Results for sardine projections under alternative future management scenarios

C.L. de Moor*

Correspondence email: *carryn.demoor@uct.ac.za*

This document gives performance statistics for a restricted set of alternative single area and two area management scenarios for directed sardine TACs. The document focuses on the sardine resource only and is written to provide background information to the key question to the panel "Is spatial management of the sardine TAC necessary?"

Background

Dunn et al. (2016) recommended that candidate Management Procedures (MPs) which include explicit spatial management should be considered during the development of OMP-18. This document gives some performance statistics for a range of alternative candidate MPs under a range of alternative OMs which assume two sardine componets which mix (see de Moor 2017a). Projection are made using the framework described by de Moor (2017b).

Single area management assumes that future catches are split by component according to a relationship based on the ratio of west coast biomass(y-1) to TAC(y) (Figure 2 of de Moor and Coetzee 2017). Two area management assumes that the catches associated with the west coast TAC all originate from the west component and the catches associated with the south coast TAC all originate from the south component.

Performance Statistics

A number of risk statistics are presented, using four risk thresholds for the west component of sardine (see de Moor 2017c for further details):

i) $Risk^{S}_{2007}$: The 2007 total biomass

ii) $Risk^{S}_{70}$: 70 000t spawner biomass

iii) $Risk^{S}_{100}$: 100 000t spawner biomass

iv) $Risk^{S}_{hinge}$: The actual hinge point of the hockey stick stock recruitment relationship.

Risk is given as (de Moor and Butterworth 2017):

a) the probability of (spawner) biomass being below this threshold at least once over the projection period,

b) the probability of (spawner) biomass being below this threshold during the 20 year projection period, and

c) the probability of (spawner) biomass being below this threshold at the end of the projection period.

In addition, the following restricted set of performance statistics are shown:

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

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

C: Annual directed catch[1]

AAV: Inter-annual variation in the directed catch

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

[1] 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.

Results

- Table 1 lists performance statistics for the range of OMs currently considered under both a no directed sardine fishing scenario and OMP-14 assuming single area management.
- While providing a summarised weighted output may prove simpler for presentation purposes, Table 2 shows that some strong differences between hypotheses can be masked through weighting, particularly if weighting over alternative future movement hypotheses. For example, the probability of future west component biomass being below the 2007 level ranges from 0.10 to 0.21 under MoveR, but is 0.01 for all alternative p values under 0.5MoveR. Weighting across all p and movement hypotheses results in a probability of 0.10 (average) or 0.12 (median).
- Table 3 lists performance statistics assuming $p = 0.2$ and MoveR for a range of alternative single area and (simple) two area management scenarios.

de Moor (2017d) showed a more comprehensive set of results for single area and two area management options for most of the OMs considered in this document. Considering, in particular, the higher risks when assuming 100% of the directed sardine TAC is allocated to the west coast, it concluded that spatial management would be required for directed sardine (see Figure 1).

Alternative forms of spatial management to those shown in Table 3 are also currently being considered. The primary one is such that spatial management would be explicit (restricted proportions west and south given on permits) during 'concerning' periods while single area management with 'fish as in the past' assumptions would apply during other years. Two sets of 'red flags' are being considered to define when explicit spatial management is required in year *y*:

i) If the survey estimate of biomass west of Cape Agulhas during November *y*-1, or the average of the survey estimates of biomass west of Cape Agulhas during November *y*-1 and *y*-2, is less than a threshold. This has been proposed with the idea of conserving the west coast biomass as the primary producer of recruitment to the whole population and as a source of escapement for, in particular, endangered range-restricted west coast top predators.

ii) If the realised proportion of catch west of Cape Agulhas during *y*-1, or the average of the realised proportion of catch west of Cape Agulhas during *y*-1 and *y*-2, is above a threshold. This has been proposed with the idea of 'fish as in the past' (single area management) unless the proportion of catch taken on the west coast is seen to be too high, with conservative measures following to correct.

Discussion Points

Discussion and recommendations towards the following question is sought:

i) Is spatial management of the sardine TAC necessary?

ii) If we consider explicit spatial management to be necessary during 'concerning periods' only, how do we best determine the 'flags' for switching such spatial management on and off?

