



Review and refinement of the harvest strategy for the Commonwealth Small Pelagic Fishery

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Executive Summary

This review of the Small Pelagic Fishery (SPF) Harvest Strategy (HS) was initiated in response to needs identified by the Australian Fisheries Management Authority (AFMA) and the Marine Stewardship Council (MSC). The AFMA identified that a review was needed to ensure that decision rules in the SPF HS were robust, scalable and responsive to changes in the fishery over time and met the requirements of the current Commonwealth Fisheries Harvest Strategy Policy (CFHSP). The MSC identified the need to establish decision rules in the SPF HS that reduce the exploitation rate as the biomass approaches the point at which recruitment is likely to be impaired. The project was funded directly by the SPF Industry Association (SPFIA) because maintaining MSC certification is critically important to the fishery as most of the catch is used to produce aquaculture feed that is used by aquaculture companies that are certified by the Aquaculture Stewardship Council, and which require their feed to come from fisheries that are certified by the MSC.

This project demonstrated that the SPF HS is consistent with the current CFHSP. Most importantly, the revised SPF HS (AFMA 2008 last revised 2024) now includes Harvest Control Rules that specify that the maximum exploitation rate applied to a stock is reduced linearly (i.e. using a hockey stick rule) if the spawning biomass falls below the Trigger Reference Point (B_{40}), and that targeted fishing ceases if the spawning biomass fishing falls below the Limit Reference Point (B_{20}). SPF RAG also recommended that the monthly catch limits (“move on rules”) that were previously in place in the SPF as a precautionary approach to reducing the potential for localised depletion should be removed.

In this project, we also updated key biological parameters for the three species targeted by the trawl sector (i.e., Jack Mackerel, Redbait and Blue Mackerel) using data collected since the last Management Strategy Evaluation (MSE) was undertaken by Smith et al. (2015). We then applied a simplified version of the model used in the previous MSE to recommend revisions to the Tier 1 exploitation rates for each species. These recommendations were supported by SPF RAG at a meeting held in October 2024 and will be considered the South East Management Advisory Committee (SEMAC) and AFMA Commission early in 2025.

Table of Contents

Executive Summary.....	1
Table of Contents.....	2
List of Figures	4
List of Tables	5
List of Appendices.....	7
Acknowledgements.....	8
Introduction	9
Background	9
Need for this review.....	10
Objectives.....	11
Additional objective	12
Approach.....	12
Methods.....	13
Consultation.....	13
Review.....	13
Blue Mackerel	13
Management Strategy Evaluation	14
Results.....	18
1. Evaluate the SPF Harvest Strategy against the current Commonwealth Harvest Strategy Policy.....	18
2. Review and where necessary revise the parameters used in the MSE using new information obtained since the study by Smith et al. (2015) was completed.	19
3. Establish robust estimates of age, growth, and maturity parameters for Blue Mackerel.	19
4. Undertake an MSE using updated parameters for each species.....	19
5. Identify revised maximum exploitation rates and maximum number of seasons at each tier for each species.	20
6. Evaluate the implications of results of DEPM surveys being applied to Tier 1 stocks approximately 6 years after a survey is completed rather than the 5 years tested by Smith et al. (2015).....	20

7. Identify and test reference points and decision rules that reduce the exploitation rate as the biomass approaches the point at which recruitment is likely to be impaired..	20
8. Establish a revised SPF HS that meets the requirements of the Commonwealth HSP and includes updated maximum exploitation rates and maximum number of seasons at each tier, and reference points and decision rules for reducing exploitation rates as the biomass approaches the point of recruitment impairment.	21
9. Evaluate the need for finer scale spatial management to address potential for localised depletion	22
Discussion.....	29
References	30

List of Figures

Figure 1. The sub-areas of the Commonwealth Small Pelagic Fishery (SPF).....	9
Figure 2. Harvest Control Rules for linearly reducing (i.e. using a hockey stick rule) the exploitation rates for each species at Tier 1 (Table 1) if the estimate of spawning biomass from the latest DEPM survey is below the proxy Trigger Reference Point of B_{40} and above the proxy Limit Reference Point of B_{20} . The maximum exploitation rate is maintained if the spawning biomass is above B_{40} . Targeted fishing is ceased if the spawning biomass is below B_{20}	28

List of Tables

Table 1. Maximum exploitation rates and maximum number of seasons at each tier (prior to this study).....	9
Table 2. Maximum exploitation rates at Tier 1 for each species in each sub-area of the SPF recommended by Smith et al. (2015).	10
Table 3. Base Case Parameters for all stocks based on Smith et al. 2010 with maximum age updated with new biological data.	16
Table 4: Base case selectivity-at-age for all stocks updated from Smith et al. (2015) using new biological data. Age, age-to-weight, maturity-at-age, initial-numbers at age were also updated (Appendix 3).	16
Table 5: Sensitivity values for cases where values vary among species.....	17
Table 6. Maximum exploitation rates estimated for Jack Mackerel using six performance indicators for median depletion using data from 2015 and 2024 from base-case model with the range of values from the 15 sensitivity analyses in brackets. Values in bold are key outputs used by SPF RAG to recommend exploitation rates shown in Table 4.	23
Table 7. Maximum exploitation rates estimated for Redbait West using six performance indicators for median depletion using data from 2015 and 2024 from base-case model with the range of values from the 15 sensitivity analyses in brackets. Values in bold are key outputs used by SPF RAG to recommend exploitation rates shown in Table 4.	24
Table 8. Maximum exploitation rates estimated for Redbait East using six performance indicators for median depletion using data from 2015 and 2024 from base-case model with the range of values from the 15 sensitivity analyses in brackets. Values in bold are key outputs used by SPF RAG to recommend exploitation rates shown in Table 4.	25
Table 9. Maximum exploitation rates estimated for Blue Mackerel West using six performance indicators for median depletion using data from 2015 and 2024 from base-case model with the range of values from the 15 sensitivity analyses in brackets. Values in bold are key outputs used by SPF RAG to recommend exploitation rates shown in Table 4.	26

Table 10. Maximum exploitation rates estimated for Blue Mackerel East using six performance indicators for median depletion using data from 2015 and 2024) from base-case model with the range of values from the 15 sensitivity analyses in brackets. Values in bold are key outputs used by SPF RAG to recommend exploitation rates shown in Table 4.27

Table 11. The revised SPF Harvest Strategy Framework showing maximum exploitation rates (Max ER) and maximum number of fishing seasons (1 May to 30 April) between applications of the DEPM (Max Seasons) for each species at each tier.....28

List of Appendices

Appendix 1. Copy of final version of the agreement between SPFIA and UTAS without financial information.....	32
Appendix 2. Description of the basic dynamics of the model used in the current report.....	40
Appendix 3. Updated data for each species and stock used in the MSE.....	42

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Introduction

Background

The Commonwealth Small Pelagic Fishery (SPF) is divided into the Eastern, Western and Sardine Sub-areas (Figure 1). The Total Allowable Catch (TAC) for each target species (Table 1) in each sub-area is set by applying an exploitation rate to latest estimate of spawning biomass obtained using the Daily Egg Production Method (DEPM). The three-tiered Harvest Strategy (HS, AFMA 2008, last revised 2022) outlined the different exploitation rates that were applied to each species depending on the number of years (fishing seasons) that have elapsed since the last DEPM survey was completed (Table 1).

