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The southern bluefin tuna stock assessment in 2023

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Contents

Abstract

The 2023 stock assessment for Southern Bluefin Tuna provides estimates of current stock status (in 2023). The assessment includes a revised reference set of 108 models and data through to 2022, following the review of preliminary models and data and decisions made at the 13th Operating Model and Management Procedure (OMMP) technical meeting, June 2023. The reference set of models indicates further rebuilding of the stock since the last assessment in 2020. The fits to the data did not indicate any areas of concern, although the fit to the CPUE index value for 2022 is poor and this is explored in sensitivity tests. The sensitivity tests were defined to assess the impacts on stock status estimates from additional areas of uncertainty that are not covered in the reference set of 108 models. Most of the sensitivity tests results indicate consistent or slightly more optimistic stock status results compared to the reference set, with results from only 2 of 12 sensitivity tests being slightly more pessimistic. Projections for the reference set of models indicate that the management procedure is on track to reach the new rebuilding target (30% Total Reproductive output (TRO), by 2035).

1. Introduction

The Southern Bluefin Tuna stock assessment in 2023 provides the best available advice on current stock status. The last full assessment was in 2020. The 2023 assessment uses a revised reference set of models and updated data, to provide information on stock rebuilding and to detect any exceptional circumstances in relation to new knowledge of the stock or fisheries. The assessment is specified as part of the schedule of activities of the Cape Town Procedure. It is run every three years, not coinciding with years when a new TAC is calculated from the management procedure (MP). This timing is to ensure that the advice about stock status is distinct from the operation of, the MP which is used to recommend the TAC.

2. Models and Data inputs

2.1 The reference set of models

The assessment of SBT is based on a reference set of operating models (OMs) that encompass a range of plausible uncertainties. The 13th Operating Model and Management Procedure (OMMP) working group meeting 2023 (Anon 2023), reviewed the data inputs, fits to data and preliminary reconditioning of the OMs, and agreed to the following changes to the reference set (relative to the 2020 assessment):

- A single Japanese longline CPUE series (GAM model: Itoh and Takahashi, 2023).
- The age range for standardising the selectivity to predict LL1 CPUE has changed from two options (8-12 and 4-18) to a single range: 5-17.
- For the Indonesian selectivity, the lower age is changed from age 8 to age 6.

The 2023 reference set (Table 1) contains 108 models that result from the combinations across the grid elements: four values of steepness (h), three values of natural mortality at age 0 (M_0), three values of mortality at age 10 (M_{10}), a single value of Omega (Ω) (implying a linear relationship between CPUE and LL1 exploitable biomass), a single age range used to standardize LL1 selectivity over time, a single CPUE (GAM), and three values of Psi (ψ) (power parameter for relative reproductive contribution by age). The values for h, M_0, M_{10}, Omega and Psi are the same as the stock assessment in 2020.

From these 108 model results, 2000 runs are sampled to provide the full reference set, which are summarised at the median and 80[th] percentile confidence intervals (CI).

Table 1. Revised reference set grid for the stock assessment. Sampling weight refers to how the grid of models is sampled to generate a distribution from 2000 parameter draws.

Parameter	Value	Cumul N	Prior	Sampling weight
H	0.55, 0.63, 0.72, 0.8	4	Uniform	Prior
M_0	0.4 0.45 0.5	12	Uniform	Posterior
M_{10}	0.065, 0.085, 0.105	36	Uniform	Posterior
Omega (Ω)	1	36	Uniform	Prior
CPUE	GAM	36	Uniform	Prior
CPUE age range	5-17	36	Uniform	Prior
Psi (ψ)	1.5, 1.75, 2.0	108	0.25, 0.5, 0.25	Prior

In addition to the range of uncertainties encapsulated in the reference set grid, a set of fixed parameters is used in the assessment (Table 2). These were reviewed at the OMMP meeting and are unchanged from 2020.

Table 2 Fixed parameters in the current set of operating models.

Variable	Role	Value
φ^{tag}	Conventional tag overdispersion	1.82
φ^{gt}	Gene tagging overdispersion	1
q^{gt}	Gene tagging GAB fraction	1
q^{hsp}	CKMR HSP "catchability"	1
π^{η}	CKMR HSP false neg. probability	0.736
σ_r	Recruitment SD	0.6
ml_{50}	Length @ 50% maturity	150cm
ml_{95}	Length @ 95% maturity	180cm
ς_{max}	Max. age estimated Indo selectivity	25

2.2 Input data

The inputs to the assessment models have been updated to include the most recent data exchanged through the CCSBT data exchange. Data are aggregated to 6 defined fisheries in the OMs. The Longline 1 fishery (LL1) represents the Japanese longline fishing in statistical areas 4-9 and includes NZ, Australian longline, Korean and other longline catches not included in the other fleet definitions, the ‘Indonesian’ fishery represents Indonesian spawning ground fishing, and the ‘surface’ fishery represents the Australian purse seine fishery in South Australia. The data inputs are:

- Catch biomass by fishery (1952-2022), and age frequency (Indonesian, surface) or length frequency (longline fleets).
- Longline CPUE (LL1 fishery) relative abundance index 1969–2022 (Itoh and Takahashi 2023)
- Aerial survey juvenile relative biomass index 1993–2017 (Eveson and Farley 2017).
- Conventional tagging data (years 1990–1994, ages 1–3)
- Gene tagging age 2 absolute abundance estimates data 2016–2021 (Preece et al, 2023)
- Close-Kin Mark Recapture (CKMR) Parent-Offspring Pairs (POPs) (2002–2018) (Farley et al, 2023)
- CKMR Half-Sibling Pairs (HSPs) (2003–2017) (Farley et al, 2023)
- Estimates of the potential scale of non-member catches (Edwards and Hoyle, 2023)
- Grid-type trolling index (GTI) (1996–2004, 2005–2014, 2016–2023) (Itoh, 2023)

The following data are missing in the assessment: The 2020 age-2 cohort data from the gene-tagging program (because the program was cancelled in that year due to COVID-19 border closures), Indonesian age frequency for year 2022 (season 2021/22) (because of COVID -19 and institutional changes in Indonesia), and the New Zealand length frequency data, which has not been fully raised to the total catch.

2.3 Sensitivity tests

The OMMP working group specified a set of sensitivity tests for exploring additional uncertainties outside of the reference set of models (Table 3).

The definition of the CPUE_0 sensitivity test required intersessional work which was reviewed at the CPUE working group (July 24/25th 2023). The working group considered the available information to define an appropriate level of CV at which unfished squares would be set to 0 in the GAM (sensitivity test CPUE_0) but decided against pursuing this option further because it would add systematic bias to the last year in the CPUE. A simple GLM model was also suggested for a sensitivity test, however, the simple_age 4+ GLM index was very similar to the existing GAM and did not provide sufficient contrast to be informative for a sensitivity test. The CPUE working group agreed that the other sensitivity tests related to CPUE, in particular the scenario which excludes the last 5 years of CPUE (CPUE_Drop5), would be adequate for checking sensitivity of assessment results to the recent high levels of CPUE and 2022 estimate.

