Some comparisons against a reference sardine harvest control rule for OMP-18

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Introduction

This document presents further ongoing work towards the development of a new OMP, OMP-18, for the South African sardine and anchovy fishery. A full set of performance statistics are given for a 'reference' Harvest Control Rule for sardine, together with some comparisons between key performance statistics for some changes to the Harvest Control Rule constraint parameters. Results are tested under a variety of potential baseline Operating Models (OMs).

Selecting Risk Levels

In previous OMPs designed for the management of South African sardine and anchovy fisheries, the risk level – the percentage of risk to the resource deemed appropriate - has been chosen by considering the leftward shift (towards lower values) in the distributions of simulated November biomass at the end of the projection period from a no catch to a catch scenario. In choosing a risk level the target has been to maintain the same "depletion" (leftward shift from a no catch scenario) at the 20%ile of the distribution, with similar depletion levels for other lower %iles. This same method has been used as an initial step to select an appropriate risk level for sardine for OMP-18, while noting that there has been a substantial change (from a single stock hypothesis to a two mixing-component hypothesis) in the underlying operating model used for OMP-14 to that being used for OMP-18. Sardine risk for OMP-18 has been defined as *the probability of the west component November biomass dropping below the 2007 level (lowest historical west component level) over the projection period of 20 years*. While the acceptable risk could be said to be a policy decision, some scientific rigor in selecting an appropriate level should nevertheless be applied. The OMP Task Team has considered using this 'leftward shift' method to give plausible results at this stage of OMP development[1]. The 'tuning Operating Model' used is one that assumes the future proportions of west component sardine moving to the south component to be randomly drawn from that estimated in the recent past ("MoveR") and the proportion of south component spawning contributing to west component recruitment[2] to be 8% (Cox et al. 2017).

Considering the depletion in not only the total biomass, but also in the south and particularly the west component biomass, the OMP task team has selected F=0.11 (which has a corresponding risk of 0.22) as the constant harvest proportion that most closely matches the leftward shift of the projected sardine biomass used in the development of previous OMPs (Table 1, Figures 1-3). Current CMP testing has thus focused on either a control parameter value

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[1] The alternative method suggested by Cox et al. (2017) did not – for a number of reasons - provide a clear risk level for the OMP Task Team to choose from. This method may be revisited again at a later stage.

[2] Modelled as west component 'effective spawner biomass' to which a stock-recruitment relationship is fit.

of $\beta = 0.11$ (which in the absence of any constraints corresponds to a constant harvest proportion of 11%) and/or a sardine risk of 0.22.

If this method is to be used to select a final risk level for sardine, the leftward shift of any final candidate management procedure(s) will need to be rechecked in order to determine the appropriate risk level for that CMP(s).

The appropriate risk to the anchovy resource has yet to be investigated.

Selecting Reference Harvest Control Rules

The reference Harvest Control Rule for anchovy remains as per OMP-14 with control parameter $\alpha = 0.889$.

The reference Harvest Control rule for sardine is simpler than that for OMP-14 in the following ways:

i) The shape of the rule below the Exceptional Circumstances threshold remains quadratic, with the directed sardine TAC reaching zero once the survey estimated biomass reaches a quarter of the threshold. However, all of the TAC calculated from this Harvest Control Rule is modelled to be given at the beginning of the year and no mid-year top-up is allowed.

ii) The two-tier threshold, enabling the directed sardine TAC to drop by greater than the constrained percentage is removed (for now). The primary benefit of this rule is to allow the TAC to increase higher/faster during years of high biomass without unduly increasing risk to the resource, as the TAC can be decreased substantially the following year if required. This is unlikely to have an impact on current projections which do not simulate any pulse in sardine biomass during the 20 year projection period.

iii) The 'buffer rule' introduced for OMP-14 is also not part of this reference rule. This is primarily a result of aiming at a Harvest Control Rule which calculates a single TAC at the beginning of each year, with no mid-year top-up based on the recruit survey.

The OMP Task Team has separately considered a variety of alternative reasonable values for the constraints in this reference rule and has subsequently selected:

- A minimum directed sardine TAC of 50 000t.
- A maximum directed sardine TAC of 200 000t.
- The maximum proportion by which the directed sardine TAC can be decreased from one year to the next (in the absence of Exceptional Circumstances and linear smoothing) to be 0.20.
- Exceptional Circumstances threshold of 350 000t on total survey estimated sardine.
- Linear smoothing of the rule from 350 000t to 700 000t[3].

[3] This is to avoid any discontinuities in the rule at the Exceptional Circumstances threshold given the 'base rule' below 350 000t does not allow for any 20% constraint in the decrease in directed sardine TAC from one year to the next.

All sardine results presented herein assume future catches are split west and east of Cape Agulhas according to the relationship fit to the median patterns observed historically (Figures 2 and 3 of de Moor and Coetzee 2017)[4].

Some Comparative Results

Three key alternatives to the reference Harvest Control Rules have been tested herein:

i) A minimum directed sardine TAC of 30 000t, 50 000t (reference) or 70 000t.

ii) A maximum anchovy TAC of 350 000t or 450 000t (reference).

iii) An Exceptional Circumstances threshold of 150 000t of survey biomass observed west of Cape Agulhas or 350 000t of total survey biomass.

The reference set of Operating Models currently includes four alternative values for the proportion, *p*, south component spawner biomass that forms part of the west component effective spawner biomass: 0%, 8%, 20% and 60%. Two alternative models for future proportions of west component sardine that permanently move to the south coast are considered: a random movement hypothesis, MoveR, as defined earlier in this document, and a west coast biomass density-dependent hypothesis MoveD (de Moor et al. 2018).