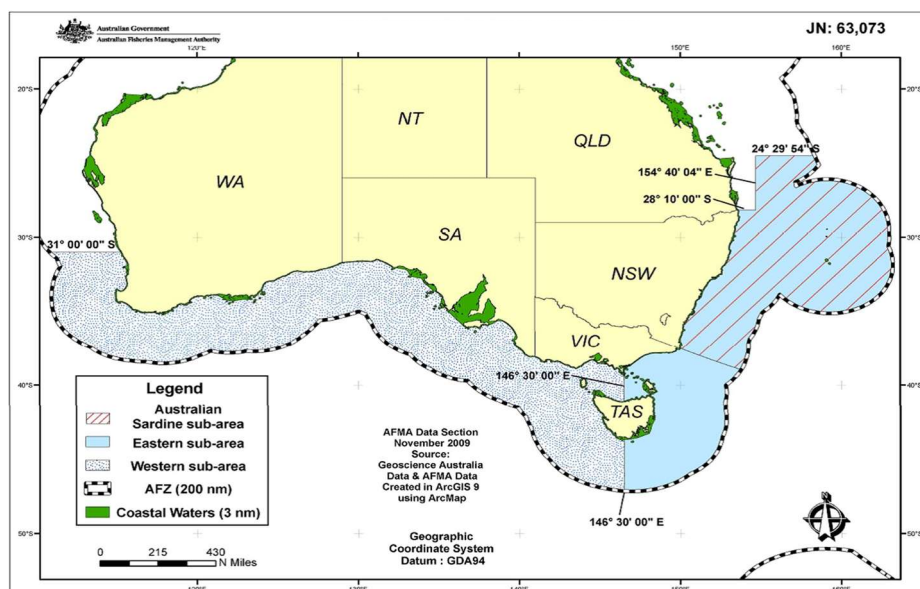


Figure 1. The sub-areas of the Commonwealth Small Pelagic Fishery (SPF)

Table 1. Maximum exploitation rates and maximum number of seasons at each tier (prior to this study).

	Tier 1	Tier 2	Tier 3
Target Species	Maximum exploitation rate (number of seasons)	Maximum exploitation rate (number of seasons)	Maximum exploitation rate (no time limit)
Australian Sardine	20% (5)	10% (5)	5.00%
Blue Mackerel	15% (5)	7.5% (5)	3.75%
Jack Mackerel	12% (5)	6% (10)	3.00%
Redbait	10% (5)	5% (10)	2.5%

A Management Strategy Evaluation (MSE) conducted by Smith et al. (2015) assumed DEPM surveys would be conducted every five years (Table 2). The maximum exploitation rates recommended by Smith et al. (2015) for each species and sub-area provide a high likelihood that stocks will be maintained, on average, at the target reference point of 50% of the unfished biomass (B_{50}), with a less than 10% chance over 50 years of falling below the limit reference point of 20% of the unfished biomass (B_{20}). The exploitation rates for Blue Mackerel in the HS were set at a precautionary 15% rather than the 23% recommended by Smith et al. (2015) because of uncertainties in the knowledge of the population dynamics of this species, especially age, growth and maturity parameters used in the MSE. The exploitation rate for Sardine was set at 20% rather than the 33% recommended by Smith et al. (2015) because that was comparable to the precautionary rate used in the South Australian Sardine Fishery (SASF) at the time. The exploitation rate for Redbait in the Eastern Sub-area was set at 10% because evidence available suggested that there may only be one stock of Redbait off south-eastern Australia (e.g. Bulman et al. 2008).

Table 2. Maximum exploitation rates at Tier 1 for each species in each sub-area of the SPF recommended by Smith et al. (2015).

Target Species	East Sub-area	West Sub-area	Sardine Sub-area
Australian Sardine			33%
Blue Mackerel	23%	23%	
Jack Mackerel	12%	12%	
Redbait	9%	10%	

Need for this review

The Australian Fisheries Management Authority (AFMA) and Marine Stewardship Council (MSC) identified several reasons why the current SPF HS should be reviewed. The AFMA Research Committee (ARC) identified that a review of the SPF HS was needed to ensure that the decision rules are robust, scalable and responsive to changes in the fishery over time and meet the requirements of the current Commonwealth Fisheries Harvest Strategy Policy (HSP, DANR 2018). The ARC also identified the need to review the current fishing mortality reference points in the SPF HS to ensure that they are appropriate for each species and reflect

new information obtained since the review by Smith et al. (2015) was completed. The need to review the harvest strategy settings was particularly important for Blue Mackerel because recent preliminary investigations (Alderson 2023) suggest that previous studies (e.g., Stewart and Ferrell 2001) may have underestimated the age of this species.

The MSC Fishery Assessment Public Certification Report (Banks et al. 2019) identified the need to establish decision rules in the SPF that reduce the exploitation rate as the biomass approaches the point at which recruitment is likely to be impaired. The MSC report also recommended that rules regarding the timing of surveys in relation to TAC setting should ensure that Tier 1 and Tier 2 decision rules are applied once survey data become 5 years old (i.e., not 5 years plus a time lag due to reporting of survey results).

Maintaining MSC certification is critically important to the SPF because most of the catch is sold to a fish meal and oil producer who sells the product to aquaculture feed manufacturers. These aquaculture feed manufacturers sell their product to aquaculture companies who are certified by the Aquaculture Stewardship Council and require feed to come from MSC certified fish stocks.

This study was needed to ensure that decision rules in the SPF Harvest Strategy are robust, scalable and responsive to changes in the fishery over time and meet the requirements of the current Commonwealth Fisheries Harvest Strategy Policy (CFHSP). The study was also needed to ensure that the SPF addresses conditions and recommendations identified in the Public Certification Report of the MSC Fishery Assessment of the SPF. The details of the agreement between SPFIA and IMAS that facilitated this project is shown in Appendix 1.

Objectives

- 1) Evaluate the SPF Harvest Strategy against the current Commonwealth Harvest Strategy Policy (DAWR 2018)
- 2) Review and where necessary revise the parameters used in the MSE using new information obtained since the study by Smith et al. (2015) was completed.

- 3) Establish robust estimates of age, growth, and maturity parameters for Blue Mackerel.
- 4) Undertake an MSE using updated parameters for each species.
- 5) Identify revised maximum exploitation rates and maximum number of seasons at each tier for each species.
- 6) Evaluate the implications of results of DEPM surveys being applied to Tier 1 stocks approximately 6 years after a survey is completed rather than the 5 years tested by Smith et al. (2015).
- 7) Identify and test reference points and decision rules that reduce the exploitation rate as the biomass approaches the point at which recruitment is likely to be impaired.
- 8) Establish a revised SPF HS that meets the requirements of the CHSP and includes updated maximum exploitation rates and maximum number of seasons at each tier, and reference points and decision rules for reducing exploitation rates as the biomass approaches the point of recruitment impairment.

