

## Comparisons between single area management and various forms of two area management for directed sardine TACs off South Africa

Carryn L de Moor\*

Correspondence email: [carryn.demoor@uct.ac.za](mailto:carryn.demoor@uct.ac.za)

### Introduction

Candidate Management Procedures (CMPs) which recommend either a single directed sardine Total Allowable Catch (TAC) for the whole western and southern coastline of South Africa, or which split the TAC by area are to be tested during the development of the next joint Operational Management Procedure (OMP) for South African sardine and anchovy. Using Operating Models (OMs) developed thus far, this document considers some simple Management Procedures under alternative area restrictions for directed sardine catches.

### Methods

CMPs are simulation tested using a framework updated from de Moor (2017a)<sup>1</sup>. This allows for simulation of the sardine and anchovy population dynamics from November 2015 until November 2036, including how CMP calculated catch tonnages are actually modelled to be removed from the populations' numbers-at-age, as well as generating future survey observations on which Harvest Control Rules are based. There is an underlying OM for both sardine and anchovy for all simulations. This document uses the baseline OM for anchovy (de Moor 2016) and a number of alternative OMs for sardine.

1000 sets of parameter values were drawn from the posterior distributions of the anchovy and sardine OM parameters. Table 1 details the OMs currently available and the length of Markov Chain Monte Carlo (Gelman et al. 1995) with burn-in and thinning applied to estimate the posterior distributions. For the sardine OMs where the stock-recruitment relationship was estimated after conditioning, a separate stock recruitment relationship was fit to each of the 1000 sets of time series of November spawner biomass and recruitment. The hockey stick OMs assumed an inflection point of 1% of carrying capacity for the south component, as assumed in the OMs with stock recruitment parameters estimated during conditioning. The non parametric and 'general parametric' (de Moor and Butterworth 2017) OMs assumed the same number of parameters for the west and south components. The process of estimating the stock recruitment relationships after conditioning was automated and resulted in a small percentage (e.g. 24 out of 1000 for p=0 case) of cases where AD model builder convergence to the MLE was not guaranteed. However, when checking the estimated parameter values corresponding to these cases, the values only differed in the 3<sup>rd</sup> decimal place when runs were repeated

---

\* MARAM (Marine Resource Assessment and Management Group), Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch, 7701, South Africa.

<sup>1</sup> Further updating to this framework will occur shortly to model catches now known to have occurred during 2017, as well as the 2017 May survey estimates of abundance.

from multiple starting values. Thus it was concluded that these cases where convergence to the MLE was not guaranteed could still be used.

A sub-set of the core decision performance statistics (de Moor 2017b) have been selected for this document:

*Risk*: The probability of total/west biomass falling below the risk threshold at least once during the projection period of 20 years. The risk threshold is taken to be the lowest (2007) historical total/west biomass for sardine and a quarter of the lowest (1996) historical biomass for anchovy.

*Minimum  $B^{sp}$* : The lowest spawner biomass over the 20 year projection period

*$B^{sp}_{2036}$* : Spawner biomass at the end of the 20 year projection period

*$B^{sp}_{2036}/B^{sp}_{2015}$* : Spawner biomass at the end of the 20 year projection period as a ratio of that at the beginning

*C*: Annual directed catch<sup>2</sup>

*AAV*: Inter-annual variation in the directed catch

*ByC*: Annual small sardine bycatch

There has been a change in the P1 and P2 performance statistics from total biomass to spawner biomass. The risk thresholds used here are for illustrative purposes and further discussion is required regarding the choice of appropriate risk thresholds and levels.

Two main sets of comparative results are considered in this document. The first considers a wider range of fixed fishing proportions (F), while the second considers a wider range of two area management scenarios.

#### *Considering a range of fixed Fs*

A range of fixed Fs (0%, 5%, 10%, 15% and 20%) were used to calculate the total directed sardine TAC, where the fishing proportion was taken to apply to the survey estimate of total sardine biomass. Projections were first run allowing the TAC to vary according to the fixed F alone, and then re-run with a constraint that the maximum inter-annual decrease in the total directed sardine TAC was 20%. Projections were run assuming either single or two area management. For the single area management under a two component OM, the future catches were split by coast according to an underlying model based on past data (see e.g. Figure 1). For the two area management, the TACs were split by coast according to the most recent survey estimate of biomass by coast. All results were also compared with a no future pelagic catch scenario and an OMP-14 scenario.

#### *Considering a range of two area management scenarios*

The impact of alternative two area management scenarios were tested assuming the total directed sardine TAC was calculated according to a fixed F of 10% or 15% (both with a maximum 20% constraint on inter-annual decrease) or OMP-14. Projections were run assuming either single or two area management. For the latter, the catches were split

---

<sup>2</sup> This can be lower than the TAC in situations where the TAC is set at >95% of available biomass or in cases where the fishery is simulated to be closed e.g. less anchovy directed catch due to the sardine bycatch limit being reached.

by coast either according to the most recent survey estimate of biomass by coast (i.e. varying from year to year) or according to time-invariant proportions where 100%, 80%, 60% or 40% of the total TAC was allocated to the west coast. All results were also compared with a  $F=0\%$  scenario. Again, the single area management scenario under a two sardine component OM assumes future catches are split by coast according to an underlying model based on past data (Figure 1).

## Results and Discussion

### *Choice of Sardine Operating Models*

Results from comparing projections under different sardine OMs are shown in Appendices A to D with the medians denoted by solid lines and the 95% probability intervals as dotted lines. While some results are repeated in more than one appendix, each appendix is designed to aid a single set of comparisons as described in each title. The threshold level corresponding to 2007 west component biomass is also shown.

The median and 95% probability intervals of biomass (Appendix A) and catch (Appendix B) show that while there is a substantial difference in the historically estimated levels of sardine biomass depending on whether a Hockey Stick stock recruitment relationship was estimated during the model conditioning or externally from (i.e. after) the conditioning, future levels do not differ as greatly for the baseline movement option MoveR. The scenario where the Hockey Stick stock recruitment relationship was estimated after conditioning will be used as a baseline OM in the short term<sup>3</sup>, noting that the OM where the Hockey Stick stock recruitment relationship was estimated during conditioning was less optimistic in absolute terms for sardine, particularly under scenarios of less west to south movement, and should be retained for future use.

When using OMs for which stock recruitment relationships were estimated after model conditioning, the median and 95% probability intervals of biomass (Appendix C) and catch (Appendix D) show that there was little difference between the Hockey Stick and General Parametric relationships for the baseline MoveR scenario. However, should future movement from the west to the south coasts be less than that under MoveR (i.e. a more optimistic scenario for the west sardine component), the projections would likely be more optimistic under the General Parametric compared to the Hockey Stick relationship. Thus the OM with the Hockey Stick stock recruitment relationship remains the most immediately suitable OM.

### *Alternative movement scenarios*

In the absence of any clear relationship between the west to south movement of sardine and, for example, coast-specific biomass levels, the baseline movement scenario has been chosen to be MoveR (de Moor et al. 2016, de Moor 2017a with further updates), in which future movement is randomly drawn from that estimated between 2006 and 2015 (Figure 2). Some results are presented using OMs that assume a more optimistic movement scenario, i.e. one in which the

---

<sup>3</sup> The OM currently used may not sufficiently account for correlations between the stock-recruitment parameters.

movement of sardine from the west to the south coast is half or a quarter of that randomly drawn under MoveR. These alternatives are more optimistic as they allow for the retention of sardine in the more productive west component.

*Considering a range of fixed Fs*

There are some general patterns in the results (Appendix E) indicating that risk to the resource (measured either by the risk or minimum spawner biomass statistics)

- i) increases as F increases,
- ii) increases as a 20% constraint is added to a constant F strategy, and
- iii) increases as the directed sardine TAC is taken to apply to a single area instead of being coast-specific.

In addition

- iv) the risk to the resource under an OMP-14-type MP is between that attained for a constant F strategy of between 0.10 and 0.15, or a constant F strategy with 20% constraint in inter-annual decrease of between 0.05 and 0.10,
- v) the directed catches naturally increase with increasing F, although the increases in median catches are not linear,
- vi) median catches under an OMP-14-type MP (with single or two-area TACs) are above that attained for a constant F strategy of 0.15, or less than that attained with a constant F strategy with 20% constraint in inter-annual decrease of 0.15,
- vii) risk to the resource is lower, and catches are higher under the more optimistic future movement alternative of a quarter MoveR,
- viii) the performance statistics become more optimistic as the proportion of south coast spawner biomass contributing to west coast effective spawner biomass increases
- ix) the OM in which 20% of south coast November recruits move to the west coast has a lower minimum biomass than when all south coast recruits are retained on the south coast, but results in an improvement over time with the final biomass being higher when recruits move to the west coast.
- x) For a given MP and movement hypothesis, the performance statistics are similar between OMs which have a 20% or 60% south coast contribution to west coast recruitment, while the OMs with no south coast contribution to west coast recruitment are less optimistic.

Figure 3 shows some sardine biomass under alternative fixed F scenarios without the 20% constraint.

The high variability about the anchovy stock recruitment curve (median  $\sigma_r^A = 0.81$  with 95% probability interval [0.62,1.12]) results in a wide range of future projected anchovy biomass, with a 13% chance of being below the risk threshold at least once during the projection period even under a no catch scenario (Figure 4). As expected, the anchovy performance statistics changed little between alternative sardine management strategies (Table E2, Appendix E).

*Considering a range of two area management scenarios*

There are again some general patterns in the results (Appendix F) indicating that risk to the resource (measured either by the risk or minimum spawner biomass statistics, Table F1, Figures F4 – F6)

- i) decreases as the TAC changes from a single area to two area with the proportion varying from year to year
- ii) increases as a higher fixed proportion of the TAC is taken on the west coast,
- iii) is similar between a two area MP with a fixed proportion of 40% of the TAC taken on the west coast each year and a two area MP with the proportion taken on the west coast varying each year according to the most recent November survey observation,
- iv) is highest for a two area MP with a fixed proportion of 100% of the TAC taken on the west coast each year, even higher than a single area MP (as that assumes some distribution of catches on both coasts, Figure 1),
- v) is similar between a single area MP and a two area MP with a fixed proportion of 80% of the TAC taken on the west coast each year, and
- vi) is less under OMP-14 for a constant F strategy of 0.10 or 0.15, with 20% constraint in inter-annual decrease.

The latter result is possibly due to OMP-14 being more conservative under Exceptional Circumstances than the constant F strategies would allow given their 20% constraint in decreases on directed sardine TACs.

In addition (Table F1, Figures F4 - F6)

- vii) except for one case, the minimum biomass is lower under a single stock OM than under a two component OM; the proportional increase in risk is also higher under a single stock OM than under a two component OM (Figure 5); one reason for this could be the lower inflection point estimated for the west component compared to the single stock hypothesis (Figure 6).

In all these simulations, the single area MP assumes that catches will be split according to components (which are assumed to be distributed west/south of Cape Agulhas) in a similar manner to that observed in the past (Figure 1). A greater proportion of catch was taken from the southern component when the TAC as a proportion of the western component biomass increased. In addition:

- viii) the median directed total sardine catches are similar under an  $F=0.1$  MP to that under OMP-14; the upper and lower probability interval of the latter are lower, with the upper being restricted by the maximum TAC constraint, while the lower 5%ile may be due to the ability of the OMP to decrease catches faster when Exceptional Circumstances are declared than the 20% constraint on inter-annual decreases in TAC will allow under the  $F=0.1$  MP (Table F1, Figure F1). The lower probability intervals of final  $B^{sp}$  are thus higher under OMP-14 compared to the  $F=0.1$  MP (Table F1, Figure F3).
- ix) the median (and range of) directed west coast catches decreases with decreasing fixed proportion of TAC being allocated to the west coast; the median west coast catches are similar between the single area and fixed two area MPs with 100% of the TAC allocated to the west coast, but this is dependent on the amount of south coast contribution to west coast recruitment; the median west coast catches are a little more under the two area MP where the proportion varies annually than the two area MP where the proportion is fixed at 40% west each year (baseline movement MoveR) or 60% west each year (0.5MoveR). The upper 95%ile

of the west coast catch under the variable two area TAC is, however, always higher than the two area MP with a fixed proportion of 60% on the west coast (Table F1, Figure F2).

- x) the average inter-annual variation (AAV) in total catches is similar over all cases for  $F=0.1$  and  $F=0.15$  with a 20% constraint, except the scenario where all future catches are simulated to be taken on the west coast (Table F1, Figure F7).
- xi) the AAV in west coast catches is much higher under the two area MP in which the proportion of catch west of Cape Agulhas varies annually according to the proportion observed in the previous November's survey (Table F1, Figure F8).
- xii) Under OMP-14, the AAV in total and west coast catches decreases from a single stock OM to a two component OM, and decreases further as the south coast contribution to west coast recruitment increases; the AAV in west coast catches is, however, highest for a two component OM managed under 2-area TAC with varying proportions of the TAC on the west coast (Table F1, Figures F7 – F8).
- xiii) Under OMP-14, the AAV in west coast catches decreases from a single stock OM to a two component OM (Table F1, Figure F8).
- xiv) The 95%PI of AAV under OMP-14 is much higher than under a  $F=0.1$  or  $F=0.15$  MP given the OMP allows for greater than 20% inter-annual decreases at both the upper (above 2-tier threshold) and lower (below 700 000t) range (Table F1, Figures F7 – F8).

Note that the example MPs tested here only have constraints on inter-annual *decreases* in catches, while the AAV measures the inter-annual changes (increases *and* decreases) (see, for example, Figure 7).

When comparing results for the same MP under alternative OMs, it is clear that if there is less movement from the west to the south coast in future years compared to the recent past, that both the risk to the resource would be lower and total and west coast catches would be slightly higher than under the baseline movement OMs.

For a given MP and movement hypothesis, the performance statistics are similar between OMs which have a 20% or 60% south coast contribution to west coast recruitment, while the OMs with no south coast contribution to west coast recruitment are less optimistic.

### **Summary and further work**

In summarising the work carried out thus far the OMP Task Team considered a few questions as listed below in italics. Some responses to these questions are offered based on these analyses.

#### *Is spatial management needed?*

The risk to the resource is highest under the scenario of two area management with 100% TAC allocated to the west coast. If one considers this risk to be unacceptable, then some spatial restrictions are required since single area TACs could result in all the catch being taken on the west coast (Table 2, Figure 8).

*If so, what form and (roughly) extent?*

Three broad types of management strategies could be considered:

- i) single area management, with some caveats for spatial distributions of catches,
- ii) two area management, with a fixed proportion of the TAC allocated west of Cape Agulhas, or
- iii) two area management, with variable proportions of TAC allocated west of Cape Agulhas.

The version of variable two area management tested herein indicates that there is sufficient information in the ‘noisy’ hydroacoustic data to inform inter-annual changes in the TAC proportions. If fixed two area management were required, 40% of the TAC would need to be allocated west of Cape Agulhas to match the risk attained under the variable two area management scenario (Figures 8 and F5 – F6). However, this variable two area management scenario results in unacceptably high AAVs, particularly on the west coast (Figures 9 and F7 - F8). Fixed two area management will require sacrificing total directed sardine catch in order to harvest a greater proportion on the west coast (Table 3).

If, for example, one took the risk under two area management with a fixed 40:60 split under an  $F=0.1$  strategy for directed sardine with a 20% constraint on inter-annual decreases to provide an acceptable level of risk, Table 3 lists the corresponding decrease in  $F$  required to attain the same level of risk if the fixed split instead allowed a greater proportion to be allocated to the west coast (i.e. a fixed 60:40 or 80:20 split). In particular, while the catches off the west coast remain similar for the downward-scaled 60:40 and 80:20 options to that of the original 40:60 split, there is a reduction in median total directed sardine catch of 20-30% when moving from a 40:60 to 60:40 split and 40-50% when moving from a 40:60 to 80:20 split.

If the same exercise is repeated using OMP-14, but instead downscaling the  $\beta$  control parameter from 0.0869 as tuned for OMP-14, then it is impossible to attain the level of risk achieved under a 40:60 split for options of 60% or 80% of the TAC being allocated to the west coast. Even the extreme of  $\beta = 0$  results in a higher risk to the sardine resource when a greater proportion of the TAC is allocated to the west coast (Table 4). This is primarily due to the constraints of OMP-14, such as the minimum TAC, which still allocate TAC even when the initial calculation using  $\beta = 0$  gives a zero TAC.

While the variable two area TAC tested thus far has unacceptable high AAV, particularly for the west coast, alternative forms of two area TACs may result in lower AAVs. Some rules that could be considered include:

- i) variable two area TAC with proportions dependent on average of survey estimated proportions west of Cape Agulhas over the preceding two years (i.e. similar to ‘Gentleman’s Agreement),
- ii) variable two area TAC with proportions varying according to the survey estimated proportion west of Cape Agulhas in the preceding November, but restricted to range between 60 and 80% of the TAC being allocated west of Cape Agulhas,
- iii) variable two area TAC with spatial restrictions only applying once the average west coast surveyed biomass (in tons, not in proportion) over the past 2 or 3 years drops below a pre-defined threshold, or

- iv) variable two area TAC with spatial restrictions only applying once the average proportional catch taken west of Cape Agulhas over the past 2 or 3 years is above a pre-defined threshold.

Note that for some scenarios that require a greater proportional catch on the west coast, a reduction in overall catch may be required to maintain an acceptable level of risk.

If the risk associated with status quo spatial restrictions, i.e. single area management, prove acceptable, then some caveats for spatial distributions of catches will be required. Results in this document assumed that a greater proportion of the catch would be taken on the south coast when the TAC is a greater proportion of the west biomass (Figure 1).

Options could, for example, include

- i) single area TACs with caveats, or ‘exceptional circumstances’ resulting in spatial restrictions if the average west coast surveyed biomass (in tons, not in proportion) over the past 2 or 3 years drops below a pre-defined threshold, or
- ii) single area TACs with caveats, or ‘exceptional circumstances’ resulting in spatial restrictions if the average proportional catch taken west of Cape Agulhas over the past 2 or 3 years is above a pre-defined threshold.

The immediate next steps in this work include:

- The choice of appropriate risk thresholds for sardine and anchovy
- The choice of appropriate risk levels for sardine and anchovy

### **Acknowledgements**

The SWG-PEL OMP Task Team is thanked for their input and comments on this work. Dagmar Merkle and Janet Coetzee are thanked for editing help with some of the tables.

### **References**

- de Moor CL (2016) Assessment of the South African anchovy resource using data from 1984-2015: results at the posterior mode. DAFF Branch Fisheries Document FISHERIES/2016/OCT/SWG-PEL/46.
- de Moor CL (2017a) Draft simulation testing framework to be used during the development of OMP-17. DAFF Branch Fisheries Document FISHERIES/2017/FEB/SWG-PEL/04.
- de Moor CL (2017b) Draft Objectives for the Management of the South African Pelagic Fishery for Anchovy and Sardine, using OMP-17. DAFF Branch Fisheries Document FISHERIES/JUN/2017/SWG-PEL/16.
- de Moor CL and Butterworth DS (2017) Alternative Stock Recruitment Relationships for South African Sardine. DAFF Branch Fisheries Document FISHERIES/2017/JUN/SWG-PEL/17.
- de Moor CL, Butterworth DS and Coetzee JC (2016) Discussion of OMP-17 simulation projection framework in respect of sardine. DAFF Branch Fisheries Document FISHERIES/2016/SEP/SWG-PEL/43.
- Gelman A, Carlin JB, Stern HS and Rubin DB (1995) Bayesian data analysis. Chapman & Hall, New York.

**Table 1.** The Operating Models considered, with length of MCMC chains, burn-in and thinning.

	SR relationship	South component contributing to west recruitment	Original Chain Length	Burn-in	Thinning	Resultant Chain Length
Anchovy	Beverton Holt estimated during conditioning		200 000 000	20 000 000	2000	90 000
Sardine single stock	Hockey Stick estimated during conditioning		71 208 000	10 000 000, and exclude additional 8000 000	2000	26 605
Sardine two components	Hockey Stick estimated during conditioning	p=0	100 000 000	10 000 000, and exclude additional 30 000 000	2000	30 000
	Hockey Stick estimated during conditioning	p=0.08 of recruitment <sup>4</sup>	87 186 000	20 000 000	2000	33 592
	Hockey Stick estimated during conditioning	p=0.2 of recruitment <sup>5</sup>	58 894 000	38 894 000	2000	10 000
	Hockey Stick estimated during conditioning	p=0.3 of recruitment <sup>6</sup>	88 880 000	10 000 000	2000	39 440
	Hockey Stick estimated during conditioning	p=0.4 of recruitment <sup>7</sup>	88 188 000	40 000 000	2000	24 094
	Hockey Stick estimated after conditioning	p=0	60 000 000	10 000 000	2000	25 000
	Hockey Stick estimated after conditioning	p=0.08 of SSB <sup>8</sup>	60 000 000	10 000 000	2000	25 000
	Hockey Stick estimated after conditioning	p=0.2 of recruitment	60 000 000	10 000 000	2000	25 000
	Hockey Stick estimated after conditioning	p=0.2 of SSB	60 000 000	10 000 000	2000	25 000
	Hockey Stick estimated after conditioning	p=0.6 of SSB	60 000 000	10 000 000	2000	25 000
	Non Parametric estimated after conditioning	p=0	60 000 000	10 000 000	2000	25 000
General Parametric estimated after conditioning	p=0	60 000 000	10 000 000	2000	25 000	

<sup>4</sup> Convergence not sufficient for use as a baseline OM.<sup>5</sup> Not used in this document.<sup>6</sup> Not used in this document.<sup>7</sup> Convergence not sufficient for use as a baseline OM.<sup>8</sup> Not used in this document.

**Table 2.** The minimum west sardine spawner biomass over the projection period under F=0.1, F=0.15 (with 20% constraint in inter-annual decrease in the TAC) or OMP-14. Results are shown for a single area, two area variable and 4 two area fixed directed TAC management scenarios, under 7 OMs considered in Appendix F and assuming an example weighting between the OMs.

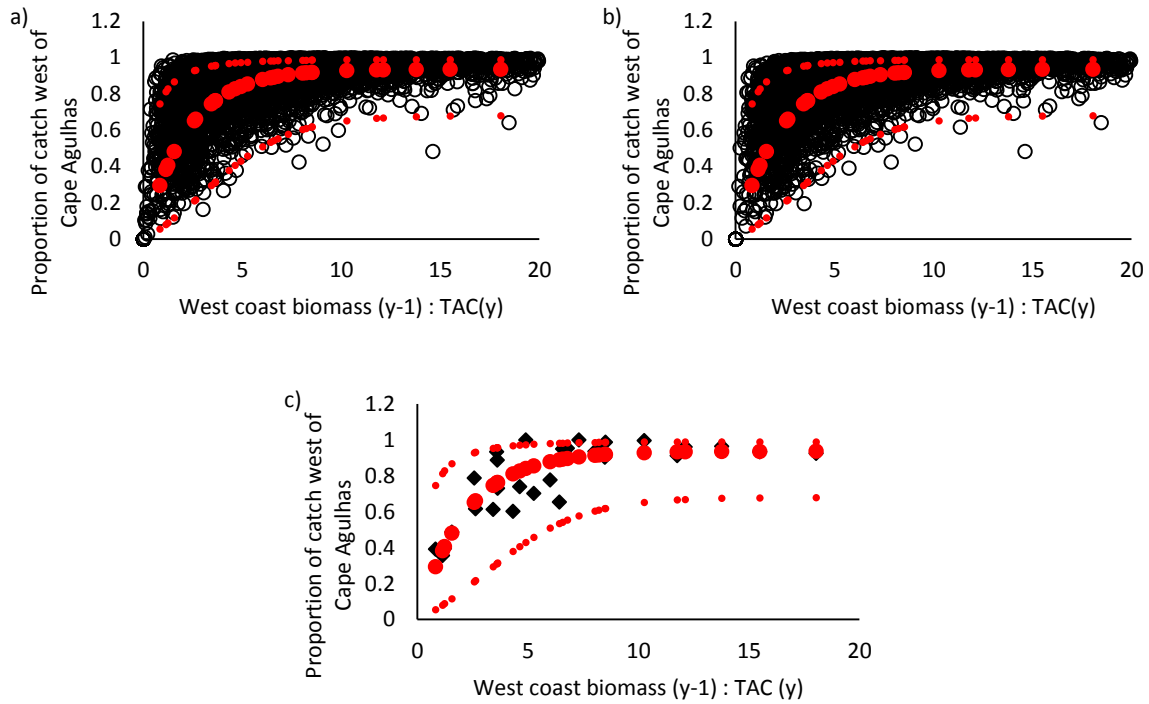
Sardine OM		F=0.10			F=0.15			OMP-14		
		Total	West	South	Total	West	South	Total	West	South
p=0 MoveR	F=0	287[94,431]	43[5,114]	136[57,229]	287[94,431]	43[5,114]	136[57,229]	287[94,431]	43[5,114]	136[57,229]
	1area	197[11,335]	25[0,84]	98[11,188]	150[2,300]	18[0,73]	76[2,163]	208[28,344]	27[0,85]	106[28,191]
	2area	217[23,354]	34[0,95]	97[21,178]	182[7,313]	29[0,88]	79[6,154]	224[49,355]	35[2,97]	103[35,182]
	100%	175[22,329]	16[0,78]	94[22,188]	53[21,284]	0[0,64]	51[21,164]	199[25,341]	22[0,84]	104[25,193]
	80%	193[21,343]	23[0,87]	95[21,185]	132[16,300]	11[0,74]	69[16,163]	209[27,347]	27[0,89]	101[27,189]
	60%	208[20,350]	30[0,95]	92[19,181]	164[8,312]	21[0,84]	68[7,156]	218[29,355]	31[0,96]	99[28,184]
p=0.2 MoveR	F=0	317[179,459]	50[10,119]	152[79,254]	317[179,459]	50[10,119]	152[79,254]	317[179,459]	50[10,119]	152[79,254]
	1area	230[38,362]	30[1,90]	115[33,205]	190[12,320]	24[0,80]	95[9,180]	239[79,384]	32[4,90]	121[50,215]
	2area	243[69,376]	39[5,101]	109[42,197]	209[17,335]	33[0,90]	88[12,170]	251[104,394]	40[7,103]	114[53,202]
	100%	222[32,359]	26[0,86]	116[31,208]	170[26,311]	13[0,66]	96[26,182]	29[2,97]	29[2,97]	122[49,215]
	80%	230[32,366]	30[0,93]	111[31,202]	187[20,317]	20[0,79]	92[20,175]	240[72,386]	33[3,95]	117[50,207]
	60%	238[43,374]	35[1,100]	107[32,196]	200[15,330]	28[0,91]	86[13,169]	247[88,394]	37[5,102]	112[49,201]
p=0.6 MoveR	F=0	319[206,456]	50[12,115]	155[88,256]	319[206,456]	50[12,115]	155[88,256]	319[206,456]	50[12,115]	155[88,256]
	1area	239[107,366]	33[5,86]	123[58,211]	205[37,321]	27[2,76]	104[18,187]	247[142,379]	35[7,88]	127[69,217]
	2area	249[120,374]	40[8,97]	115[54,198]	215[46,333]	35[4,89]	94[20,174]	257[148,388]	42[9,99]	119[60,205]
	100%	235[87,363]	28[2,81]	126[61,212]	195[43,314]	18[0,66]	110[40,193]	245[133,375]	32[5,84]	130[71,219]
	80%	240[91,368]	33[3,88]	120[56,206]	203[34,322]	24[0,78]	103[30,182]	249[140,382]	36[6,91]	125[64,214]
	60%	246[115,375]	37[6,95]	114[52,202]	210[30,330]	31[1,86]	93[20,175]	254[146,386]	39[8,96]	119[57,208]
p=0 0.5(MoveR)	F=0	358[235,522]	156[80,268]	108[63,176]	358[235,522]	156[80,268]	108[63,176]	358[235,522]	156[80,268]	108[63,176]
	1area	274[157,420]	122[56,217]	89[48,151]	235[110,368]	108[43,194]	76[26,137]	283[175,439]	126[60,224]	92[54,153]
	2area	282[165,433]	132[63,234]	79[41,137]	243[108,382]	119[49,213]	65[24,116]	292[182,445]	137[69,239]	82[46,142]
	100%	270[139,415]	116[44,211]	93[54,155]	225[31,361]	92[0,179]	84[31,144]	280[170,438]	122[55,221]	95[57,156]
	80%	277[157,427]	126[58,225]	84[45,143]	235[93,374]	108[27,202]	72[31,129]	287[176,441]	131[62,232]	86[48,147]
	60%	284[169,439]	136[64,238]	72[31,132]	246[120,387]	125[55,221]	56[13,113]	295[183,449]	139[67,245]	76[37,139]
p=0.2 0.5(MoveR)	F=0	376[252,546]	169[94,282]	112[65,183]	376[252,546]	169[94,282]	112[65,183]	376[252,546]	169[94,282]	112[65,183]
	1area	291[163,440]	131[63,230]	93[47,156]	248[100,401]	115[44,202]	79[21,142]	298[184,461]	134[68,237]	96[55,160]
	2area	299[173,452]	140[73,242]	83[42,143]	257[99,409]	126[51,225]	68[21,125]	308[192,468]	145[78,251]	86[47,149]
	100%	286[151,436]	123[48,225]	97[54,159]	237[37,390]	99[0,192]	87[34,148]	295[178,455]	131[63,234]	99[57,163]
	80%	294[164,445]	134[65,237]	87[45,151]	248[67,402]	118[23,212]	74[28,134]	303[187,461]	140[70,245]	90[49,154]
	60%	301[177,453]	144[75,251]	75[31,139]	262[116,413]	132[61,237]	57[12,115]	310[194,469]	147[78,255]	80[38,143]
p=0.6 0.5(MoveR)	F=0	371[252,532]	166[94,278]	111[65,180]	371[252,532]	166[94,278]	111[65,180]	371[252,532]	166[94,278]	111[65,180]
	1area	281[162,426]	125[63,217]	93[49,154]	242[99,382]	111[40,195]	78[23,138]	292[182,447]	132[67,233]	95[55,156]
	2area	291[168,437]	137[73,240]	82[41,139]	250[97,391]	123[46,219]	67[20,121]	301[188,457]	143[78,246]	86[47,145]
	100%	277[148,422]	120[50,213]	96[55,157]	231[61,376]	94[3,184]	88[44,145]	289[177,445]	128[63,229]	98[57,159]
	80%	286[162,430]	129[65,225]	87[45,146]	243[81,386]	112[24,203]	74[32,131]	296[185,453]	136[70,240]	89[49,148]
	60%	293[171,438]	140[74,242]	75[31,134]	254[105,396]	128[57,222]	58[12,115]	302[191,458]	145[77,252]	79[38,139]
p=0.6 0.5(MoveR)	F=0	300[178,448]	150[81,256]	64[17,124]	265[142,405]	142[76,243]	43[7,98]	308[195,463]	151[85,263]	69[25,129]

**Table 3.** The risk to the sardine resource (probability of being below the 2007 west coast threshold at least once during the projection period) and corresponding median total and west coast catches for three sardine OMs assuming two components with different proportional contributions of south component spawner biomass to west component effective spawner biomass ( $p$ ) and baseline MoveR. The risk to the resource under an  $F=0.1$  strategy with 20% constraint on inter-annual decreases in directed sardine TAC is given assuming 40% of the TAC is allocated west of Cape Agulhas each year. The results assuming either 60% or 80% of the TAC is allocated west of Cape Agulhas correspond to reduced  $F$ 's such that the risks are comparable to the 40% case.

	F=0	Risks (F with 20% constraint)			Median total catch ('000t)			Median west coast catch ('000t)		
		40:60	60:40	80:20	40:60	60:40	80:20	40:60	60:40	80:20
$p = 0$	0.43	0.50 (F=0.10)	0.494-0.507 (F=0.06-0.07)	0.492-0.509 (F=0.04-0.05)	70	49 - 53	35 - 42	30	30 - 31	28 - 33
$p = 0.2$	0.34	0.42 (F=0.10)	0.422 (F=0.08)	0.422 (F=0.06)	83	67	52	33	40	42
$p = 0.6$	0.31	0.36 (F=0.10)	0.359 (F=0.07)	0.354-0.368 (F=0.05-0.06)	85	61	47 - 52	34	36	38 - 42

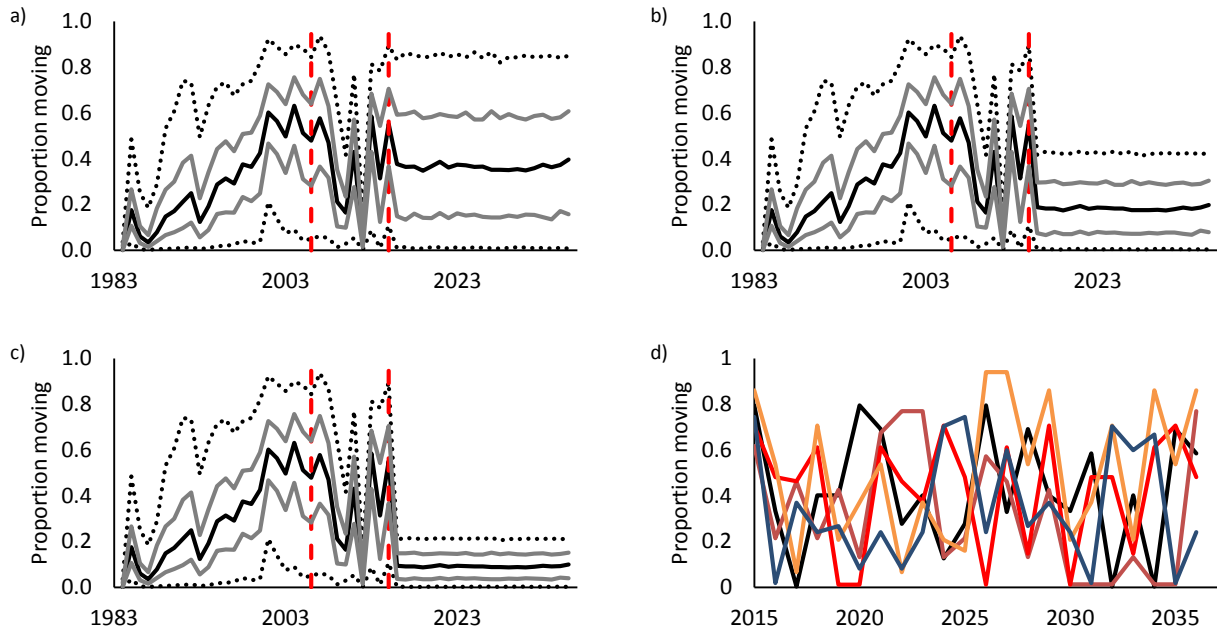
**Table 4.** The risk to the sardine resource (probability of being below the 2007 west coast threshold at least once during the projection period) for three sardine OMs assuming two components with different proportional contributions of south component spawner biomass to west component effective spawner biomass ( $p$ ) and baseline MoveR, under OMP-14 with 40% of the TAC allocated to the west coast and under OMP-14 with the  $\beta$  control parameter set to zero and 60% or 80% of the TAC allocated to the west coast.

	F=0	$\beta = 0.0869$	$\beta = 0$	$\beta = 0$
		40:60	60:40	80:20
$p = 0$	0.43	0.48	0.514	0.551
$p = 0.2$	0.34	0.40	0.419	0.443
$p = 0.6$	0.31	0.35	0.360	0.377

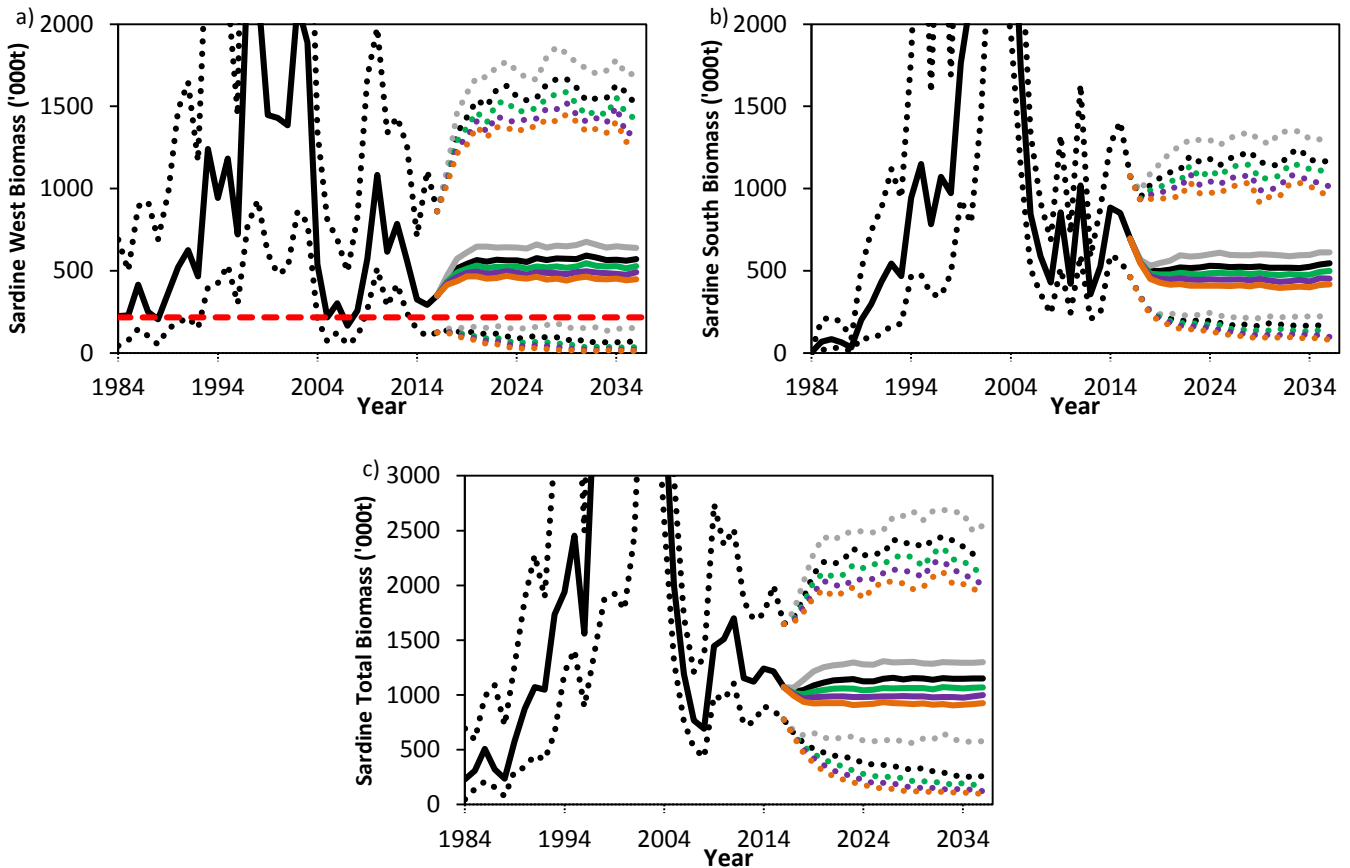


**Figure 1.** The simulated future proportion of catch modelled to be taken from the west component for cases where a directed sardine TAC is allocated for a single area, but the underlying OM consists of two sardine components for a)  $F=0.10$  with a 20% constraint in inter-annual decreases in TAC and b) OMP-14. The red dotted lines indicate the relationship assumed with  $\pm 2$  standard deviations in logit space, where the relationship was estimated by fitting to historical posterior median proportions of catch west of Cape Agulhas plotted against the historical posterior median west coast biomass<sup>9</sup> to total TAC (plot c)).