Table 3 Sensitivity tests and priority

Test name	Code	Conditioning and projection notes	Priority
UAMbycatch	UAMbycatch	Replace LL1 NCNM catches estimated using Japanese catch rates with estimates calculated using Taiwanese catch rates.	**H**
No UAM	noUAM	Remove NCNM catches from conditioning and projections.	**H**
LL1 Case 2 of MR	case2	LL1 overcatch based on Case 2 of the 2006 Market Report	**L**
CPUE_Drop5	Drop_5yrs	Eliminate the last 5 years of CPUE Series	**H**
***CPUE_0**	DropCells	Set uncertain cells w/o data to zero (based on CV of positive CPUE rates)	**H**
Omega75	cpueom75	Power function for biomass-CPUE relationship with power = 0.75	**H**
Upq2008	cpueupq	Estimate CPUE 2008 change in q for LL1 fleet	**H**
Q age range	cpue59	Age range for q equal to 5-9	**M**
LL1_sel	LL1_sel	Allow the terminal 3-years to be flexibly estimated to evaluate impact on year-class uncertainty and magnitude	**M**
Indo_sel	Indo_sel	Bi-modality in selectivity, more rigid (constrain amount of change) from 2013 on in Indonesian fishery	**H**
NoPOP&HSP	NoPOPHSP	Exclude both close-kin data (Parent-Offspring and Half-Sibling Pairs)	**H**
No HSP	NoHSP	Exclude half-sibling-pair close-kin data	**H**
GTI	troll	Includes the grid-type trolling index as additional recruitment index. Increase CV of aerial survey to preclude aerial survey dominating the fit, given apparent conflicts in the data	**H**

*Not included following further discussion at the CPUE working group.

3. Results and discussion

3.1 Stock status summary for the reference set of OMs

The 2023 estimate of depletion in Total Reproductive Output (TRO) (TRO_{2023}/TRO_0) is 0.23 (0.21-0.29) (Table 4). The estimate of depletion of the biomass of animals aged 10+ is 0.22 (0.19-0.26). These stock status estimates have continued to improve since the 2020 assessment. Figure 1 shows the relative depletion in TRO and historical recruitment estimates for the reference set of OMs.

MSY is estimated to be lower than in the previous assessment, with a narrower range (Table 4). The fishing mortality and TRO at MSY relative measures have very wide ranges of values, which make them less informative, but these measures also indicate further improvement since the 2020 assessment. Current Fishing mortality (F) is well below F_{MSY}: the F to F_{MSY} ratio is 0.46 (0.34-0.65). Current TRO is estimated to be at 0.85 of TRO_{MSY}, with the range including values greater than 1.0 (0.61-1.29). The TRO_{MSY}/TRO_0 (not shown in these tables) is currently estimated to be 0.28 (0.22-0.35).

Figure 2 shows the level plot for the grid values used to generate the reference set of OMs. The small changes to the reference set of OMs have not changed the level plot and the grid values reviewed and accepted at the OMMP meeting.

Table 4 Summary of stock status for the reference set of OMs. Presented as the median and 80% CI. The assessment results from 2020 are included for comparison.

Assessment year (y)	Relative TRO (TRO_y/TRO_0)	Relative B10+ ($B10+_y/B10+_0$)	F-to-F_{msy} ratio	TRO_y/TRO_{MSY}	MSY
2023	0.23 (0.21-0.29)	0.22 (0.19-0.26)	0.46 (0.34-0.65)	0.85 (0.61-1.29)	30,648 (29,152-31,376)
2020	0.2 (0.16-0.24)	0.17 (0.14-0.21)	0.52 (0.37-0.73)	0.69 (0.49-1.03)	33,207 (31,471-34,564)

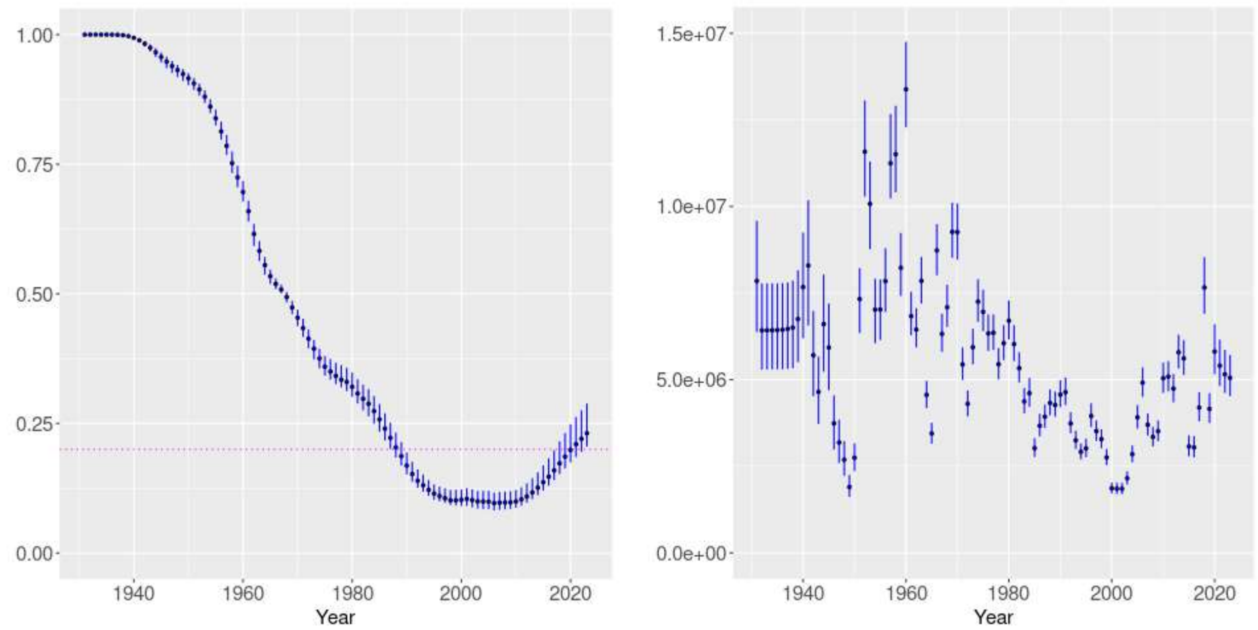

Figure 1 Relative TRO (left) and recruitment (right) summaries – median and 80% CI – for the reference set of OMs

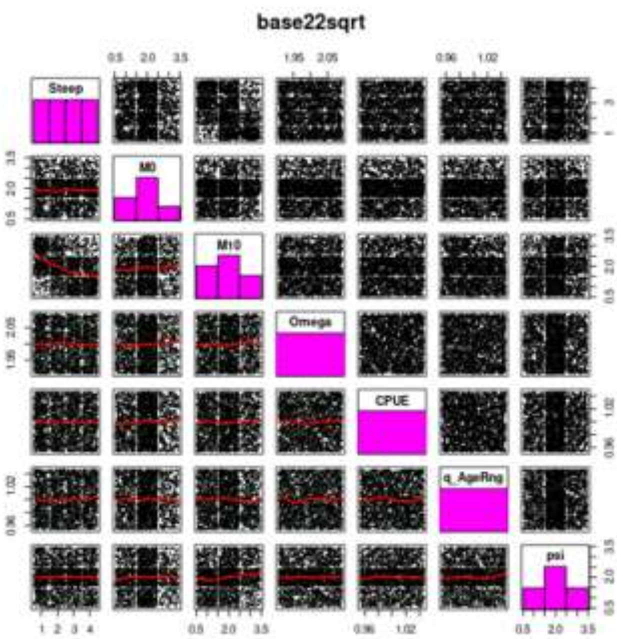

Figure 2 Level plot for grid variables in reference set of OMs.