Additional objective

- 9) Evaluate the need for finer scale spatial management to address potential for localised depletion

Approach

Outputs from this project were presented to SPF RAG in two separate meetings. At the first meeting on 12 June 2024, SPF RAG was presented with potential revisions of the SPF HS that did not require a formal MSE. This included: an overall edit to streamline and reduce repetition, removal of references to Atlantis-based estimates of spawning biomass, consolidation of descriptions of the tiered HS framework into two paragraphs and one table, and also adding a section and figure on Harvest Control Rules for reducing exploitation rates as the spawning biomass is reduced to a point where recruitment may be impaired. At this meeting, SPF RAG also reviewed the need for monthly catch limits (“move on rules”). SPF RAG endorsed a revised version of the SPF HS at the June meeting. SEMAC and the AFMA

Commission approved the proposed changes, and the revised SPF HS was posted on the AFMA website in October 2024.

At the second meeting on 24 October 2024, SPF RAG was presented with outputs from the MSE that were used to review the maximum exploitation rates at Tier 1 for each species in each sub-area of the SPF. SPF RAG endorsed the changes proposed in this report. These proposed revisions to the SPF HS will be considered by SEMAC and the AFMA Commission at meetings to be held in early 2025.

Methods

Consultation

This project responded to the need for a review of the SPF Harvest Strategy identified by both AFMA and the MSC. It was developed at the request of the SPF Industry Association (SPFIA), and was discussed with Mr Steve Hall, the SPF Fisheries Manager and Ms Sally Weekes, Senior Manager, Demersal and Midwater Fisheries. The senior author liaised with SPFIA and AFMA throughout the course of the project.

Review

The current Harvest Strategy was evaluated against the current CFHSP (DANR 2018) to assess whether revisions are needed to ensure it is fully compliant. A targeted literature review was conducted to determine whether parameters used in the previous MSE needed to be updated. Information obtained from fishery-dependent and fishery-independent sampling conducted since the review by Smith et al. (2015) was used to update estimates of key parameters used in the MSE.

Blue Mackerel

Previous estimates of age, growth and maturity of Blue Mackerel off eastern Australia were impeded by two factors: 1) most samples were dominated by relatively small and non-spawning fish and 2) previous estimates of age (e.g., Stewart and Ferrell 2001) were largely based on whole (i.e. not sectioned) otoliths. In this study, otoliths obtained from large

spawning Blue Mackerel collected off eastern Australian as part of a concurrent study of the reproductive biology of this species were be used to update estimates of age, growth and maturity parameters used in the population model. Methods used to estimate age of Blue Mackerel follow the protocols developed by Marriott and Manning (2011) and applied by Ward and Grammer (2019), Grammer et al. (2022) and Alderson (2023). Estimates of age obtained from whole and sectioned otoliths will be compared in an associated student project to evaluate the potential for biases in previous estimates of age and growth rates associated with using the two different methodologies.

Management Strategy Evaluation

The MSE was conducted using a modified version of the approach used by Smith et al. (2015). We used a conventional single-species, recruitment-driven, age-structured population model (Appendix 2) similar to that used by Smith et al. (2015). Key parameters were updated for each species based on the results of the literature review, and reanalyses were conducted using new fishery-dependent and fishery-independent data. The age, growth, and maturity parameters for Blue Mackerel were updated using information from Alderson (2023).

The MSE was used to identify the maximum exploitation rates at each tier that provide a high likelihood that stocks will be maintained, on average, above B_{50} , with a less than 10% chance over 20 years of falling below B_{20} . The approach taken was to first run the model using the same input parameters used by Smith et al. (2015) to ensure the modified version of the model provided similar results. We then ran the model using the updated input parameters listed in Appendix 3. The performance indicators used to identify the maximum exploitation rates at Tier 1 for each species in each sub-area were:

- 50% Probability $< 0.5B_0$ (average over last 20 years of the 50-year projection period)
- 50% Probability $< 0.5B_0$ (maximum annual probability in any one year over the entire 50-year projection period)
- 10% Probability $< 0.2B_0$ (average over last 20 years of the 50-year projection period)
- 10% Probability $< 0.2B_0$ (maximum annual probability in any one year over the entire 50-year projection period)

- 50% Probability $< 0.4B_0$ (average over last 20 years of the 50-year projection period)
- 50% Probability $< 0.4B_0$ (maximum annual probability in any one year over the entire 50-year projection period)

The model predictions of biomass falling below the performance indicators are based on 50-year simulations as was done in Smith et al. 2015. The base case assumed that surveys were conducted every 5 years. The exploitation rates were estimated from 1000 iterations for each year of the 50-year model simulations. There was a 75-year bleed in period before the model began simulating results.

Fifteen sensitivity analyses were conducted.

- S0 (base-case)
- S1 (DEPM CV = 0.5)
- S2 (DEPM Bias = 1.2)
- S3 (DEPM Bias = 0.5)
- S4 (DEPM Bias = 0.75)
- S5 (High Steepness)
- S6 (Low Steepness)
- S7 (Selectivity +1 year)
- S8 (Selectivity -1 year)
- S9 (Old selectivity)
- S10 (Lower σ_R)
- S11 (Higher σ_R)
- S12 (lower initial depletion)
- S13 (higher initial depletion)
- S14 (lower natural mortality)
- S15 (higher natural mortality)

Table 3. Base Case Parameters for all stocks based on Smith et al. 2010 with maximum age updated with new biological data.

	East Blue Mackerel	West Blue Mackerel	Jack Mackerel	East Redbait	West Redbait
Age (years)	11	13	15	15	15
Steepness	0.59	0.59	0.75	0.74	0.74
Natural Mortality	0.62	0.62	0.26	0.21	0.21
Sigma R	0.6	0.6	0.6	0.6	0.6

Table 4: Base case selectivity-at-age for all stocks updated from Smith et al. (2015) using new biological data. Age, age-to-weight, maturity-at-age, initial-numbers at age were also updated (Appendix 3).

Age	East Blue Mackerel	West Blue Mackerel	Jack Mackerel	East Redbait	West Redbait
0	0.15	0	0	0.1	0.04
1	0.33	0.06	0.32	0.1	0.16
2	0.66	0.39	0.61	0.62	0.59
3	0.86	0.97	0.86	0.95	0.86
4	1	1	1	1	0.95
5	1	1	1	1	1
6	1	1	1	1	1
7	1	1	1	1	1
8	1	1	1	1	1
9	1	1	1	1	1
10	1	1	1	1	1
11	1	1	1	1	1
12	1	1	1	1	1
13	NA	1	1	1	1
14	NA	1	1	1	1
15	NA	NA	1	1	1
16	NA	NA	1	1	1

Table 5: Sensitivity values for cases where values vary among species.