Discussion will also relate to the other workshop documents pertaining to

- consideration of the modelling of catch by component in the single area management scenario (key question #5)
- choice of OMs and relative weighting thereof
- choice of risk thresholds (key question #2)
- choice of risk levels (key question #3)

References

de Moor CL. 2017a. A summary of the operating models being used to simulation test OMP-18 for South African sardine and anchovy. MARAM International Stock Assessment Workshop, 27 November – 1 December 2017, Document **MARAM/IWS/2017/Sardine/P6**.

de Moor CL. 2017b. Updated simulation testing framework to be used during the development of OMP-18. MARAM International Stock Assessment Workshop, 27 November – 1 December 2017, Document **MARAM/IWS/2017/Sardine/BG7.**

de Moor CL. 2017c. Alternative risk thresholds for South African sardine and anchovy resources. MARAM International Stock Assessment Workshop, 27 November – 1 December 2017, Cape Town. Document **MARAM/IWS/2017/Sardine/P2**.

de Moor CL. 2017d. Comparisons between single area management and various forms of two area management for directed sardine TACs off South Africa. DAFF: Branch Fisheries Document FISHERIES/2017/OCT/SWG-PEL/24.

de Moor CL and Butterworth DS. 2017. Selection of acceptable levels of risk for South African small pelagics: the probability of dropping below pre-defined risk thresholds. MARAM International Stock Assessment Workshop, 27 November – 1 December 2017, Document **MARAM/IWS/2017/Sardine/P3.**

de Moor CL and Coetzee JC. 2017. Simulating single area management on two sardine components. MARAM International Stock Assessment Workshop, 27 November – 1 December 2017, Document **MARAM/IWS/2017/Sardine/P4**.

Dunn A, Haddon M, Parma AM, Punt AE. 2016. International Review Panel Report for the 2016 International Fisheries Stock Assessment Workshop. MARAM International Stock Assessment Workshop, 28 November – 2 December 2016, Cape Town. Report number MARAM/IWS/DEC16/General/7.

Table 1a. Risk statistics for the four thresholds defined in the main text and the three alternative probabilities calculated for these thresholds (probability of being below the threshold at least once during the projection period, probability of being below the threshold over the projection period, and probability of being below the threshold at the end of the projection period). Results are shown for a zero directed sardine scenario (bycatch is modelled with anchovy directed catches) compared to OMP-14 with single area management.

	Sardine OM	At least once				All Years				End Year			
		$p(B_{west,y}<Risk^S_{2007})$	$p(B^{sp}_{west,y}<Risk^S_{70})$	$p(B^{sp}_{west,y}<Risk^S_{100})$	$p(B^{sp}_{west,y}<Risk^S_{hinge})$	$p(B_{west,y}<Risk^S_{2007})$	$p(B^{sp}_{west,y}<Risk^S_{70})$	$p(B^{sp}_{west,y}<Risk^S_{100})$	$p(B^{sp}_{west,y}<Risk^S_{hinge})$	$p(B_{west,y}<Risk^S_{2007})$	$p(B^{sp}_{west,y}<Risk^S_{70})$	$p(B^{sp}_{west,y}<Risk^S_{100})$	$p(B^{sp}_{west,y}<Risk^S_{hinge})$
F=0	p=0 MoveR	0.41	0.75	0.91	0.51	0.12	0.18	0.28	0.15	0.12	0.16	0.28	0.14
	p=0.08 MoveR	0.39	0.72	0.91	0.67	0.10	0.16	0.27	0.22	0.1	0.15	0.27	0.19
	p=0.2 MoveR	0.32	0.69	0.89	0.68	0.07	0.14	0.23	0.23	0.07	0.14	0.23	0.22
	p=0.6 MoveR	0.30	0.69	0.90	0.77	0.06	0.12	0.22	0.31	0.06	0.12	0.22	0.31
	p=0 0.5(MoveR)	0.04	0.01	0.06	0.05	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00
	p=0.08 0.5(MoveR)	0.03	0.01	0.05	0.10	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
	p=0.2 0.5(MoveR)	0.03	0.00	0.04	0.14	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.01
	p=0.6 0.5(MoveR)	0.03	0.00	0.03	0.29	0.00	0.00	0.00	0.06	0.01	0.00	0.00	0.05
OMP-14	p=0 MoveR	0.54	0.89	0.97	0.64	0.21	0.32	0.44	0.25	0.25	0.36	0.48	0.28
	p=0.08 MoveR	0.52	0.89	0.97	0.77	0.18	0.30	0.42	0.33	0.20	0.33	0.46	0.34
	p=0.2 MoveR	0.44	0.86	0.96	0.76	0.13	0.25	0.37	0.33	0.16	0.26	0.38	0.34
	p=0.6 MoveR	0.38	0.86	0.97	0.83	0.10	0.21	0.34	0.41	0.11	0.22	0.36	0.42
	p=0 0.5(MoveR)	0.08	0.06	0.19	0.08	0.01	0.00	0.02	0.01	0.01	0.00	0.01	0.00
	p=0.08 0.5(MoveR)	0.07	0.04	0.17	0.17	0.01	0.00	0.02	0.03	0.01	0.00	0.01	0.02
	p=0.2 0.5(MoveR)	0.06	0.04	0.13	0.23	0.01	0.01	0.02	0.05	0.01	0.00	0.01	0.04
	p=0.6 0.5(MoveR)	0.07	0.04	0.15	0.39	0.01	0.01	0.02	0.11	0.01	0.01	0.02	0.09