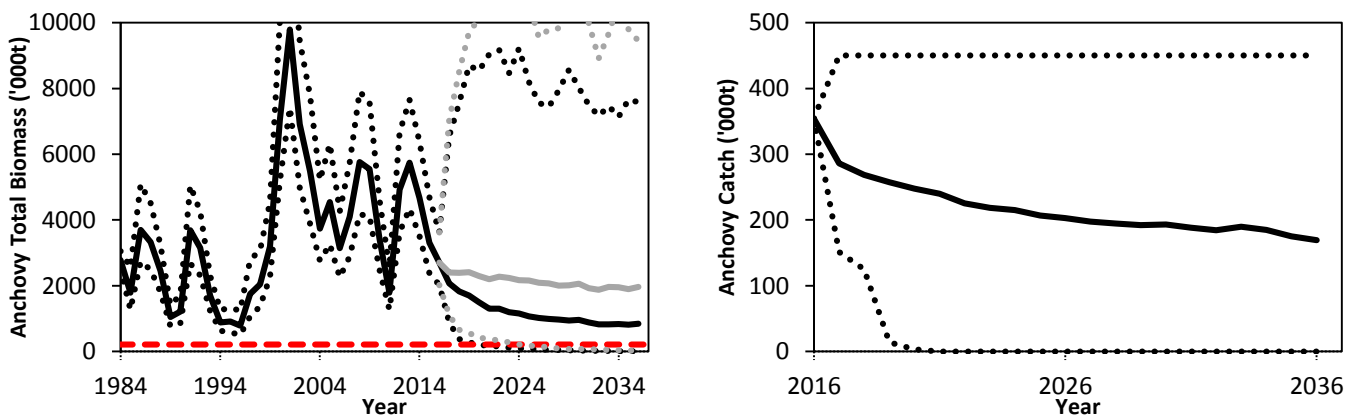
<sup>9</sup> Assuming two components of sardine with no south coast contribution to west coast recruitment and stock-recruitment relationships estimated during conditioning.



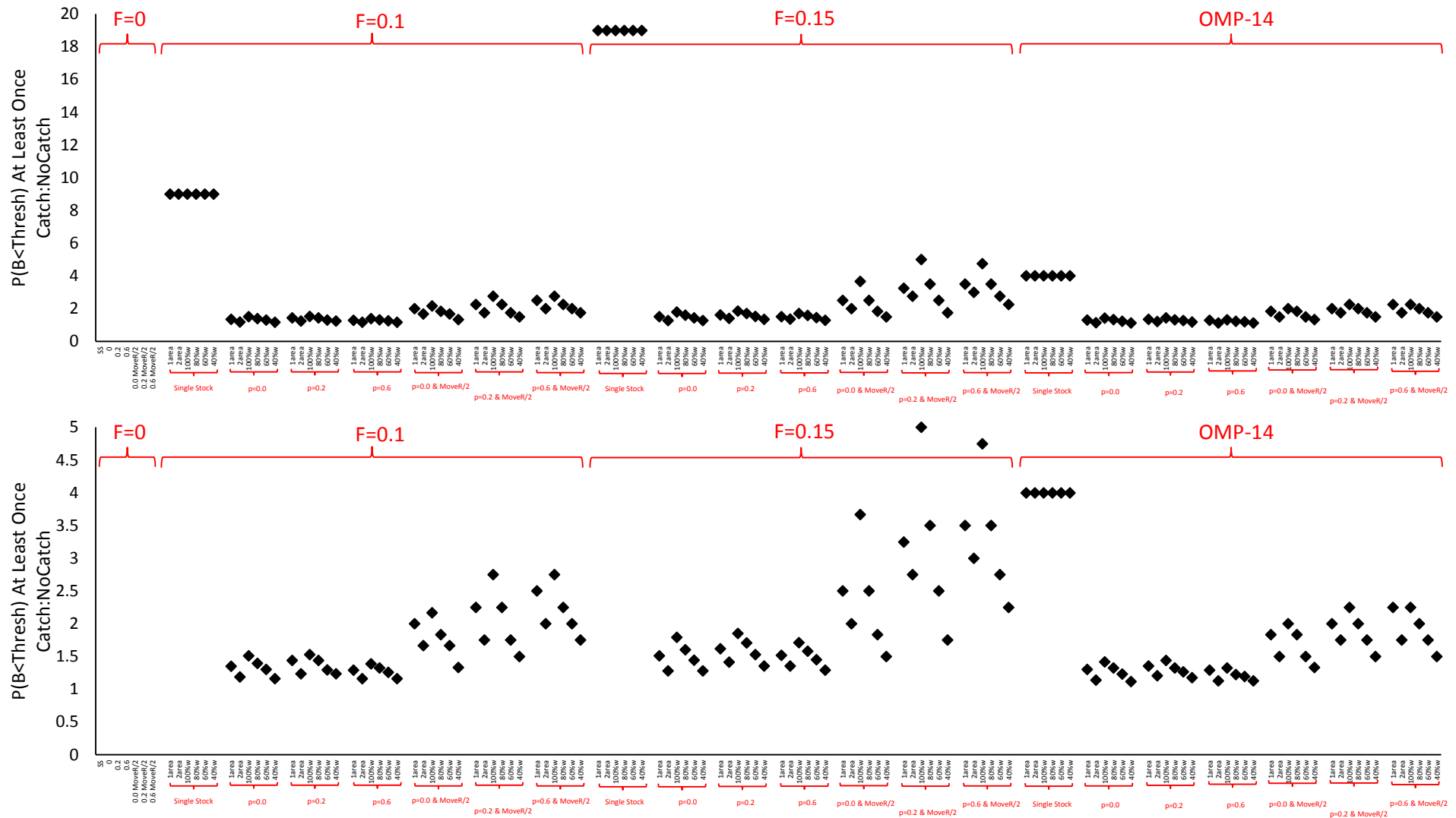
**Figure 2.** The proportion of 1-year old sardine moving from the west component to the south component in November each year under the two component hypothesis with the stock recruitment relationship estimated after conditioning for a) Move R, b) 50% of MoveR and c) 25% of MoveR. The red vertical lines denote the 2006 to 2015 period from which future movement is randomly drawn. The proportion of 2+ sardine which move from the west to the south component is linked to this variable proportion of 1-year-olds moving. Figure d) shows some example worm plots of future proportions of 1-year old sardine which move from the west to the south component.



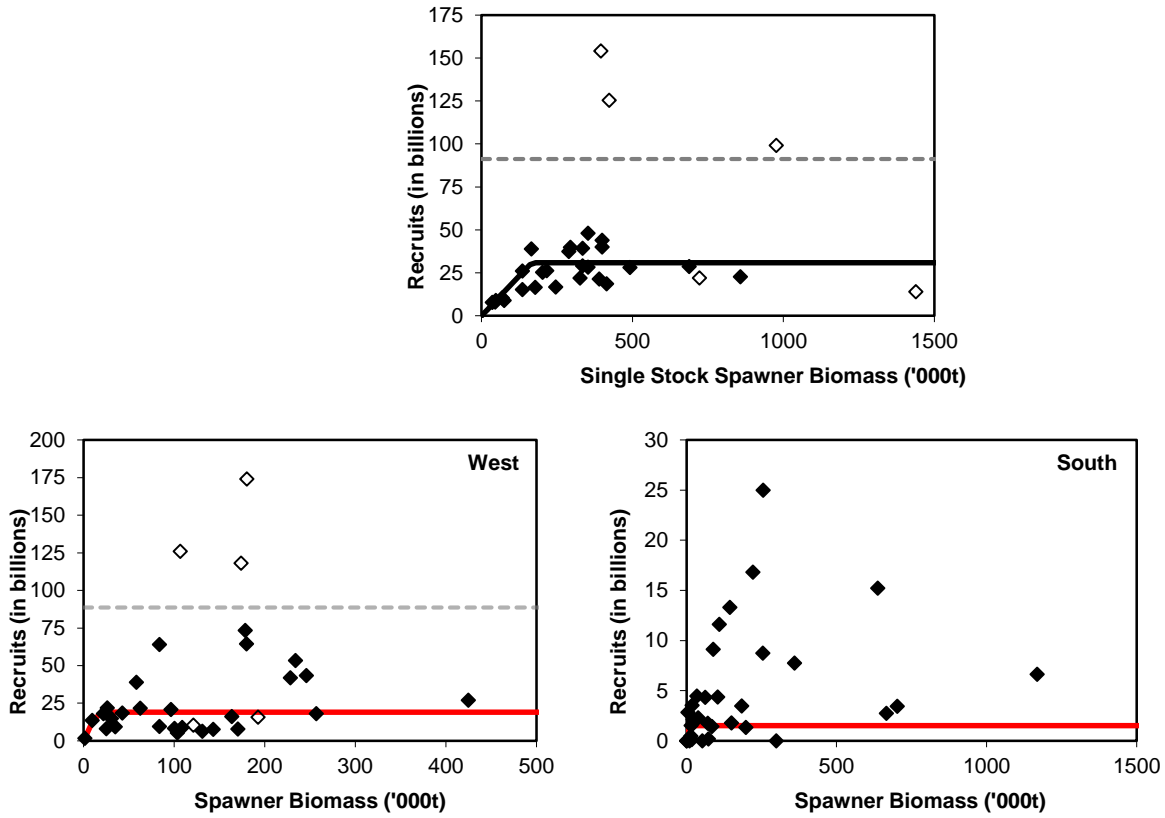
**Figure 3.** Median and 95% sardine a) west, b) south and c) total biomass assuming two components with 20% of the south coast spawner biomass contributing to west coast effective spawner biomass and baseline MoveR. Results are shown for F=5% (black), F=10% (green), F=15% (purple), F=20% (orange) and no catch (grey) scenarios, where there are no constraints in inter-annual decreases in the TAC for the catch scenarios. The red dashed line denotes the median lowest (2007) historical west component biomass.



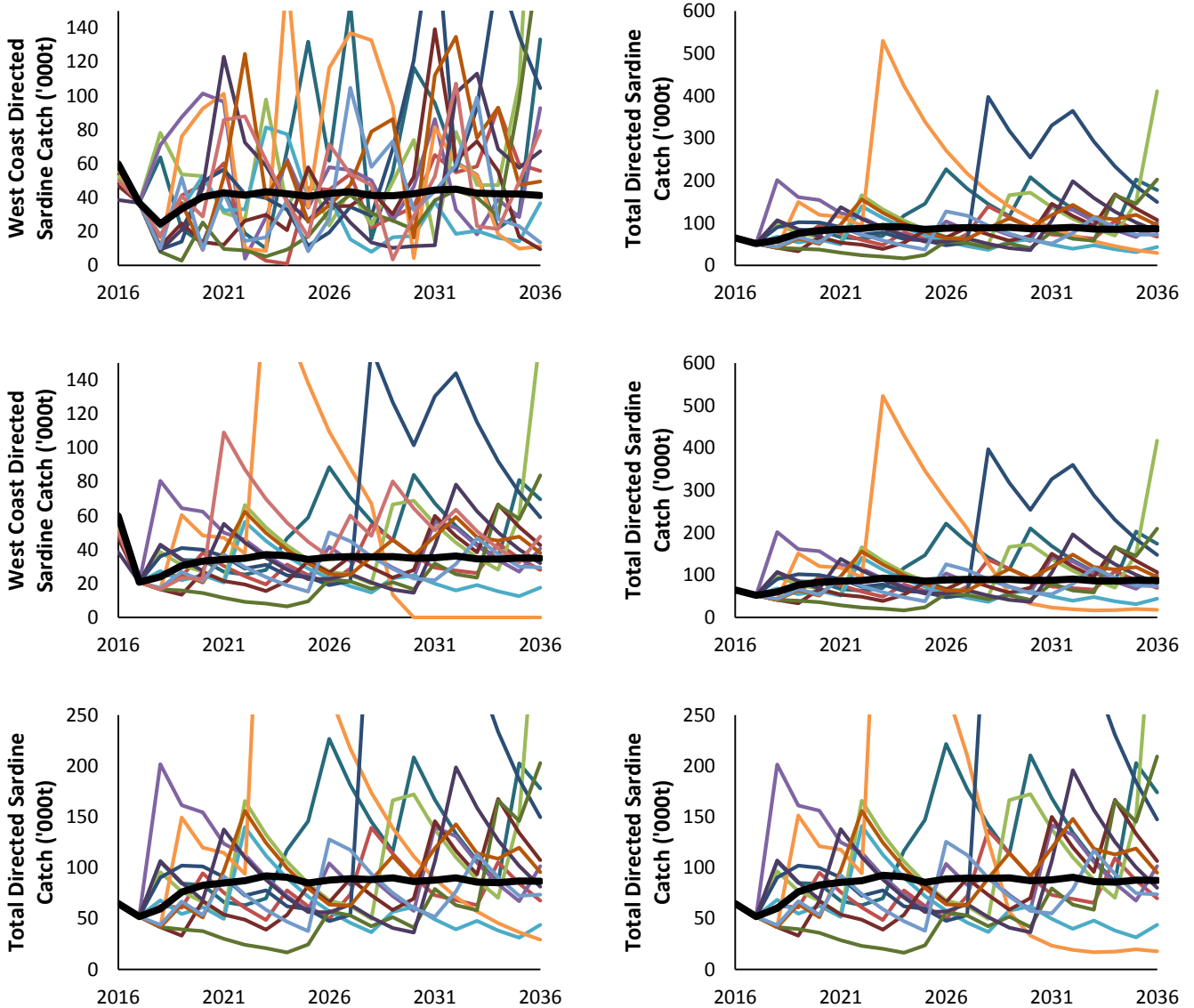
**Figure 4.** Median and 95% anchovy total biomass under catch (black) and no catch (grey) scenarios. The red dashed line denotes the median of a quarter of the lowest (1996) historical biomass. The sardine OM used for these plots assumed two components with 20% of the south coast spawner biomass contributing to west coast effective spawner biomass, with baseline MoveR, and a sardine harvest strategy of F=0.10 without constraints.



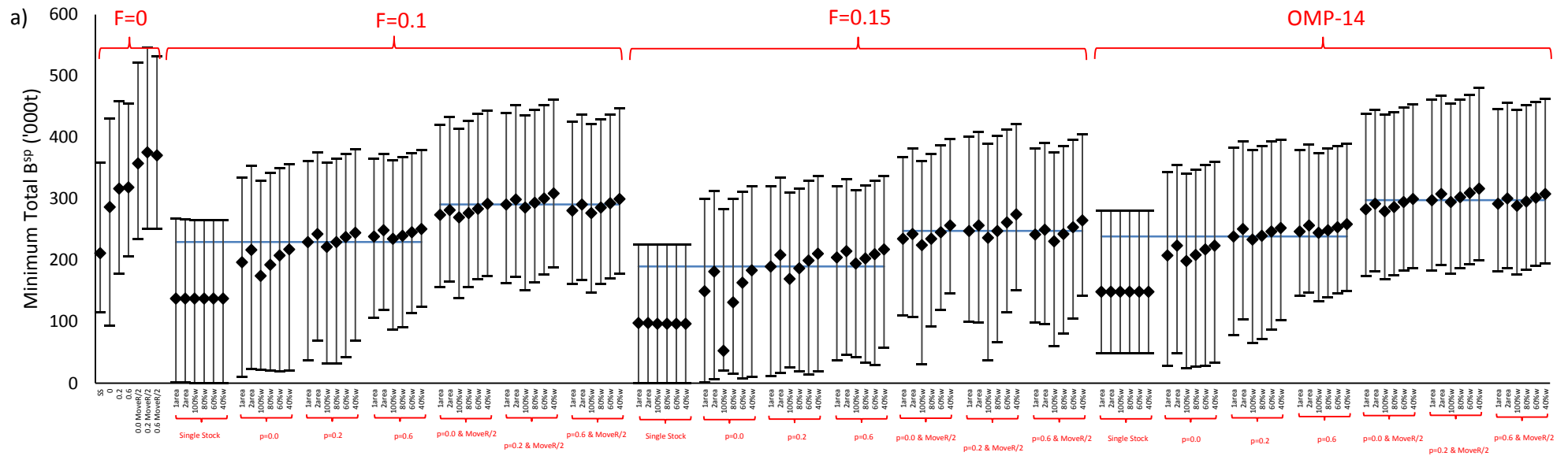
**Figure 5.** The ratio of the probability of being below the west (total for single stock OM) 2007 total biomass at least once during the projection period under catch : no directed sardine catch scenarios. Results are shown for a single area, two area variable and 4 two area fixed directed TAC management scenarios, under the 7 OMs considered in Appendix F. The lower plot is a repeat of the upper plot but over a smaller range for the vertical axis (see Figure F6, Appendix F).



**Figure 6.** The hockey-stick stock recruitment relationships at the joint posterior mode for the single stock and two component OMs. The grey dashed lines denote median recruitment during peak variability years.



**Figure 7.** Some individual trajectory plots (14 out of 1000, with the median shown in black) of simulated directed sardine catch west of Cape Agulhas and total directed sardine catch for (top row) a two-area MP with the proportion of TAC allocated west of Cape Agulhas varying according to the proportion of biomass surveyed west of Cape Agulhas during the preceding November and (middle row) a two-area MP with a fixed proportion of 40% of the TAC allocated west of Cape Agulhas. The lower row reproduces the total directed sardine catch plots over a smaller range for the vertical axis for varying proportional allocation (left) and fixed proportional allocation (right).



**Figure 8.** The a) minimum total sardine spawner biomass over the projection period, b) minimum west sardine spawner biomass over the projection period, and c) risk under sardine MPs of F=0, F=0.1, F=0.15 or OMP-14, for single area, two area variable and 4 two area fixed directed TAC MPs, under the 7 OMs considered in Appendix F (see Figures F4d, F5d, F6d). The horizontal line, shown for comparative purposes only, corresponds to the single area management scenario under the OM with p=0.2.

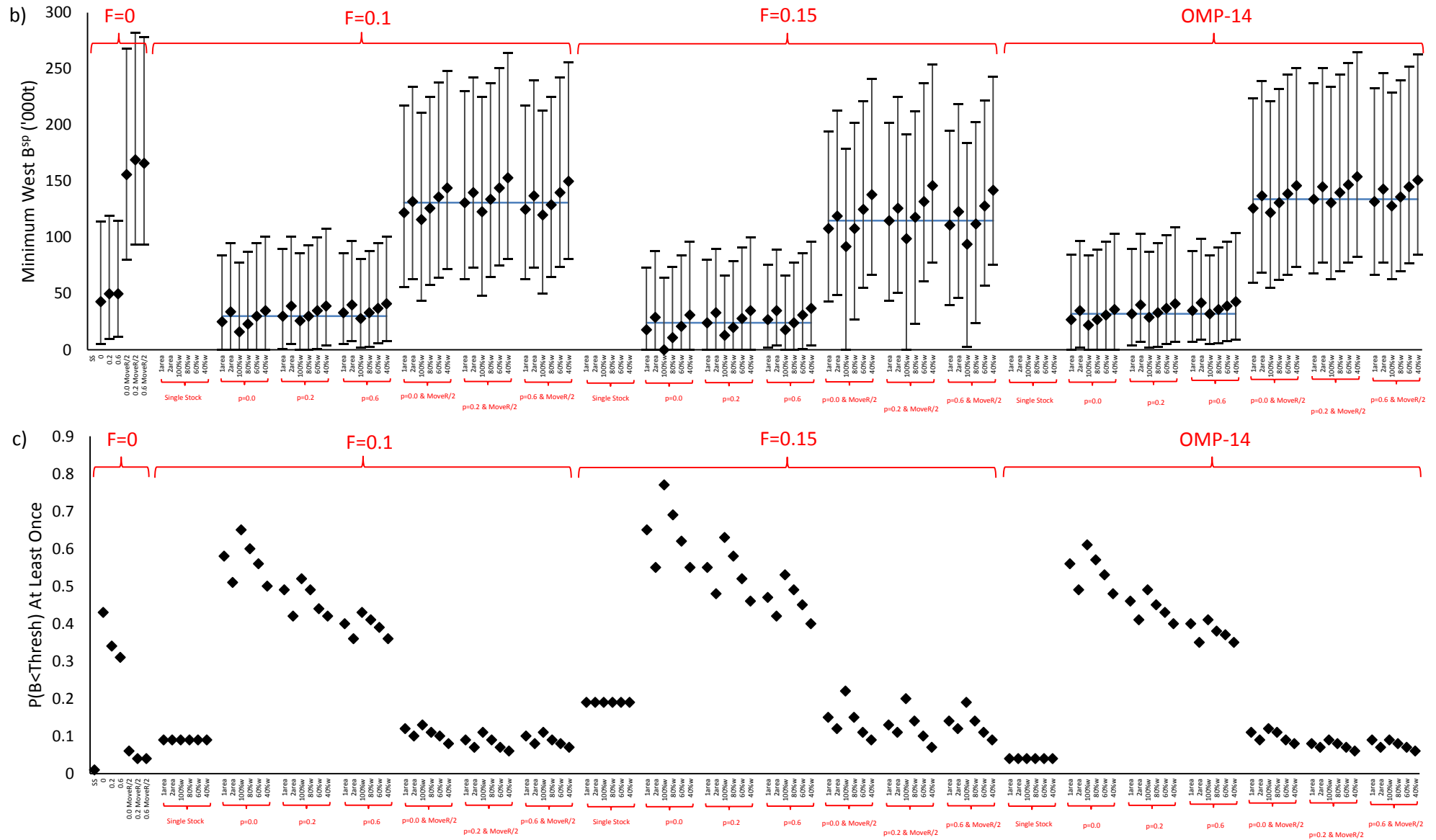
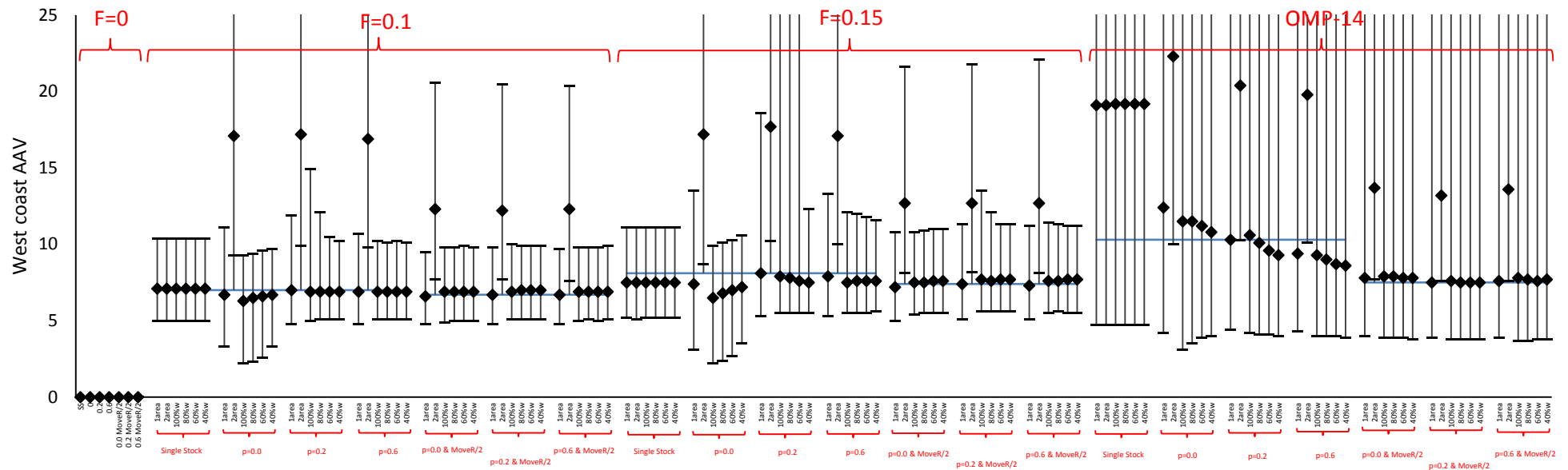
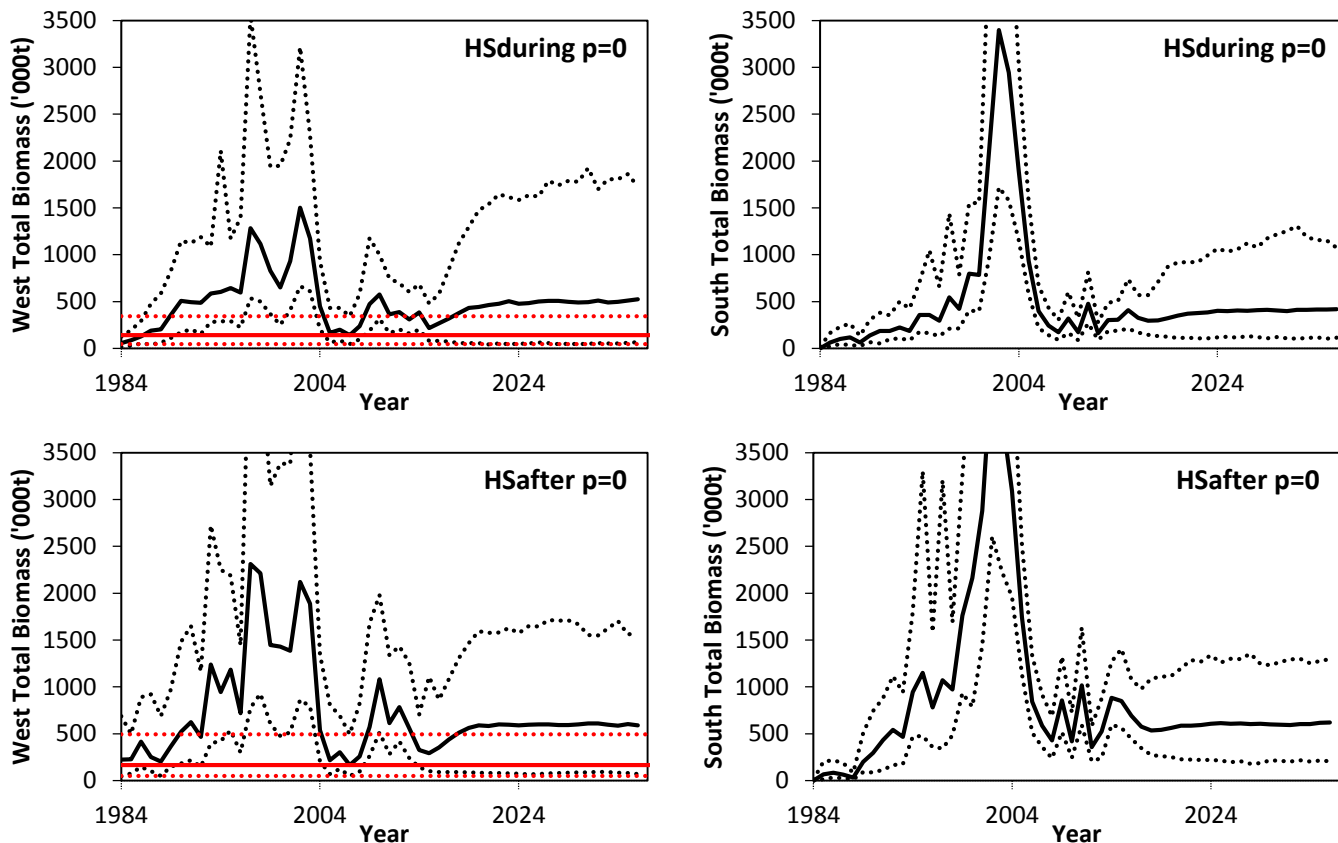


Figure 8 (cont.)

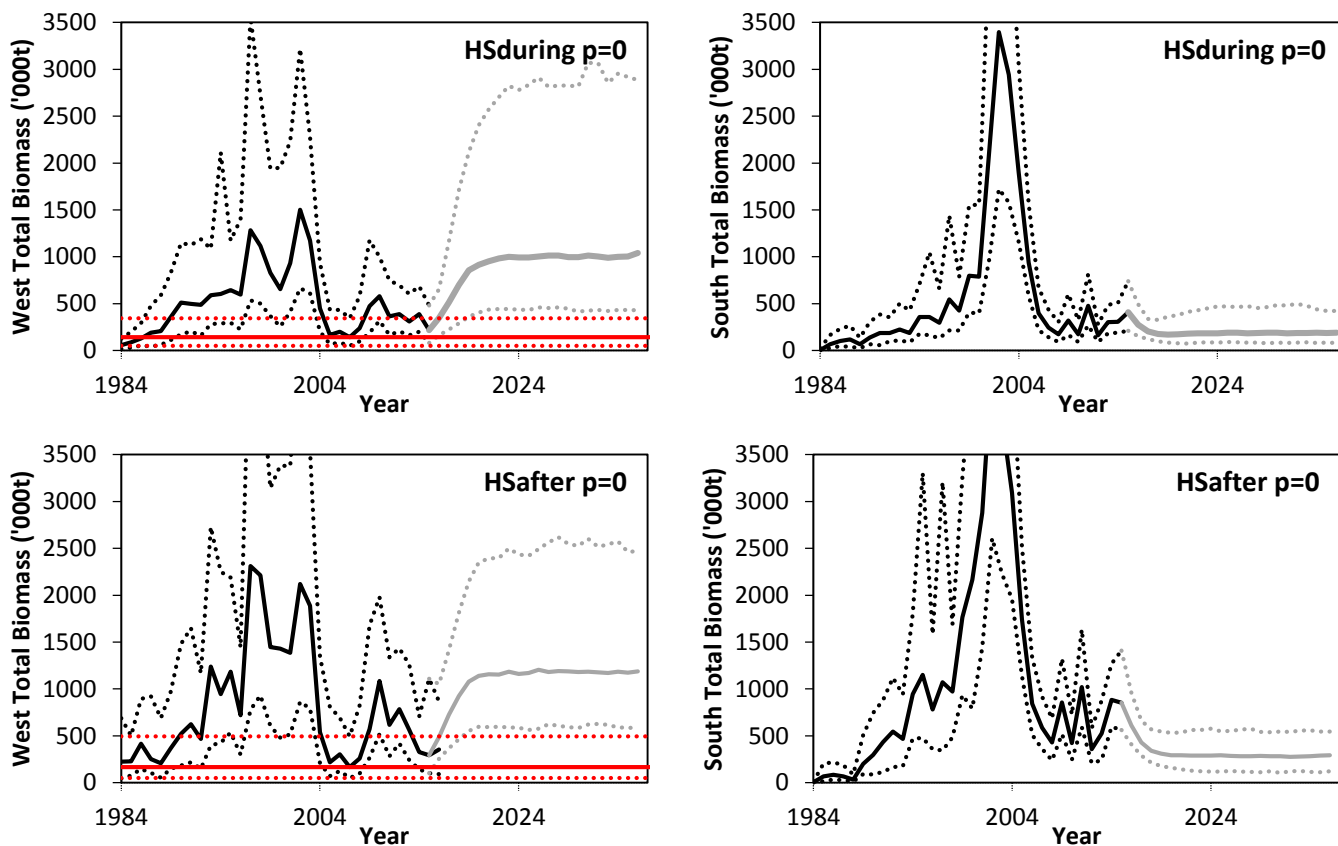


**Figure 9.** The average inter-annual variability in west directed sardine catch under sardine MPs of  $F=0$ ,  $F=0.1$ ,  $F=0.15$  or OMP-14, for single area, two area variable and 4 two area fixed directed TAC MPs, under the 7 OMs considered in Appendix F (see Figure F8d). The horizontal line, shown for comparative purposes only, corresponds to the single area management scenario under the OM with  $p=0.2$ .

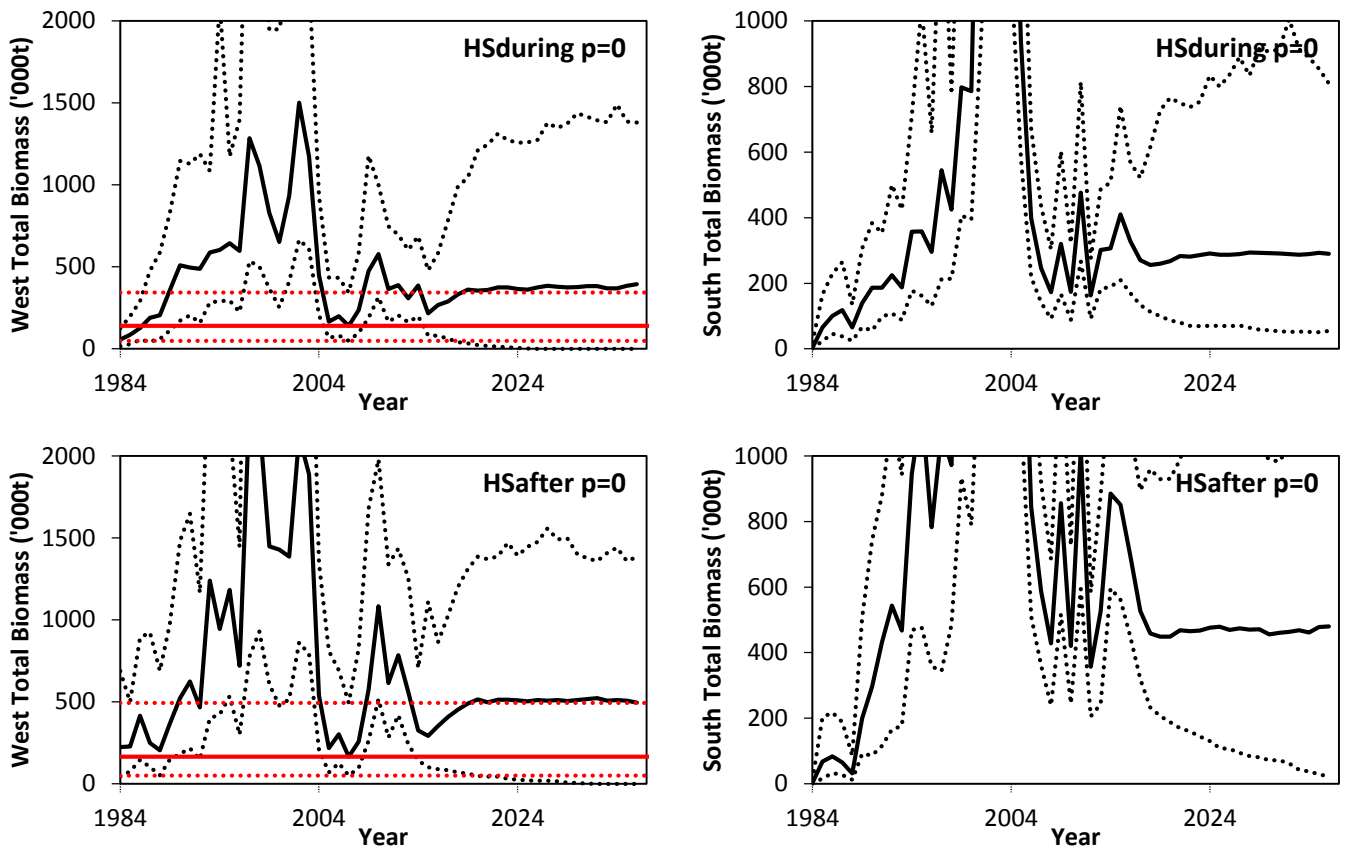
**Appendix A: Sardine biomass trajectories to compare between the OM with the Hockey Stick stock recruitment relationship estimated during or after conditioning. The  $B_w(2007)$  threshold is shown in red.**



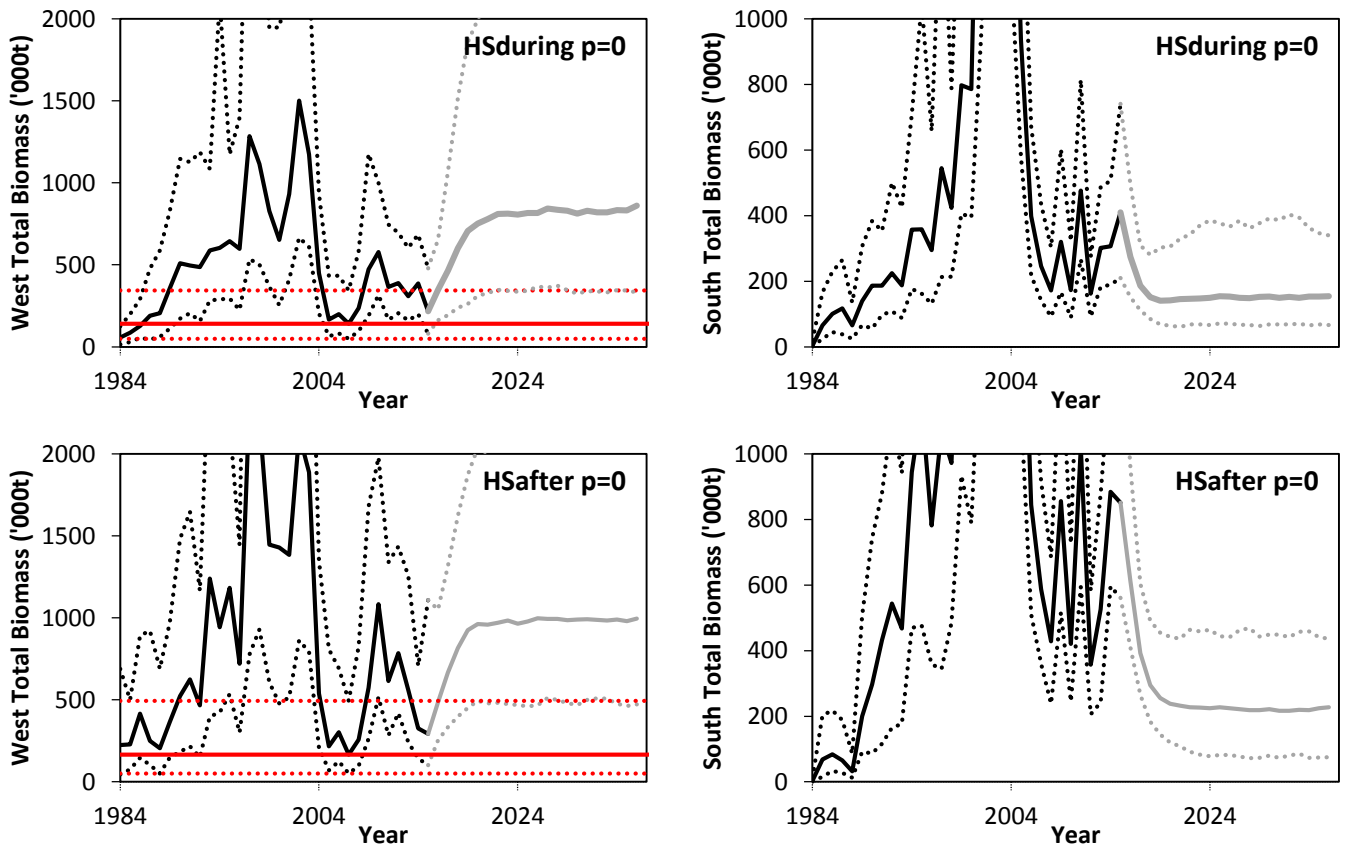
**Figure A1.** Sardine biomass for west (left) and south (right) components for Hockey Stick relationship estimated during (above) or after (below) conditioning, assuming Mover,  $p=0$  and no future catch.



