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The assessment of stock status in 2020

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Abstract

This paper details the reconditioning of the CCSBT Operating Models (OM) for the 2020 assessment of stock status. It includes updated data series, up to and including 2019, and is the first stock assessment to include the gene-tagging estimates of 2 year old abundance. The reference set of OMs and sensitivity tests agreed at the 11th OMMP meeting were run along with projections (using the adopted Cape Town Procedure (MP)) for the priority sensitivities. The revised CPUE series were fitted well; and the aerial survey is fitted fairly well apart from the very high 2016 index, which is consistent with the previous assessment. Fits to the conventional tagging data are good, and the assumed value of the over-dispersion factor for these data is still considered appropriate. The gene tagging data were fitted well, with all three estimates sitting within the OM's predictive intervals. The fits to the CKMR data – both parent offspring (POPs) and half-sibling pairs (HSPs) – were good with the overall number and age structure of 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 consistent with the POP data, also. 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. For the reference set of OMs, median (and 80% CI) estimates of: Total Reproductive Output (TRO) relative depletion were 0.2 (0.16-0.24); relative depletion of biomass aged 10+ were 0.17 (0.14-0.21); the ratio of current fishing mortality and adult biomass relative to MSY were 0.52 (0.37-0.73) and 0.69 (0.49-1.03), respectively; the relative TRO at MSY was 0.3 (0.22-0.35); and estimates of MSY were 33,207 (31,471-34,564) tonnes. All the key stock status statistics are more optimistic than in 2017 when the last assessment was completed. Projections using the MP for the reference set of OMs resulted in TRO depletion by 2035 of 0.29 (0.19-0.43) – just below the previously tuned median value of 0.3 from the 2019 MP testing. Under the same projections the target (30% TRO depletion) is projected to be achieved in 2037, with median catches of around 20,800 tonnes for the 2020 to 2035 period. The probability of the relative TRO depletion being above 20% by 2035 is 0.86 – which is greater than the previous interim rebuilding probability objective of 0.7. The reason for the slighter slower predicted rebuilding is a combination of: (i) a downward revision of the size of the 2013 year class given updated data; and (ii) the increase in the potential levels of non-member Unaccounted Mortality (UAM) assumed in the current Reference set of OMs.

Introduction

The 2020 stock assessment is the first full assessment since 2017 (Anon., 2017) and the first SBT stock assessment to use the data on juvenile abundance from the CCSBT gene-tagging program. The stock assessment is scheduled for 2020 as part of the activities of the new Cape Town Procedure (MP) adopted in 2019 (Anon., 2019b). The stock assessment is usually offset from providing TAC advice, however the first year of implementation of the MP was delayed by 1 year to allow more time for selection from the set of candidate MPs. The CCSBT Operating Models (OM) used for the stock assessment has been reconditioned to include new (gene tagging) and updated data for the regular data sources. Structural changes to the OM required for gene tagging were implemented, reviewed and accepted at the 10th OMMP meeting in June 2019 (Anon., 2019a), with the inclusion of the gene tagging data agreed at the 2019 ESC (Anon., 2019b). The 11th OMMP technical meeting in June 2020 considered the preliminary OM reconditioning and revised the reference set of OMs and sensitivity tests to be used in the 2020 assessment of stock status at the ESC. The new assessment provides current estimates of stock status and progress with rebuilding the SBT stock under the TAC recommendations from the Bali Procedure (2012-2020), which was replaced by the Cape Town Procedure in 2019 (Anon 2019b and c).

New and updated data sources

The new data source being used for the first time in a full reconditioning of the OM and associated stock assessment is the gene tagging data (Preece et al. 2020). As of 2020, there are now three years of available data which inform absolute age-2 abundance in 2016, 2017 and 2018. Table 1 summarises the gene tagging data as it is used in the OM.

Release year	Release age	Recapture year	Releases	Resamples	Matches	Abundance (% CV)
2016	2	2017	2,952	15,390	20	2.27e+6 (0.22)
2017	2	2018	6,480	11,932	67	1.15e+6 (0.12)
2018	2	2019	6,295	11,980	66	1.14e+6 (0.12)

Table 1: Summary table of the gene tagging data used for the first time in a full reconditioning of the CCSBT OM.

The updated data sources are:

- Catch and Catch composition (age or length) for each fishery
- Japanese long-line CPUE indices: two new GAM indices using 0.6 and 0.9 constant-versus-variable squares spatial weightings respectively and the base CPUE indices using 0.5 and 0.8 weightings (Anon., 2020)
- CKMR POP and HSP data ranging from 2003 to 2015 in terms of adult abundance timeframes (Farley *et al.* (2020))
- Estimates of the potential scale of non-member catches (Edwards et al., 2020)
- Grid-type trolling index (TRG) (Itoh and Tsuda, 2020)

Structural OM settings and grid configuration

While the uncertainty grid is a key part of the OM set up process, there are a number of other key parameter settings that need to be reviewed/modified when running the SBT OM reconditioning code. Table 2 details the key non-grid related parameters and settings used in the updated OM reconditioning. Table 3 outlines the uncertainty grid levels and sampling protocols agreed at the 2020 OMMP technical meeting (Anon., 2020).

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

Table 2: key non-grid related fixed parameters in the current OM reconditioning.

Variable	Value	CumulN	Prior	Sampling
h (steepness)	0.55, 0.63, 0.72, 0.8 [0.6, 0.7, 0.8]	4	Uniform	Prior
M_0	0.4, 0.45, 0.5 [0.35, 0.4, 0.45, 0.5]	12	Uniform	ObjFn
M_{10}	0.065, 0.085, 0.105 [0.05, 0.085, 0.12]	36	Uniform	ObjFn
Omega (ω)	1	36	Uniform	Prior
CPUE series	gam11 (w0.6, w0.9) [GLM-based w0.5, w0.8]	72	Uniform	Prior
CPUE age range	4-18, 8-12	144	0.67, 0.33	Prior
Psi (ψ)	1.5, 1.75, 2	432	0.25, 0.5, 0.25	Prior

Table 3: The Reference set of grid variables, values, priors and sampling protocols. The grid configuration used for the last stock assessment (2017) is also shown in square brackets for comparison.

Reference set and sensitivity tests

The reference set of OMs is specified in Table 3. Table 4 summarises the sensitivity tests agreed to at the 11th OMMP technical meeting for the current stock assessment as well as their relative priority on a scale of low (L), medium (M), and high (H).

