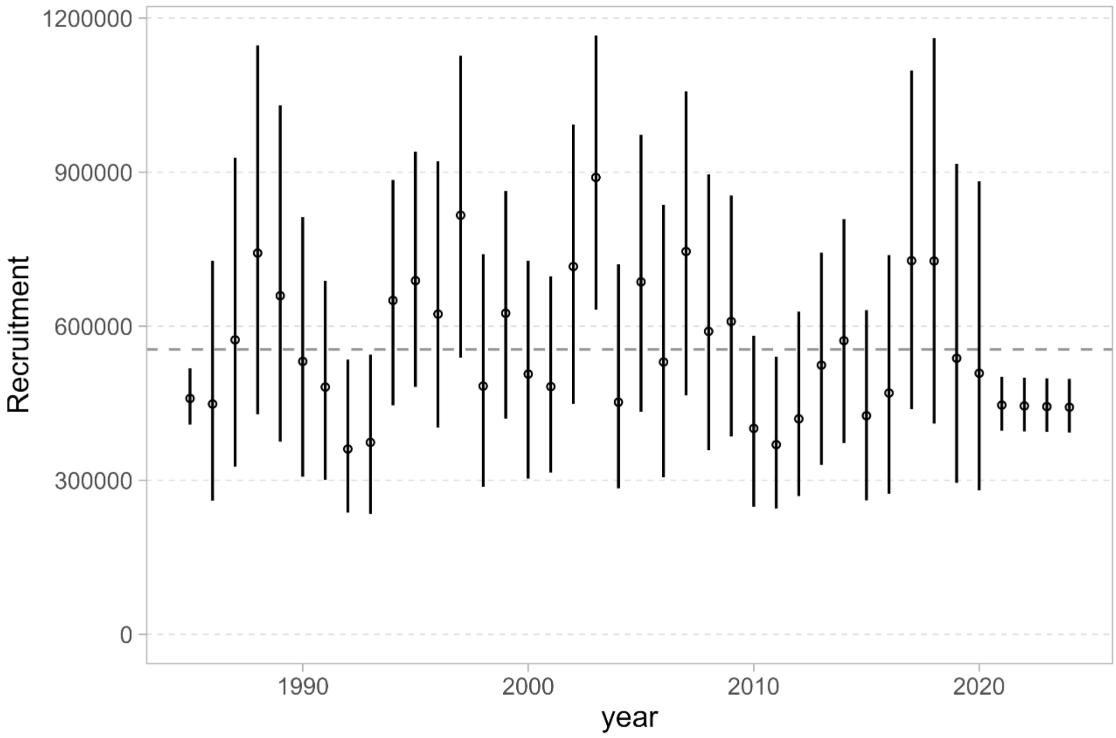

Figure 27 Posterior median and 95% credible intervals for total recruitment.

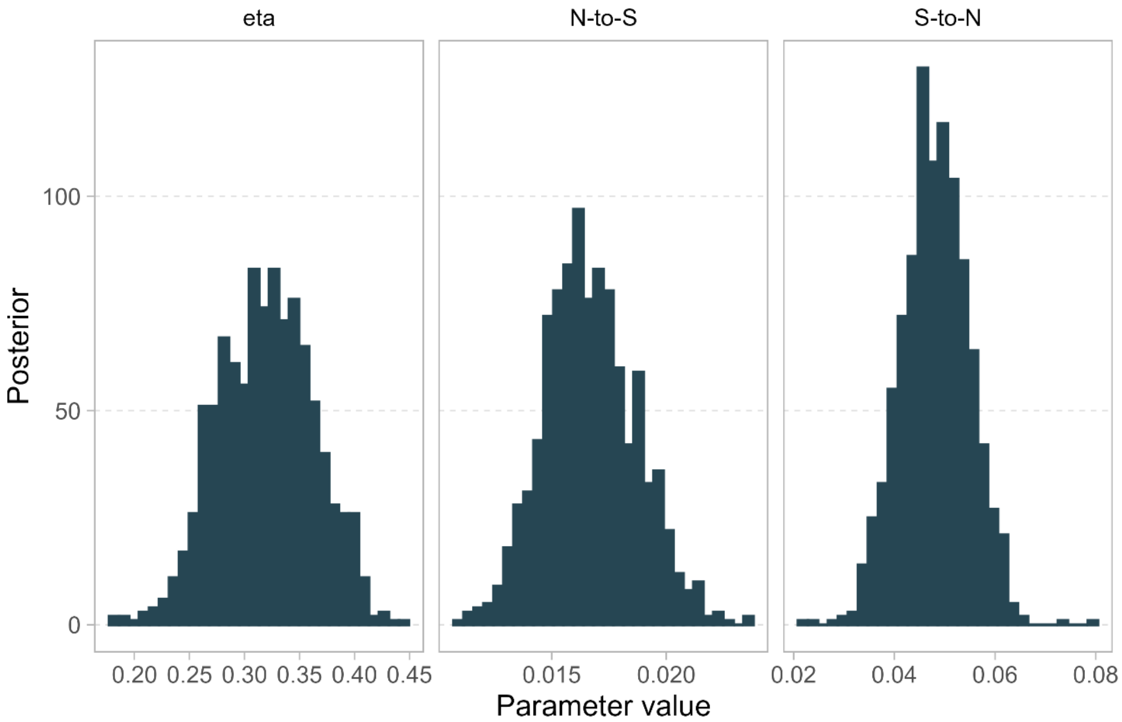

Figure 28 Posterior median and 95% credible intervals for the marginal posteriors for the three spatial parameters.

The current (*ca.* 2025) median estimate (and 95% credible interval) of overall female SSB stock status is 0.66 (0.60–0.73). As with previous assessments, the estimated overall level of female SSB is consistently higher in the Northern region relative to the Southern region. Spatially, the depletion in the Northern region is 0.83 (0.76–0.91); in the Southern region it is 0.36 (0.32–0.40). Total recruitment has generally varied randomly around the mean level, with short periods of higher or lower recruitment, but not sustained periods of either (showing intermediate levels of positive temporal auto-correlation *ca.* 0.3).

The spatial recruitment fraction to the Northern region has a median (and 95% credible interval) of 0.32 (0.24–0.40) – the same as the previous estimate from 2023 (Bessell-Browne and Hillary, 2023a). Migration point estimates are similar (around 1% *per annum*) from North to South, and 5% from South to North) – the same as in 2024.

Differences between the relative sizes of the Northern and Southern regions largely depend on the metric chosen. In terms of current female SSB, clearly the model estimates more biomass in the North than in the South. This difference between the regions is similar to that observed in the 2024 assessment. When comparing the difference between exploitable abundance currently accessible by the longline fleets, then the estimated difference between the regions is narrower. The spatial abundance in the North is by far the most uncertain given the much lower level of tag recaptures there relative to the South. Coupled with the low movement rates between regions this results in the abundance in the North - estimated to be the largest region - being a considerable source of variation in estimates of absolute abundance over time. Whereas there is little change in the absolute abundance in the South relative to the 2023 assessment, as there are over a thousand recent tag recaptures with consistent rates of recaptures per unit of catch. Due to increasing number of recaptures in the North (as seen in the last 4–5 years) the abundance will become more accurately estimated, but also prone to changes in the estimated mean as the accuracy increases, relative to the South.

5.6 Key sensitivity runs

We focus on four key sensitivity tests:

1. using the estimates of tag shedding rates instead of the previous assumption of effectively zero tag loss over time
2. assume a lower steepness of $h = 0.6$
3. assume a higher steepness of $h = 0.9$
4. assume the HIMI natural mortality of $M = 0.155$

For the tag shedding sensitivity test, we assumed what is effectively the worst-case scenario: where the tag shedding is defined as in Hillary (2019) and this defines π_t^{tag}; as a result, we are at the expected lower-bound of tag retention (for the purposes of detection post-capture). For the alternative natural mortality scenario (HIMI value of $M = 0.155$) we see the most difference in parameter and biomass estimates across the tested scenarios (Table 9). Unsurprisingly, the estimate of R_0 increases to accommodate the higher rate of attrition of recruits given the higher M value (Table 9). The stock status is lower than for the reference case, around 0.53, with the change driven by differences in spatial recruitment fraction and migration estimates (Table 9). Overall, the fit is better for the higher M value as it has been in previous assessments but, given we impose asymptotic selectivity on all the long-line fleets, this is also highly likely due to the model using additional freedom in the parameter to better fit to the age-given-length and tag data via dome-shaped selectivity (Table 9). The alternative steepness scenarios change little in terms of stock status or other key parameters - the reference steepness value of 0.75 is the best fit to the data but given how little contrast there is in the recruitment-SSB relationship over time this result is unlikely to be significant (Table 9). For the tag shedding scenario we see a very slightly lower stock status of 0.65 (Table 9). The change in female SSB and stock status for each of the scenarios is presented in Figure 29.

Table 9 Sensitivity test summaries.

Sensitivity	Stock Status	R_0 (x 10^5)	Likelihood - Length	Likelihood – Age at length	Likelihood - Tags	Likelihood - Total
Base	0.66	13.06	13,813	15,318	15,221	44,354
M=0.155	0.53	13.34	13,675	15,314	15,212	44,202
h=0.6	0.66	13.07	13,433	15,318	15,221	43,873
h=0.9	0.66	13.08	13,433	15,318	15,221	43,973
Tag shedding	0.65	13.04	13,822	15,319	15,219	44,361

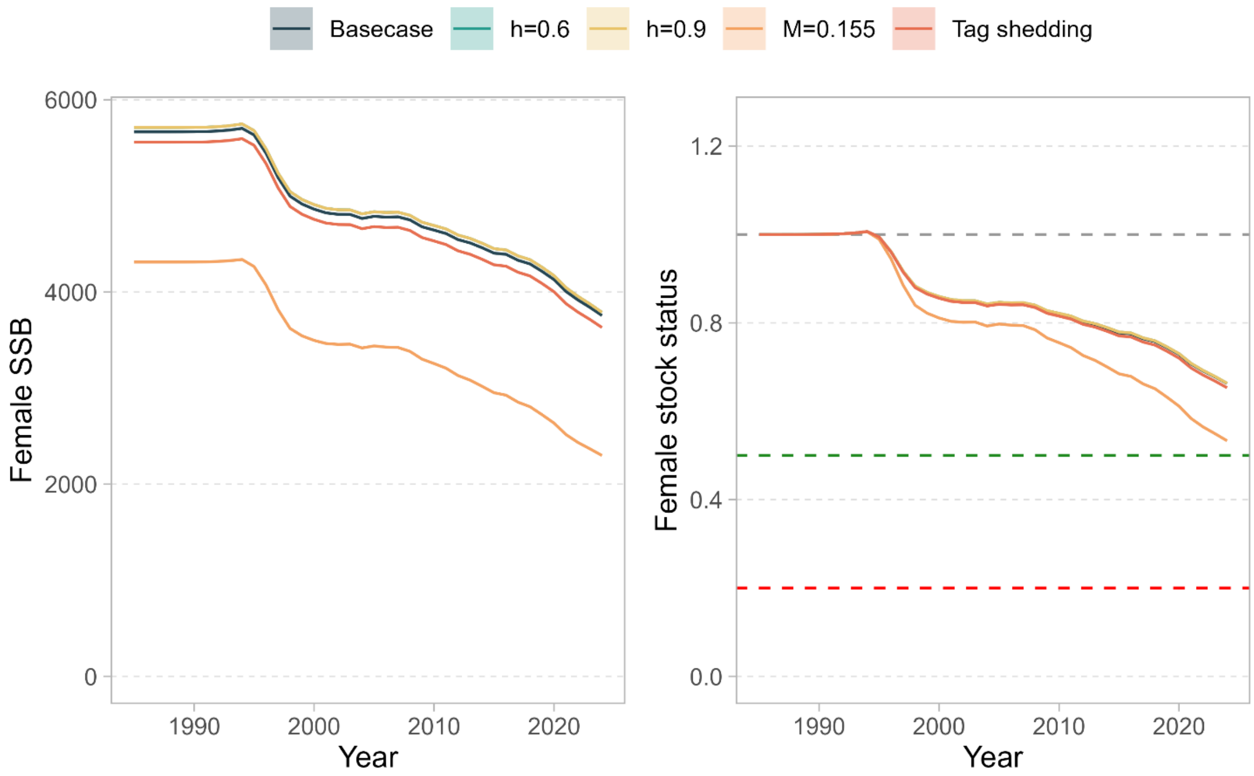

Figure 29 Female spawning stock biomass (SSB) and stock status for each of the sensitivity tests.

5.7 Recommended TAC scenarios

The CCAMLR decision rule is currently used for Macquarie Island toothfish in relation to calculating recommended TACs. As in previous calculations we explored spatial scenarios where the catch in the Aurora Trough was fixed at a given value, and then the remaining catch was shared between the North and South, given an assumed percentage for each. For the Aurora Trough we explored 200, 250 and 300 tonnes with 10:90, 20:80 and 50:50 percentage splits for the North and South remainder, the 20:80 split represents the average catch split over the past 3 years. Table 10 details the recommended TACs for these spatial catch scenarios.

Table 10 Recommended TAC scenarios for the various spatial catch distribution scenarios explored.

Aurora Trough	NMRL	SMRL	NMRL %	SMRL %	TAC
150	25	228	10	90	403
200	20	179	10	90	399
250	14	130	10	90	395
150	52	208	20	80	410
200	41	163	20	80	404
250	30	120	20	80	400
150	139	139	50	50	428
200	110	110	50	50	420
250	81	81	50	50	412
Average					408

The recommended TACs range from 395 to 428 tonnes with an average of 408 tonnes, around a 11% decrease from the 2023 average of 459 t. This is driven by the lower stock status estimates in the current assessment compared to that in 2021, as is expected when you are moving the stock down towards the target reference point.

A final piece of information to be considered when implementing the recommended TACs is detailed in Figure 30. The recommended TACs in Table 10 all meet the requisite target in 35 years, however, they reach that target on a downward trajectory, not in an equilibrating sense. This is because the starting stock status of 0.66 required a catch higher than the equilibrium catch when at target, and this level of catch will likely cause the stock to decrease below the target. This outcome assumes that estimates of abundance will not change in future assessments, which we know is not the case. This highlights the sensitivity of management advice to the CCAMLR harvest control rule.

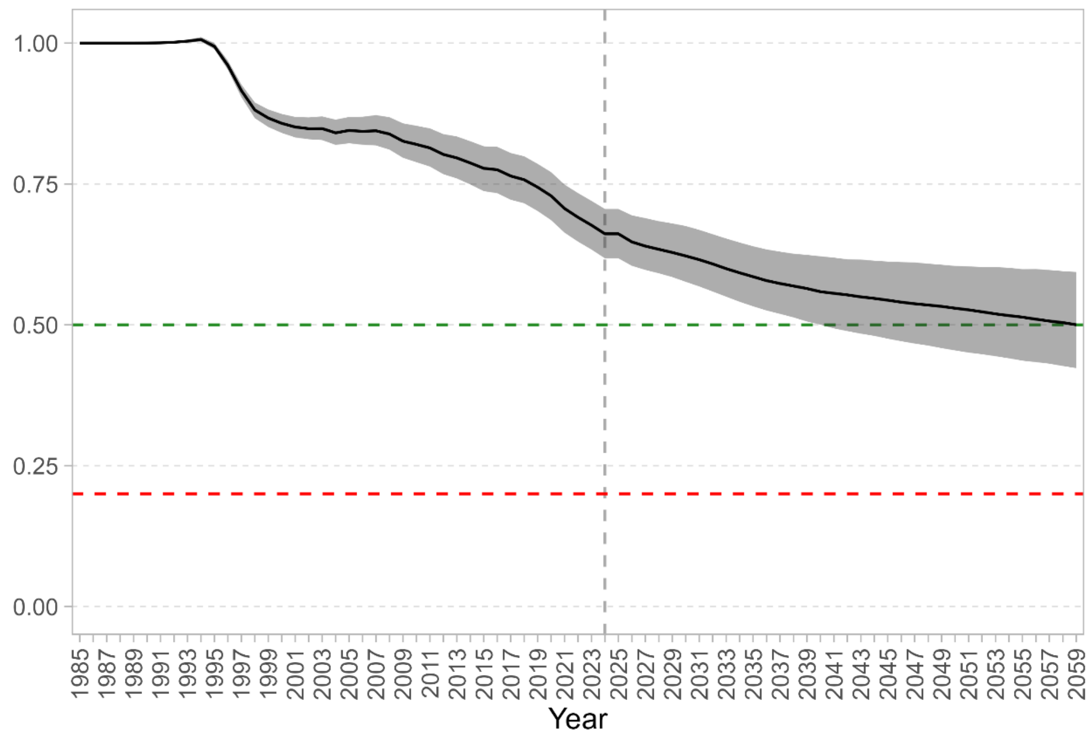

Figure 30 Projection for one of the recommended TAC scenarios. The line is the median and shaded area is the 95% credible intervals for female stock status. The green dashed line is the target reference point and the red dashed line is the limit reference point. The vertical grey dashed line shows the start of projections.

6 Discussion

In this paper we detail an update of the adopted assessment model for the Patagonian toothfish fishery around Macquarie Island first detailed in Hillary and Day (2019a). From the key management variable, female SSB based stock status has a median value of 0.66 relative to unfished levels with a 95% credible interval of 0.60–0.73, lower than the 0.73 estimate from the 2023 assessment. Fits to the various data sources (size, age given length, tags) are all acceptable and show no obvious model structure problems.

In terms of sensitivities, the steepness alternatives and the tag shedding scenario had negligible impact on model outcomes. Only the higher $M = 0.155$ showed any real difference, with a lower estimate of stock status at 0.53, driven by changes in the spatial recruitment fraction and migration estimates for this scenario. Future development of the model would benefit from exploring a more nuanced spatial recruitment model, where deviations are spatiotemporal in nature, not just estimated for the whole population and then divided between North and South by a time-independent multiplier. Such an approach would estimate not just recruitment variability but also temporal and spatial correlation and hopefully do a better job at teasing out spatial recruitment patterns if they exist (which they appear to in the tag data).

A range of recommended TACs were calculated (from 395 t–428 t) with an average of 408 t - a 11% decrease from 2023 driven by the lower stock status estimate. The CCAMLR rule will likely continue to cause short-term variability in the TAC as estimates move over time, despite there being no significant changes in overall status from one assessment to the next. MSE work, which will be presented to the SARAG in 2025, will explore possible alternatives to this rule for setting management advice, and whether they can ameliorate some, if not most, of these issues encountered for both the Macquarie Island and HIMI toothfish fisheries.

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8 Appendix

Figure 31 Residuals of fits to the tagging data for recaptures following year of release.

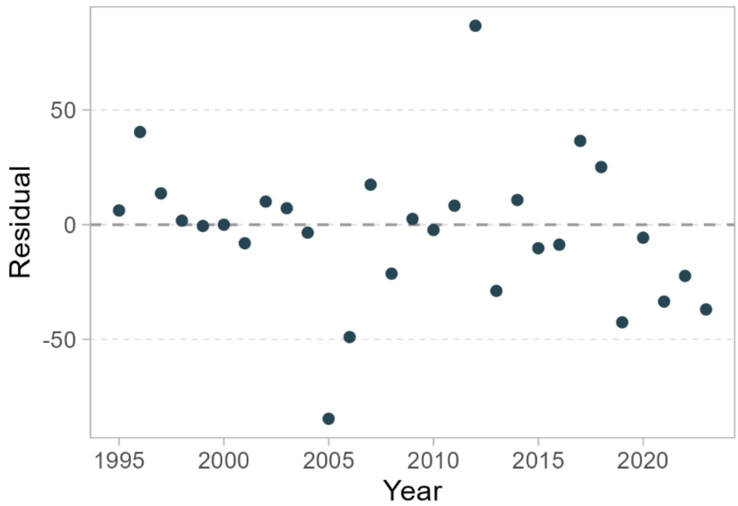

Figure 32 Residuals of fits to the tagging data for recaptures following total recaptures for each year of release.

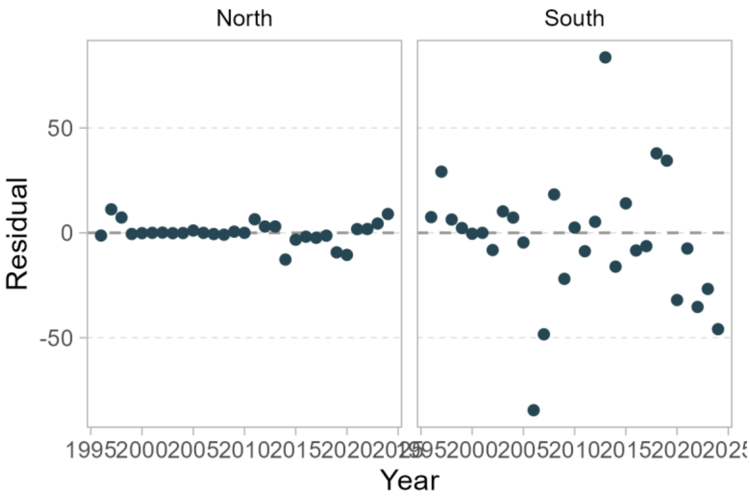

Figure 33 Residuals of fits to the recaptures for each year and region of recapture.

Table 11 Numbers of tagged fish released from trawl fleets and recaptured following at least 180 days at liberty, by release fleet and season.

Release season	Release fleet	Num released	1996/97	1997/98	1998/99	1999/00	2000/01	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
1995/96	ATT	428	57	28	3		1	1	1							1													
1995/96	NVT	4																											
1996/97	ATT	452		42	7		2		9	1	3		1	1															
1996/97	NVT	536		53	5	1			2																				
1997/98	ATT	550			18	3	4	5	21	4	15	1		2	3	1	2	2			1							1	
1997/98	NVT	502			9				1					1		1													
1998/99	ATT	661				4	5	2	30	2	9	2	2	7		1	1		1										
1998/99	NVT	315																				1							
1999/00	ATT	697					3	1	35	6	12	1	4	6	2	5	1	5					1						
1999/00	NVT	302																1											
2000/01	ATT	370						1	23	3	5	1	1	9															
2000/01	NVT	134						1			1																		
2002/03	ATT	494							60	8	29	6	15	24	2	3	10	1	6	2			1			1			
2002/03	NVT	17															1												
2003/04	ATT	674								9	23	8	4	13	2	3	2	1	1										1
2003/04	NVT	60									3																		
2004/05	ATT	572									46	7	16	43	4	4	6	3	4	1		1			1				
2004/05	NVT	264									2		1	1						1	1								
2005/06	ATT	610										25	18	27	2	5	4	4	3	1	1	1	1				1		
2005/06	NVT	290															1			2	3	1							
2006/07	ATT	467											26	13		1			4		2	1	2						
2006/07	ATT	355												31	2		2	1	3	1		2							
2008/09	ATT	727													2	6	12	10	19	6	8	8	1	4		1	1		

Release season	Release fleet	Num released	199 6/97	199 7/98	199 8/99	199 9/00	200 0/01	200 2/03	200 3/04	200 4/05	200 5/06	200 6/07	200 7/08	200 8/09	200 9/10	201 0/11	201 1/12	201 2/13	201 3/14	201 4/15	201 5/16	201 6/17	201 7/18	201 8/19	201 9/20	202 0/21	202 1/22	202 2/23	202 3/24
2008/09	NVT	15																											

Table 12 Numbers of tagged fish released from longline fleets from 2007/08--2015/16 and recaptured following at least 180 days at liberty, by release fleet and season.

Release season	Release fleet	Num released	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25
2007/08	NMRL	26		1		3	2				1								
2007/08	SMRL	189	15	4	3	6	6	4		1	4	3	1						
2008/09	NMRL	82		2		7		1	1										
2008/09	SMRL	386		9	9	18	21	11	2	2	2	6	1		1	1			
2009/10	ATL	300			27	13	9	13	4	2	3	2			1				
2009/10	NMRL	60				5	5			2	1				1	1			
2009/10	SMRL	396			26	25	8	20	2	2	4	5	3	2	1			1	1
2010/11	ATL	480				11	31	45	6	4	4	1		1		1			
2010/11	SMRL	509				27	42	34	5	8	10	8	2	1				1	1
2011/12	ATL	307					10	37	7	7	12	6	3	3	1	3			
2011/12	NMRL	116					1	2	1	3	2	1	1			1	4	1	1
2011/12	SMRL	504					9	25	4	18	10	9	7	3		1		2	
2012/13	ATL	311						37	12	12	6	6	9	7	1	1			1
2012/13	NMRL	57											1	1			1		
2012/13	SMRL	307						20		9	3	5		1		1		1	1
2013/14	ATL	532							9	26	23	16	12	11	5	3		1	
2013/14	NMRL	36								3			1				1		
2013/14	SMRL	256							9	10	1	10	6	7	1	5	1		
2014/15	ATL	300								9	19	11	13	8	3	2			
2014/15	NMRL	499									4		4	6	3	1			
2014/15	SMRL	39										2	1	1					
2015/16	ATL	361									17	13	27	21	7	6	3	3	

Release season	**Release fleet**	**Num released**	**2008/09**	**2009/10**	**2010/11**	**2011/12**	**2012/13**	**2013/14**	**2014/15**	**2015/16**	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**
2015/16	NMRL	171									2	1	5	3			1	1	1
2015/16	SMRL	172									12	4	10	4	4	2	2	4	2

Table 13 Numbers of tagged fish released from longline fleets from 2016/17 on and recaptured following at least 180 days at liberty, by release fleet and season.

Release season	Release fleet	Num released	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25
2007/08	NMRL	26		1		3	2				1								
2007/08	SMRL	189	15	4	3	6	6	4		1	4	3	1						
2008/09	NMRL	82		2		7		1	1										
2008/09	SMRL	386		9	9	18	21	11	2	2	2	6	1		1	1			
2009/10	ATL	300			27	13	9	13	4	2	3	2			1				
2009/10	NMRL	60				5	5			2	1				1	1			
2009/10	SMRL	396			26	25	8	20	2	2	4	5	3	2	1			1	1
2010/11	ATL	480				11	31	45	6	4	4	1		1		1			
2010/11	SMRL	509				27	42	34	5	8	10	8	2	1				1	1
2011/12	ATL	307					10	37	7	7	12	6	3	3	1	3			
2011/12	NMRL	116					1	2	1	3	2	1	1			1	4	1	1
2011/12	SMRL	504					9	25	4	18	10	9	7	3		1		2	
2012/13	ATL	311						37	12	12	6	6	9	7	1	1			1
2012/13	NMRL	57											1	1			1		
2012/13	SMRL	307						20		9	3	5		1		1		1	1
2013/14	ATL	532							9	26	23	16	12	11	5	3		1	
2013/14	NMRL	36								3			1				1		
2013/14	SMRL	256							9	10	1	10	6	7	1	5	1		
2014/15	ATL	300								9	19	11	13	8	3	2			
2014/15	NMRL	499									4		4	6	3	1			
2014/15	SMRL	39										2	1	1					

Release season	Release fleet	Num released	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25
2015/16	ATL	361									17	13	27	21	7	6	3	3	
2015/16	NMRL	171									2	1	5	3			1	1	1
2015/16	SMRL	172									12	4	10	4	4	2	2	4	2

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Attachment H

Australian Government

Australian Fisheries Management Authority

Sub-Antarctic Resource Assessment Group Technical Working Group (TWG)

RECOMMENDATIONS

MEETING 1

20-21 MARCH 2025

FINAL

SARAG - Technical Working Group (TWG)

CHAIR: Dr David Smith

Date: 20-21 February 2025, meeting closed at 10:30am 21 February 2025.

Venue: George Cartwright Room, Hadley's Orient Hotel, 34 Murray Street, Hobart

Attendance

Members

- Dr Philippe Ziegler
- Dr Cara Masere
- Dr Rich Hillary
- Dr Pia Bessell-Browne
- Dr Tim Ward
- Dr Graham Pilling
- Dr John Hampton
- Dr Paige Eveson
- Selina Stoute

Observers

- Anna Willock
- Kelly Buchanan
- Rhys Arangio
- Malcolm McNeil
- Brad Milic

Executive Officer: Rachel Downes, AFMA
Member interests are at **Table 1.**

TWG Terms of Reference

1. *A comprehensive review of Patagonian toothfish tagging data that is available for use within the HIMI stock assessment for Patagonian toothfish.*

   The Australian Antarctic Division (AAD) presented a detailed analysis of catch and effort, and longline tag release and recapture by month and year from 2012 by a 1-degree grid. Results for recaptured tags demonstrated little movement from the area of release. The TWG membership provided global best practice experience and advice.

2. *Recommendations and guidance from the TWG on robust approaches to incorporate the available tagging data into the HIMI toothfish integrated stock assessment. This process will include:*
   a. *consideration of the most appropriate treatments and analyses of HIMI toothfish tagging data which may include such approaches as: (i) the use of alternative mark-recapture models, including those which include elements of spatial structuring, to estimate abundance from tagging data; (ii) consideration of approaches to address non-random effort which may be specifically linked to concentrated tagging releases or recaptures in relatively small geographic areas (i.e., "hotspots"); (iii) exploration of whether any form of a "correction factor" to geographic extent or tag counts may be useful to reduce bias; and (iv) utilisation of tagging data to derive insights which may be informative for other aspects of model refinement or development (e.g., definition of movement probabilities, biological parameters, underlying stock structure etc).*

Recommendations from TWG 1 are outlined below. Overall, the TWG recommended adopting a spatial stock assessment approach to address the model misspecification apparent in the most recent assessments. While the original ToR options (number two) relate to approaches that could be applied within the current assessment structure, addressing the assessment concerns structurally provides the most comprehensive way to overcome the patterns apparent in the tagging data and was suggested as the priority moving forward.

The TWG recommended that any consideration of alternative biomass estimators (mark recapture models) that could be used external to CASAL2 should be delayed until the spatial analyses recommended below have been undertaken.

Workplan

The recommendations below should be progressed to inform the next meeting of the TWG in July 2025. Subject to member availability, technical experts on the TWG are willing to collaborate intersessionally and if necessary, the TWG may convene ahead of the July meeting.

The TWG noted that a high priority for SARAG was to undertake sensitivity tests removing the Sum to 0 assumption in the recruitment deviates (Year Class Strength). However, this is not currently possible in CASAL2.

Recommendations

Recommendation 1 (Highest priority) ***Incorporate spatial structuring into the stock assessment model.***

The detailed analyses undertaken by AAD describing the longline tag release and recaptures in a 1-degree grid should provide an initial basis for determining the appropriate spatial scale and structure for future analyses in CASAL2. Determination of the appropriate spatial structure could be supported by:

a) using simple tagging models (for example Brownie model, tag recapture only models, Chapman's estimator) independent of CASAL2 to provide insights into the areas chosen;
b) reviewing spatial trends in tag recaptures per unit of catch; and
c) the inclusion of tagging information from the trawl fishery in a stepwise manner.

Informed by the data and life history knowledge of toothfish, a range of approaches may be considered for specifying movement between areas with the view to having as simple as possible parametrisation of movement.

Recommendation 2 ***Include tags that have been at liberty for greater than 6 years in the tagging analysis noting CASAL2 now supports such an approach.***

Recommendation 3 ***Disaggregate all available data to enable a sex-based assessment***

Recommendation 4. ***An additional, but lower priority activity, is to explore Length OR age-based selectivity by sex. Length based selectivity may be used as a diagnostic.***

Table 1 TWG member and observer interests

Name	Interest
Dr David Smith	Senior Scientific Advisor to AFMA
Dr Philippe Ziegler	Fish & Fisheries Scientist, Southern Ocean Ecosystems Program, AAD. SARAG Scientific Member.
Dr Cara Masere	Senior Research Scientist, Southern Ocean Ecosystem Program, AAD. SARAG Scientific Member.
Dr Rich Hillary	Senior Principal Research Scientist, CSIRO. SARAG Scientific Member
Dr Pia Bessell-Browne	Research Scientist, CSIRO. SARAG invited participant.
Dr Tim Ward	UTAS/IMAS, Associate Professor and Fisheries Scientist. SARAG Scientific Member
Dr Graham Pilling	Deputy Director, Fisheries, Aquaculture and Marine Ecosystems (FAME) (Oceanic Fisheries), The Pacific Community (SPC)
Dr John Hampton	Chief Scientist, FAME, SPC
Dr Paige Eveson	Research Scientist, CSIRO
Selina Stoute	Senior Manager, Tuna and International Fisheries, AFMA
Rachel Downes	Senior Management Officer, Antarctic Fisheries, AFMA, SARAG Executive Officer
Anna Willock	Deputy CEO, AFMA
Kelly Buchanan	Branch Head, Policy & Strategy Branch AAD, Australian Commissioner to the CCAMLR.
Rhys Arangio	General Manager of Science and Policy, Austral Fisheries. SARAG Industry member
Malcolm McNeil	Managing Director, Australian Longline
Brad Milic	Senior Manager of Policy and Resource, Australian Longline. SARAG Industry member

Australian Government
Australian Fisheries Management Authority

Sub-Antarctic Resource Assessment Group Technical Working Group (TWG)

RECOMMENDATIONS

MEETING 2

22-23 JULY 2025

FINAL

SARAG - Technical Working Group (TWG)

CHAIR: Dr David Smith

Date: 22-23 July 2025, meeting closed at 10:13 am 23 July 2025.

Venue: John Webb Room, Hadley's Orient Hotel, 34 Murray Street, Hobart

Attendance

Members

- Dr Philippe Ziegler
- Dr Cara Masere
- Dr Rich Hillary
- Dr Pia Bessell-Browne (online)
- Dr John Hampton (online)
- Selina Stoute

Executive Officer: Rachel Downes, AFMA

Observers

- Anna Willock
- Kelly Buchanan (online)
- Rhys Arangio
- Malcolm McNeill
- Brad Milic
- Elissa Mastroianni (online)

Apologies

- Dr Tim Ward
- Dr Graham Pilling
- Dr Paige Eveson

Member interests are at **Table 1.**

Progress against TWG meeting 1 recommendations

The meeting focused on Recommendation 1 from the first meeting of the TWG which was to incorporate spatial structuring into the stock assessment model. TWG Meeting 1 advised that doing so was the highest priority action to address the TWG Terms of Reference number 2.