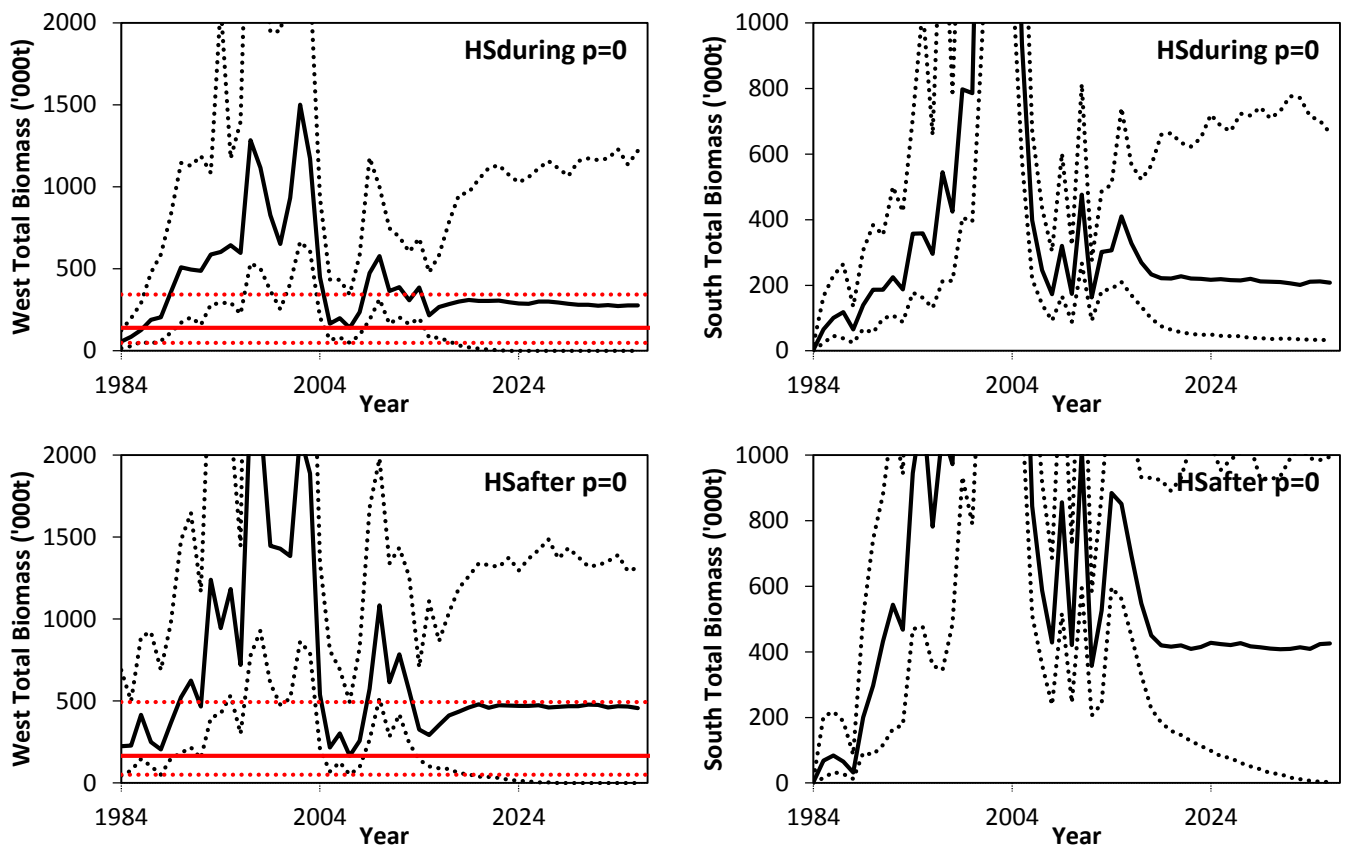
**Figure A2.** Sardine biomass for west (left) and south (right) components for Hockey Stick relationship estimated during (above) or after (below) conditioning, assuming  $0.25 * \text{Mover}$ ,  $p=0$  and no future catch.



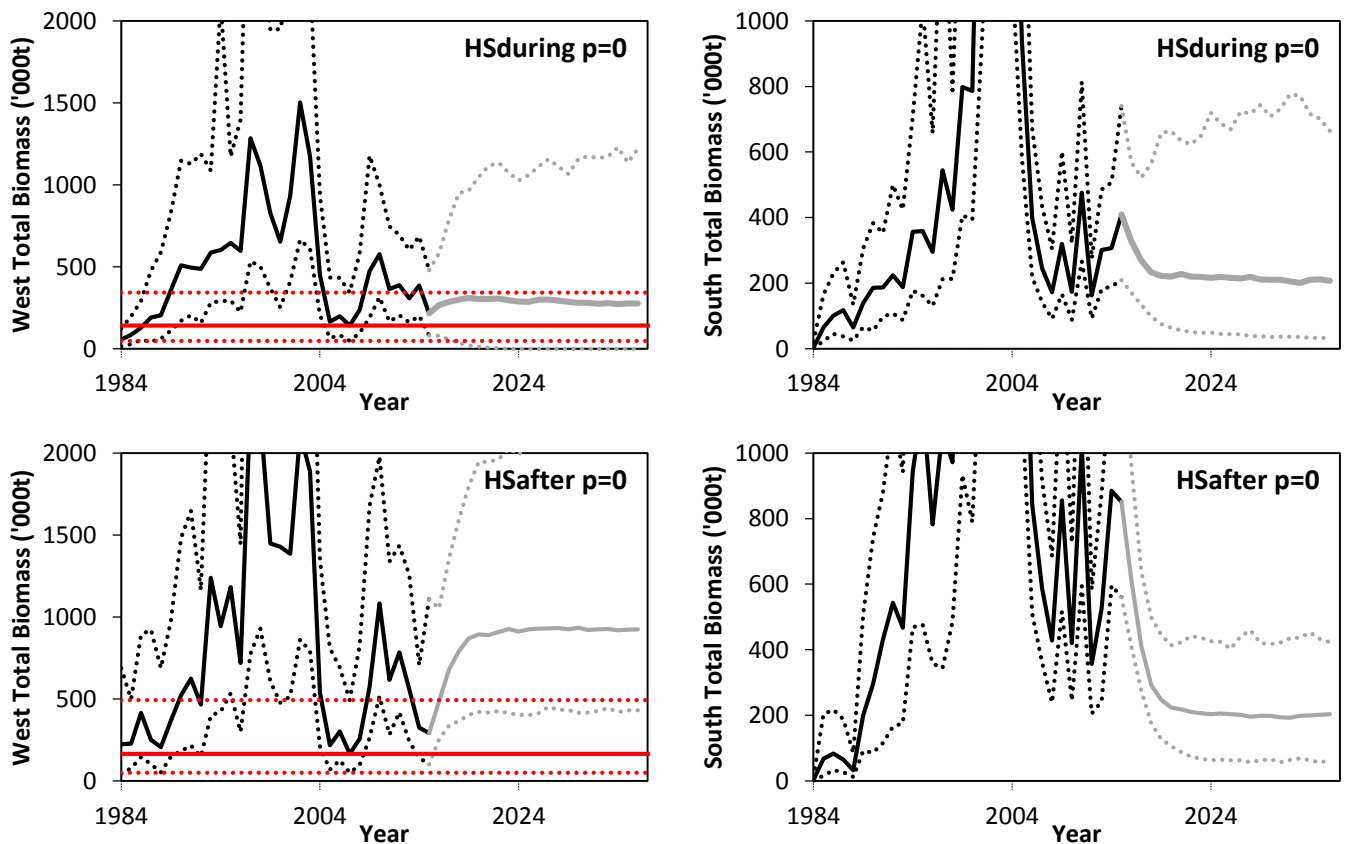
**Figure A3.** Sardine biomass for west (left) and south (right) components for Hockey Stick relationship estimated during (above) or after (below) conditioning, assuming Mover,  $p=0$  and future TACs set at 10% true biomass.



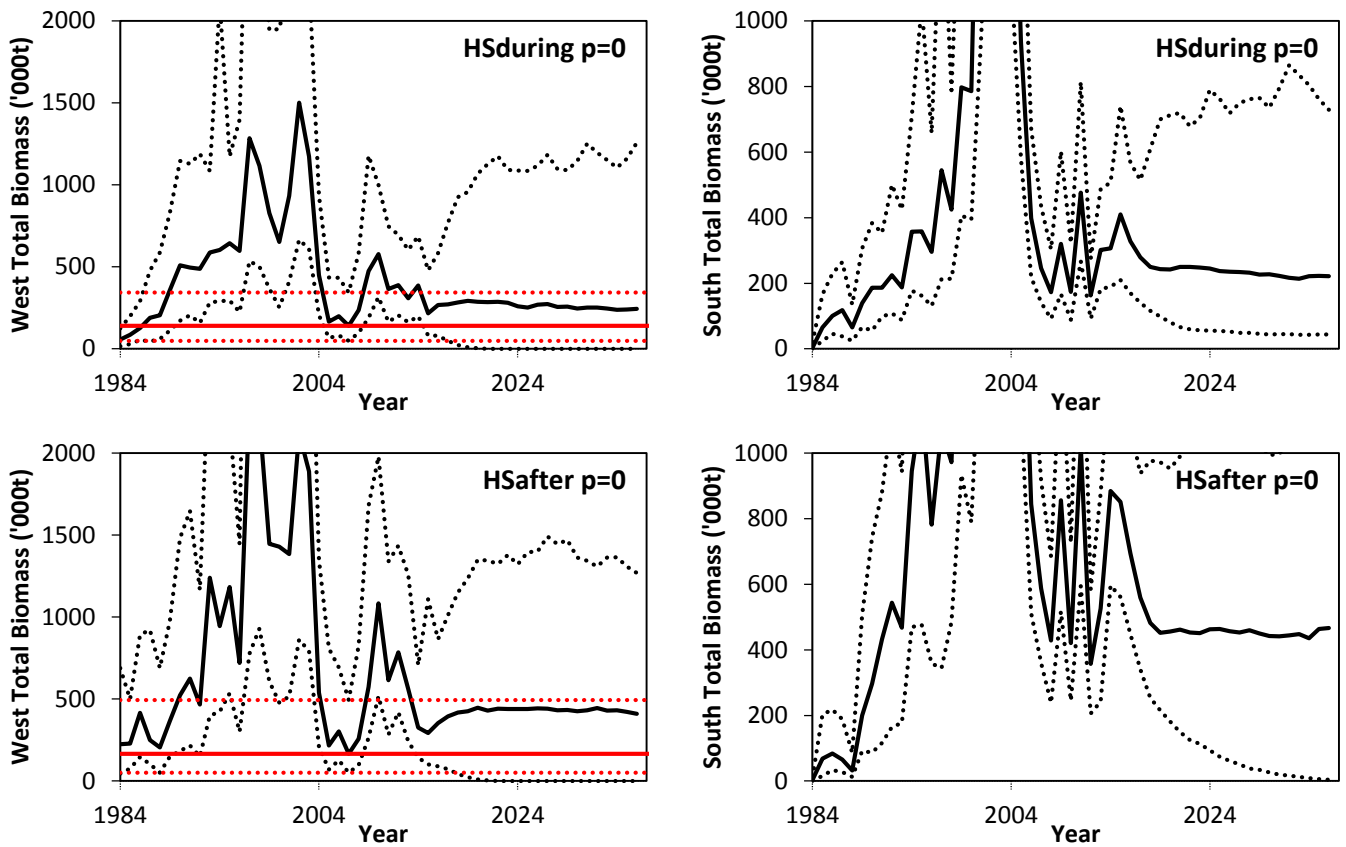
**Figure A4.** Sardine biomass for west (left) and south (right) components for Hockey Stick relationship estimated during (above) or after (below) conditioning, assuming  $0.25 \cdot \text{Mover}$ ,  $p=0$  and future TACs set at 10% true biomass.



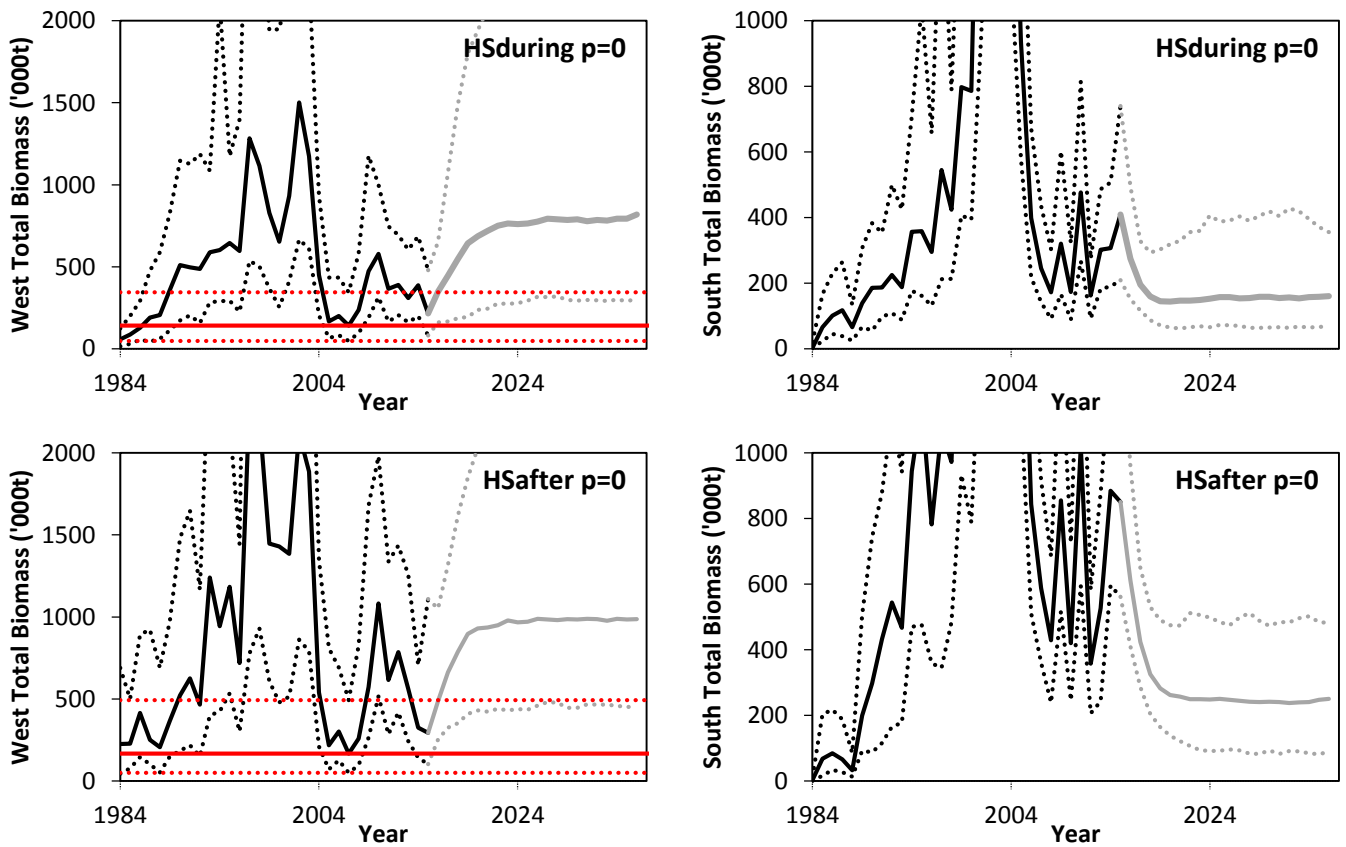
**Figure A5.** Sardine biomass for west (left) and south (right) components for Hockey Stick relationship estimated during (above) or after (below) conditioning, assuming MoveR,  $p=0$  and future TACs set at 20% observed biomass.



**Figure A6.** Sardine biomass for west (left) and south (right) components for Hockey Stick relationship estimated during (above) or after (below) conditioning, assuming  $0.25 \cdot \text{MoveR}$ ,  $p=0$  and future TACs set at 20% observed biomass.

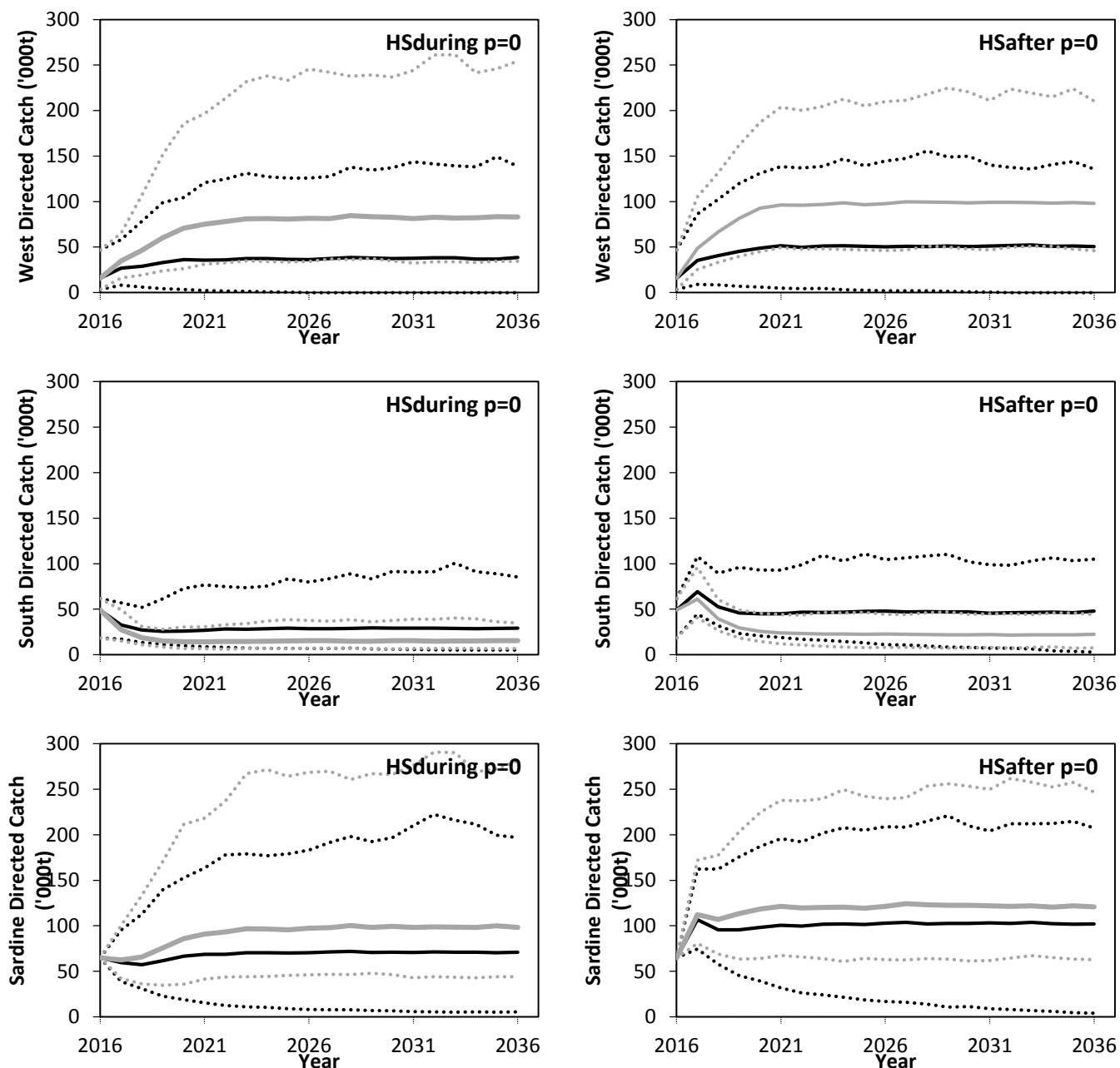


**Figure A7.** Sardine biomass for west (left) and south (right) components for Hockey Stick relationship estimated during (above) or after (below) conditioning, assuming MoveR,  $p=0$  and future TACs set using OMP-14-like HCR with single area sardine TAC.

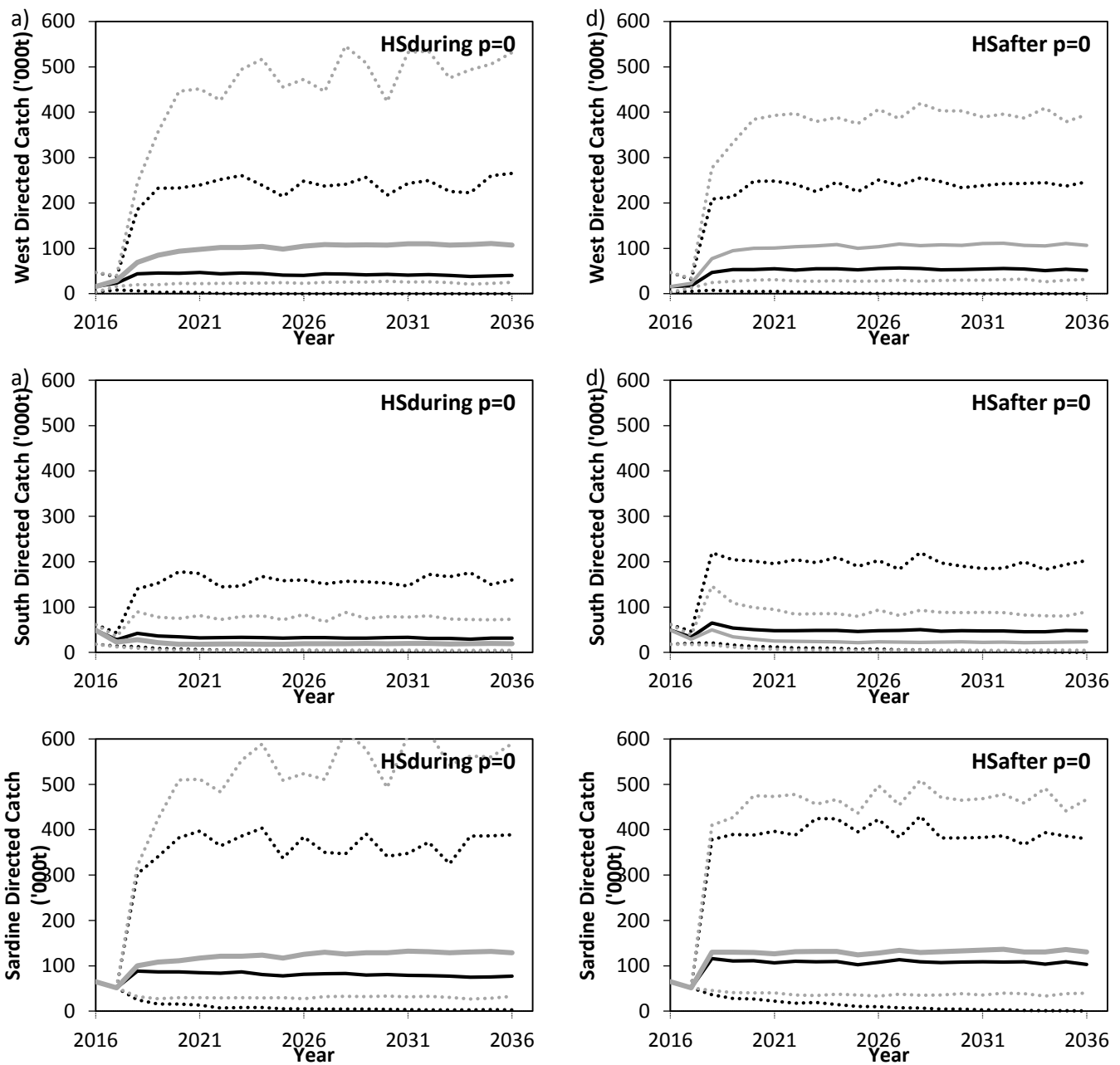


**Figure A8.** Sardine biomass for west (left) and south (right) components for Hockey Stick relationship estimated during (above) or after (below) conditioning, assuming  $0.25 * \text{MoveR}$ ,  $p=0$  and future TACs set using OMP-14-like HCR with single area sardine TAC.

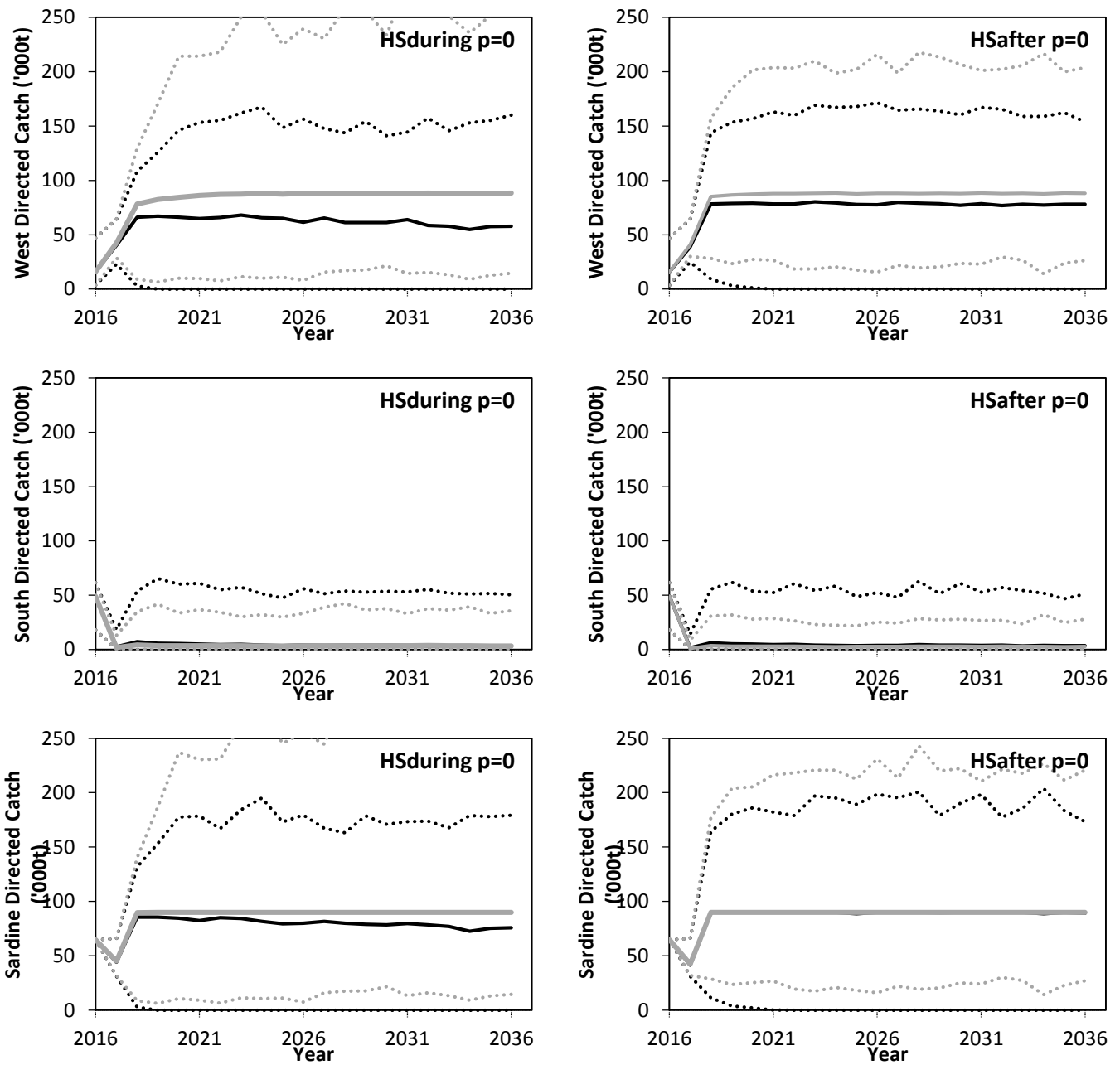
**Appendix B: Sardine catch trajectories to compare between the OM with the Hockey Stick stock recruitment relationship estimated during or after conditioning.**



**Figure B1.** Sardine catch for west (top) and south (middle) coasts and total catch (bottom) for Hockey Stick relationship estimated during (left) or after (right) conditioning, assuming MoveR,  $p=0$  and future TACs set at 10% true biomass. The grey lines show the same results, but assuming  $0.25 \cdot \text{MoveR}$ .

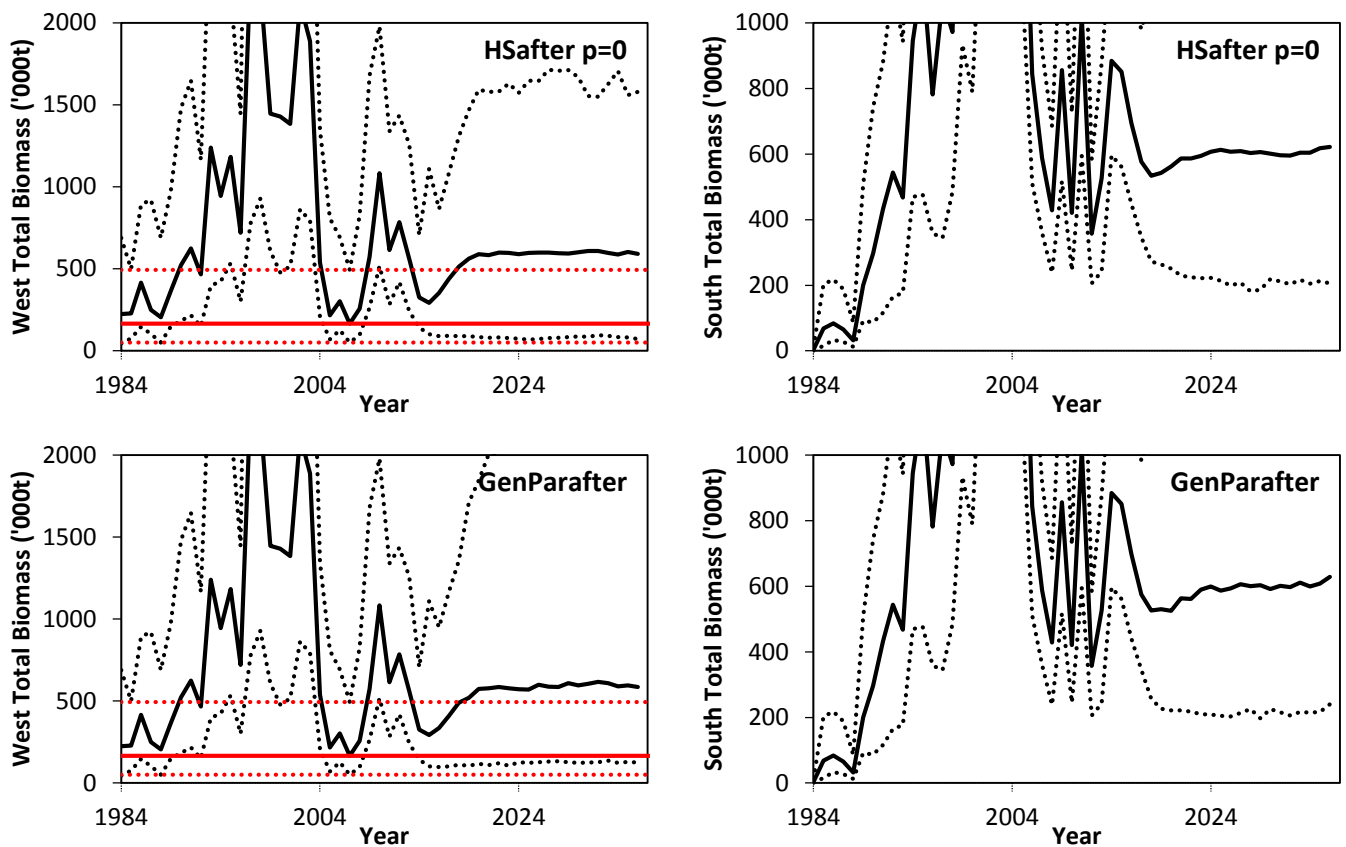


**Figure B2.** Sardine catch for west (top) and south (middle) coasts and total catch (bottom) for Hockey Stick relationship estimated during (left) or after (right) conditioning, assuming MoveR,  $p=0$  and future TACs set at 20% observed biomass. The grey lines show the same results, but assuming  $0.25 \cdot \text{MoveR}$ .

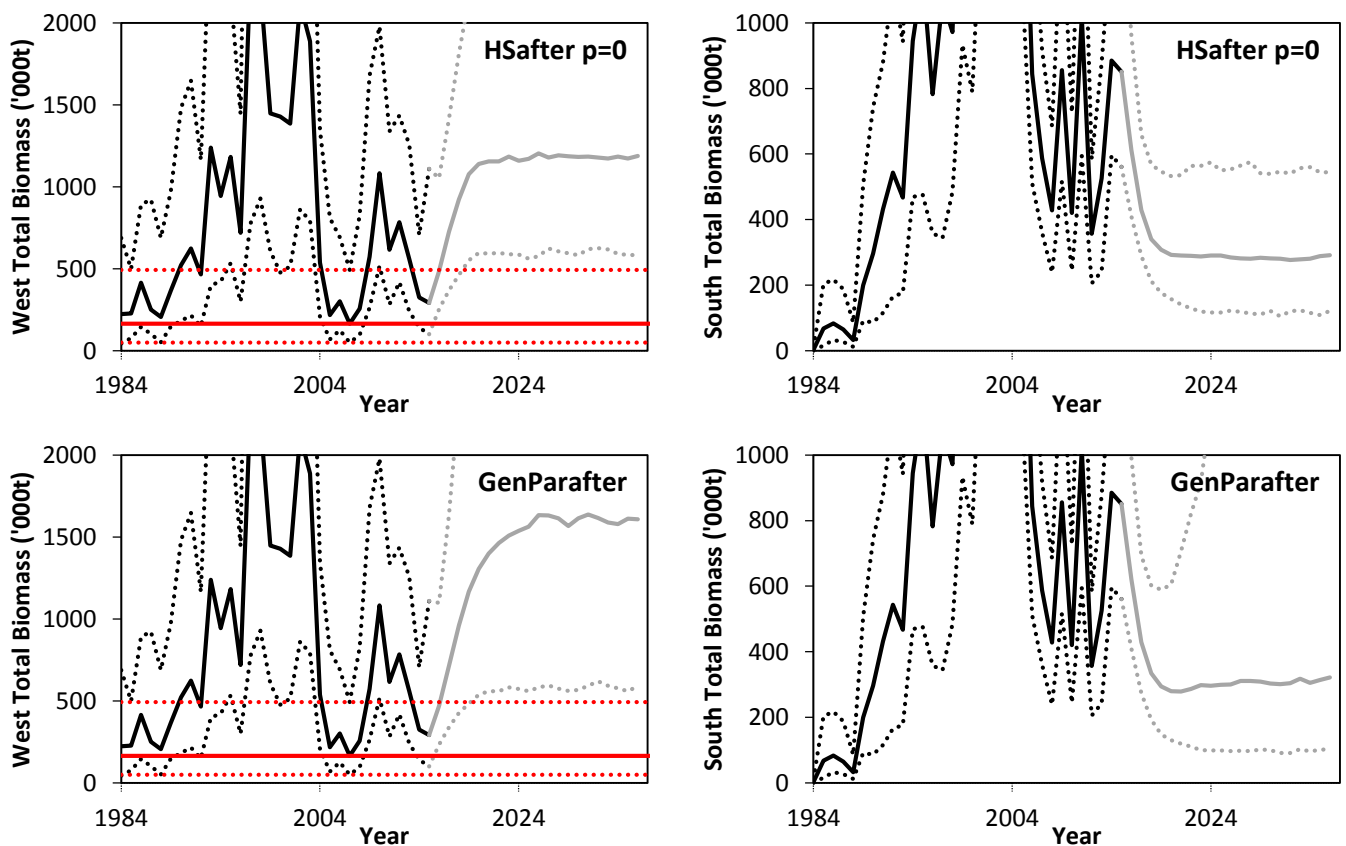


**Figure B3.** Sardine catch for west (top) and south (middle) coasts and total catch (bottom) for Hockey Stick relationship estimated during (left) or after (right) conditioning, assuming MoveR,  $p=0$  and future TACs set using OMP-14-like HCR with single area sardine TAC. The grey lines show the same results, but assuming  $0.25 \cdot \text{MoveR}$ .