Figures 4 to 8 and 10 compare some key performance statistics for the same control parameter $\beta = 0.11$. Figure 9 compares some key performance statistics for the same risk level of 0.22. While there is some difference between the alternative baseline Operating Models, the differences appear minimal (e.g. Table 2).

These results indicate

i) For the same risk to the resource, there is an increase in median directed sardine catch with increasing minimum directed sardine TAC due to the regular impact of this constraint on the TAC calculation under these OM projections (e.g. Figure 9).

ii) A lower risk to the fishery (in terms of the directed sardine TAC<50 000t and in terms of AAV) AND a higher median directed sardine catch may be attained for the same level of risk to the resource by basing Exceptional Circumstances on the survey estimate of biomass west of Cape Agulhas rather than on the total survey estimate of biomass.

iii) Under baseline OMs there is little difference in the sardine performance statistics for a lower maximum anchovy TAC of 350 000t.

A full set of performance statistics for the reference Harvest Control Rule are given in Table 3.

Discussion

Cox et al. (2017) suggested the probability of fishery closure be incorporated as a performance statistic. Given the shape of the Harvest Control Rule, such that TACs are brought quadratically down to zero and there is no cut-off biomass at which the fishery is closed, the OMP Task Team selected a performance statistic of the probability of the

[4] Future work will include a different relationship fit to each draw from the posterior distribution, rather than a single relationship for all 1000 draws.

directed sardine TAC being less than 50 000t. Some feedback as to the appropriateness of this TAC value would be appreciated.

The impact of a lower maximum anchovy TAC (together with the impact of alternative small sardine bycatch with anchovy allowances including changes to the initial sardine TAB) will be tested against not only the baseline OMs, but also OMs that allow for an increase in sardine recruitment in the short term to effectively see the impact of these alternatives.

References

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de Moor CL, Bergh M, Butterworth DS, Coetzee JC and van der Lingen CD. 2018. Density dependent movement of South African sardine. DAFF: Fisheries Branch document FISHERIES/2018/MAR/SWG-PEL/02.

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Table 1. The ratio of the lower percentiles of the distribution of sardine biomass at the end of the projection period under a constant harvest proportion catch : no catch scenario. In the catch scenarios directed sardine TACs are set at 0%, 10%, 11% or 12% of survey estimated biomass, and all catch options additionally model sardine bycatch with anchovy. Risk, the probability of the west component spawner biomass falling below the 2007 level over the projection period, is 9% for the no catch scenario.

			Total Biomass				West Component				South Component			
	OMP-08	OMP-14	F=0	F=0.10	F=0.11	F=0.12	F=0	F=0.10	F=0.11	F=0.12	F=0	F=0.10	F=0.11	F=0.12
10%ile	0.50	0.59	0.88	0.63	0.61	0.57	0.90	0.63	0.58	0.53	0.89	0.63	0.60	0.57
20%ile	**0.68**	**0.68**	0.91	0.70	0.68	0.66	0.94	0.72	0.71	0.69	0.90	0.68	0.66	0.64
30%ile	0.72	0.73	0.92	0.74	0.72	0.71	0.92	0.74	0.73	0.71	0.89	0.69	0.67	0.65
40%ile	0.73	0.76	0.92	0.76	0.75	0.73	0.92	0.77	0.76	0.75	0.91	0.71	0.68	0.67
50%ile	0.72	0.78	0.88	0.63	0.61	0.57	0.90	0.63	0.58	0.53	0.89	0.63	0.60	0.57
Risk			0.12	0.21	0.22	0.23								

Table 2. Summary performance statistics *Risk*, the probability of November total sardine biomass being below the 2007 level during the 20 year projection period, and *C*, the median directed sardine catch (in thousands of tons) over the 20 year projection period, under the reference Harvest Control Rule scenario.

		Risk	Risk	C
		No catch	Reference HCR	
MoveR	$p = 0.0$	0.10	0.22	45
	$p = 0.08$	0.09	0.20	46
	$p = 0.2$	0.09	0.20	49
	$p = 0.6$	0.08	0.18	50
MoveD	$p = 0.0$	0.10	0.19	47
	$p = 0.08$	0.09	0.17	48
	$p = 0.2$	0.09	0.17	50
	$p = 0.6$	0.08	0.16	50

Table 3. Performance statistics for the reference Harvest Control Rule with $\beta = 0.11$ assuming the sardine OM of p=0.08 and MoveR and MoveD. Where appropriate, medians [90% probability intervals] are provided. All biomasses are given in thousands of tons.