	East Blue Mackerel	West Blue Mackerel	Jack Mackerel	East Redbait	West Redbait
S5 High Steepness	0.71	0.71	0.90	0.89	0.89
S6 Low Steepness	0.47	0.47	0.60	0.59	0.59
S10 Lower σ_R	0.4	0.4	0.4	0.4	0.4
S11 Higher σ_R	1.0	1.0	1.0	1.0	1.0
S12 Initial depletion	0.95	1	1	1	1
S13 Initial depletion	0.85	0.5	0.77	0.5	0.5
S14 Natural Mortality Low	0.50	0.50	0.26	0.62	0.62
S15 Natural Mortality High	0.74	0.74	0.26	0.62	0.62

Results

1. Evaluate the SPF Harvest Strategy against the current Commonwealth Harvest Strategy Policy

The background section of the previous version of the SPF HS (AFMA 2008, last revised 2022) stated that it “reflects obligations under the Commonwealth Fisheries Harvest Strategy Policy and Guidelines 2018”. The background recognises that the approach taken in the SPF HS is similar to that used in other small pelagic fisheries, including the South Australian Sardine Fishery. It also identifies key aspects of the biology and ecology of small pelagic fishes, the lack of dependence of predators in Australia’s marine ecosystems on one or two prey species and the economic constraints that have historically impeded the development of the SPF. The background also indicates that the HS adopts exploitation rates that:

- maintain the spawning stock biomass, on average, at the target reference point of 50% of the unfished level (B_{50})
- achieve a less than 10% chance over a 50-year period of the spawning stock biomass falling below the limit reference point of 20% of the unfished level (B_{20})

Consistent with the HSP, the objective of the SPF HS is.

The sustainable and profitable utilisation of the SPF in perpetuity through the implementation of a harvest strategy that maintains key commercial stocks at ecologically sustainable levels and, within this context, maximises the net economic returns to the Australian community.

Actions

- 1) Update HS to reflect current state of the fishery
- 2) Define the three sub-areas: Eastern, Western and Sardine. Use consistent terminology (i.e. sub-areas not zones)
- 3) Undertake a thorough edit of HS to reduce repetition and increase readability.

4) Combine description of tiered HS framework into one table.

5) Consolidate description of HS framework into one paragraph.

2. Review and where necessary revise the parameters used in the MSE using new information obtained since the study by Smith et al. (2015) was completed.

The revised estimates of biological parameters for each species and stock used in the MSE are shown in Appendix 3.

Action

Use revised estimates of biological parameters for each species in the MSE.

3. Establish robust estimates of age, growth, and maturity parameters for Blue Mackerel.

The estimates of age, growth, and maturity parameters for Blue Mackerel used in the MSE are shown in Appendices 3.4 and 3.5.

Action

Use revised estimates of biological parameters for Blue Mackerel in the MSE.

4. Undertake an MSE using updated parameters for each species.

The key outputs from the MSE conducted using the updated biological parameters are shown in Tables 3.1 to 3.5. The maximum exploitation rates required to meet the performance indicators using data available in 2015 and 2024 and based on mean and median depletion levels were generally similar. The key performance indicators used by SPF RAG to make recommendations about the exploitation rates that should be established in the revised SPF HS were 50% Probability of $<0.5B_0$ (average over the last 20 years of a 50-year projection period) and 10% Probability of $<0.2B_0$ (average over the last 20 years of a 50-year projection period) (Tables 3.1-3.5).

5. Identify revised maximum exploitation rates and maximum number of seasons at each tier for each species.

The revised exploitation rates recommended by SPF RAG at the meeting on 24 October 2024 are shown in Table 4.

6. Evaluate the implications of results of DEPM surveys being applied to Tier 1 stocks approximately 6 years after a survey is completed rather than the 5 years tested by Smith et al. (2015).

The MSE did not explicitly test this question (available resources were allocated to higher priorities), but the authors note that differences in the estimated exploitation rates for surveys conducted every two and five years provided Smith et al. (2015) by were low. We consider that adding one more year would be unlikely to significantly change the estimates.

7. Identify and test reference points and decision rules that reduce the exploitation rate as the biomass approaches the point at which recruitment is likely to be impaired.

The SPF HS now harvest control rules for reducing the exploitation rate as the biomass approaches the point at which recruitment is likely to be impaired (see Figure 2). The text below is from pages 5 and 6 of the revised SPF HS. Note that this HCR was not tested using by MSE because it is more conservative than the constant exploitation rate approach that was previously applied.

“The SPF HS Framework has Harvest Control Rules (HCRs) that reduce the exploitation rates if the spawning biomass of a stock declines more than 20% below the Target Reference Point of B_{50} and towards the Limit Reference Point of B_{20} where recruitment is likely to be impaired.

As the DEPM has now been applied to each target species in each sub-area (e.g. Grammer et al. 2022), some information is now available about the spawning biomass of all stocks. In many cases, especially in the Western Sub-area, the DEPM surveys have only covered a limited portion of the potential spawning area and therefore provide conservative estimates of the spawning biomass of each stock. In most cases, the DEPM has been applied when levels of fishing mortality were relatively low and the surveys therefore provide conservative estimates of the unfished spawning biomass of each stock. In applying the HCRs, the highest

robust estimate of spawning biomass available for each stock is used as the proxy for B_0 against which other estimates of spawning biomass are compared.

*The HCRs specify that the maximum exploitation rates applied to a stock (Table 1) is reduced linearly (i.e. using a hockey stick rule, Figure 2) if the estimate of spawning biomass from the latest DEPM survey is below the **Trigger Reference Point of B_{40}** and above the **Limit Reference Point of B_{20}** . The maximum exploitation rate for a stock is maintained if the spawning biomass is above B_{40} (Figure 2). Targeted fishing is ceased if the spawning biomass is below B_{20} . Reductions in the exploitation rate for each species at Tier 1 (i.e. a DEPM survey conducted within the last five years) under these HCRs are shown in Figure 2. Maximum exploitation rates at Tiers 2 and 3 are also reduced (i.e. to 50% and 25% of the Tier 1 level, respectively) if the estimate of spawning biomass from the latest DEPM survey was between B_{40} and B_{20} . The maximum exploitation rate at each tier is maintained if the estimate of spawning biomass from the latest DEPM survey was above of B_{40} . Targeted fishing is ceased at all tiers if the spawning biomass is below B_{20} .*

In applying the HCRs, SPF RAG recognises that the reliability of estimates of spawning biomass can vary over time and often increases as knowledge of the population improves. Rigor and caution must be applied when estimates of spawning biomass with different levels of accuracy and precision are compared.”

8. Establish a revised SPF HS that meets the requirements of the Commonwealth HSP and includes updated maximum exploitation rates and maximum number of seasons at each tier, and reference points and decision rules for reducing exploitation rates as the biomass approaches the point of recruitment impairment.

A revised version of the SPF that included the additional Harvest Control Rules and other changes recommended by SPF RAG at the meeting on 12 June 2024 were approved by SEMAC and the AFMA Commission and published on the AFMA website in October 2024 (AFMA 2008 revised 2024). The changes to exploitation rates recommended by SPF RAG at the meeting on 24 October 2024 will be considered by SEMAC and AFMA early in 2025.

9. Evaluate the need for finer scale spatial management to address potential for localised depletion

At the meeting on 12 June 2024, SPF RAG meeting recommended that monthly catch limits implemented to reduce potential for localised depletion should be removed. This recommendation was approved by SEMAC and the AFMA Commission in October 2024. It is likely that these changes will be implemented for the 2025-26 fishing season.

Table 6. Maximum exploitation rates estimated for Jack Mackerel using six performance indicators for median depletion using data from 2015 and 2024 from base-case model with the range of values from the 15 sensitivity analyses in brackets. Values in bold are key outputs used by SPF RAG to recommend exploitation rates shown in Table 4.