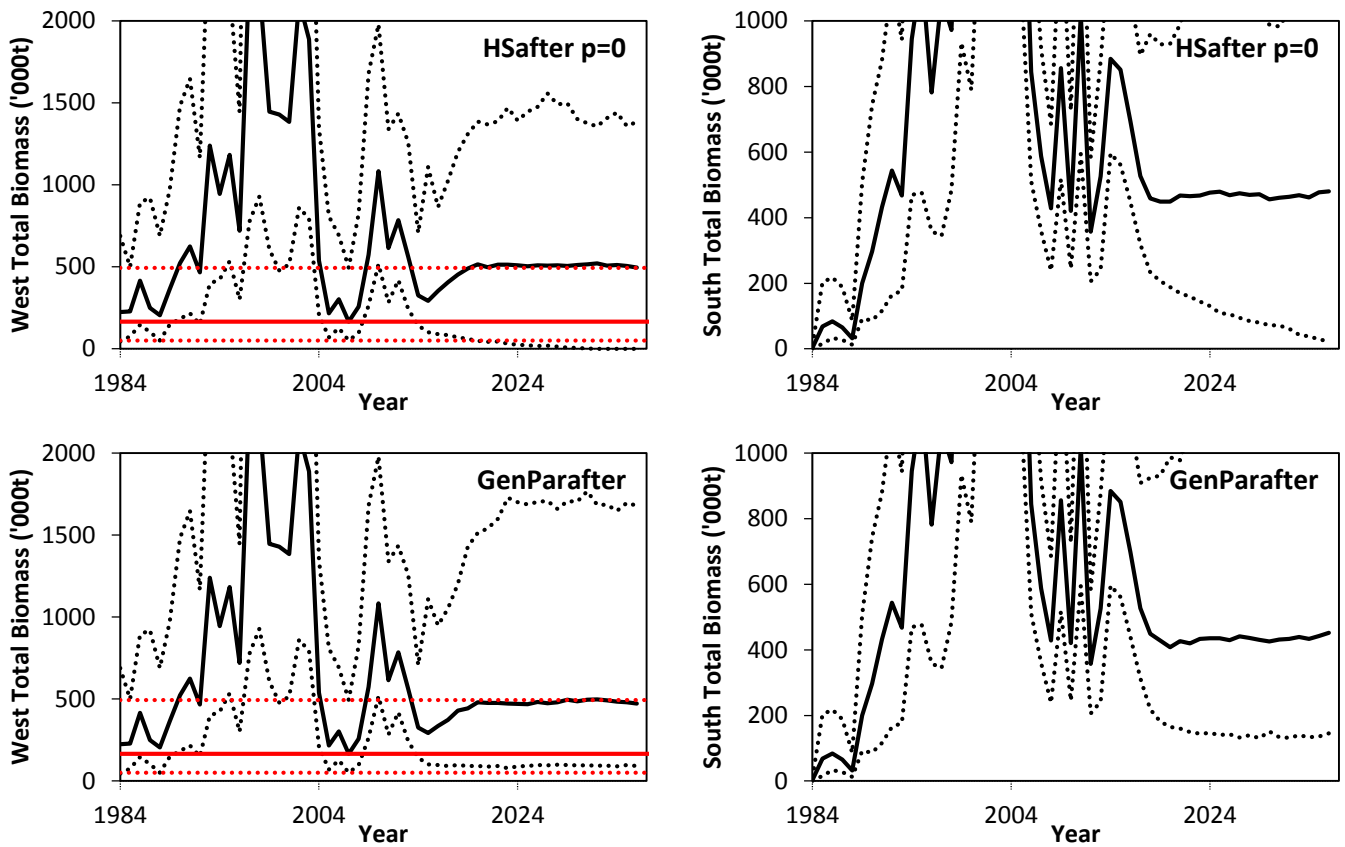
**Appendix C: Sardine biomass trajectories from the OM with the stock recruitment relationship estimated after conditioning, to compare between the Hockey Stick and General Parametric stock recruitment relationships. The  $B_w(2007)$  threshold is shown in red.**



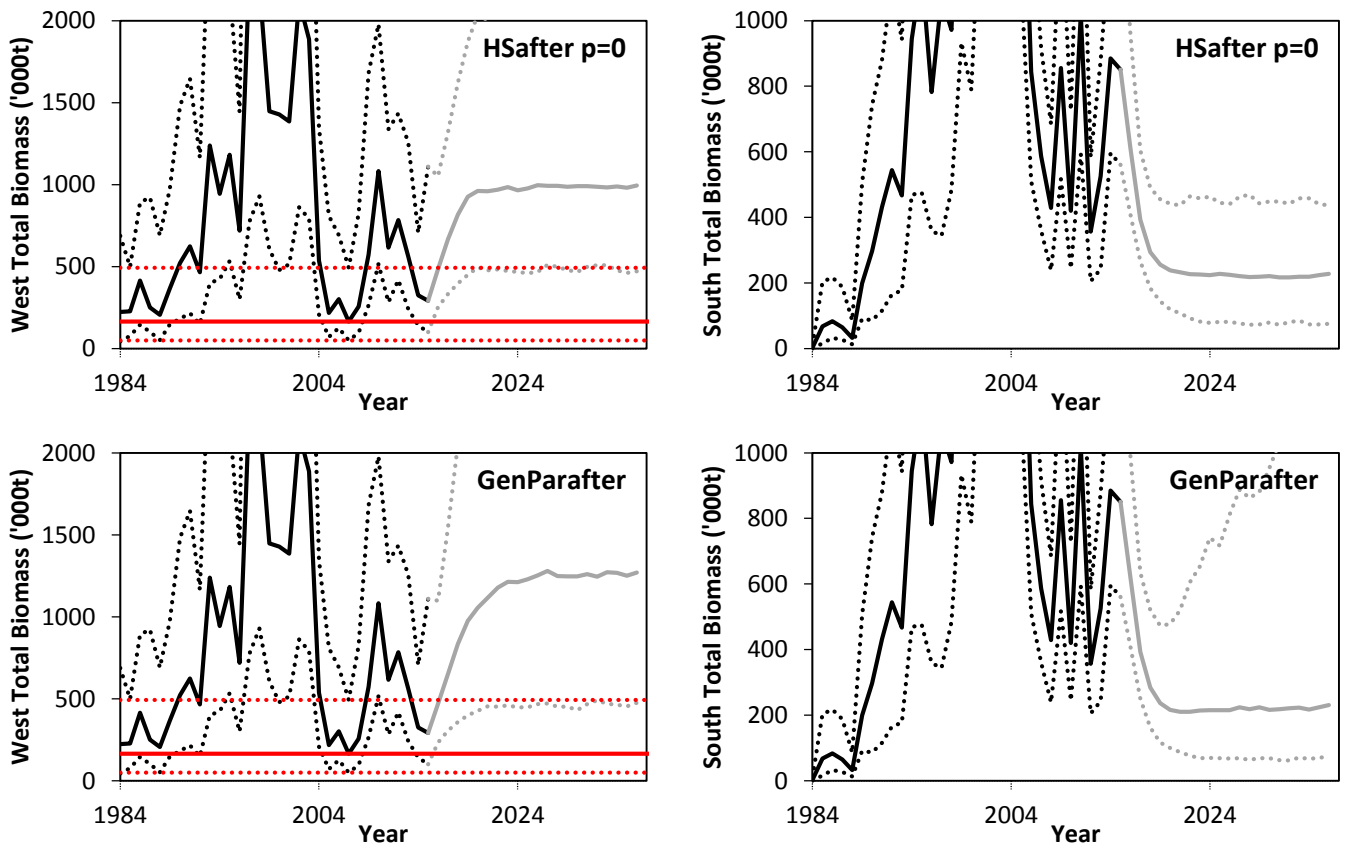
**Figure C1.** Sardine biomass for west (left) and south (right) components for Hockey Stick (above) and General Parametric (below) stock relationship estimated after conditioning, assuming MoveR,  $p=0$  and no future catch.



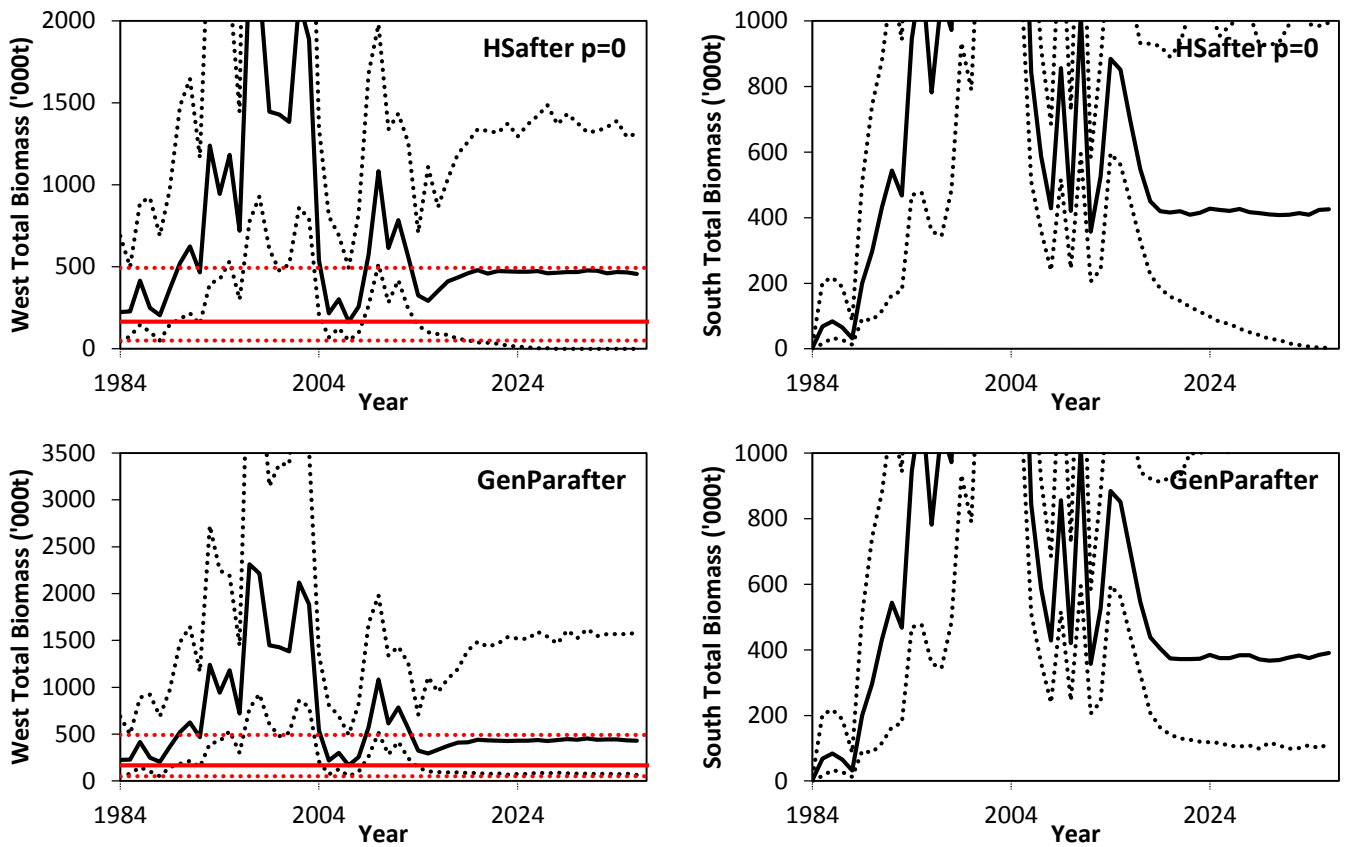
**Figure C2.** Sardine biomass for west (left) and south (right) components for Hockey Stick (above) and General Parametric (below) stock relationship estimated after conditioning, assuming  $0.25 * \text{MoveR}$ ,  $p=0$  and no future catch.



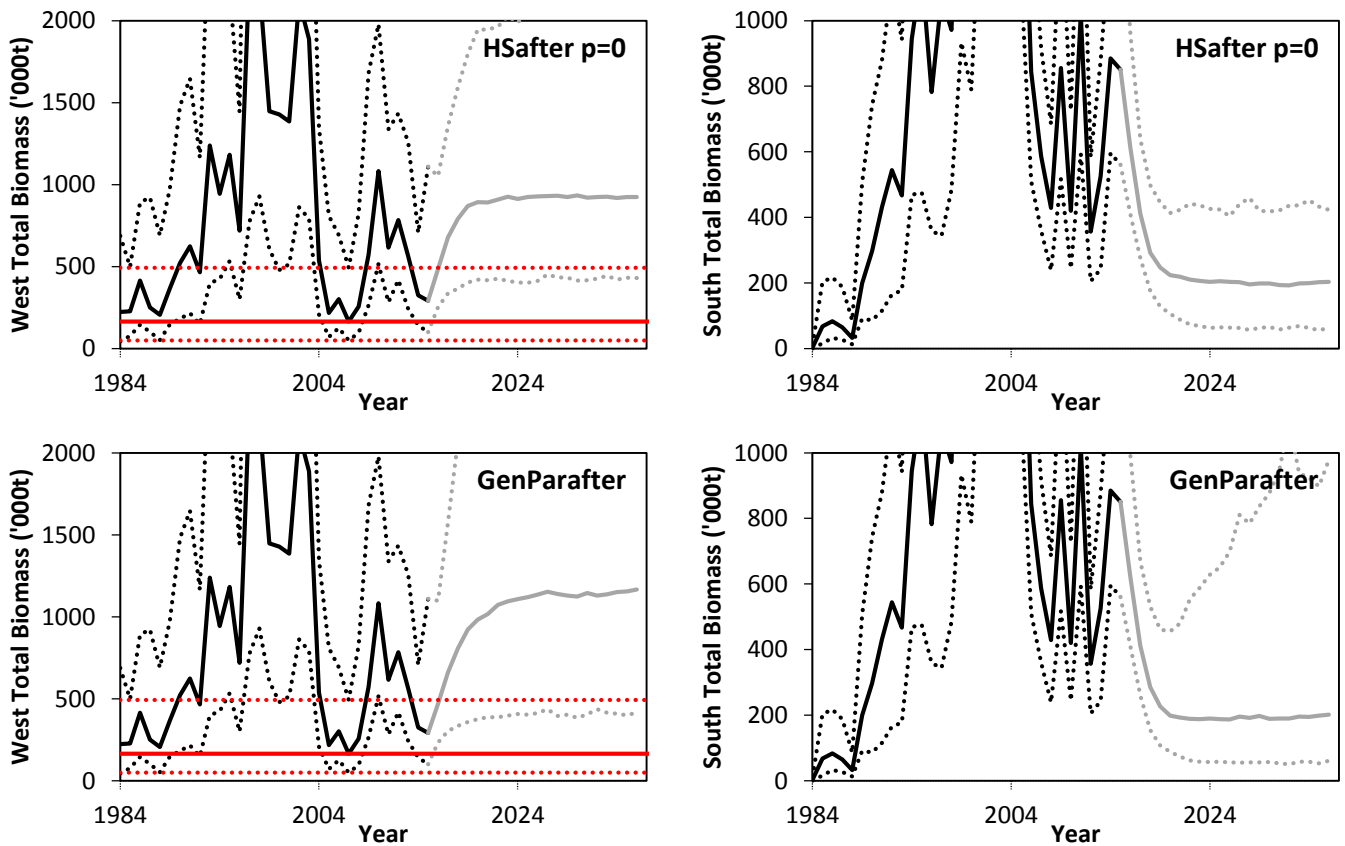
**Figure C3.** Sardine biomass for west (left) and south (right) components for Hockey Stick (above) and General Parametric (below) stock relationship estimated after conditioning, assuming MoveR,  $p=0$  and future TACs set at 10% true biomass.



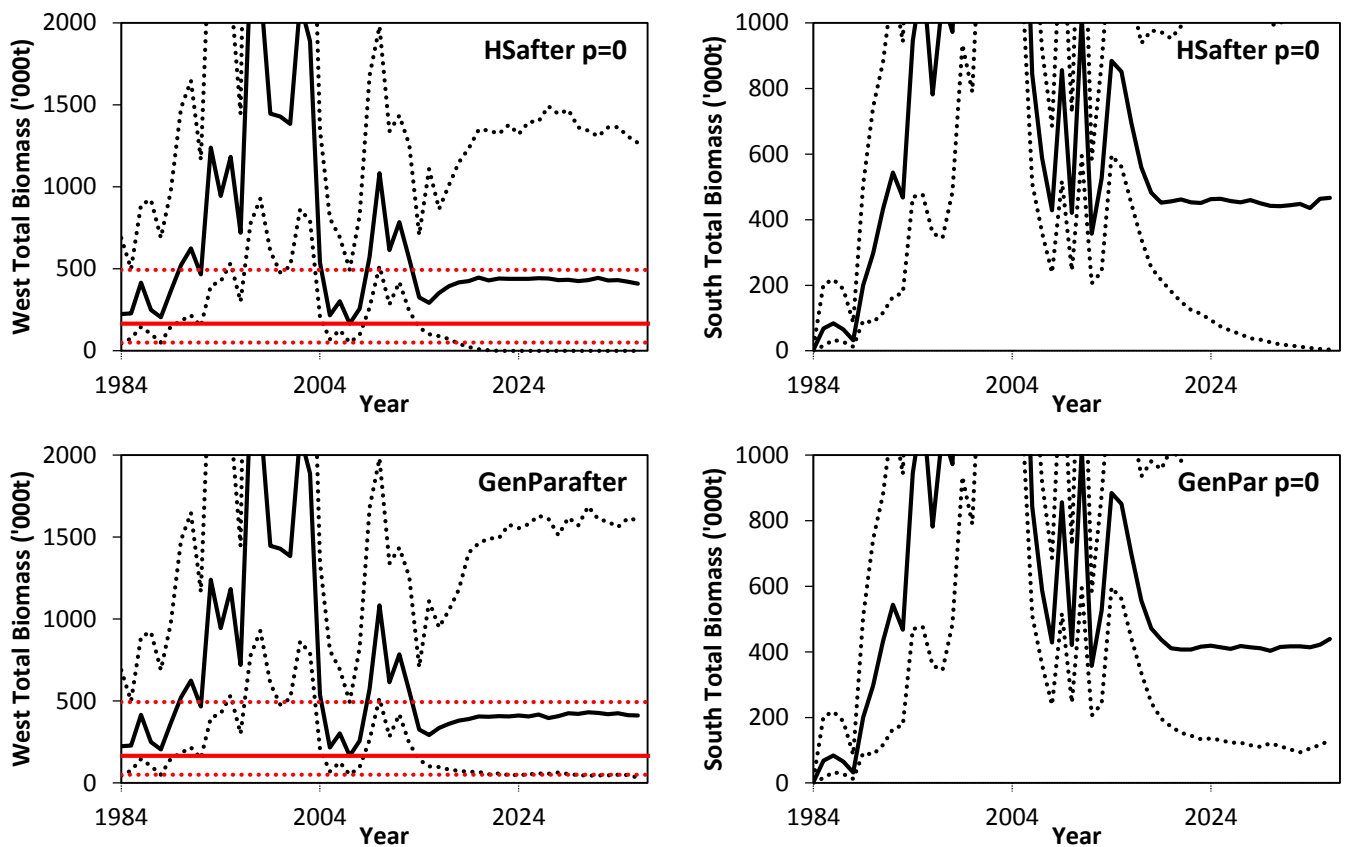
**Figure C4.** Sardine biomass for west (left) and south (right) components for Hockey Stick (above) and General Parametric (below) stock relationship estimated after conditioning, assuming  $0.25 \cdot \text{MoveR}$ ,  $p=0$  and future TACs set at 10% true biomass.



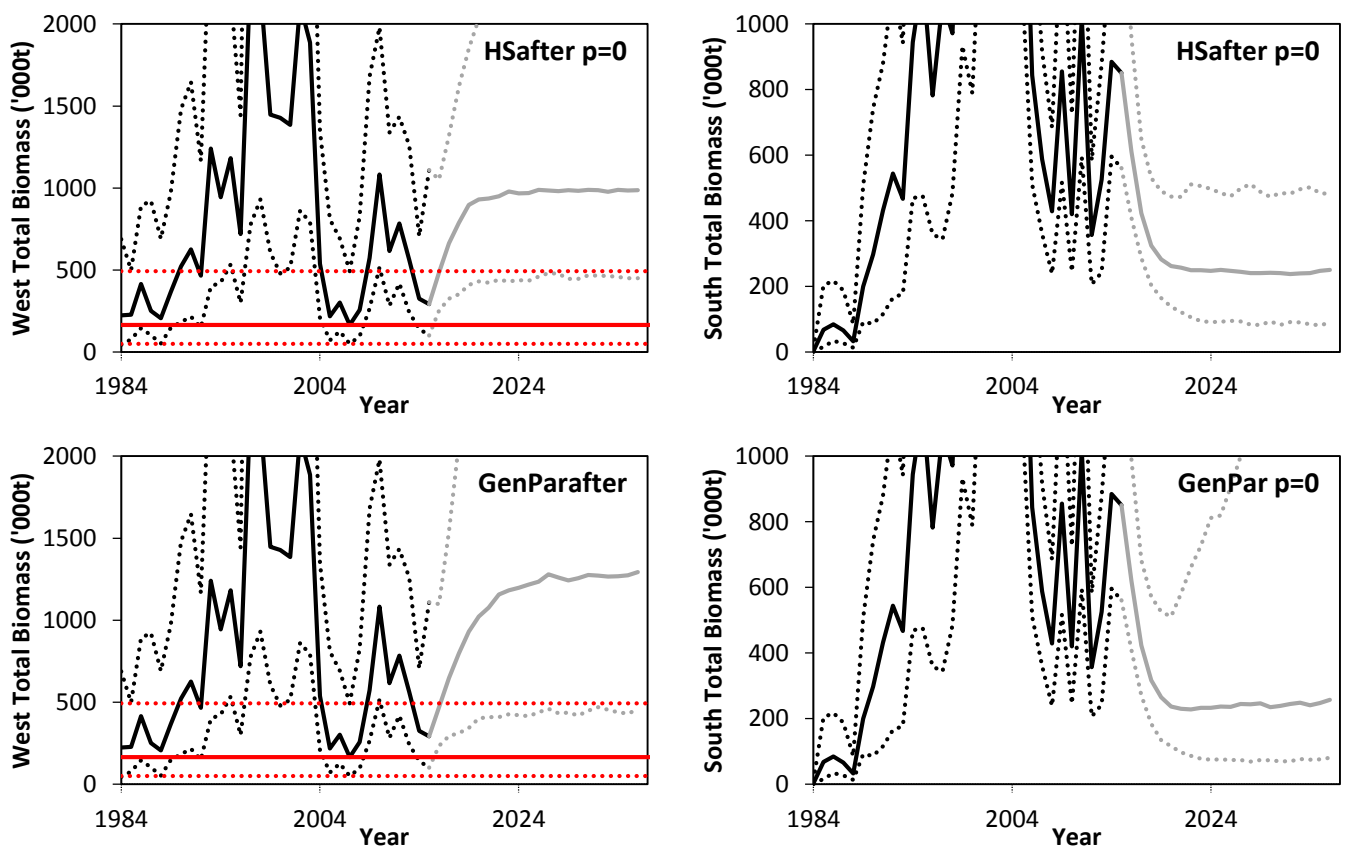
**Figure C5.** Sardine biomass for west (left) and south (right) components for Hockey Stick (above) and General Parametric (below) stock relationship estimated after conditioning, assuming MoveR,  $p=0$  and future TACs set at 20% observed biomass.



**Figure C6.** Sardine biomass for west (left) and south (right) components for Hockey Stick (above) and General Parametric (below) stock relationship estimated after conditioning, assuming  $0.25 \cdot \text{MoveR}$ ,  $p=0$  and future TACs set at 20% observed biomass.

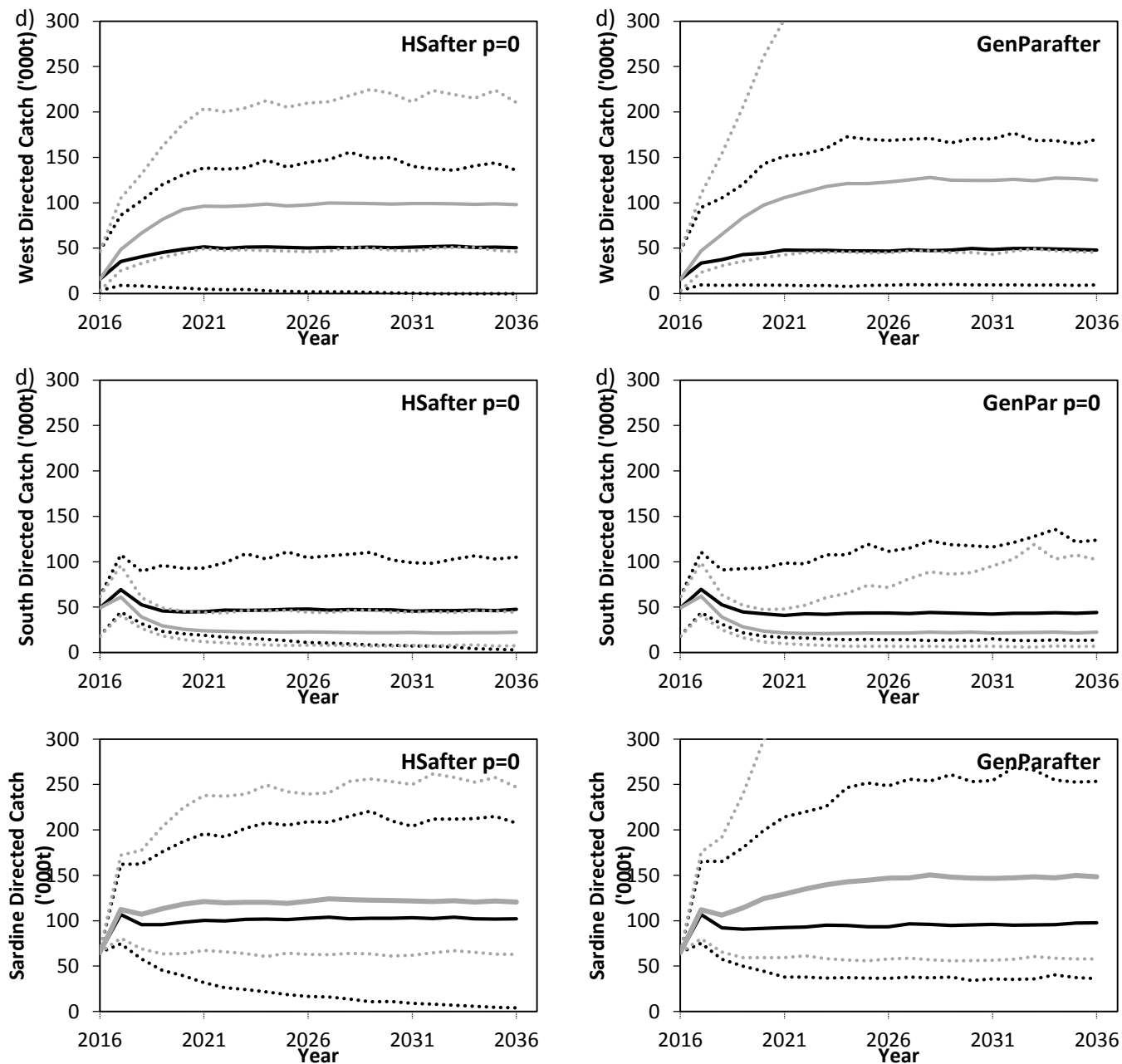


**Figure C7.** Sardine biomass for west (left) and south (right) components for Hockey Stick (above) and General Parametric (below) stock relationship estimated after conditioning, assuming MoveR,  $p=0$  and future TACs set using OMP-14-like HCR with single area sardine TAC.

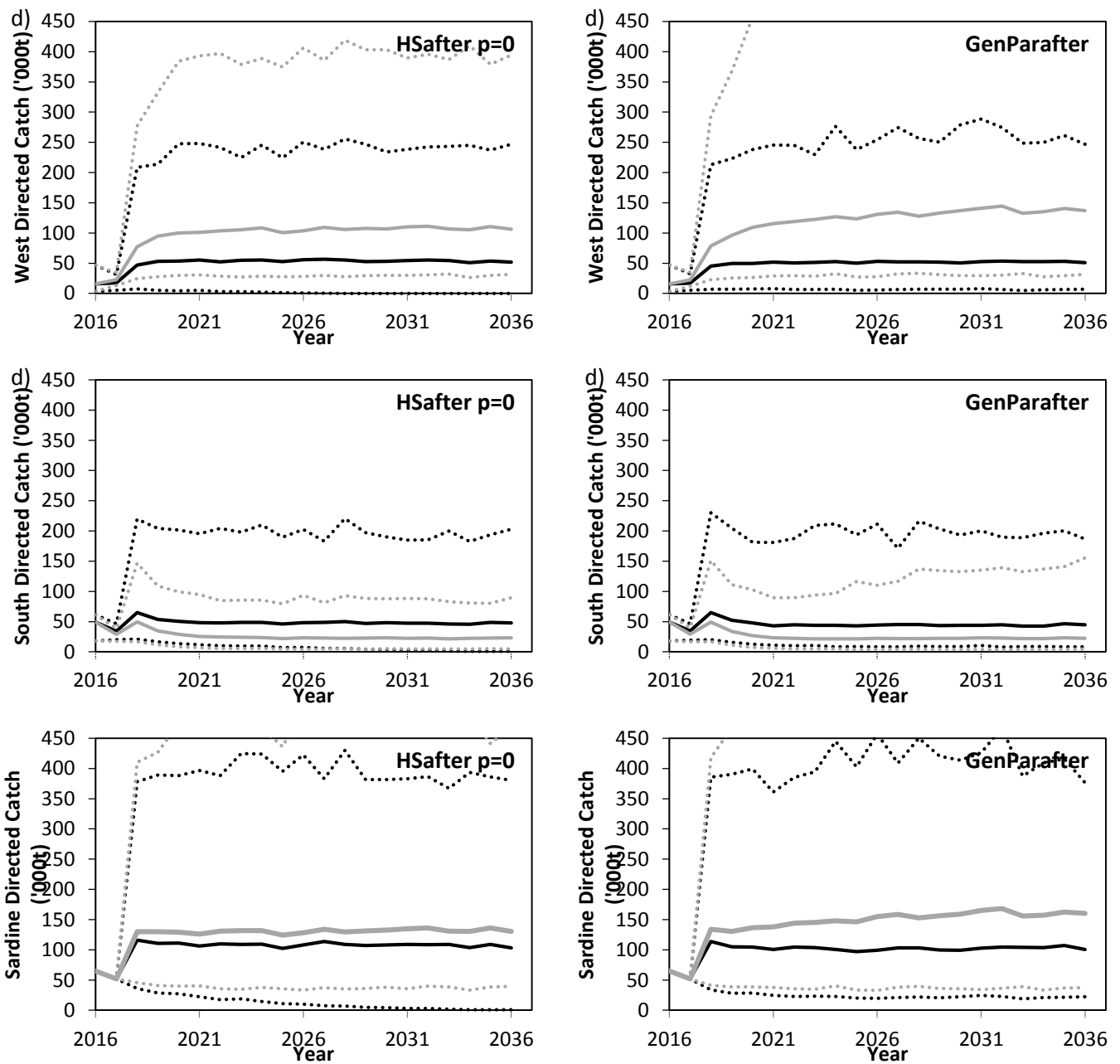


**Figure C8.** Sardine biomass for west (left) and south (right) components for Hockey Stick (above) and General Parametric (below) stock relationship estimated after conditioning, assuming  $0.25 \cdot \text{MoveR}$ ,  $p=0$  and future TACs set using OMP-14-like HCR with single area sardine TAC.

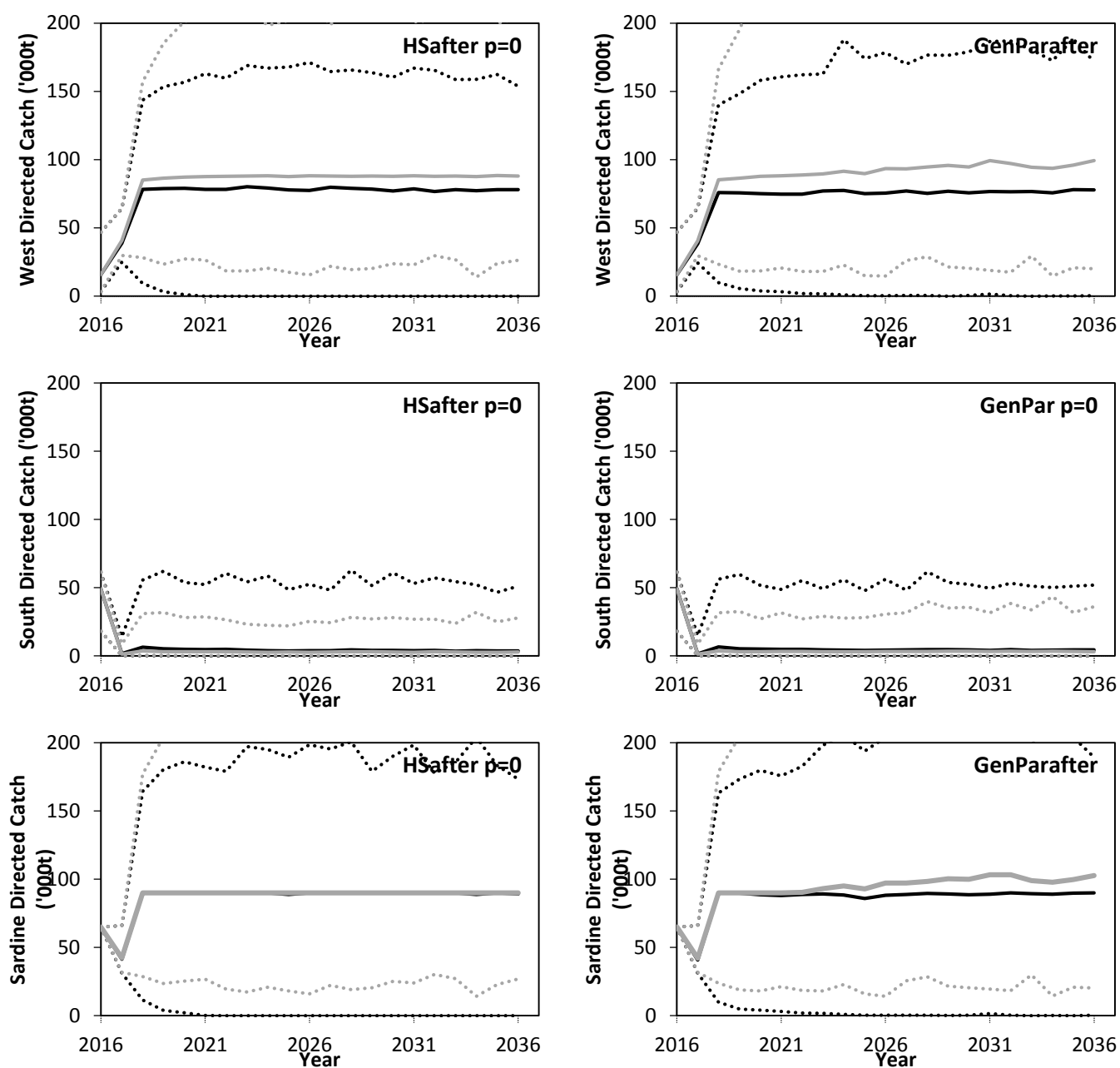
**Appendix D: Sardine catch trajectories from the OM with the stock recruitment relationship estimated after conditioning, to compare between the Hockey Stick and General Parametric stock recruitment relationships.**



**Figure D1.** Sardine catch for west (top) and south (middle) coasts and total catch (bottom) for Hockey stick (left) or General Parametric (right) stock relationship estimated after conditioning, assuming Mover,  $p=0$  and future TACs set at 10% true biomass. The grey lines show the same results, but assuming  $0.25 \cdot \text{Mover}$ .



**Figure D2.** Sardine catch for west (top) and south (middle) coasts and total catch (bottom) for Hockey stick (left) or General Parametric (right) stock relationship estimated after conditioning, assuming MoveR,  $p=0$  and future TACs set at 20% observed biomass. The grey lines show the same results, but assuming  $0.25 * \text{MoveR}$ .



**Figure D3.** Sardine catch for west (top) and south (middle) coasts and total catch (bottom) for Hockey stick (left) or General Parametric (right) stock relationship estimated after conditioning, assuming MoveR,  $p=0$  and future TACs set using OMP-14-like HCR with single area sardine TAC. The grey lines show the same results, but assuming  $0.25 \cdot \text{MoveR}$ .

**Appendix E: Performance statistics for a range of fixed fishing mortality (F) scenarios for the directed sardine TAC, with and without a constraint of a maximum 20% inter-annual decrease in the TAC.**

The performance statistics are represented by median and [95% probability interval]. All catches and biomasses are given in thousands of tons.

The sardine risk threshold used here is the lowest historical (2007) biomass for the west component, or, in the case of the single sardine stock Operating Model (OM), for the total population. The risk statistics are thus not directly comparable between the single stock and two component OMs. The anchovy risk threshold used here is a quarter of the lowest historical (1996) biomass. The three risk statistics are as follows:

*At least once*: probability of total biomass falling below the risk threshold at least once during the projection period of 20 years;

*Overall*: probability of total biomass being below the risk threshold during the projection period of 20 years; and

*End*: probability of total biomass being below the risk threshold at the end of the 20 year projection period.

All management scenarios, except the no catch case, use (updated<sup>1</sup>) OMP-14 for anchovy TACs. The F=0 scenario allows anchovy catch (with associated sardine bycatch), but no directed sardine catches. The fixed fishing mortality scenarios are based on the total survey estimate of sardine abundance. The single area TAC is split between components for the two sardine component hypotheses according to the rule proposed to be used based on historical data (Figure 1). The two area TAC is split between west and south coasts based on the observed proportional split of sardine biomass during the November survey. Updated<sup>1</sup> OMP-14 is also used as a management scenario for sardine.

The baseline anchovy OM is used for all cases. The sardine OMs tested here include

- i) A single stock hypothesis
- ii) A two component hypothesis with no contribution of south coast spawning to west coast recruitment ( $p=0$ ) and baseline west to south movement (MoveR)
- iii) A two component hypothesis with some contribution of south coast spawning to west coast recruitment ( $p=0.2$ ) where 20% of recruits spawned on the south coast move to the west coast in November, and baseline west to south movement (MoveR)
- iv) A two component hypothesis with some contribution of south coast spawning to west coast recruitment ( $p=0.2$ ) where 20% of the south coast spawner biomass contributes to 'effective' west coast spawner biomass, and baseline west to south movement (MoveR)
- v) A two component hypothesis with some contribution of south coast spawning to west coast recruitment ( $p=0.6$ ) where 60% of the south coast spawner biomass contributes to 'effective' west coast spawner biomass, and baseline west to south movement (MoveR)
- vi) Hypotheses ii) and v) are also re-run with a more optimistic scenario of west to south movement, in which all the random proportions sampled under MoveR are divided by 4 resulting in higher retention of sardine on the west coast.

---

<sup>1</sup> Average historical sardine recruitment of 12.74 billion (13.74 is used in OMP-14) and average historical anchovy recruitment back-calculated to November of 221.8 billion (217.3 is used in OMP-14).