Performance Statistic	No Catch		Constant Harvest Rate		Reference HCR	
	MoveR	MoveD	MoveR	MoveD	MoveR	MoveD
$Risk^S$	0.09	0.09	0.22	0.18	0.20	0.18
p(TAC^S<50 000t)	1.00	1.00		0.41	0.49	0.48
$B^S_{tot,2036}$	231 [125,435]	238 [126,440]	157 [44,328]	163 [66,330]	159 [65,323]	162 [72,326]
$B^S_{west,2036}$	102 [25,286]	118 [22,286]	62 [7,206]	77 [8,213]	64 [11,209]	79 [11,211]
$B^S_{south,2036}$	118 [54,246]	115 [48,246]	82 [24,180]	78 [27,176]	83 [32,178]	78 [30,170]
$B^S_{tot,2036}/B^S_{tot,2015}$	2.6 [1.1,9.8]	2.7 [1.0,12.1]	1.7 [0.4,6.9]	1.8 [0.5,9.0]	1.7 [0.6,6.8]	1.8 [0.6,8.9]
$B^S_{west,2036}/B^S_{west,2015}$	1.8 [0.4,9.3]	2.0 [0.3,11.6]	1.1 [0.1,6.5]	1.3 [0.1,8.6]	1.2 [0.2,6.4]	1.3 [0.2,8.5]
$B^S_{south,2036}/B^S_{south,2015}$	0.7 [0.3,1.3]	0.6 [0.3,1.4]	0.5 [0.2,1.0]	0.4 [0.1,1.0]	0.5 [0.2,1.0]	0.4 [0.1,1.0]
$B^S_{tot,min}$	147 [91,215]	150 [95,223]	91 [28,149]	92 [39,154]	91 [39,149]	93 [46,151]
$B^S_{west,min}$	29 [8,69]	23 [5,67]	17 [1,48]	15 [2,49]	17 [3,47]	15 [2,47]
$B^S_{south,min}$	64 [32,110]	54 [29,95]	40 [13,79]	35 [13,67]	41 [17,79]	35 [15,66]
C^S_{tot}	0 [0,27[5]]	0 [0,28]	37 [11,113]	38 [12,115]	46 [0,122]	48 [1,129]
C^S_{west}	0 [0,24]	0 [0,24]	34 [10,94]	34 [11,97]	38 [0,101]	39 [1,108]
C^S_{south}	0 [0,4]	0 [0,4]	2 [0,25]	2 [0,24]	2 [0,30]	2 [0,31]
ByC^S_{tot}	0.0 [0.0,5.2]	0.0 [0.0,5.2]	9.7 [1.3,48.5]	9.9 [1.3,49.2]	9.8 [1.2,48.9]	10.0 [1.2,49.3]
ByC^S_{west}	0.0 [0.0,5.2]	0.0 [0.0,5.2]	9.7 [1.3,48.5]	9.9 [1.3,49.2]	9.8 [1.2,48.9]	10.0 [1.2,49.3]
ByC^S_{south}	0.0 [0.0,0.0]	0.0 [0.0,0.0]	0.0 [0.0,0.0]	0.0 [0.0,0.0]	0.0 [0.0,0.0]	0.0 [0.0,0.0]
AAV^S_{tot}[6]	1 [1,1]	1 [1,1]	16 [10,26]	16 [10,25]	96 [16,823]	90 [17,865]
AAV^S_{west}	1 [1,1]	1 [1,1]	14 [9,22]	14 [9,22]	90 [15,734]	83 [16,733]
AAV^S_{south}	1 [1,1]	1 [1,1]	93 [36,320]	94 [38,317]	171 [53,581]	172 [52,617]
$Risk^A$	0.02	0.02	0.07	0.07	0.07	0.07
B^A_{2036}	960 [70,3678]	960 [70,3678]	405 [25,2742]	405 [24,2742]	405 [25,2742]	405 [24,2742]
B^A_{2036}/B^A_{2015}	0.7 [0.1,2.7]	0.7 [0.1,2.7]	0.3 [0.0,2.0]	0.3 [0.0,2.0]	0.3 [0.0,2.0]	0.3 [0.0,2.0]
B^A_{min}	447 [51,1130]	447 [51,1130]	175 [18,698]	176 [18,698]	175 [18,699]	176 [18,699]
C^A	0 [0,271]	0 [0,271]	248 [0,450]	248 [0,450]	248 [0,450]	248 [0,450]
AAV^A	1 [1,1]	1 [1,1]	12 [4,631]	12 [4,635]	12 [4,631]	12 [4,628]

[5] A no catch scenario still simulates catches to occur in 2016 and 2017.

[6] Median and 90%ile of $AAV^b_y = \left(C^{S,b}_{tot,y} - C^{S,b}_{tot,y-1}\right)/C^{S,b}_{tot,y-1}$

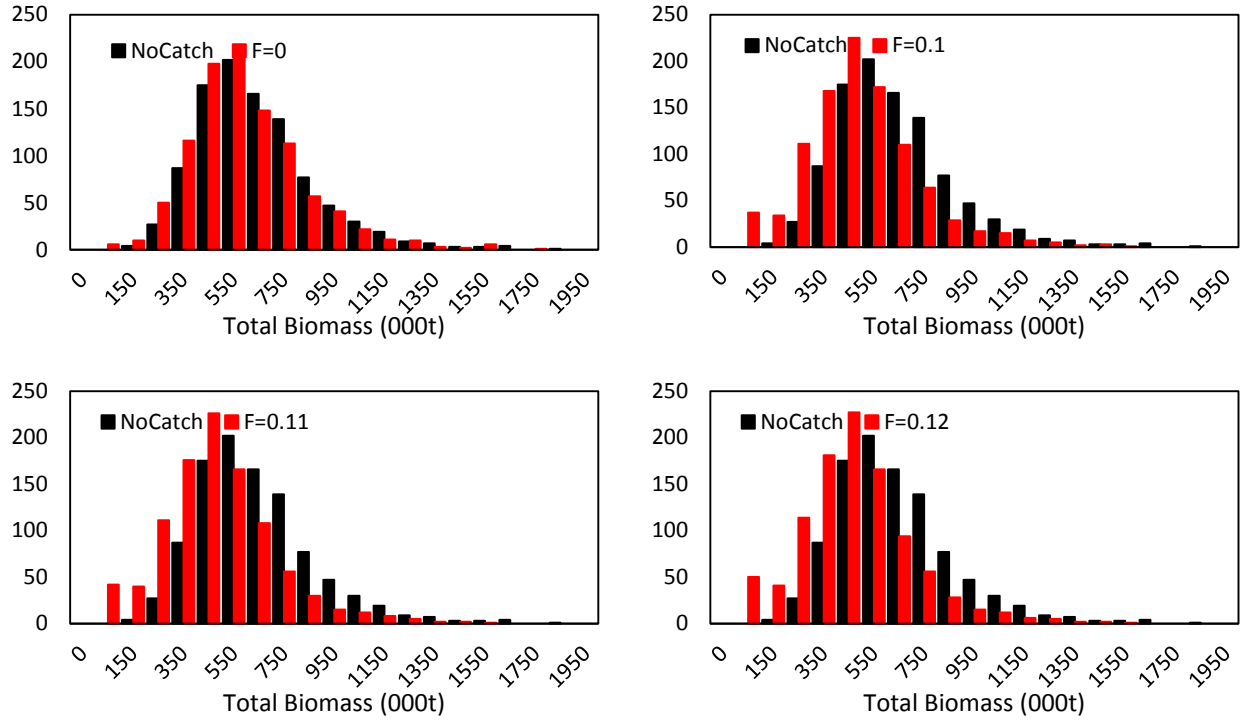

Figure 1. Histograms of total sardine November biomass under a no-catch scenario and a scenario with a constant harvest proportion (0%, 10%, 11% and 12%). Note that under "F=0" there is sardine bycatch, but no directed sardine catch.