Performance indicators	ER JMK 2015	ER JMK 2024
	Median Depletion	Median Depletion
50% Prob < 0.5 B_0 (average last 20 years)	0.14 (0.11-0.0.28)	0.14 (0.12-0.29)
50% Prob < 0.5 B_0 (maximum any one year)	0.12 (0.10-0.25)	0.13 (0.11-0.26)
10% Prob < 0.2 B_0 (average last 20 years)	0.20 (0.12-0.40)	0.21 (0.13-0.43)
10% Prob < 0.2 B_0 (maximum any one year)	0.15 (0.10-0.30)	0.16 (0.11-0.33)
50% Probability < 0.4 B_0 (average last 20 years)	0.18 (0.15-0.37)	0.19 (0.17-0.40)
50% Probability < 0.4 B_0 (maximum any one year)	0.16 (0.13-0.31)	0.17 (0.14-0.33)

Table 7. Maximum exploitation rates estimated for Redbait West using six performance indicators for median depletion using data from 2015 and 2024 from base-case model with the range of values from the 15 sensitivity analyses in brackets. Values in bold are key outputs used by SPF RAG to recommend exploitation rates shown in Table 4.

Performance indicators	ER RBT WEST 2015	ER RBT WEST 2024
	Median Depletion	Median Depletion
50% Prob < 0.5 B_0 (average last 20 years)	0.13 (0.10-0.54)	0.13 (0.10-0.48)
50% Prob < 0.5 B_0 (maximum any one year)	0.12 (0.11-0.16)	0.12 (0.10-0.36)
10% Prob < 0.2 B_0 (average last 20 years)	0.21 (0.13-0.80)	0.20 (0.12-0.55)
10% Prob < 0.2 B_0 (maximum any one year)	0.16 (0.11-0.42)	0.15 (0.10-0.32)
50% Probability < 0.4 B_0 (average last 20 years)	0.18 (0.15-0.84)	0.18 (0.15-0.69)
50% Probability < 0.4 B_0 (maximum any one year)	0.15 (0.13-0.50)	0.15 (0.13-0.45)

Table 8. Maximum exploitation rates estimated for Redbait East using six performance indicators for median depletion using data from 2015 and 2024 from base-case model with the range of values from the 15 sensitivity analyses in brackets. Values in bold are key outputs used by SPF RAG to recommend exploitation rates shown in Table 4.

Performance indicators	ER RBT EAST 2015 Median Depletion	ER RBT EAST 2024 Median Depletion
50% Prob < 0.5 B_0 (average last 20 years)	0.10 (0.8-0.0.26)	0.12 (0.10-0.45)
50% Prob < 0.5 B_0 (maximum any one year)	0.09 (0.0.08-0.20)	0.12 (0.10-0.34)
10% Prob < 0.2 B_0 (average last 20 years)	0.15 (0.09-0.31)	0.20 (0.12-0.50)
10% Prob < 0.2 B_0 (maximum any one year)	0.12 (0.10-0.23)	0.14 (0.10-0.30)
50% Probability < 0.4 B_0 (average last 20 years)	0.13 (0.10-0.37)	0.17 (0.14-0.63)
50% Probability < 0.4 B_0 (maximum any one year)	0.12 (0.10-0.24)	0.15 (0.12-0.41)

Table 9. Maximum exploitation rates estimated for Blue Mackerel West using six performance indicators for median depletion using data from 2015 and 2024 from base-case model with the range of values from the 15 sensitivity analyses in brackets. Values in bold are key outputs used by SPF RAG to recommend exploitation rates shown in Table 4.

Performance indicators	ER BM WEST 2015 Median Depletion	BM WEST 2024 Median Depletion
50% Prob < 0.5 B_0 (average last 20 years)	0.24(0.20-0.49)	0.25 (0.21-0.51)
50% Prob < 0.5 B_0 (maximum any one year)	0.21 (0.17-0.41)	0.21 (0.18-0.43)
10% Prob < 0.2 B_0 (average last 20 years)	0.28 (0.23-0.38)	0.29 (0.23-0.58)
10% Prob < 0.2 B_0 (maximum any one year)	0.18 (0.15-0.36)	0.18 (0.15-0.39)
50% Probability < 0.4 B_0 (average last 20 years)	0.33 (0.27-0.65)	0.34 (0.25-0.69)
50% Probability < 0.4 B_0 (maximum any one year)	0.25 (0.21-0.51)	0.26 (0.22-0.52)

Table 10. Maximum exploitation rates estimated for Blue Mackerel East using six performance indicators for median depletion using data from 2015 and 2024) from base-case model with the range of values from the 15 sensitivity analyses in brackets. Values in bold are key outputs used by SPF RAG to recommend exploitation rates shown in Table 4.

Performance indicators	ER BM EAST 2015 Median Depletion	ER BM EAST 2024 Median Depletion
50% Prob < 0.5 B_0 (average last 20 years)	0.24(0.20-0.47)	0.26 (0.21-0.51)
50% Prob < 0.5 B_0 (maximum any one year)	0.21 (0.17-0.42)	0.22 (0.18-0.43)
10% Prob < 0.2 B_0 (average last 20 years)	0.23 (0.19-0.45)	0.25 (0.18-0.50)
10% Prob < 0.2 B_0 (maximum any one year)	0.15 (0.13-0.30)	0.18 (0.15-0.35)
50% Probability < 0.4 B_0 (average last 20 years)	0.31 (0.22-0.65)	0.33 (0.28-0.45)
50% Probability < 0.4 B_0 (maximum any one year)	0.26 (0.22-0.52)	0.26 (0.22-0.52)

Table 11. The revised SPF Harvest Strategy Framework showing maximum exploitation rates (Max ER) and maximum number of fishing seasons (1 May to 30 April) between applications of the DEPM (Max Seasons) for each species at each tier.

Species Sub-area(s)	Tier 1		Tier 2		Tier 3	
	Max ER	Max Seasons	Max ER	Max Seasons	Max ER	Max Seasons
Sardine Sardine	20%	5 seasons	10%	5 seasons	5%	Indefinite
Blue Mackerel Eastern	20%	5 seasons	10%	5 seasons	5%	Indefinite
Western	20%	5 seasons	10%	5 seasons	5%	Indefinite
Jack Mackerels Eastern	14%	5 seasons	7%	10 seasons	3.5%	Indefinite
Western	14%	5 seasons	7%	10 seasons	3.5%	Indefinite
Redbait Eastern	12%	5 seasons	6%	10 seasons	3%	Indefinite
Western	12%	5 seasons	6%	10 seasons	3%	Indefinite