Test name	Code	Role	Priority
UAM1	UAM1	Alternative UAM scenario	H
UAMbycatch	UAMbycatch	Uses LL2 catchability to estimate UAM	H
No UAM	noUAM	Removal of all UAM	H
LL1 Case 2 of MR	case2	Alternative historical LL1 overcatch series	L
SFO00	sfo00	Zero surface fishery overcatch	L
Old CPUE series	oldbase	Uses the previous w0.5 and w0.8 GLM standardisation	H
S50CPUE	cpues50	50% of LL1 overcatch influences CPUE	M
Omega75	cpueom75	Sublinear relationship between CPUE and abundance	H
Upq2008	cpueupq	25% increase in LL1 q from 2008 onwards	H
GLMM	glmm	Use of mixed model CPUE index standardisation	M
CPUE ages 5 to 9	cpue59	Use ages 5 to 9 in LL1 q calculation	M
Bridging	bridge	As feasible, link 2017 assessment to 2020 assessment	H
IS20	fis20	Indonesian selectivity fixed after age 20 not 25	M
Aerial2016	as2016	Remove 2016 aerial survey index	H
NoPOP or HSP	noCKMR	Exclude all the CKMR data	H
Omit GT	getout	Exclude all the gene tagging data	H
GTI	troll	Include the GTI recruitment index	M
POPs only	justPOPs	Use only the POPs not the HSPs	H

Table 4: Sensitivity tests (and associated codes), role, and priority ranked from low (L), to medium (M) to high (H).

Stock status summary for the reference set of OMs

Figure 1 shows the level plot for the grid used to generate the reference set of OMs. Table 5 provides the key stock status variables (in terms of medians and 80% CI) such as the depletion and MSY ratios. The current depletion estimates are 0.2 (0.16-0.24) for Total Reproductive Output (TRO) and 0.17 (0.14-0.21) for the biomass of animals aged 10+. Figure 2 shows a boxplot summary of all the key stock status ratios. Figure 3 shows the relative TRO and historical recruitment estimates for the reference set of OMs. **All of the key stock status summary ratios are improvements on their 2017 counterparts, except the F-to-F_{msy} ratio which is very similar.**

Statistic	Assessment year	Relative TRO	Relative B10+	F-to-F_{msy} ratio	B-to-B_{msy} ratio	B_{msy}-to-B_0 ratio	MSY
Summary	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)	0.3 (0.22-0.35)	33,207 (31,471-34,564)
	2017	0.13 (0.11-0.17)	0.11 (0.09-0.13)	0.5 (0.38-0.66)	0.49 (0.38-0.69)	0.27 (0.22-0.32)	33,036

Table 5: Key stock status summaries in terms of the median and 80% CI in brackets. The results of the last stock assessment (2017) are also shown for comparison.

Summary of data fits for the reference set of OMs

CPUE indices

Figure 4 shows the predictive summary for the two CPUE indices used in the reference set. The fits to both indices are good with all the observed points sitting within the 95% predictive interval. In terms of predictive *p*-value, 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 15%.

Aerial survey

Figure 5 shows the predictive summary for the aerial survey index. The survey index is generally fitted 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 a little more variable than the predicted data, which is a consequence of fixing the process error SD at 0.22, whereas the empirical estimate is a little higher at around 0.25.

Conventional tagging data

Figure 6 shows a summary of the fits to the conventional tagging data for the best fitting grid cell within the reference set at the pooled and cohort of release aggregation levels. 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 crux 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 1.01 with minimal variability across grid cells (range of 0.99-1.04). This suggests that the current estimate of $\varphi^{tag} = 1.82$ is appropriate.

The final additional checks are to ensure that this result is consistent across the key conventional tagging release covariates: tagger, release cohort, and release age. The average overdispersion values for the tagger group was 0.99; for the cohort of release it was 0.99; and for the age of release it was 1.02. There were no systematic departures from an average overdispersion of 1 for any of the tag release covariate groupings. For the grid-averaged residuals we also explore any potential linear effects on recaptures, given the release covariates, using a simple model with three covariates as factors. Only one term was significant: that for tagger number 6; all other terms were insignificant. The conclusion is that the conventional tag data are appropriately statistically weighted and that there are no obvious trends in the recaptures related to the key release covariates.

Gene tagging data

Figure 7 shows the predictive summary of the gene tagging data used in the reference set. The three years of data are fitted well, with all the observed points sitting well within the predictive 95% interval. The last two years' matches are *slightly* underestimated, which reflects a minor tension between the recruitment penalty pulling the OM estimates back up towards the mean. We do not attempt to estimate the *a posteriori* over-dispersion variable for the gene tagging for this assessment given the short length (three 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 between 5-10 years of data before we can robustly estimate this parameter.

CKMR data

Figure 8 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 juvenile cohort and adult capture year level. Figure 9 shows the predictive fits to the HSP data aggregated to the initial cohort level and the fully disaggregated HSP data. Figure 10 shows the predictive p-value 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 defining 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 all suggest that the likelihood in the OM is doing a good 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.

Size and age frequency data

Figure 11 shows the fits to the size frequency data for the LL_1 to LL_4 fleets, respectively. Figure 12 shows the fits to the surface fishery and Indonesian age data, respectively. The fits to the main fleets (LL_1, LL_2, surface, Indonesian) are all good and consistent with previous assessments (Anon., 2017).

Summary of projection results for the reference set of OMs

As has been done in the past, we completed projections using the Cape Town Procedure (CTP) and the *historical* GLM-based w0.5 and w0.8 indices adopted with it, using the current reference set of OMs (which use the revised GAM CPUE indices using the w0.6 and w0.9 spatial weightings). Table 6 summarises the key performance statistics for these projections.

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
base	0.86	0.47	0.24 (0.19-0.29)	0.29 (0.19-0.43)	0.31 (0.17-0.51)	20,816 (17,83-21,282)

Table 6: Projection summary - medians and 80% CI - for the CTP using the updated reference set of OMs and using the w0.5 and 0.8 CPUE indices adopted as part of the CTP.

Summary of sensitivity tests

Table 7 and 8 detail the key stock status summaries and projections results, respectively, for the sensitivity tests in Table 4. The projections show that the CTP does not quite achieve the tuning target of a median TRO depletion of 0.3 by 2035 – it reaches a median of 0.29 with a probability of 0.47 for being above 0.3. For the reference set, the target is attained in 2037, with a slow but consistent increase to 0.37 by 2050. Given the estimated level of current depletion (TRO_{2020}/TRO_0) is more optimistic relative to the reconditioning in 2019 for final MP testing, when the CTP was tuned, what is causing this slight decrease in projected rebuilding performance? There are two very likely factors at play:

1. A new CPUE series was used in the historical conditioning which has altered (revised downwards) the very high estimates of the 2013 year-class. The new CPUE series (which lacks the extreme spike in 2018 evident in the previous series), which should have seen the 2013 cohort at least twice, is not as consistent with such a high value for this year-class as the CPUE series used to test and tune the MP in 2019.

2. The new non-member estimates of potential unaccounted mortality have been added as catches in the LL1 fishery, which has resulted in a higher level of LL1 catch than used in the testing of the MP (NB: the Non-member catches are less than the total UAM1 scenario which also has a substantial (1000t) small fish component). This means a higher level of catch in LL1 is being taken from the stock in the future years, than was the case for the MP testing, thus affecting projected recovery dynamics.