Dr Cara Masere presented excellent and extensive analyses that are expected to help guide the development of spatially explicit stock assessment models. Dr Masere presented detailed analyses on possible quantitative methods to define spatial areas for Patagonian Toothfish in the HIMI fishery, including an approach using length based distributional regression trees. A conceptual model of factors influencing stock structure of Patagonian Toothfish at HIMI was also presented. Dr Masere presented a simple summary of initial results that use four different spatial area scenarios to calculate subarea abundance estimates using the Chapman estimator.

The TWG noted that the approach of biomass estimation from tagging data with an external Chapman estimator and subsequent inclusion in the 2024 Casal2 stock assessment has been unsuccessful. The inclusion of external Chapman's biomass estimates based on tagging data from the core fishing area (which accounted for around 70% of recaptured tags from longline operations since 2012) resulted in catchability q estimates for this biomass time series that were much greater than 1, unless artificially constrained. The TWG also noted that it remains uncertain whether issues around model-derived recruitment trends can be resolved with a single-area stock assessment.

Recommendations

1. As a starting point, a spatially explicit stock assessment model should be developed based on approximately 3-4 areas. The analyses undertaken by Dr Masere should be used to define the spatial areas (including the recapture rates conditional on catch).

2. Using the Chapman biomass estimator continues to give unrealistic biomass estimates and alternative mark recapture models should be explored.

3. A standalone/bespoke spatially structured stock assessment should be used noting:

a) Casal2 can accommodate a spatial structure stock assessment approach for the HIMI Fishery, however Casal2 will require additional programming to explore e.g.:
    i. alternative mark recapture models
    ii. different types of movement patterns e.g., accounting for different dispersion characteristics in subareas.
    iii. alternative likelihood functions

b) Additional programming may require additional coding resources and depend on external expertise from software providers.

c) Dr Masere's work provides the necessary analyses to guide the development of a standalone/bespoke spatially structured stock assessment model.

d) Source code for an alternate spatially structured stock assessment model already exists and is used successfully for the Macquarie Island Toothfish Fishery.

e) This model can be used for 3-4 spatial areas but could accommodate up to 10 spatial areas relatively easily. It could also be developed over time to investigate finer spatial scales.

f) Whilst the use of this bespoke model would replicate as much as possible of the population dynamics used in the current Casal2 assessment, it will provide the necessary flexibility to adjust as required:
    i. population dynamics e.g., spatial-temporal heterogeneity in growth, migratory patterns, and recruitment processes
    ii. alternative mark recapture models
    iii. likelihoods e.g., spatial-temporal heterogeneity in the expected probability of recapture

g) It is anticipated that development of the bespoke model can be undertaken in the required timeframe necessary to deliver an updated stock assessment in May 2026.

h) Importantly it can form the basis for future defensible MSE testing.

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Name	Interest
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Initial investigations of a sex-specific stock assessment model for *Dissostichus eleginoides* in Division 58.5.2.

Dale Maschette[1,2], Simon Wotherspoon[2], Cara Masere[2], Philippe Ziegler[2]

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Abstract

Following the recommendations of the 2023 independent review of CCAMLR toothfish assessments, this paper presents an investigation into a fitting sex-specific stock assessment model to Patagonian toothfish (*Dissostichus eleginoides*) in Division 58.5.2. Using an iterative model fitting approach showed that inclusion of sex-specific growth provided the largest change to B_0, B_{2024} and spawning stock biomass status. This however also coincided with generally poorer fits of the stock assessment model, likely due to the large uncertainty associated with female growth estimates (CV = 0.208). A sensitivity run using a halved CV (0.104) for female growth resulted in better stock assessment fits to the input data. Given this sensitivity to the uncertainty associated with input parameters, we recommend further work is needed before a sex-specific model is used for catch setting advice.

Introduction

In 2023, the independent review of CCAMLR toothfish assessments (Welsford et al., 2023) recommended that where data allows, toothfish assessments should use sex-specific estimates of biological parameters. Here, we investigate the inclusion of sex-specific parameters into the Casal2 stock assessment of Patagonian toothfish (*Dissostichus eleginoides*) in the vicinity of Heard Island and McDonald Islands in Division 58.5.2 in sex-specific stock assessment models (SAM), and compare the results to the currently used single-sex SAM.

Methods

The first step to investigate the effects of introducing sex-specific biological parameter estimates into the single-sex SAM was auditing the input parameters and observations and determining which had sufficient sex-specific data available. Broad categories for these and the changes needed to the Casal2 input files are shown in Table 1, whilst the specific input file calls are summarised in Appendix 1. The type of parameters and data e.g., years of observations used in the sex-specific SAM, match those presented in the single-sex SAM conducted by Masere and Ziegler (2024). This is to allow for a direct comparison between the outputs of the single-sex and sex-specific SAMs.

Table 1: Summary of broad categories of Casal2 input parameters for the Patagonian Toothfish stock assessment which were set to be sex-specific.

Parameter group	Parameter call	Summary of change
Categories	categories	Set a category for each sex
Recruitment	process	Update categories and set recruitment proportions
SSB	derived_quantity	Update selectivities
Mortality - catches	process	Update selectivities
Selectivities	selectivity	Set for each sex
Selectivities	estimate	Set for each sex, fix male alphas at 1
Maturity	selectivity	Set for each sex
Age-to-length relationship	age_length	Set for each sex
Tagging age-to-length relationship	age_length	Set for each sex
Weight-to-length relationship	length_weight	Set for each sex
Proportions at age	observation	Update categories and selectivities, split into males and females
Tag Releases	process	Update categories
Tag Recaptures	observation	Update categories

Estimation of sex-specific input parameters

Maturity

The currently used estimates for age at maturity originate from Ziegler & Dell (2019) which was based on Yates et al. (2018) with a correction to define all young fish up to 5 years of age as immature (Ziegler 2019).

Yates et al. (2018) estimated maturity for males, females, and both sexes combined with a logistic regression model with the natural logarithm of the odds of an individual being mature (i.e., logit link) as a linear function of the explanatory variable, age, where maturity was assumed to follow a Bernoulli distribution. Non-parametric bootstraps with 10,000 iterations were used to calculate confidence intervals. In doing this, Yates et al. (2018) considered all individuals with macroscopic stage 2 gonads and above to be mature, based on previous histology work by Welsford et al. (2012) which showed that a large proportion of individuals identified as stage 2 by observers were in fact stage 3 or above.

To address the comments by WG-FSA-2017, Ziegler & Dell (2019) introduced two modifications to the maturity function, 1) adding a two-year offset for stage 2 individuals, and 2) defining all individuals up to the age of 5 as immature and then increases linearly up to the estimated value at age 10. These modifications allowed the maturity estimates to account for both the expectation that fish up to age 5 are likely to be immature, and that fish which are truly stage 2 will be mature within 2 years.

To estimate the maturity function for each sex we have followed the same approach in fitting a modified curve using the data from Yates et al. (2018) for males and females respectively.

Length-to-weight relationship

The length-to-weight relationship used in the single-sex SAM were estimated by Ziegler (2019). The length and weight data used by Ziegler (2019) however contains a large number (~21%) of fish for which sex information is not available. To test the effect of this data being included or not, length-to-weight relationships were fitted for males and females combined (without unsexed data), and individually for males and females.

Growth

A von Bertalanffy growth function was estimated by Masere & Ziegler (2023) for both sexes combined that accounted for length-bin sampling and gear selectivity. The definition of the likelihood function was based on variable probability sampling due to the pre-specified length-dependent fishing selectivity function and the effect of length-bin sampling on the sampling probabilities following the approach of Candy et al. (2007). Accounting for a dome-shaped selectivity function reflected the combined effects of fish selection by the trawl, longline and trap gear, with lower selectivity of fish smaller than about 500 mm and larger than 1200 mm total length. Accounting for length-bin sampling was necessary as aged fish were not randomly selected from the catch, with an over-representation of aged fish smaller than 500 mm and fish 1000-1500 mm compared to the catch. We used the same approach here to estimate separate von Bertalanffy growth functions for both males and females.

Proportions/Removals at age

Within the single-sex SAM in Casal2, observations for annual bootstrapped biomass estimates and catch proportions at age from the random stratified trawl survey (RSTS) are used to estimate population biomass and contributions of individual age classes as observed through the survey selectivity. The stock assessment uses survey biomass to calculate the number of individuals for both the observed and expected value based on mean weight of individuals within each age (Casal2 Development Team, 2024).

Similarly, the removals at age process is used for commercial catch, to inform the relative number of individuals at age, part way through an application of instantaneous mortality in the related time step of the assessment.

In both cases, the SAM requires an input of annual proportions at age from the catch of either the RSTS or the respective sub-fisheries. For the single-sex SAM this is done by calculating catch-weighted length frequencies within each year and each sub-fishery to which an annual age-length key is applied to convert to proportions at age. For the RSTS, the length frequency data are both catch and stratum-weighted prior to the application of a survey-specific age-length key.

For the sex-specific SAM, annual proportions at age were estimated for each sex, however two issues were encountered in this process: 1) the historic length frequency data contains a large amount of unsexed length frequency data, and 2) there are insufficient age data available to estimate annual sex-specific age-length keys for some sex and years. To estimate catch-weighted length frequencies for each sex, unsexed data was assigned a sex based on the proportion of each sex in a given length bin in a given sub-fishery following the method described in Appendix 2. Since there is currently not enough data available for annual sex-specific age-length keys in all years, we used a combined sex age-length key applied to the length frequencies of each sex.

Model fitting procedure.

To explore the effect of each parameter on the transition from a single-sex to sex-specific SAM, an initial sex-specific SAM was fitted using identical parameters and observations for each sex (i.e. a single sex SAM implemented using a sex-specific model, Model 2). Subsequent models were then fitted implementing a change to one biological parameter at a time (Figure 1).

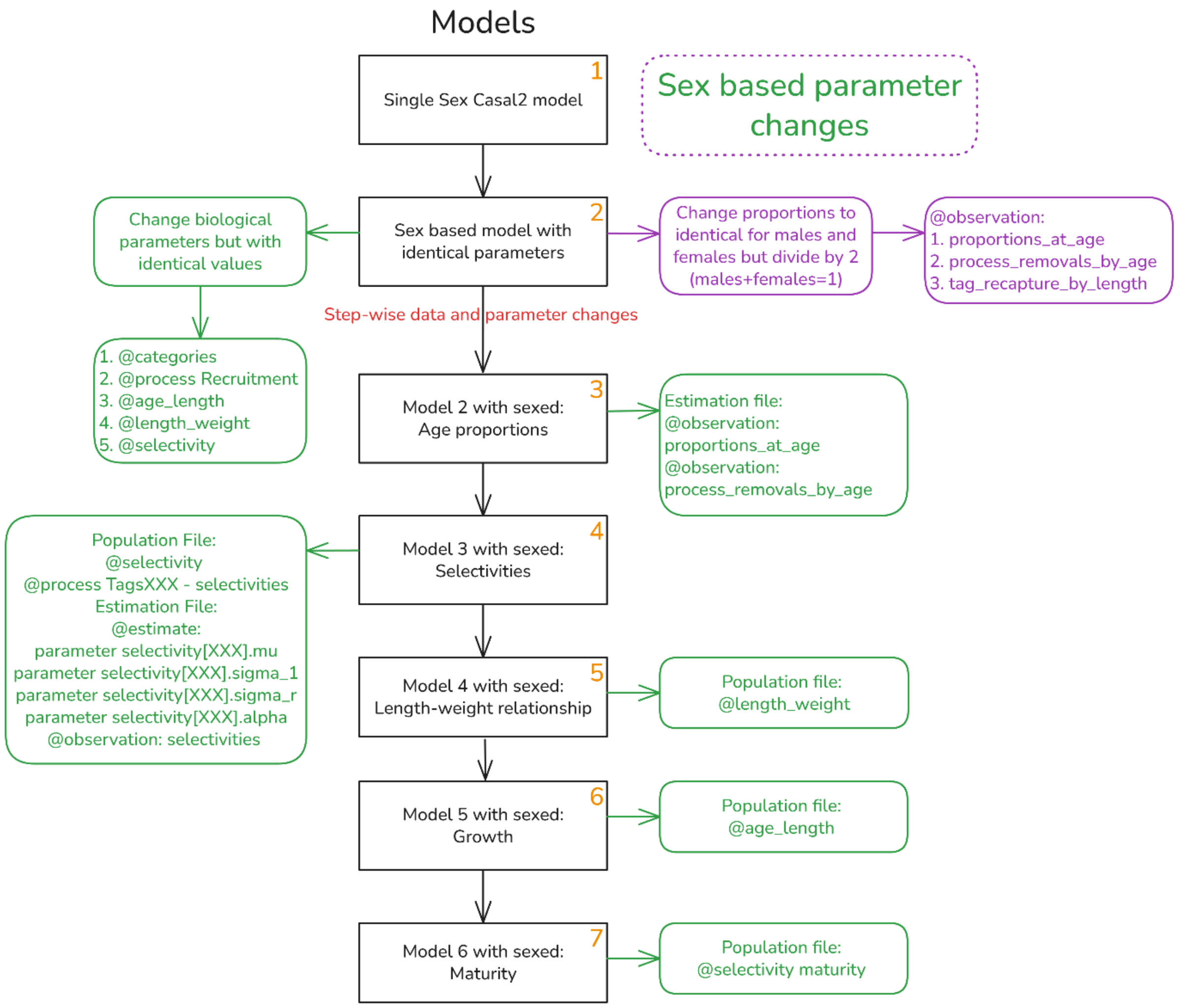

Figure 1: Iterative model fitting steps for the transition from a single-sex to sex-specific stock assessment for Patagonian Toothfish in Division 58.5.2.

To be consistent with the single-sex SAM of Masere & Ziegler (2024), the same processes were followed for data weighting, and all other parameter estimates, with all penalties assumed to be the same. The assessment models estimated the unfished spawning biomass B_0, survey catchability q, annual year class strength (YCS), and the parameters of the selectivity functions for the survey and all sub-fisheries.

All models included penalties for *YCS* and catch. A penalty for YCS was intended to force the average of estimated *YCS* towards 1. Strong catch penalties prohibited the model from returning an estimated fishable biomass where the catch in any given year would exceed the maximum exploitation rate set at U = 0.995 for each sub-fishery.

Iterative data re-weighting followed the method TA1.8 described by Francis (2011a and 2011b) to allow for correlations within the observed composition data. The reweighting was applied first to the commercial catch composition data of all sub-fisheries, then to the survey composition data, and lastly to the tag-recapture data.

For catch-at-age composition data, the weight w_j for each age j observed by a sub-fishery or the RSTS was estimated as:

$$w_j = \frac{1}{var_i\left[\left(O_{ij} - E_{iy}\right)/\sqrt{\left(v_{iy}/N_{iy}\right)}\right]}$$

where O_{ij} is the observed and E_{ij} is the expected proportions for age or length class i in year y, v_{iy} is the variance of the expected age or length distribution, and N_{iy} was the number of multinomial cells. The weight was then multiplied with the sample size from the previous step before re-running the model.

Initially, a point estimate (maximum posterior density MPD) and its approximate covariance matrix for all free parameters as the inverse Hessian matrix were estimated. To allow for better comparison among models, a seed was set for each of the MPD runs.

Consistent with the approach for the single-sex SAM, the impact of tagging data on the assessment model was explored using a “tag peel” in which annual tagging data (release cohorts with associated recaptures) were step-wise omitted from the assessment base case model. All other data sources including catch, catch composition, RSTS biomass and composition estimates, and pre-specified biological parameters were not changed. For each tag peel, MPD estimates were compared for spawning stock biomass, stock status, year class multipliers and number of recruits.

Results

Estimation of sex-specific input parameters

Maturity

The estimates for 50% maturity were similar, though females were estimated to mature at a slightly older age than males (Figure 2).

Length-to-weight relationship

Of the 847,208 individuals used in the analysis by Ziegler (2019) to estimate the length-weight relationship, 78.5% contained sex information. The comparison of the length-to-weight relationship fitted by Ziegler (2019) with unsexed individuals removed showed near identical fits (Figure 3, Table 3). Given this, the data were further divided to provide estimates for males and females. All four relationships show similar relationships until approximately 1000 mm total length, after which males are predicted to be of a lower weight than females (Figure 3, Table 2).

Table 2: Length-to-weight relationship estimates for Patagonian toothfish from 1997-2018.

Relationship fit	*a*	*b*
Ziegler (2019)	3.615E-12	3.1518
Combined male + female	3.427E-12	3.159
Females	5.039E-12	3.1030
Males	2.954E-12	3.1810

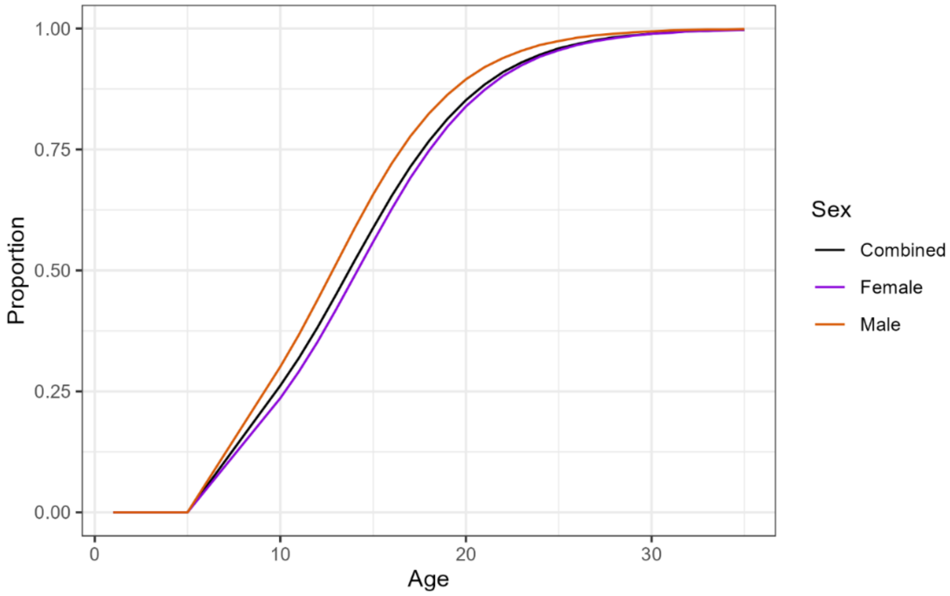

Figure 2: Maturity functions for Patagonian Toothfish used in the stock assessments in Division 58.5.2 using the modified method from Ziegler & Dell (2019).

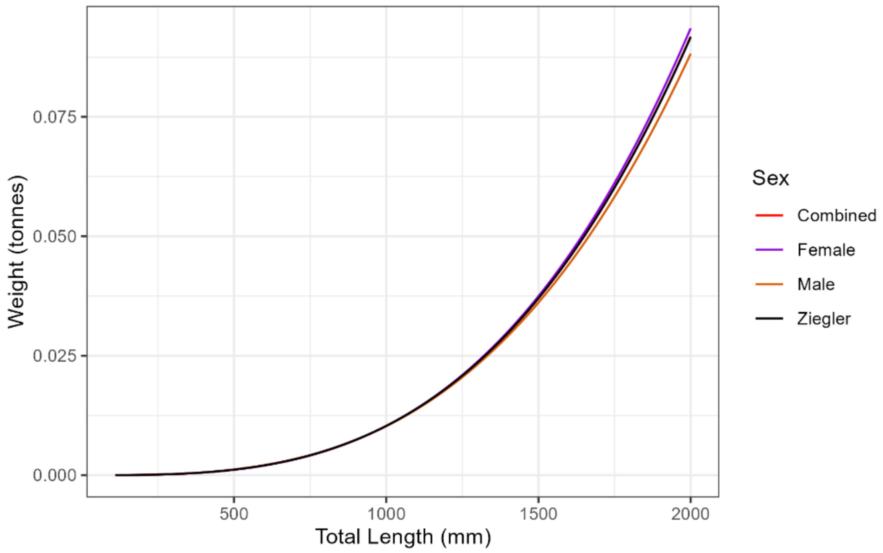

Figure 3: Estimated single-sex length-weight relationship (black) for Patagonian toothfish in Division 58.5.2 fitted by Ziegler (2019) for all observations from years 1997-2018 and sexed data only (red, directly underneath the black line), and sex-specific length-weight relationship estimated for males (orange) and females (purple).

Growth

Estimation of growth for each sex showed substantial differences between sexes irrespective of the model fitted (Figure 4, Table 3).

For males, model fits to unweighted data showed similar trends to the weighted single-sex model by Masere and Ziegler (2023). The application of adjusting for length-bin sampling and then dome-shaped selectivity reduced estimates of L_∞ and increased estimates of growth rate. For females, estimates based on unweighted data were much higher for L_∞ at 2042 mm with a much smaller growth rate (0.038). Growth estimates were similar when accounting for both length-bin sampling and dome-shaped selectivity (L_∞= 2001 mm and K = 0.054), although with a very large *CV* (0.20), but much smaller (L_∞ = 1507 mm K = 0.057) when accounting for length-bin sampling only.

Given the large effect of the inclusion of the dome-shaped selectivity on estimates of female growth and the large corresponding *CV*, a sensitivity run was added to the final stock assessment which used half the estimated *CV* for female growth (0.104).

Table 3: Parameters estimates of the von Bertalanffy growth functions for combined sexes that accounted for dome-shaped selectivity and length-bin sampling from Masere & Ziegler (2023), and estimated for each sex.

Sex	Model	L_∞	K	t_0	CV
Combined	Masere & Ziegler (2023)	1413	0.066	-3.00	0.138
Females	Unweighted	2042	0.038	-3.90	0.139
	Weighted for length bin sampling (LB)	1507	0.057	-4.07	0.126
	Weighted for LB and domed selectivity	2001	0.054	-0.81	0.208
Males	Unweighted	1489	0.051	-4.31	0.133
	Weighted for length bin sampling (LB)	1219	0.073	-4.12	0.119
	Weighted for LB and domed selectivity	1149	0.090	-2.79	0.128

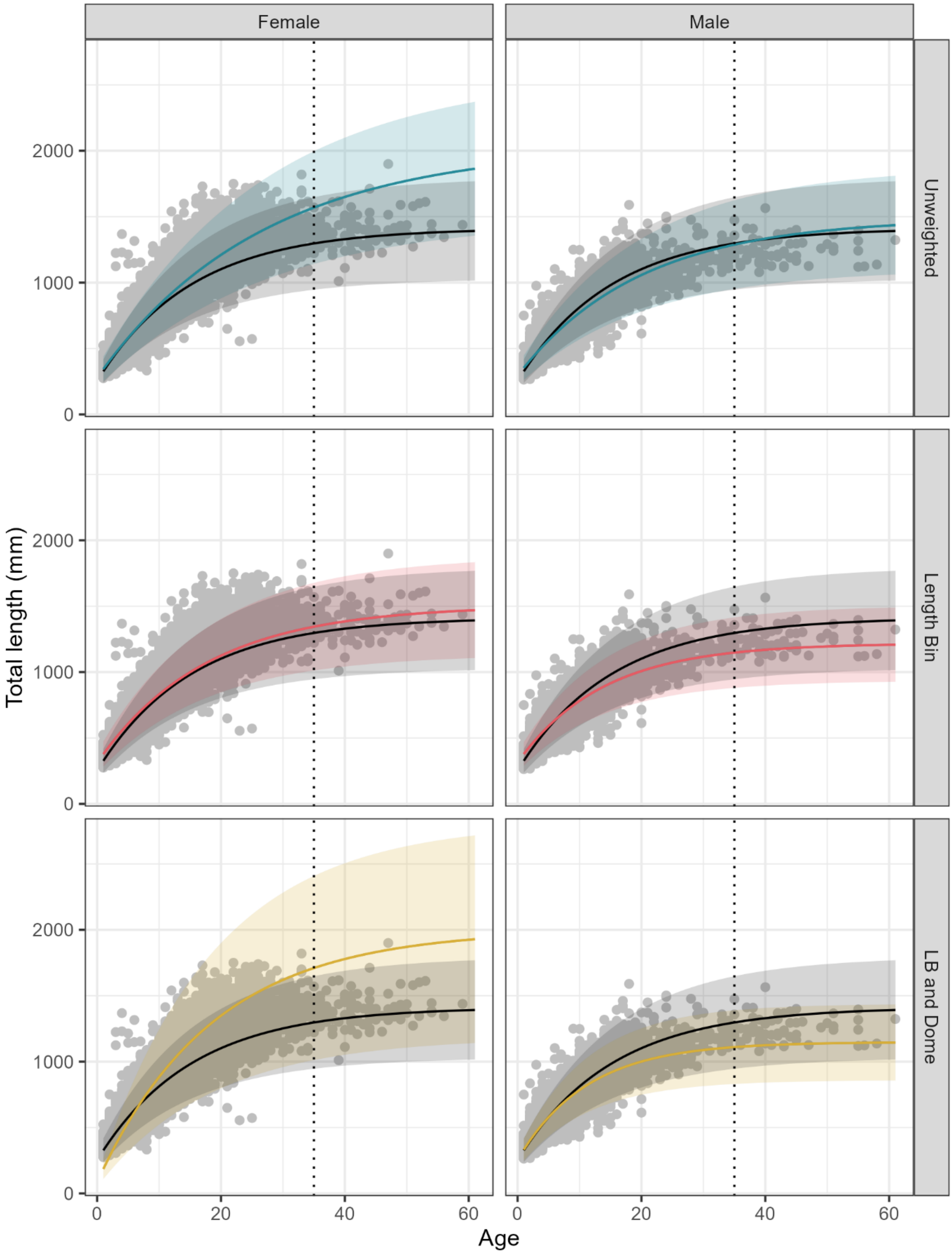

Figure 4. Length-at-age data (grey) and estimated single-sex von Bertalanffy growth model (black) by Masere and Ziegler (2023) and estimated von Bertalanffy models for females and males. Models were fitted with unweighted data (blue), weighted to account for length-bin sampling (red), and weighted to account for length-bin sampling and dome-shaped selectivity (yellow), all with approximate 95% confidence intervals of the data based on the estimated *CV* (respective shades).

Model estimates

Seven models were fitted in a transition between the single-sex SAM (Model 1) to a sex-specific SAM with sex-specific age proportions, selectivity, length-to-weight relationship, growth, and maturity (Model 7). Between Model 1 and Model 7, the MPD estimates showed increases in B_0, B_{2024} and spawning stock biomass (*SSB*) status. B_0 increased from 64,609 t to 83,579 t, B_{2024} from 24,375 t to 35,433 t, and *SSB* status from 37.7% to 42.4% between these models. Conversely, the estimates for survey catchability q reduced slightly from 1.27 to 1.22 (Figure 5). The largest driver of change for the biomass related estimates was the introduction of sex-specific growth (Model 6) which resulted in an increase of B_0 by ~ 20,000 t. The subsequent introduction of sex-specific maturity slightly decreased B_0, B_{2024}, and *SSB* status (Figures 5 – 7, Table 5).

Year class strength in the seven models showed similar trends across the time period estimated, with no strong differences seen between models (Figure 8).

Table 5: MPD estimates of unfished spawning stock biomass B_0 in tonnes, *SSB* status at the end of 2024, R_0 (mean recruitment in millions that gives rise to B_0), and survey catchability q) in each model run.

Model	Description	B_0	B_{2024}	*SSB* status	R_0	q
1	Single-sex implementation	64,609	24,375	37.7%	5.59	1.27
2	Sex-specific model with identical inputs	64,589	24,370	37.7%	5.59	1.27
3	+ Sex-specific catch-at-age observations	64,295	23,716	36.9%	5.56	1.19
4	+ Sex-specific selectivity	63,660	24,004	37.7%	5.51	1.29
5	+ Sex-specific length-weight	63,422	23,848	37.6%	5.50	1.29
6	+ Sex-specific growth	85,184	37,210	43.7%	5.33	1.29
7	+ Sex-specific maturity	83,579	35,433	42.4%	5.22	1.22

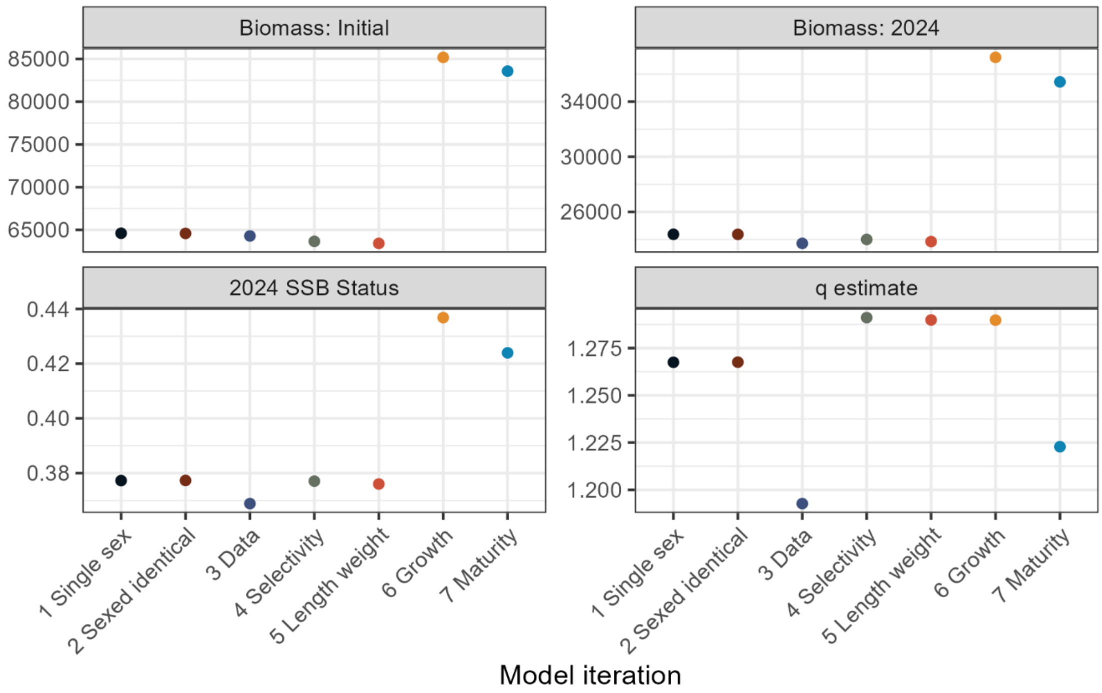

Figure 5: MPD estimates of unfished spawning stock biomass B_0 in tonnes, *SSB* at the end of 2024 (B_{2024}), *SSB* status at the end of 2024, and survey catchability q) in each model run.

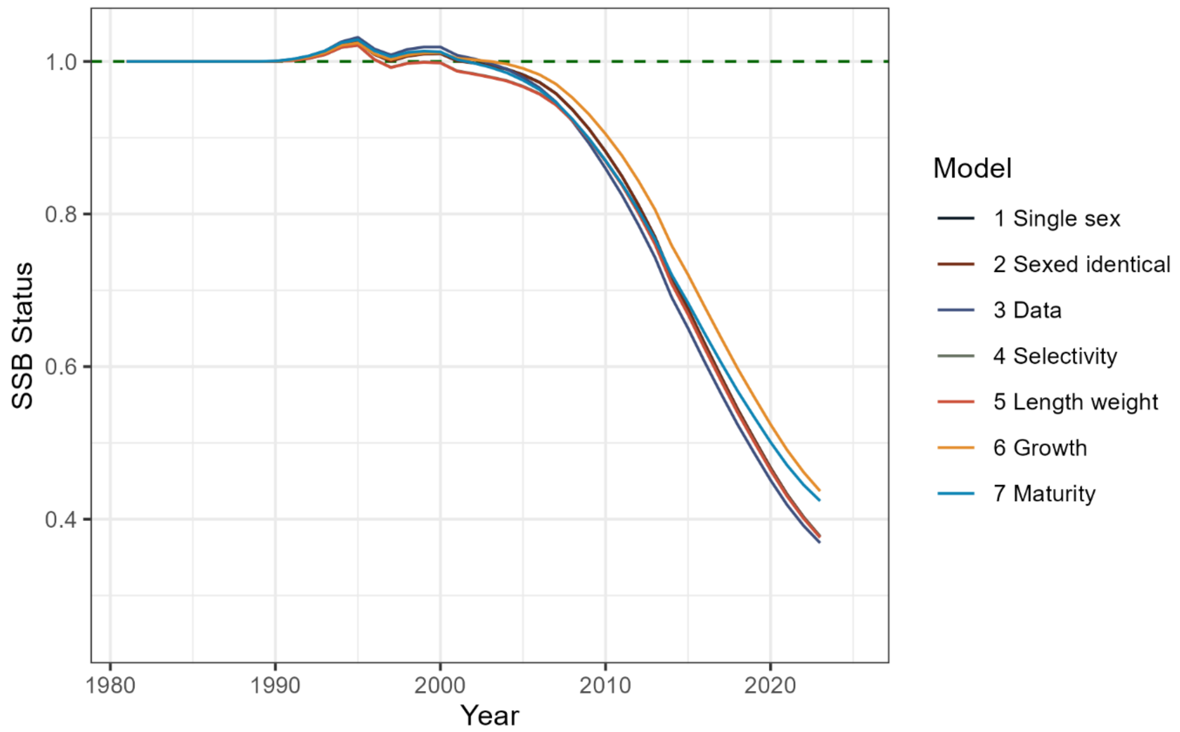

Figure 6: Estimated SSB status for stock assessment models 1 – 7.