Table E1. Sardine performance statistics

Stock	20% constraint	# Areas	P(B<Thresh)				B <sup>20%</sup>		B <sup>20%</sup> / B <sup>2015</sup>		Minimum B <sup>*</sup>			Directed Sardine Catch			Sardine Bycatch			AAV					
			At least once	Overall	End	Total	West	South	Total	West	South	Total	West	South	Total	West	South	Total	West	South	West	South			
			NoC	0	0.01	0.00	404 [174,970]			1.7 [0.8,4.1]			222 [117,405]			0 [0,0]			0.0 [0,0,0,0]			0.0 [0,0,0,0]			
Single Stock	No	5%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		10%	0.01	0.01	0.01	0.02	296 [63,759]			1.3 [0.4,3.0]			189 [81,361]			30 [7,129]			10.2 [1,0,60.6]			17.5 [10,32.7]			17.9 [10,134.1]
		15%	0.06	0.02	0.04	0.25	135 [33,970]			1.1 [0.1,2.7]			133 [50,290]			25 [12,324]			10.9 [1,61.1]			18.1 [9,836.4]			18.1 [9,836.4]
		20%	0.09	0.04	0.06	0.22	101 [20,590]			0.9 [0.2,4.0]			107 [0,257]			92 [9,389]			10.8 [1,0,61.2]			18.1 [9,741.8]			18.1 [9,741.8]
		5%	0.01	0.00	0.01	0.01	337 [129,843]			1.4 [0.3,3.3]			189 [81,361]			30 [7,129]			10.2 [1,0,60.6]			17.5 [10,32.7]			17.9 [10,134.1]
		10%	0.03	0.01	0.02	0.06	136 [37,759]			1.3 [0.4,3.0]			162 [35,328]			56 [11,238]			10.6 [1,61.0]			17.9 [10,134.1]			18.1 [9,836.4]
	15%	0.06	0.02	0.04	0.26	126 [27,672]			1.1 [0.1,2.7]			133 [50,290]			25 [12,324]			10.9 [1,61.1]			18.1 [9,836.4]			18.1 [9,836.4]	
	20%	0.09	0.04	0.06	0.22	101 [20,590]			0.9 [0.2,4.0]			107 [0,257]			92 [9,389]			10.8 [1,0,61.2]			18.1 [9,741.8]			18.1 [9,741.8]	
	1	5%	0.01	0.00	0.01	0.01	337 [129,843]			1.4 [0.3,3.3]			189 [81,361]			30 [7,129]			10.2 [1,0,60.6]			17.5 [10,32.7]			17.9 [10,134.1]
		10%	0.03	0.01	0.02	0.06	136 [37,759]			1.3 [0.4,3.0]			162 [35,328]			56 [11,238]			10.6 [1,61.0]			17.9 [10,134.1]			18.1 [9,836.4]
		15%	0.06	0.02	0.04	0.26	126 [27,672]			1.1 [0.1,2.7]			133 [50,290]			25 [12,324]			10.9 [1,61.1]			18.1 [9,836.4]			18.1 [9,836.4]
		20%	0.09	0.04	0.06	0.22	101 [20,590]			0.9 [0.2,4.0]			107 [0,257]			92 [9,389]			10.8 [1,0,61.2]			18.1 [9,741.8]			18.1 [9,741.8]
		5%	0.03	0.01	0.02	0.06	136 [37,759]			1.3 [0.4,3.0]			162 [35,328]			56 [11,238]			10.6 [1,61.0]			17.9 [10,134.1]			18.1 [9,836.4]
		10%	0.09	0.04	0.07	0.29	119 [30,300]			1.1 [0.2,9.5]			139 [30,300]			17 [12,324]			10.5 [1,61.4]			18.1 [9,836.4]			18.1 [9,836.4]
	2	5%	0.01	0.00	0.01	0.01	337 [129,843]			1.4 [0.3,3.3]			189 [81,361]			30 [7,129]			10.2 [1,0,60.6]			17.5 [10,32.7]			17.9 [10,134.1]
		10%	0.03	0.01	0.02	0.06	136 [37,759]			1.3 [0.4,3.0]			162 [35,328]			56 [11,238]			10.6 [1,61.0]			17.9 [10,134.1]			18.1 [9,836.4]
		15%	0.06	0.02	0.04	0.26	126 [27,672]			1.1 [0.1,2.7]			133 [50,290]			25 [12,324]			10.9 [1,61.1]			18.1 [9,836.4]			18.1 [9,836.4]
		20%	0.09	0.04	0.06	0.22	101 [20,590]			0.9 [0.2,4.0]			107 [0,257]			92 [9,389]			10.8 [1,0,61.2]			18.1 [9,741.8]			18.1 [9,741.8]
		5%	0.03	0.01	0.02	0.06	136 [37,759]			1.3 [0.4,3.0]			162 [35,328]			56 [11,238]			10.6 [1,61.0]			17.9 [10,134.1]			18.1 [9,836.4]
		10%	0.09	0.04	0.07	0.29	119 [30,300]			1.1 [0.2,9.5]			139 [30,300]			17 [12,324]			10.5 [1,61.4]			18.1 [9,836.4]			18.1 [9,836.4]
	Yes	5%	0.03	0.01	0.02	0.06	136 [37,759]			1.3 [0.4,3.0]			162 [35,328]			56 [11,238]			10.6 [1,61.0]			17.9 [10,134.1]			18.1 [9,836.4]
		10%	0.09	0.04	0.07	0.29	119 [30,300]			1.1 [0.2,9.5]			139 [30,300]			17 [12,324]			10.5 [1,61.4]			18.1 [9,836.4]			18.1 [9,836.4]
		15%	0.19	0.08	0.16	0.57	199 [10,563]			0.9 [0.2,5.2]			98 [0,257]			101 [0,339]			10.3 [0,60.6]			7.6 [4,6,12.3]			7.6 [4,6,12.3]
		20%	0.21	0.15	0.28	1.40	140 [4,899]			0.6 [0.2,2.2]			61 [0,210]			117 [0,397]			9.8 [0,60.6]			7.8 [4,7,13.1]			7.8 [4,7,13.1]
5%		0.03	0.01	0.02	0.06	136 [37,759]			1.3 [0.4,3.0]			162 [35,328]			56 [11,238]			10.6 [1,61.0]			17.9 [10,134.1]			18.1 [9,836.4]	
10%		0.09	0.04	0.07	0.29	119 [30,300]			1.1 [0.2,9.5]			139 [30,300]			17 [12,324]			10.5 [1,61.4]			18.1 [9,836.4]			18.1 [9,836.4]	
1	5%	0.03	0.01	0.02	0.06	136 [37,759]			1.3 [0.4,3.0]			162 [35,328]			56 [11,238]			10.6 [1,61.0]			17.9 [10,134.1]			18.1 [9,836.4]	
	10%	0.09	0.04	0.07	0.29	119 [30,300]			1.1 [0.2,9.5]			139 [30,300]			17 [12,324]			10.5 [1,61.4]			18.1 [9,836.4]			18.1 [9,836.4]	
	15%	0.19	0.08	0.16	0.57	199 [10,563]			0.9 [0.2,5.2]			98 [0,257]			101 [0,339]			10.3 [0,60.6]			7.6 [4,6,12.3]			7.6 [4,6,12.3]	
	20%	0.21	0.15	0.28	1.40	140 [4,899]			0.6 [0.2,2.2]			61 [0,210]			117 [0,397]			9.8 [0,60.6]			7.8 [4,7,13.1]			7.8 [4,7,13.1]	
	5%	0.03	0.01	0.02	0.06	136 [37,759]			1.3 [0.4,3.0]			162 [35,328]			56 [11,238]			10.6 [1,61.0]			17.9 [10,134.1]			18.1 [9,836.4]	
	10%	0.09	0.04	0.07	0.29	119 [30,300]			1.1 [0.2,9.5]			139 [30,300]			17 [12,324]			10.5 [1,61.4]			18.1 [9,836.4]			18.1 [9,836.4]	
2	5%	0.03	0.01	0.02	0.06	136 [37,759]			1.3 [0.4,3.0]			162 [35,328]			56 [11,238]			10.6 [1,61.0]			17.9 [10,134.1]			18.1 [9,836.4]	
	10%	0.09	0.04	0.07	0.29	119 [30,300]			1.1 [0.2,9.5]			139 [30,300]			17 [12,324]			10.5 [1,61.4]			18.1 [9,836.4]			18.1 [9,836.4]	
	15%	0.19	0.08	0.16	0.57	199 [10,563]			0.9 [0.2,5.2]			98 [0,257]			101 [0,339]			10.3 [0,60.6]			7.6 [4,6,12.3]			7.6 [4,6,12.3]	
	20%	0.21	0.15	0.28	1.40	140 [4,899]			0.6 [0.2,2.2]			61 [0,210]			117 [0,397]			9.8 [0,60.6]			7.8 [4,7,13.1]			7.8 [4,7,13.1]	
	5%	0.03	0.01	0.02	0.06	136 [37,759]			1.3 [0.4,3.0]			162 [35,328]			56 [11,238]			10.6 [1,61.0]			17.9 [10,134.1]			18.1 [9,836.4]	
	10%	0.09	0.04	0.07	0.29	119 [30,300]			1.1 [0.2,9.5]			139 [30,300]			17 [12,324]			10.5 [1,61.4]			18.1 [9,836.4]			18.1 [9,836.4]	
1	5%	0.03	0.01	0.02	0.06	136 [37,759]			1.3 [0.4,3.0]			162 [35,328]			56 [11,238]			10.6 [1,61.0]			17.9 [10,134.1]			18.1 [9,836.4]	
	10%	0.09	0.04	0.07	0.29	119 [30,300]			1.1 [0.2,9.5]			139 [30,300]			17 [12,324]			10.5 [1,61.4]			18.1 [9,836.4]			18.1 [9,836.4]	
	15%	0.19	0.08	0.16	0.57	199 [10,563]			0.9 [0.2,5.2]			98 [0,257]			101 [0,339]			10.3 [0,60.6]			7.6 [4,6,12.3]			7.6 [4,6,12.3]	
	20%	0.21	0.15	0.28	1.40	140 [4,899]			0.6 [0.2,2.2]			61 [0,210]			117 [0,397]			9.8 [0,60.6]			7.8 [4,7,13.1]			7.8 [4,7,13.1]	
	5%	0.03	0.01	0.02	0.06	136 [37,759]			1.3 [0.4,3.0]			162 [35,328]			56 [11,238]			10.6 [1,61.0]			17.9 [10,134.1]			18.1 [9,836.4]	
	10%	0.09	0.04	0.07	0.29	119 [30,300]			1.1 [0.2,9.5]			139 [30,300]			17 [12,324]			10.5 [1,61.4]			18.1 [9,836.4]			18.1 [9,836.4]	
2	5%	0.03	0.01	0.02	0.06	136 [37,759]			1.3 [0.4,3.0]			162 [35,328]			56 [11,238]			10.6 [1,61.0]			17.9 [10,134.1]			18.1 [9,836.4]	
	10%	0.09	0.04	0.07	0.29	119 [30,300]			1.1 [0.2,9.5]			139 [30,300]			17 [12,324]			10.5 [1,61.4]			18.1 [9,836.4]			18.1 [9,836.4]	
	15%	0.19	0.08	0.16	0.57	199 [10,563]			0.9 [0.2,5.2]			98 [0,257]			101 [0,339]			10.3 [0,60.6]			7.6 [4,6,12.3]			7.6 [4,6,12.3]	
	20%	0.21	0.15	0.28	1.40	140 [4,899]			0.6 [0.2,2.2]			61 [0,210]			117 [0,397]			9.8 [0,60.6]			7.8 [4,7,13.1]			7.8 [4,7,13.1]	
	5%	0.03	0.01	0.02	0.06	136 [37,759]			1.3 [0.4,3.0]			162 [35,328]			56 [11,238]			10.6 [1,61.0]			17.9 [10,134.1]			18.1 [9,836.4]	
	10%	0.09	0.04	0.07	0.29	119 [30,300]			1.1 [0.2,9.5]			139 [30,300]			17 [12,324]			10.5 [1,61.4]			18.1 [9,836.4]			18.1 [9,836.4]	
1	5%	0.03	0.01	0.02	0.06	136 [37,759]			1.3 [0.4,3.0]			162 [35,328]													

Table E1 (continued). Sardine performance statistics

20% constraint	Hockey Stick $p=0.05$ (Mover)	# Areas	P(B<Thresh)				B <sup>20%</sup>			B <sup>20%/B<sup>20%</sup></sup>			Minimum B <sup>20%</sup>			Directed Sardine Catch			Sardine Bycatch			AAV		
			At least once	Overall	End	Total	West	South	Total	West	South	Total	West	South	Total	West	South	Total	West	South	Total	West	South	
			NoC	0.28	0.06	0.06	523 [272,1034]	196 [37,638]	305 [129,629]	3.0 [1.1,14.4]	2.1 [0.3,13.9]	0.8 [0.4,1.7]	336 [203,509]	54 [9,143]	163 [80,283]	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	0.31	0.06	0.06	497 [246,1001]	188 [35,615]	293 [123,613]	2.9 [1.0,14.0]	2.0 [0.3,13.5]	0.8 [0.3,1.7]	319 [183,488]	50 [9,135]	155 [77,270]	0 [0,0]	0 [0,0]	0 [0,0]	10.3 [1.0,59.2]	10.3 [1.0,59.2]	0.0 [0.0,0.0]	0.0 [0.0,0.0]
1	No				5%	0.34	0.08	0.07	448 [205,896]	168 [28,569]	269 [109,570]	2.6 [0.8,12.2]	1.8 [0.2,11.8]	0.7 [0.3,1.6]	291 [146,449]	43 [7,121]	145 [70,254]	33 [10,114]	31 [9,105]	1 [1,13]	11.1 [1.0,60.0]	11.1 [1.0,60.0]	0.0 [0.0,0.0]	0.0 [0.0,0.0]
					10%	0.37	0.09	0.10	409 [156,825]	148 [22,523]	248 [97,527]	2.3 [0.7,11.2]	1.6 [0.2,10.8]	0.7 [0.3,1.5]	263 [115,416]	38 [6,209]	134 [65,238]	61 [18,216]	57 [16,187]	2 [0,51]	11.8 [1.1,60.9]	11.8 [1.1,60.9]	0.0 [0.0,0.0]	0.0 [0.0,0.0]
					15%	0.39	0.11	0.12	376 [122,767]	130 [15,477]	228 [80,492]	2.1 [0.6,10.2]	1.4 [0.1,9.7]	0.6 [0.2,1.4]	237 [90,384]	33 [4,981]	122 [62,223]	87 [24,309]	77 [21,249]	5 [0,103]	12.2 [1.1,61.5]	12.2 [1.1,61.5]	0.0 [0.0,0.0]	0.0 [0.0,0.0]
					20%	0.43	0.12	0.14	346 [88,713]	117 [11,442]	209 [63,462]	2.0 [0.4,9.3]	1.3 [0.1,8.4]	0.6 [0.2,1.3]	212 [68,350]	29 [3,90]	108 [33,205]	110 [28,392]	92 [23,399]	9 [0,155]	12.4 [1.1,61.9]	12.4 [1.1,61.9]	0.0 [0.0,0.0]	0.0 [0.0,0.0]
2	No				5%	0.33	0.07	0.07	456 [213,907]	176 [31,587]	286 [107,570]	2.7 [0.9,13.2]	1.7 [0.3,12.4]	0.7 [0.3,1.6]	294 [156,451]	47 [8,125]	146 [70,250]	33 [10,115]	15 [7,125]	13 [3,74]	10.7 [1.0,59.7]	10.7 [1.0,59.7]	0.0 [0.0,0.0]	0.0 [0.0,0.0]
					10%	0.35	0.08	0.08	422 [176,864]	167 [28,556]	242 [90,527]	2.5 [0.7,12.1]	1.7 [0.2,11.7]	0.7 [0.2,1.5]	271 [127,422]	44 [8,120]	125 [57,230]	63 [19,219]	28 [5,145]	25 [5,139]	11.1 [1.0,60.2]	11.1 [1.0,60.2]	0.0 [0.0,0.0]	0.0 [0.0,0.0]
					15%	0.36	0.09	0.10	391 [144,801]	156 [23,527]	221 [76,491]	2.3 [0.6,11.4]	1.6 [0.2,10.9]	0.6 [0.2,1.4]	246 [100,387]	41 [6,113]	112 [46,209]	90 [25,315]	41 [6,211]	34 [7,198]	11.5 [1.1,60.6]	11.5 [1.1,60.6]	0.0 [0.0,0.0]	0.0 [0.0,0.0]
					20%	0.39	0.10	0.11	360 [108,758]	142 [18,488]	201 [61,454]	2.1 [0.5,10.3]	1.5 [0.2,9.9]	0.6 [0.2,1.3]	222 [80,359]	38 [5,106]	98 [33,194]	113 [31,403]	53 [8,271]	43 [8,252]	11.7 [1.1,61.1]	11.6 [1.1,61.1]	0.0 [0.0,0.0]	0.0 [0.0,0.0]
1	Yes				5%	0.36	0.09	0.09	431 [174,875]	160 [24,557]	263 [107,570]	2.5 [0.7,12.0]	1.7 [0.2,11.5]	0.7 [0.3,1.6]	295 [152,456]	40 [6,115]	139 [67,248]	47 [20,130]	11.4 [1.1,60.4]	11.4 [1.1,60.4]	0.0 [0.0,0.0]	0.0 [0.0,0.0]		
					10%	0.40	0.11	0.12	387 [94,806]	132 [12,504]	235 [63,512]	2.1 [0.4,10.6]	1.4 [0.1,10.3]	0.6 [0.2,1.4]	239 [65,389]	33 [3,102]	104 [32,207]	83 [33,244]	74 [27,200]	5 [0,73]	12.1 [1.1,61.3]	12.1 [1.1,61.3]	0.0 [0.0,0.0]	0.0 [0.0,0.0]
					15%	0.47	0.14	0.17	336 [24,736]	110 [2,450]	204 [19,467]	1.8 [0.1,9.5]	1.2 [0.0,8.6]	0.6 [0.1,1.3]	205 [11,358]	27 [9,91]	124 [42,244]	116 [40,337]	96 [24,262]	11 [1,135]	12.3 [1.1,61.6]	12.3 [1.1,61.6]	0.0 [0.0,0.0]	0.0 [0.0,0.0]
					20%	0.52	0.18	0.23	254 [0,683]	95 [0,385]	174 [0,436]	1.6 [0.0,7.8]	1.0 [0.0,7.2]	0.5 [0.0,1.2]	170 [0,322]	22 [0,78]	84 [0,161]	143 [33,417]	7 [3,08]	12.0 [1.0,61.8]	12.0 [1.0,61.8]	0.0 [0.0,0.0]	0.0 [0.0,0.0]	
2	Yes				5%	0.34	0.08	0.07	440 [185,900]	174 [30,579]	260 [100,551]	2.6 [0.8,13.2]	1.8 [0.2,12.4]	0.7 [0.3,1.6]	280 [137,440]	45 [7,122]	133 [62,244]	47 [20,132]	23 [6,85]	19 [4,82]	10.8 [1.0,60.0]	10.8 [1.0,60.0]	0.0 [0.0,0.0]	0.0 [0.0,0.0]
					10%	0.36	0.09	0.1	397 [112,831]	156 [19,536]	227 [63,505]	2.3 [0.5,12.1]	1.6 [0.2,11.3]	0.6 [0.2,1.4]	249 [88,403]	45 [5,114]	115 [39,217]	87 [25,249]	40 [7,165]	35 [6,153]	11.3 [1.1,60.4]	11.3 [1.1,60.4]	0.0 [0.0,0.0]	0.0 [0.0,0.0]
					15%	0.42	0.12	0.14	352 [27,775]	133 [13,494]	196 [15,454]	2.1 [0.1,10.4]	1.4 [0.0,10.0]	0.5 [0.0,1.3]	215 [10,371]	35 [1,104]	94 [7,194]	119 [42,348]	57 [8,232]	48 [8,212]	11.5 [1.1,61.1]	11.5 [1.1,61.1]	0.0 [0.0,0.0]	0.0 [0.0,0.0]
					20%	0.48	0.16	0.21	308 [0,713]	113 [0,445]	165 [0,427]	1.8 [0.0,9.6]	1.2 [0.0,8.8]	0.5 [0.0,1.2]	178 [0,330]	29 [0,94]	75 [0,188]	147 [32,429]	71 [3,292]	58 [8,258]	11.4 [1.0,61.1]	11.4 [1.0,61.1]	0.0 [0.0,0.0]	0.0 [0.0,0.0]
1	OMP-1A				0.40	0.10	0.11	392 [145,818]	139 [19,510]	238 [88,521]	2.2 [0.6,11.3]	1.5 [0.1,10.7]	0.6 [0.2,1.4]	247 [104,400]	35 [5,106]	127 [58,232]	90 [19,196]	82 [10,170]	4 [0,48]	12.0 [1.1,61.1]	12.0 [1.1,61.1]	0.0 [0.0,0.0]	0.0 [0.0,0.0]	
					0.45	0.09	0.09	404 [160,845]	162 [26,548]	234 [82,517]	2.4 [0.7,13.2]	1.7 [0.2,13.1]	0.6 [0.2,1.5]	257 [115,408]	42 [7,117]	119 [51,233]	90 [13,202]	43 [4,133]	36 [4,124]	11.3 [1.0,60.3]	11.3 [1.0,60.3]	0.0 [0.0,0.0]	0.0 [0.0,0.0]	

**Table E2. Anchovy performance statistics**

Sardine OM		Single Stock								Hockey Stick p=0 MoveR								Hockey Stick p=0.6onSSB 0.25(MoveR)													
20% constraint	# Areas	P(B<Thresh)								P(B<Thresh)								P(B<Thresh)													
		NoC	>On ce	Ove rall	End	B <sup>2016</sup>	B <sup>2016</sup> / B <sup>2015</sup>	Minimum B <sup>o</sup>	Directed Catch	AAV	>On ce	Ove rall	End	B <sup>2016</sup>	B <sup>2016</sup> / B <sup>2015</sup>	Minimum B <sup>o</sup>	Directed Catch	AAV	>On ce	Over all	End	B <sup>2016</sup>	B <sup>2016</sup> / B <sup>2015</sup>	Minimum B <sup>o</sup>	Directed Catch	AAV					
		0	0.34	0.10	0.18	388 [4,3567]	0.3 [0.0,2.8]	373 [9,1046]	154 [3,694]	221 [0,450]	20.0 [2.9,1513.7]	0.33	0.09	0.18	389 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	155 [3,711]	218 [0,450]	218 [0,450]	19.2 [2.9,1513.7]	0.34	0.09	0.18	394 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,705]	217 [0,450]	217 [0,450]	19.1 [3.0,1465.7]
No	1	5%	0.34	0.10	0.18	387 [4,3567]	0.3 [0.0,2.8]	373 [9,1046]	154 [3,694]	221 [0,450]	20.0 [2.9,1522.4]	0.34	0.09	0.18	387 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,711]	218 [0,450]	218 [0,450]	19.2 [2.9,1522.4]	0.34	0.09	0.18	394 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,705]	217 [0,450]	217 [0,450]	19.1 [3.0,1467.1]
		10%	0.34	0.10	0.18	387 [4,3567]	0.3 [0.0,2.8]	373 [9,1046]	154 [3,694]	221 [0,450]	20.0 [2.9,1523.0]	0.34	0.09	0.18	387 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,711]	218 [0,450]	218 [0,450]	19.3 [2.9,1523.0]	0.34	0.09	0.18	395 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,705]	217 [0,450]	217 [0,450]	19.1 [3.0,1468.5]
		15%	0.34	0.10	0.18	387 [4,3567]	0.3 [0.0,2.8]	373 [9,1046]	154 [3,694]	221 [0,450]	20.0 [2.9,1523.6]	0.34	0.09	0.18	384 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	157 [3,711]	219 [0,450]	219 [0,450]	19.3 [2.9,1523.6]	0.33	0.09	0.18	395 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,705]	217 [0,450]	217 [0,450]	19.2 [3.0,1358.4]
		20%	0.34	0.10	0.18	383 [4,3567]	0.3 [0.0,2.8]	373 [9,1046]	154 [3,694]	221 [0,450]	20.0 [2.9,1496.7]	0.34	0.09	0.18	384 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,711]	219 [0,450]	219 [0,450]	19.3 [2.9,1496.7]	0.33	0.09	0.18	395 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,705]	217 [0,450]	217 [0,450]	19.2 [3.0,1471.0]
	2	5%	0.33	0.10	0.18	387 [4,3567]	0.3 [0.0,2.8]	373 [9,1046]	154 [3,694]	221 [0,450]	20.0 [2.9,1509.2]	0.33	0.09	0.18	389 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,711]	218 [0,450]	218 [0,450]	19.2 [2.9,1509.2]	0.34	0.09	0.18	394 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,705]	217 [0,450]	217 [0,450]	19.1 [3.0,1467.0]
		10%	0.34	0.10	0.18	387 [4,3567]	0.3 [0.0,2.8]	373 [9,1046]	154 [3,694]	221 [0,450]	20.0 [2.9,1505.2]	0.34	0.09	0.18	389 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,711]	218 [0,450]	218 [0,450]	19.2 [2.9,1505.2]	0.34	0.09	0.18	394 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,705]	217 [0,450]	217 [0,450]	19.1 [3.0,1468.2]
		15%	0.34	0.10	0.18	387 [4,3567]	0.3 [0.0,2.8]	373 [9,1046]	154 [3,694]	221 [0,450]	20.0 [2.9,1501.5]	0.34	0.09	0.18	387 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,711]	218 [0,450]	218 [0,450]	19.3 [2.9,1501.5]	0.33	0.09	0.18	395 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,705]	217 [0,450]	217 [0,450]	19.2 [3.0,1380.7]
		20%	0.34	0.10	0.18	383 [4,3567]	0.3 [0.0,2.8]	373 [9,1046]	154 [3,694]	221 [0,450]	20.0 [2.9,1524.0]	0.34	0.09	0.18	387 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,711]	218 [0,450]	218 [0,450]	19.3 [2.9,1524.0]	0.33	0.09	0.18	395 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,705]	217 [0,450]	217 [0,450]	19.2 [3.0,1470.6]
Yes	1	5%	0.34	0.10	0.18	385 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	153 [3,693]	222 [0,450]	20.3 [2.9,1522.5]	0.34	0.09	0.18	384 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	157 [3,711]	218 [0,450]	218 [0,450]	19.3 [2.9,1522.5]	0.34	0.09	0.18	394 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,705]	217 [0,450]	217 [0,450]	19.1 [3.0,1467.0]
		10%	0.34	0.10	0.18	385 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	153 [3,693]	222 [0,450]	20.2 [2.9,1523.1]	0.34	0.09	0.18	384 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	157 [3,711]	218 [0,450]	218 [0,450]	19.5 [2.9,1523.1]	0.33	0.09	0.18	395 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,705]	217 [0,450]	217 [0,450]	19.2 [3.0,1452.6]
		15%	0.34	0.10	0.18	382 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	153 [3,693]	222 [0,450]	20.4 [2.9,1496.1]	0.34	0.10	0.18	384 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	155 [3,711]	218 [0,450]	218 [0,450]	19.3 [2.9,1496.1]	0.33	0.09	0.18	395 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,705]	217 [0,450]	217 [0,450]	19.1 [3.0,1469.8]
		20%	0.34	0.10	0.18	382 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	153 [3,693]	222 [0,450]	20.5 [2.8,1524.5]	0.34	0.10	0.18	384 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	154 [3,711]	219 [0,450]	219 [0,450]	19.3 [2.8,1524.5]	0.33	0.09	0.18	395 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,705]	217 [0,450]	217 [0,450]	19.1 [3.0,1471.0]
	2	5%	0.34	0.10	0.18	385 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	153 [3,693]	222 [0,450]	20.3 [2.9,1507.8]	0.34	0.09	0.18	387 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,711]	218 [0,450]	218 [0,450]	19.2 [2.9,1507.8]	0.34	0.09	0.18	394 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,705]	217 [0,450]	217 [0,450]	19.1 [3.0,1467.0]
		10%	0.34	0.10	0.18	385 [4,3567]	0.3 [0.0,2.8]	373 [9,1046]	153 [3,693]	222 [0,450]	20.2 [2.9,1522.9]	0.34	0.09	0.18	384 [4,3567]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,711]	218 [0,450]	218 [0,450]	19.3 [2.9,1522.9]	0.34	0.09	0.18	395 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,705]	217 [0,450]	217 [0,450]	19.1 [3.0,1487.6]
		15%	0.34	0.10	0.18	382 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	153 [3,693]	222 [0,450]	20.4 [2.9,1523.4]	0.34	0.09	0.18	387 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,711]	218 [0,450]	218 [0,450]	19.4 [2.9,1523.4]	0.33	0.09	0.18	395 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,705]	217 [0,450]	217 [0,450]	19.1 [3.0,1469.4]
		20%	0.34	0.10	0.18	382 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	153 [3,693]	222 [0,450]	20.5 [2.9,1524.0]	0.34	0.09	0.18	387 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,711]	219 [0,450]	219 [0,450]	19.5 [2.9,1524.0]	0.33	0.09	0.18	395 [4,3572]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,705]	218 [0,450]	218 [0,450]	19.1 [3.0,1470.6]
1	2	5%	0.34	0.10	0.18	384 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	153 [3,693]	222 [0,450]	20.2 [2.8,1521.3]	0.34	0.09	0.18	387 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	157 [3,711]	218 [0,450]	218 [0,450]	19.3 [2.8,1521.3]	0.33	0.09	0.18	395 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,705]	217 [0,450]	217 [0,450]	19.1 [3.0,1362.2]
		20%	0.34	0.10	0.18	384 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	153 [3,693]	222 [0,450]	20.2 [2.9,1511.6]	0.34	0.09	0.18	387 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,711]	218 [0,450]	218 [0,450]	19.3 [2.9,1511.6]	0.34	0.09	0.18	395 [4,3566]	0.3 [0.0,2.8]	373 [9,1046]	156 [3,705]	217 [0,450]	217 [0,450]	19.0 [3.0,1405.3]

## **Appendix F: Performance statistics for a range area-based management scenarios for the directed sardine TAC.**

The performance statistics are represented by median and [95% probability interval]. All catches and biomasses are given in thousands of tons.

The sardine risk threshold used here is the lowest historical (2007) biomass for the west component, or, in the case of the single sardine stock Operating Model (OM), for the total population. The risk statistics are thus not directly comparable between the single stock and two component OMs. The anchovy risk threshold used here is a quarter of the lowest historical (1996) biomass. The three risk statistics are as follows:

*At least once*: probability of total biomass falling below the risk threshold at least once during the projection period of 20 years;

*Overall*: probability of total biomass being below the risk threshold during the projection period of 20 years; and

*End*: probability of total biomass being below the risk threshold at the end of the 20 year projection period.

All management scenarios use (updated<sup>1</sup>) OMP-14 for anchovy TACs. The F=0 scenario allows anchovy catch (with associated sardine bycatch), but no directed sardine catches. The fixed fishing mortality scenarios are based on the total survey estimate of sardine abundance and include a 20% constraint in the inter-annual decrease of the total directed sardine TAC. The single area TAC is split between components for the two sardine component hypotheses according to the rule proposed to be used based on historical data (Figure 1). The two area TAC is either split between west and south coasts based on the observed proportional split of sardine biomass during the most recent November survey (i.e. variable and denoted by '2area' in the tables and figures) or according to a time-invariant proportion of 100%, 80%, 60% or 40% of the TAC allocated to the west coast.

The baseline anchovy OM is used for all cases. The sardine OMs tested here include

- i) A single stock hypothesis
- ii) A two component hypothesis with no contribution of south coast spawning to west coast recruitment ( $p=0$ ) and baseline west to south movement (MoveR)
- iii) A two component hypothesis with some contribution of south coast spawning to west coast recruitment ( $p=0.2$ ) where 20% of the south coast spawner biomass contributes to 'effective' west coast spawner biomass, and baseline west to south movement (MoveR)
- iv) A two component hypothesis with some contribution of south coast spawning to west coast recruitment ( $p=0.6$ ) where 60% of the south coast spawner biomass contributes to 'effective' west coast spawner biomass, and baseline west to south movement (MoveR)
- v) Hypotheses ii) - iv) are also re-run with a more optimistic scenario of west to south movement, in which all the random proportions sampled under MoveR are halved resulting in higher retention of sardine on the west coast.

---

<sup>1</sup> Average historical sardine recruitment of 12.74 billion (13.74 is used in OMP-14) and average historical anchovy recruitment back-calculated to November of 221.8 billion (217.3 is used in OMP-14). There is also a small change from OMP-14 to the calculation of the projected biomass for Exceptional Circumstances testing.