Run	Relative TRO	Relative B10+	F-to-F_{msy}	TRO-to-TRO_{msy}	TRO_{msy}-to-TRO_0	MSY
base19	0.2 (0.16-0.24)	0.17 (0.14-0.21)	0.52 (0.37-0.73)	0.69 (0.49-1.03)	0.3 (0.22-0.35)	33,207 (31,471-34,564)
getout	0.2 (0.17-0.25)	0.17 (0.14-0.21)	0.43 (0.3-0.61)	0.71 (0.52-1.06)	0.3 (0.22-0.35)	33,663 (31,652-35,378)
noCKMR	0.16 (0.13-0.2)	0.13 (0.11-0.17)	0.62 (0.48-0.8)	0.56 (0.43-0.78)	0.3 (0.22-0.35)	33,407 (31,397-34,619)
justPOPs	0.18 (0.15-0.22)	0.16 (0.13-0.2)	0.55 (0.39-0.76)	0.64 (0.46-0.96)	0.3 (0.22-0.34)	33,003 (31,328-34,159)
as2016	0.19 (0.16-0.23)	0.17 (0.14-0.21)	0.56 (0.4-0.81)	0.67 (0.47-1)	0.3 (0.22-0.34)	32,686 (31,013-33,990)
Omega75	0.2 (0.16-0.24)	0.17 (0.14-0.21)	0.48 (0.38-0.68)	0.7 (0.5-1.06)	0.3 (0.22-0.34)	34,645 (32,650-36,320)
is20	0.22 (0.18-0.26)	0.19 (0.15-0.22)	0.53 (0.35-0.73)	0.73 (0.51-1.17)	0.31 (0.22-0.35)	34,003 (32,255-34,998)
a59	0.22 (0.18-0.26)	0.2 (0.16-0.23)	0.44 (0.32-0.61)	0.76 (0.57-1.13)	0.3 (0.22-0.34)	34,054 (32,302-35,793)
cpues50	0.19 (0.15-0.23)	0.16 (0.13-0.19)	0.55 (0.39-0.76)	0.65 (0.47-0.97)	0.3 (0.22-0.34)	32,666 (30,935-33,828)
UAM1	0.2 (0.16-0.23)	0.17 (0.14-0.20)	0.6 (0.43-0.85)	0.68 (0.49-1.01)	0.3 (0.22-0.35)	32,947 (31,153-34,347)
noUAM	0.2 (0.17-0.24)	0.18 (0.14-0.21)	0.52 (0.37-0.73)	0.7 (0.5-1.05)	0.3 (0.22-0.34)	32,642 (30,906-33,991)
bridging	0.18 (0.14-0.23)	0.15 (0.12-0.19)	0.54 (0.4-0.71)	0.64 (0.49-0.94)	0.27 (0.22-0.32)	33,405 (32,246-34,738)
case2	0.19 (0.16-0.23)	0.17 (0.14-0.2)	0.52 (0.37-0.72)	0.67 (0.48-1)	0.3 (0.22-0.34)	33,728 (31,878-35,066)
UAMbycatch	0.2 (0.16-0.24)	0.18 (0.14-0.21)	0.52 (0.37-0.73)	0.7 (0.5-1.04)	0.3 (0.22-0.34)	32,793 (31,062-34,134)
glmm	0.18 (0.14-0.22)	0.15 (0.12-0.18)	0.58 (0.4-0.79)	0.61 (0.44-0.92)	0.3 (0.22-0.34)	33,060 (31,337-34,506)
troll	0.21 (0.17-0.25)	0.19 (0.15-0.22)	0.54 (0.39-0.75)	0.72 (0.51-1.07)	0.3 (0.22-0.35)	31,952 (30,496-33,160)
oldbase	0.18 (0.14-0.22)	0.15 (0.12-0.19)	0.55 (0.39-0.76)	0.63 (0.46-0.95)	0.3 (0.22-0.34)	33,211 (31,427-34,656)
sfo00	0.19 (0.16-0.23)	0.16 (0.14-0.2)	0.47 (0.34-0.68)	0.68 (0.48-1.01)	0.3 (0.22-0.34)	32,083 (30,341-33,251)

Table 7: Stock status summaries – medians and 80% CI - for the sensitivity tests outlined in Table 4.

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
Base	0.86	0.47	0.24 (0.19-0.29)	0.29 (0.19-0.43)	0.31 (0.17-0.51)	20,816 (17,83-21,282)
UAM1	0.82	0.41	0.24 (0.19-0.29)	0.28 (0.19-0.42)	0.3 (0.16-0.48)	20,572 (17,833-21,049)
noUAM	0.9	0.53	0.25 (0.2-0.31)	0.31 (0.2-0.45)	0.33 (0.19-0.53)	20,990 (17,835-21,479)
bridging	0.84	0.42	0.22 (0.18-0.28)	0.28 (0.18-0.42)	0.3 (0.17-0.49)	20,610 (17,833-21,115)
oldbase	0.81	0.41	0.23 (0.17-0.28)	0.28 (0.17-0.42)	0.3 (0.16-0.5)	20,453 (17,832-20,921)

Table 8: Projection summaries- medians and 80% CI - for prioritised sensitivity tests.

Discussion

This paper details the reconditioning of the CCSBT OM, and subsequent stock assessment, for data up to and including 2019. As is customary, the reference set of OM and sensitivity grid structures agreed at the 11th OMMP meeting (Anon., 2020) were run and 2,000 samples from these grids were taken to be used in the various summaries and projections. The reference and sensitivity grids were fitted to the agreed and updated data sets, with projections (using the adopted Cape Town Procedure) run on the sensitivities agreed at the OMMP meeting.

For the reference set of OMs, median (and 80% CI) estimates of TRO relative depletion were 0.2 (0.16-0.24); estimates of the relative depletion of aged 10+ were 0.17 (0.14-0.21); the ratio of current fishing mortality and adult biomass relative to MSY were 0.52 (0.37-0.73) and 0.69 (0.49-1.03), respectively; the relative TRO at MSY was 0.3 (0.22-0.35); and estimates of MSY were 33,207 (31,471-34,564) tonnes. All the key ratio status variables are more optimistic than 2017 when the last assessment was undertaken (Table 5). In terms of projections for the reference set of OMs, the TRO depletion by 2035 is 0.29 (0.19-0.43) – just below the previously tuned median value of 0.3 from 2019. The target (30% TRO depletion) is projected to be attained in 2037, with median catches of around 20,800 tonnes from 2020 to 2035. The probability of the relative TRO depletion being above 20% by 2035 is 0.86 – which is greater than the previous interim rebuilding probability objective of 0.7. The reason for the slighter slower projected rebuilding is a combination of: (i) a downward revision of the size of the 2013 year class, given updated data; and (ii) the increase in the historical levels of non-member UAM being assumed in the current Reference set of OMs, which then flows into the future overall removals in projections.