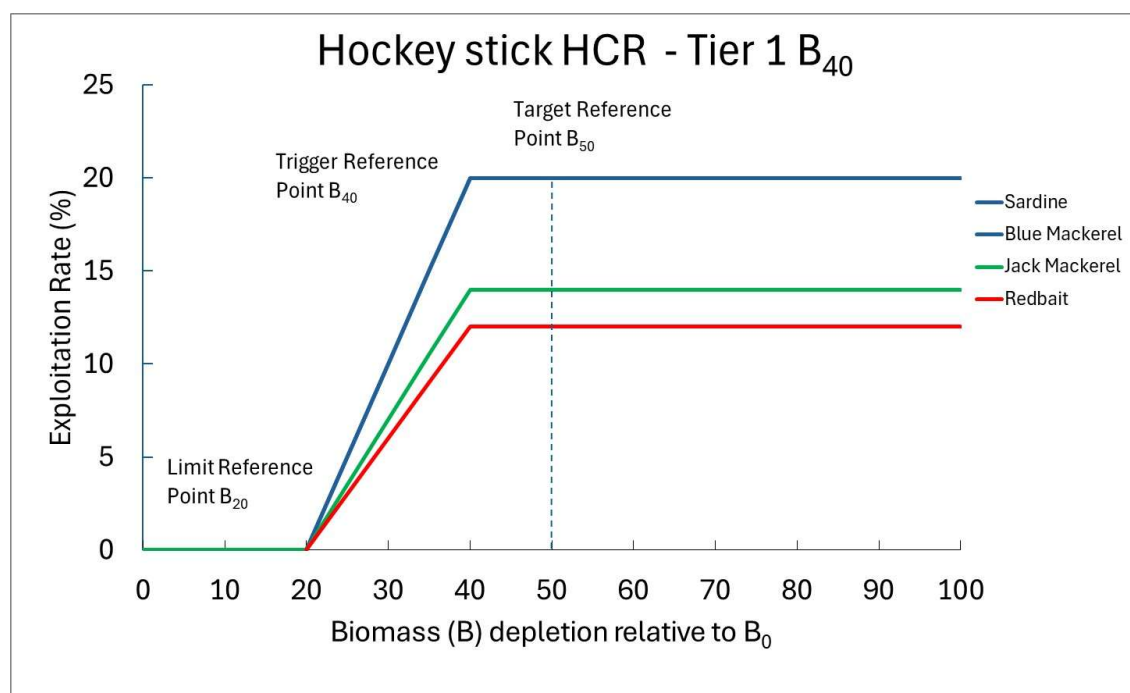


Figure 2. Harvest Control Rules for linearly reducing (i.e. using a hockey stick rule) the exploitation rates for each species at Tier 1 (Table 1) if the estimate of spawning biomass from the latest DEPM survey is below the proxy Trigger Reference Point of B_{40} and above the proxy Limit Reference Point of B_{20} . The maximum exploitation rate is maintained if the spawning biomass is above B_{40} . Targeted fishing is ceased if the spawning biomass is below B_{20} .

Discussion

The most important outcome of this project was the inclusion in the SPF HS (AFMA 2008 last revised 2024) of Harvest Control Rules that specify that the maximum exploitation rate applied to a stock is reduced linearly (i.e. using a hockey stick rule, Figure 2) if the spawning biomass falls below the Trigger Reference Point (B40), and that targeted fishing ceases if the spawning biomass fishing falls below the Limit Reference Point (B20). This outcome is important because most of the SPF catch is used to produce aquaculture feed that is used by companies that are certified by the Aquaculture Stewardship Council and require their feed to come from fisheries that are certified by the MSC.

Updating the key biological parameters for the species targeted by the trawl sector (i.e., Jack Mackerel, Redbait and Blue Mackerel) was also important because a considerable amount of new data has been generated since the previous MSE was done by Smith et al. (2015). One of the major long-term benefits of undertaking this study was simplifying the model used by Smith et al. (2015) and securing its availability for use in future studies.

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Appendix 1. Copy of final version of the agreement between SPFIA and UTAS without financial information

CLIENT

Small Pelagic Fishing Industry Association (SPFIA)

ABN 97 249 119 260

Contact Mr Simon Boag

Contracted Executive Officer SPFIA

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CLIENT NEED

This SPFIA Board has requested n the University of Tasmanian to undertake a project that will maintain the Small Pelagic Fishery’s (SPF) Marine Stewardship Council (MSC) accreditation by meeting the year-3 condition milestone.

The MSC SPF Assessment Public Certification Report for the fishery identified the need to establish decision rules in the fishery that reduce the exploitation rate as the biomass approaches the point at which recruitment is likely to be impaired. The MSC report also recommended that rules regarding the timing of surveys in relation to TAC setting should ensure that Tier 1 and Tier 2 decision rules are applied once survey data become 5 years old (i.e., not 5 years plus a time lag due to reporting of survey results).

The relevant MSC condition reads: “A proposal to establish well defined HCRs that ensure that the exploitation rate is reduced as the PRI is approached for the three SPF target stocks, that are expected to keep the stocks fluctuating around a target level consistent with (or above) MSY, in the event that exploitation rates reach Tier 1 levels.”

The Year-3 milestone for this condition is, “The client will present the revised draft HS to the Australian Fisheries Management Authority (AFMA) for consideration by AFMA’s SPF

Resource Assessment Group and South East Management Advisory Committee before seeking an AFMA Commission decision to implement the revised harvest strategy.”

The SPFIA board has also agreed that the project to address the conditions and recommendations of the MSC should be conducted within the context of broader review of the harvest strategy including reference points and decision rules for each species, especially the exploitation rate for Blue Mackerel.

RESEARCH PROPOSAL

Review and refinement of the Harvest Strategy for the Small Pelagic Fishery

Background

The Total Allowable Catch (TAC) for each target species (Table 1) in each sub-area of the Commonwealth Small Pelagic Fishery (SPF) is set by applying an exploitation rate to latest estimate of spawning biomass obtained using the Daily Egg Production Method (DEPM). The three-tiered Harvest Strategy (AFMA 2008, last revised 2022) outlines the different exploitation rates that are applied to each species depending on the number of years (fishing seasons) that have elapsed since the last DEPM survey was completed (Table 1).

Table 1. Maximum exploitation rates and maximum number of seasons at each tier.

	Tier 1	Tier 2	Tier 3
Target Species	Maximum exploitation rate (number of seasons)	Maximum exploitation rate (number of seasons)	Maximum exploitation rate (no time limit)
Australian Sardine	20% (5)	10% (5)	5.00%
Blue Mackerel	15% (5)	7.5% (5)	3.75%
Jack Mackerel	12% (5)	6% (10)	3.00%
Redbait	10% (5)	5% (10)	2.5%

The maximum exploitation rates and maximum number of seasons at each tier were adopted because they provide a high likelihood that stocks will be maintained, on average, at the target reference point of 50% of the unfished biomass (B_{50}), with a less than 10% chance over 50 years of falling below the limit reference point of 20% of the unfished biomass (B_{20}) (Smith et al. 2015). The settings in the Harvest Strategy are largely based on the recommendations of the Management Strategy Evaluation (MSE) conducted by Smith et

al. (2015). The exception is the exploitation rate for Blue Mackerel which was set at 15% rather than the 23% recommended by Smith et al. (2015) because of uncertainties in the knowledge of the population dynamics of this species, especially age, growth and maturity parameters.