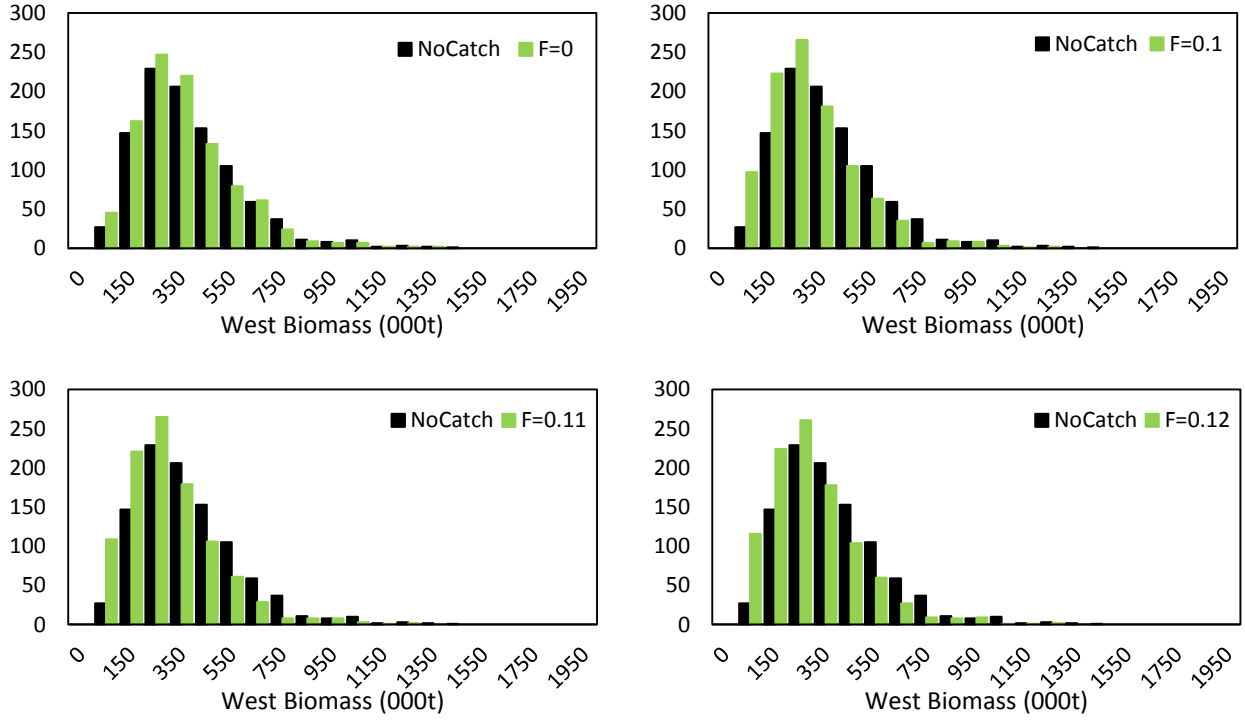

Figure 2. Histograms of sardine west component November biomass under a no-catch scenario and a scenario with a constant harvest proportion (0%, 10%, 11% and 12%). Note that under "F=0" there is sardine bycatch, but no directed sardine catch.