3.2 Summary of data fits for the reference set of OMs

3.2.1 CPUE index

Figure 3 shows the predictive summary for the single longline CPUE indices used in the reference set. The fits to the index are good with all but two of the observed points sitting within the 95% predictive interval. In terms of predictive *p*-value (a value of 0.08), we see that the observed data are *less* variable than the predicted data. This is a direct consequence of the minimum CV of 0.2 used for the CPUE data, whereas the empirical SD is closer to 18%. The model cannot, however, fit well to the large increase from 2021 to 2022 and the index value for 2022 is just contained by the upper 95% envelope. The impact of this has been explored in sensitivity tests.

3.2.2 Aerial survey

Figure 3 also shows the predictive summary for the aerial survey index. The survey index generally fits well except for the 2016 high point that sits well outside the 95% predictive interval. The predictive *p*-value suggests that the observed data is more variable than the predicted data (*p*-value of 0.87), which is a consequence of fixing the process error SD at 0.22, whereas the empirical estimate is a little higher at around 0.29.

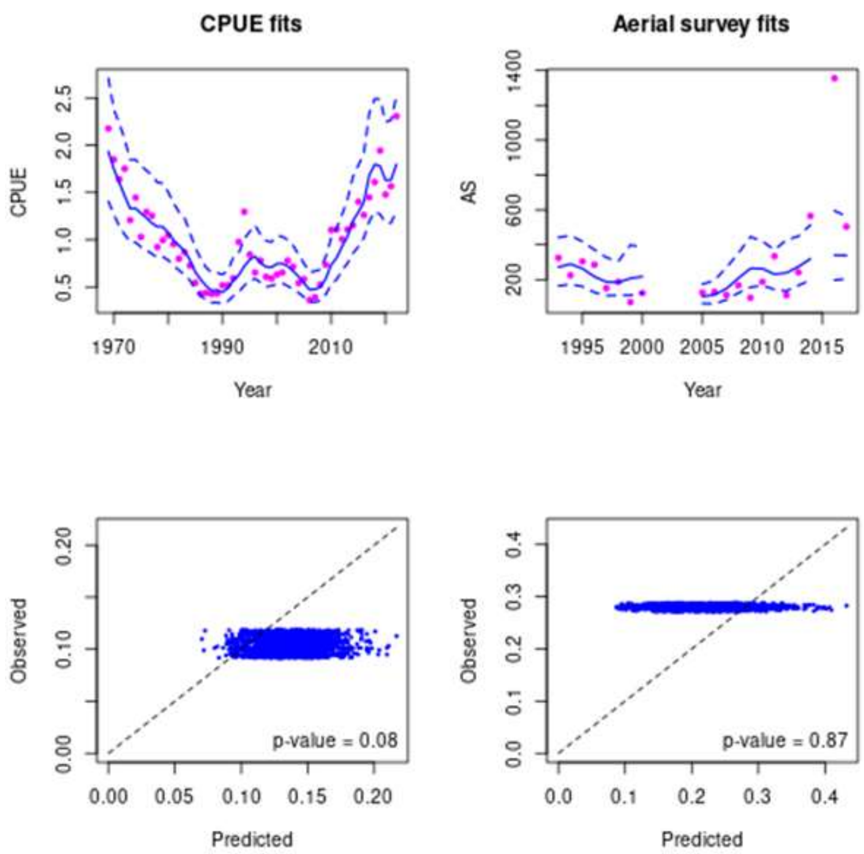

Figure 3 Abundance indices (CPUE, left; Aerial survey, right) predictive summary (distribution top, p-values bottom) with observed data magenta circles and predictive median (blue full line) and approximate 95% CI (blue dotted lines).

3.2.3 Conventional tagging data

Figure 4 shows a summary of the fits to the conventional tagging data, for the best fitting grid cell within the reference set, for pooled and cohort of release aggregation levels. Figure 5 shows the fits to the tagging data for the best fitting grid cell aggregated only across the tagger groups (at the release/recapture age and year level). For each full reconditioning of the OMs we reassess the value of the conventional tagging overdispersion parameter, φ^{tag}. This value has been calculated as the level of overdispersion that ensures that the variance in the *overall* standardised tag residuals is equal to 1: this is the most important feature of the "variability assumed going into the model is the same as that after fitting the model" approach to statistical data weighting. For the updated reference set of OMs, the mean value of the variance of the standardised conventional tag residuals was 1.02 with minimal variability across grid cells (range of 0.99-1.05). This suggests that the current estimate of $\varphi^{tag} = 1.82$ is appropriate.

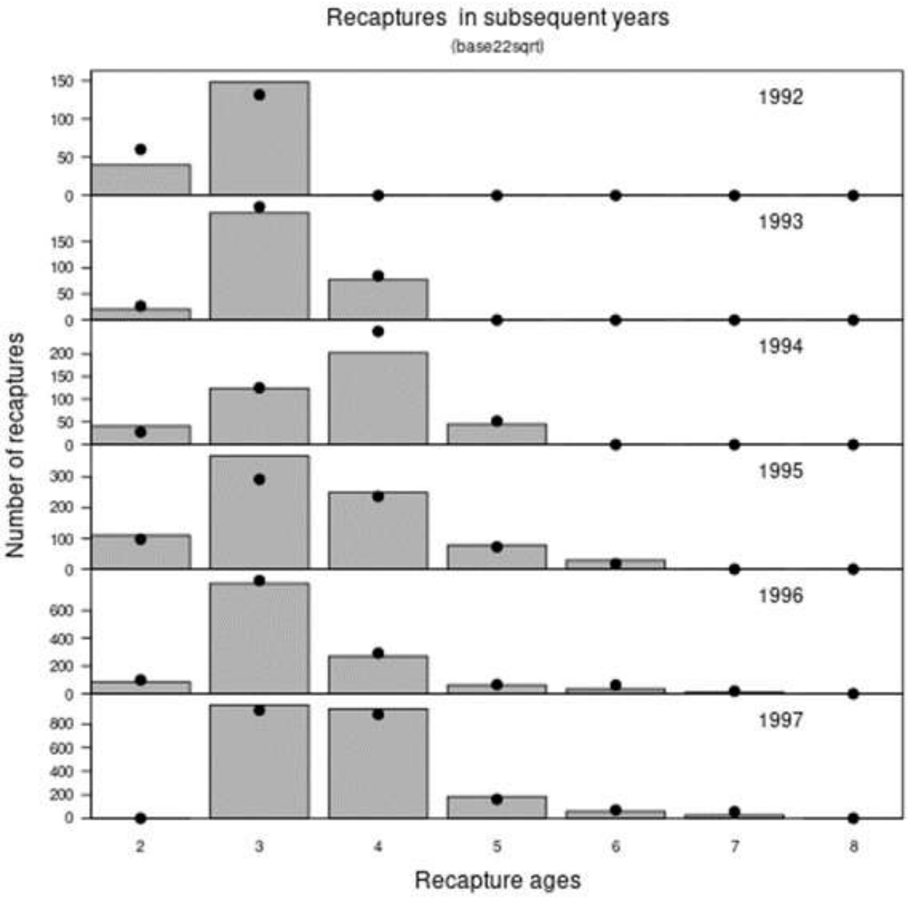

Figure 4 Conventional tagging data fits, for the best fitting grid element, aggregated to the recapture age and year level.