Table 1b. Median and 90% probability intervals for sardine spawner biomass at the end of the 20 year projection period, the lowest sardine spawner biomass over the 20 year projection period, annual directed sardine catch, and, inter-annual variation in the directed sardine catch. All performance statistics are shown for the total population/coastline and separately for the west and south component/coast. Results are shown for a zero directed sardine scenario (bycatch is modelled with anchovy directed catches) compared to OMP-14 with single area management.

	Sardine OM	B^{sp}_{2036}			Minimum B^{sp}			Directed Sardine Catch			AAV		
		Total	West	South	Total	West	South	Total	West	South	Total	West	South
F=0	p=0 MoveR	452[185,863]	169[23,490]	270[104,517]	300[108,440]	45[6,118]	143[63,237]	0[0,28]	0[0,24]	0[0,4]	1.0[1.0,1.0]	1.0[1.0,1.0]	1.0[1.0,1.0]
	p=0.08 MoveR	467[207,876]	173[31,512]	279[119,526]	309[138,448]	48[8,118]	146[72,241]	0[0,28]	0[0,24]	0[0,4]	1.0[1.0,1.0]	1.0[1.0,1.0]	1.0[1.0,1.0]
	p=0.2 MoveR	505[245,917]	189[38,534]	293[124,552]	327[185,464]	52[11,121]	156[81,255]	0[0,28]	0[0,24]	0[0,4]	1.0[1.0,1.0]	1.0[1.0,1.0]	1.0[1.0,1.0]
	p=0.6 MoveR	496[279,887]	188[44,503]	292[145,544]	327[212,459]	52[13,119]	158[89,258]	0[0,28]	0[0,24]	0[0,4]	1.0[1.0,1.0]	1.0[1.0,1.0]	1.0[1.0,1.0]
	p=0 0.5(MoveR)	571[327,1042]	368[180,756]	192[96,364]	371[243,535]	167[91,272]	109[64,182]	0[0,28]	0[0,24]	0[0,4]	1.0[1.0,1.0]	1.0[1.0,1.0]	1.0[1.0,1.0]
	p=0.08 0.5(MoveR)	583[339,1094]	380[186,784]	197[98,377]	378[251,539]	171[99,280]	111[64,184]	0[0,28]	0[0,24]	0[0,4]	1.0[1.0,1.0]	1.0[1.0,1.0]	1.0[1.0,1.0]
	p=0.2 0.5(MoveR)	609[345,1101]	399[189,798]	203[103,394]	389[263,547]	177[105,288]	114[66,186]	0[0,28]	0[0,24]	0[0,4]	1.0[1.0,1.0]	1.0[1.0,1.0]	1.0[1.0,1.0]
	p=0.6 0.5(MoveR)	579[339,1045]	381[187,768]	199[101,374]	383[254,540]	174[106,282]	112[65,182]	0[0,28]	0[0,24]	0[0,4]	1.0[1.0,1.0]	1.0[1.0,1.0]	1.0[1.0,1.0]
OMP-14	p=0 MoveR	335[40,699]	104[0,375]	206[37,436]	214[30,354]	29[0,91]	109[29,197]	89[0,181]	77[0,160]	4[0,50]	13.9[5.3,678.2]	13.0[5.6,328.1]	76.7[27.7,516.2]
	p=0.08 MoveR	344[73,713]	109[6,398]	214[58,441]	226[54,360]	30[2,91]	113[41,199]	90[0,186]	78[0,161]	4[0,50]	13.2[5.3,531.3]	13.3[5.9,360.8]	74.8[28.8,502.5]
	p=0.2 MoveR	387[103,741]	127[14,408]	230[76,460]	246[85,387]	35[4,94]	123[53,219]	90[3,197]	81[3,171]	4[0,50]	11.2[5.1,480.0]	11.4[5.7,334.5]	66.7[26.8,445.4]
	p=0.6 MoveR	392[192,733]	138[27,410]	238[106,469]	253[143,385]	37[7,90]	130[70,221]	90[11,199]	82[10,170]	4[0,49]	10.3[5.1,115.1]	10.8[5.5,100.9]	62.2[26.2,301.1]
	p=0 0.5(MoveR)	457[250,887]	290[132,635]	166[81,317]	291[180,451]	139[69,235]	93[55,157]	90[22,204]	86[21,191]	3[0,30]	9.0[5.0,38.4]	9.2[5.4,36.7]	48.9[22.6,154.3]
	p=0.08 0.5(MoveR)	472[253,905]	297[133,645]	168[82,334]	295[180,459]	143[73,237]	95[55,162]	90[23,205]	86[22,195]	4[0,30]	8.9[4.9,37.1]	9.2[5.3,36.1]	48.1[22.9,155.2]
	p=0.2 0.5(MoveR)	488[256,929]	311[130,660]	172[84,340]	308[186,465]	149[76,245]	98[55,163]	90[25,209]	87[24,198]	4[0,30]	8.7[4.9,34.2]	9.0[5.3,33.1]	46.7[22.6,153.9]
	p=0.6 0.5(MoveR)	465[251,870]	293[126,630]	168[84,322]	297[183,452]	145[73,239]	97[55,158]	90[23,204]	87[22,191]	4[0,30]	8.9[4.9,36.3]	9.2[5.3,34.3]	47.8[22.6,153.4]