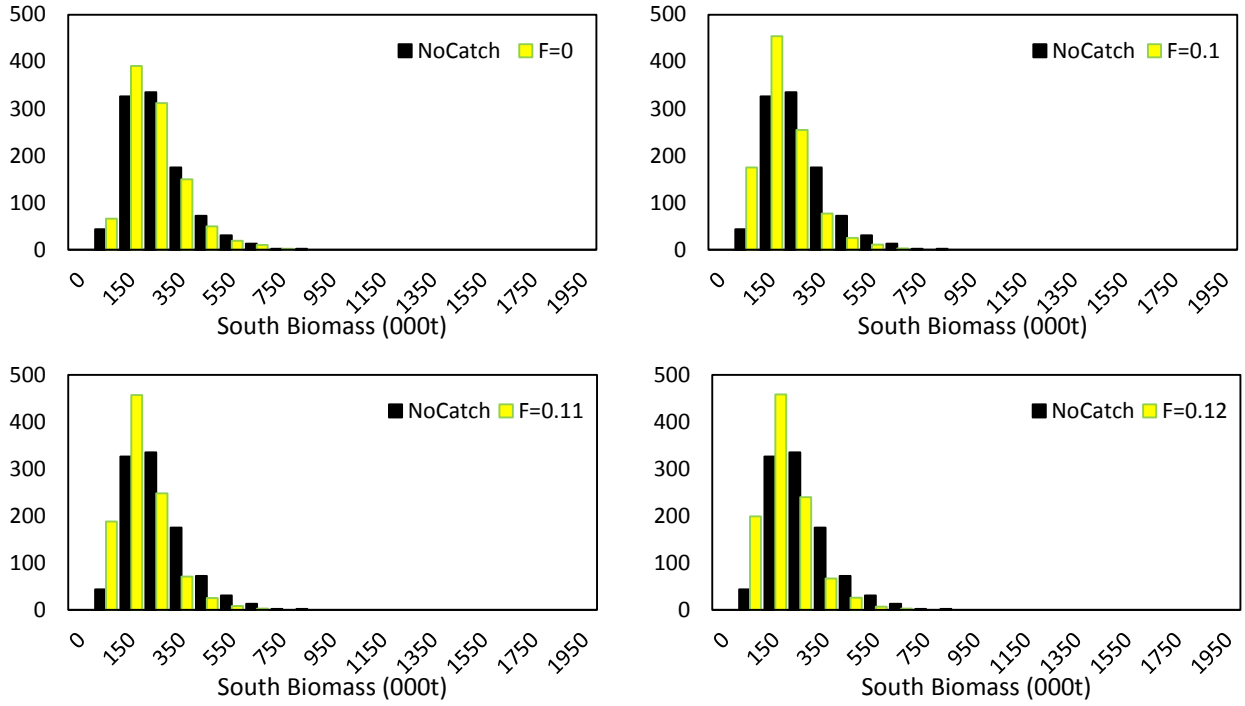

Figure 3. Histograms of sardine south component November biomass under a no-catch scenario and a scenario with a constant harvest proportion (0%, 5%, 6% and 7%). Note that under "F=0" there is sardine bycatch, but no directed sardine catch.

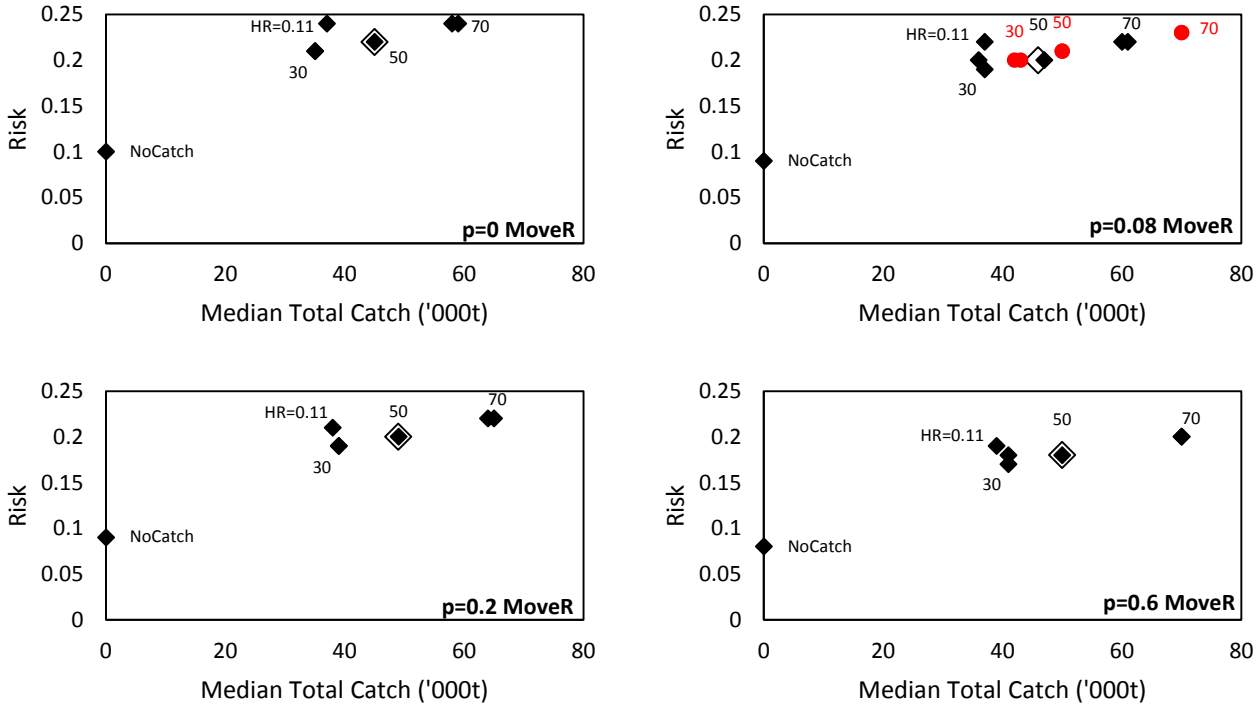

Figure 4. Risk to the sardine resource plotted against median total directed sardine catch, assuming MoveR and $\beta = 0.11$ for all Harvest Control Rules. The data labels indicate the minimum directed sardine TACs (30, 50 or 70 000t) or the no catch or constant harvest proportion scenarios. The large open diamond denotes the reference Harvest Control Rule. The red markers for the p=0.08 OM show results assuming an Exceptional Circumstances threshold of 150 000t on survey estimated biomass west of Cape Agulhas, while the black markers show results assuming an Exceptional Circumstances threshold of 350 000t on total survey biomass. For each set of minimum sardine TACs there are two very near markers, with the difference between these being a maximum anchovy TAC of 350 or 450 000t.