**Table F1. Sardine performance statistics**

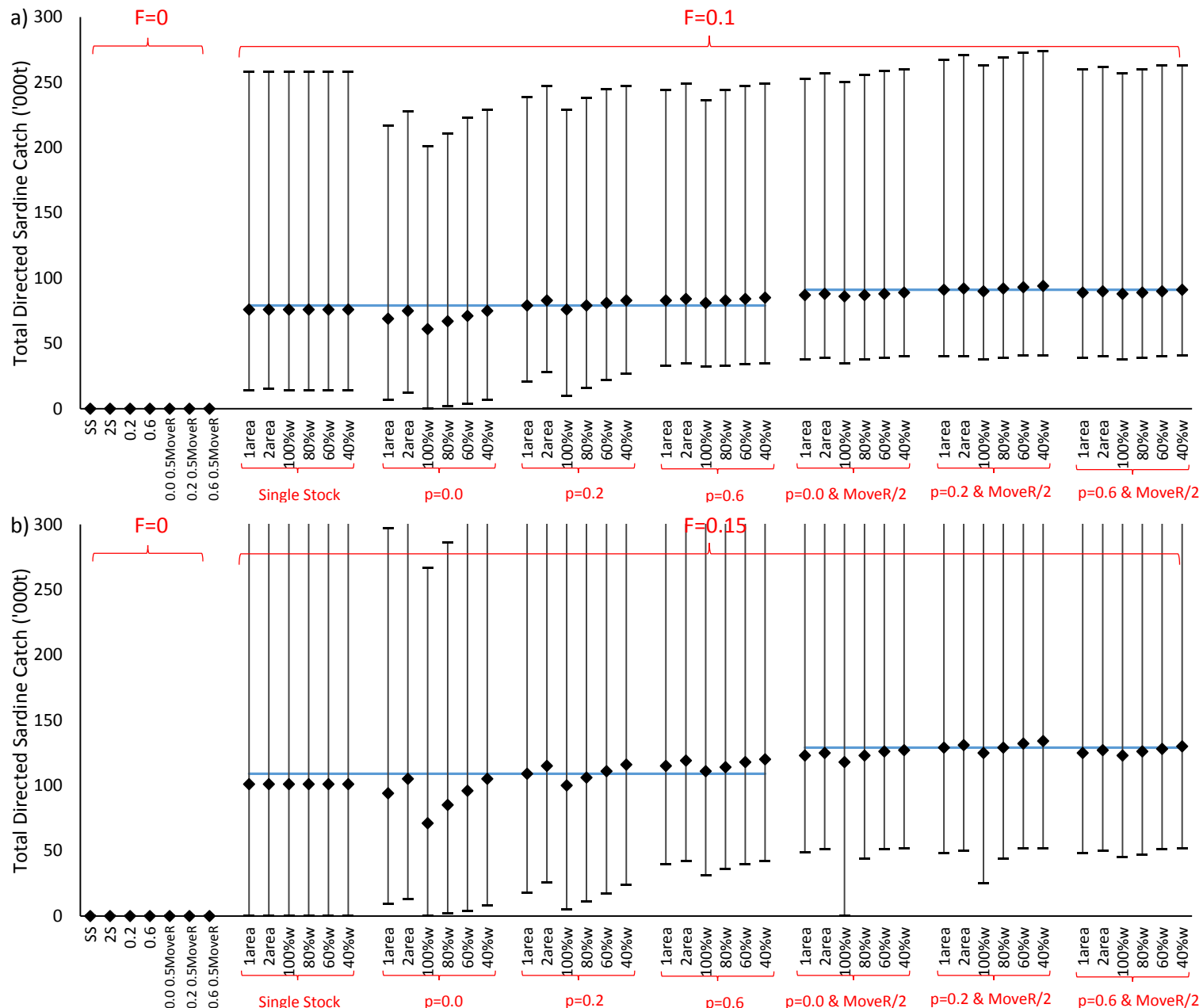
F#D	Sardine OM	P(B<Thresh)			B <sup>2016</sup>			B <sup>2016</sup> / B <sup>2015</sup>			Minimum B <sup>w</sup>			Directed Sardine Catch			Sardine Bycatch			AAV		
		At least once	Overall	End	Total	West	South	Total	West	South	Total	West	South	Total	West	South	Total	West	South	West	South	
F#D	Single Stock	0.01	0.00	0.00	383[185,790]	383[185,790]		1.7[0.8,3.4]	1.7[0.8,3.4]		212[116,359]	212[116,359]		0[0,0]	0[0,0]		9.7[1.0,59.7]	9.7[1.0,59.7]		0.0[0.0,0.0]	0.0[0.0,0.0]	
	p=0.2 MoverR	0.43	0.33	0.12	453[181,859]	169[21,485]	270[103,515]	2.6[0.8,9.4]	1.8[0.2,8.1]	0.7[0.3,1.4]	287[94,431]	43[5,114]	136[67,229]	0[0,0]	0[0,0]	0[0,0]	9.1[0.57,7]	9.1[0.57,7]	0.0[0.0,0.0]	0.0[0.0,0.0]	0.0[0.0,0.0]	
	p=0.6 MoverR	0.34	0.08	0.07	506[244,922]	190[38,535]	294[125,553]	2.9[1.0,10.5]	2.0[0.4,9.9]	0.8[0.4,1.5]	317[179,459]	50[10,119]	152[79,254]	0[0,0]	0[0,0]	0[0,0]	10.3[1.0,59.5]	10.3[1.0,59.5]	0.0[0.0,0.0]	0.0[0.0,0.0]	0.0[0.0,0.0]	
	p=0.5 Mover	0.31	0.06	0.06	496[279,888]	188[44,504]	293[145,544]	2.9[1.1,10.3]	2.0[0.4,9.5]	0.8[0.4,1.5]	319[166,456]	50[12,115]	155[88,256]	0[0,0]	0[0,0]	0[0,0]	10.4[1.0,59.2]	10.4[1.0,59.2]	0.0[0.0,0.0]	0.0[0.0,0.0]	0.0[0.0,0.0]	
	p=0.5 Mover	0.06	0.01	0.01	571[327,1043]	388[80,756]	192[96,364]	3.7[1.5,9.3]	3.2[1.0,8.7]	0.6[0.3,1.0]	358[235,522]	156[80,268]	108[63,176]	0[0,0]	0[0,0]	0[0,0]	10.3[1.0,59.3]	10.3[1.0,59.3]	0.0[0.0,0.0]	0.0[0.0,0.0]	0.0[0.0,0.0]	
	p=0.2 0.5(MoverR)	0.04	0.00	0.00	610[347,1102]	400[90,798]	203[103,393]	3.9[1.6,9.4]	3.3[1.1,8.9]	0.6[0.3,1.1]	376[252,546]	169[94,282]	112[65,183]	0[0,0]	0[0,0]	0[0,0]	10.9[1.0,61.9]	10.9[1.0,61.9]	0.0[0.0,0.0]	0.0[0.0,0.0]	0.0[0.0,0.0]	
	p=0.6 0.5(Mover)	0.04	0.00	0.01	580[339,1044]	383[187,765]	199[101,374]	3.7[1.6,8.8]	3.1[1.0,8.2]	0.6[0.3,1.1]	371[252,532]	166[94,278]	111[65,180]	0[0,0]	0[0,0]	0[0,0]	10.5[1.0,59.6]	10.5[1.0,59.6]	0.0[0.0,0.0]	0.0[0.0,0.0]	0.0[0.0,0.0]	
	F#D.10	1area	0.09	0.04	0.07	259[1,590]			1.1[0.0,2.4]			138[1,268]			76[14,258]			10.6[1.0,60.9]			7.1[5.0,10.4]	
		2area	0.09	0.04	0.07	259[1,590]			1.1[0.0,2.4]			138[1,267]			76[15,258]			10.5[1.0,60.9]			7.1[5.0,10.4]	
		100%	0.09	0.04	0.07	258[0,590]			1.1[0.0,2.4]			138[0,266]			76[14,258]			11.1[1.0,61.9]			7.1[5.0,10.4]	
80%		0.09	0.04	0.07	258[0,590]			1.1[0.0,2.4]			138[0,266]			76[14,258]			11.1[1.0,61.9]			7.1[5.0,10.4]		
60%		0.09	0.04	0.07	258[0,590]			1.1[0.0,2.4]			138[0,266]			76[14,258]			11.1[1.0,61.9]			7.1[5.0,10.4]		
40%		0.09	0.04	0.07	258[0,590]			1.1[0.0,2.4]			138[0,266]			76[14,258]			11.1[1.0,61.9]			7.1[5.0,10.4]		
1area		0.58	0.27	0.32	312[192,573]	89[0,364]	190[22,428]	1.5[0.1,6.3]	0.8[0.0,5.5]	0.5[0.1,1.2]	197[11,335]	25[0,84]	98[11,188]	69[7,217]	61[0,181]	6[0,72]	8.9[0.0,57.7]	8.9[0.0,57.7]	0.0[0.0,0.1]	6.7[3.3,11.1]	50.5[11.9,176.8]	
2area		0.51	0.18	0.2	356[137,721]	122[0,405]	203[33,431]	2.0[0.1,7.3]	1.3[0.0,6.6]	0.6[0.1,1.2]	217[23,354]	34[0,95]	97[21,178]	75[12,228]	37[0,153]	31[5,142]	9.5[0.0,58.1]	9.5[0.0,58.1]	0.0[0.0,0.2]	6.8[4.8,9.8]	17.1[9.3,36.2]	
100%		0.65	0.35	0.46	259[128,636]	53[0,329]	164[28,402]	1.1[0.1,5.4]	0.5[0.0,4.8]	0.4[0.1,1.1]	175[22,329]	16[0,78]	94[22,188]	61[0,201]	0[0,0]	0[0,0]	7.5[0.0,56.3]	7.5[0.0,56.3]	0.0[0.0,0.0]	6.3[2.9,9.3]	6.3[2.9,9.3]	
80%		0.6	0.3	0.38	303[26,668]	81[0,358]	179[26,416]	1.4[0.1,6.2]	0.7[0.0,5.4]	0.5[0.1,1.1]	193[21,343]	23[0,87]	95[21,185]	67[2,211]	53[0,168]	14[4,43]	8.2[0.0,56.9]	8.2[0.0,56.9]	0.0[0.0,0.1]	6.7[4.9,9.6]	6.6[4.5,9.6]	
60%	0.56	0.24	0.29	334[28,703]	103[0,400]	188[28,424]	1.7[0.1,6.8]	1.0[0.0,6.1]	0.5[0.1,1.1]	208[20,350]	30[0,95]	92[19,181]	71[4,223]	43[0,133]	29[2,90]	8.8[0.0,57.2]	8.8[0.0,57.2]	0.0[0.0,0.2]	6.7[4.9,9.7]	6.6[4.6,9.7]		
40%	0.5	0.2	0.22	356[30,730]	125[0,437]	197[29,432]	1.9[0.1,7.4]	1.3[0.0,6.7]	0.5[0.1,1.1]	218[21,357]	35[0,101]	90[18,174]	75[7,229]	30[0,92]	45[7,138]	9.0[0.0,57.7]	9.0[0.0,57.7]	0.0[0.0,0.4]	6.8[4.9,9.8]	6.7[3.9,9.7]		
F#D.10	1area	0.49	0.16	0.19	371[54,722]	119[4,394]	223[45,451]	2.0[0.2,7.0]	1.3[0.0,6.3]	0.6[0.1,1.3]	230[38,362]	30[1,90]	115[33,205]	79[21,239]	70[11,199]	5[0,73]	11.3[1.1,60.3]	11.3[1.1,60.3]	0.0[0.0,0.1]	6.8[5.0,9.9]	7.0[4.8,11.9]	
	2area	0.42	0.12	0.14	392[100,747]	149[16,436]	224[61,455]	2.3[0.5,8.7]	1.5[0.2,8.0]	0.6[0.1,1.2]	243[69,376]	39[5,101]	109[42,197]	83[28,247]	39[5,162]	33[6,153]	10.9[1.0,60.2]	10.9[1.0,60.2]	0.0[0.0,0.3]	6.9[5.1,10.1]	17.2[9.9,36.0]	
	100%	0.52	0.19	0.24	352[43,714]	104[0,380]	217[41,448]	1.8[0.1,6.7]	1.1[0.0,6.0]	0.6[0.1,1.2]	222[32,359]	26[0,86]	116[31,208]	76[10,229]	0[0,0]	0[0,0]	11.2[1.1,60.5]	11.2[1.1,60.5]	0.0[0.0,0.0]	6.9[5.0,14.9]	0.0[0.0,0.0]	
	80%	0.49	0.17	0.21	369[46,730]	119[1,409]	219[43,450]	2.0[0.2,7.3]	1.2[0.0,6.5]	0.6[0.1,1.3]	230[32,366]	30[0,93]	111[31,202]	79[16,238]	63[11,190]	16[4,48]	11.1[1.1,60.2]	11.1[1.1,60.2]	0.0[0.0,0.1]	6.9[5.1,10.2]	6.8[5.0,10.0]	
	60%	0.44	0.14	0.17	383[62,743]	136[4,431]	222[51,455]	2.2[0.2,8.4]	1.4[0.1,7.2]	0.6[0.1,1.3]	238[43,374]	39[1,100]	107[32,196]	81[22,245]	49[12,147]	33[9,98]	11.0[1.1,60.2]	10.9[1.1,60.1]	0.0[0.0,0.3]	6.9[5.1,10.5]	6.9[5.0,10.0]	
	40%	0.42	0.12	0.14	399[90,764]	154[14,460]	222[59,454]	2.4[0.5,9.0]	1.6[0.1,8.3]	0.6[0.1,1.3]	245[70,381]	39[4,108]	102[35,192]	83[27,247]	33[11,99]	50[17,148]	10.7[1.0,59.7]	10.7[1.0,59.7]	0.0[0.0,0.4]	6.9[5.1,10.1]	6.9[5.1,10.1]	
	1area	0.4	0.11	0.12	385[147,717]	132[19,399]	235[93,460]	2.1[0.6,7.9]	1.4[0.2,7.1]	0.6[0.2,1.3]	239[107,366]	33[5,86]	123[58,211]	83[33,244]	73[27,200]	5[0,73]	12.2[1.1,61.3]	12.2[1.1,61.3]	0.0[0.0,0.0]	6.9[5.1,10.2]	6.9[4.8,10.7]	
	2area	0.36	0.09	0.1	397[179,751]	156[29,429]	227[90,453]	2.3[0.8,8.9]	1.6[0.3,8.4]	0.6[0.2,1.2]	249[120,374]	40[8,97]	115[54,198]	84[35,249]	40[7,163]	35[6,153]	11.4[1.1,60.4]	11.4[1.1,60.3]	0.0[0.0,0.3]	6.9[5.1,10.1]	16.9[9.8,34.0]	
	100%	0.43	0.12	0.14	378[127,714]	123[11,392]	234[90,456]	2.0[0.5,7.6]	1.3[0.1,6.7]	0.6[0.2,1.3]	235[87,363]	28[2,81]	126[61,212]	81[32,236]	61[32,236]	0[0,0]	12.4[1.1,61.8]	12.4[1.1,61.8]	0.0[0.0,0.0]	6.9[5.1,10.2]	0.0[0.0,0.0]	
	80%	0.41	0.11	0.13	388[136,723]	135[16,410]	232[89,458]	2.2[0.6,8.0]	1.4[0.2,7.4]	0.6[0.2,1.2]	246[115,375]	33[3,88]	120[56,206]	83[34,247]	66[27,194]	17[7,49]	12.0[1.1,61.1]	11.9[1.1,61.1]	0.0[0.0,0.1]	6.9[5.1,10.1]	6.9[5.1,10.2]	
60%	0.39	0.1	0.11	396[161,741]	148[23,425]	230[87,462]	2.3[0.7,8.6]	1.5[0.2,7.8]	0.6[0.2,1.2]	246[115,375]	37[6,95]	114[52,202]	84[34,247]	50[20,148]	34[14,99]	11.6[1.1,60.5]	11.6[1.1,60.5]	0.0[0.0,0.3]	6.9[5.1,10.2]	6.9[5.1,10.2]		
40%	0.36	0.09	0.09	463[181,756]	163[28,451]	226[84,458]	2.4[0.8,9.0]	1.7[0.3,8.4]	0.6[0.2,1.2]	251[125,380]	41[8,101]	107[41,195]	85[35,249]	34[14,100]	51[21,149]	11.2[1.1,60.0]	11.1[1.0,60.0]	0.0[0.0,0.4]	6.9[5.1,10.1]	6.9[5.1,10.1]		
F#D.10	1area	0.12	0.02	0.01	451[238,874]	288[121,623]	163[77,316]	2.9[1.1,7.5]	2.4[0.7,6.9]	0.5[0.2,0.9]	274[157,420]	122[56,217]	89[48,151]	87[38,253]	81[35,225]	3[0,46]	12.5[1.1,62.1]	12.5[1.1,62.1]	0.0[0.0,0.0]	6.6[4.8,9.5]	51.0[22.5,141.3]	
	2area	0.1	0.01	0.01	463[247,892]	308[140,648]	154[71,300]	3.1[1.2,8.0]	2.6[0.8,7.3]	0.4[0.2,0.9]	282[165,433]	132[63,234]	79[41,137]	88[39,257]	58[15,208]	23[4,108]	12.0[1.1,61.6]	12.0[1.1,61.6]	0.0[0.0,0.2]	6.9[5.0,9.8]	12.3[7.7,20.6]	
	100%	0.13	0.03	0.03	446[220,869]	277[101,606]	165[78,315]	2.8[1.0,7.2]	2.3[0.6,7.7]	0.5[0.2,0.9]	270[139,415]	116[44,211]	93[54,155]	86[35,250]	86[35,250]	0[0,0]	12.5[1.1,62.2]	12.5[1.1,62.2]	0.0[0.0,0.0]	6.9[4.9,9.8]	0.0[0.0,0.0]	
	80%	0.11	0.02	0.02	455[240,881]	298[126,639]	158[71,308]	3.0[1.1,7.8]	2.5[0.7,7.3]	0.4[0.2,0.9]	277[157,427]	126[58,225]	84[45,143]	87[38,256]	70[30,204]	17[8,51]	12.2[1.1,61.7]	12.2[1.1,61.7]	0.0[0.0,0.2]	6.9[5.0,9.8]	6.9[5.0,9.8]	
	60%	0.1	0.01	0.01	446[248,903]	315[140,670]	149[59,301]	3.1[1.2,8.1]	2.7[0.8,7.6]	0.4[0.2,0.9]	284[169,439]	136[64,238]	72[31,132]	88[39,259]	53[23,155]	35[6,104]	11.8[1.1,61.1]	11.8[1.1,61.1]	0.0[0.0,0.3]	6.9[5.0,9.9]	6.9[5.0,9.9]	
	40%	0.08	0.01	0.01	475[263,913]	332[158,666]	140[52,292]	3.3[1.2,8.4]	2.8[0.9,8.0]	0.4[0.2,0.8]	292[175,443]	144[72,248]	61[16,122]	89[40,260]	36[16,105]	53[24,154]	11.3[1.1,60.3]	11.3[1.1,60.3]	0.0[0.0,0.5]	6.9[5.0,9.9]	6.9[5.0,9.9]	
	1area	0.09	0.02	0.02	472[244,896]	304[120,647]	168[80,328]	3.0[1.1,7.5]	2.5[0.7,6.9]	0.5[0.2,0.9]	291[163,440]	131[63,230]	93[47,156]	91[40,267]	30[0,48]		13.1[1.1,63.1]	13.1[1.1,63.1]	0.0[0.0,0.0]	6.9[5.1,9.8]	51.2[22.9,143.4]	
	2area	0.07	0.01	0.01	488[253,921]	330[142,675]	159[74,318]	3.1[1.2,8.0]	2.6[0.8,7.4]	0.5[0.2,0.9]	299[173,452]	140[73,242]	83[42,143]	92[40,271]	61[15,219]	24[4,113]	12.6[1.1,62.7]	12.6[1.1,62.7]	0.0[0.0,0.2]	7.0[5.1,9.9]	12.2[7.7,20.5]	
	100%	0.11	0.02	0.03	468[224,883]	294[109,641]	171[81,329]	2.9[1.0,7.4]	2.4[0.6,6.8]	0.5[0.2,0.9]	286[151,436]	124[68,225]	97[54,159]	90[38,263]	90[38,263]	0[0,0]	13.6[1.1,63.6]	13.6[1.1,63.6]	0.0[0.0,0.0]	6.9[5.1,10.0]	0.0[0.0,0.0]	
	80%	0.09	0.02	0.02	481[242,915]	316[127,666]	162[73,324]	3.1[1.1,7.8]	2.6[0.7,7.2]	0.5[0.2,0.9]	294[164,445]	134[65,237]	87[45,151]	92[39,269]	73[31,215]	18[8,54]	12.8[1.1,62.8]	12.8[1.1,62.8]	0.0[0.0,0.2]	7.0[5.1,9.9]	7.0[5.1,9.9]	
60%	0.07	0.01	0.01	494[260,931]	339[145,692]	153[61,314]	3.2[1.2,8.1]	2.7[0.8,7.7]	0.4[0.2,0.9]	301[177,453]	144[75,251]	75[31,139]	93[41,273]	56[24,164]	37[16,109]	12.4[1.1,61.9]	12.4[1.1,61.9]	0.0[0.0,0.3]	7.0[5.1,9.9]	7.0		

Table F1 (continued). Sardine performance statistics

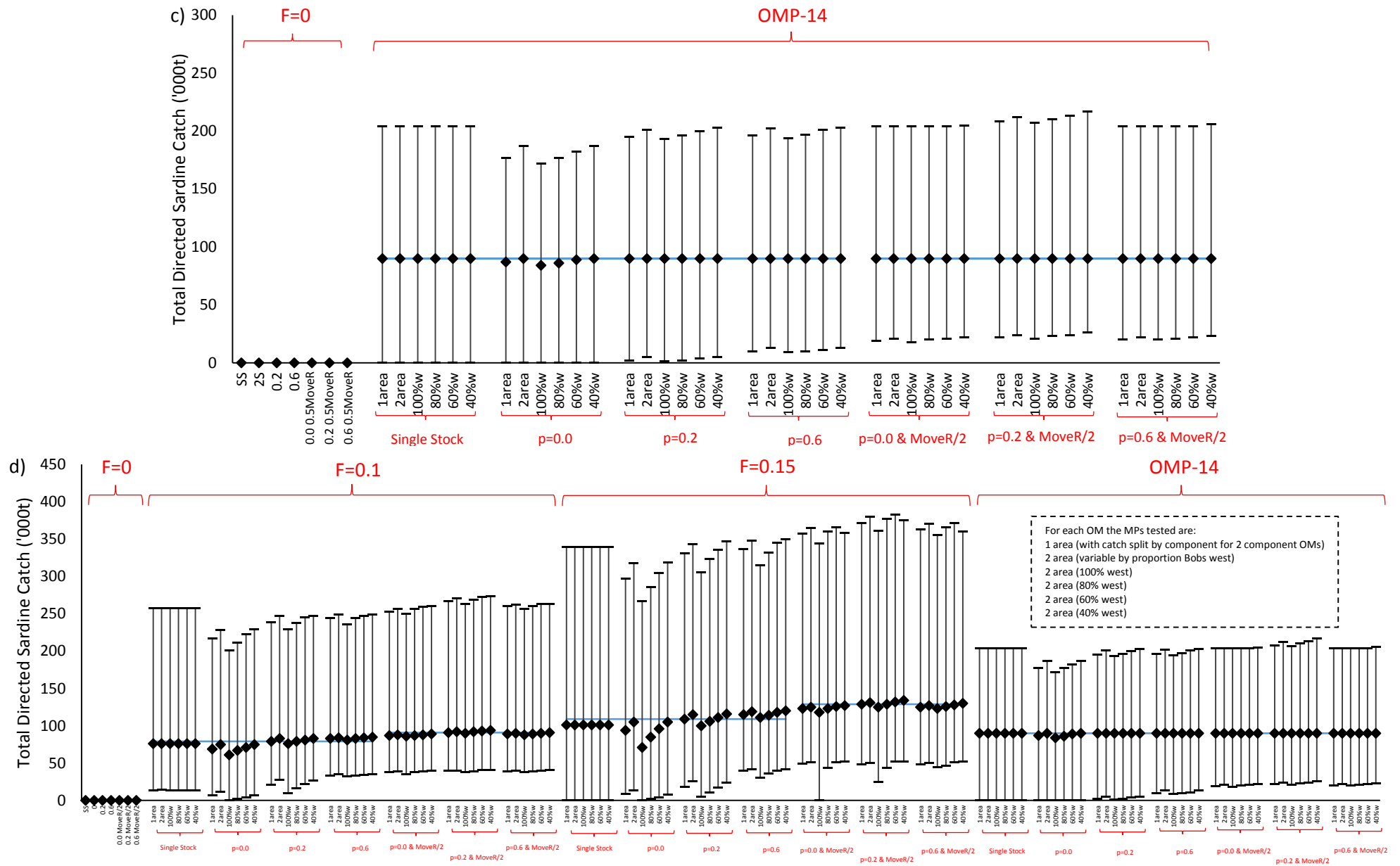
F10	Sardine OM	P(B>Thresh)			B <sup>2024</sup>			B <sup>2024</sup> / B <sup>2015</sup>			Minimum B <sup>*</sup>			Directed Sardine Catch			Sardine Bycatch			AAV					
		At least once	Overall	End	Total	West	South	Total	West	South	Total	West	South	Total	West	South	Total	West	South	West	South				
Single-Stock	1area	0.19	0.08	0.16	199(0,497)			0.9(0.0,2.0)			98(0,226)			101(0,339)			10(4,0,60.6)			7.5(5,2.1,1)					
	2area	0.19	0.09	0.17	198(0,498)			0.9(0.0,2.0)			98(0,226)			101(0,339)			10(2,0,60.6)			7.5(5,1.1,1)					
	100%	0.19	0.09	0.17	198(0,497)			0.9(0.0,2.0)			97(0,226)			101(0,339)			10(9,0,62.1)			7.5(5,2.1,1)					
	80%	0.19	0.09	0.17	198(0,497)			0.9(0.0,2.0)			97(0,226)			101(0,339)			10(9,0,62.1)			7.5(5,2.1,1)					
	60%	0.19	0.09	0.17	198(0,497)			0.9(0.0,2.0)			97(0,226)			101(0,339)			10(9,0,62.1)			7.5(5,2.1,1)					
	40%	0.19	0.09	0.17	198(0,497)			0.9(0.0,2.0)			97(0,226)			101(0,339)			10(9,0,62.1)			7.5(5,2.1,1)					
	p=0	1area	0.65	0.32	0.4	258(11,604)	68(0,311)	155(10,389)	12(0,0.5,3)	0.6(0,0.4,7)	0.4(0,0,1,0)	150(2,300)	18(0,73)	76(2,163)	94(9,297)	76(0,235)	12(1,124)	8(4,0,57.3)	8(4,0,57.3)	0(0,0,0,1)	7(2,5,10.6)	7(4,3,13.5)	50(2,10,9,200.4)		
		2area	0.55	0.22	0.27	309(17,657)	104(0,366)	169(16,395)	16(0,0,6,6)	1.0(0,0,1,1)	0.5(0,0,1,1)	182(7,313)	29(0,88)	79(6,154)	105(13,318)	47(0,216)	42(7,198)	9(30,0,58.1)	9(30,0,58.1)	0(0,0,0,3)	7(3,5,210.8)	17(28,7,37.1)	21(0,10,43.6)		
		100%	0.77	0.46	0.62	67(26,532)	0(0,252)	67(26,532)	0(2,0,1,4)	0(0,0,3,7)	0(0,0,1,1)	0(0,64)	0(0,64)	71(0,267)	0(0,0)	0(0,0)	5(9,0,55.4)	5(9,0,55.4)	0(0,0,0,0)	6(5,2,2.9)	0(0,0)	0(0,0,0,0)			
		80%	0.69	0.38	0.52	203(23,575)	31(0,292)	122(23,500)	0(0,1,5,0)	0(3,0,1,1)	0(0,0,1,0)	132(16,300)	11(0,74)	69(16,163)	85(2,286)	68(0,228)	18(2,60)	1(7,0,56.4)	7(10,56,4)	0(0,0,0,1)	7(2,5,10.4)	6(2,4,10.1)	7(0,5,10.2)		
		60%	0.62	0.31	0.4	265(19,629)	74(0,351)	149(19,382)	1(3,0,1,6)	0(7,0,5,3)	0(4,0,1,1)	164(8,312)	21(0,84)	68(7,156)	96(4,305)	57(0,182)	3(8,0,124)	8(10,57,0)	8(10,57,0)	0(0,0,0,1)	7(2,5,10.6)	7(2,4,10.6)	7(3,5,10.6)		
		40%	0.55	0.23	0.28	309(23,671)	106(0,402)	161(20,391)	1(6,0,1,6)	1(1,0,6,2)	0(4,0,1,0)	184(11,321)	31(0,96)	66(9,152)	105(8,319)	42(0,129)	6(38,190)	8(9,0,57.4)	8(8,0,57.3)	0(0,0,0,5)	7(3,5,210.8)	7(2,5,10.6)	7(3,5,10.6)		
		p=0.2	1area	0.55	0.21	0.26	314(26,663)	92(0,352)	188(22,417)	1(6,0,1,6)	1(0,0,5,5)	0(5,0,1,1,1)	190(12,320)	24(0,80)	95(9,180)	109(18,331)	9(5,260)	11(1,134)	11(1,0,60.7)	11(1,0,60.7)	0(0,0,0,1)	7(4,5,11.1)	8(1,5,18.6)	57(0,23,196.6)	
			2area	0.42	0.2	0.24	340(26,699)	125(0,395)	190(17,417)	1(9,0,1,7)	1(3,0,0,6)	0(5,0,1,1,1)	209(17,335)	33(0,90)	88(12,170)	115(26,343)	54(2,232)	45(8,210)	10(8,1,60.3)	10(8,1,60.3)	0(0,0,0,4)	7(4,5,11.1)	17(7,10,230.1)	21(6,12,43.5)	
			100%	0.63	0.28	0.37	278(33,641)	67(0,323)	178(33,410)	1(3,0,1,5,6)	0(7,0,4,9)	0(5,0,1,1,1)	170(26,311)	13(0,66)	96(26,182)	100(5,306)	100(5,306)	0(0,0)	10(9,1,61.3)	10(9,1,61.3)	0(0,0,0,0)	7(9,5,150.5)	7(9,5,150.5)	0(0,0,0,0)	
			80%	0.58	0.24	0.32	307(29,662)	89(0,357)	179(28,410)	1(5,0,1,1,1)	0(9,0,5,5)	0(5,0,1,1,1)	187(20,317)	20(0,79)	92(0,175)	101(1,323)	22(4,67)	10(8,1,1,60.5)	10(8,1,1,60.5)	0(0,0,0,2)	7(8,5,580.3)	7(8,5,580.3)	7(3,5,210.9)		
			60%	0.52	0.2	0.24	329(27,685)	108(0,390)	183(26,415)	1(8,0,1,6,8)	1(1,0,6,2)	0(5,0,1,1,1)	200(15,330)	28(0,91)	86(13,169)	111(17,336)	67(5,201)	45(9,136)	10(7,1,1,60.0)	10(7,1,1,60.0)	0(0,0,0,4)	7(4,5,11.0)	7(6,5,29.6)	7(4,5,31.0)	
			40%	0.46	0.16	0.19	349(37,704)	132(1,431)	185(30,417)	2(0,1,7,5)	1(4,0,0,6,8)	0(5,0,1,1,1)	231(20,337)	35(0,100)	78(11,164)	116(24,347)	46(7,140)	70(16,205)	10(6,1,59.7)	10(6,1,59.6)	0(0,0,0,6)	7(5,5,12.3)	7(5,5,12.3)	7(4,5,11.1)	
			p=0.6	1area	0.47	0.14	0.17	336(66,653)	110(8,354)	205(48,414)	1(8,0,3,6,8)	1(2,0,1,5,9)	0(6,0,1,1,1)	205(37,321)	27(2,76)	104(18,187)	115(40,337)	96(24,263)	11(1,135)	12(4,1,1,61.6)	12(4,1,1,61.6)	0(0,0,0,1)	7(5,5,11.1)	7(9,5,31.3)	59(7,26,2,206.6)
				2area	0.42	0.12	0.14	352(77,677)	133(15,394)	196(48,412)	2(1,0,4,7,9)	0(5,0,1,1,1)	215(46,333)	35(4,89)	94(20,174)	119(42,348)	57(8,233)	48(8,211)	11(6,1,1,61.0)	11(6,1,1,61.0)	0(0,0,0,4)	7(5,5,11.1)	7(17,10,0,35.7)	22(1,12,7,45.5)	
100%				0.53	0.17	0.21	324(62,645)	93(3,336)	203(55,413)	1(7,0,2,6,2)	1(0,0,6,6)	0(6,0,2,1,1)	195(43,314)	18(0,66)	110(40,193)	111(31,315)	11(31,315)	0(0,0)	12(7,1,1,62.7)	12(7,1,1,62.7)	0(0,0,0,0)	7(5,5,12.1)	7(5,5,12.1)	0(0,0,0,0)	
80%				0.49	0.15	0.18	335(62,662)	109(5,368)	201(53,411)	1(8,0,2,6,3)	1(2,0,0,6,6)	0(6,0,2,1,1)	203(34,322)	24(0,78)	103(30,182)	114(36,368)	11(27,263)	23(8,68)	12(3,1,1,61.8)	12(3,1,1,61.8)	0(0,0,0,0)	7(5,5,12.1)	7(5,5,12.1)	0(0,0,0,0)	
60%				0.45	0.13	0.16	347(71,675)	125(7,392)	198(47,412)	2(0,0,3,7,4)	1(3,0,1,6,7)	0(5,0,1,1,1)	210(30,330)	31(1,86)	93(20,175)	118(40,345)	70(22,206)	47(7,138)	11(8,1,1,60.7)	11(8,1,1,60.7)	0(0,0,0,4)	7(5,5,11.0)	7(6,5,11.8)	7(6,5,11.2)	
40%				0.4	0.04	0.13	368(89,697)	143(14,426)	196(47,410)	2(2,0,4,8,1)	1(5,0,1,7,6)	0(5,0,1,1,1)	248(68,337)	37(4,96)	84(15,167)	120(42,350)	48(17,142)	72(5,207)	13(3,1,1,60.1)	13(3,1,1,60.1)	0(0,0,0,6)	7(6,5,11.4)	7(6,5,11.4)	7(6,5,11.9)	
p=0.5 (flowery)				1area	0.15	0.03	0.03	404(190,801)	256(0,456)	147(61,292)	2(5,0,9,6,8)	2(1,0,5,6,4)	0(4,0,2,0,8)	235(10,368)	108(43,194)	76(25,137)	123(49,357)	11(142,303)	7(0,100)	13(11,1,63.2)	13(11,1,63.2)	0(0,0,0,0)	7(6,5,10.8)	7(6,5,10.8)	57(25,6,180.6)
				2area	0.12	0.02	0.02	419(199,828)	275(11,597)	136(54,273)	2(7,0,9,7,4)	2(3,0,6,8)	0(4,0,2,0,8)	243(08,382)	119(49,213)	65(24,116)	125(51,365)	83(20,297)	31(6,150)	12(6,1,1,62.7)	12(5,1,1,62.6)	0(0,0,0,2)	7(6,5,11.0)	12(7,8,12.6)	24(11,7,47.9)
	100%			0.22	0.08	0.12	381(41,775)	227(0,422)	146(41,293)	2(3,0,1,6,4)	1(8,0,5,8)	0(4,0,1,0,8)	225(31,361)	92(0,179)	84(31,144)	118(0,340)	9(0,0)	12(6,0,63.1)	12(6,0,63.1)	0(0,0,0,0)	7(6,5,11.0)	7(5,4,10.8)	0(0,0,0,0)		
	80%			0.15	0.04	0.05	409(160,809)	262(79,580)	140(51,284)	2(6,0,7,7,0)	2(1,0,4,6,5)	0(4,0,1,0,8)	235(93,374)	108(27,202)	72(31,129)	123(44,360)	98(35,288)	50(1,172)	12(7,1,62.8)	12(7,1,62.8)	0(0,0,0,2)	7(6,5,11.0)	7(5,5,10.9)	7(6,5,10.9)	
	60%			0.11	0.02	0.02	424(201,835)	292(120,623)	128(42,274)	2(8,1,0,7,4)	2(4,0,6,7,1)	0(4,0,1,0,8)	246(120,387)	125(55,221)	56(31,113)	126(51,366)	76(30,223)	25(2,1,162)	12(3,1,1,61.9)	12(3,1,1,61.9)	0(0,0,0,4)	7(6,5,11.1)	7(6,5,11.1)	7(6,5,11.4)	
	40%			0.09	0.01	0.01	437(222,862)	317(147,622)	114(33,263)	3(1,1,1,8,1)	2(7,0,8,7,6)	0(3,0,1,0,7)	257(146,398)	138(67,241)	41(7,97)	127(52,358)	51(21,152)	76(31,210)	11(8,1,1,61.1)	11(7,1,1,61.0)	0(0,0,0,7)	7(6,5,10.8)	7(6,5,11.0)	7(6,5,11.3)	
	p=0.2 (flowery)			1area	0.13	0.03	0.04	419(170,818)	267(83,595)	151(56,302)	2(6,0,7,6,9)	2(4,0,2,0,9)	0(4,0,2,0,9)	248(100,401)	115(44,202)	79(24,162)	129(48,372)	11(6,4,135)	7(1,104)	13(6,1,1,64.1)	13(6,1,1,64.1)	0(0,0,0,1)	7(4,5,11.3)	7(4,5,11.3)	57(6,26,1,185.9)
				2area	0.11	0.03	0.04	434(183,845)	294(100,619)	159(50,287)	2(8,0,8,7,3)	2(3,0,5,6,9)	0(4,0,1,0,9)	257(99,409)	126(51,225)	68(21,125)	131(50,380)	87(19,311)	33(6,157)	13(1,1,63.8)	13(1,1,63.8)	0(0,0,0,2)	7(7,6,11.2)	12(7,8,21.8)	24(13,8,48.2)
		100%		0.2	0.07	0.1	405(152,799)	244(1,566)	151(48,305)	2(3,0,2,6,5)	1(9,0,0,5,9)	0(4,0,1,0,9)	237(37,390)	99(0,192)	87(34,148)	125(25,361)	125(25,361)	0(0,0)	13(5,1,1,64.8)	13(5,1,1,64.8)	0(0,0,0,0)	7(7,6,11.3)	7(7,6,11.3)	0(0,0,0,0)	
		80%		0.14	0.04	0.05	425(141,827)	277(54,615)	143(51,296)	2(7,0,6,7,0)	2(2,0,3,6,4)	0(4,0,1,0,8)	248(67,402)	118(23,212)	74(28,134)	129(44,377)	103(34,302)	26(10,76)	13(2,1,1,63.8)	13(2,1,1,63.8)	0(0,0,0,2)	7(6,5,11.2)	7(6,5,11.2)	7(6,5,11.4)	
		60%		0.07	0.01	0.01	438(209,813)	305(124,611)	131(41,288)	2(8,0,6,7,4)	2(5,0,2,7,0)	0(4,0,1,0,8)	251(104,394)	132(47,237)	57(32,153)	129(52,383)	79(23,151)	33(21,151)	12(9,1,1,63.1)	12(9,1,1,63.1)	0(0,0,0,0)	7(7,6,11.3)	7(7,6,11.3)	7(7,6,11.4)	
		40%		0.04	0.01	0.01	460(224,879)	341(145,694)	119(32,274)	3(1,1,1,8,0)	2(8,0,8,7,7)	0(3,0,1,0,8)	275(51,422)	146(78,254)	42(7,101)	134(52,375)	54(21,160)	79(31,220)	12(4,1,1,61.9)	12(4,1,1,61.8)	0(0,0,0,0)	7(7,6,11.1)	7(7,6,11.1)	7(7,6,11.4)	
		p=0.6 (flowery)		1area	0.14	0.03	0.04	407(163,790)	253(78,556)	147(56,293)	2(5,0,7,6,6)	2(0,0,4,1,0)	0(4,0,2,0,8)	242(99,382)	111(40,195)	78(23,138)	125(48,363)	11(242,303)	7(0,102)	13(4,1,1,63.3)	13(4,1,1,63.2)	0(0,0,0,1)	7(6,5,11.1)	7(3,5,11.2)	58(0,25,8,186.1)
				2area	0.12	0.03	0.04	420(171,807)	274(96,581)	135(49,277)	2(6,0,7,6,9)	2(2,0,5,6,4)	0(4,0,1,0,8)	250(97,391)	123(46,191)	67(20,121)	127(50,370)	83(19,294)	32(6,153)	12(7,1,1,62.7)	12(7,1,1,62.6)	0(0,0,0,0)	7(6,5,11.1)	12(7,8,12.2)	23(13,8,47.4)
			100%	0.19	0.05	0.																			