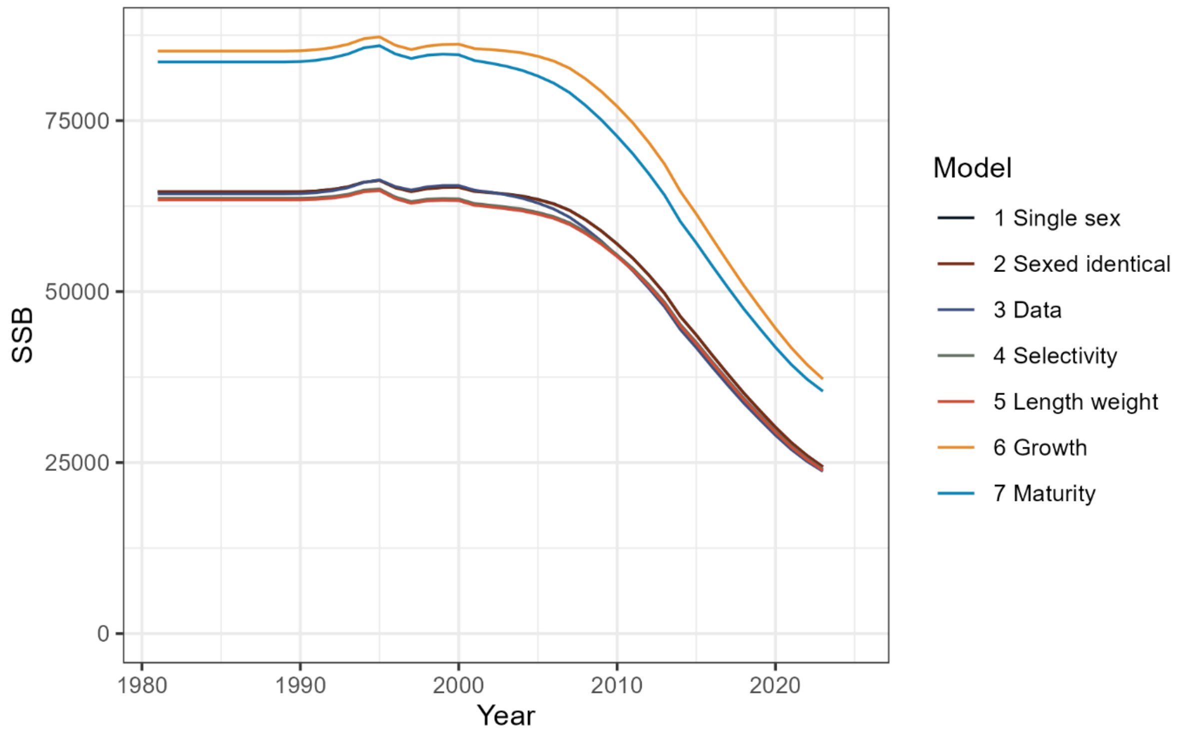

Figure 7: Estimated spawning stock biomass (SSB) for stock assessment models 1 – 7.

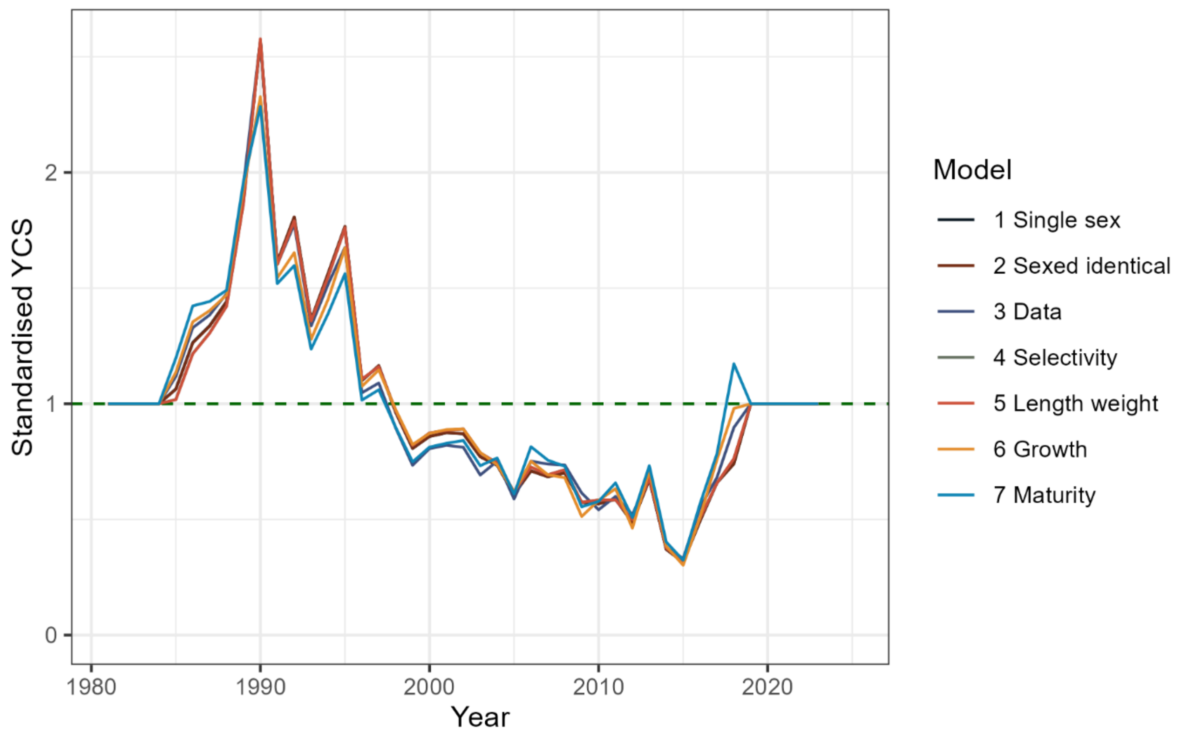

Figure 8: Estimated year-class strength from 1986 – 2019 for stock assessment Models 1 – 7.

While the scaling selectivity parameter alpha is set to 1 by default for each sub-fishery in the single-sex SAM, alphas in the sex-specific SAM in each sub-fishery were fixed at one for males and estimated for females by the model. The estimated survey selectivity is almost identical for females, males and in the single-sex SAM, however this is likely due to all selectivities hitting the lower bound of the priors.

When comparing the selectivity functions between the single-sex model and sex-specific model 7 (Figure 10), the dome shaped selectivities for males in Trawl1 and Trawl2 typically follow similar trends to the single-sex selectivity although they tend to decrease faster on the right-hand side. In both Trawl1 and Trawl2, female selectivity peaks at 0.58, and 0.82 respectively, and for Trawl2 this peak is at one year younger (4) than for males. From age 12 –20 however, females are expected to be slightly better selected by the trawls than males.

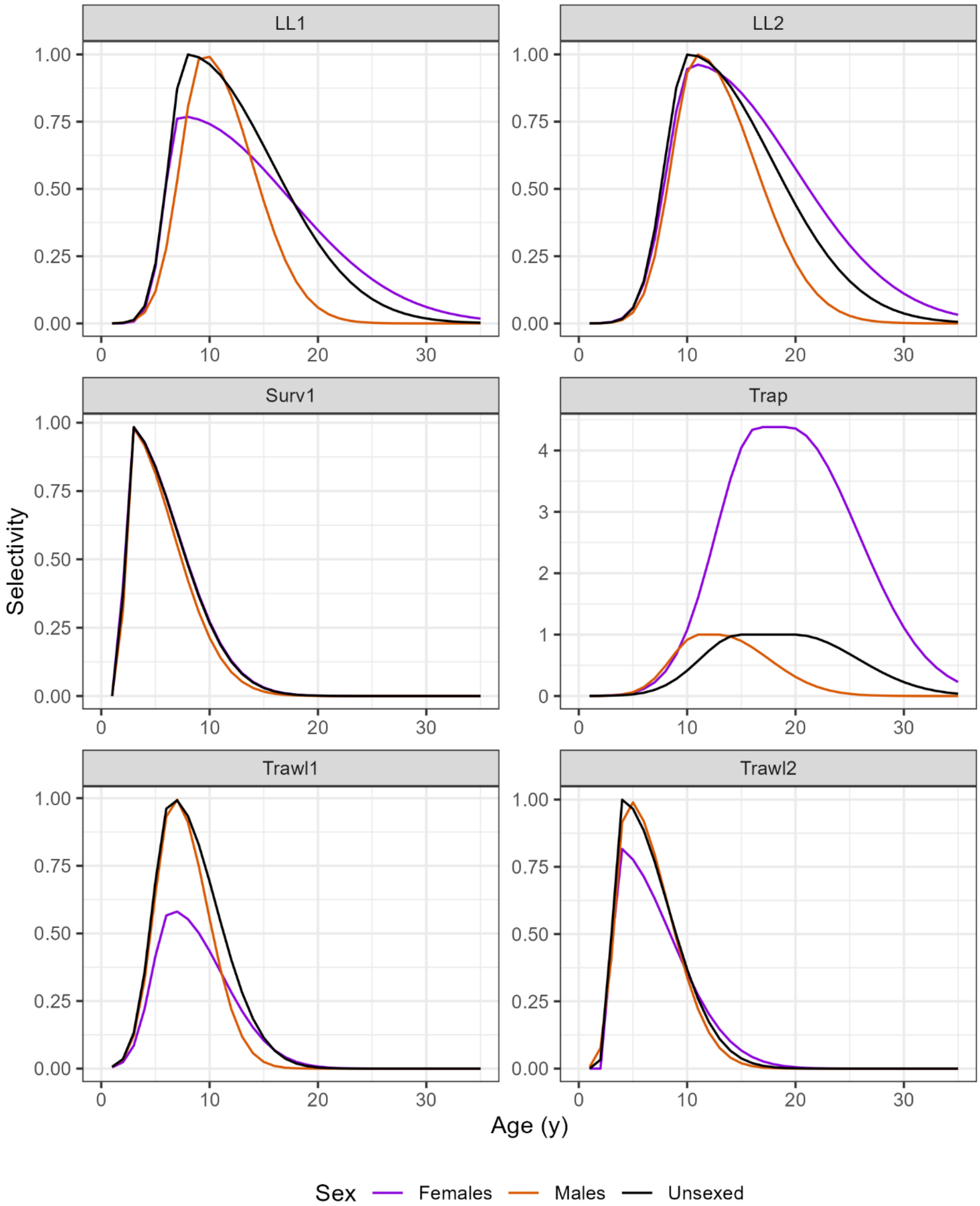

Figure 9: Selectivity estimates for single-sex Model 1 and sex-specific Model 7 by sub-fishery.

For LL1, male selectivity peaks at age 10 whilst the female peak is slightly lower at 0.77 at age 8. In LL2, both males and females peak at age 11, with the top of the peak for female being 0.96. In both LL1 and LL2 the selectivities indicate a higher selectivity for females older than 14 years. The Trap sub-fishery tended to contain predominantly females at older ages. Male selectivity peaks at ages 11 – 13 whilst female selectivity peaks at ages 17 – 19 at a level of over four times that of males.

Final Model MPD fits comparisons

Contributions to likelihood

When considering the contributions to the objective function in the seven models (Table 6), due to the difference in number of parameters, comparisons cannot be made between Models 1 – 3 and the remaining models. Between Models 4 – 7, the introduction of sex-specific growth in Model 6 leads to a much poorer fit to the tagging data, which is subsequently carried over to Model 7.

Table 6: Contributions to the objective function for models transitioning from single-sex to sex-specific specifications for Patagonian Toothfish. Note: Models 1, 2 and 3 cannot be compared with the other models as they have a different number of model parameters.

Component	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Survey Index	-9.8	-9.8	17.1	-9.8	-9.8	-10.5	13.4
Survey Age Prop	220.7	338.2	343.5	341.5	341.5	341.2	342.1
LL1 Age Prop	394.4	585.3	595.0	576.4	576.4	589.6	589.5
LL2 Age Prop	367.9	544.6	558.6	532.8	532.8	542.6	542.6
Trawl1 Age Prop	57.9	84.7	84.8	84.5	84.5	85.6	85.3
Trawl2 Age Prop	115.9	169.9	170.1	169.8	169.8	170.1	170.1
Trap Age Prop	5.0	6.4	6.4	5.9	5.9	5.9	5.9
Tags 2012	97.6	97.6	99.0	97.9	97.9	102.0	103.7
Tags 2013	99.1	99.1	98.3	99.2	99.2	95.9	95.2
Tags 2014	104.1	104.1	104.1	104.3	104.3	110.9	111.1
Tags 2015	176.6	176.6	176.1	177.1	177.1	207.0	207.2
Tags 2016	144.4	144.4	144.1	144.4	144.4	159.2	159.2
Tags 2017	164.9	164.9	164.2	165.8	165.8	190.1	190.0
Tags 2018	138.6	138.6	138.7	138.4	138.4	146.7	146.8
Tags2019	178.0	178.0	182.2	179.0	179.0	189.9	193.4
Tags2020	79.5	79.5	78.6	79.8	79.8	87.8	87.3
Tags2021	51.1	51.1	52.0	50.7	50.7	55.0	56.3
Tags2022	34.2	34.2	34.9	34.1	34.1	31.8	32.9
Prior for B0	11.1	11.1	11.1	11.1	11.1	11.4	11.3
Total	**2564.2**	**3131.4**	**3191.0**	**3115.4**	**3115.4**	**3244.6**	**3274.4**

Fits to survey

Model predicted survey biomass showed similar trends to the single-sex model, with the exception of Model 3, which implemented the sex-specific observations, and Model 7 which used sex-specific maturity. These two models predicted lower biomass in the survey for 1997 – 2017 (Figure 10).

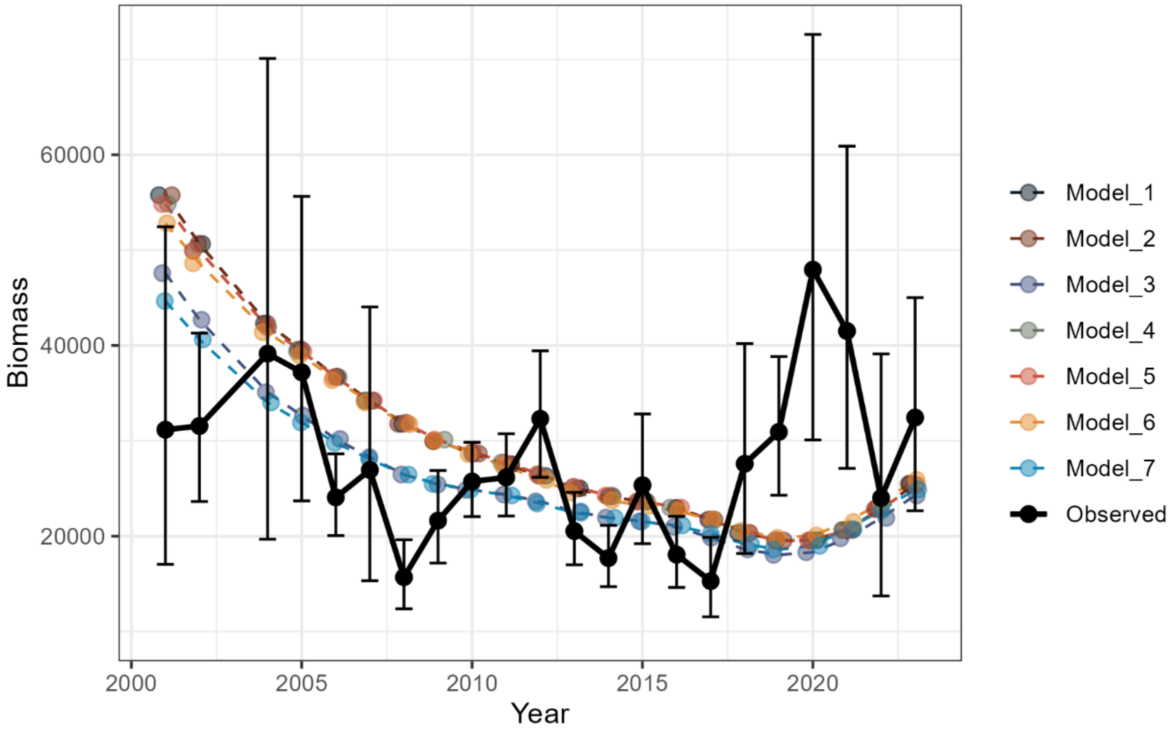

Figure 10: Observed (black line with 95% CI) and model predicted (colours) survey biomass for stock assessment Models 1 – 7. Note, a small jitter was applied to the 'Year' for model estimates to allow over plotting to be viewed.

Fits to tag recaptures

The expected tag recaptures in Models 6 and 7 are biased and consistently (~15 – 55%) higher than that of the single-sex SAM (Figures 11 for Model 7). This results in a worse fit to the observed values in most years with expected values often not overlapping with the observed values at all. Similarly, the model consistently expects to see more recaptures from larger fish than is currently observed whilst simultaneously expecting less recaptures in some length classes of smaller toothfish.

Due to these poor fits, a model sensitivity run was conducted with a *CV* for female growth of 0.104 (half the original estimate) which resulted in unbiased fits to the tagging data similar to those of the single-sex model. This result indicates that the poor fit to the tagging data in Model 7 may be related to the large *CV* estimated for the growth function for females (Figure 11, Appendix 3). Further investigation into this issue are ongoing.

Age fits

In Model 7, fits to age classes (Appendix 3) showed generally good fits for both males and females in the longline and trap fisheries, though seemed to struggle with larger peaks in the trawl fisheries and survey.

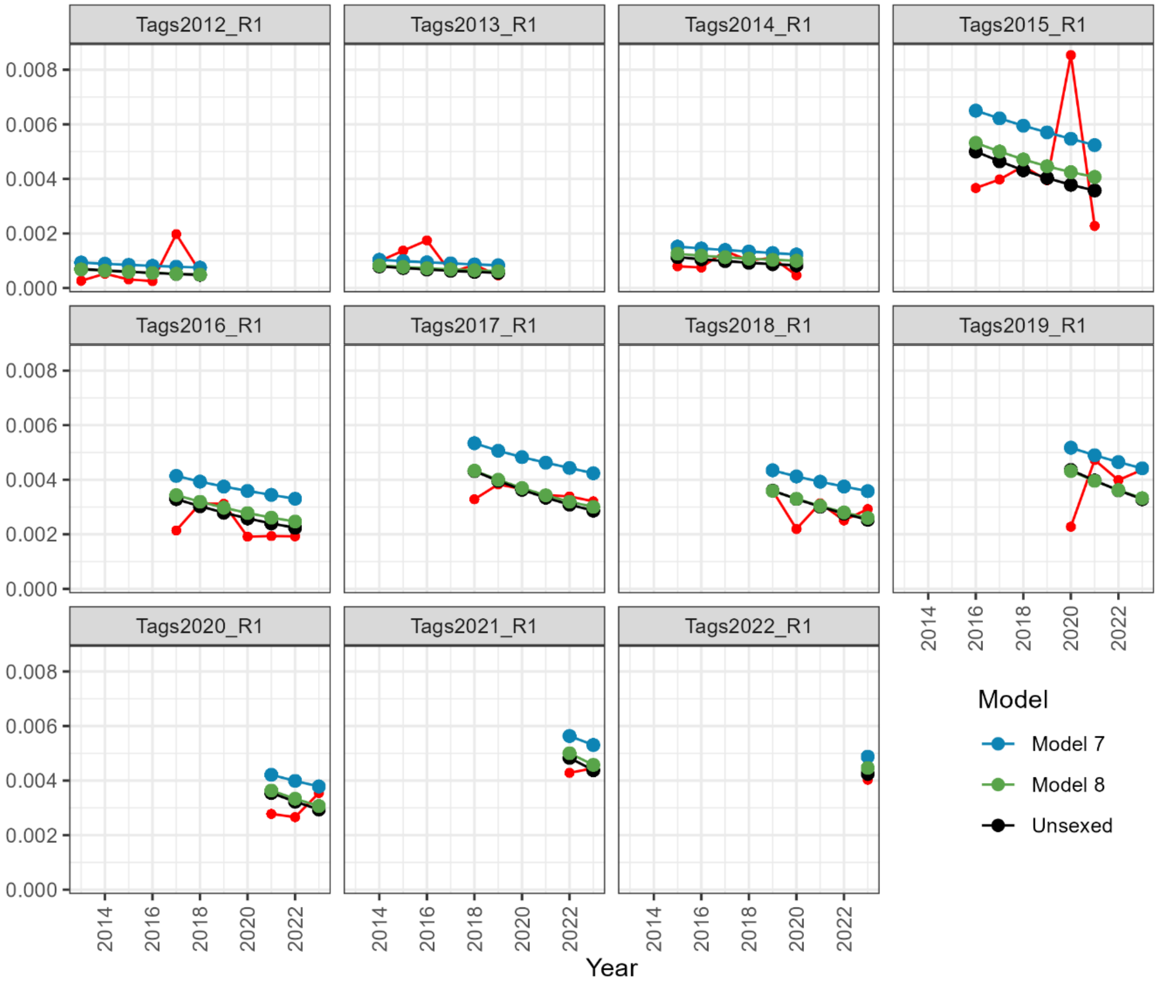

Figure 11: Numbers of annual observed (red) tag recaptures for tag cohorts released from 2012 – 2022 and expected recaptures for single-sex Model 1 (black), sex-specific Model 7 (blue) and the Model 7 sensitivity run with a lower estimate for female growth CV (green).

Likelihood profiles

The likelihood profiles for the Model 7, as well as the minimum values from the single-sex SAM are shown in Figure 12.

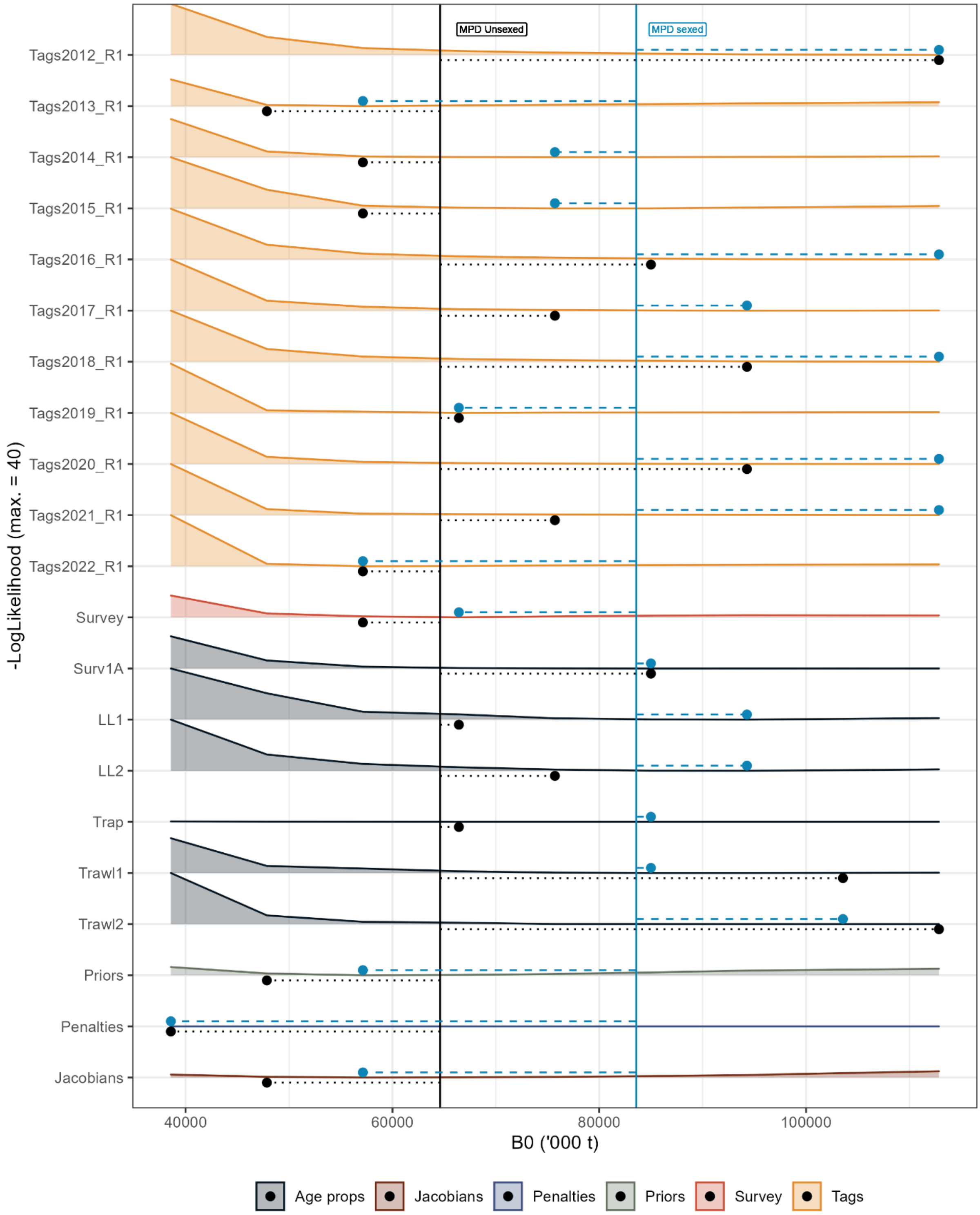

Figure 12: Likelihood profiles for Model 7 across a range of B_0 values for separate observations. Dots indicate the location of the minimum values for Model 1 (single-sex, black) and Model 7 (Sex-specific, blue). For reference, the MPD estimate for B_0 for Model 1 is 64,609 t and for Model 7 is 83,579 t.

Tagging peel

Stepwise removal of tagging data ("tagging peel") showed similar trends to those of the single-sex SAM, however trends in *SSB* status and biomass showed were less variable as tagging data were removed (Figure 13). With regards to standardised YCS, when only using tag releases from 2014 – 2016 both the single-sex Model 1 and sex-specific Model 7 have similar trajectories. The inclusion of 2017 – 2019 release cohorts, however, show differing trends with the single-sex SAM estimating decreasing recent recruitment, whilst Model 7 estimated an increase. Inclusion of 2020 – 2022 release cohorts resulted in both models predicting a decline in recruitment as each cohort was included, though Model 7 still predicts above average recent recruitment (Figure 13).

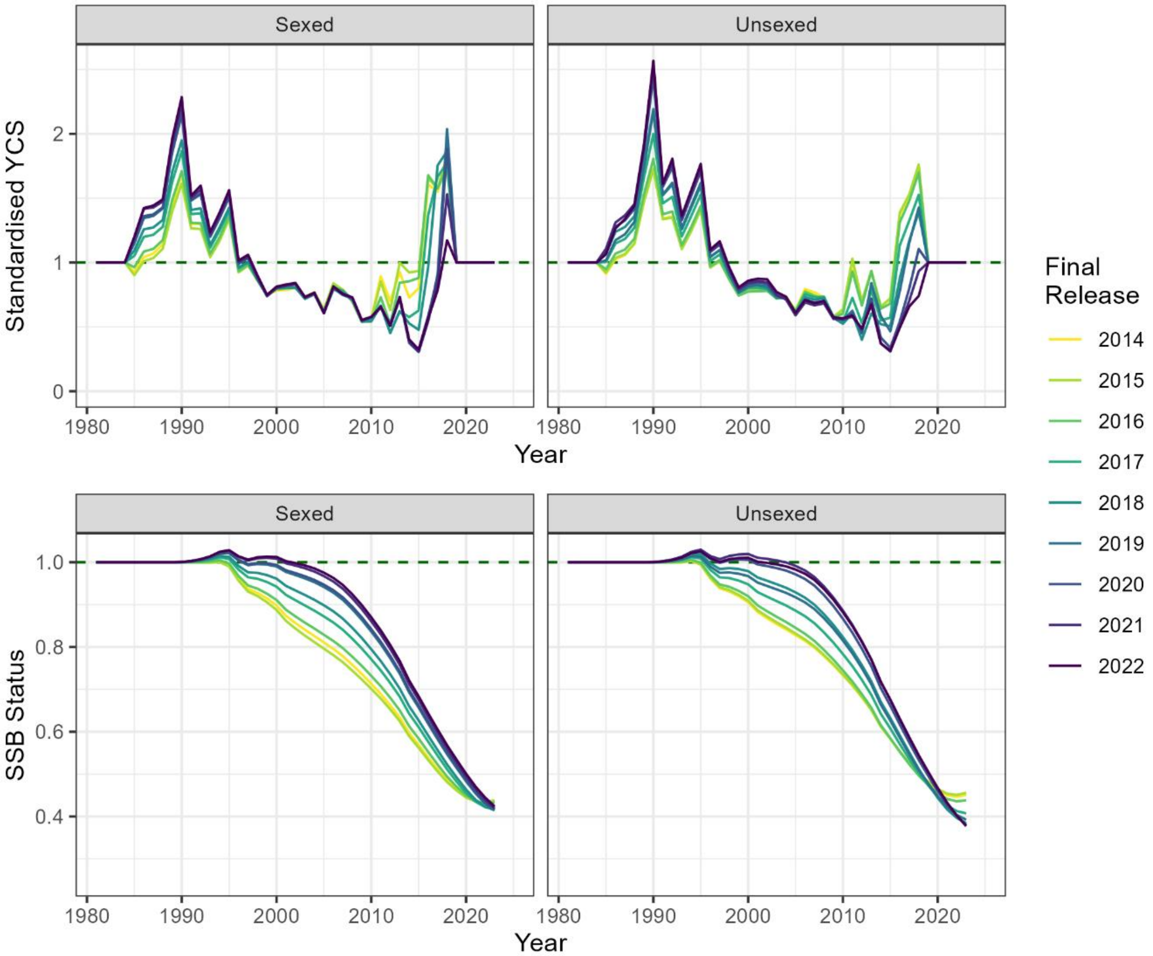

Figure 13: Standardised year class strength and *SSB* status comparison of Model 7 (sexed) and Model 1 (unsexed) tagging peel exploration.

Discussion

Many fish species exhibit sexually dimorphic life history parameters such as growth, length-to-weight relationships, age at maturity and natural mortality. Patagonian toothfish are no exception to this with a number of studies, including this one, indicating differences in life history parameters between males and females (Marsh et al., 2022, Yates et al., 2018, Brigden et al., 2017). Given that sexual dimorphism in biological parameters such as body size are potentially related to natural mortality, reproductive success or gear selectivity, it is crucial to account for, or at least test the effects of, these processes within the stock assessments used for management advice (Cheng et al., 2025, Punt, 2023).

Model fits

Here we have used iterative models to investigate the effects of incorporating sex-specific parameter estimates and data on the integrated stock assessment model for Division 58.5.2. When compared to the single-sex model (Masere and Ziegler, 2024), the final sex-specific model (Model 7) resulted in a higher estimate of B_0, B_{2024} and *SSB* status. The predicted biomass from the survey shows better fits within the earlier years of the timeseries, however still fails to reflect the trend towards larger biomass estimates between 2018 – 2021. Fits to age classes (Appendix 3) showed generally good fits for males and females in the longline and trap sub-fisheries, though seemed to struggle fitting to the larger peaks in the trawl sub-fisheries and the survey. There are also some trends in the age residuals and the predicted sex ratios that require further investigation.

The fit of the final model to the tagging data showed a poor and biased fit with expected tag-recapture numbers consistently being higher than that of the single-sex model and often not overlapping with the observed values at all. This and the poor fits in some years to tag recapture lengths occurred at the step from Model 5 to Model 6, with the introduction of sex-specific estimates of growth. It may be related to how the tagging module within Casal2 handles the translation from length class to age class internally. This was indicated by a model sensitivity run which used a smaller CV for the female growth estimate and provided much more robust fits to the tagging data. Further work is in progress to address this issue. Firstly, the estimated CV for female growth of 0.20 is very high and needs to be explored further. Secondly, tagging data could be provided to the model as numbers at age rather than length to compare the effect of converting length to age of tagging data internally or externally to Casal2. This was also tested by Mormede et al. (2023) for the Ross Sea, who concluded that the approach required further investigation.

The tagging peel resulted in a similar trend for the sex-specific model compared to that of the single-sex model whereby, as each cohort of tag releases is added, significant changes are seen in early and recent year class strength. The tagging peels for the two models differs however in the magnitude of the changes with the peel of the sex-specific model suggesting much higher recent recruitment, and much less variation in the estimates of year class strength between 1995 – 2010 than that of the single-sex model. Similarly, whilst the tagging peel showed similar changes in trajectory for *SSB* status, the variation in the 2024 estimate was reduced compared to the single-sex model. This however may be a consequence of the poor fit of the tag data in the sex-specific model.

Biological parameters

To allow for easier comparison between the current single-sex model and a sex-specific model, biological parameters for each sex were estimated, thereby limiting the data to those which were used in estimating the combined sex parameters to compare “like with like” in terms of time-period and collection method. Consistent with the estimates of Marsh et al. (2022) and Soeffker et al. (2022), our estimates for L_∞ in females (2001 mm) were much higher than that of males (1149 mm), while estimates of the growth rate (K) were lower. In addition to growing much larger than males, females also weigh more than males for a given length. This may be a result of either flexibility in diet between the two sexes, or the impact of ripe ovaries during measurement (Abreu et al., 2024). Given the higher uncertainty resulting from the inclusion of dome-shaped selectivity in the estimation of growth, particularly for females, and the subsequent effects observed the in the stock assessment fits, we recommend further investigation into the effects of including selectivity into the estimation of growth.

The estimates of maturity used in both this paper and Masere and Ziegler (2024) are based on the estimates of Yates et al. (2018) and modified by Ziegler and Dell (2019) to account for the reasonable expectations that very young fish are immature. Whilst the estimates used here are the best estimates available for this area, they are based on macroscopic staging, which as shown in Yates et al. (2018) are prone to misinterpretation. Work on estimating sex-specific maturity using histology for Division 58.5.2 is underway.