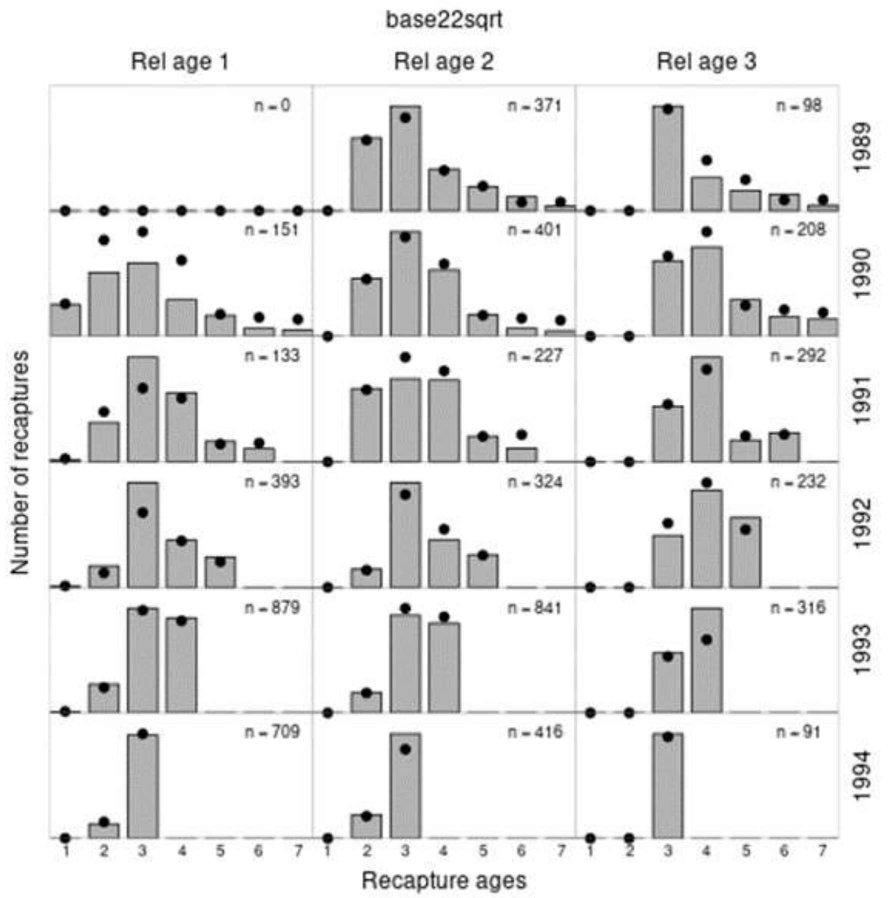

Figure 5 Conventional tagging data fits, for the best fitting grid element, at the release/recapture/year level.

3.2.4 Gene tagging data

Figure 6 shows the predictive summary of the gene tagging data used in the reference set. The five years of data are fitted well, with all the observed points sitting well within the predictive 95% interval. We do not attempt to estimate the a posteriori over-dispersion variable for the gene tagging for this assessment, given the short length (five years) of the time series. Given the observed number of matches all sit well within the predictive intervals from the OM there is certainly no strong indication of overdispersion in these data. It will likely take up to 10 years of data before we can robustly estimate this parameter. Note we do not have a gene tagging estimate of age 2 abundance for 2020 due to the impacts of the COVID pandemic on the program in that year.

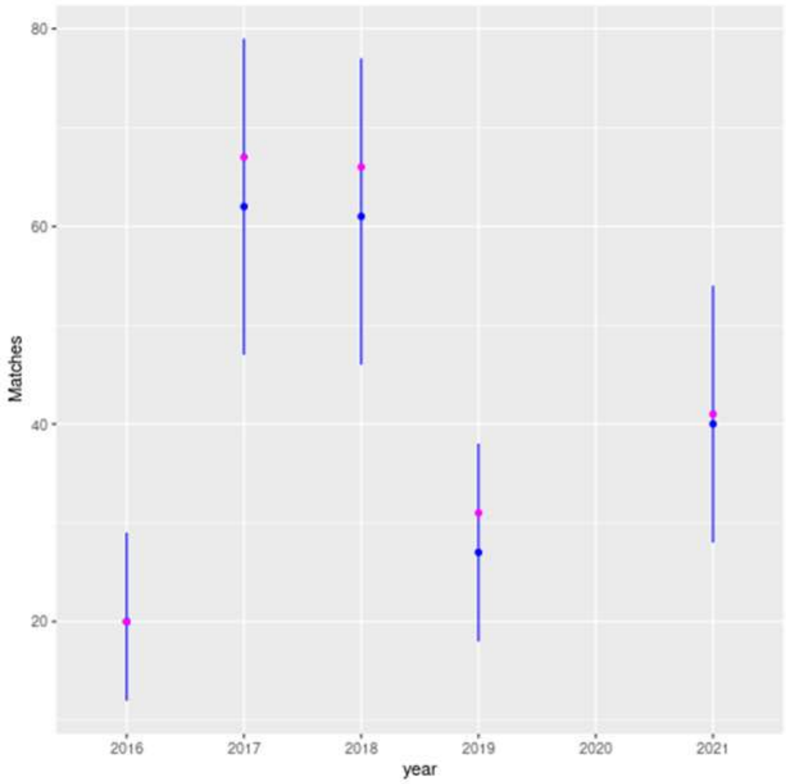

Figure 6 Predictive summary for the gene tagging matches (minus 2020 which is a missing year for these data) in terms of observed (magenta) and predicted (blue dots and 95% CI whiskers) across the OM.

3.2.5 CKMR data

Figure 7 shows the predictive fits to the POP data aggregated to: a) the juvenile cohort level, b) to the adult capture age level, and c) to the adult capture year level. Figure 8 shows the predictive fits to the HSP data aggregated to the initial cohort level and the fully disaggregated (i.e. both cohorts of the juveniles being compared) HSP data. Figure 9 shows the predictive summary for both the POP and HSP data. The CKMR data are fitted well at all aggregation levels with no obvious issues around specific juvenile cohort effects (e.g. spawning failure), adult age effects (e.g. misspecification of the $\varphi_{y,a}$ relationship, which defines the relative reproductive output-at-age in the OMs), or adult sampling year effects (e.g. years where we sampled only a subset of the adults). The predictive *p*-values (Figure 9) all suggest that the likelihood in the OM is doing an acceptable job of explaining the variability in the data without the need for additional variance (i.e. overdispersion). This means that we are very likely to be weighting these important data correctly.