**Table F2.** Comparing sardine performance statistics given different sets of random numbers for a two component hypothesis with some contribution of south coast spawning to west coast recruitment ( $p=0.2$ ) where 20% of the south coast spawner biomass contributes to ‘effective’ west coast spawner biomass, and baseline west to south movement (Mover)

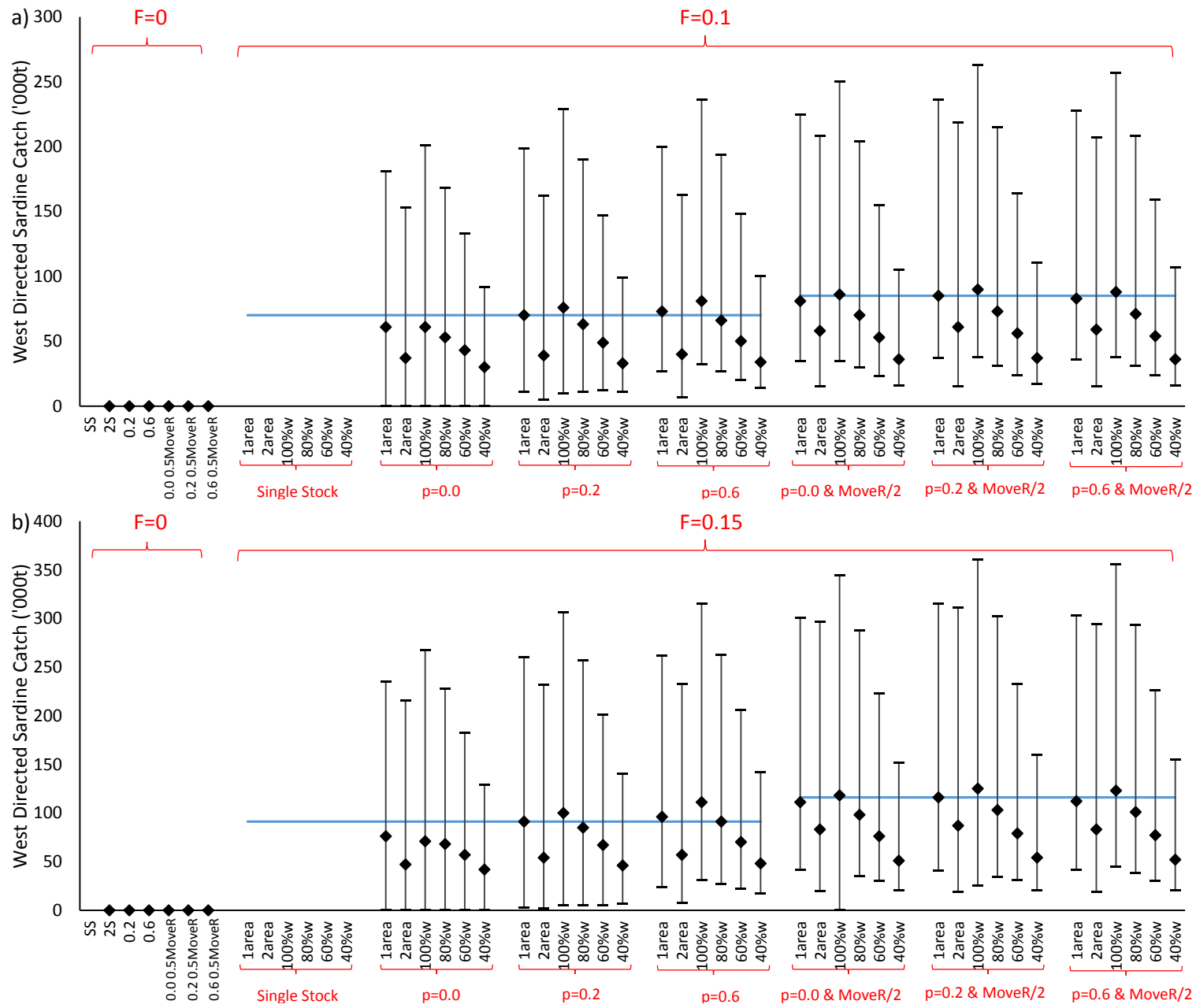
Rand om Num ber Set	F=0	P(B<Thresh)			B <sup>2008</sup>			B <sup>2008</sup> / B <sup>2015</sup>			Minimum B <sup>w</sup>			Directed Sardine Catch			Sardine Bycatch			AAV			
		At least once	Overall	End	Total	West	South	Total	West	South	Total	West	South	Total	West	South	Total	West	South	Total	West	South	
Baseline	F=0	0.34	0.07	0.07	506[244,922]	190[38,535]	294[125,553]	2.9[1.0,10.5]	2.0[0.4,9.9]	0.8[0.4,1.5]	317[179,459]	50[10,119]	152[79,254]	0[0,0]	0[0,0]	0[0,0]	10.3[10.5,9.5]	10.3[10.5,9.5]	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]
Alternative	F=0	0.32	0.07	0.07	504[266,931]	190[41,568]	288[135,559]	3.0[1.1,11.4]	2.1[0.3,10.7]	0.8[0.4,1.6]	318[178,466]	48[10,129]	154[79,250]	0[0,0]	0[0,0]	0[0,0]	10.2[10.5,9.8]	10.2[10.5,9.8]	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]
Baseline	F=0.10	1area	0.49	0.16	0.19	371[54,722]	119[4,394]	223[45,451]	2.0[0.2,7.0]	1.3[0.6,3.3]	0.6[0.1,1.3]	230[38,362]	30[1,90]	115[33,205]	79[21,239]	70[11,199]	5[0,73]	11.3[11.6,10.3]	11.3[11.6,10.3]	0[0,0.0,0.1]	6[8]5,0,9,9	7[0]4,8,11,9	54,7[24,175,7]
	2area	0.42	0.12	0.14	392[100,747]	149[16,436]	224[61,455]	2.3[0.5,8.7]	1.5[0.2,1.3]	0.6[0.2,1.3]	243[69,376]	39[5,101]	109[42,197]	83[28,247]	39[5,162]	33[6,153]	10.9[10.6,10.3]	10.9[10.6,10.3]	0[0,0.0,0.3]	6[9]5,1,10,1	17,2[9,9,36,0]	20,2[11,7,40,9]	
	100%	0.52	0.19	0.24	352[43,714]	104[0,380]	217[41,448]	1.8[0.1,6.7]	1.1[0.6,0.6]	0.6[0.1,1.2]	222[32,359]	26[0,86]	116[31,208]	76[10,229]	76[10,229]	0[0,0]	11.2[11.6,10.5]	11.2[11.6,10.5]	0[0,0.0,0.0]	6[9]5,0,14,9	6[9]5,0,14,9	0[0]0,0,0,0	
	80%	0.49	0.17	0.21	369[46,730]	119[1,409]	219[43,450]	2.0[0.2,7.3]	1.2[0.6,5.5]	0.6[0.1,1.3]	230[32,366]	30[0,93]	111[31,202]	79[16,238]	63[11,190]	16[4,48]	11.1[11.6,10.2]	11.0[11.6,10.2]	0[0,0.0,0.1]	6[9]5,1,12,1	6[9]5,1,12,1	6[8]5,0,10,0	
	60%	0.44	0.14	0.17	383[62,743]	136[4,431]	222[51,455]	2.2[0.2,8.4]	1.4[0.1,7.2]	0.6[0.1,1.3]	238[43,374]	35[1,100]	107[32,196]	81[22,245]	49[12,147]	33[9,98]	11.0[11.6,10.2]	10.9[11.6,10.2]	0[0,0.0,0.3]	6[9]5,1,10,0	6[9]5,1,10,5	6[9]5,0,10,0	
Alternative	F=0.10	1area	0.42	0.12	0.14	399[90,764]	154[4,460]	222[59,454]	2.4[0.5,9.0]	1.6[0.1,8.3]	0.6[0.2,1.3]	245[70,381]	39[0,108]	102[35,192]	83[27,247]	33[1,39]	50[7,148]	10.7[10.5,9.7]	10.7[10.5,9.7]	0[0,0.0,0.4]	6[9]5,1,10,1	6[9]5,1,10,2	6[9]5,1,10,1
	2area	0.41	0.12	0.14	400[109,788]	152[16,474]	217[65,446]	2.3[0.5,9.7]	1.6[0.2,9.0]	0.6[0.2,1.3]	241[68,379]	38[4,105]	110[40,193]	84[26,257]	39[4,169]	34[6,159]	10.8[10.6,10.5]	10.8[10.6,10.5]	0[0,0.0,0.3]	6[9]5,0,10,4	17,5[10,1,38,5]	20,6[11,8,41,7]	
	100%	0.51	0.17	0.23	350[43,738]	111[0,420]	209[41,436]	1.8[0.1,8.3]	1.1[0.0,7.7]	0.6[0.1,1.3]	220[31,362]	25[0,88]	117[31,204]	77[9,243]	77[9,243]	0[0,0]	11.1[11.6,10.3]	11.1[11.6,10.3]	0[0,0.0,0.0]	7[0]5,0,21,1	7[0]5,0,21,1	0[0]0,0,0,0	
	80%	0.47	0.17	0.23	372[46,754]	126[1,454]	214[42,439]	2.0[0.2,8.9]	1.3[0.8,2.1]	0.6[0.1,1.3]	229[29,368]	30[0,95]	112[28,200]	80[14,249]	64[10,199]	16[4,51]	10.9[11.6,10.9]	10.9[11.6,10.8]	0[0,0.0,0.1]	6[9]5,0,10,8	6[9]5,0,10,8	6[8]4,9,10,3	
	60%	0.44	0.14	0.17	388[56,771]	140[4,476]	215[50,443]	2.2[0.2,9.4]	1.5[0.1,8.7]	0.6[0.1,1.3]	237[32,375]	35[0,104]	107[26,196]	82[19,256]	49[9,153]	33[9,103]	10.8[10.6,10.4]	10.8[10.6,10.4]	0[0,0.0,0.3]	6[9]5,0,10,4	6[9]5,0,10,4	6[8]4,9,10,4	
40%	0.4	0.12	0.14	402[87,792]	157[12,501]	212[54,438]	2.4[0.5,9.9]	1.6[0.1,9.3]	0.6[0.1,1.3]	243[53,382]	40[2,113]	101[28,191]	84[24,259]	34[9,104]	50[15,154]	10.6[11.6,10.2]	10.6[11.6,10.2]	0[0,0.0,0.4]	6[8]4,9,10,4	6[9]5,0,10,7	6[9]5,0,10,4		
Baseline	F=0.15	1area	0.55	0.21	0.26	314[26,663]	92[0,352]	188[22,417]	1.6[0.1,6.0]	1.0[0.5,5.5]	0.5[0.1,1.1]	190[12,320]	24[0,80]	95[9,180]	109[18,331]	91[3,260]	11[1,134]	11.1[10.6,10.7]	11.1[10.6,10.7]	0[0,0.0,0.1]	8[1]5,3,11,1	8[1]5,3,11,6	57,0[23,6,196,6]
	2area	0.48	0.16	0.2	340[26,692]	125[2,395]	187[29,414]	1.9[0.1,7.2]	1.3[0.6,6.6]	0.5[0.1,1.1]	209[17,335]	33[0,90]	88[12,170]	115[26,343]	54[2,232]	45[8,210]	10.8[10.6,10.3]	10.8[10.6,10.3]	0[0,0.0,0.4]	7[4]5,4,11,1	17,7[10,2,39,1]	21,6[12,2,43,5]	
	100%	0.63	0.28	0.37	278[33,641]	67[0,323]	178[33,410]	1.3[0.1,5.6]	0.7[0.4,9.9]	0.5[0.1,1.1]	170[26,311]	13[0,66]	96[26,182]	100[5,306]	100[5,306]	0[0,0]	10.9[11.6,10.3]	10.9[11.6,10.3]	0[0,0.0,0.0]	7[9]5,5,150,5	7[9]5,5,150,5	0[0]0,0,0,0	
	80%	0.58	0.24	0.32	307[29,662]	89[0,357]	179[28,410]	1.5[0.1,6.1]	0.9[0.5,5.5]	0.5[0.1,1.1]	187[20,317]	20[0,79]	92[20,175]	106[11,323]	85[5,257]	22[4,67]	10.8[11.6,10.6]	10.8[11.6,10.5]	0[0,0.0,0.2]	7[6]5,5,11,6	7[8]5,5,80,3	7,3[5,2,10,9]	
	60%	0.52	0.2	0.24	329[27,685]	108[0,390]	183[26,415]	1.8[0.1,6.8]	1.1[0.6,5.2]	0.5[0.1,1.1]	200[15,330]	28[0,91]	86[13,169]	111[17,336]	67[5,201]	45[9,136]	10.7[11.6,10.0]	10.6[11.6,10.0]	0[0,0.0,0.4]	7[4]5,5,11,0	7[4]5,5,29,6	7[4]5,5,11,0	
Alternative	F=0.15	1area	0.46	0.16	0.19	349[37,704]	132[1,431]	185[30,417]	2.0[0.1,7.5]	1.4[0.6,8.8]	0.5[0.1,1.1]	211[20,337]	35[0,100]	78[11,164]	116[24,347]	46[7,140]	10.6[10.5,9.7]	10.6[10.5,9.7]	0[0,0.0,0.6]	7[5]5,4,11,1	7[5]5,4,11,1	7[5]5,4,11,1	
	2area	0.55	0.22	0.26	308[20,679]	97[0,384]	177[18,402]	1.6[0.1,7.4]	1.0[0.6,9.9]	0.5[0.1,1.1]	184[6,327]	22[0,82]	91[4,181]	110[16,350]	90[2,268]	11[1,141]	10.9[10.6,10.0]	10.9[10.6,10.0]	0[0,0.0,0.1]	7[5]5,4,11,7	8[2]5,2,18,5	53,9[23,199,5]	
	100%	0.64	0.3	0.38	257[33,635]	62[0,349]	158[32,394]	1.2[0.1,6.2]	0.6[0.5,5.5]	0.4[0.1,1.1]	157[26,314]	11[0,73]	93[26,185]	100[5,324]	100[5,324]	0[0,0]	10.5[11.6,10.8]	10.5[11.6,10.8]	0[0,0.0,0.0]	7[9]5,5,135,7	7[9]5,5,135,7	0[0]0,0,0,0	
	80%	0.58	0.25	0.31	289[29,665]	86[0,394]	167[29,391]	1.5[0.1,7.0]	0.9[0.6,6.6]	0.5[0.1,1.1]	176[19,326]	19[0,82]	90[18,180]	107[11,342]	85[4,273]	22[4,70]	10.7[11.6,10.9]	10.7[11.6,10.9]	0[0,0.0,0.2]	7[7]5,5,12,4	7[8]5,6,118,8	7[4]5,3,11,3	
	60%	0.5	0.2	0.24	321[28,708]	115[0,434]	174[27,392]	1.8[0.1,8.3]	1.1[0.8,0.8]	0.5[0.1,1.1]	195[13,337]	28[0,93]	83[11,174]	113[16,355]	68[4,143]	46[8,143]	10.6[10.6,10.7]	10.6[10.6,10.7]	0[0,0.0,0.3]	7[5]5,4,11,6	7[7]5,5,5,1,7	7[5]5,3,11,5	
40%	0.44	0.15	0.19	351[37,736]	137[2,470]	180[30,397]	2.1[0.1,9.3]	1.4[0.8,8.7]	0.5[0.1,1.1]	207[16,346]	35[0,105]	118[22,360]	47[5,146]	71[16,213]	10.5[10.6,10.3]	10.5[10.6,10.3]	0[0,0.0,0.5]	7[5]5,4,11,6	7[6]5,5,13,6	7[5]5,3,11,9			
Baseline	OMP=1.4	1area	0.46	0.14	0.16	387[102,740]	127[13,401]	230[75,463]	2.1[0.5,7.7]	1.4[0.1,7.1]	0.6[0.2,1.3]	239[79,384]	32[4,90]	121[50,215]	90[2,195]	80[2,169]	4[0,49]	11.4[11.6,10.8]	11.4[11.6,10.8]	0[0,0.0,0.0]	10,3[4,1,465,0]	10,3[4,1,465,0]	77,4[30,0,461,4]
	2area	0.41	0.11	0.12	408[138,763]	158[24,449]	232[80,466]	2.4[0.7,8.9]	1.7[0.2,8.4]	0.6[0.2,1.3]	251[104,394]	40[7,103]	114[53,202]	90[5,201]	42[1,133]	35[2,124]	11.0[10.6,10.2]	11.0[10.6,10.2]	0[0,0.0,0.2]	9,2[4,0,311,6]	20,4[10,3,185,4]	25,9[13,5,257,9]	
	100%	0.49	0.16	0.18	378[86,736]	120[9,396]	228[69,457]	2.1[0.4,7.3]	1.3[0.1,6.7]	0.6[0.2,1.3]	234[66,380]	29[2,87]	122[49,215]	90[1,193]	90[1,193]	0[0,0]	11.4[11.6,10.9]	11.4[11.6,10.9]	0[0,0.0,0.0]	10,6[4,2,508,3]	10,6[4,2,508,3]	0[0]0,0,0,0	
	80%	0.45	0.14	0.16	390[98,743]	133[12,426]	229[74,458]	2.2[0.5,8.0]	1.4[0.1,7.2]	0.6[0.2,1.3]	240[72,386]	33[3,95]	117[50,207]	90[2,196]	72[2,157]	180[39]	11.2[11.6,10.6]	11.2[11.6,10.6]	0[0,0.0,0.2]	10,1[4,1,537,7]	10,1[4,1,537,7]	0[0]1,1,161,8	
	60%	0.43	0.12	0.14	401[115,762]	149[16,446]	230[77,468]	2.3[0.6,8.8]	1.5[0.2,8.1]	0.6[0.2,1.3]	247[88,394]	37[5,102]	112[49,201]	90[4,200]	54[2,120]	36[1,80]	11.0[10.6,10.2]	11.0[10.6,10.2]	0[0,0.0,0.3]	9,6[4,1,441,6]	9,6[4,1,441,6]	9,6[4,1,245,3]	
Alternative	OMP=1.4	1area	0.46	0.14	0.15	389[105,780]	133[16,455]	225[76,461]	2.2[0.5,8.8]	1.4[0.2,8.2]	0.6[0.2,1.3]	239[74,381]	32[4,95]	122[51,211]	90[2,204]	81[2,179]	4[0,49]	11.4[10.6,11.1]	11.4[10.6,11.1]	0[0,0.0,0.0]	10,0[4,0,312,3]	10,0[4,0,312,3]	78,4[29,0,433,8]
	2area	0.39	0.11	0.11	415[152,799]	159[26,491]	225[86,461]	2.4[0.7,9.9]	1.7[0.3,9.2]	0.6[0.2,1.3]	251[101,391]	40[7,109]	114[53,202]	90[4,204]	42[1,137]	35[2,131]	11.0[10.6,10.4]	11.0[10.6,10.4]	0[0,0.0,0.2]	9,4[3,9,405,6]	20,8[11,0,240,5]	26,6[13,7,314,0]	
	100%	0.48	0.16	0.17	382[88,771]	124[12,445]	225[70,452]	2.0[0.4,8.7]	1.3[0.1,8.0]	0.6[0.2,1.3]	231[64,379]	28[1,93]	123[48,213]	90[1,202]	90[1,202]	0[0,0]	11.4[10.6,10.0]	11.4[10.6,10.0]	0[0,0.0,0.0]	10,8[4,0,611,9]	10,8[4,0,611,9]	0[0]0,0,0,0	
	80%	0.45	0.14	0.15	394[104,785]	136[15,465]	225[73,459]	2.2[0.5,9.1]	1.4[0.2,8.4]	0.6[0.2,1.3]	241[72,385]	33[2,100]	119[49,207]	90[1,204]	72[1,163]	18[0,41]	11.2[11.6,10.8]	11.2[11.6,10.8]	0[0,0.0,0.2]	10,3[4,0,548,1]	10,3[4,0,548,1]	10,3[4,0,185,7]	
	60%	0.41	0.12	0.13	405[124,799]	150[18,491]	225[76,458]	2.3[0.6,9.6]	1.6[0.2,8.9]	0.6[0.2,1.3]	246[82,390]	37[4,107]	112[47,204]	90[3,204]	54[2,122]	36[1,82]	10.9[10.6,10.4]	10.9[10.6,10.4]	0[0,0.0,0.3]	9,8[4,0,510,0]	9,8[4,0,510,0]	9,8[4,0,291,1]	
40%	0.39	0.11	0.11	416[148,811]	163[24,517]	222[73,462]	2.4[0.7,10.0]	1.8[0.2,9.6]	0.6[0														



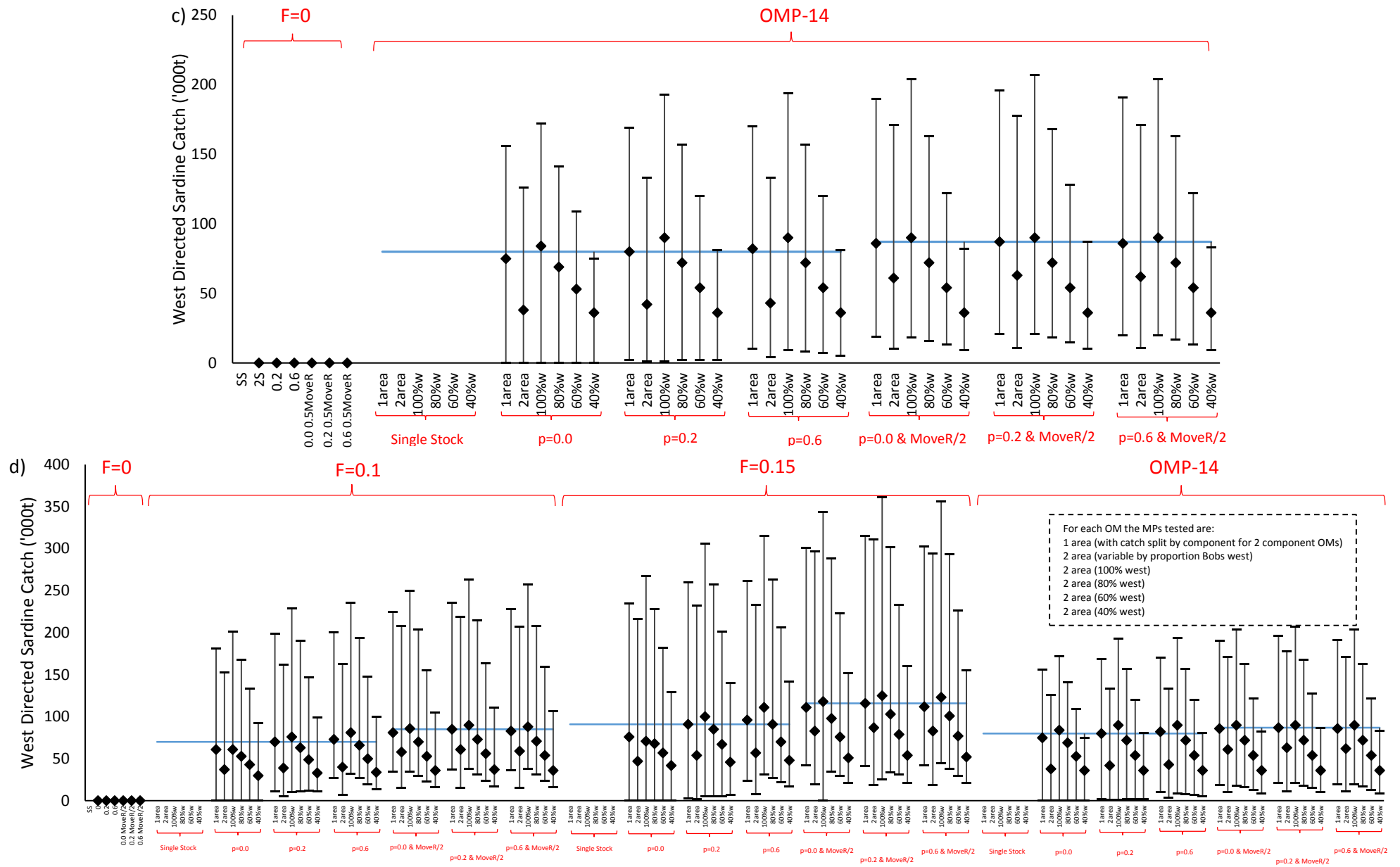
**Figure F1.** The total directed sardine catch under a)  $F=0.1$ , b)  $F=0.15$ , c) OMP-14 and d) all scenarios, with  $F=0$  included. Results are shown for a single area, two area variable and 4 two area fixed directed TAC management scenarios, under the 7 OMs considered in this appendix. The horizontal line, shown for comparative purposes only, corresponds to the single area management scenario under the OM with  $p=0.2$ .



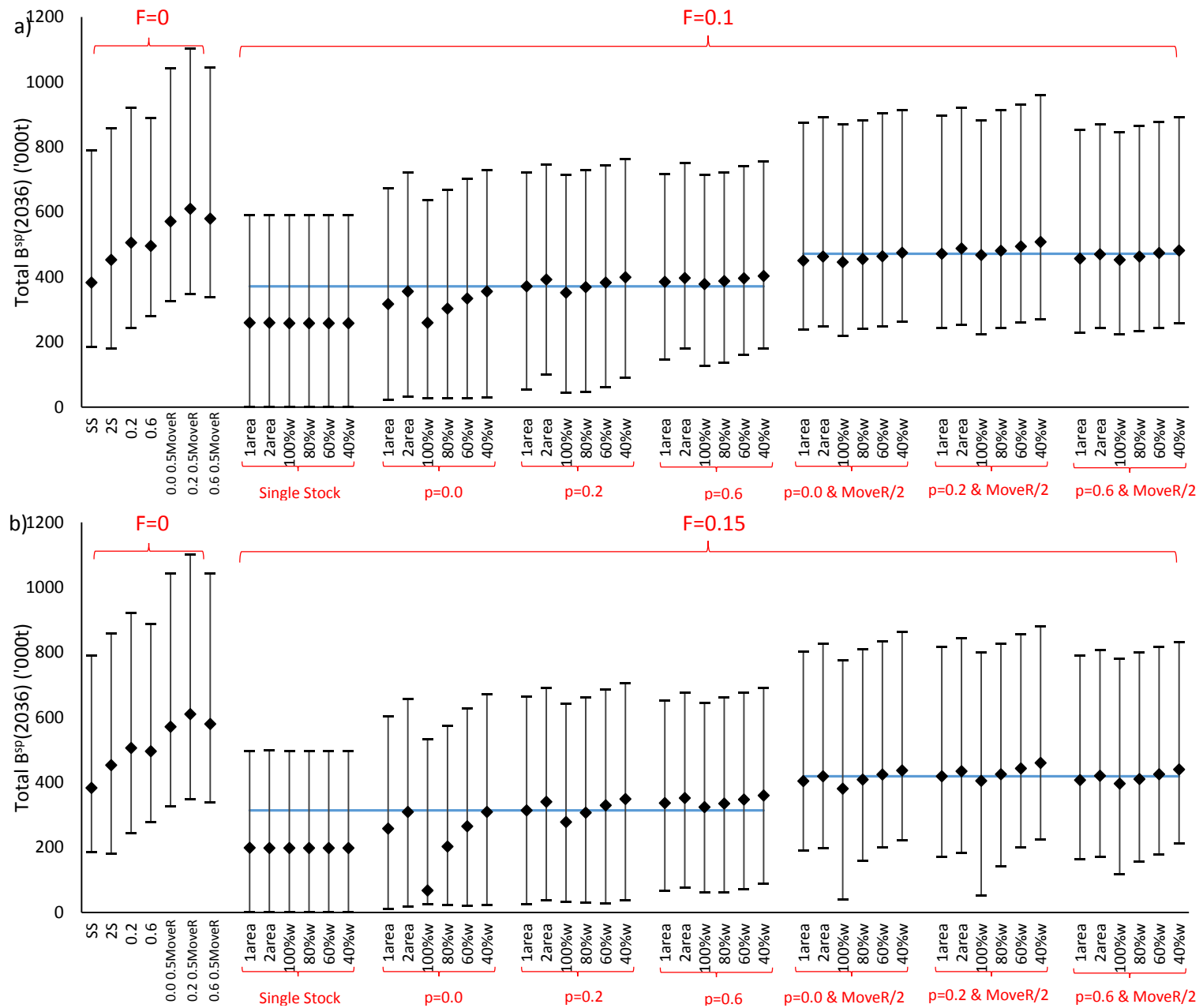
**Figure F1 (cont).** The total directed sardine catch under a) F=0.1, b) F=0.15, c) OMP-14 and d) all scenarios, with F=0 included. Results are shown for a single area, two area variable and 4 two area fixed directed TAC management scenarios, under the 7 OMs considered in this appendix. The horizontal line, shown for comparative purposes only, corresponds to the single area management scenario under the OM with p=0.2.



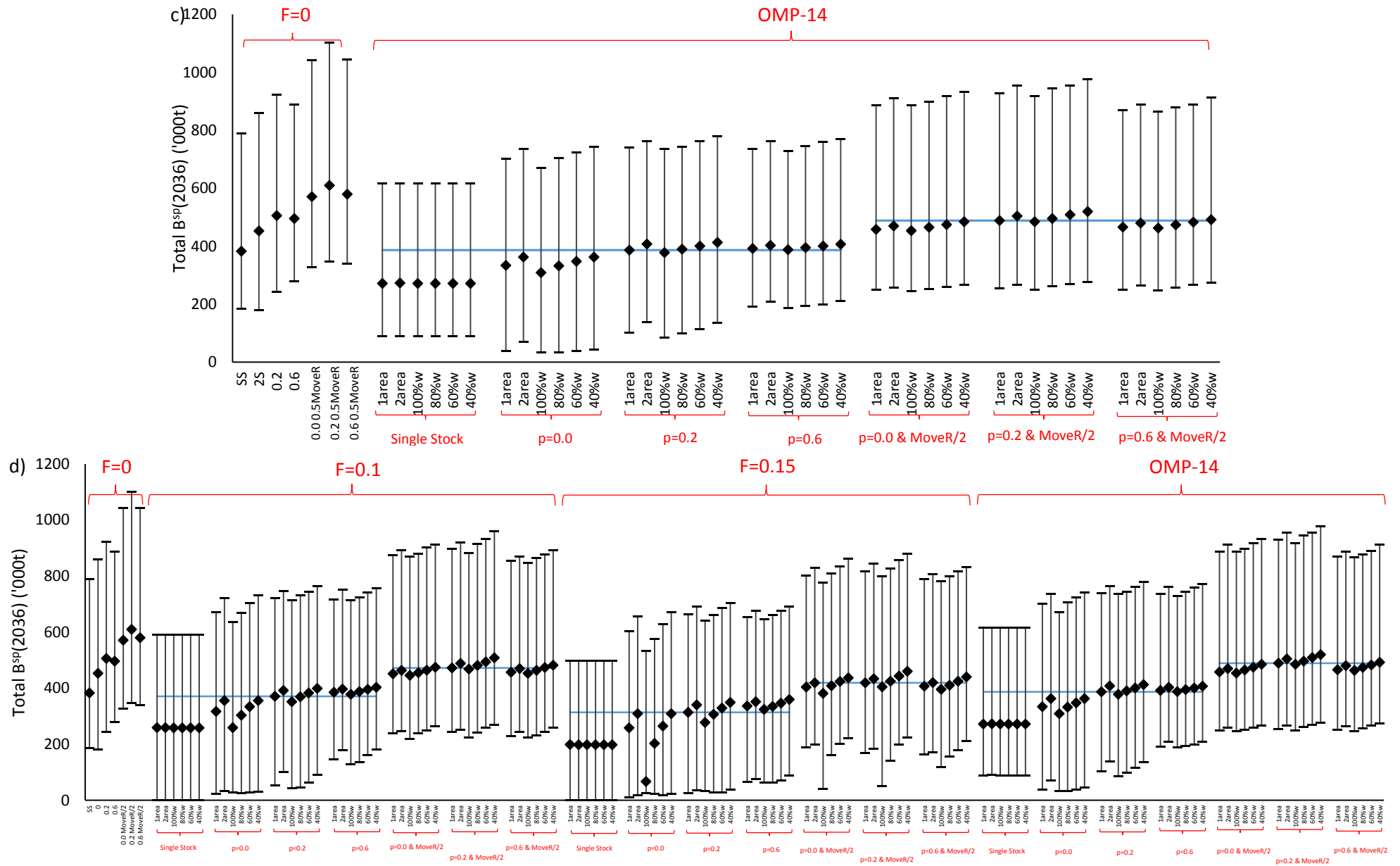
**Figure F2.** The directed sardine catch on the west coast under a)  $F=0.1$ , b)  $F=0.15$ , c) OMP-14 and d) all scenarios, with  $F=0$  included. Results are shown for a single area, two area variable and 4 two area fixed directed TAC management scenarios, under the 7 OMs considered in this appendix. The horizontal line, shown for comparative purposes only, corresponds to the single area management scenario under the OM with  $p=0.2$ .



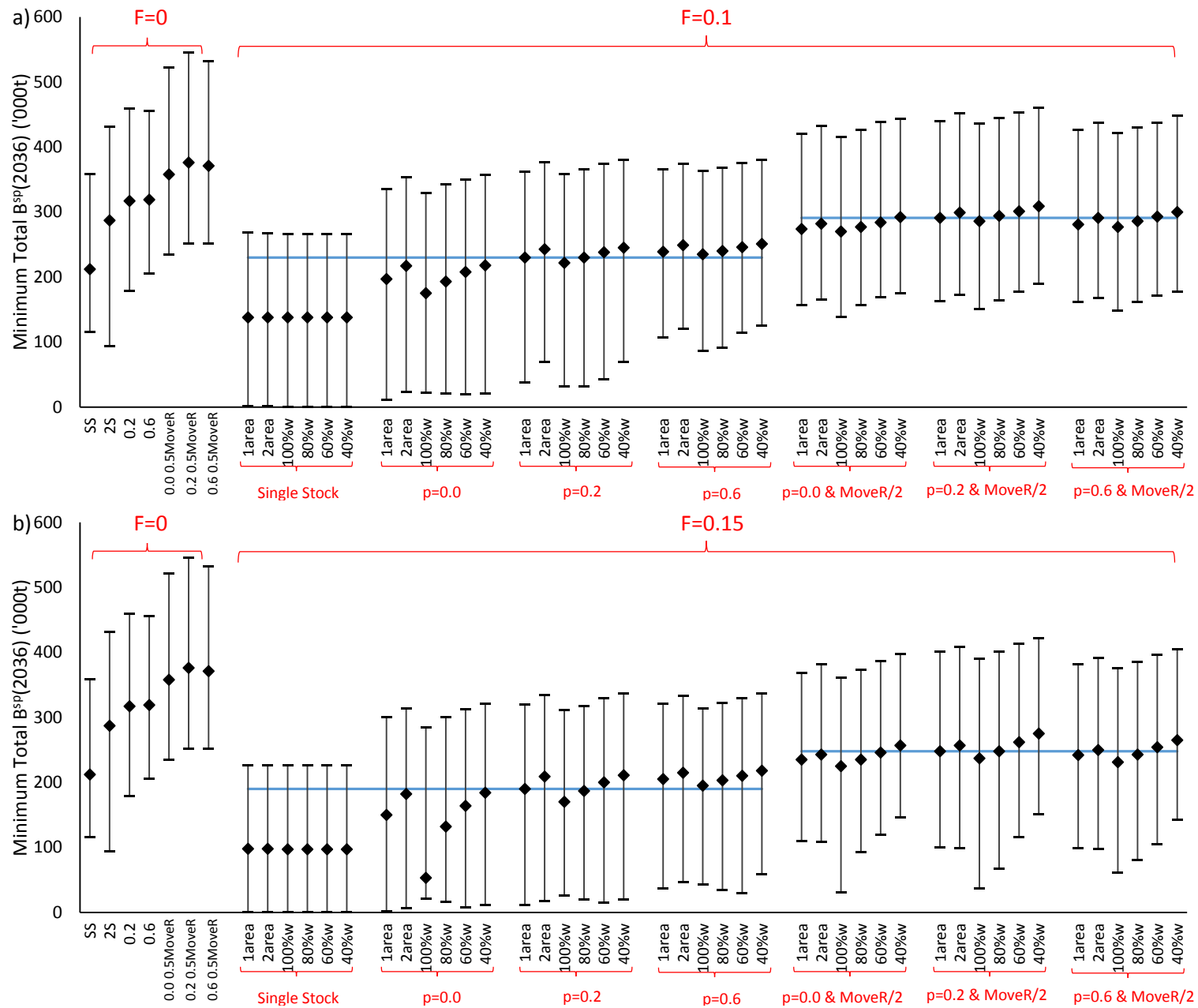
**Figure F2 (cont).** The directed sardine catch on the west coast under a) F=0.1, b) F=0.15, c) OMP-14 and d) all scenarios, with F=0 included. Results are shown for a single area, two area variable and 4 two area fixed directed TAC management scenarios, under the 7 OMs considered in this appendix. The horizontal line, shown for comparative purposes only, corresponds to the single area management scenario under the OM with p=0.2.



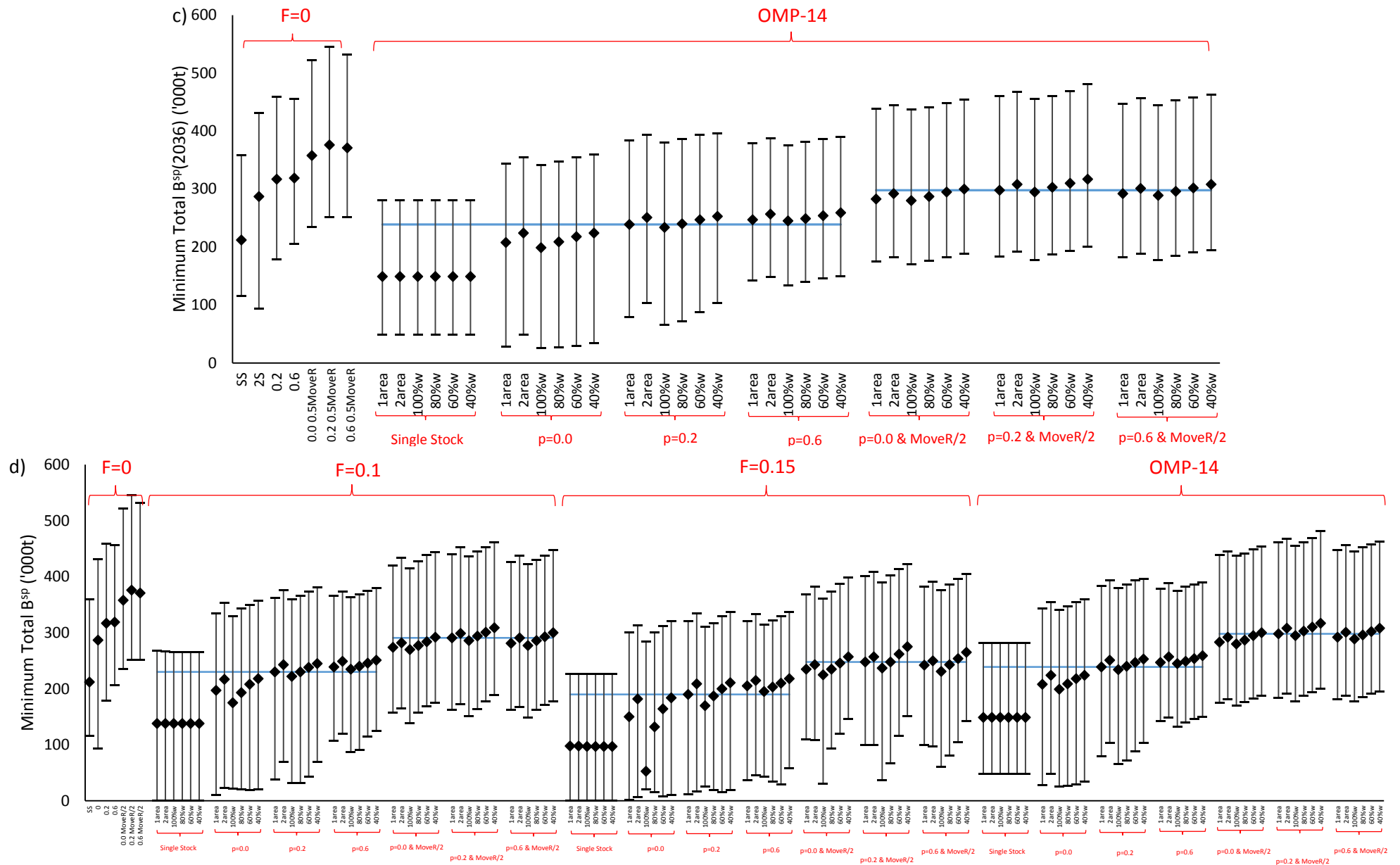
**Figure F3.** The total sardine spawner biomass at the end of the projection period under a)  $F=0.1$ , b)  $F=0.15$ , c) OMP-14 and d) all scenarios, with  $F=0$  included. Results are shown for a single area, two area variable and 4 two area fixed directed TAC management scenarios, under the 7 OMs considered in this appendix. The horizontal line, shown for comparative purposes only, corresponds to the single area management scenario under the OM with  $p=0.2$ .