Age-length keys

One of the largest limitations of this investigation is the use of a single-sex age-length key for assigning survey and sub-fishery length frequencies to age. Historically otolith ageing within Division 58.5.2 has been based on length-bin sampling with no specific aim of targeting even sample sizes across sexes. In some years, this has resulted in skewed numbers towards females, in particular for large fish where females are the dominant sex. Whilst it is possible to age additional fish in poorly sampled length bins where otolith samples are available, this is both a costly and time-consuming process (see Maschette et al., 2025). As such, we propose that SARAG discuss both 1) the feasibility with associated cost of ageing additional samples, and 2) the use of forward-inverse age-length (FIAL) keys as proposed by Ailoud et al. (2019) as an interim step between single-sex age length keys and sex-specific age length keys. The premise of the FIAL keys is to link the concepts of forward and inverse keys using Bayes rule in a maximum likelihood framework. FIAL keys essentially create an age length distribution across all years that is used to penalise estimates within each year if they deviate from the overall distribution of length at age (Ailoud et al., 2019). This also potentially allows for more accurate estimation of age frequencies in fish for which few otoliths are collected in a given length class, such as very large individuals. This same method could also be explored for early years of survey data for which length, but no age data exists, or for data-limited fisheries which contain limited data.

Conclusions

Accurately accounting for biological parameters of a species in a stock assessment is a key task of management organisations. We have shown that sufficient data exists to estimate a sex-specific model to Patagonian toothfish in Division 58.5.2, and that there is enough dissimilarity between the population parameters of each sex to warrant one. Given the sensitivity of the sex-specific model to the estimates of biological parameters, particularly growth, more work is underway to be able to use a sex-specific model for providing management advice.

Despite this, we believe that this work fulfills the Heard Island and McDonald Islands Patagonian Toothfish Fishery consolidated workplan task 6a, to 'Develop the structural set-up to run a sex-based assessment model' and is the first step in 6b 'Evaluate the performance and results of a sex-based model.' Whilst we have deemed that the performance of the model is currently inadequate to provide management advice, we believe this is a result of the available ageing data and subsequent parameter estimates, not the model structure.

Acknowledgements

We would like to thank Tim Lamb for assistance in the preparation of data for analysis, and Peter Yates for insights into the maturity estimation process. We would also like to thank Paul Burch and Kerrie Swadling for their useful comments on the paper.

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Appendix 1: Guide to changes in input file specifications for sex-specific models.

Grouping	Parameter call	Sub-command	Description of change
Categories	@categories	format	Change to sex.TagYear
		names	Set to male and female categories for untagged and tag years e.g. M.untagged M.2012
		age_lengths	Age length for each sex and category, e.g., AgeLengthM AgeLengthMTag*11
Recruitment	@process	categories	Update to each untagged sex category
		proportions	Set for each category e.g., 0.5 0.5
SSB	@derived_quantity	selectivities	Update for the maturity for each sex, e.g., maturityM*12 maturityF*12
Catch	@process	table method	Set row for each sex and/or selectivity
Maturity	@selectivity	all	Duplicate and set values for each sex.
Selectivity	@selectivity	all	Duplicate and set values for each sex.
	@estimate	all	Duplicate for each sex.
	@estimate	lower_bound	For alphas, set to 1 for males, 0.1 for females
		upper_bound	For alphas, set to 1 for males, 20 for females
Growth	@age_length	all	Duplicate and set values for each sex.
Tag Growth	@age_length	all	Duplicate and set values for each sex.
Length weight	@length_weight	all	Duplicate and set values for each sex.
Tag release	@process	from	Update to sexed untagged categories
		to	Update to relevant sexed tag categories.
		selectivity	Update to sexed selectivities
Survey biomass	@observation	categories	Update to sexed untagged categories
		selectivities	Update to sexed selectivities
Catch at age	@observation	categories	Update to sexed untagged categories
		selectivities	Update to sexed selectivities
		table	For each year set age columns for all ages of sex one, then all ages of sex two. Rows should sum to 1.
Tag recaptures	@observation	tagged_categories	Update for each sexed tag category

Appendix 2: Process for assigning sex to unsexed length data to allow for use in sex-based stock assessments.

Whilst many fish have been sampled for length within the toothfish fisheries, only a subset of these have also been sampled for sex. In order to use these lengths within a sex-based stock assessment they need to be assigned a sex. We do this through the following steps:

1. Catch weighting,
2. Group Aggregation,
3. Calculating Sex Proportion,
4. Assigning Sex,
5. Combined Counts, and
6. Final Proportion Calculation.

Catch Weighting

Within each haul h, each sampled individual is given the catch weighting

$$W_h = \frac{N_h}{n_h}$$

where N_h is the total number of individuals caught in haul h and n_h is the number of individuals sampled for length in haul h.

To assign a sex to the unsexed individuals the data is split into two groups: - Group 1: Observations with both sex (s) and length (l) data available - Group 2: Observations with length data but no sex data.

Group Aggregation

For Group 1, where both sex and length of individuals were recorded, let $\mathfrak{I}_{sl}$ be the set of sampled individuals with sex s in length class l, and let $h_{(i)}$ be the haul from which individual i is sampled. Then the number of individuals $N_{sl}^{(1)}$ with sex s and length l is

$$N_{sl}^{(1)} = \sum_{i \in (\mathfrak{I}_{sl})} W_{h_{(i)}}.$$

For Group 2, where only length of individuals were recorded, let $\mathfrak{I}_l$ be the set of sampled individuals in length class l, and the number of individuals $N_l^{(2)}$ with length l is

$$N_l^{(2)} = \sum_{i \in (\mathfrak{I}_l)} W_{h_{(i)}}.$$

Calculating Sex Proportion

For Group 1, the proportion $P_{sl}^{(1)}$ of each sex in length class l is

$$P_{sl}^{(1)} = \frac{N_{sl}^{(1)}}{\sum_{s'} N_{s'l}^{(1)}}.$$

If the total count for a length class is zero, each sex gets an equal proportion,

$$P_{sl}^{(1)} = \frac{1}{|S|}$$

where $|S|$ is the number of sex categories.

Assigning Sex

Observations with unknown sex are distributed according to the proportions observed in the Group 1 individuals.

$$N_{sl}^{(2)} = N_{l}^{(2)} \times P_{sl}^{(1)}.$$

Combined Counts

The Group 1 $N^{(1)}$ and Groups 2 $N^{(2)}$ totals are combined to form the total counts for each sex in each length class as

$$N_{sl} = N_{sl}^{(1)} + N_{sl}^{(2)}.$$

Final Proportion Calculation

Finally, the total counts are used to calculate the overall proportions of length classes by sex

$$P_{sl} = \frac{N_{sl}}{\sum_{s'l'} N_{s'l'}}.$$

Appendix 3: Diagnostic plots for final sex-specific stock assessment Model 7.

Age fits

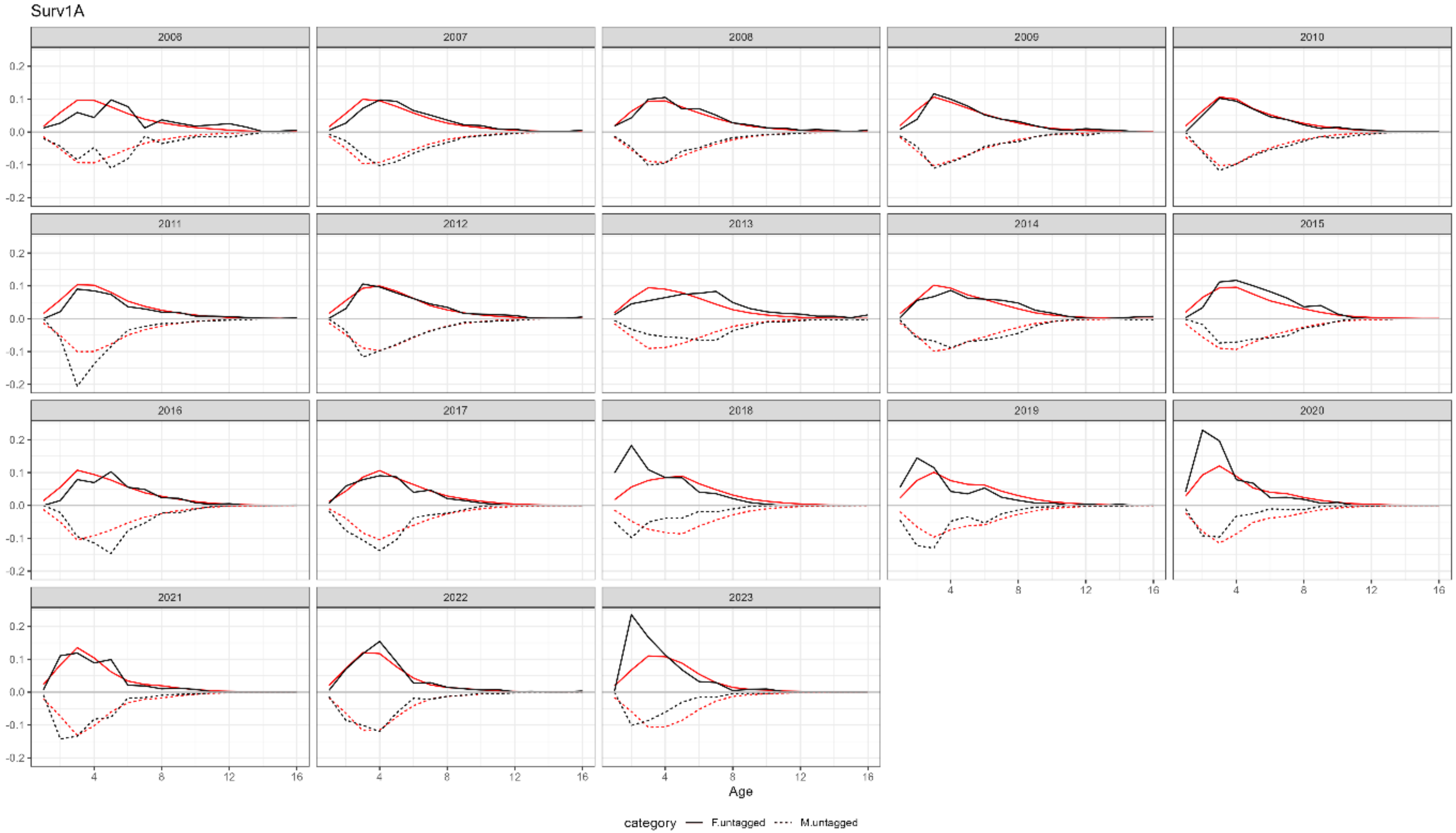

Figure A4.1: Observed (black) and predicted (red) age profiles for females (solid line) and males (dotted line) for the survey.

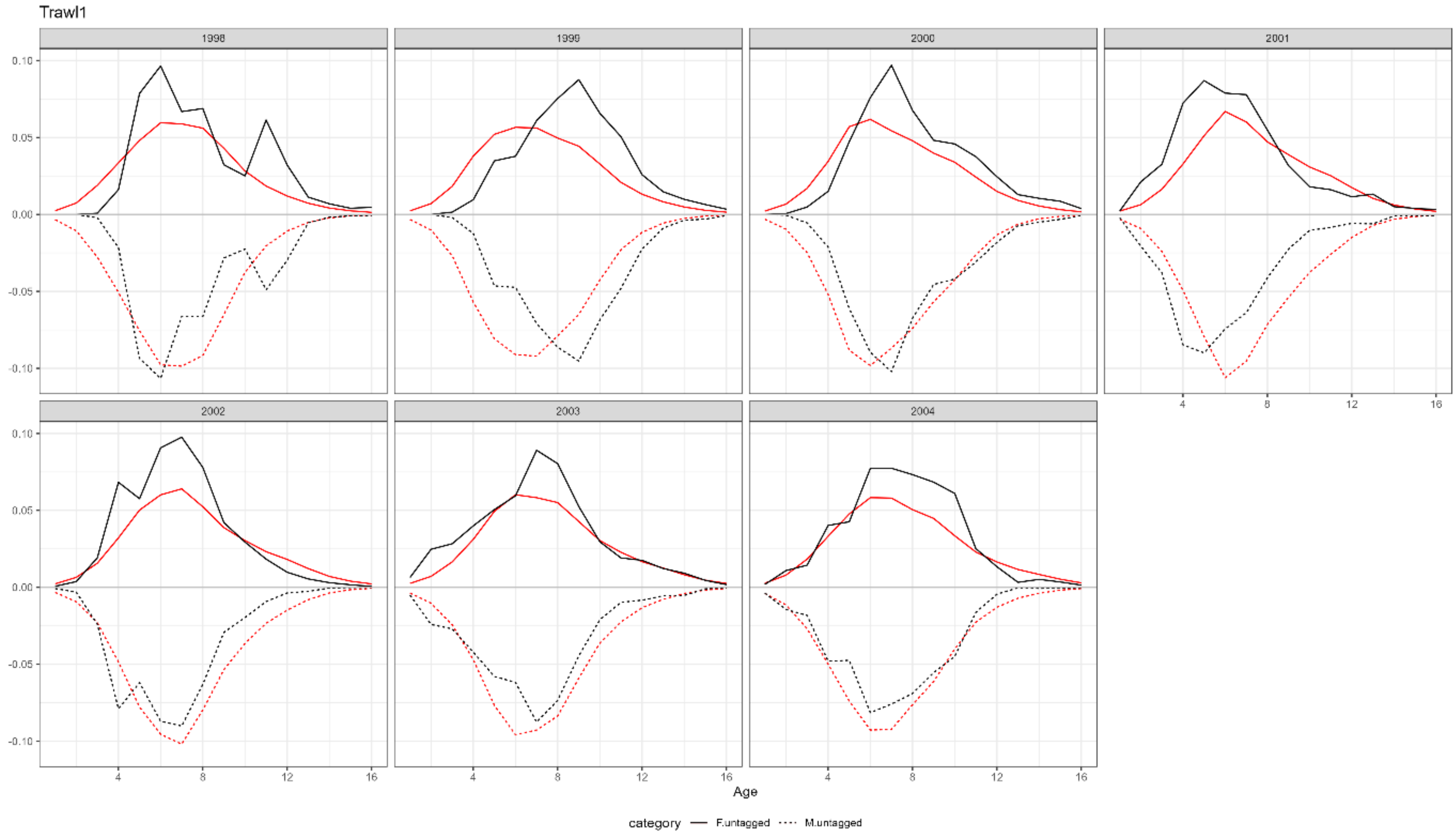

Figure A4.2: Observed (black) and predicted (red) age profiles for females (solid line) and males (dotted line) in Trawl1 observations.

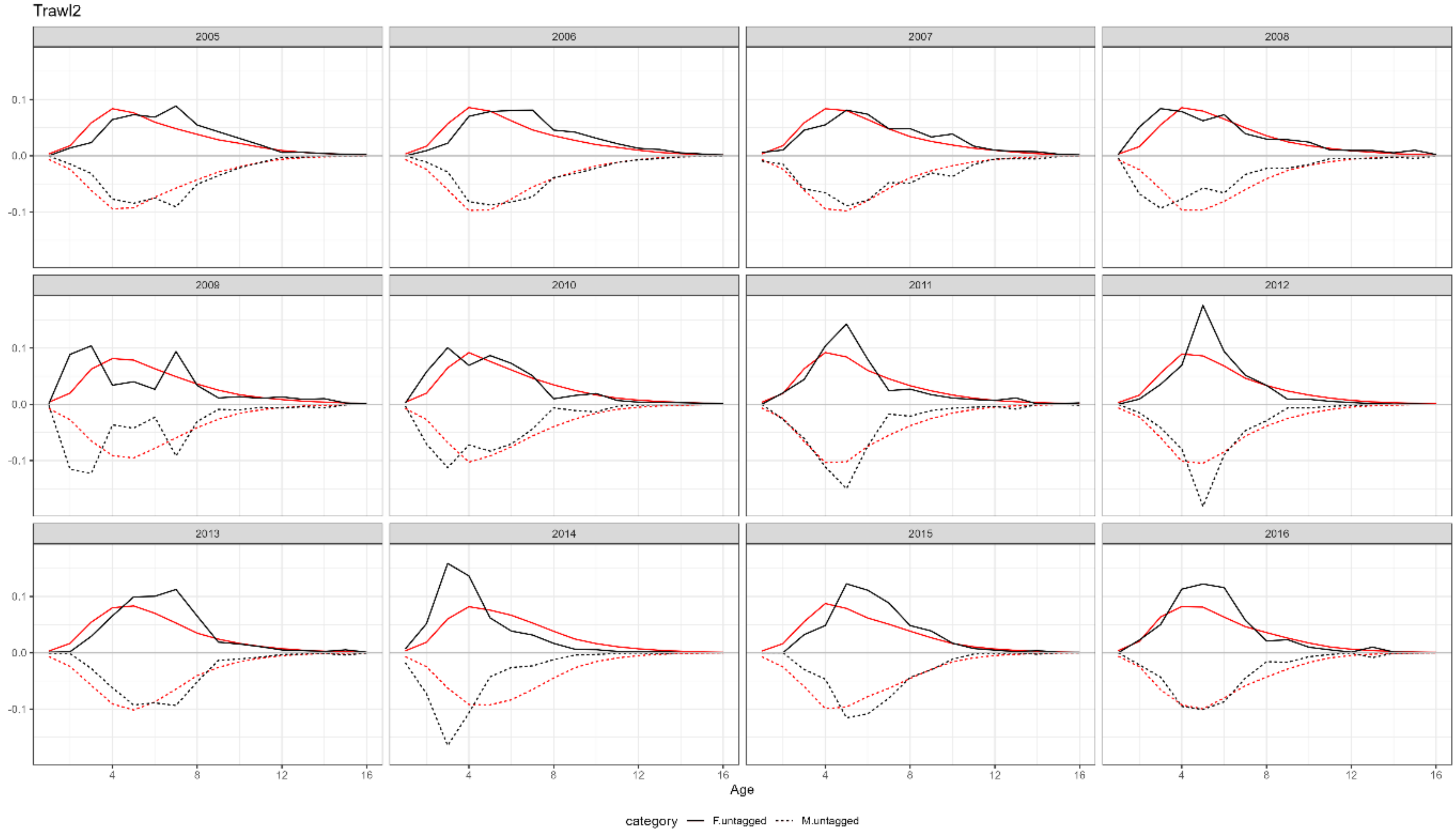

Figure A4.3: Observed (black) and predicted (red) age profiles for females (solid line) and males (dotted line) in Trawl2 observations.

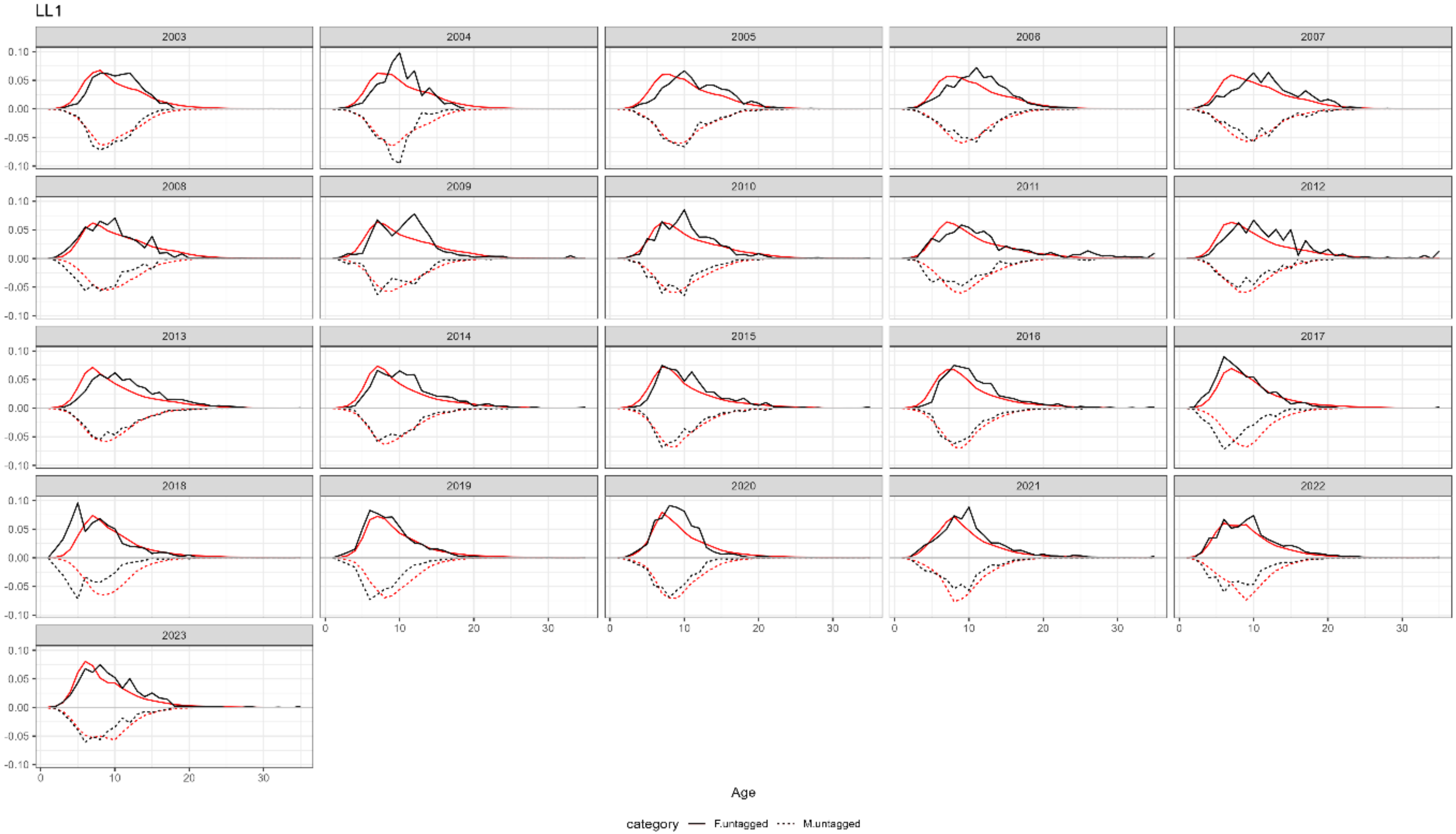

Figure A4.4: Observed (black) and predicted (red) age profiles for females (solid line) and males (dotted line) in LL1 observations.

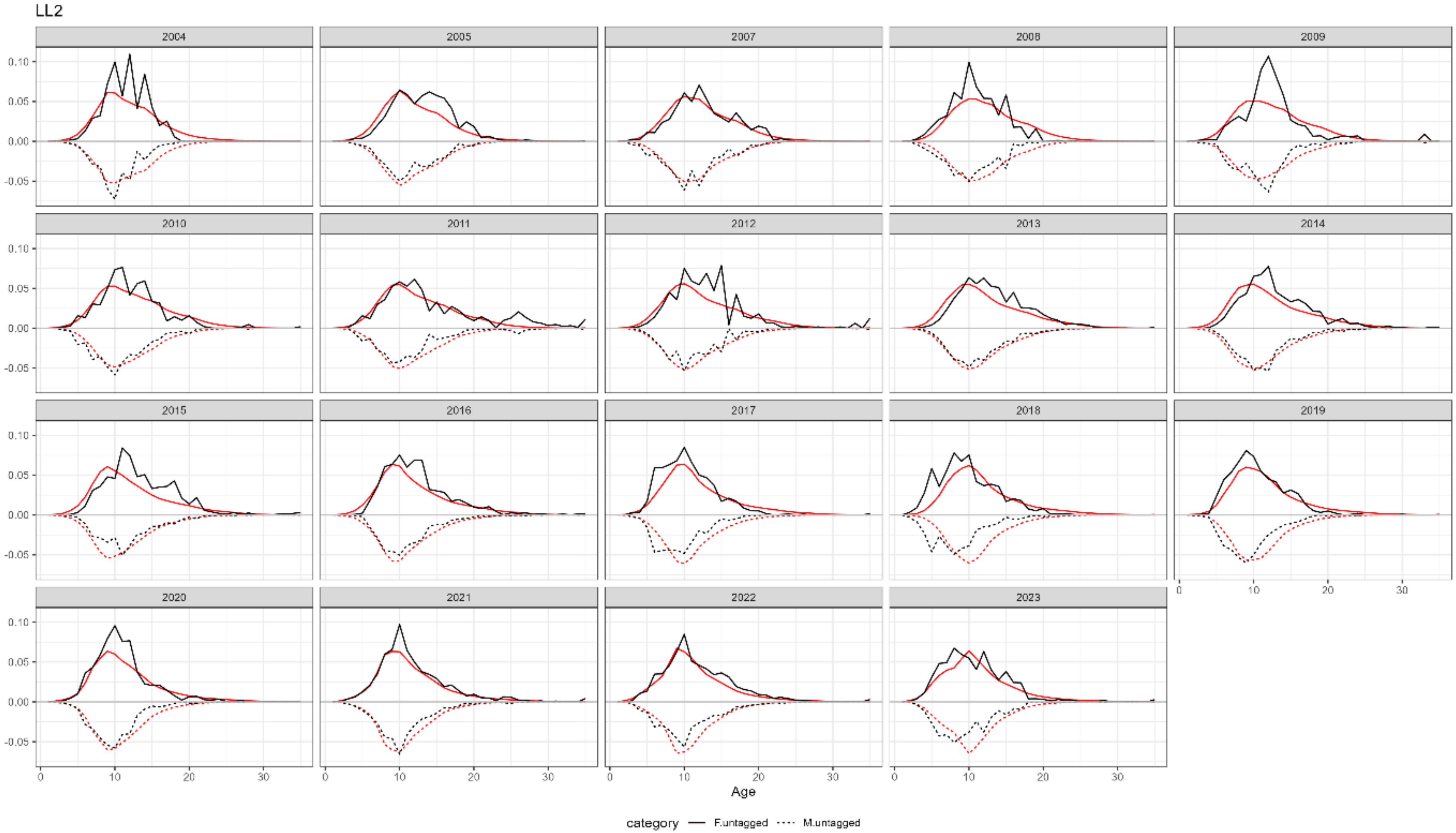

Figure A4.5: Observed (black) and predicted (red) age profiles for females (solid line) and males (dotted line) in LL2 observations.

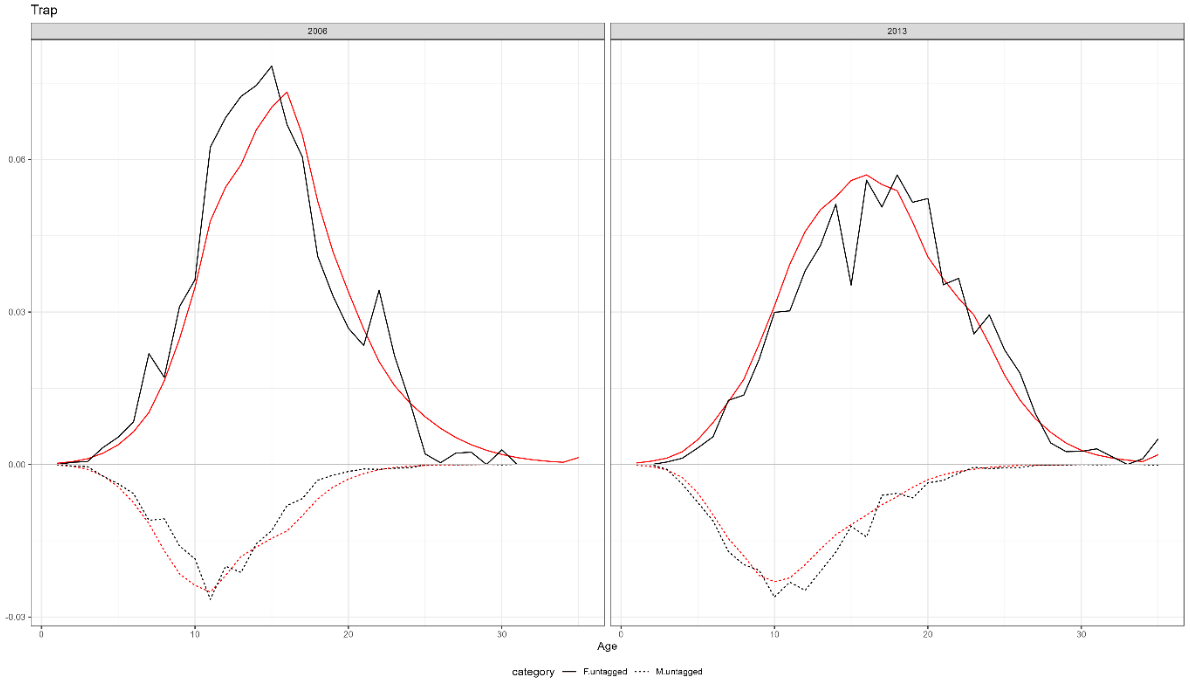

Figure A4.6: Observed (black) and predicted (red) age profiles for females (solid line) and males (dotted line) in Trap observations.

Sex Ratios

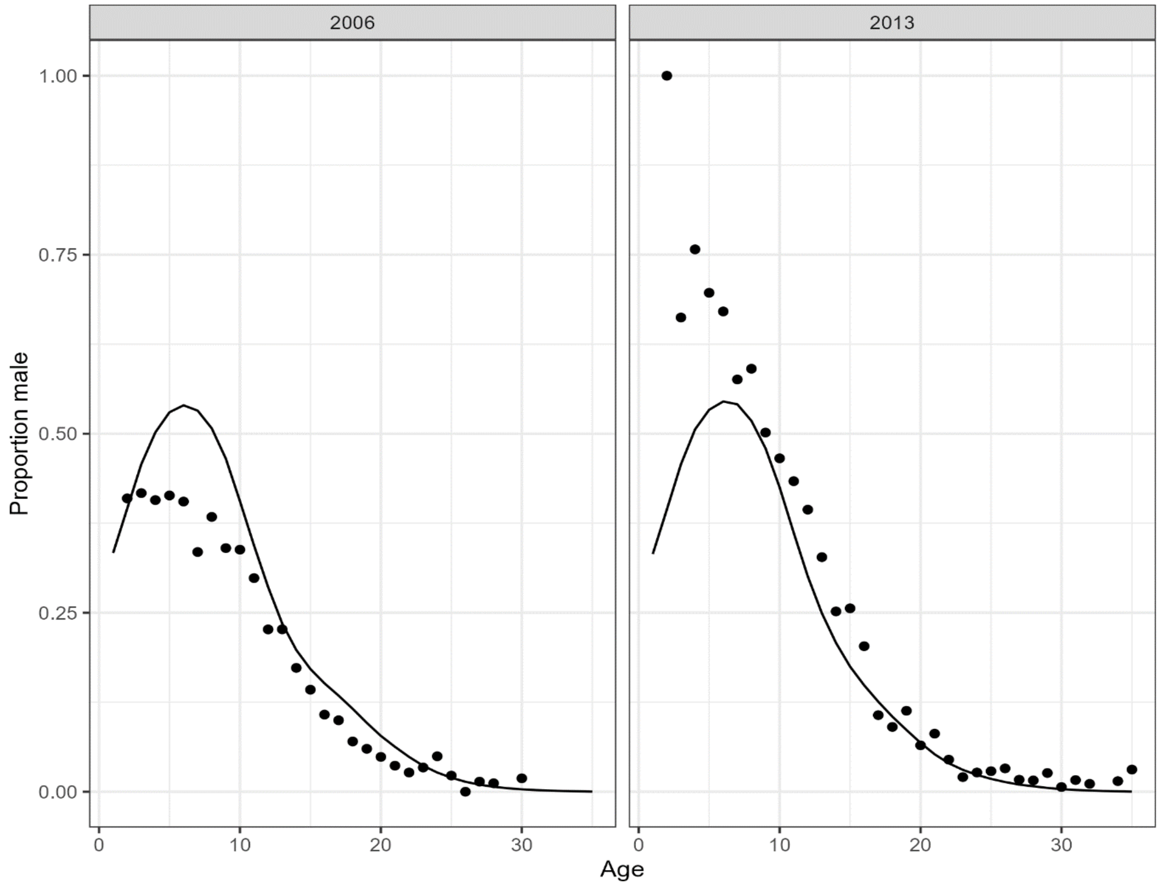

Figure A4.7: Observed (dots) and predicted (line) ratio of males by age in Trap observations.

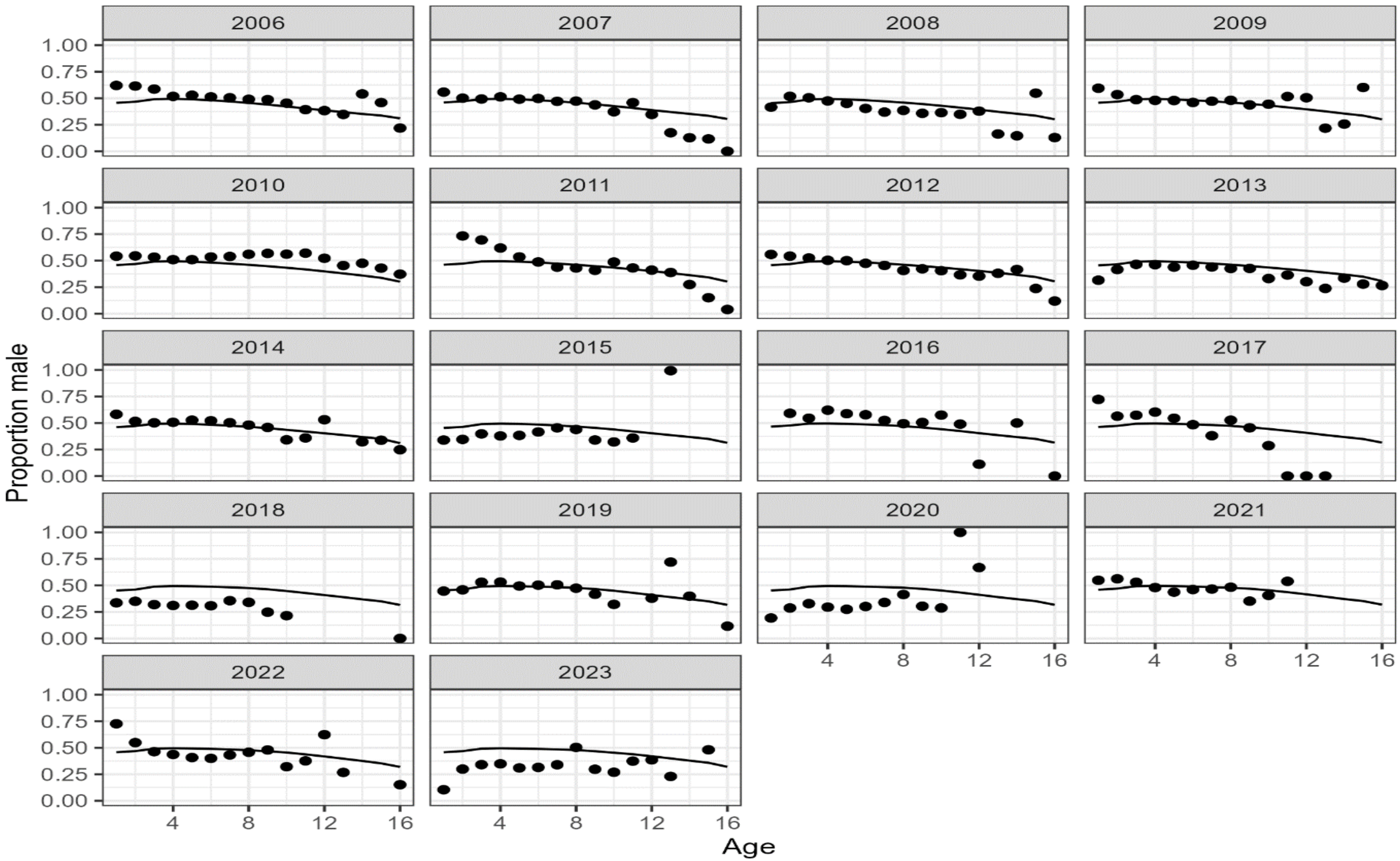

Figure A4.8: Observed (dots) and predicted (line) ratio of males by age in survey observations.