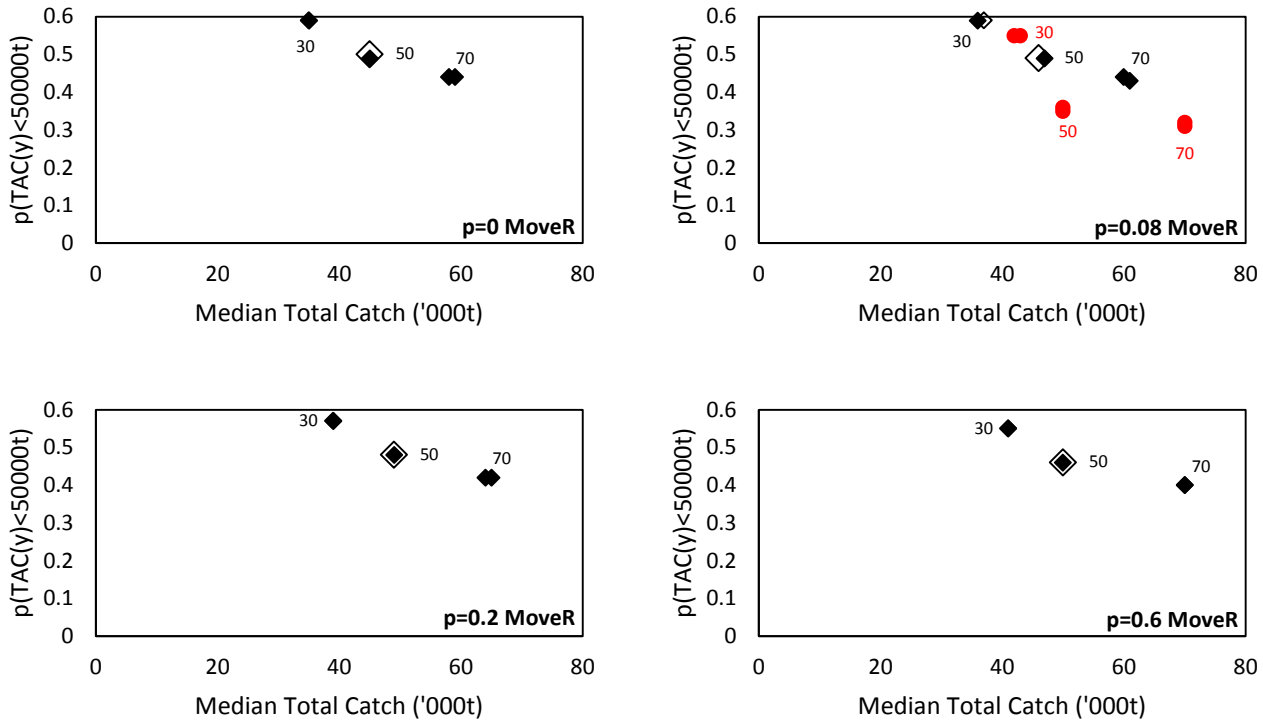

Figure 5. The probability of the directed sardine TAC being less than 50 000t[7] plotted against median total directed sardine catch, assuming MoveR and $\beta = 0.11$ for all Harvest Control Rules. The data labels indicate the minimum directed sardine TACs (30, 50 or 70 000t) or the no catch or constant harvest proportion scenarios. The large open diamond denotes the reference Harvest Control Rule. The red markers for the p=0.08 OM show results assuming an Exceptional Circumstances threshold of 150 000t on survey estimated biomass west of Cape Agulhas, while the black markers show results assuming an Exceptional Circumstances threshold of 350 000t on total survey biomass. For each set of minimum sardine TACs there are two very near markers, with the difference between these being a maximum anchovy TAC of 350 or 450 000t.

[7] This performance statistic is considered instead of a probability of the fishery being closed.