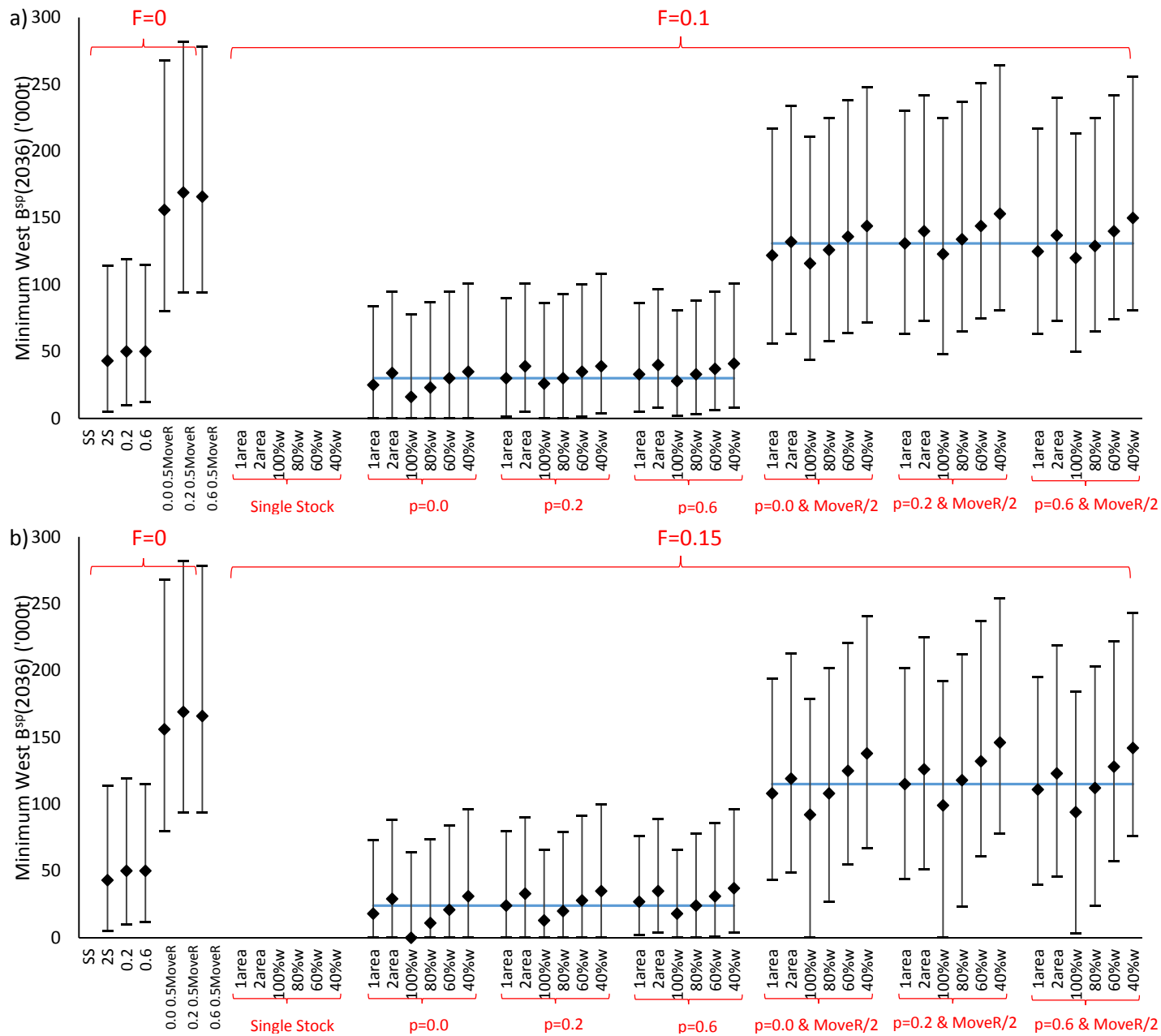
**Figure F3 (cont).** The total sardine spawner biomass at the end of the projection period under a)  $F=0.1$ , b)  $F=0.15$ , c) OMP-14 and d) all scenarios, with  $F=0$  included. Results are shown for a single area, two area variable and 4 two area fixed directed TAC management scenarios, under the 7 OMs considered in this appendix. The horizontal line, shown for comparative purposes only, corresponds to the single area management scenario under the OM with  $p=0.2$ .



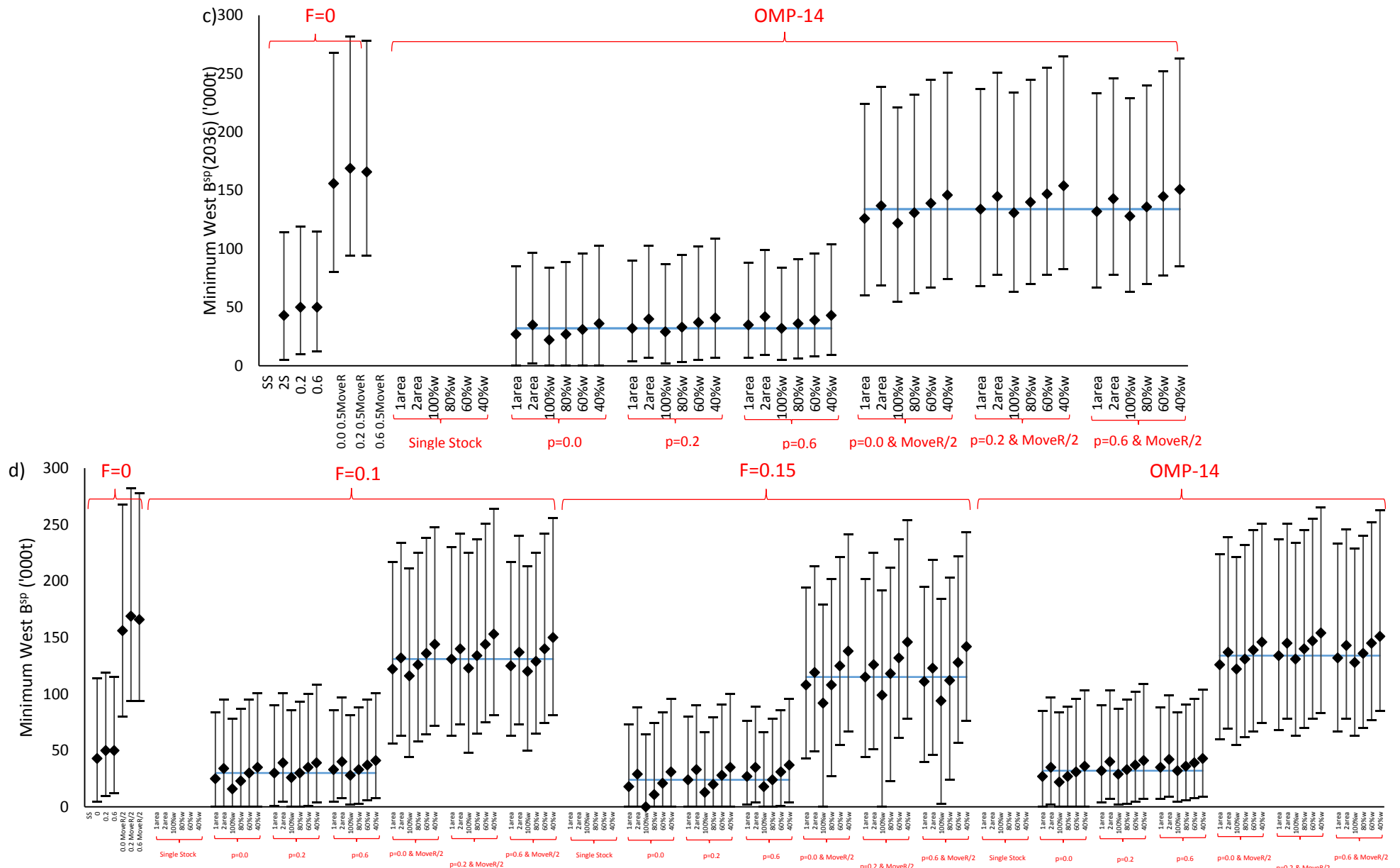
**Figure F4.** The minimum total sardine spawner biomass over the projection period under a) F=0.1, b) F=0.15, c) OMP-14 and d) all scenarios, with F=0 included. Results are shown for a single area, two area variable and 4 two area fixed directed TAC management scenarios, under the 7 OMs considered in this appendix. The horizontal line, shown for comparative purposes only, corresponds to the single area management scenario under the OM with p=0.2.



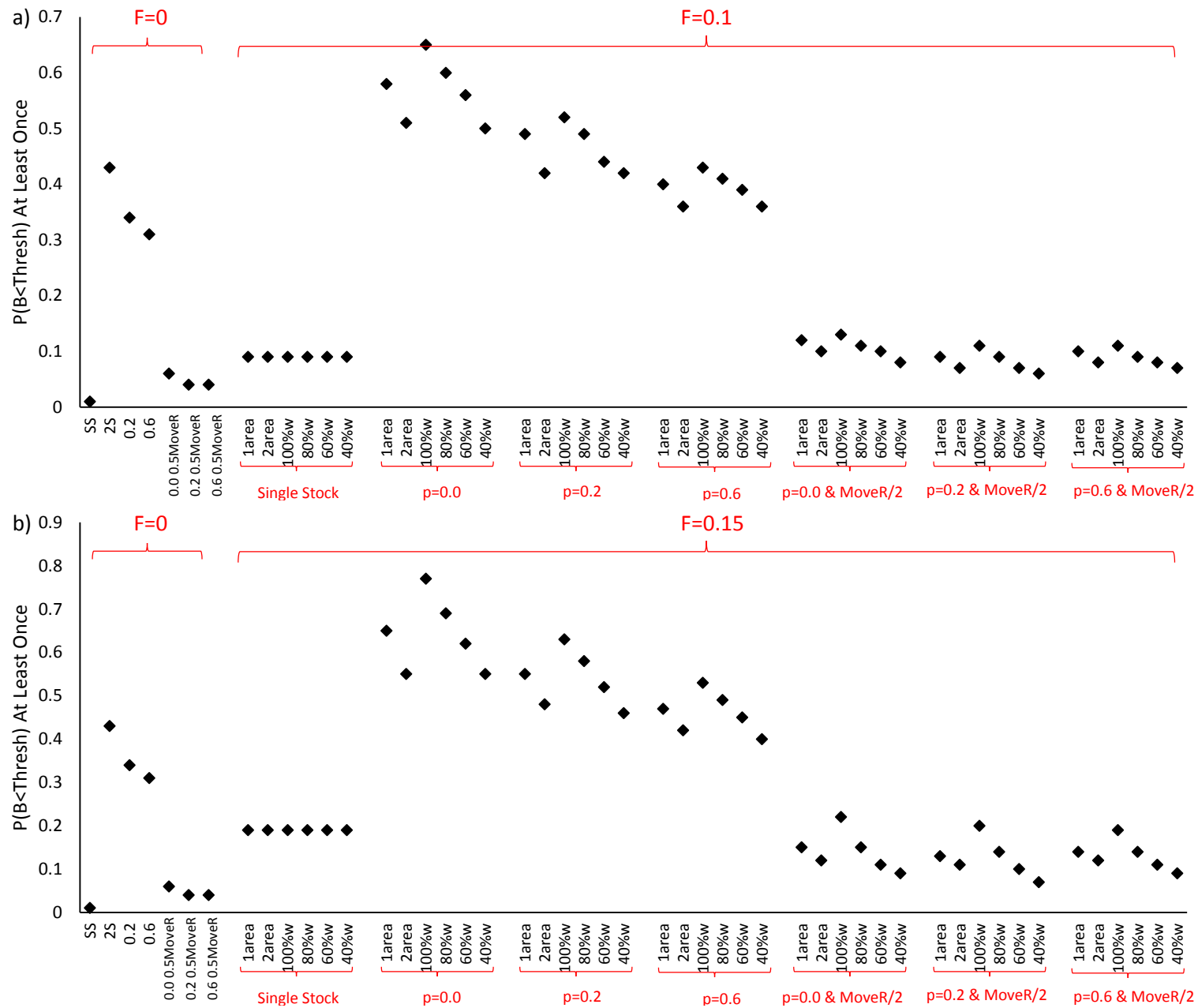
**Figure F4 (cont).** The minimum total sardine spawner biomass over the projection period under a)  $F=0.1$ , b)  $F=0.15$ , c) OMP-14 and d) all scenarios, with  $F=0$  included. Results are shown for a single area, two area variable and 4 two area fixed directed TAC management scenarios, under the 7 OMs considered in this appendix. The horizontal line, shown for comparative purposes only, corresponds to the single area management scenario under the OM with  $p=0.2$ .



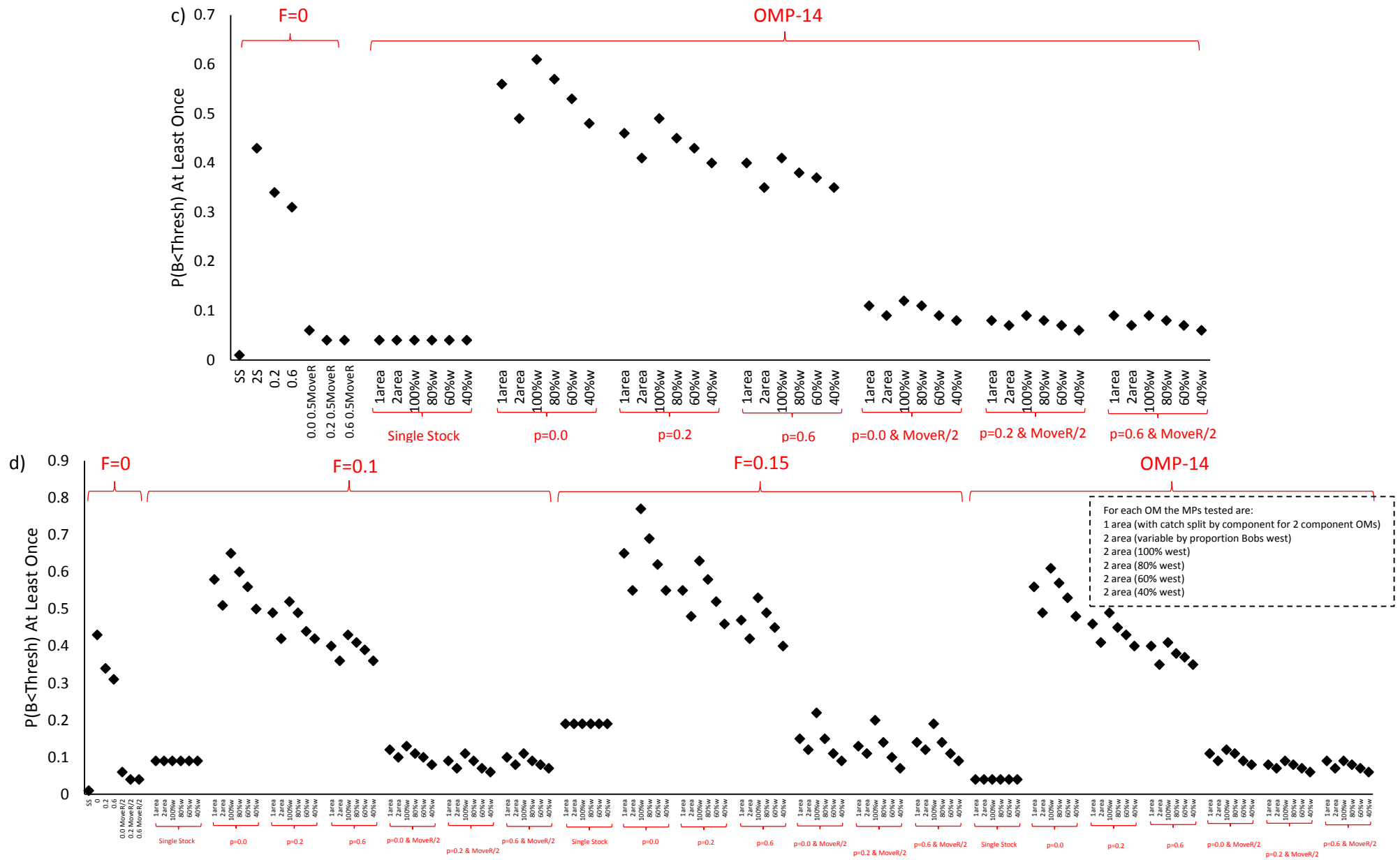
**Figure F5.** The minimum west sardine spawner biomass over the projection period under a) F=0.1, b) F=0.15, c) OMP-14 and d) all scenarios, with F=0 included. Results are shown for a single area, two area variable and 4 two area fixed directed TAC management scenarios, under the 7 OMs considered in this appendix. The horizontal line, shown for comparative purposes only, corresponds to the single area management scenario under the OM with p=0.2.



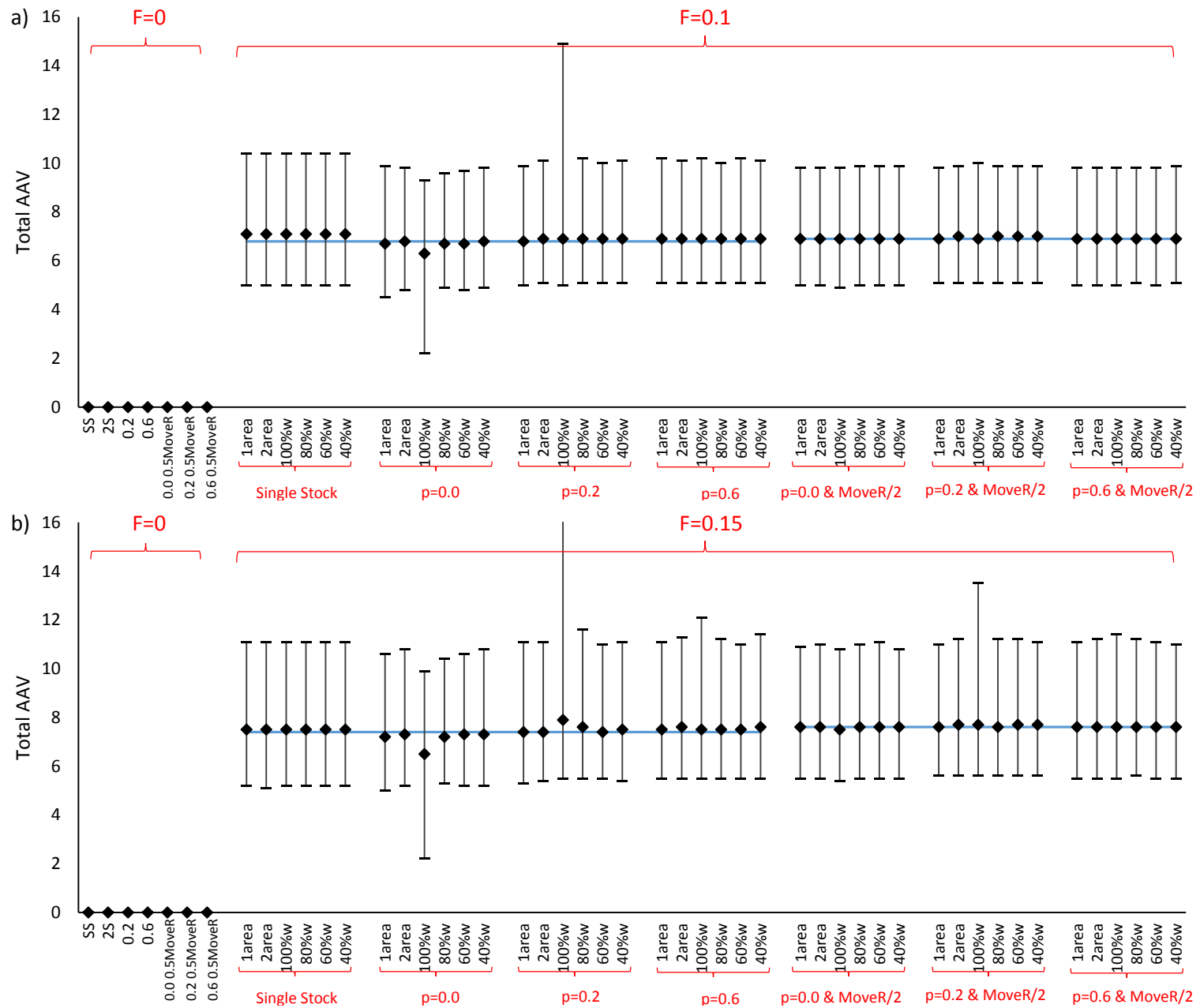
**Figure F5 (cont).** The minimum west sardine spawner biomass over the projection period under a) F=0.1, b) F=0.15, c) OMP-14 and d) all scenarios, with F=0 included. Results are shown for a single area, two area variable and 4 two area fixed directed TAC management scenarios, under the 7 OMs considered in this appendix. The horizontal line, shown for comparative purposes only, corresponds to the single area management scenario under the OM with p=0.2.



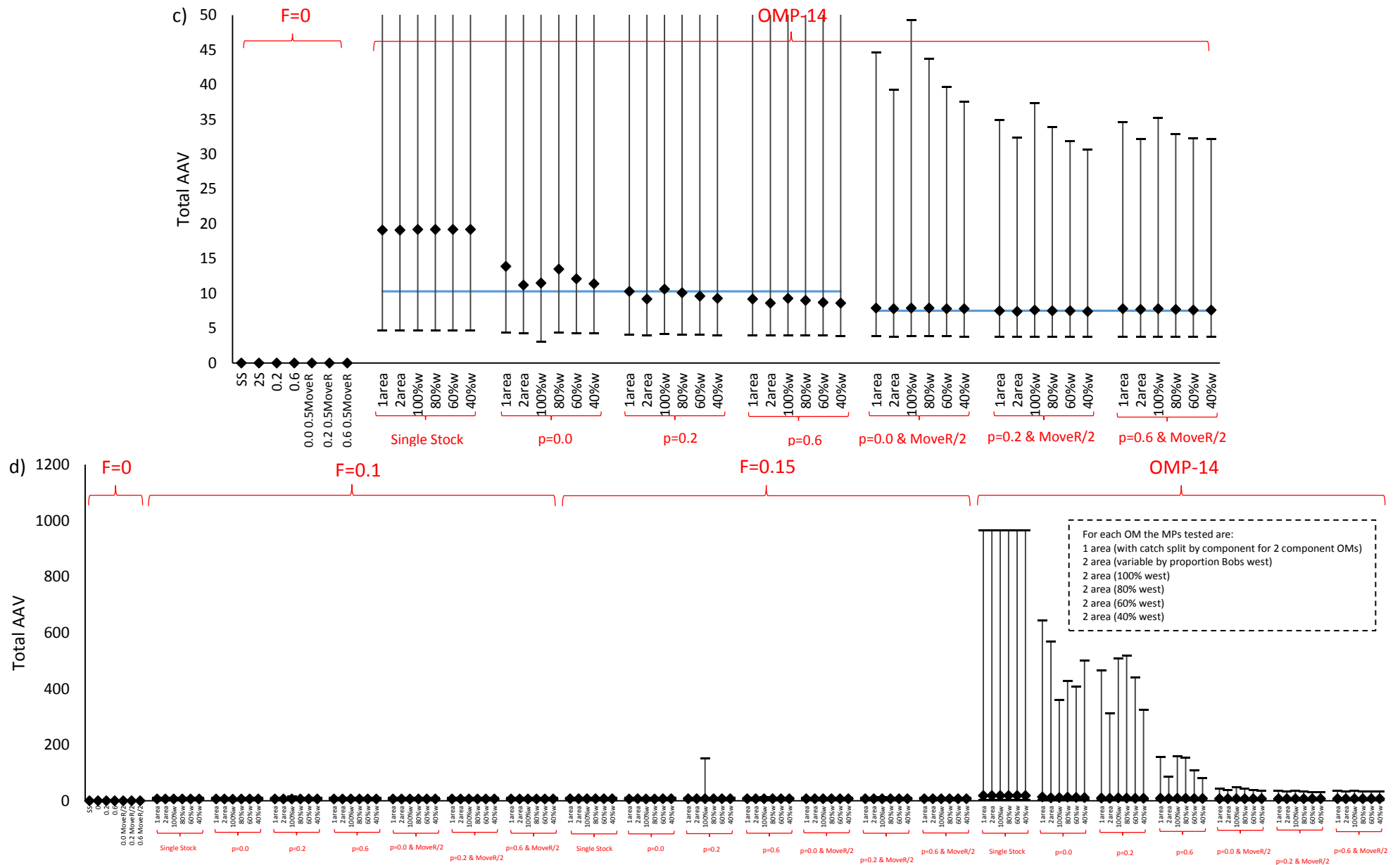
**Figure F6.** The probability of being below the west (total for single stock OM) 2007 total biomass at least once during the projection period under a)  $F=0.1$ , b)  $F=0.15$ , c) OMP-14 and d) all scenarios, with  $F=0$  included. Results are shown for a single area, two area variable and 4 two area fixed directed TAC management scenarios, under the 7 OMs considered in this appendix.



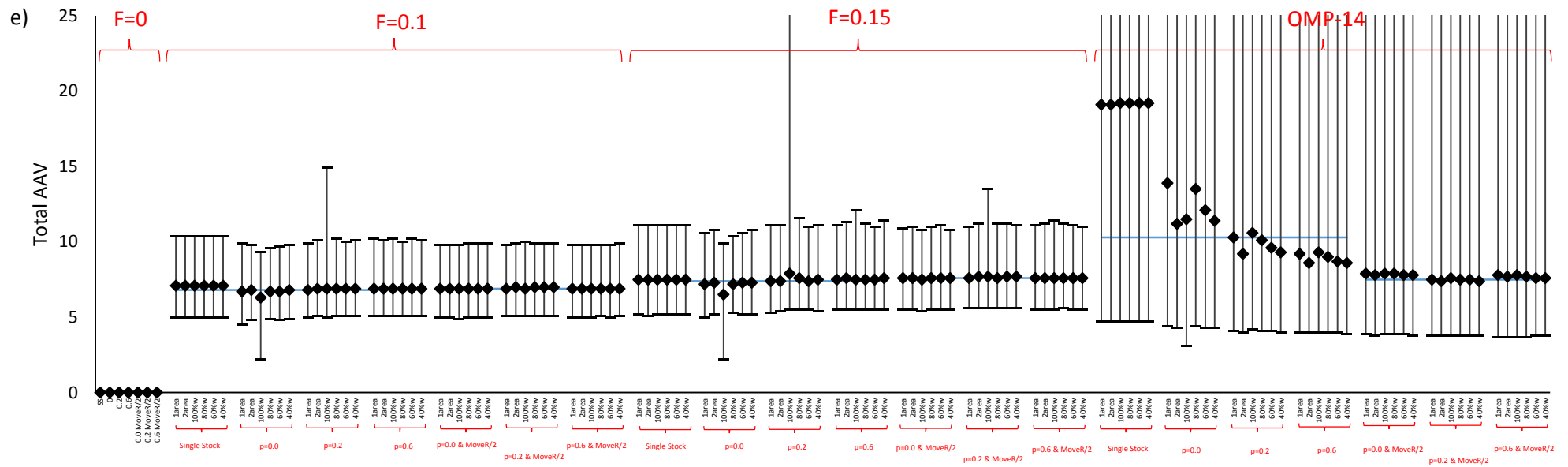
**Figure F6 (cont).** The probability of being below the west (total for single stock OM) 2007 total biomass at least once during the projection period under a)  $F=0.1$ , b)  $F=0.15$ , c) OMP-14 and d) all scenarios, with  $F=0$  included. Results are shown for a single area, two area variable and 4 two area fixed directed TAC management scenarios, under the 7 OMs considered in this appendix.



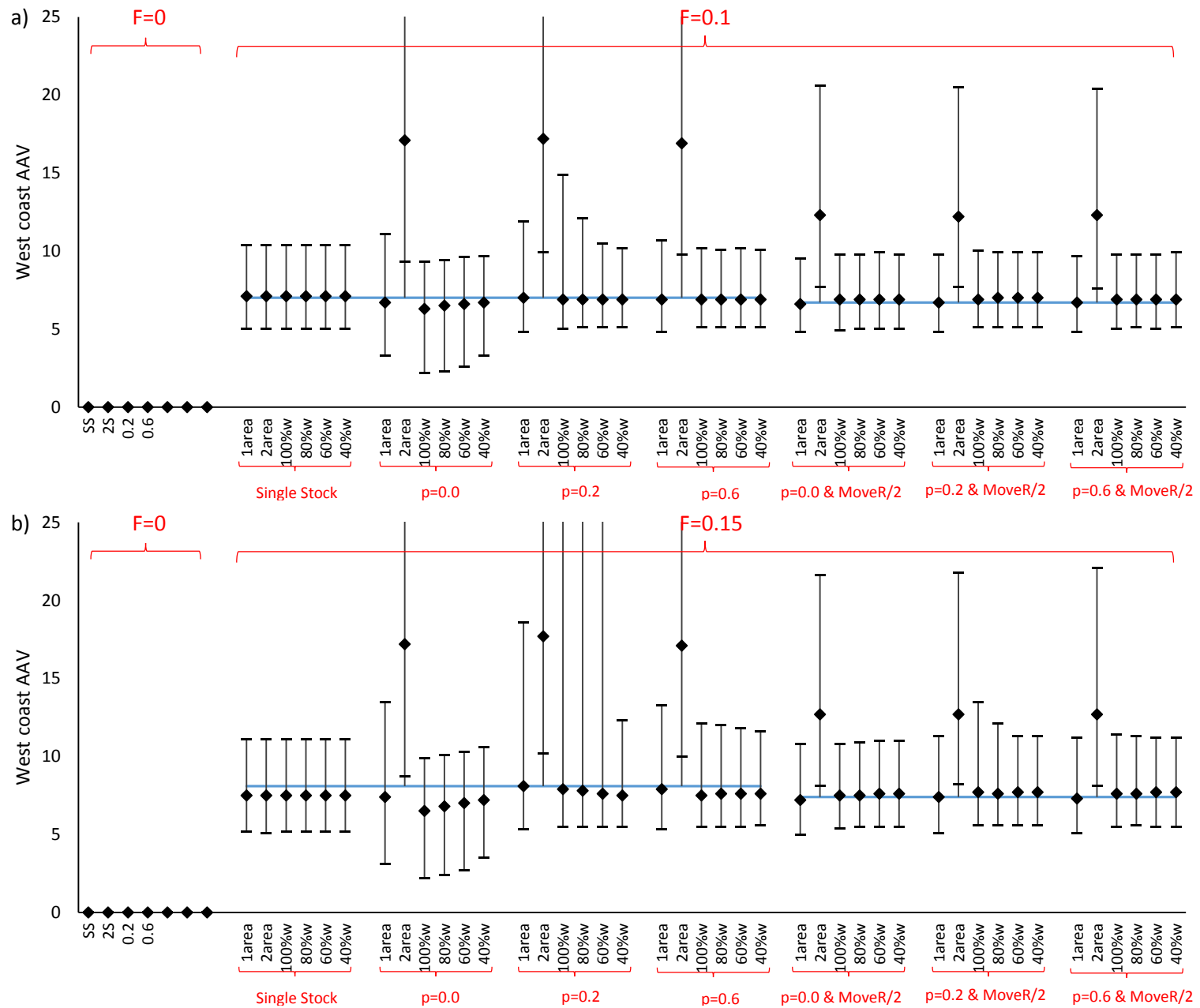
**Figure F7.** The average inter-annual variability in total directed sardine catch under a)  $F=0.1$ , b)  $F=0.15$ , c) OMP-14 and d) all scenarios, with  $F=0$  included. Results are shown for a single area, two area variable and 4 two area fixed directed TAC management scenarios, under the 7 OMs considered in this appendix. The horizontal line, shown for comparative purposes only, corresponds to the single area management scenario under the OM with  $p=0.2$ .



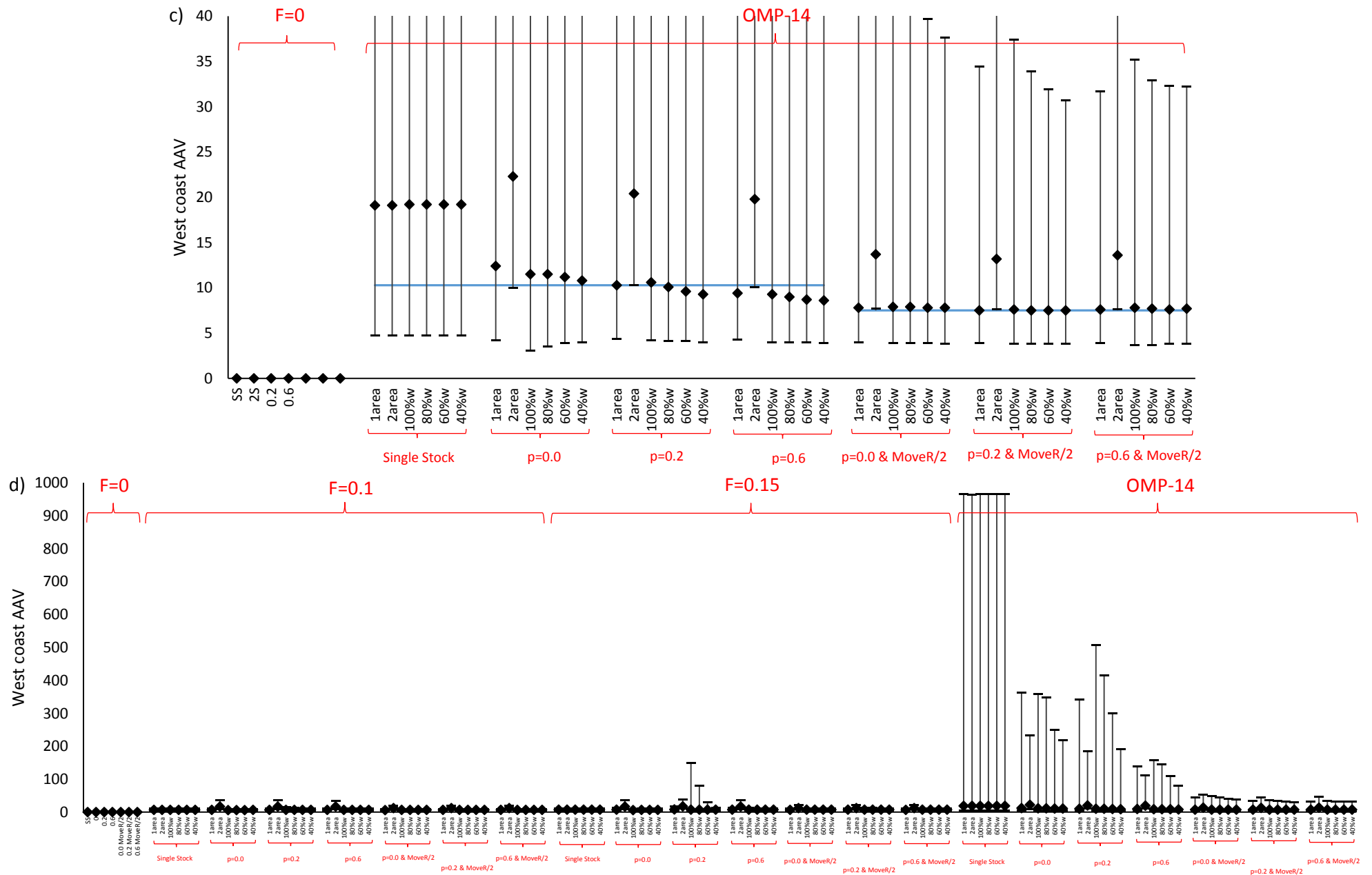
**Figure F7 (cont).** The average inter-annual variability in total directed sardine catch under a)  $F=0.1$ , b)  $F=0.15$ , c) OMP-14 and d-e) all scenarios, with  $F=0$  included. Results are shown for a single area, two area variable and 4 two area fixed directed TAC management scenarios, under the 7 OMs considered in this appendix. The horizontal line, shown for comparative purposes only, corresponds to the single area management scenario under the OM with  $p=0.2$ .



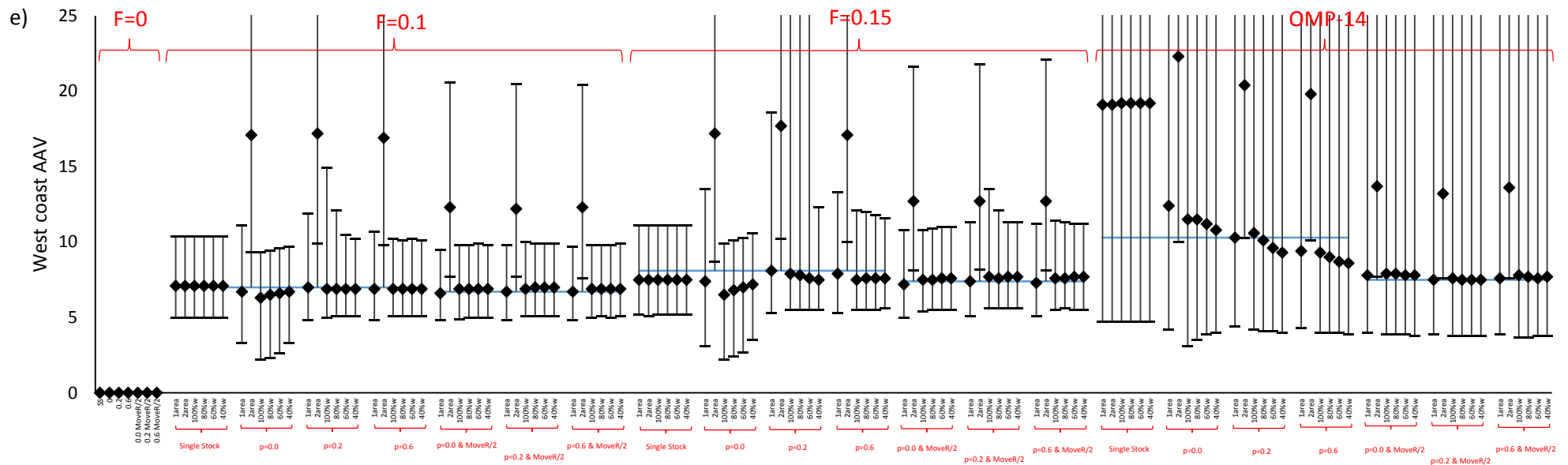
**Figure F7 (cont).** The average inter-annual variability in total directed sardine catch under a) F=0.1, b) F=0.15, c) OMP-14 and d-e) all scenarios, with F=0 included. Results are shown for a single area, two area variable and 4 two area fixed directed TAC management scenarios, under the 7 OM's considered in this appendix. The horizontal line, shown for comparative purposes only, corresponds to the single area management scenario under the OM with p=0.2.



**Figure F8.** The average inter-annual variability in west directed sardine catch under a)  $F=0.1$ , b)  $F=0.15$ , c) OMP-14 and d-e) all scenarios, with  $F=0$  included. Results are shown for a single area, two area variable and 4 two area fixed directed TAC management scenarios, under the 7 OMs considered in this appendix. The horizontal line, shown for comparative purposes only, corresponds to the single area management scenario under the OM with  $p=0.2$ .



**Figure F8 (cont).** The average inter-annual variability in west directed sardine catch under a)  $F=0.1$ , b)  $F=0.15$ , c) OMP-14 and d-e) all scenarios, with  $F=0$  included. Results are shown for a single area, two area variable and 4 two area fixed directed TAC management scenarios, under the 7 OMs considered in this appendix. The horizontal line, shown for comparative purposes only, corresponds to the single area management scenario under the OM with  $p=0.2$ .



**Figure F8 (cont).** The average inter-annual variability in west directed sardine catch under a)  $F=0.1$ , b)  $F=0.15$ , c) OMP-14 and d-e) all scenarios, with  $F=0$  included. Results are shown for a single area, two area variable and 4 two area fixed directed TAC management scenarios, under the 7 OMs considered in this appendix. The horizontal line, shown for comparative purposes only, corresponds to the single area management scenario under the OM with  $p=0.2$ .