Table 2a. Two summary performance statistics from Table 1, under a no directed sardine scenario, with average and median weightings applied i) over the alternative *p* hypotheses and ii) applied over alternative *p* and west to south movement hypotheses.

		$p(B_{west,y} < Risk^{S}_{2007})$	$p(B^{sp}_{west,y} < Risk^{S}_{hinge})$	Weighting			
				Average		Median	
				(i)	(ii)	(i)	(ii)
MoveR	$p = 0.0$	**0.12**	**0.15**	0.064	0.044	0.053	0.040
	$p = 0.08$	**0.10**	**0.22**	0.376	0.256	0.526	0.395
	$p = 0.2$	**0.07**	**0.23**	0.310	0.211	0.316	0.237
	$p = 0.6$	**0.06**	**0.31**	0.250	0.17	0.105	0.079
0.5MoveR	$p = 0.0$	**0.01**	**0.01**	0.064	0.02	0.053	0.013
	$p = 0.08$	**0.00**	**0.01**	0.376	0.12	0.526	0.131
	$p = 0.2$	**0.00**	**0.03**	0.310	0.099	0.316	0.079
	$p = 0.6$	**0.00**	**0.06**	0.250	0.08	0.105	0.026
Avg MoveR		0.08	0.24				
Avg 0.5MoveR		0.00	0.03				
Avg		0.06	0.17				
Med MoveR		0.09	0.23				
Med 0.5MoveR		0.00	0.02				
Med		0.07	0.18				

Table 2b. Four summary performance statistics from Table 1, under OMP-14 with single-area management, with average and median weightings applied i) over the alternative *p* hypotheses and ii) applied over alternative *p* and west to south movement hypotheses.