The fits to the abundance indices for the reference set of OMs are generally good: both CPUE series are fitted well; the aerial survey is fairly well fitted apart from the very high 2013 index, which is consistent with the previous assessment. Fits to the conventional tagging data are good and, understandably, similar to previous years – the currently assumed over-dispersion factor for these data was still appropriate also. The gene tagging data – a new data set not included in previous assessments – was fitted well with all three 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, LL_1 and LL_2, 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.

Summarising the stock status across the sensitivity tests (Table 7) we see a generally consistent pattern across the key variables of interest. For relative TRO depletion the median range was 0.16-0.22 while the lowest and highest 80% CI were 0.13 and 0.26, respectively. For relative depletion in 10+ biomass, the median range was 0.13-0.2 and the lowest and highest 80% CI were 0.11 and 0.23, respectively. Median current-to-MSY ratios for fishing mortality and relative TRO were 0.43-0.62 and 0.56-0.76, respectively. The TRO depletion at which MSY would be attained had a median range of 0.27-0.31, with the lowest and highest 80% CI were 0.22 and 0.35, respectively. Values of median MSY ranged from 32,000-34,700 tonnes.

Summarising the projections for the subset of sensitivity tests (Table 8), we do see some clearer differences in projection dynamics. The tests with the bridging, oldbase (CPUE) and UAM1 scenarios, all look similar. They all miss reaching the MP tuning objective (median TRO depletion of 30% by 2035) by a small amount, but hit the target by 2040. The base and noUAM scenarios are fairly similar – the noUAM scenario is obviously more optimistic and slightly overshoots the target, while the base scenario just misses the target (but reaches it by 2037). Overall the sensitivity tests do not indicate any issues with the 2020 stock assessment and rebuilding of the stock in future.

Acknowledgements

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Figures

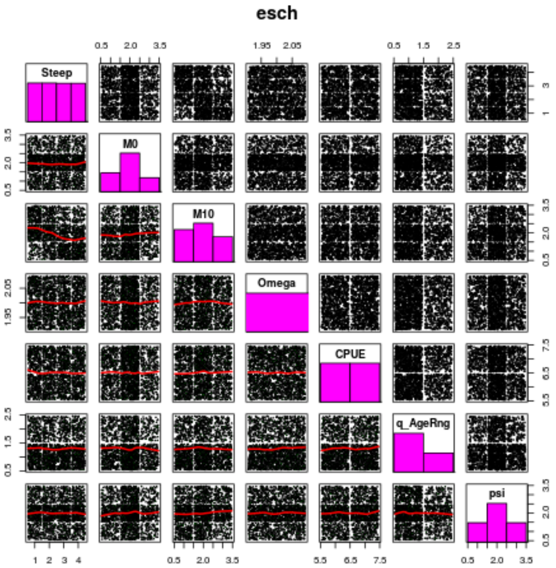

Figure 1: Level plot for grid variables in reference set of OMs (see Table 3 for details).

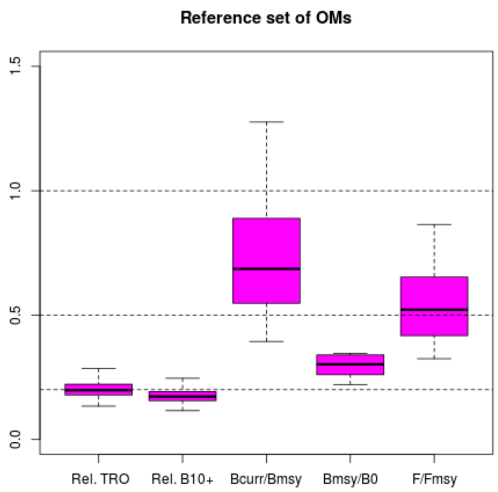

Figure 2: Summary of stock status ratio statistics for reference set of OMs.

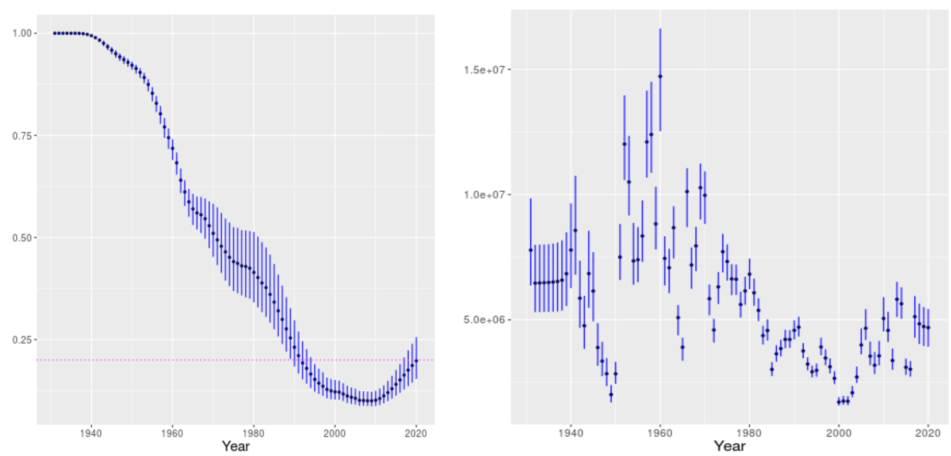

Figure 3: Relative TRO (left) and recruitment (right) summaries – median and 80% CI – for the reference set of OMs.