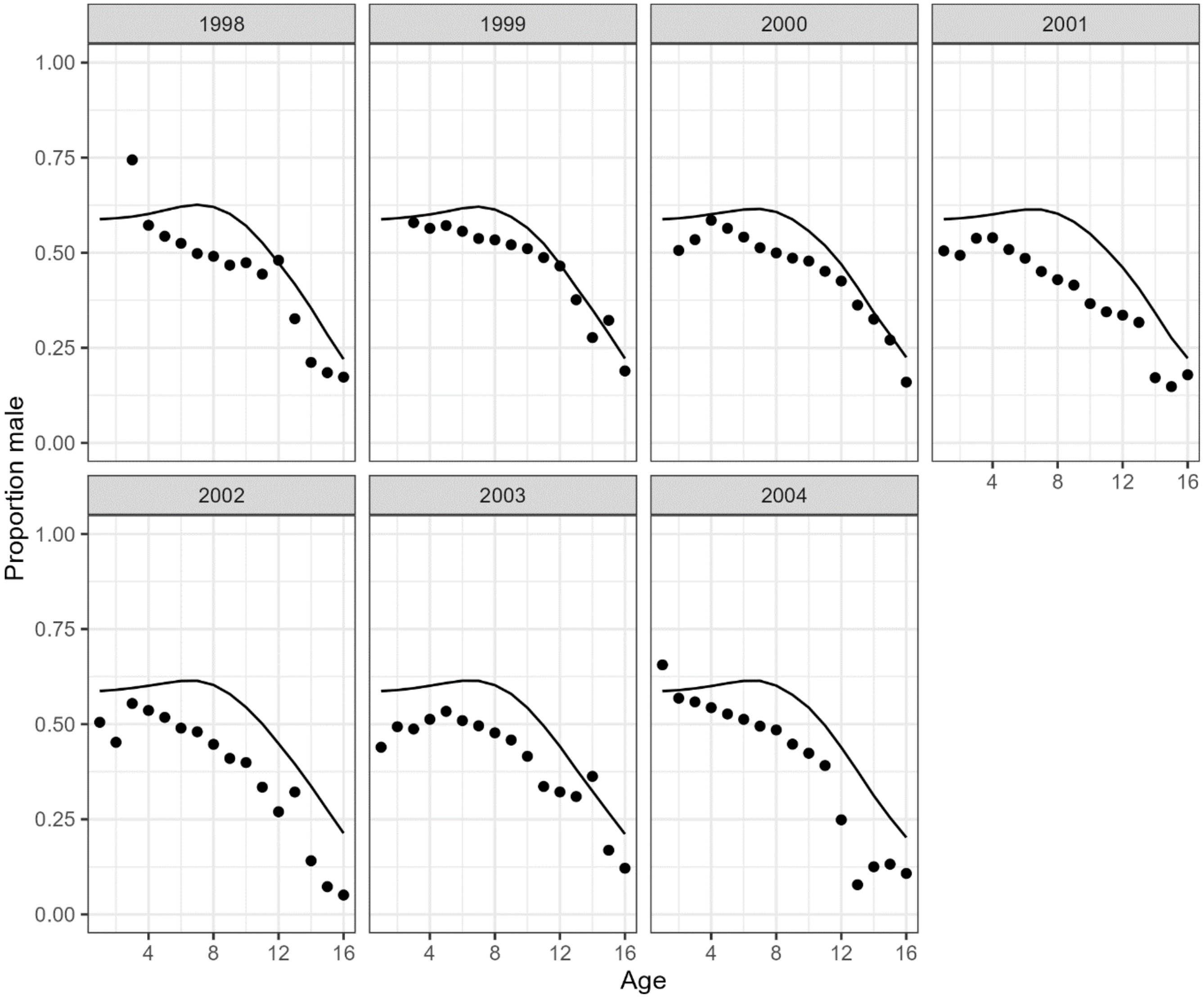

Figure A4.9: Observed (dots) and predicted (line) ratio of males by age in Trawl1 observations.

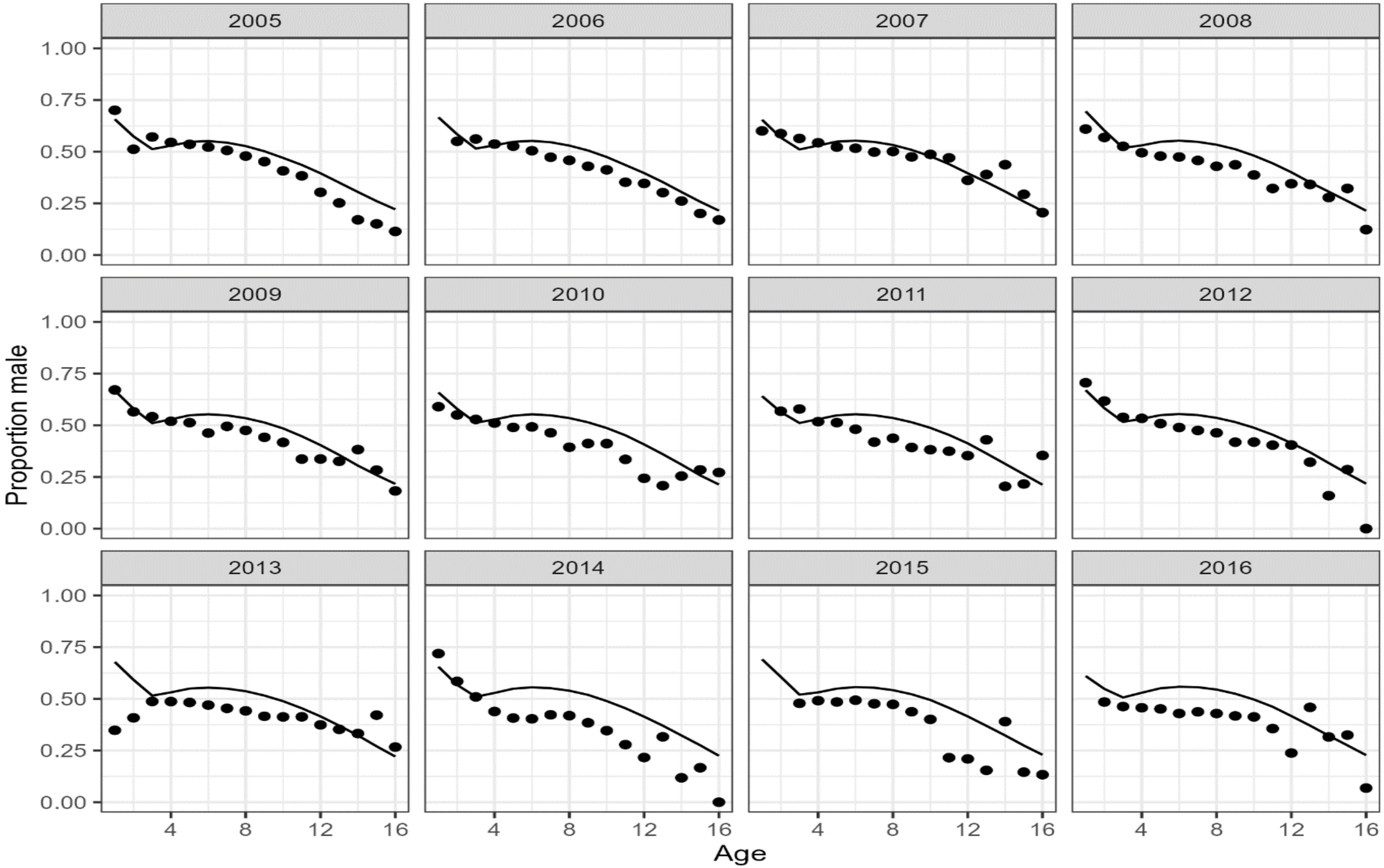

Figure A4.10: Observed (dots) and predicted (line) ratio of males by age in Trawl2 observations.

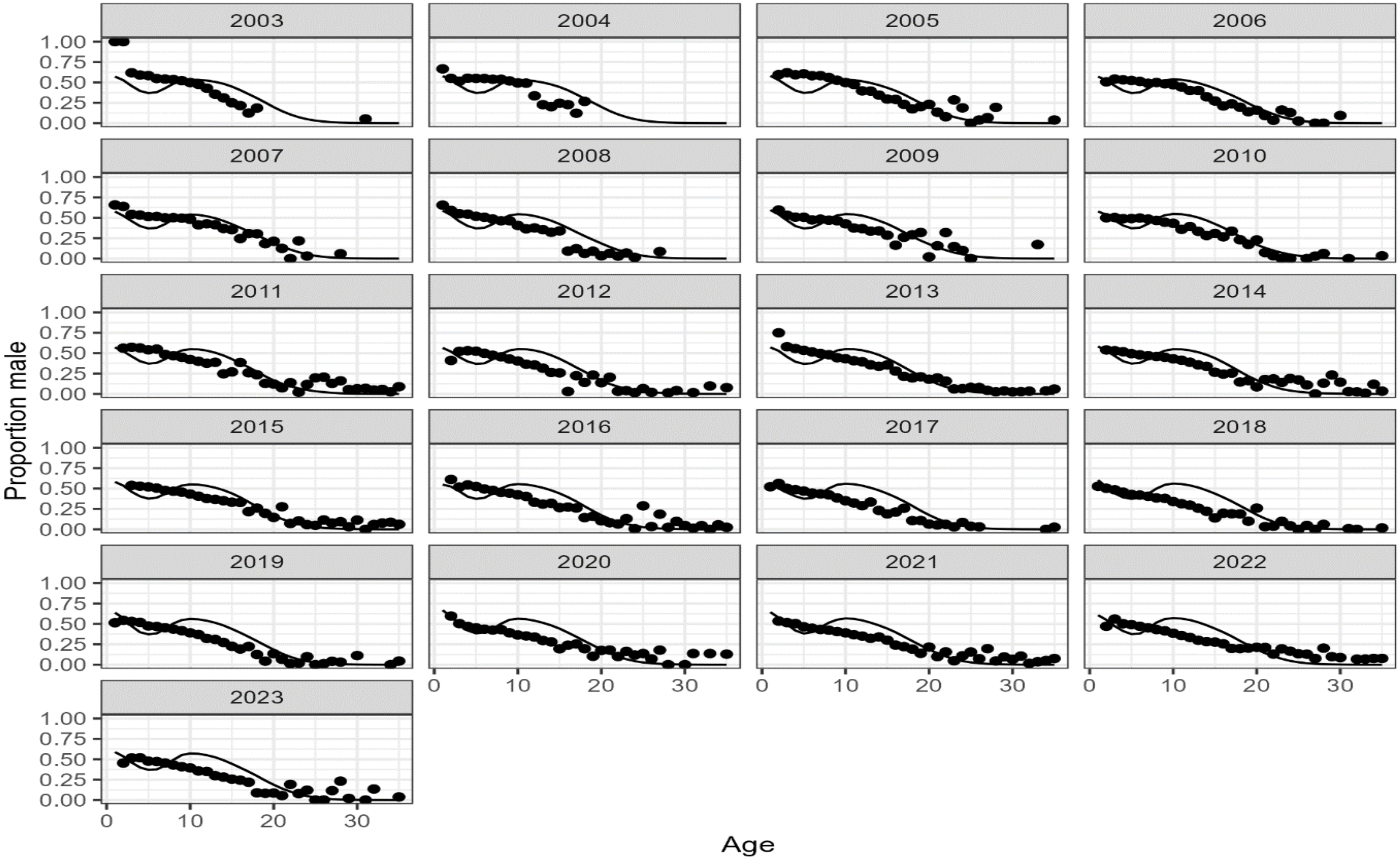

Figure A4.11: Observed (dots) and predicted (line) ratio of males by age in LL1 observations.

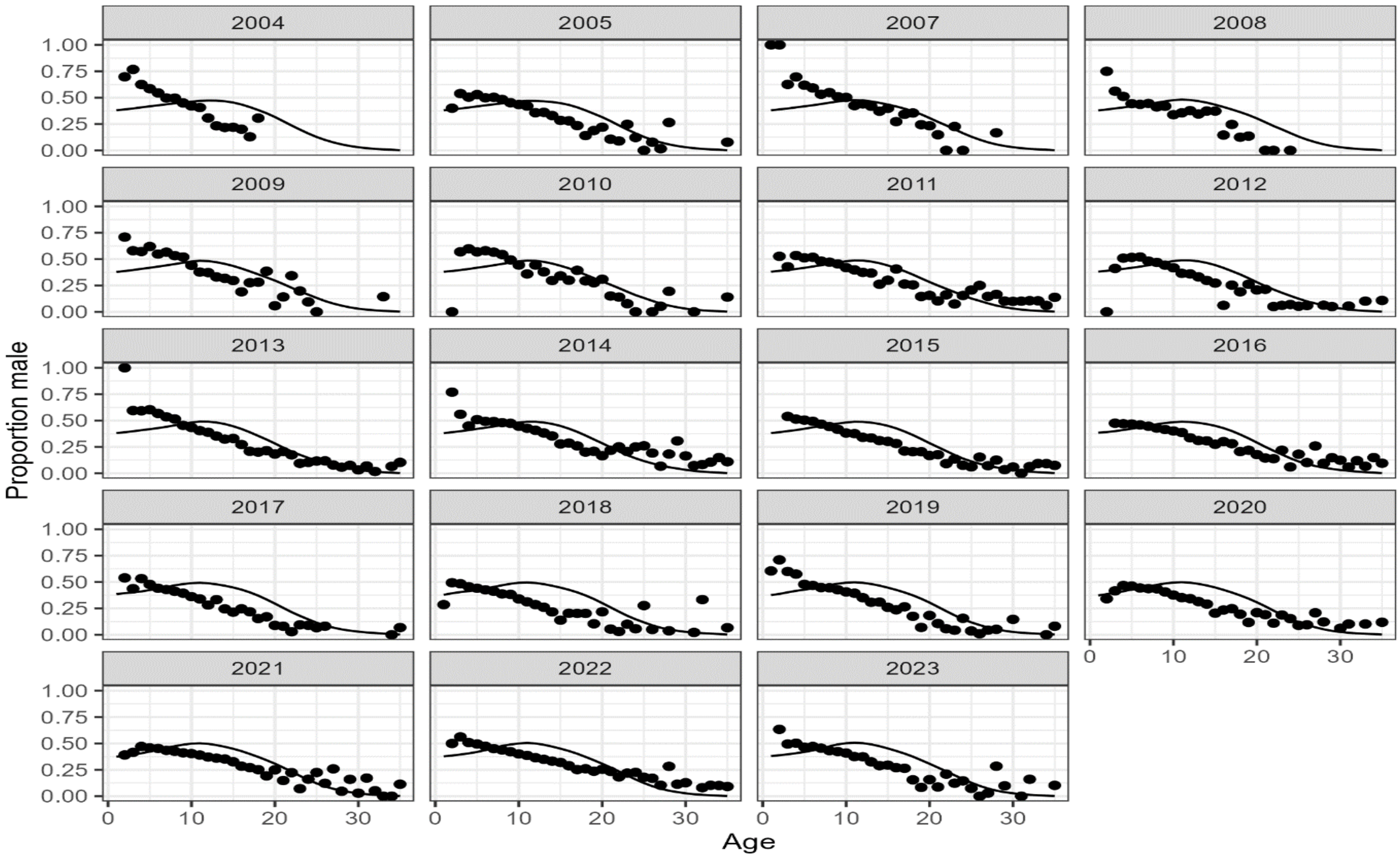

Figure A4.12: Observed (dots) and predicted (line) ratio of males by age in LL2 observations.

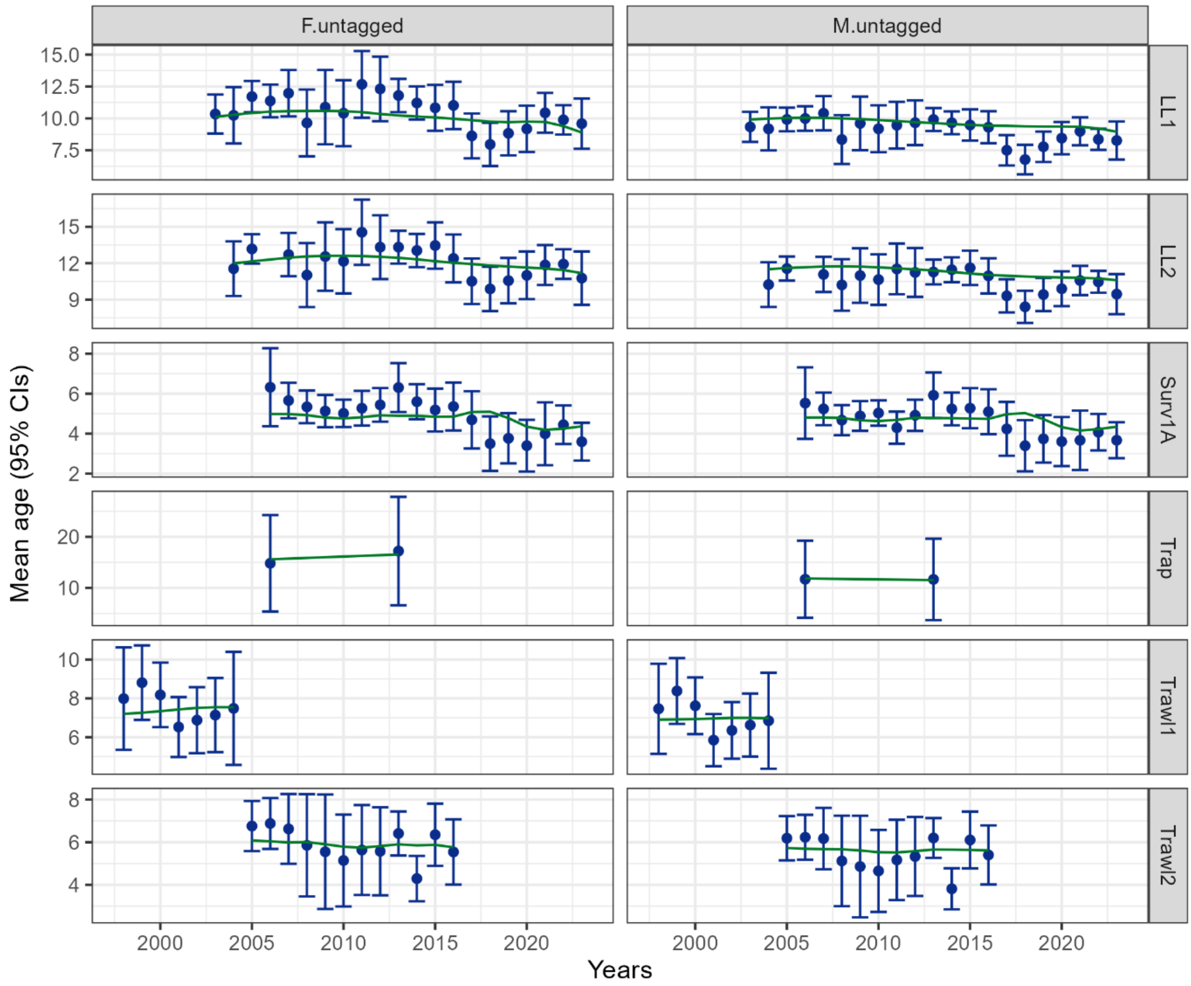

Figure A4.14: MPD mean age fits for females and males.

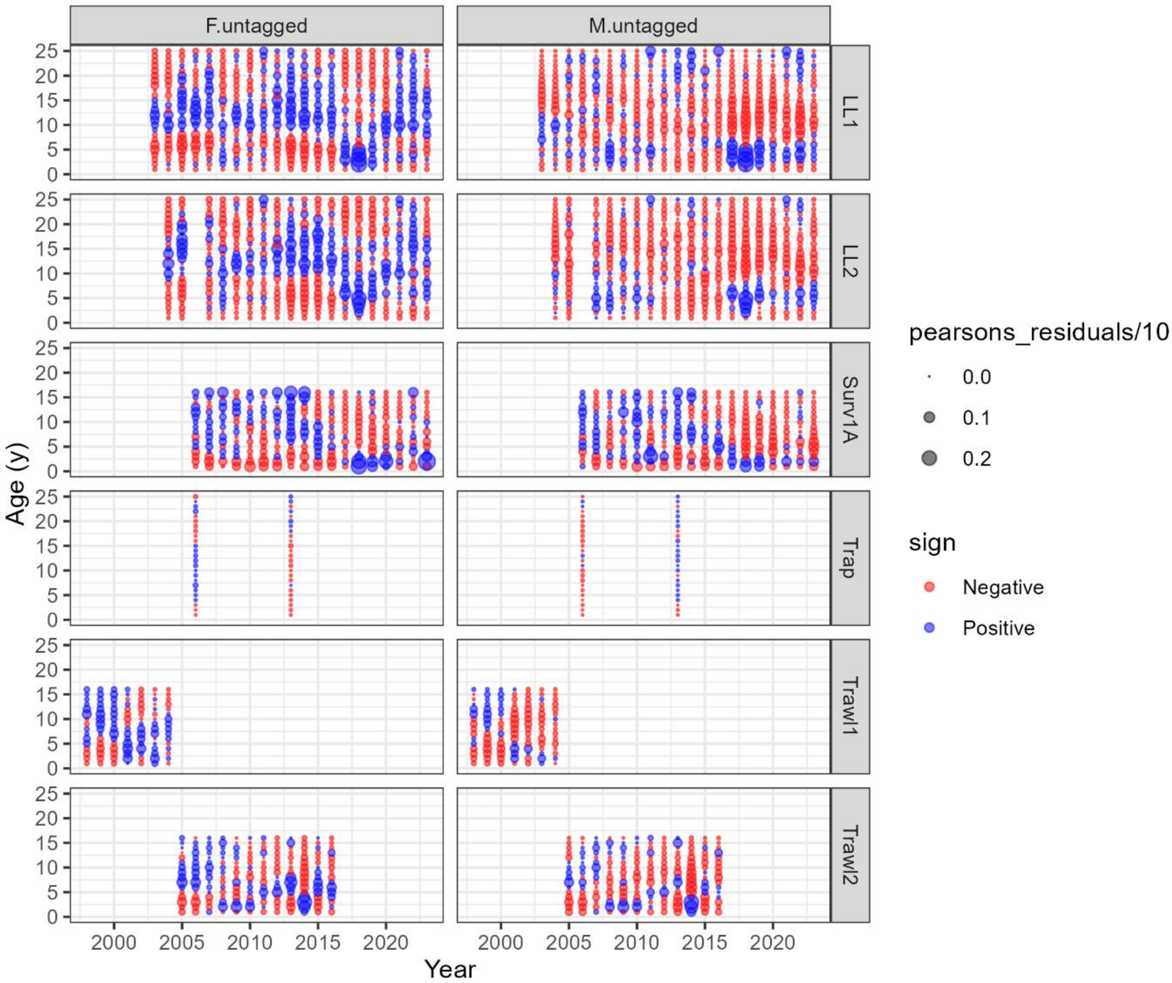

Figure A4.14: MPD age frequency Pearson residuals for females and males.

Results from the 2025 random stratified trawl survey in the waters surrounding Heard Island in Division 58.5.2

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Abstract

During March 2025, the annual random stratified trawl survey (RSTS) around Heard Island and McDonald Islands (HIMI) was conducted in CCAMLR Division 58.5.2, with the completion of 163 stations. The survey was conducted on the *FV Cape Arkona*. Sampling protocols such as the design and the duration of the hauls were similar to recent surveys, but with a new set of randomly selected haul stations. The catch of Patagonian toothfish (*Dissostichus eleginoides*) was 69.9 t. The catch of mackerel icefish (*Champsocephalus gunnari*) was 23.8 t. Biomass estimates for most of the managed by-catch species were similar to the survey averages in recent years. Length and weight measurements were taken for 16,362 fish.

Introduction

The fisheries for Patagonian toothfish (*Dissostichus eleginoides*) and mackerel icefish (*Champsocephalus gunnari*) have been operating since 1997 in the Australian Fishing Zone around the Australian territory of Heard Island and McDonald Islands (HIMI) in Division 58.5.2. The fisheries started as trawl fisheries, but moved to both trawl and longline gears in 2003 for *D. eleginoides*. Changes in the fishery for *D. eleginoides* have seen an increase in the number of longline vessels and from 2015 a phasing out of trawling.
In each year since 1997, a random stratified trawl survey (RSTS) has been conducted to assess the abundance and biology of fish and invertebrate species. The survey provides information for input into the stock assessments for the two target species, *D. eleginoides* and *C. gunnari*. Surveys have been conducted as consistently as possible each year to ensure a continuous data time series from the fisheries.

The random stratified trawl surveys have two principal long-term aims, namely 1) to assess the abundance of juvenile and adult *D. eleginoides* on the shallow and deep parts of the

Heard Island Plateau (300 to 1000m); and 2) to assess the abundance of *C. gunnari* on the Heard Island Plateau.

For the annual survey, the area of the plateau down to 1000 m was divided into ten strata, each covering an area of similar depth and/or abundance of target species. Although the number and boundaries of strata have been adjusted over the years, they have been consistent since 2002 (Welsford *et al.* 2006). The first three surveys of this series were focused on sampling icefish habitat (1997 and 1998) and toothfish habitat (1999), and are included in the relevant assessments. From 2000, the surveys were designed to sample both toothfish and icefish populations in waters to a depth of 1000 m, although in 2000 and 2003 some of the strata in deeper waters were not sampled. Since a review of the survey design in 2003 (Candy *et al.* 2004), a minimum of 10 stations have been sampled in each of nine strata. The tenth stratum, Shell Bank, is closed to fishing but has been occasionally included in the survey, the two most recent being 2005 and 2014. The sampling regime has been stable, with the same number of hauls in each stratum between 2006 and 2014. From 2015 onwards, an additional 5 hauls were included in the Ground B stratum. This report presents the outcomes of the survey for 2025.

Methods

Survey design

The target species for six strata in the survey area was *D. eleginoides*, while both *D. eleginoides* and *C. gunnari* were targeted together in the remaining three strata (Table 1). The survey strata boundaries and the number of stations chosen for sampling in eight strata has remained the same since the 2006 survey (Nowara et al. 2006). The sampling strategy for the ninth stratum, Ground B, was changed in 2015 to make it more consistent with that of the rest of the survey. Prior to the 2015 survey the ground was divided into 29 squares and a subset of 20 were sampled with one haul in each. From 2015, the ground was stratified into two areas with randomly allocated stations, 15 in the first area and 10 in the second. Thus, there were 5 more stations added to the total hauls in this stratum. As in previous surveys, unique random starting locations and headings for each trawl station were selected, with variable station numbers per strata (Table 1).
A set of starting position co-ordinates and headings for each station in each stratum was provided to the fishing vessel conducting the survey, including first choice and reserve positions. If it was not possible to trawl at one of the first choice locations due to unsuitable bottom conditions, the first suitable station on the reserve list for that stratum was chosen instead. If weather conditions made it difficult to follow the prescribed heading, the tow was made in the reverse direction, terminating approximately at the nominated starting point.

Attachment A

Table 1: Allocation of stations to strata and time of day for sampling of principal species for the survey.

Stratum	Name	Number of stations	Principal species	Time of day for sampling
1	Plateau Southeast	30	Toothfish, Icefish	Daytime only
2	Gunnari Ridge	18	Toothfish, Icefish	Daytime only
3	Plateau West	10	Toothfish, Icefish	Daytime only
4	Plateau North	15	Toothfish	Any time of day
5	Plateau Deep Northeast	15	Toothfish	Any time of day
6	Plateau Deep East	30	Toothfish	Any time of day
7	Plateau Deep Southeast	10	Toothfish	Any time of day
8	Plateau Deep West	10	Toothfish	Any time of day
9	Ground B	25	Toothfish	Any time of day

Vessel and gear specifications

The annual survey was conducted aboard the *FV Cape Arkona* (Table 2). The same Champion trawl net was used as in previous years (Table 3) which included a small mesh (50 mm) codend liner, designed to retain small organisms.

Table 2: Vessel specifications for the Cape Arkona. Source: CCAMLR

Vessel specifications	
Year built	2018
Length	66.9 m
Beam	15.0 m
Engine power	3075 kW
Gross tonnage	2954 t
Carrying capacity	600 t
Fish hold capacity	1270 m3

Table 3: Champion trawl net specifications.

Net specifications	
Headrope length	38.5 m
Groundrope length	45 m (18.1 m rig)
Bobbin diameter	55 cm
Horizontal opening	23.5 m
Vertical opening	3.8 m
Belly mesh size	152 mm
No. meshes in belly	480
Throat mesh size	120 mm
Codend mesh size	90 mm (50 mm liner)
Codend mesh orientation	diamond
Trawl board type	Mobydick
Trawl board weight	3000 kg
Trawl board to wing length	150 m

Trawling procedure

Each survey trawl was of approximately 30 minutes duration on the bottom at a towing speed of 3 knots. For strata 1-3, which targeted *C. gunnari* as well as *D. eleginoides*, tows were conducted only between sunrise and sunset when icefish are concentrated near the bottom (van Wijk et al. 2001). Strata designed to target *D. eleginoides* only (strata 4-9, Table 1) were sampled throughout the day.

The survey design required all tows within a particular stratum to be completed within as short a time frame as possible. In two of the icefish strata Gunnari Ridge and Plateau Southeast sampling was required to take place without large delays in between, in case there was movement of icefish between these strata. All shots were conducted as far as possible within the specifications for towing speed and gear configuration. Under the circumstances where a shot had to be aborted, it was counted as valid as long as 15 minutes of fishing time was completed. Otherwise, the shot was repeated at the same or a reserve location, depending on the reason for abandoning the shot. Tow distance was calculated as the shortest distance between start and finish positions of the trawl established by GPS. A standard effective net opening of 19 m was applied to the tow distance to calculate swept area. Estimates of headline height of 7 m and wingspread of 19 m during normal fishing operations were provided by the skipper.

Attachment A

Catch and biological sampling

The catch was recorded separately for each haul. Start and end time, geographical location and depth at the start and end of each haul were recorded in the database. The catch was first sorted into species/taxon groups, then weighed and sampled for biological measurements. For catches of less than 400 kg of each target fish species (*C. gunnari* and *D. eleginoides*) as well as for grey rockcod (*Lepidonotothen squamifrons*) and unicorn icefish (*Channichthys rhinoceratus*), the entire catch was weighed. If the catch was greater than 400 kg, the skipper's estimate and the weight from factory production were recorded.
Length measurements were taken from a random sub-sample of fish (numbers dependent on the species and availability) on an electronic measuring board and biological measurements from a smaller sample. For *C. gunnari*, *D. eleginoides*, *L. squamifrons* and *C. rhinoceratus*, up to 200 individuals of each species were measured for each haul. For *Bathyraja spp.*, up to 50 individual length measurements were taken. Numbers and weights of any other species of by-catch were recorded and similar measurements were taken for benthos where practical.
For each haul, biological measurements were taken from a random sample of up to 50 of each of the four main species of fish and from skates. Measurements recorded were individual weight, standard length and total length (TL), sex, and gonad stage. Otoliths were collected from *D. eleginoides* and some of the fish by-catch species which had biological measurements taken.

Tagging

Dissostichus eleginoides were tagged with two T-bar tags (Hallprint). As biological sampling was the first priority, fish were tagged only if time permitted.

Biomass estimates

Total biomass estimates of the targeted and main by-catch fish and skate species in the survey area were calculated in three stages.

For each stratum, biomass was first estimated at the haul level by:

$$\text{catch weight (per haul)} \times \left(\frac{\text{stratum area (km}^2)}{\text{swept area (per haul, km}^2)} \right)$$

which scales each haul's catch to the total area of the stratum, assuming that each haul is a representative random sample. While each haul is assumed to provide an independent estimate of the total biomass in the stratum, because no single haul can be assumed to perfectly represent the whole stratum (we expect variation between hauls), we average across hauls to produce a stratum-level biomass estimate.This is then summed across strata to provide a survey level biomass estimate.

To estimate uncertainty around our biomass estimate, we used a stratified non-parametric bootstrap. In each bootstrap iteration, hauls were resampled (with replacement) within each stratum, to calculate stratum-level mean biomass estimates. These stratum-level estimates were then summed to produce a total biomass estimate for the whole survey. This process was repeated 10,000 times to generate a distribution of total survey biomass estimates, from which 95% confidence intervals were derived (using the 2.5th and 97.5th percentile).