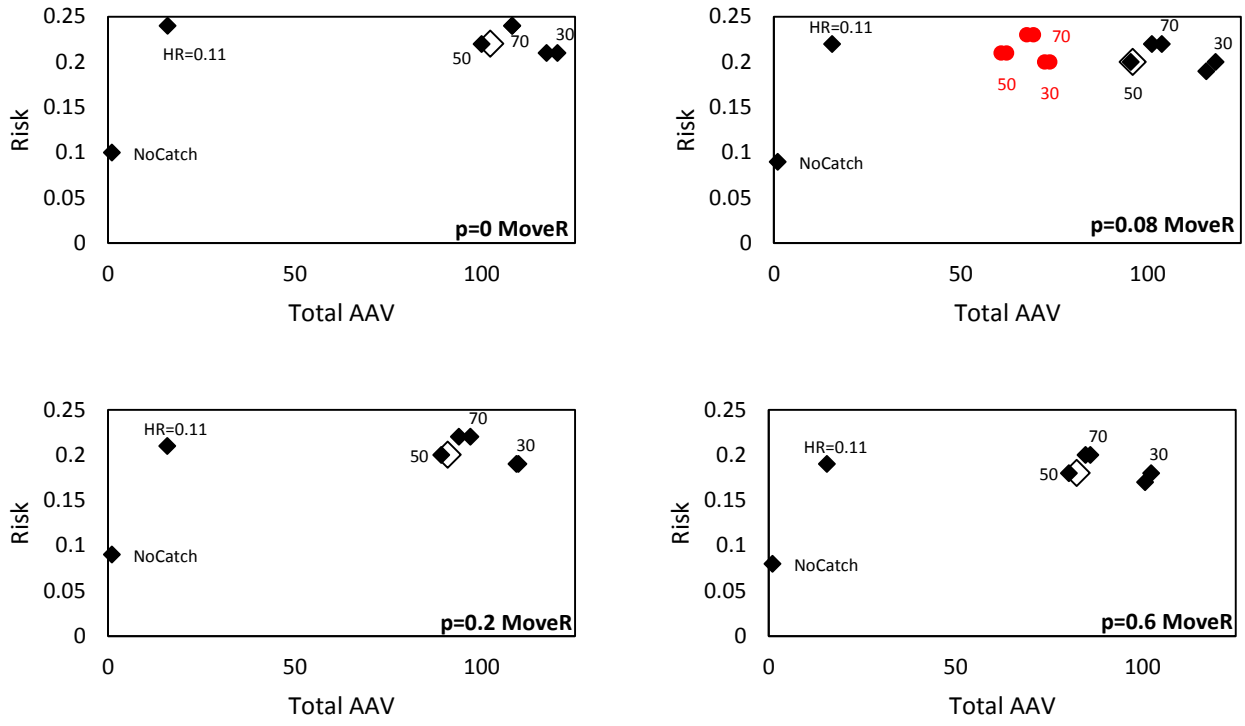

Figure 6. Risk to the sardine resource plotted against median annual variation in the total directed sardine catch[8], assuming MoveR and $\beta = 0.11$ for all Harvest Control Rules. The data labels indicate the minimum directed sardine TACs (30, 50 or 70 000t) or the no catch or constant harvest proportion scenarios. The large open diamond denotes the reference Harvest Control Rule. The red markers for the p=0.08 OM show results assuming an Exceptional Circumstances threshold of 150 000t on survey estimated biomass west of Cape Agulhas, while the black markers show results assuming an Exceptional Circumstances threshold of 350 000t on total survey biomass. For each set of minimum sardine TACs there are two very near markers, with the difference between these being a maximum anchovy TAC of 350 or 450 000t.

[8] Median of $AAV_y^b = \left(C_y^{S,b} - C_{y-1}^{S,b}\right)/C_{y-1}^{S,b}$

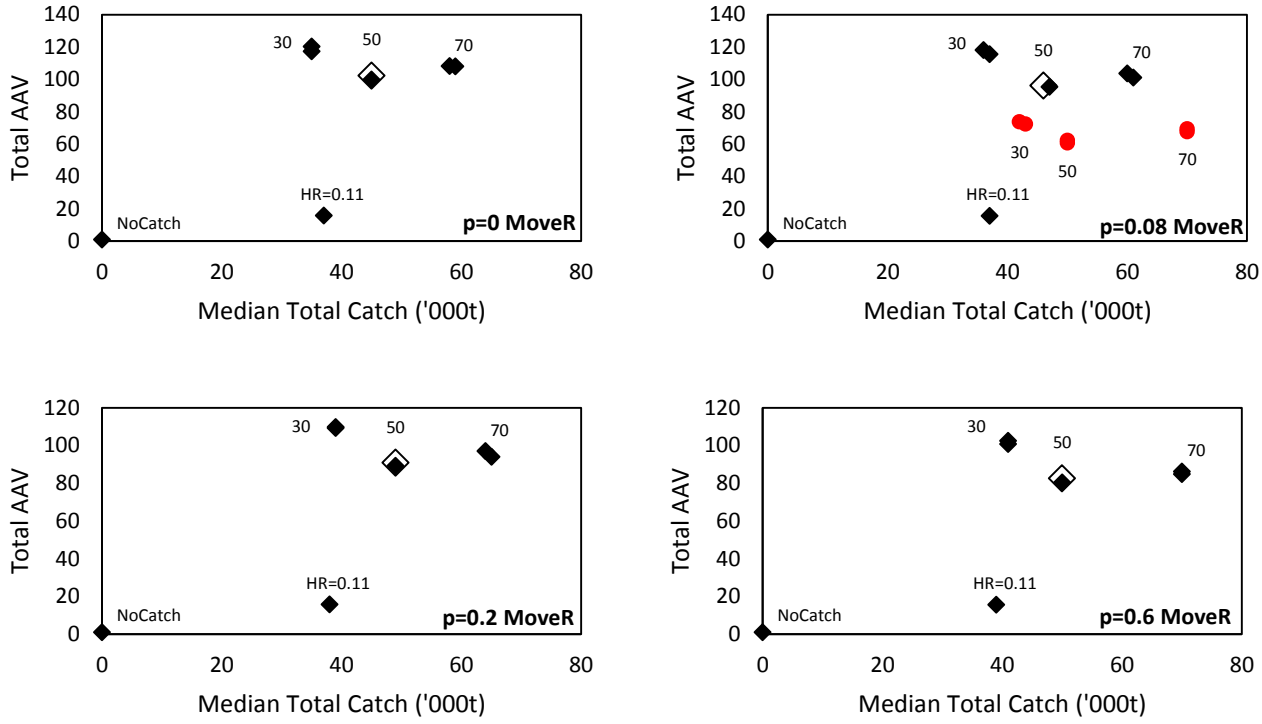

Figure 7. Median annual variation in the total directed sardine catch plotted against the median total directed sardine catch, assuming MoveR and $\beta = 0.11$ for all Harvest Control Rules. The data labels indicate the minimum directed sardine TACs (30, 50 or 70 000t) or the no catch or constant harvest proportion scenarios. The large open diamond denotes the reference Harvest Control Rule. The red markers for the p=0.08 OM show results assuming an Exceptional Circumstances threshold of 150 000t on survey estimated biomass west of Cape Agulhas, while the black markers show results assuming an Exceptional Circumstances threshold of 350 000t on total survey biomass. For each set of minimum sardine TACs there are two very near markers, with the difference between these being a maximum anchovy TAC of 350 or 450 000t.

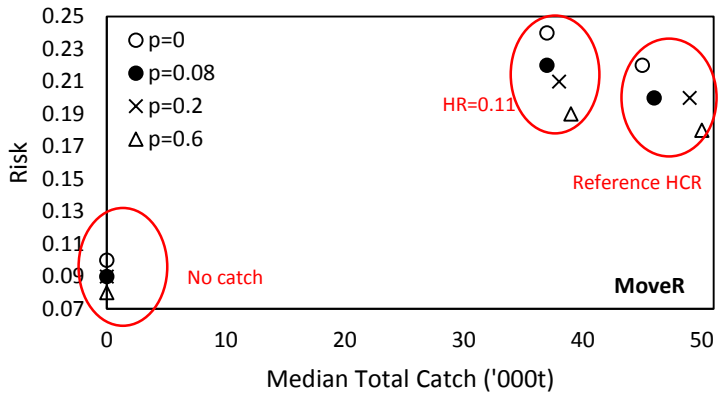

Figure 8. Risk to the sardine resource plotted against median total directed sardine catch, assuming MoveR and for i) a no catch scenario, ii) a constant directed sardine harvest proportion and iii) the reference directed sardine Harvest Control Rule with $\beta = 0.11$.