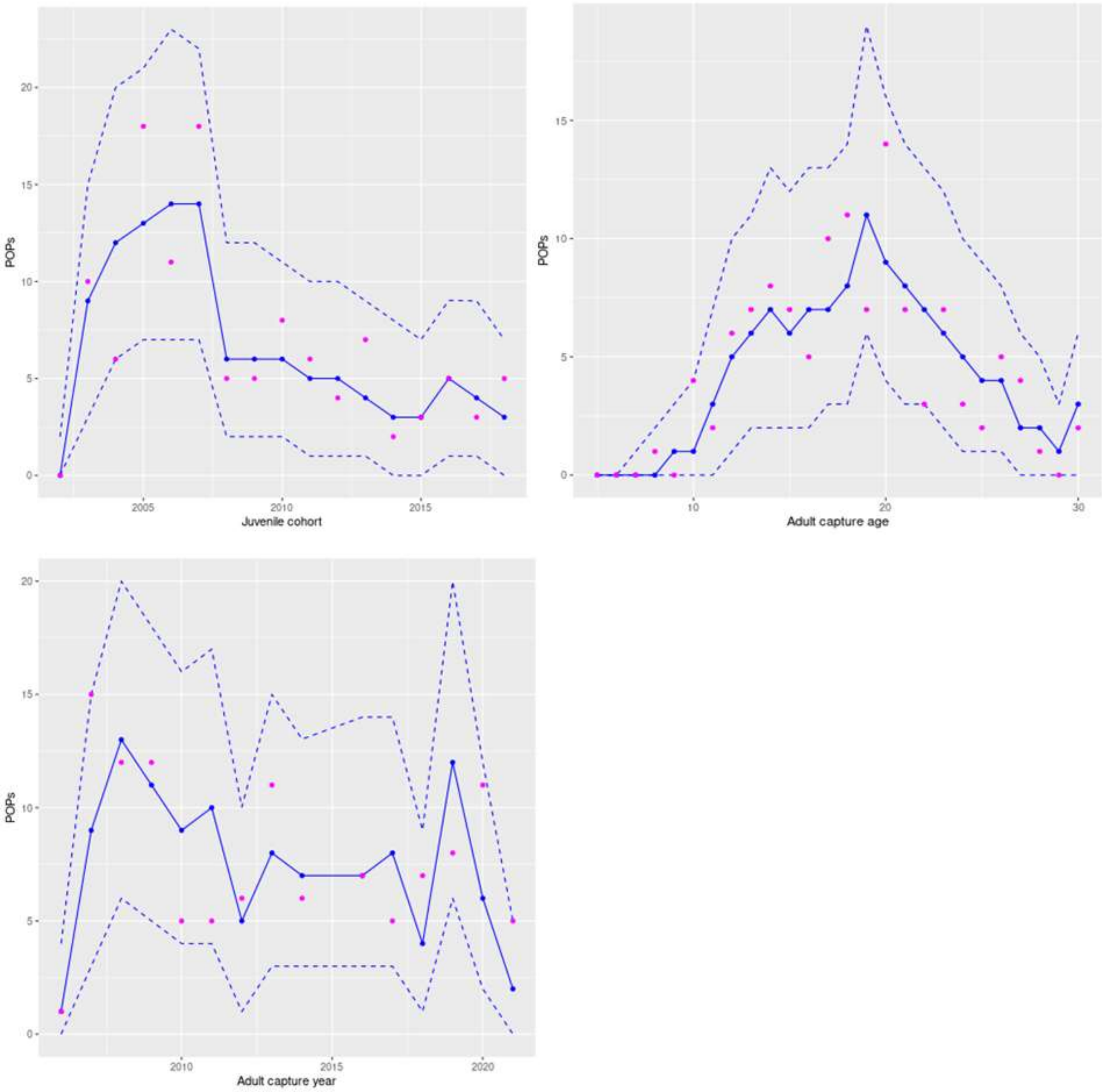

Figure 7 Predictive summary for the CKMR POP data at the juvenile cohort (top left), adult capture age (top right), and adult capture year (bottom) level in terms of observations (magenta circles) and predicted median (blue line) and 95% CI (dotted blue line).

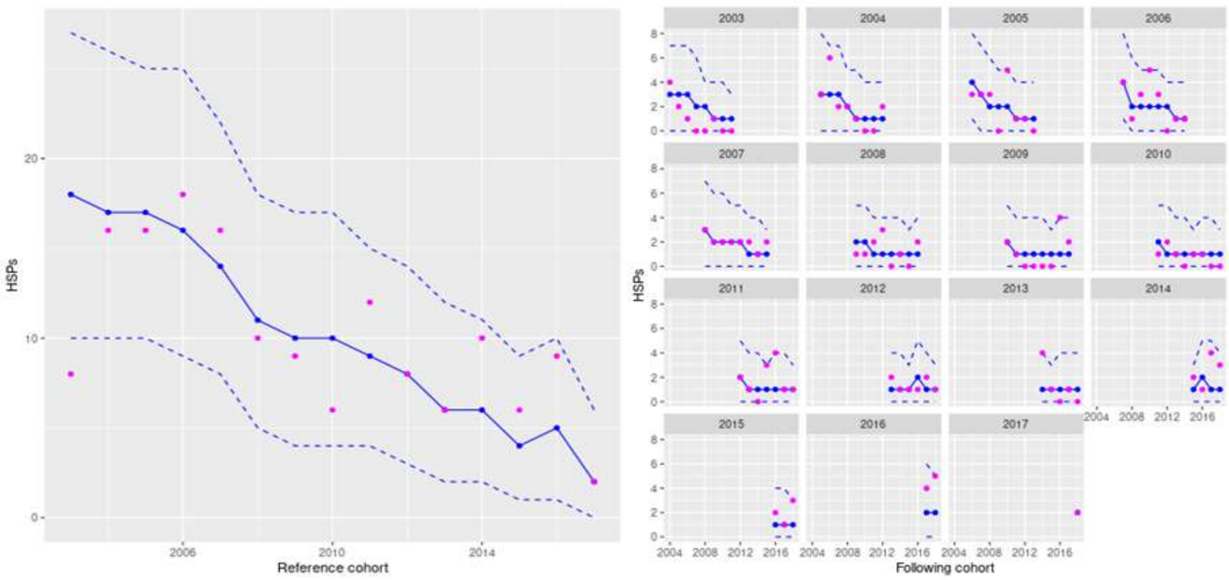

Figure 8 Predictive summary for the CKMR HSP data at the initial cohort (left) and base aggregation (right) level in terms of observations (magenta circles) and predicted median (blue line) and 95% CI (dotted blue line).