RESULTS AND DISCUSSION

Survey coverage

A total of 163 valid stations were completed for the survey between the 1st of March and 29th of March (Table 4).

Table 4: Dates and number of planned and completed hauls for each stratum in the survey.

Stratum	Start Date	End Date	Area (km2)	No hauls allocated	No hauls completed	No valid hauls
Plateau Southeast	06-Mar	19-Mar	10,404	30	28	28
Gunnari Ridge	14-Mar	20-Mar	521	18	18	18
Plateau West	03-Mar	10-Mar	10,440	10	11	11
Plateau North	01-Mar	03-Mar	15,170	15	15	15
Plateau Deep Northeast	21-Mar	23-Mar	15,090	15	15	15
Plateau Deep East	23-Mar	27-Mar	13,120	30	30	30
Plateau Deep Southeast	05-Mar	29-Mar	5,340	10	12	12
Plateau Deep West	01-Mar	04-Mar	13,370	10	9	9
Ground B	07-Mar	18-Mar	481	25	25	25
All Strata	01-Mar	29-Mar	83,936	163	163	163

Attachment A

Catch

The most abundant fish caught during the survey was *D. eleginoides*, with 69.9 t primarily caught on Ground B. Catches of *C. gunnari*, were 23.8 t taken, primarily on Gunnari Ridge (Table 5). The catches of managed by-catch species were dominated by *C. rhinoceratus* and *Bathyraja* spp. (namely, *B. eatonii*), followed by *Macrourus* spp. (namely, *M. caml*) and *L. squamifrons* (Table 5). Sessile invertebrates were the most abundant invertebrate group in the catch (cnidarians, sponges, ascidians), followed by echinoderms (asteroids, echinoids, holothuroids, and ophiurids), cephalopods (octopus and squid), and crustaceans (isopods, decopods, prawns and shrimps). The catches of both *C. rhinoceratus* and *Bathyraja spp.* were similar to these species average catches from the past ten years of the survey, with the catches of *Macrourus* spp. and *L. squamifrons* lower than the past ten year average.

Table 5: Catches of main taxa (kg) in the 2020 to 2025 surveys.

Taxon	2020[1]	2021	2022	2023	2024	2025
Target species						
D. eleginoides	86,252	77,936	36,192	66,801	86,322	69,902

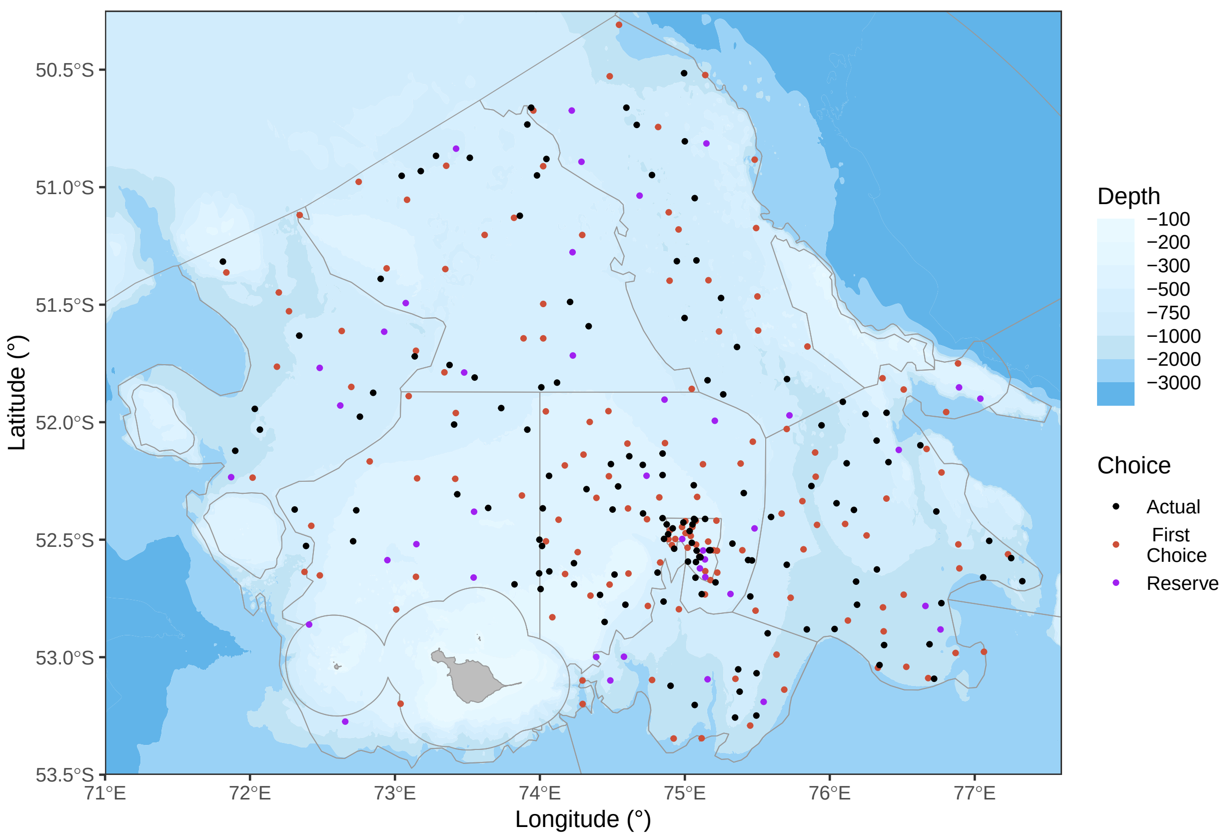

Figure 1: The distribution of sampling hauls within strata for the survey. Hauls on the main trawling ground (Ground B) are not shown.

Attachment A

Table 5: Catches of main taxa (kg) in the 2020 to 2025 surveys.

Taxon	2020[1]	2021	2022	2023	2024	2025
C. gunnari	7,291	35,665	71,027	16,014	25,630	23,844
Managed by-catch species						
C. rhinoceratus	5,897	8,313	5,435	7,012	5,843	5,195
L. squamifrons	3,556	3,370	3,042	2,000	4,436	356
Macrourus spp.	1,406	961	659	649	661	466
Bathyraja spp.	2,203	1,871	1,954	1,505	1,656	1,924
Other Fish						
Other bony fish	722	526	419	474	737	680
Other elasmobranchs	438	72	46	97	241	33
Invertebrates						
Crustaceans	7	25	28	20	35	29
Molluscs	16	5	2	71	2	3
Cephalopods	126	69	58	73	77	38
Jellyfish	9	16				
Other invertebrates	12,932	4,939	2,250	5,427	3,479	2,763

1. Only 15 of 30 stations were completed in Plateau Deep East in 2020.

Attachment A

Biomass estimates

Mean biomass estimates from the surveys for the last 10 years for *C. gunnari* have ranged from approximately 1,400 to 53,000 t, with 2025 being ~19,700 t (Figure 2). *C. gunnari* biomass estimates had a survey strata with a single large haul which lead to multi-modal bootstap outputs. This haul was removed from the biomass estimate and the bootstraps rerun. At just over ############ tonnes, the mean biomass estimate for *D. eleginoides* in 2025 was slightly ############ than in the previous year.
Among the managed bycatch species, the biomass estimates for *C. rhinoceratus* and *Macrourus* spp. showed a slight increase in biomass (Figure 3). Meanwhile, *L. squamifrons* biomass estimates exhibited a decrease in relation to the previous year. For the *Bathyraja* species, biomass estimates were found to be slightly higher than those of 2024 (Figure 4).

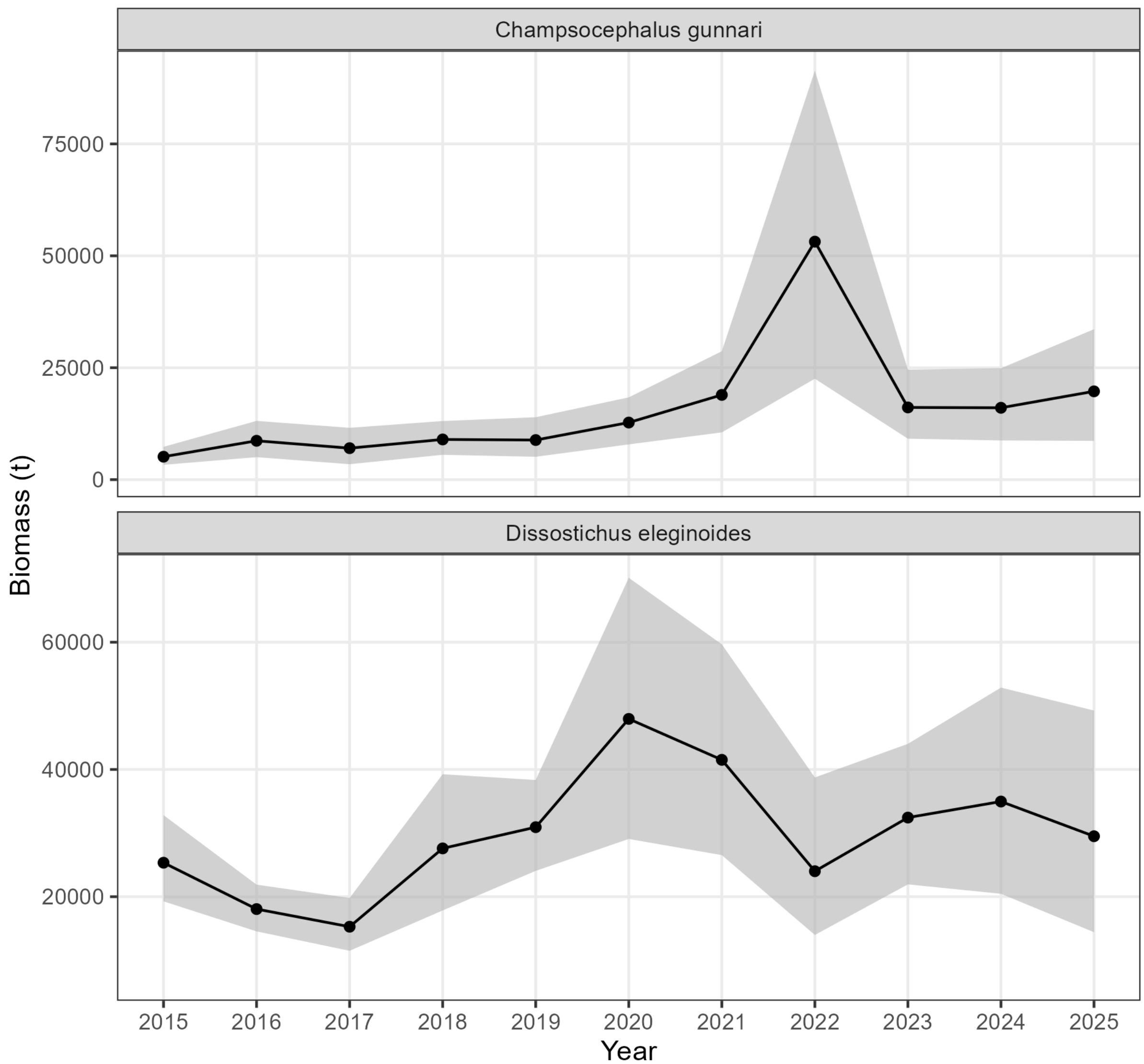

Figure 2: Biomass estimates (tonnes, mean and 95% CIs) for target fish species for the last 10 surveys.

Attachment A

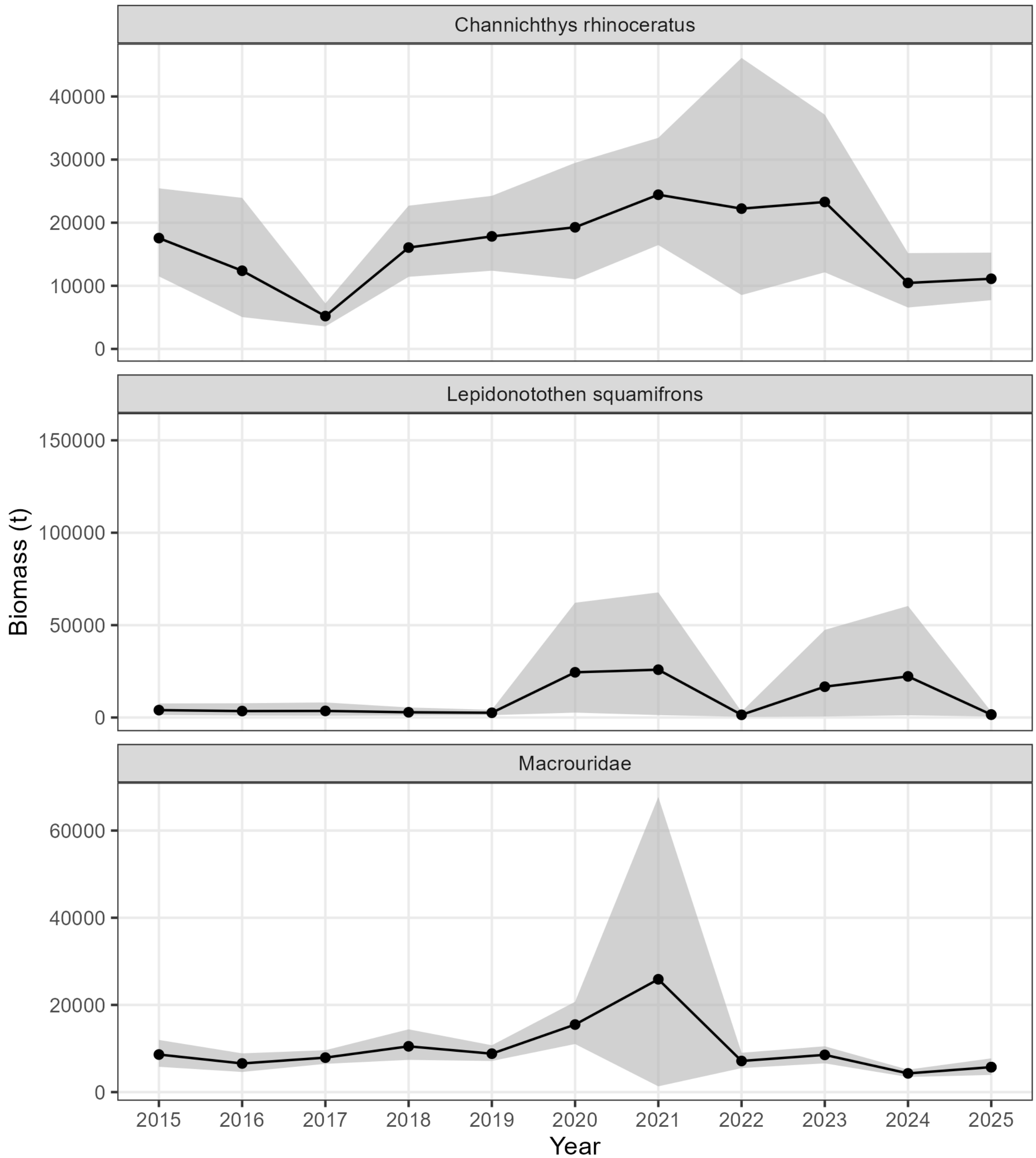

Figure 3: Biomass estimates (tonnes, mean and 95% CIs) for managed fish by-catch species for the last 10 surveys.

Attachment A

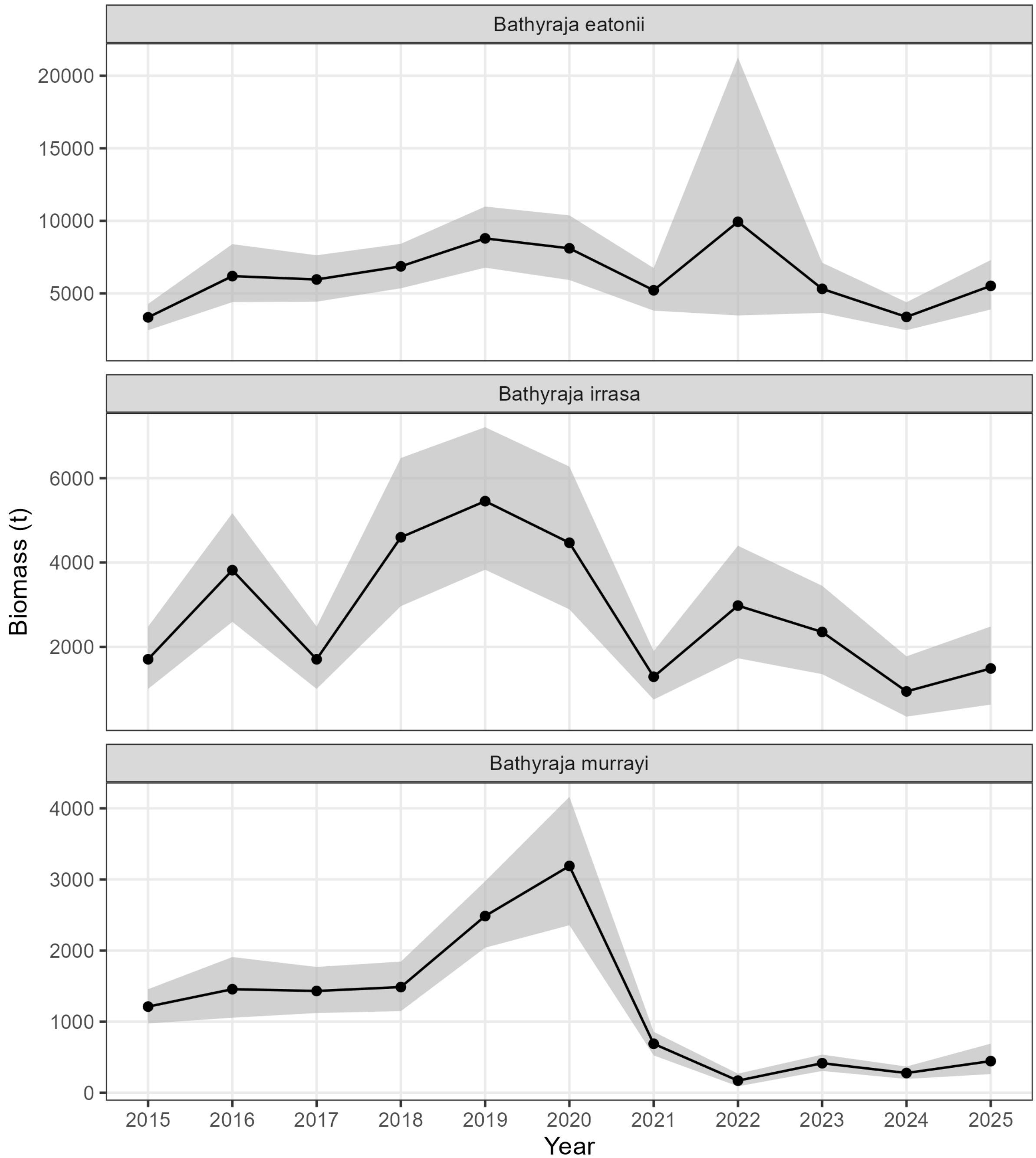

Figure 4: Biomass estimates (tonnes, mean and 95% CIs) for skate species for the last 10 surveys.

Biological data

A total of 16,362 fish were measured during the 2025 survey (Table 6). Otoliths were taken from 2 species, namely *Dissostichus eleginoides* and *Lepidonotothen squamifrons*.

Table 6: Number of length measurements and otoliths taken by species in the survey.

Species	Lengths	Otoliths
Fish		
Channichthys rhinoceratus	4,888	0
Champsocephalus gunnari	4,884	0
Dissostichus eleginoides	3,711	622
Macrourus caml	1,409	0
Lepidonotothen squamifrons	1,006	105
Macrourus holotrachys	11	0
Macrourus sp.	2	0
Amblyraja taaf	2	0
Skates		
Bathyraja eatonii	288	0
Bathyraja murrayi	134	0
Bathyraja irrasa	27	0
Total	16,362	727

The sex of 10,655 fish was recorded (Table 7, for species where >10 were seen in the survey) and gonad maturity examined for most of these (Table 8). Gonad maturity of bony fish was assessed on a scale of 1-6 and skates 1-3, with mature gonads represented in both fish and skates by stage 3. Most fish were found to be immature. The majority of female and male *D. eleginoides* were found to be at stage 1 and 2. Most *C. gunnari*, *C. rhinoceratus*, *L. squamifrons* and *M. caml* were found at stages 1 to 3, although lower numbers of later stages were observed for other bony fish assessed. *Bathyraja murrayi*, were found in all 3 stages, with the majority being immature. *B. etonii* individuals were primarily immature, with all stages observed for males, and only stages 2 and 3 observed for females. *B. irrasa* females were only observed at stage 2, with males at stage 1 and 3.

Attachment A

Table 7: Number of each sex identified for species where >10 were seen in the survey. F = female, M = male, J = Juvenile, U = unable to be determined

Species	F	M	J/U	Total
Fish				
Dissostichus eleginoides	1,799	1,679	1	3,479
Channichthys rhinoceratus	1,552	1,019	72	2,643
Champsocephalus gunnari	957	934	40	1,931
Macrourus caml	721	507	79	1,307
Lepidonotothen squamifrons	428	374	29	831
Macrourus holotrachys	7	3	1	11
Skates				
Bathyraja eatonii	121	167		288
Bathyraja murrayi	67	66	1	134
Bathyraja irrasa	17	10		27
Total	5,669	4,759	223	10,651

Attachment A

Table 8: Maturity stage (by sex) found in species where >20 individuals were examined for gonad maturity in the survey. Stage 3 represent mature gonads (blue numbers) in scales for both fish and skates. Staged counts will not always add to the count of fish that are sexed (N), as not all fish that are sexed are able to be staged (e.g. juveniles).

	Females							Males						
		Stage							Stage					
Species	N	1	2	3	4	5	6	N	1	2	3	4	5	6
Fish[1]														
Dissostichus eleginoides	1,799	1,779	19					1,679	1,195	484				
Channichthys rhinoceratus	1,552	329	659	368	144	48	3	1,019	299	438	271	3	7	
Champsocephalus gunnari	957	150	755	52				934	223	670	41			
Macrourus caml	721	386	232	98	2	2		507	166	139	174	1	27	
Lepidonotothen squamifrons	428	318	70	38	1			374	266	100	6		2	
Skates[2]														
Bathyraja eatonii	121		6	6				167	12	59	96			
Bathyraja murrayi	67	1	2	1				66	25	11	29			
Bathyraja irrasa	17			2				10	3		7			

1: Maturity scale for fish: 1 Immature, 2 Maturing or resting, 3 Developing, 4 Gravid (females) or Ripe (males), 5 Spent, 6 Resting

2: Maturity scale for skates: 1 Immature, 2 Maturing, 3 Mature

Tagging

A total of 231 *D. eleginoides* were tagged during the survey in 2025, distributed across survey strata.

Attachment A

ACKNOWLEDGEMENTS

We are grateful to Austral Fisheries and Australian Longline for providing research support necessary to undertake this survey at sea, to the observers, Tim Hall (AFMA) and Dawie Potgieter (CapMarine).

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A preliminary assessment for mackerel icefish (*Champsocephalus gunnari*) in Division 58.5.2, based on results from the 2025 random stratified trawl survey

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Recommendations

We recommend the catch limits in Conservation Measure 42-02 be set at 1 429 t in the 2025/26 season and 1 126 t in the 2026/27 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 2025. 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 2025 survey showed a large 3+ cohort in the population and a high biomass. Based on the Grym implementation, catches of 1 429 t in the 2025/26 season and 1 126 t in the 2026/27 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 2025 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 in 2025/26 and 2026/27 seasons.

Methods

2025 survey

The design of the survey conducted in 2025 used the same principles as previous surveys in Division 58.5.2 (Coghlan *et al.* 2025). 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. Station locations and catches are detailed in Coghlan *et al.* (2025) with density estimates ranging from 0 – 116 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. Work undertaken as part of the krill management strategy (SC-CAMLR-38 Table 1, para 3.34) re-implementing the Generalized Yield Model 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 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_∞ of 559.1 mm, a 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 monitored.

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).

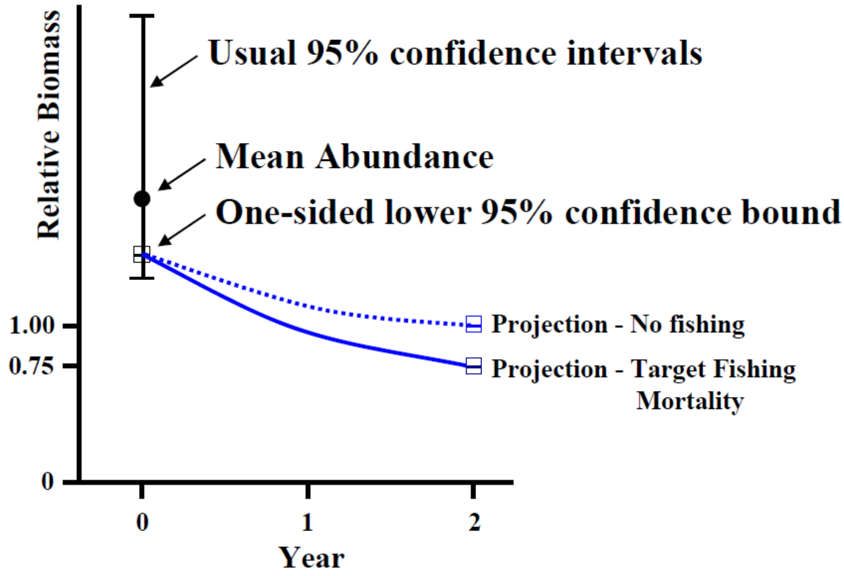

Figure 1. Decision rule for determining yield for mackerel icefish in year 1 and 2 after a survey (from Constable *et al.* 2005).

Few fish in the mackerel icefish population in Division 58.5.2 survive beyond age 4, with a drop in abundance between 3+ and 4+ cohorts 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 3+ cohort dominated the 2025 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 2025 random stratified trawl survey in Division 58.5.2.

	Mixture Components			
	1 (1+)	2 (2+)	3 (3+)	4 (4+)
Mean length (mm)	168	263	338	386
SD (mm)	13	16	18	20
Intercept of CV	8.3			
Slope of CV	0.03			
Total density ($n.km^{-2}$)	73	494	3517	37
SD ($n.km^{-2}$)	58	119	793	77
Sum of observed densities	4156			
Sum of expected densities	4121			

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 2023, 2024 and 2025 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 2023 is the same as 3+ cohort observed in 2024.

Year	Month	Overall Density		Cohort Density			
		Expected	Observed	1+	2+	3+	4+
2023	March	4670	4680	292.3	539.7	1843.2	2004.5
2024	March	23155	23221	2331	20339	226	260
2025	March	4121	4156	73	494	3517	37

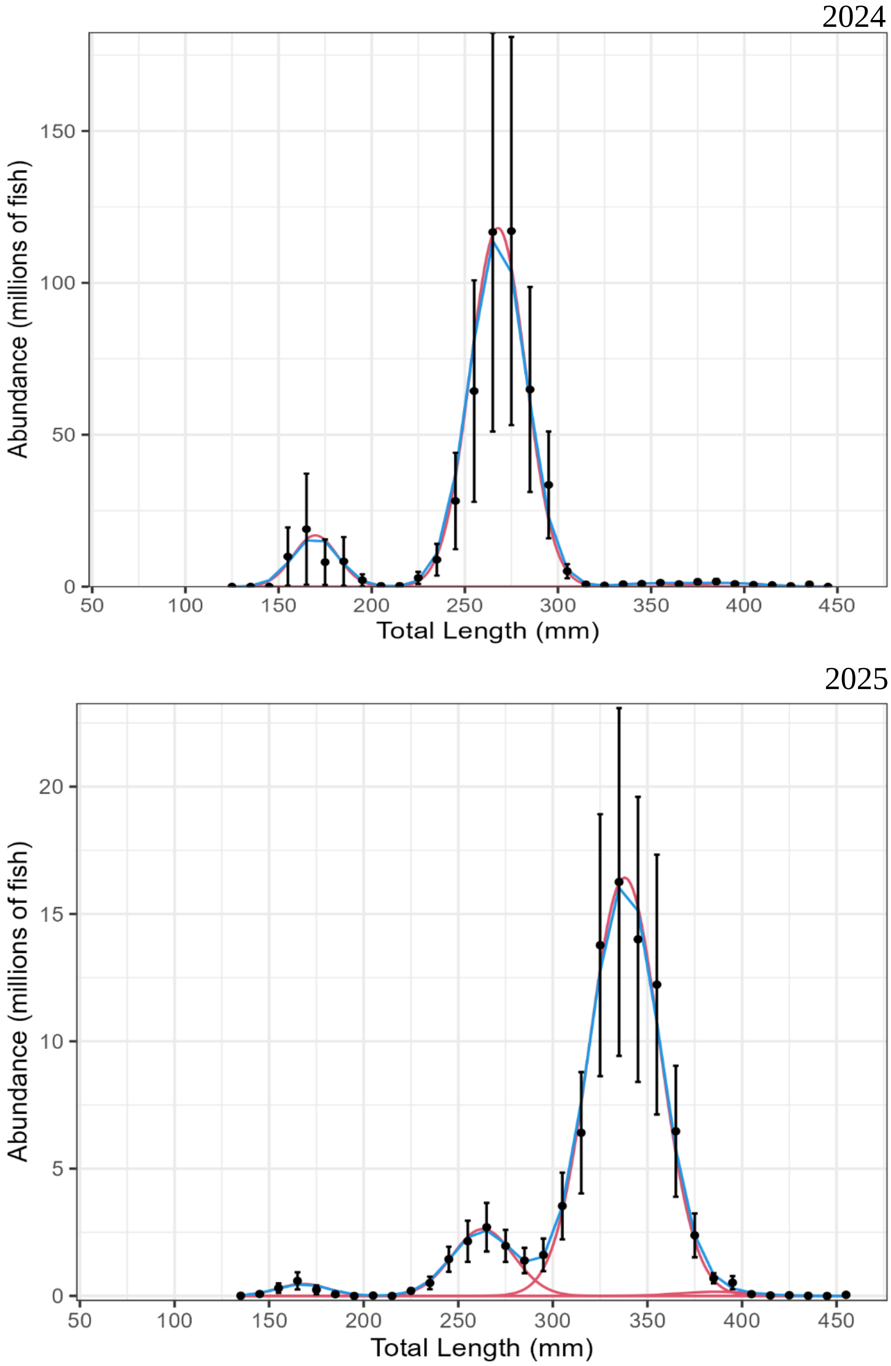

Figure 2. Observed and estimated length densities using CMIX for mackerel icefish in the surveys from March 2024 (upper panel) and March 2025 (lower panel). Shown are observed mean abundances at length (black circles, ± SE), fitted total abundances at length (blue lines), and fitted abundances at length for the different components (red lines).

Weight-at-length relationship

The weight-at-length relationship was re-estimated based on 4 772 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 2024 and 2025 in Division 58.5.2.

Model	Parameter	
	a	*b*
2024	3.406E-09	3.090
2025	2.842E-09	3.123

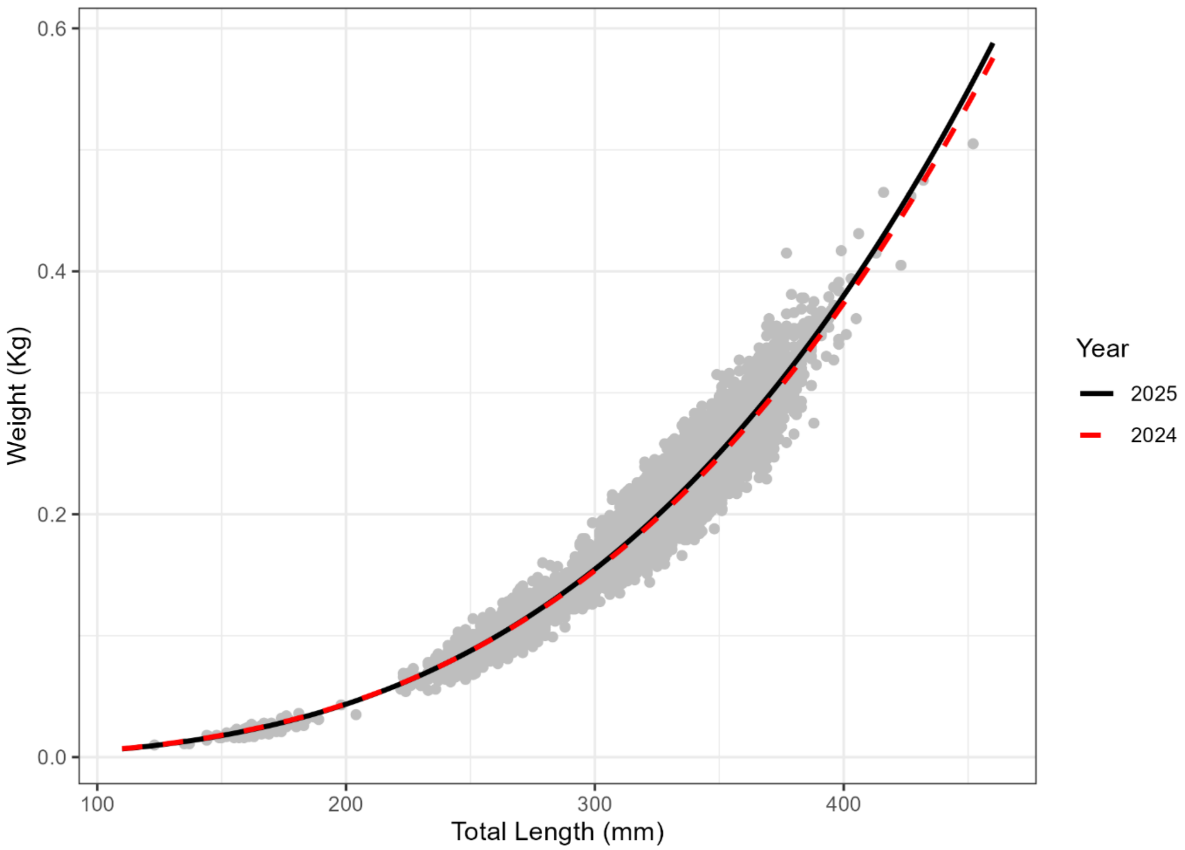

Figure 3. Weight-at-length data for mackerel icefish sampled during the 2025 random stratified trawl survey in Division 58.5.2 (grey dots) with fitted non-linear least squares regression (solid black line), and fitted regression to the 2024 survey (dashed red line, Maschette *et al*. 2024).