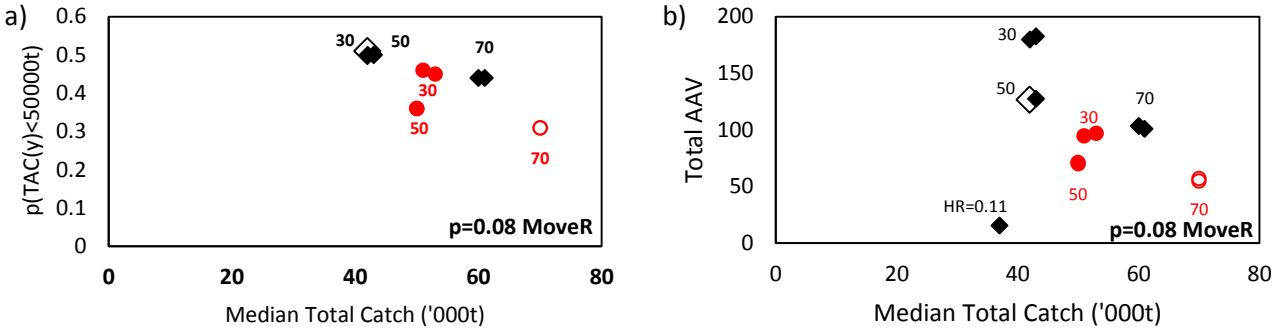

Figure 9. The a) probability of the directed sardine TAC being less than 50 000t and b) median annual variation in the total directed sardine catch plotted against median total directed sardine catch, assuming MoveR and a sardine risk of <0.22 for all Harvest Control Rules and p=0.08. The data labels indicate the minimum directed sardine TACs (30, 50 or 70 000t) or the no catch or constant harvest proportion scenarios. The large open diamond denotes the reference Harvest Control Rule. The red markers for the p=0.08 OM show results assuming an Exceptional Circumstances threshold of 150 000t on survey estimated biomass west of Cape Agulhas, while the black markers show results assuming an Exceptional Circumstances threshold of 350 000t on total survey biomass. For each set of minimum sardine TACs there are two very near markers, with the difference between these being a maximum anchovy TAC of 350 or 450 000t. NOTE: The red open circles for a minim directed sardine TAC of 70 000t did not meet the requirement of a risk of <0.22 for $\beta = 0$.

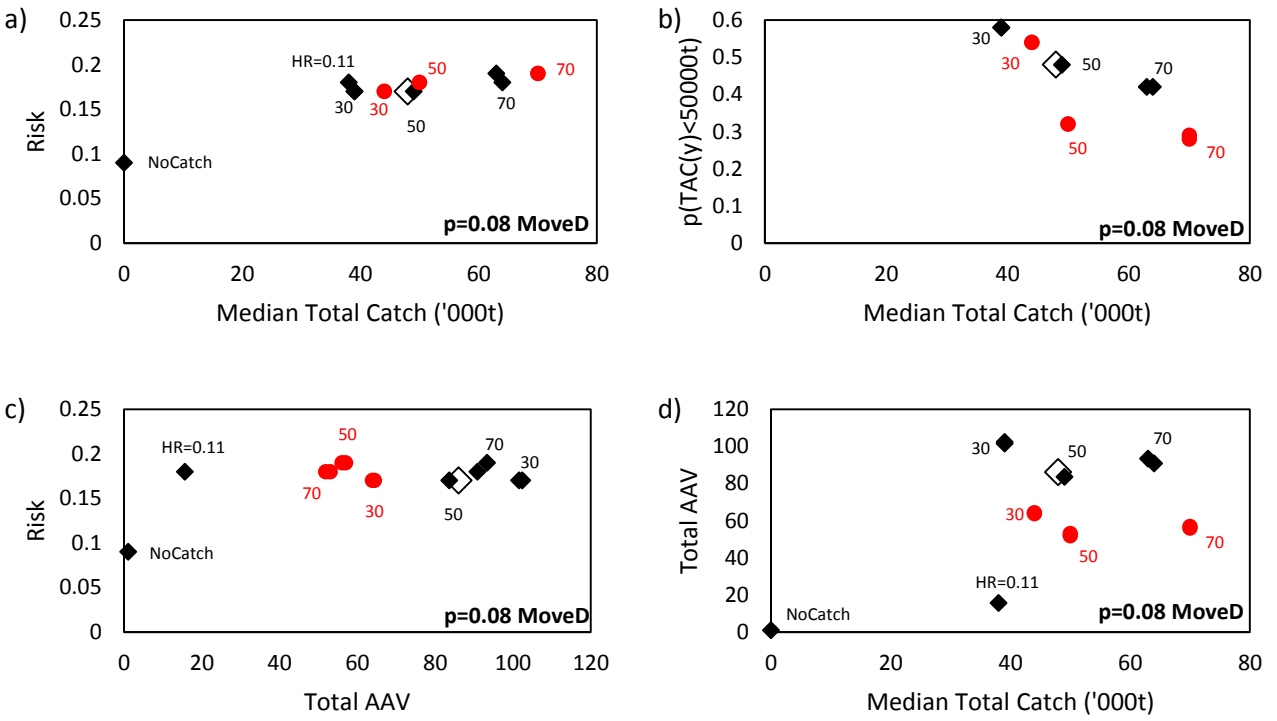

Figure 10. A repeat of Figures 4 to 7, but for the sardine Operating Model assuming p=0.08 and MoveD.