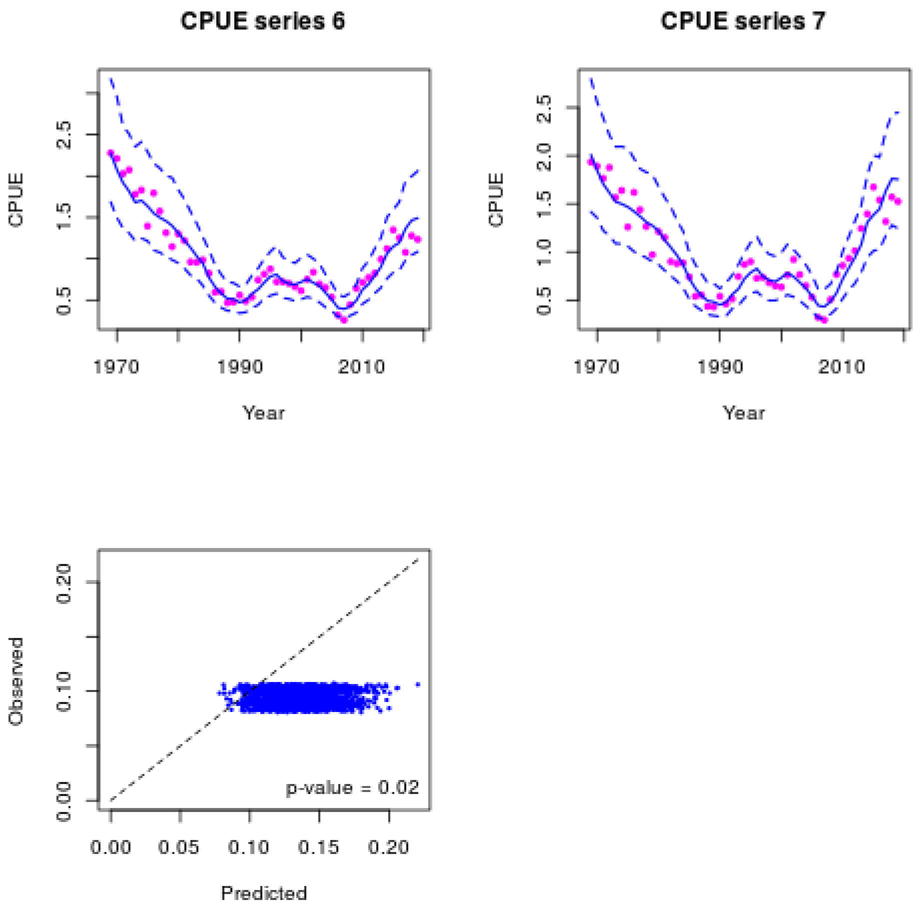

Figure 4: Predictive summary for the two CPUE series used in reference set of OMs. The upper two panels show the fits to the data (magenta); the lower panel the overall predictive p-value for the two series.

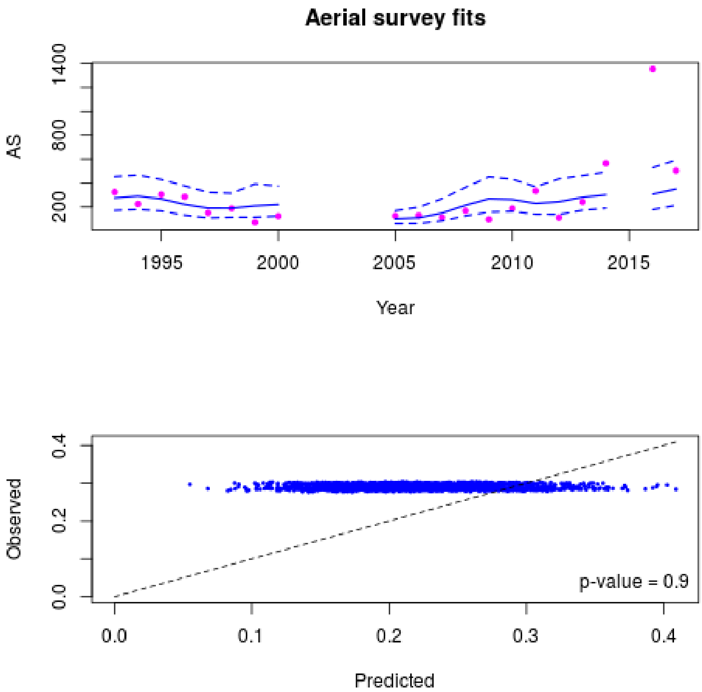

Figure 5: Predictive summary for the aerial survey index used in reference set of OMs. The upper panel show the fits to the data; the lower panel the overall predictive p-value for the series.

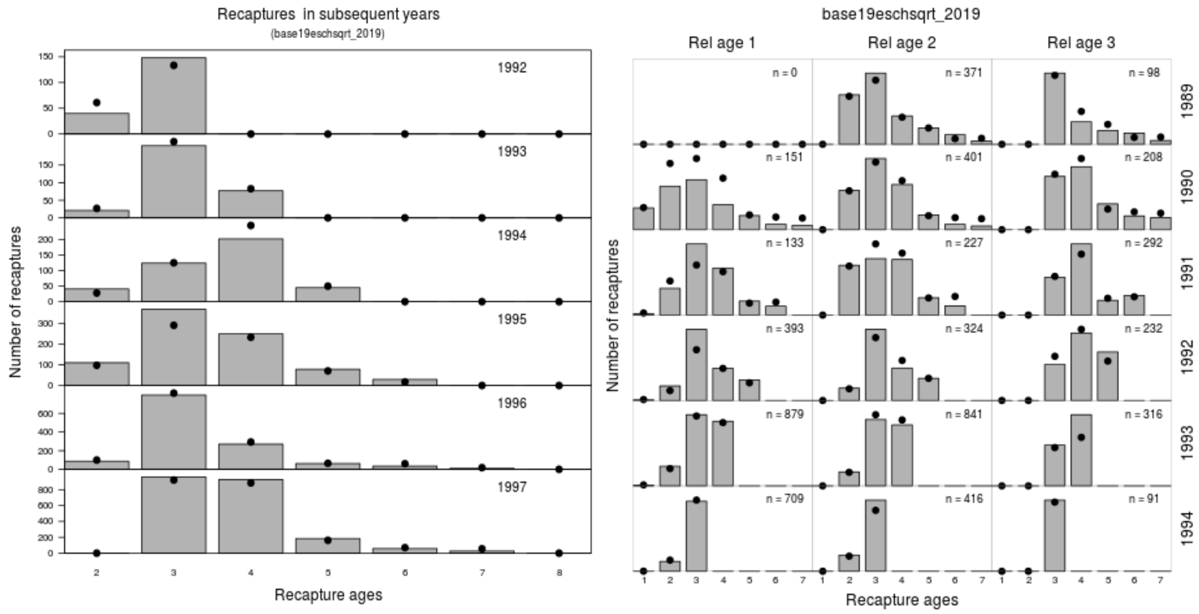

Figure 6: Fits to the conventional tag data (dots) for the pooled (left) and cohort of release (right) aggregation levels for the best fitting grid cell in the reference set of OMs.

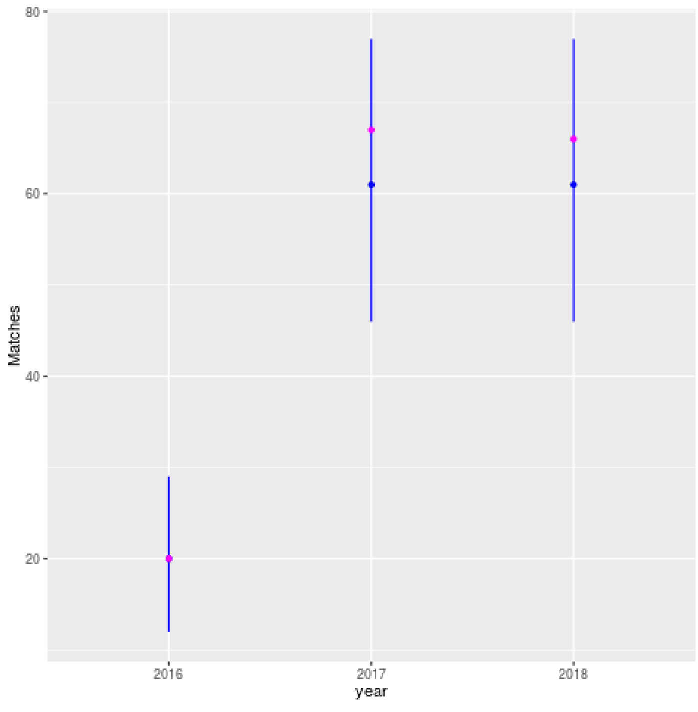

Figure 7: Predictive summary for the gene tagging data (magenta) included in the reference set of OMs. We plot only the predictive fits to the data as the series is currently too short to calculate a meaningful predictive p-value.