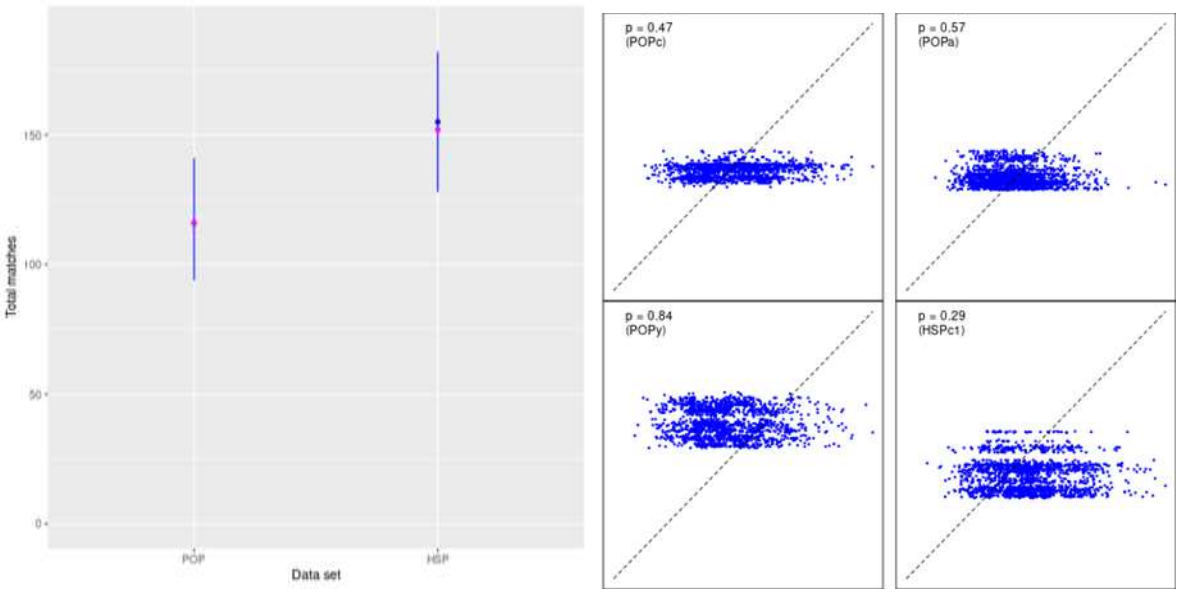

Figure 9 Predictive summary for overall POPs and HSPs (left) and predictive p-values (right) across the data aggregations for both POPs and HSPs.

3.2.6 Size and age frequency data

Figure 10 shows the fits to the size frequency data for the LL_1 to LL_4 fleets, respectively. Figure 11 shows the fits to the age data for the surface fishery and Indonesian fishery, respectively. The fits to the main fleets (LL_1, LL_2, surface, Indonesian) are all good and consistent with previous assessments (Anon., 2020).

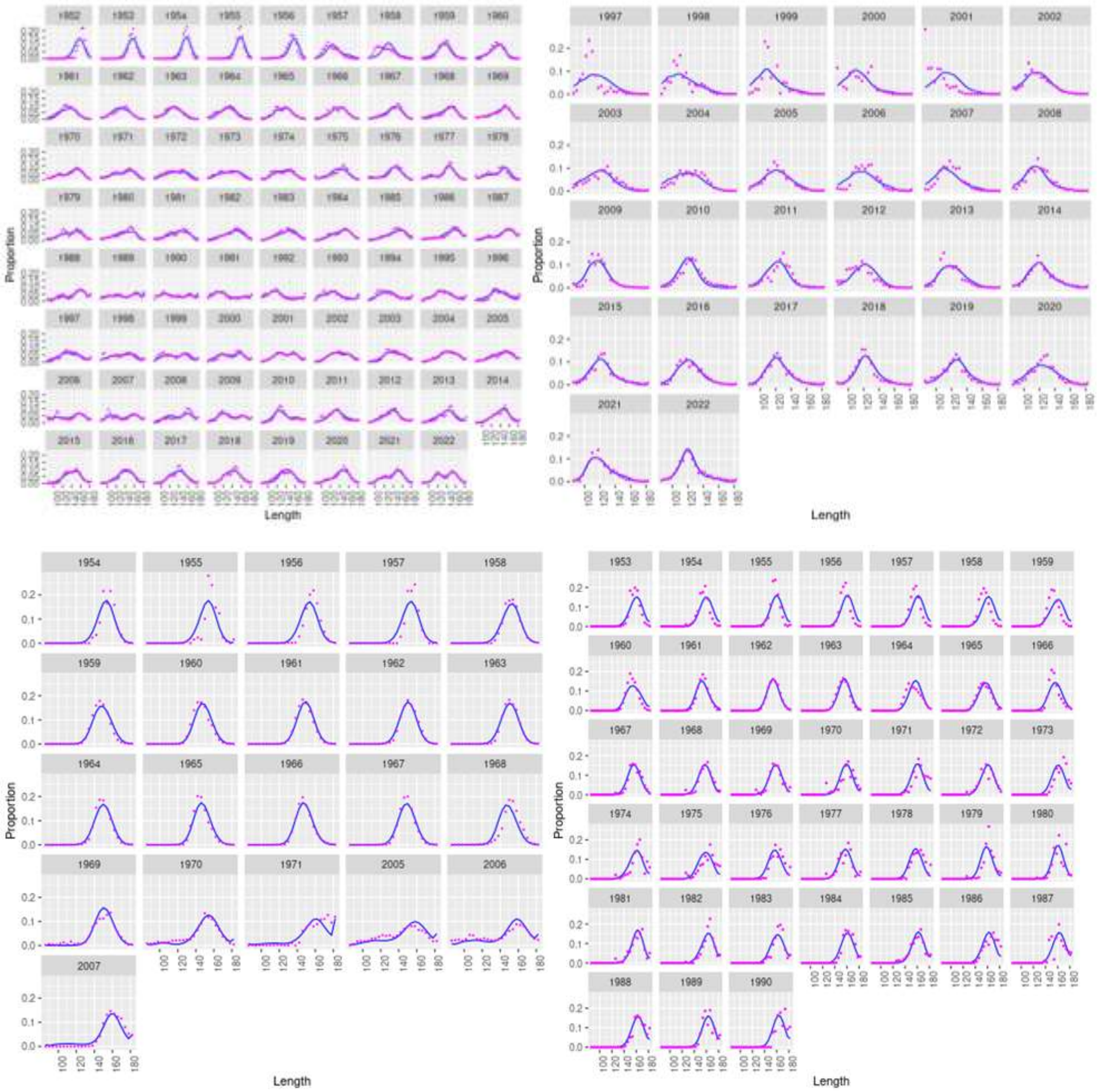

Figure 10 Fitting summary for the LL fleets (LL1 to LL4 clockwise from the top left) for the best fitting grid cell.