The Australian Fisheries Management Authority (AFMA) and Marine Stewardship Council (MSC) have identified several reasons why the current SPF Harvest Strategy should be reviewed. The AFMA Research Committee (ARC) identified that a review of the SPF Harvest Strategy is needed to ensure that the decision rules are robust, scalable and responsive to changes in the fishery over time and meet the requirements of the current Commonwealth Fisheries Harvest Strategy Policy (DANR 2018). The ARC also identified the need to review the current reference points in the SPF Harvest Strategy to ensure that they are appropriate for each species and reflect new information obtained since the review by Smith et al. (2015) was completed. The need to review the harvest strategy settings is particularly important for Blue Mackerel because recent preliminary investigations (University of Tasmania, unpublished data) suggest that previous studies (e.g., Stewart and Ferrell 1990) are likely to have underestimated the age of this species.

The MSC Fishery Assessment Public Certification Report (Banks et al 2019) identified the need to establish decision rules in the SPF that reduce the exploitation rate as the biomass approaches the point at which recruitment is likely to be impaired. The MSC report also recommended that rules regarding the timing of surveys in relation to TAC setting should ensure that Tier 1 and Tier 2 decision rules are applied once survey data become 5 years old (i.e., not 5 years plus a time lag due to reporting of survey results).

Maintaining MSC certification is critically important to the SPF because most of the catch is sold to a fish meal and oil producer who sells the product to aquaculture feed manufacturers. These aquaculture feed manufacturers sell to their product to aquaculture companies who are certified by the Aquaculture Stewardship Council and require feed to come from MSC certified fish stocks.

Consultation

This proposal responds to the need for a review of the SPF Harvest Strategy identified by both AFMA and the MSC. It was developed at the request of the SPF Industry Association, and has been discussed with Mr Steve Hall, the SPF Fisheries Manager and Ms Sally Weekes, Senior Manager, Demersal and Midwater Fisheries.

Objectives

- 1) Evaluate the SPF Harvest Strategy against the current Commonwealth Harvest Strategy Policy (DANR 2018)
- 2) Review and where necessary revise the parameters used in the MSE using new information obtained since the study by Smith et al. (2015) was completed.
- 3) Establish robust estimates of age, growth, and maturity parameters for Blue Mackerel.
- 4) Undertake an MSE using updated parameters for each species.
- 5) Identify revised maximum exploitation rates and maximum number of seasons at each tier for each species.
- 6) Evaluate the implications of results of DEPM surveys being applied to Tier 1 stocks approximately 6 years after a survey is completed rather than the 5 years tested by Smith et al. (2015).
- 7) Identify and test reference points and decision rules that reduce the exploitation rate as the biomass approaches the point at which recruitment is likely to be impaired.
- 8) Establish a revised SPF Harvest Strategy that meets the requirements of the Commonwealth Harvest Strategy Policy and includes updated maximum exploitation rates and maximum number of seasons at each tier, and reference points and decision rules for reducing exploitation rates as the biomass approaches the point of recruitment impairment.

Need

This study is needed to ensure that decision rules in the SPF Harvest Strategy are robust, scalable and responsive to changes in the fishery over time and meet the requirements of the current Commonwealth Fisheries Harvest Strategy Policy. The study is also needed to ensure that the SPF addresses conditions and recommendations identified in the Public Certification Report of the MSC Fishery Assessment of the SPF.

Outcomes, Benefits and Extension (updated to reflect changes during the project)

14 September 2023	Proposal presented to the MSC assessors at annual surveillance meeting.
7 December 2023	Proposal presented to SPF RAG.
June 2024 August 2024 October 2024 MSE	Preliminary results presented to SPF RAG for feedback. HCR approved by SPF RAG, SEMAC and AFMA Commission Preliminary MSE results presented to SPF RAG
June 2024 September 2024	Results incorporating feedback from SPF RAG presented to MSC assessors at the annual surveillance meeting.
December 2024 January 2024	Presentation of the results to SPF RAG. Final report completed.

Methods

Review

The current Harvest Strategy will be evaluated against the current Commonwealth Harvest Strategy Policy (DANR 2018) to assess whether revisions are needed to ensure it is fully compliant. A targeted literature review will be conducted to determine whether parameters used in the previous MSE need to be updated. Information obtained from fishery-dependent and fishery-independent sampling conducted since the review by Smith et al.

(2015) was completed will also be collated to determine if these data should be used to update estimates of key parameters used in the MSE.

Blue Mackerel

Previous estimates of age, growth and maturity of Blue Mackerel off eastern Australia were impeded by two factors: 1) most samples were dominated by relatively small and non-spawning fish and 2) previous estimates of age (e.g., Stewart and Ferrell) were largely based on whole (c.f., sectioned) otoliths. In the proposed study, otoliths obtained from large spawning Blue Mackerel collected off eastern Australian as part of a concurrent study of the reproductive biology of this species will be used to update estimates of age, growth and maturity parameters used in the population model. Methods used to estimate age of Blue Mackerel will follow the protocols developed by Marriott and Manning (2011) and applied by Ward and Grammer (2019) and Grammer et al. (2022). Estimates of age obtained from whole and sectioned otoliths will be compared to evaluate the potential for biases in previous estimates of age and growth rates of this species.

Management Strategy Evaluation

The MSE will be conducted using the same code and approach that was used by Smith et al. (2015). Key parameters will be updated for each species based on the results of the literature review, reanalyses conducted using new fishery-dependent and fishery-independent data and revised estimate of age, growth, and maturity parameters for Blue Mackerel. The MSE will be used to ensure that maximum exploitation rates and maximum number of seasons at each tier provide a high likelihood that stocks will be maintained, on average, above B_{50} , with a less than 10% chance over 50 years of falling below B_{20} . The MSE will also be used to develop and test trigger reference points and decision rules to reduce exploitation rates as the biomass approaches the point of recruitment impairment.

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Appendix 2. Description of the basic dynamics of the model used in the current report.

The operating model is age-structured, and recruitment is driven by spawning biomass. The basic population dynamics are governed by the equation:

$$N_{y+1,a} = \begin{cases} R_{y+1} & \text{if } a = 1 \\ N_{y,a-1} e^{-M-S_{a-1}F_y} & \text{if } 1 < a < x \\ N_{y,x-1} e^{-M-S_{x-1}F_y} + N_{y,x} e^{-M-S_x F_y} & \text{if } a = x \end{cases} \quad (\text{A2.1})$$

where $N_{y,a}$ is the number of animals of age a at the start of year y , M is the rate of natural mortality, S_a is the selectivity of the fishery of animals of age a , F_y is the fully-selected fishing mortality during year y , and x is the maximum (plus-group) age. The final term R_y represents recruitment, which is governed by a Beverton-Holt stock-recruitment relationship, parameterized in terms of steepness (h) and unfished recruitment, R_0 :

$$R_y = \frac{4 h R_0 SSB_y / SSB_0}{(1-h)+(5h-1)SSB_y / SSB_0} e^{\varepsilon_y - \sigma_R^2/2} \quad \varepsilon_y \sim N(0; \sigma_R^2) \quad (\text{A2.2})$$

where SSB_y is spawning stock biomass in year y , SSB_0 is the unexploited spawning stock biomass, σ_R^2 is the extent of variation in recruitment about the stock-recruitment relationship due to un-modelled white-noise processes. The value of SSB_y is calculated using:

$$SSB_y = \sum_{a=1}^x mat_a w_{a+1/2} N_{y,a} \quad (\text{A2.3})$$

where $w_{a+1/2}$ is the weight of an animal of age a in the middle of the year.