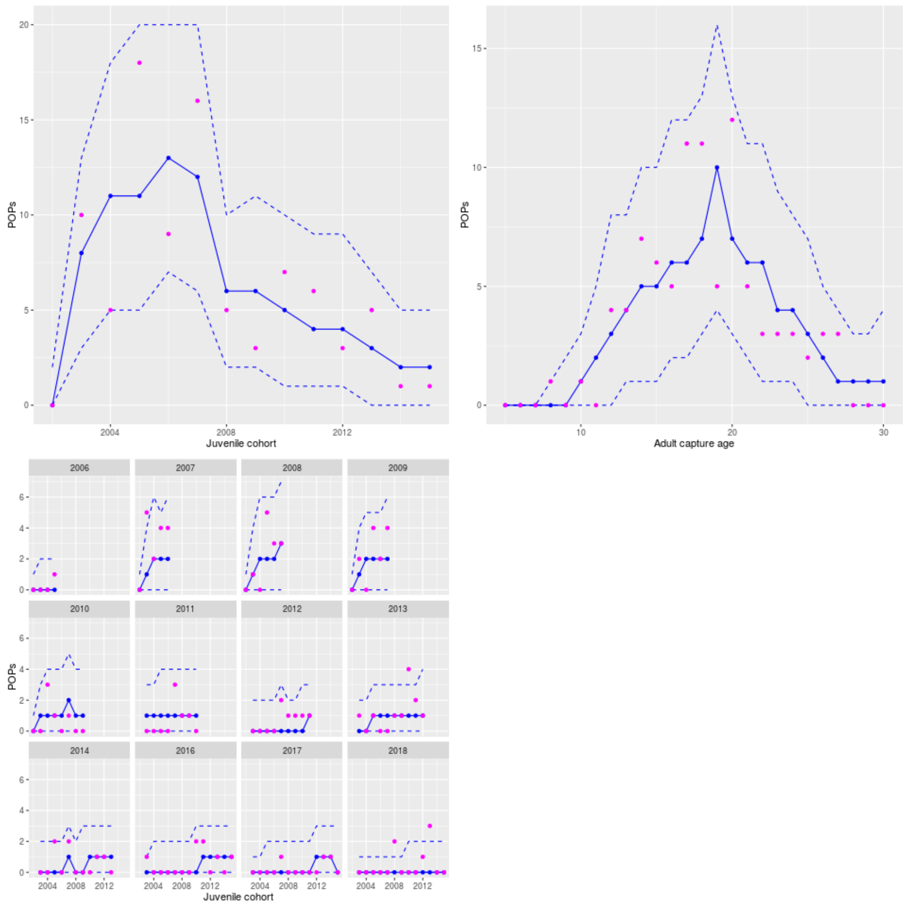

Figure 8: Predictive fits to the POP data (magenta) for the juvenile cohort aggregation level (top left), adult capture age level (top right), and juvenile cohort and adult capture year level (bottom right).

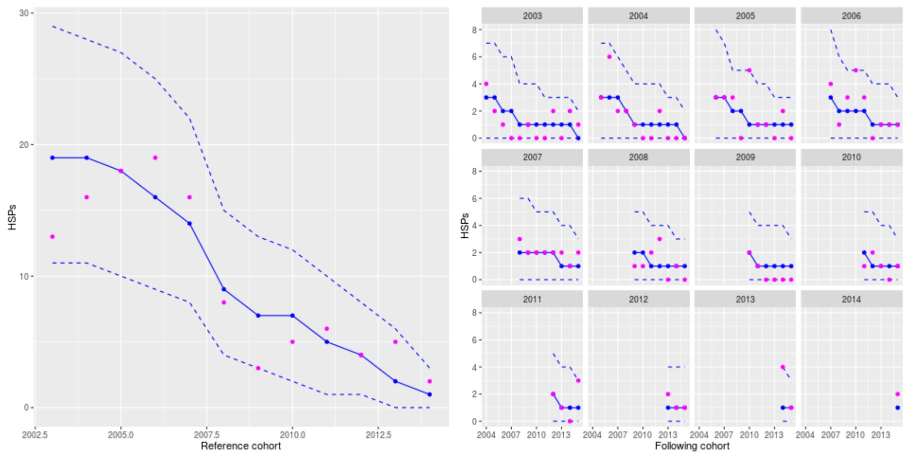

Figure 9: Predictive fits to the HSP data (magenta) for the initial cohort aggregation level (left), and the full disaggregation level (right).

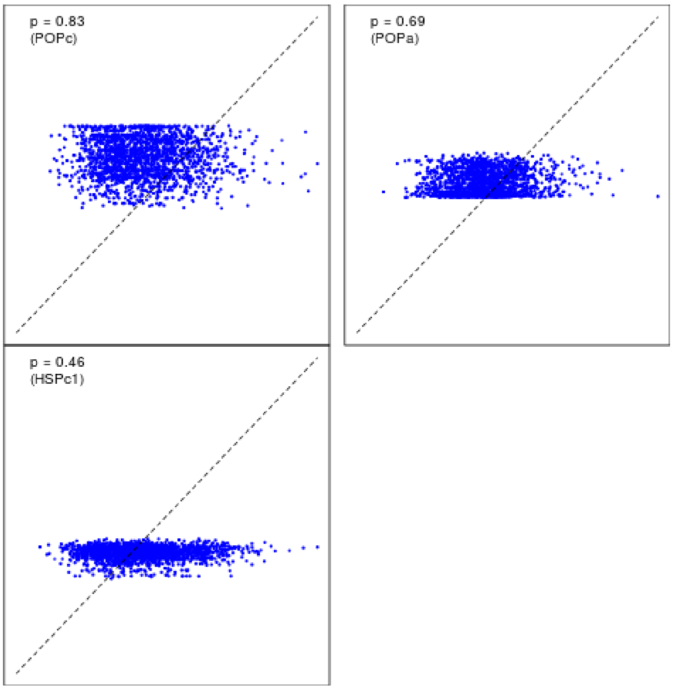

Figure 10: Predictive p-value summary for the CKMR data: POPs at initial cohort level (top right); POPs at adult capture age level (top left); HSPs at initial cohort level (bottom right).