Using the estimated weight-at-length relationship for 2025, the contribution of each age class to the overall biomass present during the survey was estimated, indicating that fish up to 3+ constituted around 98.52% of the biomass present across the three icefish strata (Table 4).

Table 4. Proportion of mackerel icefish biomass at age in the 2025 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+	168	73	0.025	0.22
2+	263	494	0.103	5.92
3+	338	3517	0.225	92.38
4+	386	37	0.340	1.48

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 2025 survey showed a slightly higher mean biomass, and a similar lower one-sided 95% confidence interval biomass as 2024 (Appendix 1, Figure B.2).

Table 5. Abundance (tonnes) of mackerel icefish in Division 58.5.2 estimated by bootstrapping hauls from the 2025 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	15 127	5 710	5 393	26 726	6 645
Plateau SE	3 111	1 376	970	6 138	1 179
Plateau W	1 488	578	694	2 706	760
Pooled	19 726	6 491	8 663	33 598	10 049

The stock projection used the proportion of overall biomass made up by the 1+, 2+ and 3+ cohorts (98.52%, Table 4). This means that 9 901 t of the overall 10 049 t lower 95% CI (Table 5) was used in the Grym projection. The Grym projection indicated that catches of 1 429 t in the 2025/26 season and 1 126 t in the 2026/27 season satisfy the CCAMLR decision rules depending on the growth curve used (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, using the parameters shown in Table B.2.

Initial biomass estimate (t)	**Target fishing mortality rate (yr^{-1})**	**Catch after survey**	**Yield (tonnes)**	
			2025/26	**2026/27**
9 901	0.1447	0	1429	1126

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 (see also Maschette *et al*. 2024) 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 2025 survey showed a large 3+ 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 2024 assessment as a 2+ cohort. As in previous years, this preliminary assessment removes the 4+ cohort as it is unlikely that it will be available to the fishery in the coming years and only uses the 1+ to 3+ cohorts in the forward projections.

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 1 429 t in the 2025/26 season and 1 126 t in the 2026/27 season satisfy the CCAMLR decision rules. We recommend that catch limits be set for the 2025/26 and 2026/27 seasons based on this assessment, and a revised assessment be conducted based on survey data collected in 2026 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.

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Appendix 1: Diagnostic Information for 2024 *Champsocephalus gunnari* preliminary assessment

Diagnostics

During the 2018 Working Group of Statistics, Assessments and Modelling (WG-SAM) the working group agreed to the standard diagnostic examples presented in Maschette et al. (2018) for future Mackerel Icefish (*Champsocephalus gunnari*) Assessments presented to WG-FSA. Here we present the diagnostic information for the assessment presented in the main text.

Survey information:

1. Haul data - Location (map with bubbles) and catch and CPUE (table) including strata.
2. Haul by haul CPUE (kg/km^2) column chart including strata.
3. Number of fish measured and weighed from the survey used in the assessment.
4. Time series of length frequency distribution.

Assessment:

5. Distribution plot of the bootstrap runs.
6. Survey biomass time series plot (Estimates of biomass with confidence intervals and lower one-sided 95th percentile).
7. CMIX plots
8. Code used for conducting calculations and assessment.
9. Table of parameters used and their source.
10. Previous lower 95th stock assessment projection vs survey estimated time series.

Appendix A Survey Diagnostics

Diagnostic A1: Haul data

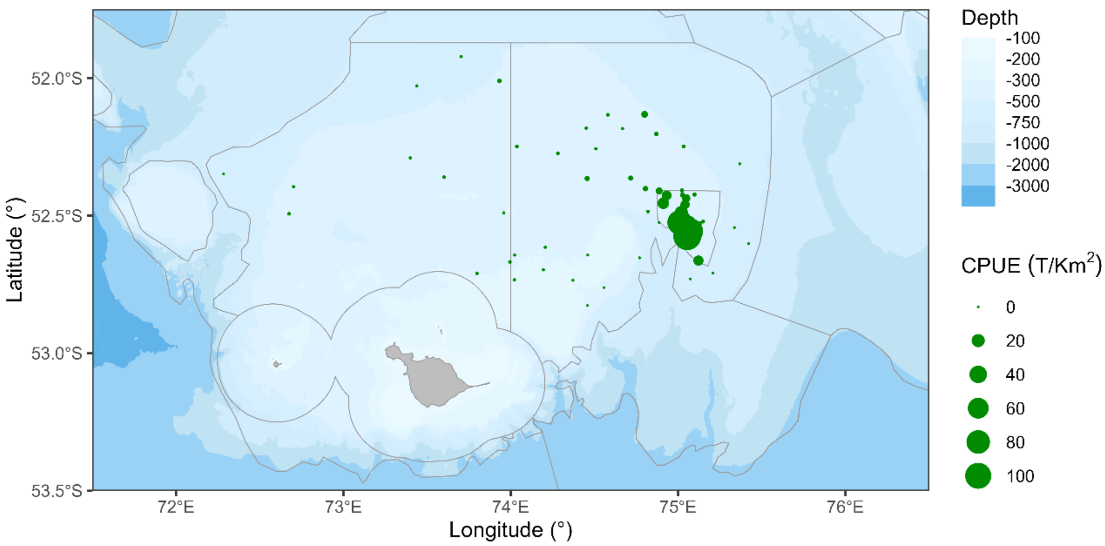

Figure A.1: Catch rates (t/km2) in the 2025 RSTS for mackerel icefish (Champsocephalus gunnari) in Division 58.5.2

Table A.1: Haul details from the 2025 Random Stratified Trawl Survey mackerel icefish (Champsocephalus gunnari) in Division 58.5.2.

Haul	Strata	Catch Weight (Kg)	CPUE (T/Km2)
16	Plateau West	32.77	0.62
17	Plateau West	4.06	0.07
18	Plateau West	2.84	0.05
27	Plateau West	0.00	0.00
28	Plateau West	7.66	0.14
30	Plateau West	3.42	0.05
31	Plateau West	3.03	0.05
32	Plateau West	6.92	0.12
34	Plateau Southeast	10.57	0.20
35	Plateau Southeast	10.59	0.18
36	Plateau Southeast	65.32	1.09
37	Plateau Southeast	2.91	0.05
38	Plateau Southeast	4.83	0.09
39	Plateau Southeast	8.16	0.15
40	Plateau Southeast	1.61	0.03
41	Plateau Southeast	171.42	2.86
42	Plateau Southeast	29.47	0.55
43	Plateau Southeast	14.83	0.26
44	Plateau Southeast	22.87	0.40
49	Plateau Southeast	0.00	0.00
52	Plateau West	6.46	0.12
53	Plateau Southeast	1.45	0.02
58	Plateau Southeast	5.28	0.09
59	Plateau West	8.51	0.16
61	Plateau West	3.41	0.06
62	Plateau Southeast	2.81	0.05
66	Plateau Southeast	0.00	0.00
67	Plateau Southeast	0.85	0.01
68	Plateau Southeast	2.45	0.04

Haul	Strata	Catch Weight (Kg)	CPUE (T/Km2)
69	Plateau Southeast	0.26	0.00
74	Plateau Southeast	50.16	0.95
75	Plateau Southeast	73.01	1.29
76	Gunnari Ridge	176.64	3.13
77	Gunnari Ridge	519.64	9.22
78	Gunnari Ridge	793.71	14.09
79	Gunnari Ridge	5.08	0.07
81	Gunnari Ridge	637.76	10.06
85	Plateau Southeast	0.29	0.00
86	Gunnari Ridge	1,097.20	19.48
87	Gunnari Ridge	435.15	7.92
88	Gunnari Ridge	311.08	5.52
89	Gunnari Ridge	62.09	1.03
90	Gunnari Ridge	22.35	0.37
91	Plateau Southeast	7.04	0.13
92	Gunnari Ridge	0.00	0.00
93	Gunnari Ridge	5,010.78	89.00
94	Gunnari Ridge	1,918.32	41.93
95	Gunnari Ridge	12.21	0.20
102	Plateau Southeast	0.00	0.00
103	Plateau Southeast	0.00	0.00
104	Plateau Southeast	0.00	0.00
105	Plateau Southeast	0.26	0.00
106	Plateau Southeast	0.48	0.01
108	Gunnari Ridge	0.00	0.00
109	Gunnari Ridge	6,531.13	116.00
110	Gunnari Ridge	17.75	0.29
111	Gunnari Ridge	6,014.00	98.79

Diagnostic A2: Haul catch per unit effort

```
ggplot(dat, aes(x=Area.Name, y=cpue_tkm2,fill=Area.Name,group=reorder(Haul,-cpue_t
km2)))+
  geom_col(position="dodge")+ scale_fill_discrete(guide="none")+
  labs(x="Strata", y=expression(CPUE~(t/km^{2})))
```

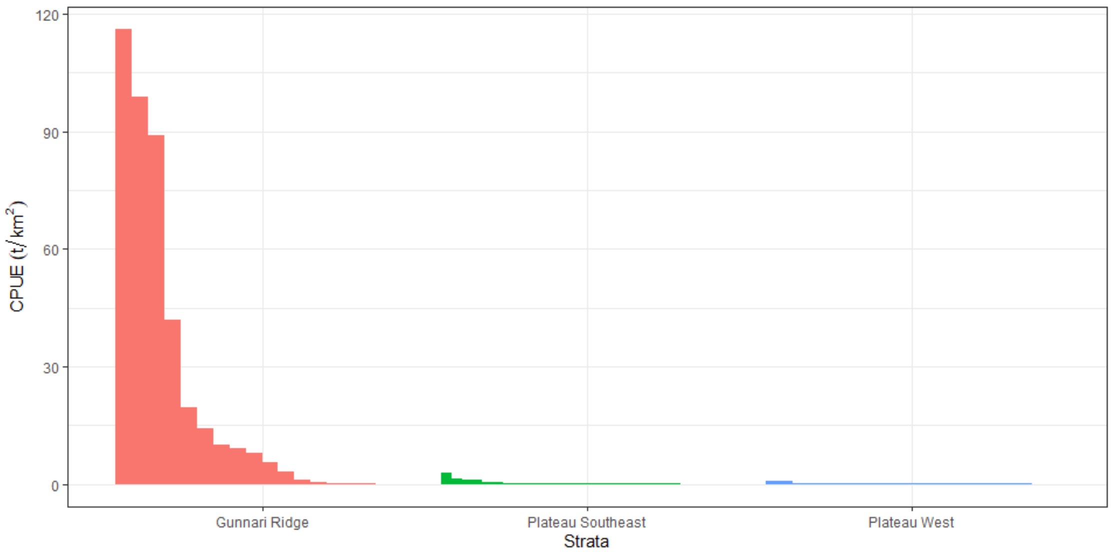

Figure A.2: Catch rate (t/km^2) by haul within strata in the 2025 Random Stratified Trawl Survey for mackerel icefish (Champsocephalus gunnari) in Division 58.5.2.

Diagnostic A3: Number of fish measured and weighed from the survey used in the assessment.

During the survey the length weight data from 4 772 fish caught were available and used.

Diagnostic A4: Time series of length frequency distribution

```
len<-length %>% filter(Year >= max(Year)-4) %>%  group_by(Strata,Year,Bins) %>% su
mmarise(Dens= mean(Density))

## `summarise()` has grouped output by 'Strata', 'Year'. You can override using
## the `.groups` argument.

ggplot(dat=len, aes(x=Bins, y=Dens)) + geom_col(width=10) +
  facet_grid(Year~Strata, scale="free_y") +
  labs(y=expression(Numbers/km^{2}), x="Length (mm)")+
  theme_bw()
```

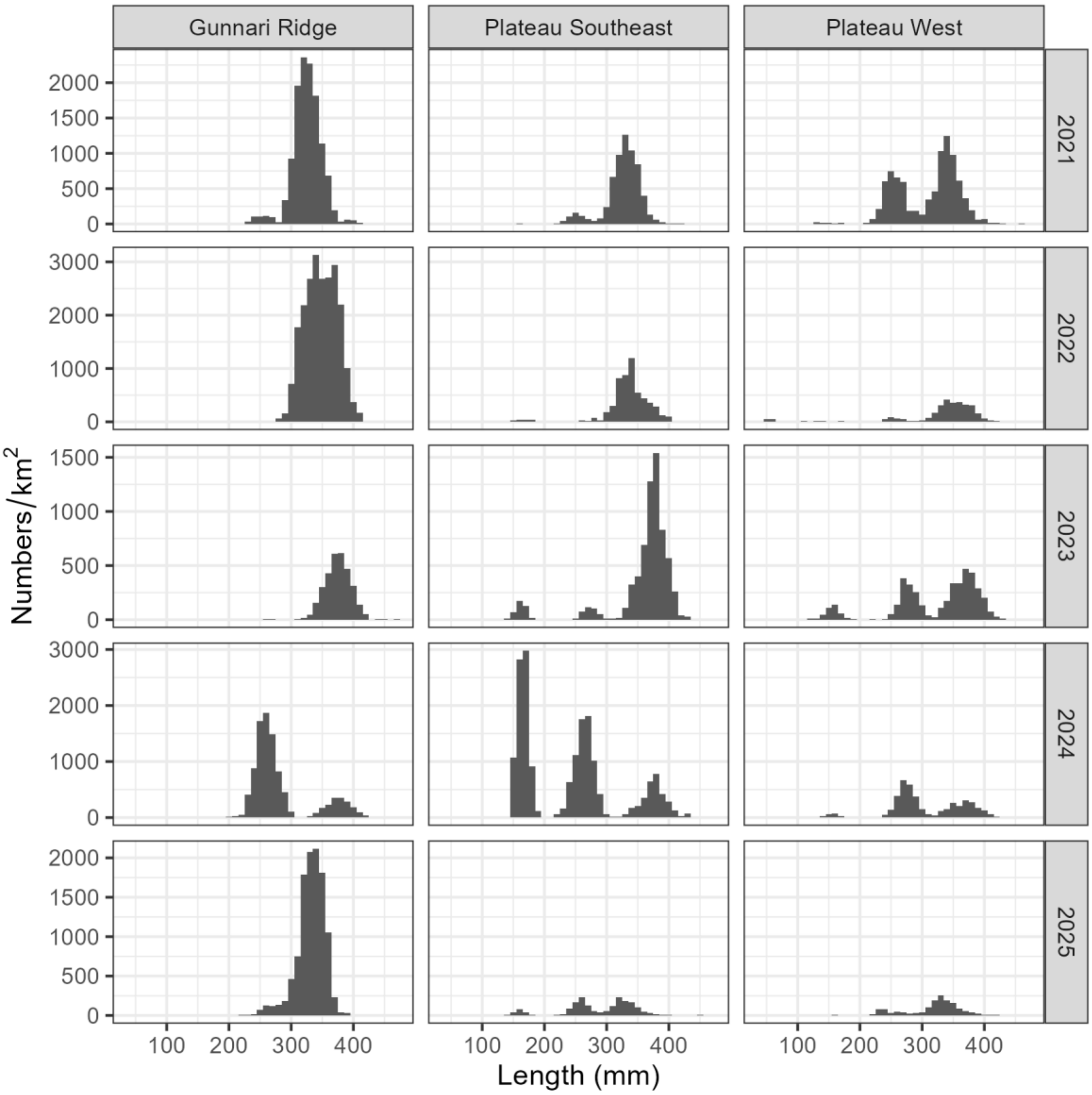

Figure A.3: Fish length distribution by strata in the 2025 Random Stratified Trawl Survey for mackerel icefish (Champsocephalus gunnari) in Division 58.5.2.

Appendix B Assessment Diagnostics

Diagnostic B1: Distribution of bootstrap run

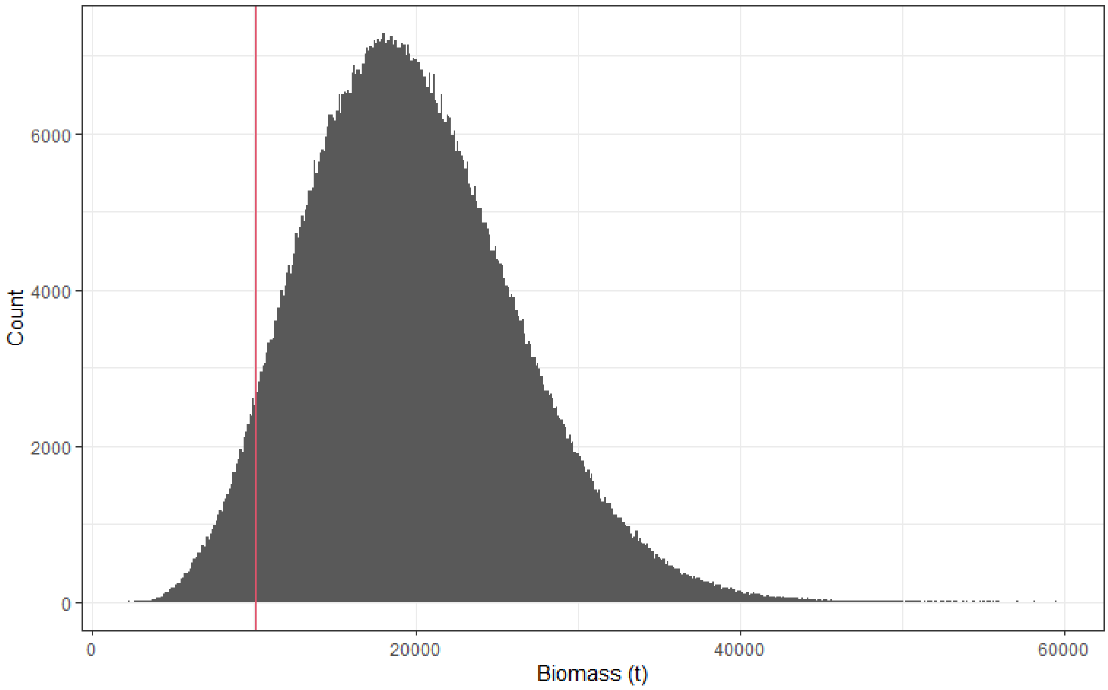

Figure B.1.1: Distribution of bootstrapped biomass estimates for 2025 mackerel icefish (Champsocephalus gunnari) in Division 58.5.2 after removal of one large haul in stratum Plateau SE with lower one-sided 95th confidence bound (red).

Diagnostic B2: Survey biomass time series

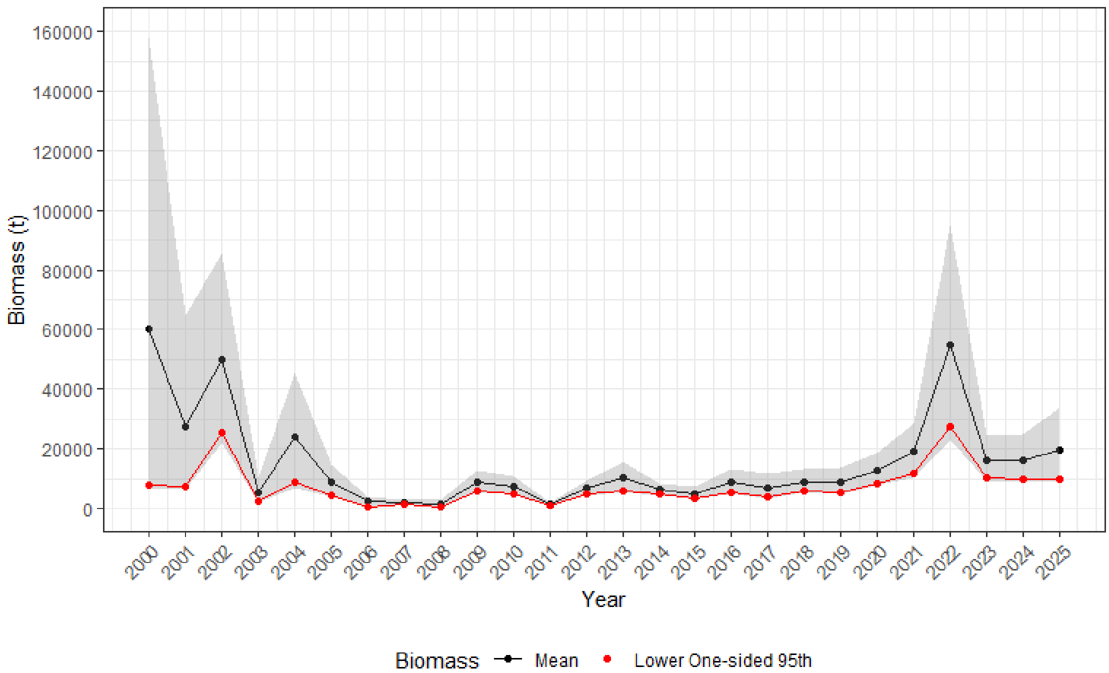

Figure B.2: Time series of estimated biomass for mackerel icefish (Champsocephalus gunnari) in Division 58.5.2 with mean (black) and lower one-sided 95th confidence bound (red).

Diagnostic B3: Length Cohorts

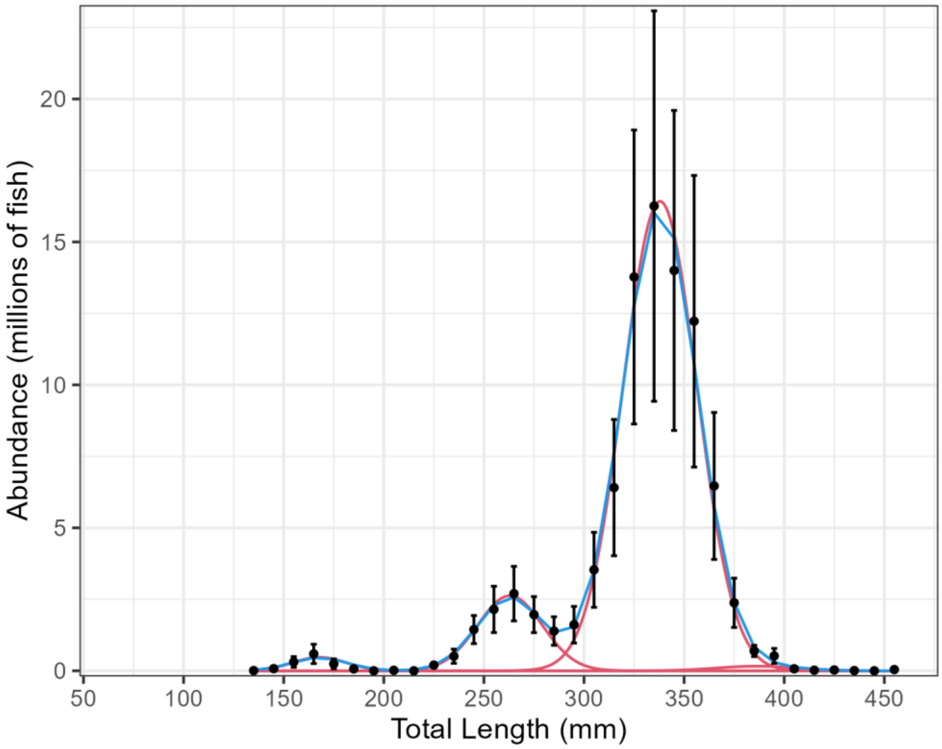

Figure B.3: Observed and estimated length densities using CMIX for mackerel icefish in the 2025 Random Stratified Trawl Survey. Shown are observed mean abundances at length (black circles, +SE), fitted total abundances at length (blue line), and fitted abundances at length for the different components (red lines).

Diagnostic B4: CMIX Code for calculations

```
path<- "./CMIX/"
data<-paste0(path,'ANI_2025.csv')
input<-paste0(path,'2025CMIXinput.dat')
output<-paste0(path,'2025CMIXoutput.dat')
buildCMIX(infilepath=input, hauldatafilepath = data,
          components=matrix(c(140,180,250,300,310,360,365, 430), ncol=2, byrow=TRU
E),
          linearlyRelated = TRUE, upLinIntr= 10, upLinSlope=0.03, stepLenSlope=0.0
01, stValIntr=3, stValSlope=0.01, skipLeadInts=0,stoppingCrit=1E-10)

###Run CMIX
runCMIX(input, output)
resultsCMIX(output)
```

Length to weight parameters

```
library(CMIX)
library(plotrix)

LW<-read.csv(paste0(Data.dir,'ANI Assessment LW.csv'))
W<-LW$Weight/1000 #gram to kg
L<-LW$TL
model<-nls(W~a*L^b,start=c(a=1.3E-9,b=3.26),  trace=TRUE)
summary(model)
```

Components biomass

```
ANI<-resultsCMIX(output)                                          ## Get results fro
m CMIX Output file.
Comps<-round(ANI$components$mean, digits = 0)                     ## Get mean length
from each component.
CompsWeight<-round(predict(model,data.frame(L=Comps)), digits=5)## Use Length Weig
ht Model to predict weight of each components mean length.
NDens<-round(ANI$components$totaldensity, digits = 5)            ## Get the total d
ensity of each component from CMIX output.
WDens<-round(CompsWeight*NDens, digits=5)                         ## Multiply the de
nsity of each component by its calculated weight.
TotalWeight<-round(sum(WDens), digits=5)                          ## Sum the weights
of all components together.
Proportion<-round(WDens/TotalWeight*100, digits=2)               ## Calculate the p
roportion of biomass each components makes up.
Components<-as.data.frame(cbind(Comps,CompsWeight,NDens,WDens,Proportion))
## Proportion of Biomass made up by the 1+ - 3+ components.
ProportionOfBiomass<-sum(Components[1:4,"Proportion of Biomass"])
ProportionOfBiomass
```

Bootstrap

Table B.1: Bootstrap summary from 2025 mackerel Icefish (Champsocephalus gunnari) assessment in Division 58.5.2

Area	Mean	SE	LowerCL	UpperCL	OneSided95
Gunnari Ridge	8,456.3	3,362.5	2,841.9	15,487.1	3,525.2
Plateau Southeast	5,500.7	2,232.0	1,935.2	10,381.0	2,306.6
Plateau West	2,093.8	791.5	715.8	3,630.5	905.0
Plateau strata	13,957.1	4,109.3	6,812.3	22,663.0	7,755.9
All Strata	16,050.9	4,178.6	8,756.7	24,883.6	9,731.1

Grym Running Code

The Icefish assessment aims to determine the fishing mortality and hence a total allowable catch that yields a prescribed two year escapement relative to an unfished population.

```
library(Grym)
library(CMIX)
```

Data

Set the year of the assessment

```
year <- 2025
```

Define the reference date that sets the start of the season

```
SeasonDate <- as.Date(paste0(year-1,"-12-01"))
```

Define the survey date and the corresponding time increments, and the observed relative numbers and biomass. Note that GYM averages over the start and end of the survey increment, so to match we provide two survey increments.

Load the cmix data and biomass data.

```
path<- "./CMIX/"
output<-paste0(path,year,'CMIXoutput.dat')
ANI<-resultsCMIX(output)

boot_summ<-read.csv(file="./Output data/Bootstrap_summary.csv")

SurveyDate <- as.Date("2025-03-20")
surveyI <- as.numeric(SurveyDate-SeasonDate)+c(0,1)
surveyN <- c(round(ANI$components$totaldensity, digits = 5)[1:3],rep
(0,7))
surveyB <- boot_summ$OneSided95[5]
```

Adjust the survey biomass for proportion of 0-3 year olds

```
surveyB <- surveyB*0.9852
```

Check the numbers.

```
SurveyDate
[1] "2025-03-20"
surveyI
[1] 109 110
surveyN
 [1]   73.1428  493.5510 3516.9800    0.0000    0.0000    0.0000
0.0000
 [8]    0.0000    0.0000    0.0000
surveyB
[1] 9900.584
```

Define the spawning date and the corresponding time increments.

```
#SpawnDate <- as.Date("2022-11-30")
spawnI <- c(364,365) #as.numeric(SpawnDate-SeasonDate) + c(0,1)
```

Projection

The current strategy is to project forward two years for a range of potential fishing mortalities, and then subsequently determine the mortality that yields the target relative escapement by inverse interpolation.

The population is projected forward for two years with a range of potential fishing mortalities to determine the mortality that yields the target escapement by inverse interpolation.

Determine target Escapement

The above process is easily extended to automate the search for the fishing mortality that yields a target escapement.

The function *icefishRE* uses *uniroot* to determine the fishing mortality that produces a desired relative escapement and then projects forward for both zero fishing and the target fishing mortality. The arguments are

- `target` - target escapement
- `M` - natural mortality
- `F` - range of fishing mortalities to search
- `Catch` - remaining catch allocation after survey in survey year
- `surveyN` - relative numbers in each cohort from survey
- `surveyB` - biomass estimate from survey
- `surveyI` - increments (ie days of season) over which survey is taken
- `spawnI` - increments (ie days of season) over which spawning numbers and biomass are estimated
- `VB.t0`, `VB.K`, `VB.Linf` - parameters for von Bertalanffy length at age relation
- `WLa`, `WLb` - parameters for allometric weight at length relation
- `age.selectivity` - age selectivity function.
- `Fmax` - maximum allowable fishing mortality
- `tol` - error tolerance for `uniroot`

```
icefishRE <- function(target,M,F,
                      Catch=0,surveyN,surveyB,surveyI,spawnI,
                      VB.t0=0.06671238,VB.K=0.36842178,VB.Linf=489.7
3706791,
                      WLa=1.150e-10,WLb=3.275,
                      age.selectivity=approxfun(c(0,2.5,3),c(0,0,1),
rule=2),
                      Fmax=2.5,tol=1.0E-6) {

  ## Extract summary data from a projection
  annualSummary <- function(yr,F,pr) {
  }

  ## Ensure 0 included in test fishing mortalities
  F <- sort(union(0,F))

  ## Two year projections of 10 age classes with a daily time step
  n.yr <- 2
  n.inc <- 365
  Ages <- 1:10
  Days <- seq(0,1,length=n.inc+1)

  ## Matrices of ages, lengths and weights for each day and age clas
s
  as <- outer(Days,Ages,FUN="+")
  ls <- vonBertalanffyAL(as,t0=VB.t0,K=VB.K,Linf=VB.Linf)
  ws <- powerLW(ls,a=WLa,b=WLb)

  ## Constant intra-annual natural mortality
  ms <- matrix(1,n.inc+1,length(Ages))
  Ms <- ctrapz(ms,1/n.inc)
  MMs <- M*Ms
```

```
  ## Within year fishing mortality is determined by an age based sel
ectivity
  fs <- array(age.selectivity(as),dim(as))
  Fs <- ctrapz(fs,1/n.inc)

  ### Projection to end of year from survey data
  if(Catch>0) {
    ## Adjust with-year fishing mortality for post-survey Catch
    fs0 <- rep.int(c(0,1),c(max(surveyI),n.inc+1-max(surveyI)))
    fs0 <- fs0/trapz(fs0,1/n.inc)*fs
    Fs0 <- ctrapz(fs0,1/n.inc)
    pr0 <- projectC(ws,MMs,Fs0,fs0,Catch,surveyN,surveyI,surveyB,sur
veyI,yield=1,Fmax=Fmax)
    if(pr0$F==Fmax) warning("Target catch could not be recovered")
  } else {
    pr0 <- project(ws,MMs,0,0,surveyN,surveyI,surveyB,surveyI,yield=
0)
    pr0$F <- 0
  }
  ## Numbers at end of survey year - no recruitment
  N0Survey <- advance(pr0$N)
  SSB0 <- meanStock(pr0$B,1,spawnI)

  ## Project ahead and return final SSB
  ProjectSSB <- function(F,target=0) {
    ## Project and compute SSB for final year
    N0 <- N0Survey
    for(yr in seq_len(n.yr)) {
      pr <- project(ws,MMs,F*Fs,F*fs,N0,yield=0)
      N0 <- advance(pr$N)
    }
    SSB <- meanStock(pr$B,1,spawnI)
    SSB-target

  }

  SSB1 <- ProjectSSB(0)
  r <- uniroot(ProjectSSB,F,target=target*SSB1)
  F <- c(0,r$root)

  ## Annual cohort totals
  d <- data.frame(Year=c(rep(0:n.yr,length(F))),F=0,Nf=0,Bf=0,Y=0,SS
N=0,SSB=0,Bmon=0,Escapement=0)
  k <- 0

  ## Project forward for prescribed fishing mortalities.
  for(Fk in F) {
    ## Reset to survey year
    pr <- pr0
    d[k <- k+1,] <- data.frame(Year=0,F=pr$F,Nf=sum(final(pr$N)),Bf=
sum(final(pr$B)),Y=sum(pr$Y),
```

```
                          SSN=meanStock(pr$N,1,spawnI),SSB=SSB0
,Bmon=meanStock(pr$B,1,305),Escapement=1)
    for(yr in seq_len(n.yr)) {
      ## Project
      N0 <- advance(pr$N)
      pr <- project(ws,MMs,Fk*Fs,Fk*fs,N0,yield=1)
      SSB <- meanStock(pr$B,1,spawnI)
      BMon <- meanStock(pr$B,1,305)
      d[k <- k+1,] <- data.frame(Year=yr,F=Fk,Nf=sum(final(pr$N)),Bf
=sum(final(pr$B)),Yield=sum(pr$Y),
                            SSN=meanStock(pr$N,1,spawnI),SSB=SS
B,Bmon=BMon,Escapement=SSB/SSB0)
    }
  }
  d
}
```

No Remaining Allocation

Estimate the fishing mortality that gives 75% escapement after two years relative to unfished, assuming no catch allocation remains after the survey.

```
d <- icefishRE(target=0.75,M=0.4,F=c(0,0.5),Catch=0,surveyN,surveyB,
surveyI,spawnI,
               WLa=3.406e-09,WLb=3.090, VB.t0=0.06585126 ,VB.K=0.294
0745 ,VB.Linf=559.1367)
d$RelEscapement <- d$SSB/d$SSB[1:3]
```

Year	Fishing Mortality	Yield (tonnes)	Spawning Stock Biomass	Escapement	Relative Escapement
0	0.0000000	0.000	10,729.291	1.0000000	1.0000000
1	0.0000000	0.000	10,317.222	0.9615940	1.0000000
2	0.0000000	0.000	8,839.482	0.8238644	1.0000000
0	0.0000000	0.000	10,729.291	1.0000000	1.0000000
1	0.1447365	1,429.315	8,940.341	0.8332648	0.8665454
2	0.1447365	1,125.541	6,629.604	0.6178976	0.7499992

The recommended TAC will be 1429 t in year 1 and 1126 t in year 2.