The catch during (future) year y , C_y , is determined by the equation:

$$C_y = \sum_{a=0}^x w_{a+1/2} \frac{S_a F_y}{M+S_a F_y} N_{y,a} (1 - e^{-M-S_{a-1}F_y}) \quad (\text{A2.4})$$

Data generation

The control rules are based on estimates of spawning stock biomass based on the DEPM method, i.e.:

$$\widehat{SSB}_y = SSB_y e^{\eta_y - \tau^2} \quad \eta_y \sim N(0; \tau^2) \quad (\text{A2.5})$$

Control rules

The RBCs are set based on estimates of biomass from the DEPM method. The maximum RBC for a given year is given by:

$$RBC_y = \widehat{SSB}_{y-n} \times HR_n \quad (A.2.6)$$

where \widehat{SSB}_{y-n} is the estimate of spawning stock biomass from the most recent DEPM survey, n is the age of the DEPM survey in years, and HR_n is the maximum harvest rate for a DEPM survey of age n . The harvest rate is the maximum as long as n is less than 5 years. If n is larger than 5, the HR is set to half the maximum rate, and if n is larger than 15 (Redbait and Jack Mackerel) or 10 (Blue Mackerel) the harvest rate is set to 25% of the maximum rate.

Appendix 3. Updated data for each species and stock used in the MSE.

3.1 Jack Mackerel

```
# Number of simulation years
50
# Maximum age
15
# Weight-age-age
5.3 85 156 219 278 325 373 420 460 495 522 547
    570 590 602 610
# maturity-at-age
0 0.05 0.15 0.35 0.55 0.75 0.85 0.95 1 1 1 1
  1 1 1 1
# Initial numbers-at-age (proportion)
0.250 0.208 0.174 0.145 0.121 0.100 0.084 0.070 0.058 0.048 0.040
    0.034 0.028 0.023 0.019 0.016
# Initial Numbers at age (total); Initial depletion
4896.161 0.9
# Selectivity - Base case
0 0.32 0.61 0.86 1 1 1 1 1 1 1 1
  1 1 1 1
# Selectivity - Knuckey basic selectivity
0.3 1 1 1 1 1 1 1 1 1 1 1
  1 1 1 1
# natural mortality
0.26
# R0 Steepness // Recruitment parameteres
800.000 0.75
# Initial_Eps, ProwR, SigmaR, Rerr, Rtype // Recruitment
uncertainty
0.000 0.0 0.6 1 0
# Sigma B Berr// Uncertainty of the assesement
0.300 1
# Initial depletion
1.0
```

3.2 Redbait West

```
# Number of simulation years
50
# Maximum age
15
# Weight-age-age
43   96   148  193  230  260  285  310  335  356  372
     385  400  412  420  425
# maturity-at-age
0    0.04 0.16 0.45 0.59 0.75 0.86 0.95 1    1    1    1
     1    1    1    1
# Initial numbers-at-age (proportion)
0.200 0.167 0.139 0.116 0.096 0.080 0.067 0.056 0.047 0.039 0.032
     0.027 0.022 0.019 0.016 0.013
# Initial Numbers at age (total); Initial depletion
253   1
# Selectivity - Base case
0.04 0.16 0.59 0.86 0.95 1    1    1    1    1    1    1
     1    1    1    1
# Selectivity - Knuckey basic selectivity
0.3  1    1    1    1    1    1    1    1    1    1    1
     1    1    1    1
# natural mortality
     0.21
# R0 Steepness // Recruitment parameteres
800.000 0.74
# Initial_Eps, ProwR, SigmaR, Rerr, Rtype // Recruitment
uncertainty
     0.000 0.0 0.6 1 0
# Sigma_B Berr// Uncertainty of the assesement
0.300 1
# Initial depletion
1
```

3.3 Redbait East

```
# Number of simulation years
50
# Maximum age
15
# Weight-age-age
8.0 55.0 95.0 130.0 155.0 174.0 190.0 205.0 220.0 234.0 247.0
260.0 270.0 279.0 285.0 290.0
# maturity-at-age
0.1 0.04 0.16 0.45 0.59 0.75 0.86 0.95 1 1 1 1
1 1 1 1
# Initial numbers-at-age (proportion)
0.200 0.167 0.139 0.116 0.096 0.080 0.067 0.056 0.047 0.039 0.032
0.027 0.022 0.019 0.016 0.013
# Initial Numbers at age (total); Initial depletion
889.0 0.9
# Selectivity - Base case
0.1 0.1 0.62 0.95 1 1 1 1 1 1 1 1
1 1 1 1
# Selectivity - Knuckey basic selectivity
0.30 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1
# natural mortality
0.21
# R0 Steepness // Recruitment parameteres
800.000 0.74
# Initial_Eps, ProwR, SigmaR, Rerr, Rtype // Recruitment
uncertainty
0.000 0.0 0.6 1 0
# Sigma_B Berr// Uncertainty of the assesement
0.300 1
# Initial depletion
1.0
```

3.4 Blue Mackerel West

```
50
# Maximum age
13
# Weight-age-age
10 110 205 292 375 455 530 600 660 710 765
    810 840 860
# maturity-at-age
0 0.09 0.47 0.84 1 1 1 1 1 1 1
  1 1
# Initial numbers-at-age (proportion)
0.470 0.362 0.278 0.214 0.165 0.127 0.097 0.075 0.058 0.044 0.034
  0.026 0.020 0.016
# Initial Numbers at age (total); Initial depletion
300 1
# Selectivity - Base case
0 0.06 0.39 0.97 1 1 1 1 1 1 1
  1 1
# Selectivity - Knuckey basic selectivity
0.3 1 1 1 1 1 1 1 1 1 1
  1 1
# natural mortality
    0.62
# R0 Steepness // Recruitment parameteres
800.000 0.59
# Initial_Eps, ProwR, SigmaR, Rerr, Rtype // Recruitment
uncertainty
    0.000 0.0 0.6 1 0
# Sigma_B Berr// Uncertainty of the assesement
0.300 1
# Initial depletion
1
```

3.5 Blue Mackerel East

```
# Number of simulation years
50
# Maximum age
11
# Weight-age-age
35      260      360      440      500      560      600      650      685      720      735      750
# maturity-at-age
0.01    0.17    0.69    0.91    0.99    1        1        1        1        1        1        1
# Initial numbers-at-age (proportion)
0.45    0.38    0.31    0.26    0.22    0.18    0.15    0.13    0.10    0.09    0.07    0.06
# Initial Numbers at age (total); Initial depletion
1183    1
# Selectivity - Base case
0.15    0.33    0.66    0.86    1        1        1        1        1        1        1        1
# Selectivity - Knuckey basic selectivity
0.38    0.60    0.87    0.99    0.99    0.91    0.71    0.50    0.37    0.30    0.28    0.27
# natural mortality
0.62
# R0 Steepness // Recruitment parameteres
800.000 0.59
# Initial_Eps, ProwR, SigmaR, Rerr, Rtype // Recruitment uncertainty
0.000 0.0 0.6 1 0
# Sigma_B Berr// Uncertainty of the assesement
0.300 1
# Initial depletion
1
```