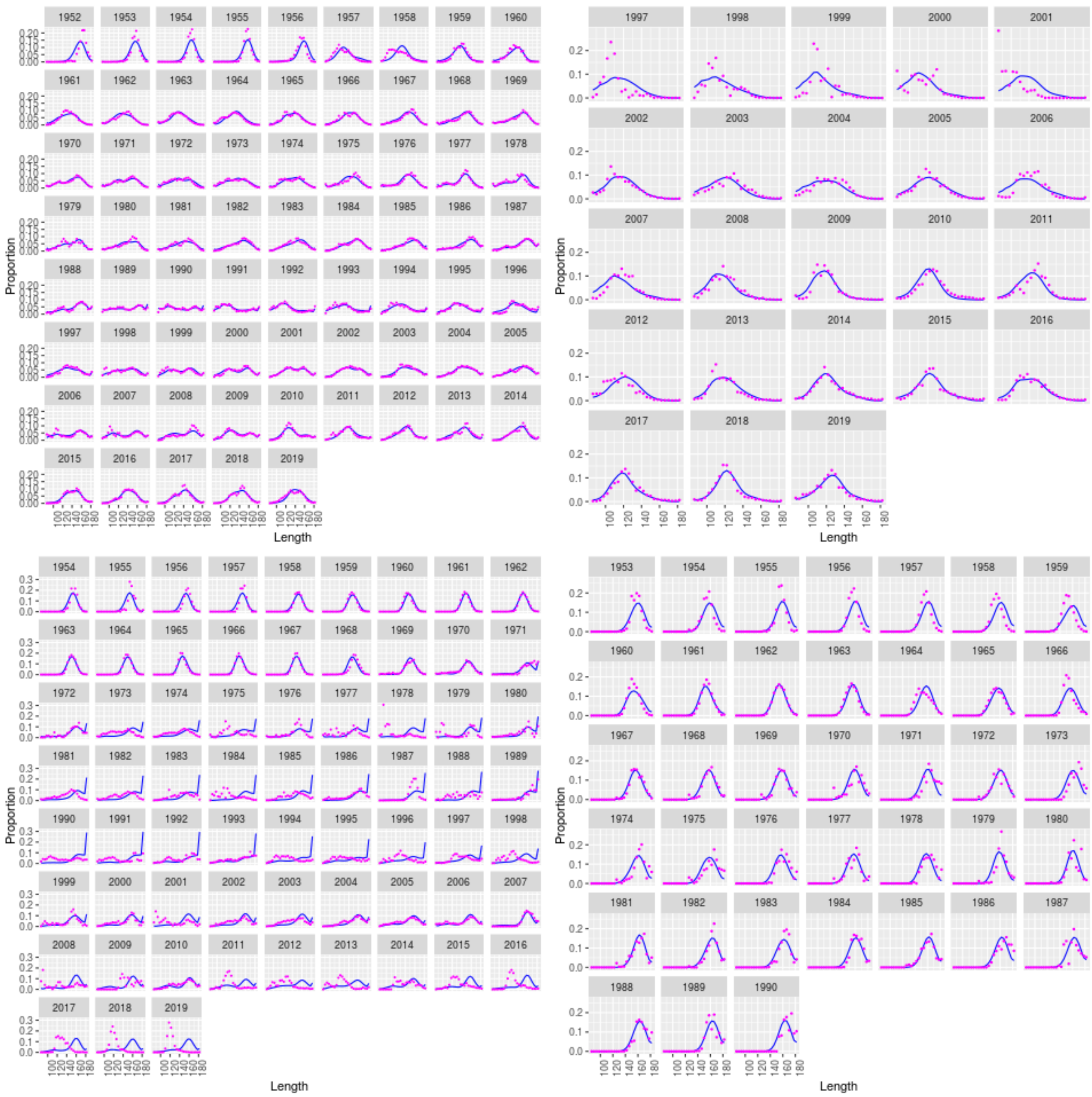

Figure 11: Fits to the size frequency data (magenta) for the LL_1 (top left), LL_2 (top right), LL_3 (bottom left) and LL_4 (bottom right) fleets for the best fitting grid.

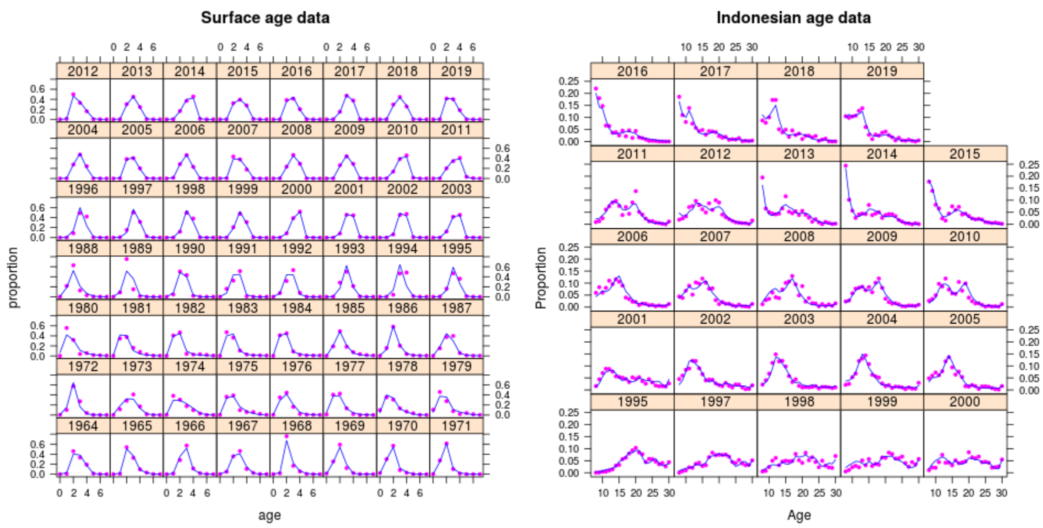

Figure 12: Fits to the age frequency data(magenta) for the surface (left) and Indonesian (right) fisheries for the best fitting grid.