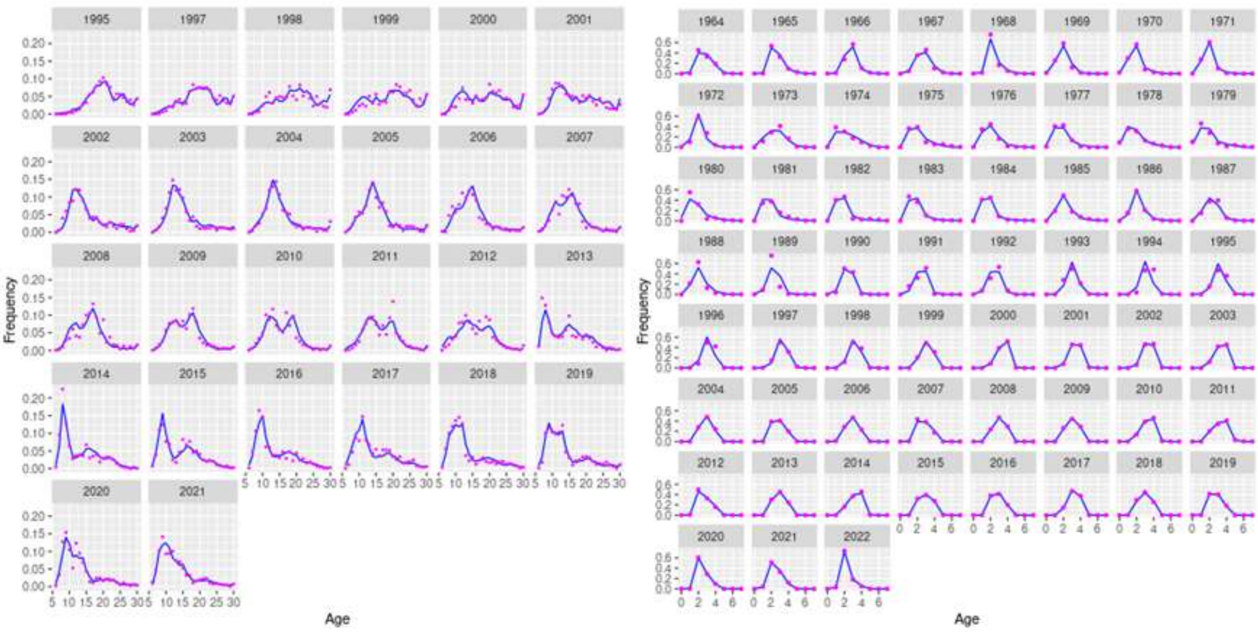

Figure 11 Fitting summary for the Indonesian (left) and surface (right) fishery age data for the best fitting grid cell.

3.3 Summary of stock status results for the sensitivity tests

The stock status results for the sensitivity tests are compared with the reference set (top row) in Table 5. The estimates of current stock status (relative TRO depletion, i.e., TRO_{2023}/TRO_0) are reasonably consistent across the sensitivity tests. Most sensitivity test results are the same as, or slightly more optimistic than, the reference set of models. The highest current stock status estimates are from the 'Q age range' scenario. The 'Upq2008' and 'No_Pop&HSP' sensitivity tests are pessimistic relative to reference set, but both have a median depletion in TRO (TRO_{2023}/TRO_0) that is greater than or equal to 0.2 (the original interim rebuilding target).

Table 5 Stock status sensitivity test results

Run	Relative TRO (TRO_{2023}/TRO_0)	Relative B10+	F-to-F_{msy}	TRO_{2023}/TRO_{MSY}	MSY
Reference Set 2023: base22	0.23 (0.21-0.29)	0.22 (0.19-0.26)	0.46 (0.34-0.65)	0.85 (0.61-1.29)	30,648 (29,152-31,376)
UAMbycatch	0.23 (0.21-0.29)	0.22 (0.19 -0.27)	0.46 (0.34-0.65)	0.86 (0.61-1.30)	30,325 (28,832-31,052)
No UAM	0.23 (0.21-0.29)	0.22 (0.20-0.27)	0.46 (0.33-0.66)	0.87 (0.62-1.31)	30,072 (28,594-30,820)
LL1 case2 of MR	0.23 (0.20-0.28)	0.21 (0.19-0.26)	0.46 (0.33-0.65)	0.84 (0.60-1.26)	30,968 (29,370-31,688)
CPUE_Drop5	0.23 (0.20-0.29)	0.22 (0.19-0.27)	0.48 (0.35-0.68)	0.85 (0.59-1.29)	30,534 (29,026-31,290)
Omega75	0.25 (0.22-0.30)	0.23 (0.20-0.28)	0.42 (0.31-0.61)	0.90 (0.64-1.36)	31,580 (29,862-32,435)
Upq2008	0.2 (0.17-0.25)	0.18 (0.15-0.23)	0.52 (0.37-0.76)	0.73 (0.5-1.13)	30,278 (28,810-31,162)
Q age range	0.26 (0.23-0.32)	0.25 (0.22-0.30)	0.40 (0.30-0.56)	0.98 (0.69-1.34)	31,467 (29,871-32,307)
LL1_sel	0.23 (0.21-0.29)	0.22 (0.19-0.26)	0.48 (0.35-0.67)	0.85 (0.61-1.29)	30,343 (28,880-31,071)
Indo_sel	0.25 (0.22-0.31)	0.23 (0.2-0.28)	0.46 (0.32-0.63)	0.88 (0.64-1.39)	30,809 (29,554-31,508)
No POP & HSP	0.22 (0.2-0.24)	0.2 (0.19-0.22)	0.5 (0.39-0.62)	0.77 (0.65-1.05)	31,011 (29,118-31,637)
No HSP	0.24 (0.21-0.28)	0.22 (0.19-0.27)	0.46 (0.35-0.65)	0.86 (0.62-1.18)	30,733 (29,239-31,382)
GTI	0.24 (0.21-0.29)	0.22 (0.19-0.27)	0.58 (0.42-0.82)	0.87 (0.61-1.31)	28,796 (27,538-29,477)

3.4 Summary of projection results for the reference set of OMs

Projections are run for the reference set of models to review the estimated probability of rebuilding the stock to the target level by 2035. The projections were run using the Cape Town Procedure (CTP) to set future TACs in the simulations and the results are in Table 6. These show there is a 51% probability of being greater than 30% of TRO_0 in 2035, which is slightly above the target (50% probability of being 0.3TRO in 2035 is the current target of the CTP). The estimated probability is likely to change over time as new data is included in the models, and the timeframe gets shorter. The projections show there is a very high probability (96%) of being greater than the original interim target of $0.2TRO_0$ by 2035 (the original interim target was 70% probability of being greater than $0.2TRO_0$ by 2035). The estimated depletion in 2035 is 0.3 (0.22-0.41) which is on target and an improvement on the estimates from 2022 when projections were run to check performance of the MP. The estimated depletion in 2040 is also 0.3 which indicates that the MP will attempt to maintain TRO at this target level. The mean TAC from the current year through to 2035 is 22,884t (22,528-23,938), indicating that current global TAC is approaching upper limits under the current reference set.

In addition to the reference set, the full set of sensitivity tests results are reported this year (Table 6). As expected from results in previous years, the projection results for the sensitivity tests show a much wider range of results than in the stock status estimates. Overall, the probability of rebuilding to the target is greater than 50% for 7 of the 12 sensitivity tests. All sensitivity test projections indicate that rebuilding performance is better than the interim rebuilding target (Pr 70% of $0.2TRO_0$ by 2035). The mean TAC from current through to 2035 is reasonably consistent across sensitivity tests.

The alternative UAM scenarios (‘UAM bycatch’ and ‘No UAM’) are more optimistic than the reference set, as less catch is being taken in future in these scenarios. The more constrained selectivity changes for the Indonesian fishery (‘IndoSel’) gives more optimistic results.

The CPUE related sensitivity tests ‘Case 2 MR’, ‘Omega75 and ‘Q-age-range’ also have more optimistic estimates. The other CPUE sensitivity tests (‘CPUE_Drop5’, ‘LL1sel’, ‘upq2008’) are more pessimistic. The Drop5 sensitivity test, where the last five years of the CPUE index are excluded, has a probability of reaching the 2035 target of 45% (below target of 50%), and the estimated TRO in 2035 is 0.29 (0.21-0.40) which is similar to the reference set results but slightly under the target of 0.3. The ‘LL1sel’ allows for more flexibility in estimating the last 3-years selectivity to evaluate impact on year-class uncertainty and magnitude, and the results are very similar to the ‘CPUE_Drop5’ sensitivity test. The ‘upq2008’ sensitivity test uses an estimated increase in LL1 q (catchability) from 2008 onwards. This test, for uncertainty in the relationship between CPUE and abundance, was developed to address changes in fishing operations and possible increases in catchability which don’t relate to increased abundance (Anon, 2011). Even under this most pessimistic test the projections show further rebuilding, although slower and below the current target.