Diagnostic B5: Table of parameters used and their source.

Table B.2: Parameters used within the 2025 mackerel Icefish (Champsocephalus gunnari) assessment in Division 58.5.2.

Category	Parameter	Values	Source
Age Structure	Recruitment age	2 years	de la Mare et al. 1998
	Plus class accumulation	10 years	de la Mare et al. 1998
	Oldest age in initial structure	11 years	de la Mare et al. 1998
Initial population structure	Age class density	See tables 2,3 and 4	Estimated in this paper
	Biomass	9901	Estimated in this paper
	Date of estimate (survey)	20-Mar-25	
Natural Mortality	Mean Annual M	0.4	de la Mare et al. 1997
von Bertalanffy growth	t0	0.06	Maschette et al. 2024
	Linf	559.8 mm	Maschette et al. 2024
	k	0.29	Maschette et al. 2024
Weight at Length (kg, mm)	Weight-length parameter – A (kg)	2.482 x 10-09 kg	Estimated in this paper
	Weight-length parameter - B	3.123	Estimated in this paper
Maturity	Lm50 (set so that the status of the whole stock is being monitored)	0 mm	
	Range: 0 to full maturity	0 mm	
Fishery parameters	Age fully selected	3	de la Mare et al. 1998
	Age first selected	2.5	de la Mare et al. 1998
	Season	1 Dec – 30 Nov	CCAMLR Season
	Catch between survey and season (mt)	0	Fishery reports
Spawning Season	Set so that status of the stock is determined at the end of each year	30 Nov – 30 Nov	
Simulation specifications	Number of runs in simulation	1	
Individual trial specifications	Years to remove initial age structure	0	
	Reference Start Date in year	1-Dec	
	Increments in year	365	
	Years to project stock in simulation	2	
	Reasonable upper bound for Annual F	5	
	Tolerance for finding F in each year	0.000001	

Diagnostic B6: Previous lower 95th stock assessment projection vs survey estimated time series.

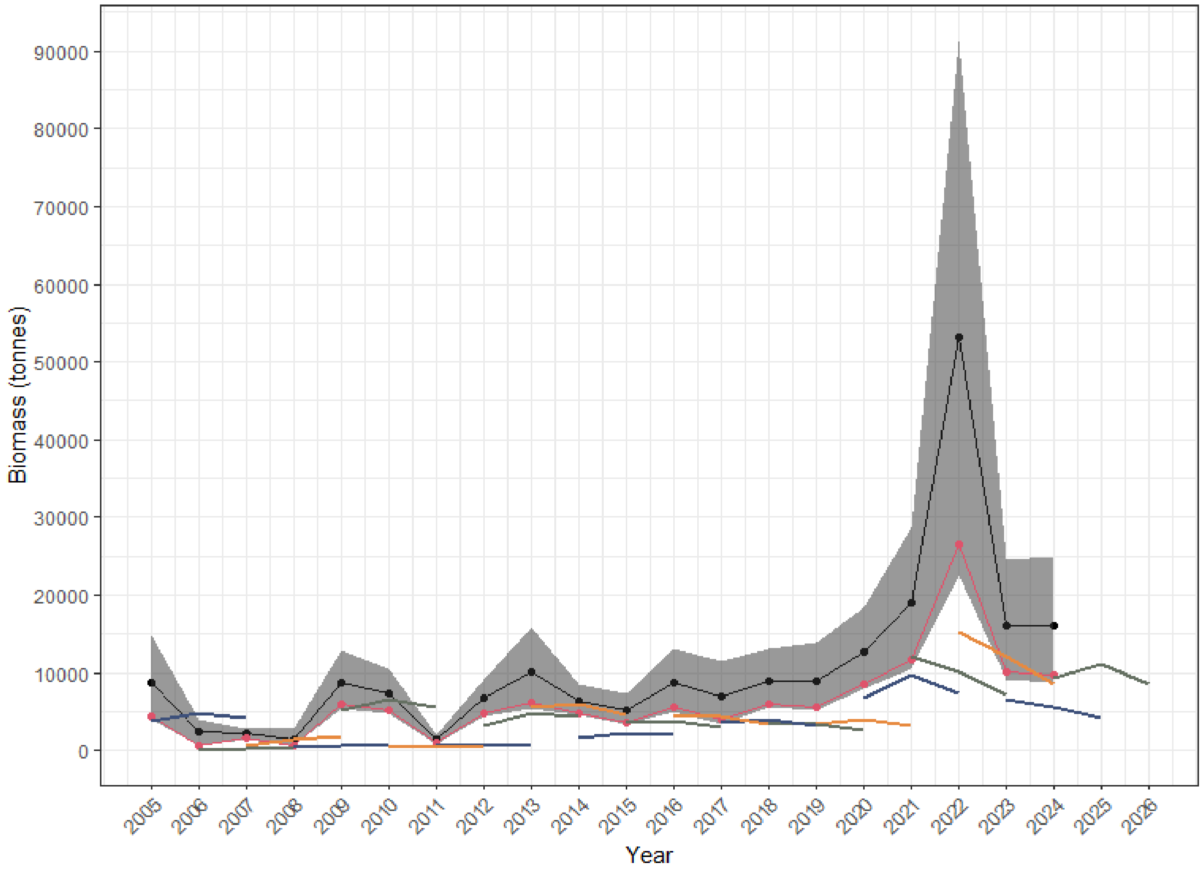

Figure B.4: Mean time series of estimated biomass (including 4+ and 5+ cohorts; black) with confidence intervals (grey) and lower one-sided 95th confidence bound (red), and stock assessment projections (excluding 4+ and 5+ cohorts; colors) that were used to determine catch limits for mackerel icefish (Champsocephalus gunnari) in Division 58.5.2.

```
sessionInfo()
R version 4.4.1 (2024-06-14 ucrt)
Platform: x86_64-w64-mingw32/x64
Running under: Windows 10 x64 (build 19045)

Matrix products: default


locale:
[1] LC_COLLATE=English_Australia.utf8  LC_CTYPE=English_Australia.utf8
[3] LC_MONETARY=English_Australia.utf8 LC_NUMERIC=C
[5] LC_TIME=English_Australia.utf8

time zone: Australia/Hobart
tzcode source: internal

attached base packages:
[1] stats     graphics  grDevices utils     datasets  methods   base
```

```
other attached packages:
 [1] CMIX_0.5.7      Grym_0.1.2      flextable_0.9.7 knitr_1.48
 [5] lubridate_1.9.3 forcats_1.0.0   stringr_1.5.1   dplyr_1.1.4
 [9] purrr_1.0.2     readr_2.1.5     tidyr_1.3.1     tibble_3.2.1
[13] ggplot2_3.5.1   tidyverse_2.0.0
```

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
Recruitment: 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.	

Attachment M

Revising management at Macquarie Island

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Outline

- Project to explore new management approaches for MI
- Current approach (history, implementation, issues)
- Outline of alternative approaches
- Simple example
- Management objectives and practical constraints
- Process timeline

Current management approach for Macq. Is.

- Last decade or so we've applied "The CCAMLR Rule"
- Approach used in CCAMLR for major toothfish fisheries
- Constant catch strategy based on future projections
- Idea:
  1. Obtain estimate of current spawning stock biomass
  2. Find catch that leaves 50% of unifished level after 35 yrs
  3. Find catch where it's above 20% unfished 90% of the time
  4. Pick the lowest of those two for your TAC
- Original context: do a survey, get biomass, calculate TAC
- Current context: complex integrated assessment, calculate TAC

Issues with CCAMLR rule

- The logic behind it doesn't apply anymore
- It's never been *fully* simulation tested
- How sensible is projecting 35 years into the future?
- Driven by complicated assessments
- When things change it's hard to nail down exactly why
- There are no constraints on TAC variability
- Assessment issues at HIMI are amplified by the rule

Idea on alternative to CCAMLR approach

- At Macca the tagging data are the main information source
- Almost all abundance information coming from these data
- Idea is to use tag data in simplified model:
  - Aggregate across release size, sex
  - Perhaps even location (non-spatial model)
  - Estimate “average” exploitation rates/abundance
- These are then input to suite of candidate HCRs

Operating Models & data generation

- OM structure: time/sex/age/size/age population
- Time-varying options for:
  - Growth, natural mortality, recruitment
  - Migration
  - Selectivity, spatial fishing pattern
- Data generation options:
  - Mark-recapture data
  - Length composition, age-given-length data
  - Abundance indices

Tagging estimators

- Two variants:
  1. Non-spatial Brownie model
  2. Spatially structured Brownie model
- Both require an assumed value of natural mortality
- Model 1: annual harvest rates
- Model 2: annual spatial harvest rates and migration
- Model 2 closer to assessment tagging module

Motivational MSE example

- Assume basically same life-history as Macca toothfish
- Spatial: two-area model with 10% annual migration
- Fishery: longline, one fleet in each region
- Initial conditions: unfished equilibrium
- Fishing: 20 yrs @ implied effort yielding 50% depletion
- Tagging: 10 yrs after fishing starts @ 3 t.p.t
- MP implementation:
  1. Start after 20 years of fishing
  2. TAC decision every 5 years
  3. Projections go 20 years into the future

Candidate Management Procedures

- General form:

$$TAC_{y+1} = TAC_y \times \text{HCR multiplier}$$

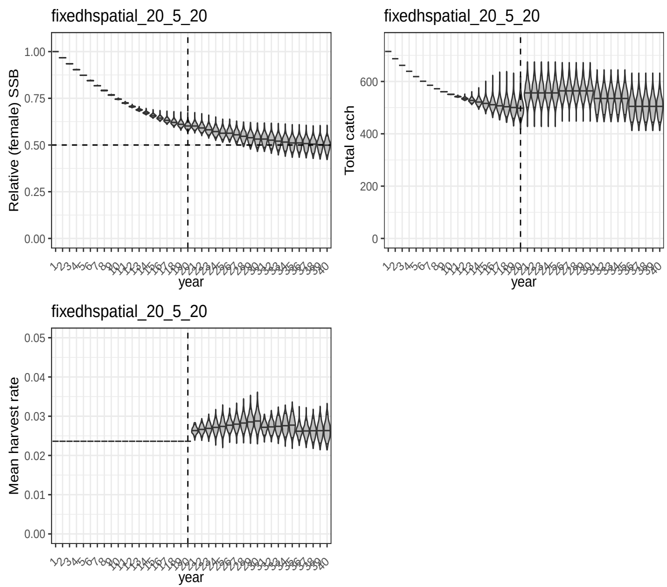
- **MP1**:
  - Non-spatial tagging estimator
  - Input: 4 year moving average harvest rate
  - HCR: ratio of target and average harvest rate
- **MP2**:
  - Spatial tagging estimator
  - Input: spatially-averaged 4 year MA harvest rate
  - HCR: same as for **MP1**

Objectives, tuning & operational parameters

- Objective: SSB depletion 50% prob. 0.5 after 20 yrs
- Tuning: target harvest rate key HCR tuning parameter
- TAC frequency: every 5 years
- TAC constraints: symmetric maximum change of 20%
- Performance statistics:
  1. SSB depletion during MP implementation period
  2. Average TAC following MP implementation
  3. AAV (TAC variation percentage)
  4. Probability maximum TAC change constraint triggered

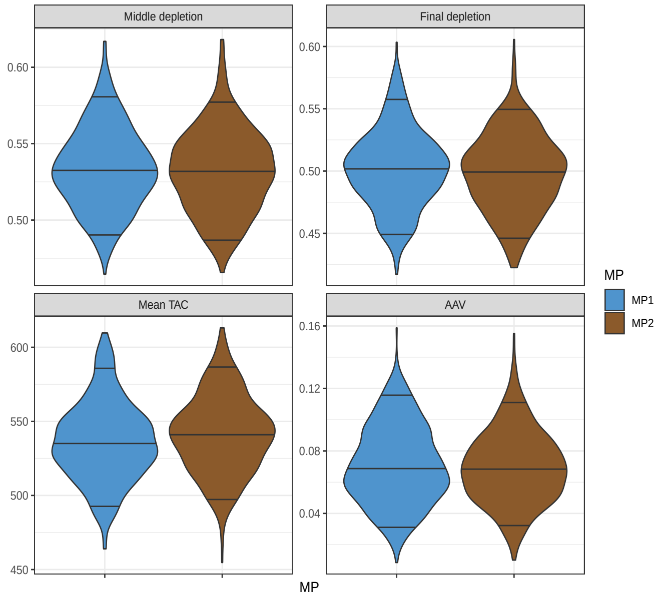
Simple MSE summary: time-series

- Relative SSB (TL), TAC (TR), and harvest rate (BL)
- Violins are median with 95% probability interval



Simple MSE summary: performance statistics

- Intermediate and final SSB depletion (top)
- Mean TAC (left) and AAV (right)
- Max. TAC change probability: **MP1** is 0.015, **MP2** is 0.011



Simple MSE summary

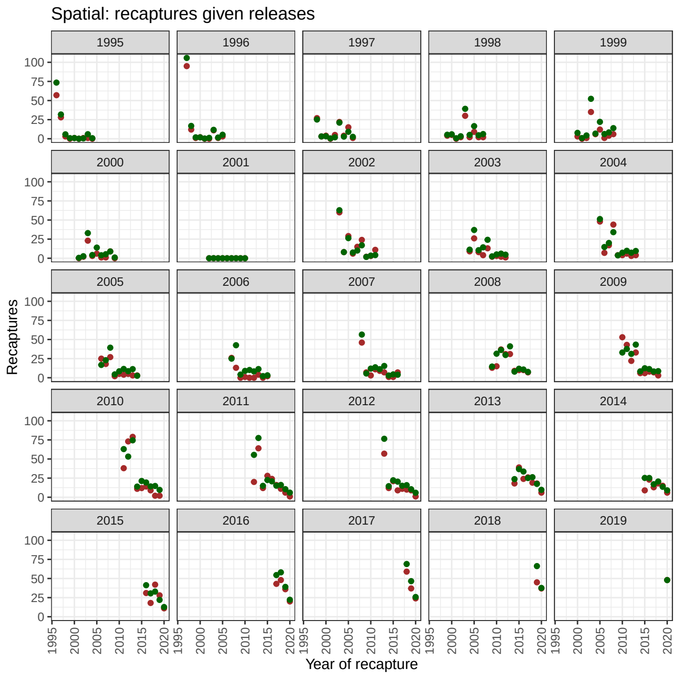
- **MP2** *marginally* better than **MP1**
- Spatially balanced population and fishery reasons why
- Takeaways:
    1. Even simple tag-driven MPs can do the job
    2. Data variability, population+fishery *very* Macca-like
    3. TAC variation well below 20%
- Don't need complexity of assessment to get what we need
- Very likely don't have to change TAC every two years...

Fitting models to actual Macca data

- Further tested potential of simpler tag models
- Fitted spatial model to Macca data *ca.* 2021
- Questions:
  1. Can we fit to the actual data?
  2. How well do we replicate mean harvest rates?
  3. How well do we replicate migration estimates?

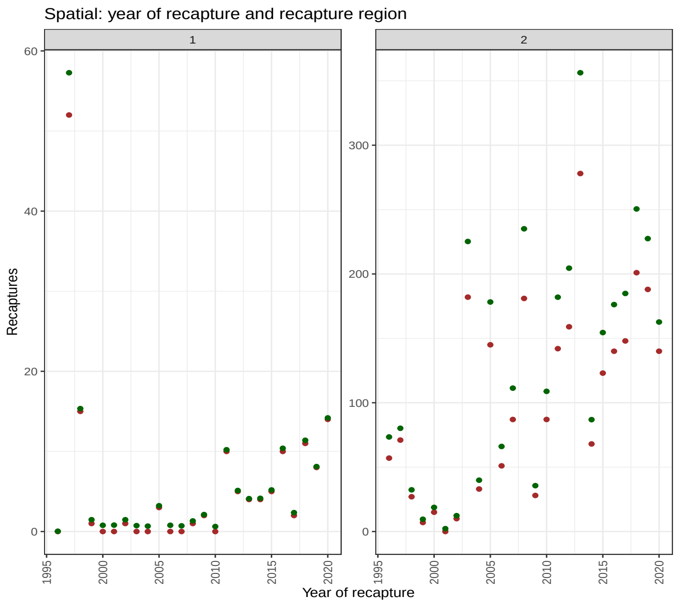
Fits to Macca tag data I

- Each panel release year and subsequent recaptures



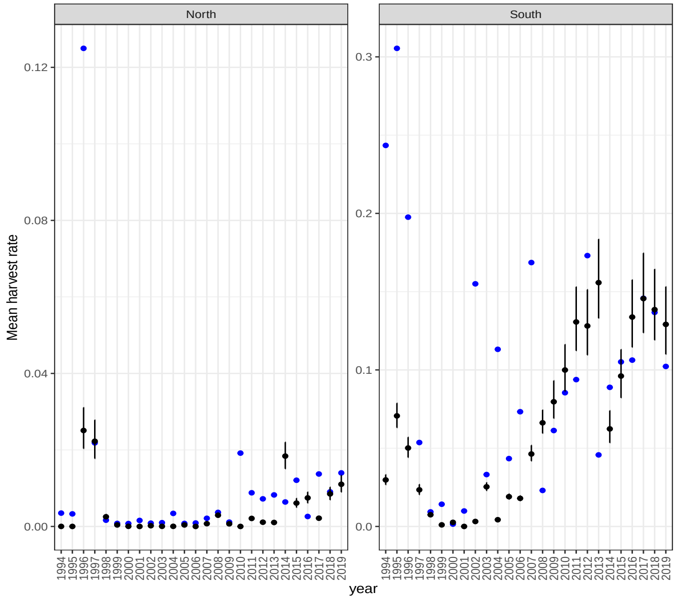
Fits to Macca tag data II

- Each panel is recapture region



Mean harvest rate comparison

- Northern (left) & Southern (regions)
- Black stock assessment, blue simpler MP estimator



MP model fitting summary

- Fits to data as well as assessment does
- Early (trawl) harvest rates over-estimated
- Recent (longline) estimates fairly good
- Migration *slightly* lower than assessment
- Overall - getting recent averages about the same
- Initial exploration looks promising

Summary of initial MSE work

- Exploration of tag driven MPs looks encouraging
- Candidate MPs could:
  1. Reasonably estimate average harvest rate
  2. Use as input in simplified HCR
  3. Attain current “objective” over meaningful time-frame
  4. No obvious need for 2 year TACs
  5. Also kept AAV clearly below 20%
- Obviously lots more work to do...
- ...but no reason to assume approach couldn’t work

Practical next steps

- Discuss management objectives & time-frames
- Range of uncertainties required in OMs
- Robustness tests (e.g. climate change, operational)
- Discuss operational practicalities:
  1. Form and magnitude of TAC change constraints
  2. Frequency of TAC change (currently 2 year cycle)
  3. Timing and role of stock assessment
  4. Exceptional Circumstances

Current timeline

- This SARAG: first look at general idea
- Looking for extensive feedback
- Integrate feedback, come with candidate MPs @ SARAG 2025
- Ideally look to adopt new MP for Macquarie Island

Thank You

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Attachment N

Table 1. Bycatch workplan action items, extracted from the Bycatch Strategy (Table 2).

Action	Responsibility	Timing
ERA Updates		
HIMIF ERA to be updated as proposed.[1]	CSIRO	2027
AFMA and SARAG to review re-assessment triggers and indicators	AFMA, SARAG	Every 4 years since assessment • 2029 for MITF • 2032 for HIMIF[2]
Recommendation from previous ERAs (see above)		
Continue short term (annual) and long term (e.g. inter-annual, trends) monitoring of protected species interactions, including for albatross species.	AFMA, SARAG	Ongoing/continuous AFMA to continue monitoring interactions, to continue providing annual updates papers to SARAG, and consider advice as appropriate.
General Bycatch Species		
Data Collection and Improvement Ongoing data collection on bycatch species to continue to support formal stock assessments and assess risk for bycatch species. Explore additional observer training on species identification. Collect data for deep-sea biomass estimates of macrouids (outside of RSTS).	Industry, AAD, AFMA (including observer team)	Ongoing/continuous • Ongoing data collection by industry and observers • Consider observer training as needs arise
Bycatch Limits Continue short term (annual) and long term (e.g. inter-annual, trends) monitoring of bycatch species catch against limits for each fishery. Consider the advice of SARAG on bycatch species risks and information, and make recommendations on appropriate management action as necessary.	AFMA	Annually • Monitor bycatch levels against limits each season • Consider risks and advice through SARAG each year
Bycatch trend analysis carried out for the MITF. Includes consideration of short term (annual) and long term (e.g. inter-annual) trends.	CSIRO	Annually , through SARAG

Updated assessments conducted for key bycatch species in the HIMIF.	AAD	To be updated in 2027/28 • Unicorn icefish (*Channichthys rhinoceratus*) • Grey rockcod (*Lepidonotothen squamifrons*) • Grenadiers *(Macrourus caml & M. whitsoni)* • Grenadiers (*M. halotrachys* & *M. carinatus*)
Skates and Rays		
Data Collection and Improvement Continue tagging of skates and rays, to support stock assessment and assess risk for these species. Explore options for more easily detected tag colours. Collect data for deep-sea biomass estimates of skates (outside of RSTS).	Industry, AAD, AFMA (including observer team)	Ongoing/continuous
Stock Assessment Update to the preliminary stock assessment conducted, and presented/provided to SARAG and AFMA. Consider stock assessment results and include in consideration of bycatch TACs as appropriate.	AAD and AFMA (with the advice of SARAG and SouthMAC).	• Stock assessment to be presented in 2027, or as available • AFMA, with the advice of SARAG and SouthMAC, to consider and incorporate results in TACs as result become available.
Post release survival Additional presentation and publication to be provided to SARAG	AAD/UTAS	May 2026

[1] Note the MITF is not currently scheduled for reassessment, having been recently completed.

[2] Provided ERA is updated in 2027 as scheduled

Attachment O

ANTARCTIC FISHERIES FIVE YEAR STRATEGIC RESEARCH PLAN 2026 – 2030

The *Heard Island and McDonald Islands Fishery Management Plan 2002* and the *Macquarie Island Toothfish Fishery Management Plan 2006* both require that a five-year strategic research program be developed and implemented, to support assessment and management of the fisheries. The Management Plans also require that the five year strategic research program be reviewed annually. Due to Australia's involvement in CCAMLR Exploratory Fisheries, some research for these areas has also been included however this is not a comprehensive list.

To meet the Management Plan requirements, the Sub-Antarctic Resource Assessment Group (SARAG) and Sub-Antarctic Fisheries Management Advisory Committee (SouthMAC) will develop the Antarctic Fisheries Five Year Strategic Research Plan. The Plan identifies areas of priority research for Antarctic Fisheries for 2026 – 2030, and should be considered in conjunction with the Australian Antarctic Division (AAD) 5 year Southern Ocean Work Plan. The work under the Southern Ocean Work Plan will be funded through AAD core funding and industry through the Industry/FRDC Southern Ocean Industry Partnership Agreement.

The Antarctic Fisheries Five Year Strategic Research Plan includes research for the Heard Island and McDonald Islands (HIMI) Fishery, Macquarie Island Toothfish Fishery (MITF) and CCAMLR Exploratory fisheries. There is also a small component for toothfish fisheries within SIOFA and SPRFMO due to the interaction between HIMI and MITF (Item 13). The numbering is for ease of reference but does not reflect any order of priority.

SARAG and SouthMAC recognise that significant resources and funding will be required to complete all the items listed below. Given the current funding environment it is possible that not all of these will be completed within the five year timeframe. However, the Plan tries to present a picture of the level of research required to address issues in relation to the management of the fisheries.
The Antarctic Fisheries Five Year Strategic Research Plan should be read in conjunction with [AFMA's Strategic Research Plan 2023 – 2028].

	Heard Island & McDonald Islands	Priority	Funded?	2026	2027	2028	2029	2030
1.	Project: HIMI toothfish stock assessment Details: Includes whale depredation estimation, consideration of tagging data and approaches to integrate this, provision of a updated stock assessment, and additional relevant items from the HIMI Stock Assessment Technical Working Group workplan. Funding: Industry/FRDC IPA, AAD	High	Yes	X		X		X
2.	Project: CCAMLR MSE Details: Development and testing of CCAMLR MSE in relation to HIMI. Funding: AAD	High	Partially	X	X			
3	Project: HIMI Icefish Assessment Details: Annual stock assessment of icefish at HIMI Funding: FRDC IPA	High	Funded through to 2027	X	X	X	X	X
4.	Project: HIMI Bycatch Assessments Details: Development of a skate stock assessment, updates to assessments for both macrourid species, unicorn icefish, and grey rockcod Funding: FRDC IPA	High	Yes		X			
5.	Project: HIMI RSTS Details: Undertaking the RSTS, exploration of frequency and model-based indicators. Funding: Industry/FRDC IPA	High	Yes	X	X*	X*	X*	X*
6.	Project: HIMI Random Longline Survey Details: distribution of longline effort in line with AAD survey design Funding: Industry	High	Yes	X	X	X	X	X
7.	Project: HIMI Patagonian Toothfish Close Kin Mark Recapture Details: Exploration of viability for CKMR, estimated cost $1,400,000 Funding: Possibly sourced from Industry/FRDC IPA	Low	No				X	X

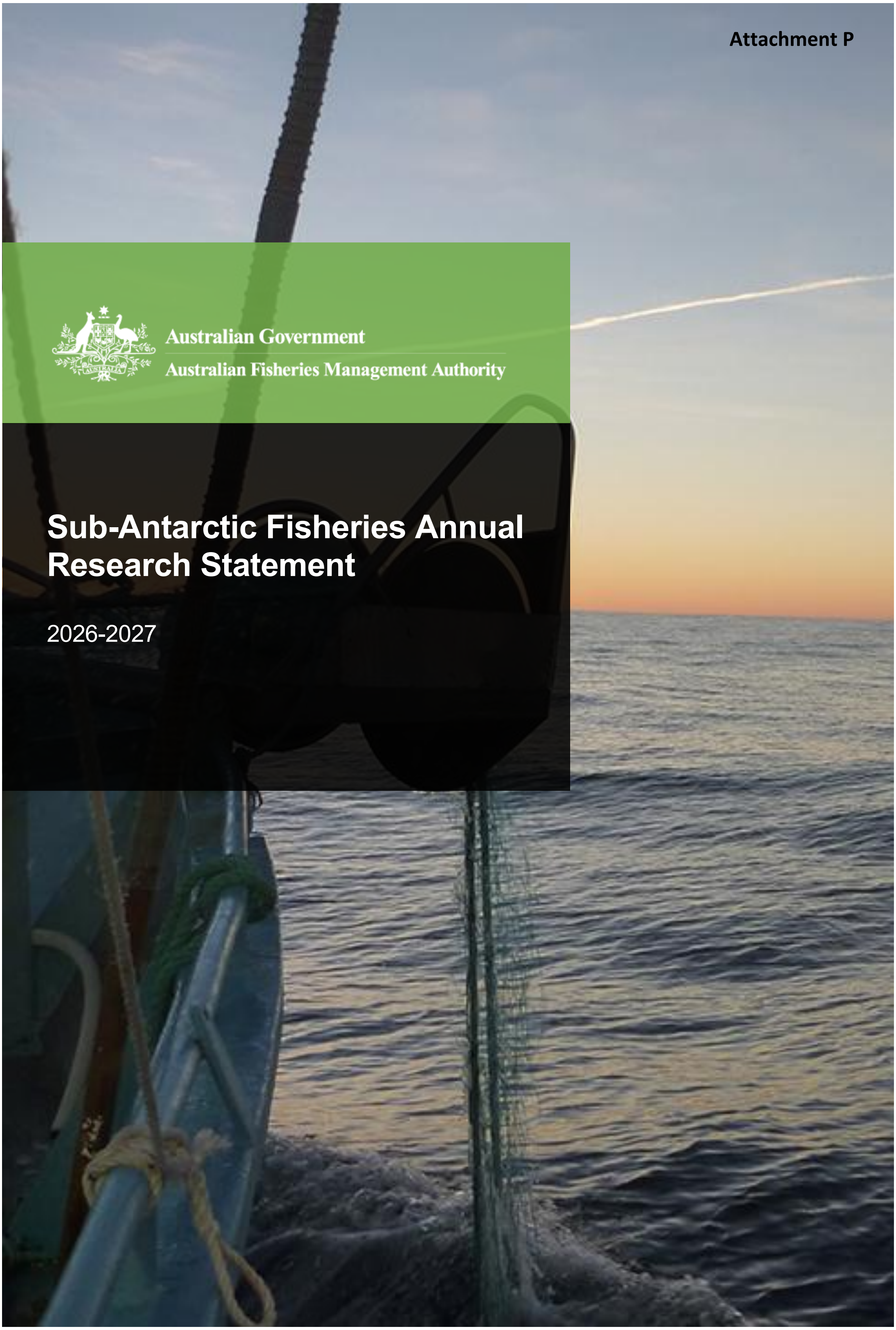
8.	Project: Ecology of the HIMI marine ecosystem Details: Specific outcomes and costs to be determined Funding: to be determined	Low	No					

*subject to results from exploration of RSTS frequency.

	Macquarie Island Toothfish fishery	Priority	2026	2027	2028	2029	2030
9.	Project: MITF toothfish stock assessment and management advice Details: running the toothfish stock assessment, updating bycatch analysis, providing TAC advice. Frequency to be determined following updated project results in 2026. Funding: CSIRO/Industry through AFMA levy base	High		x		x	
	CCAMLR Exploratory Fisheries						
10.	Project: Ecosystem impact of fishing in CCAMLR Details: Evaluation of impacts of fishing on marine ecosystems, discussion ongoing at CCAMLR Funding: Government	Medium					
11.	Project: Exploratory fisheries research Details: Includes annual research plans for East Antarctic and associated research plans, and relevant work for other exploratory fisheries Funding: Government/FRDC IPA	High	X	X	X	X	X
	Climate Change						
	Project: Climate change impacts on Sub-Antarctic fisheries Details: Research directions to be identified through the two HIMI and MITF workshop processes, timing also to be determined Funding: To be determined	High					
	Cross Fishery Research						

12.	Project: Southern Ocean Fisheries Electronic Monitoring Trial Details: Assessing the viability and capability of electronic monitoring for Southern Ocean Fisheries Funding: AFMA EM Program	High	X				
13.	Project: RFMO participation and activity. Details: Engagement at SIOFA and SPRFMO, work associated with exploratory fishing (including data collection and research plans) Funding: Industry/government	High	X	X	X	X	X

Attachment P



Australian Government
Australian Fisheries Management Authority

Sub-Antarctic Fisheries Annual Research Statement

2026-2027

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Fishery Annual Research Statement 2026-2027

AFMA funding in 2025-2026 (AFMA Research Committee (ARC))

Title	Objectives and component tasks	Evaluation		
		Total cost (approx. only)	Priority/rank	Feasibility
CURRENT RESEARCH UNDERWAY WITH ONGOING COMMITMENTS				
Stock assessment and MSE of the Macquarie Island toothfish fishery: 2025-2026	1. To provide an updated integrated stock assessment to the SARAG in the next scheduled assessment year (2025) 2. To provide the SARAG with updated MSE analyses of the suite of alternative managementy strategies initially explored in the previous project 3. To continue monitoring the stock through the mark-recapture program	$195,846 (2 year project: 2024/25 $117,378; 2025/26 $78,468)	Essential	High
NEW IDENTIFIED RESEARCH				
Stock assessment and management procedure (TAC recommendations) for the Macquarie Island toothfish fishery:	1. To provide an updated stock assessment to the SARAG in the next scheduled assessment year (2027) 2. To provide the SARAG with updated TAC recommendations, via application of the management proedure. 3. To continue monitoring the stock through the mark-recapture program	High (3 year project)	Essential	High

FRDC and AAD funding in 2025-26 (Industry Partnership Agreement (IPA))

Title	Objectives and component tasks	Evaluation		
		Total cost (approx. only)	Priority/rank	Feasibility
Current funded projects				
Investigating sources of variability in the Heard Island and McDonald Islands Patagonian Toothfish fishery (Project 2020-097**)**	Commercial in confidence	**$840,000**	Essential	High
Science to support Australia's Southern Ocean Fisheries 2024-2027 (Project 2023-173)	Commercial in confidence	**$2,612,000**	Essential	High
Metal Detector installation on Toothfish vessels to improve PIT tag recovery rates (Project 2023-066)	Commercial in confidence	**$78,619**	Medium	High
New identified research				

Additional Industry funded research in 2025/26

Title	Objectives and component tasks	Evaluation		
		Total cost (approx. only)	Priority/rank	Feasibility
Current funded projects				
HIMI Random Longline Survey	Undertake surveys to estimate the longline fishable abundance and biomass of Patagonian toothfish within HIMI	High (vessel time provided in-kind)	High	High
New identified research				

Evaluation key:

Cost	Priority categories	Feasibility categories
High: >$200,000	Essential	High
Medium: $100,000 - $200,000	High	Medium
Low: <$100,000	Medium	Low
	Low	