		$p(B_{west,y} < Risk^{S}_{2007})$	$p(B^{sp}_{west,y} < Risk^{S}_{hinge})$	Median C_{west}	Median AAV_{tot}	Weighting			
						Average		Median	
						(i)	(ii)	(i)	(ii)
MoveR	$p = 0.0$	0.21	0.25	77	13.9	0.064	0.044	0.053	0.040
	$p = 0.08$	0.18	0.33	78	13.2	0.376	0.256	0.526	0.395
	$p = 0.2$	0.13	0.33	81	11.2	0.310	0.211	0.316	0.237
	$p = 0.6$	0.10	0.41	82	10.3	0.250	0.17	0.105	0.079
0.5MoveR	$p = 0.0$	0.01	0.01	86	9.0	0.064	0.02	0.053	0.013
	$p = 0.08$	0.01	0.03	86	8.9	0.376	0.12	0.526	0.131
	$p = 0.2$	0.01	0.05	87	8.7	0.310	0.099	0.316	0.079
	$p = 0.6$	0.01	0.11	87	8.9	0.250	0.08	0.105	0.026
Avg MoveR		0.15	0.34	80	11.9				
Avg 0.5MoveR		0.01	0.05	87	8.8				
Avg		0.10	0.25	82	10.9				
Med MoveR		0.16	0.33	79	12.3				
Med 0.5MoveR		0.01	0.04	86	8.8				
Med		0.12	0.26	81	11.4				

Table 3a. Risk statistics for the four thresholds defined in the main text and the three alternative probabilities calculated for these thresholds (probability of being below the threshold at least once during the projection period, probability of being below the threshold over the projection period, and probability of being below the threshold at the end of the projection period). Results are shown for alternative management scenarios assuming the OM with $p = 0.2$ and MoveR: i) no directed sardine catch, OMP-14 with ii) single area management, iii) 100% of TAC for west coast, iv) 70% of TAC for west coast and 30% for south coast, v) 40% of TAC for west coast and 60% for south coast, vi) variable TAC proportions according to the "Gentleman's Agreement"[2].

	Management Option	At least once				All Years				End Year			
		$p(B_{west,y}<Risk^S_{2007})$	$p(B^{sp}_{west,y}<Risk^S_{70})$	$p(B^{sp}_{west,y}<Risk^S_{100})$	$p(B^{sp}_{west,y}<Risk^S_{hinge})$	$p(B_{west,y}<Risk^S_{2007})$	$p(B^{sp}_{west,y}<Risk^S_{70})$	$p(B^{sp}_{west,y}<Risk^S_{100})$	$p(B^{sp}_{west,y}<Risk^S_{hinge})$	$p(B_{west,y}<Risk^S_{2007})$	$p(B^{sp}_{west,y}<Risk^S_{70})$	$p(B^{sp}_{west,y}<Risk^S_{100})$	$p(B^{sp}_{west,y}<Risk^S_{hinge})$
P=0.2 MoveR	F=0	0.32	0.69	0.89	0.68	0.07	0.14	0.23	0.23	0.07	0.14	0.23	0.22
	Single Area	0.44	0.86	0.96	0.76	0.13	0.25	0.37	0.33	0.16	0.26	0.38	0.34
	100:0	0.46	0.87	0.96	0.77	0.14	0.26	0.38	0.34	0.17	0.28	0.41	0.35
	70:30	0.44	0.85	0.96	0.76	0.13	0.24	0.36	0.33	0.15	0.26	0.37	0.33
	40:60	0.42	0.84	0.96	0.74	0.12	0.22	0.34	0.31	0.14	0.23	0.35	0.31
	Variable	0.41	0.84	0.96	0.75	0.11	0.21	0.34	0.31	0.13	0.23	0.35	0.31

Table 1b. Median and 90% probability intervals for sardine spawner biomass at the end of the 20 year projection period, the lowest sardine spawner biomass over the 20 year projection period, annual directed sardine catch, and, inter-annual variation in the directed sardine catch. All performance statistics are shown for the total population/coastline and separately for the west and south component/coast. Results are shown for alternative management scenarios assuming the OM with $p = 0.2$ and MoveR: i) no directed sardine catch, OMP-14 with ii) single area management, iii) 100% of TAC for west coast, iv) 70% of TAC for west coast and 30% for south coast, v) 40% of TAC for west coast and 60% for south coast, vi) variable TAC proportions according to the "Gentleman's Agreement".