The sensitivity test where HSP is excluded is slightly more pessimistic and in the case where all CKMR data are excluded from the models the results are much more pessimistic. These results indicate that these data are highly informative (POP and HSP data) and influential in the models.

The GTI (trolling index) sensitivity run gave the estimated TRO in 2035 of 0.25 (0.18-0.35). The probability of being above 0.3 TRO_0 in 2035 for this sensitivity scenario is 0.24. This illustrates the impact of the lower levels of recruitment indicated from the troll survey on future recovery. This highlights the importance of continuing to monitor recruitment at this stage of rebuilding the stock and the value of the information from the trolling survey, gene-tagging program, and longline CPUE.

Table 6 Projection summary (median and 80% CI), using the updated reference set of OMs and the CTP, and projections results for the sensitivity tests.

Run	$P(TRO_{2035} > 0.2TRO_0)$	$P(TRO_{2035} > 0.3TRO_0)$	TRO_{2025}/TRO_0	TRO_{2035}/TRO_0	TRO_{2040}/TRO_0	Mean TAC to 2035
Base22 (reference set)	0.96	0.51	0.25 (0.22-0.31)	0.30 (0.22-0.41)	0.30 (0.19-0.45)	22,884 (22,528-23,938)
UAMbycatch	0.97	0.56	0.26 (0.23-0.31)	0.31 (0.23-0.42)	0.31 (0.20-0.46)	22,939 (22,528-23,939)
NoUAM	0.99	0.60	0.26 (0.23-0.32)	0.32 (0.23-0.42)	0.32 (0.21-0.47)	22,897 (22,528-23,939)
case2 MR	0.96	0.52	0.25 (0.22-0.31)	0.30 (0.22-0.41)	0.30 (0.19-0.45)	22,851 (22,528-23,937)
CPUE_Drop5	0.93	0.45	0.25 (0.22-0.31)	0.29 (0.21-0.40)	0.29 (0.18-0.44)	23,546 (20,556-24,771)
Omega75	0.98	0.63	0.27 (0.24-0.33)	0.33 (0.24-0.43)	0.32 (0.20-0.48)	23,548 (20,556-24,493)
Indosel	0.97	0.56	0.27 (0.24-0.34)	0.31 (0.22-0.43)	0.31 (0.19-0.48)	23,590 (22,575-23,983)
LL1sel	0.94	0.46	0.25 (0.22-0.31)	0.29 (0.21-0.40)	0.29 (0.18-0.44)	22,816 (22,528-23,938)
Upq2008	0.79	0.29	0.22 (0.18-0.27)	0.25 (0.17-0.36)	0.24 (0.14-0.40)	23,913 (22,619-24,079)
Q age range	1.0	0.73	0.29 (0.26-0.35)	0.35 (0.26-0.45)	0.34 (0.22-0.50)	22,594 (22,528-23,881)
No HSP	0.95	0.5	0.26 (0.23-0.31)	0.30 (0.22-0.40)	0.3 (0.19-0.44)	22,877 (22,528-23,939)
No CKMR	0.94	0.35	0.24 (0.22-0.26)	0.28 (0.21-0.36)	0.27 (0.18-0.41)	23,913 (22,528-24,167)
GTI	0.80	0.24	0.25 (0.22-0.30)	0.25 (0.18-0.35)	0.24 (0.14-0.38)	23,509 (20,556-24,263)

4. Summary

The 2023 stock assessment, which incorporates recent data up to 2022 and a revised reference set of OMs, indicates that the stock has continued to rebuild since the last assessment in 2020. The median (and 80% CI) estimate of TRO depletion for the reference set is 0.23 (0.21-0.29). The estimate of B10+ depletion ($B10^{+}_{2023}/B10^{+}_{0}$), which was a metric used historically because of limited knowledge of maturity and no close-kin data, is also above interim target for rebuilding the stock at 0.22 (0.19-0.26). Fishing mortality is estimated to be below estimates of F_{MSY} levels 0.46 (0.34-0.65). The estimated MSY is lower than in the previous assessment.

The fits to data are generally good. The fit to the CPUE index is reasonably good apart from lack of fit to the large increase from 2021 to 2022. The OMMP working group explored potential reasons for the CPUE increase, and recommended sensitivity tests that check on the impacts of these high points on the assessment results. The pessimistic CPUE related sensitivity tests had only a small impact on current stock status estimates.

The aerial survey data are well fitted with the exception of the very high 2013 index point, which is consistent with the result in the previous assessment. Fits to the conventional tagging data are good and similar to previous years – the currently assumed over-dispersion factor for these data is still appropriate. The gene tagging data are fitted well with all five estimates sitting within the OM's predictive intervals. The fits to the CKMR data – both POPs and HSPs – were good with the overall number and age structure in the POPs well explained and no obvious adult capture year or juvenile cohort effects apparent in the fits. The HSPs were also well explained with no obvious juvenile cohort effects and were very consistent with the POP data as well. The fits to the size data for the main long-line fleets, LL1 and LL2, were good, as were the fits to the age data for the Indonesian and surface fisheries. There were no obvious issues with the fits to any of the data sets used in conditioning the reference set of OMs.

The sensitivity tests showed results consistent with the reference set of models for current stock status metrics. Median current depletion ranged from 0.2 to 0.26 across sensitivity tests with lowest and highest 80% CI estimates of 0.17 and 0.32 respectively.

The projections using the reference set of models indicate that the CTP is on track to meet the current target of $0.3TRO_0$ in 2035. The estimated depletion in 2035 is 0.3 (0.22-0.41), and the probability of being greater the 0.3 TRO_0 in 2035 is 0.51. This result is a slight improvement on the projection estimates from 2020 which indicated that rebuilding may be slightly slower than planned (Hillary et al, 2020). These results are likely to change again in future with more data informing recent higher recruitments and the high CPUE data points in 2022.

The CPUE sensitivity test where the most recent 5 years of the index are not used ('CPUE_Drop5') and the 'LL1sel' sensitivity test both shows that the estimated depletion in 2035 is close to the target of 0.3. The probability of being above 0.3 TRO_0 in 2035 is 0.45 and 0.46 respectively, which is less than the target probability of 0.5. The 'upq2008' sensitivity test is the most pessimistic: estimated depletion in 2035 is 0.25, and probability of being above $0.3TRO_0$ is 0.29. In the assessment of stock status there is a small negative impact on the current depletion estimate compared to the reference set, but even under this most pessimistic test the estimated current median depletion is 0.2 (above the original interim rebuilding target). The projections results show further rebuilding above current levels, although it is slower and below the current rebuilding target.

Overall, the sensitivity tests do not indicate any issues with the estimates of current stock status, or with rebuilding of the stock in future.

The 2023 stock assessment indicates that the stock is continuing to rebuild, is above the interim rebuilding target and commonly used limit reference point equivalent to $0.2TRO_0$, and the stock is predicted to continue rebuilding under catches determined by the CTP.

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