Additional figures

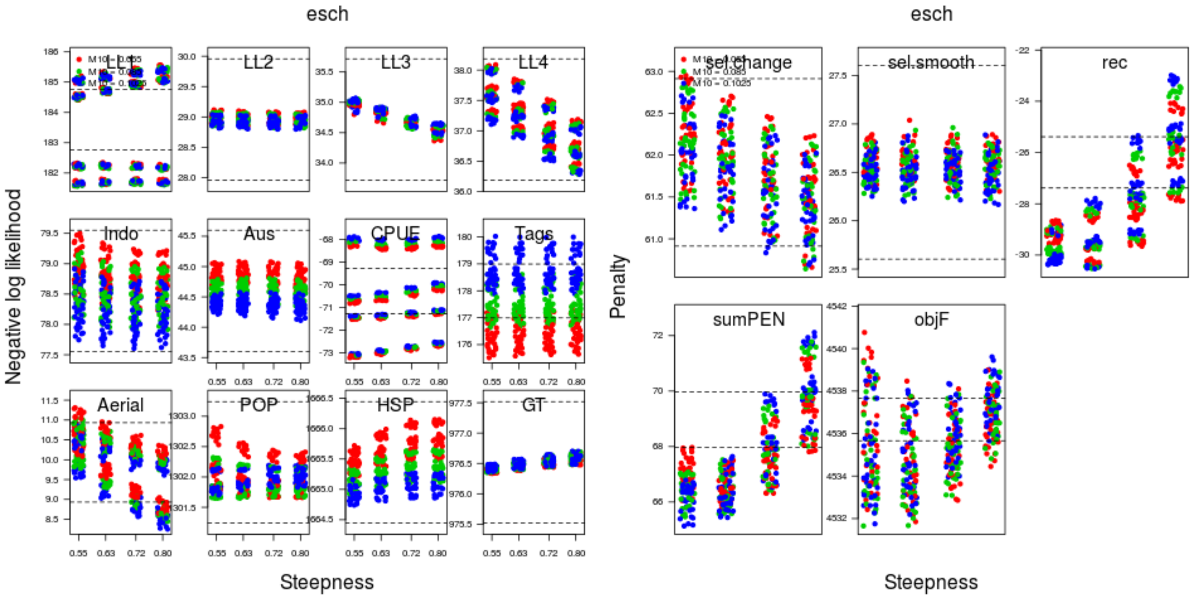

Figure A1: Likelihood (left) and penalty (right) profile summaries for steepness given reference set of OMs.

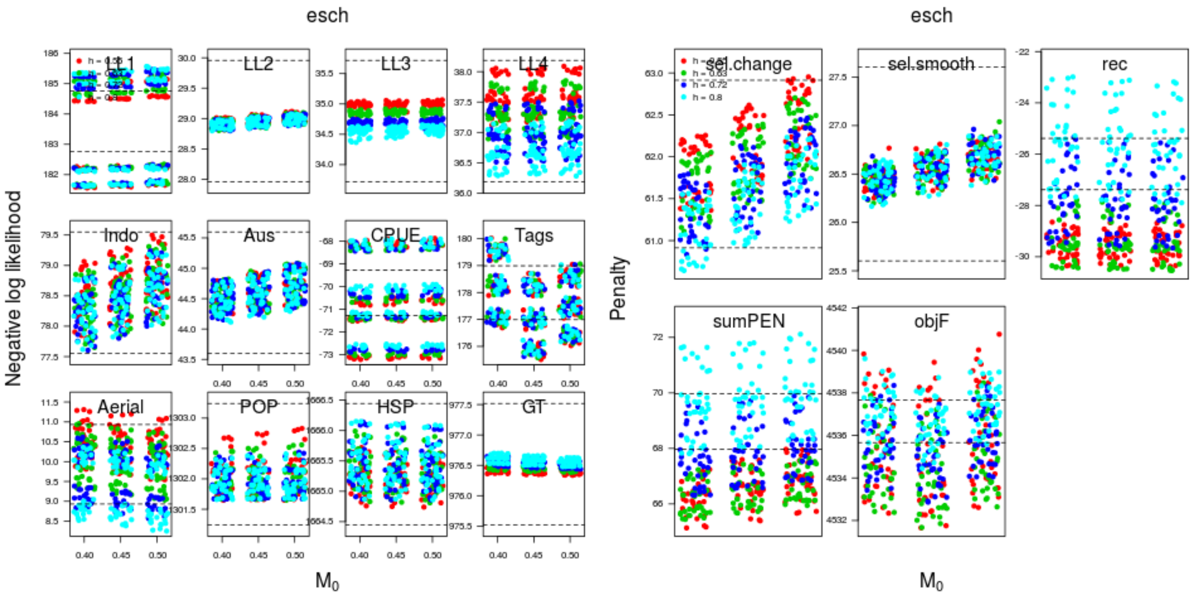

Figure A2: Likelihood (left) and penalty (right) profile summaries for M_0 given reference set of OMs

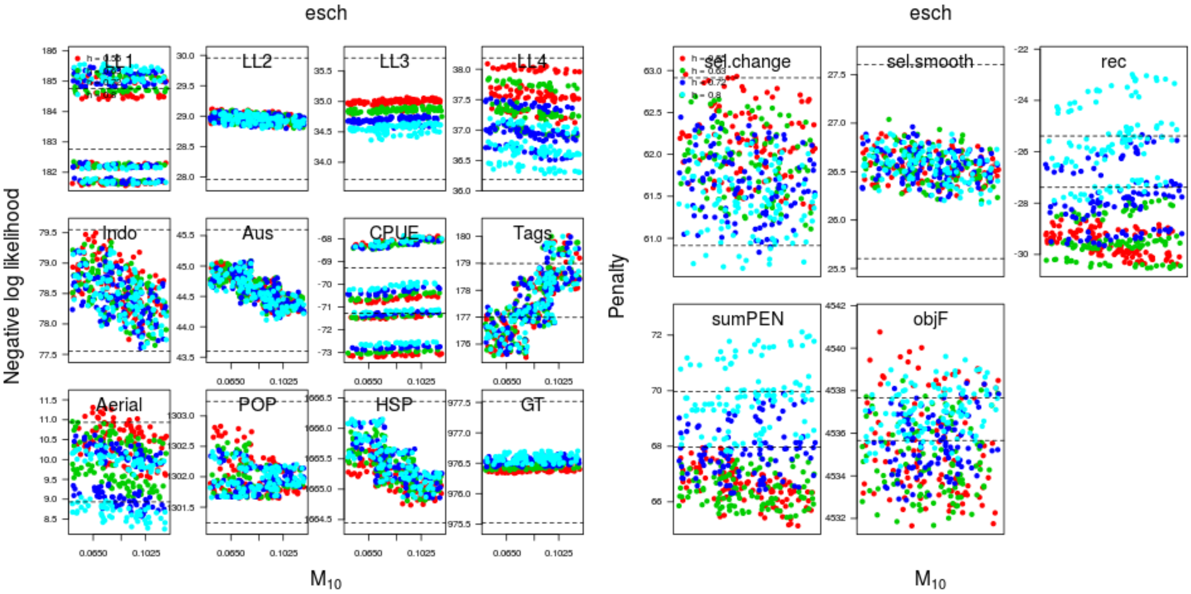

Figure A3: likelihood (left) and penalty (right) profile summaries for M_{10} given reference set of OMs