	Management Option	B^{sp}_{2036}			Minimum B^{sp}			Directed Sardine Catch			AAV		
		Total	West	South	Total	West	South	Total	West	South	Total	West	South
P=0.2 MoveR	F=0	505[245,917]	189[38,534]	293[124,552]	327[185,464]	52[11,121]	156[81,255]	0[0,28]	0[0,24]	0[0,4]	1.0[1.0,1.0]	1.0[1.0,1.0]	1.0[1.0,1.0]
	Single Area	387[103,741]	127[14,408]	230[76,460]	246[85,387]	35[4,94]	123[53,219]	90[3,197]	81[3,171]	4[0,50]	11.2[5.1,480.0]	11.4[5.7,334.5]	66.7[26.8,445.4]
	100:0	381[95,741]	123[10,400]	228[74,457]	244[74,384]	32[3,92]	123[51,219]	90[2,196]	84[2,174]	2[0,38]	11.5[5.1,442.1]	11.3[5.6,409.2]	271.4[59.5,921.4]
	70:30	391[102,741]	131[14,411]	231[77,459]	248[83,388]	36[4,93]	122[53,218]	90[3,197]	77[2,170]	7[0,46]	11.0[5.0,498.9]	13.1[6.3,369.5]	53.8[25.8,214.3]
	40:60	395[121,748]	140[19,416]	234[80,463]	252[93,389]	39[6,95]	121[54,215]	90[5,199]	76[2,170]	8[0,70]	10.7[5.1,339.2]	18.8[9.0,276.1]	76.0[34.9,307.6]
	Variable	395[134,748]	143[22,419]	235[85,465]	252[98,388]	39[7,95]	122[54,215]	90[5,199]	76[2,171]	8[0,84]	10.6[5.1,300.9]	20.6[9.7,224.0]	75.9[33.9,308.2]

[2] The proportion west is set equal to the average proportion of survey biomass observed west of Cape Agulhas during the most recent preceding two years.

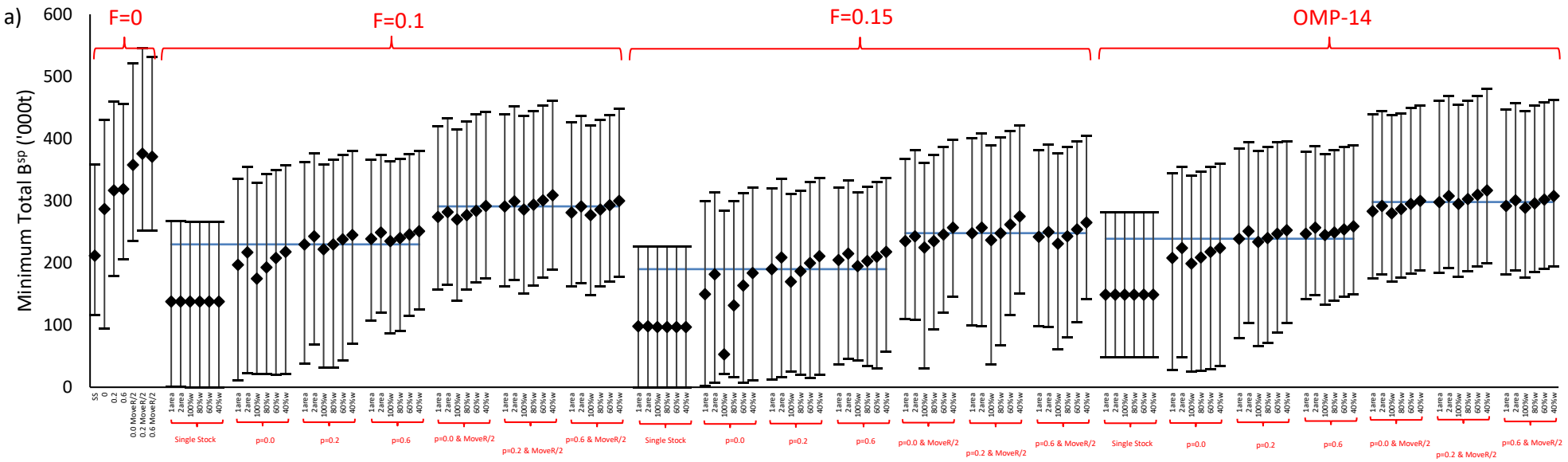

Figure 1. (Figure 8 of de Moor (2017d)) The a) minimum total sardine spawner biomass over the projection period, b) minimum west sardine spawner biomass over the projection period, and c) risk under sardine MPs of F=0, F=0.1, F=0.15 or OMP-14, for single area, two area variable and 4 two area fixed directed TAC MPs, under 7 OMs. The horizontal line, shown for comparative purposes only, corresponds to the single area management scenario under the OM with p=0.2.

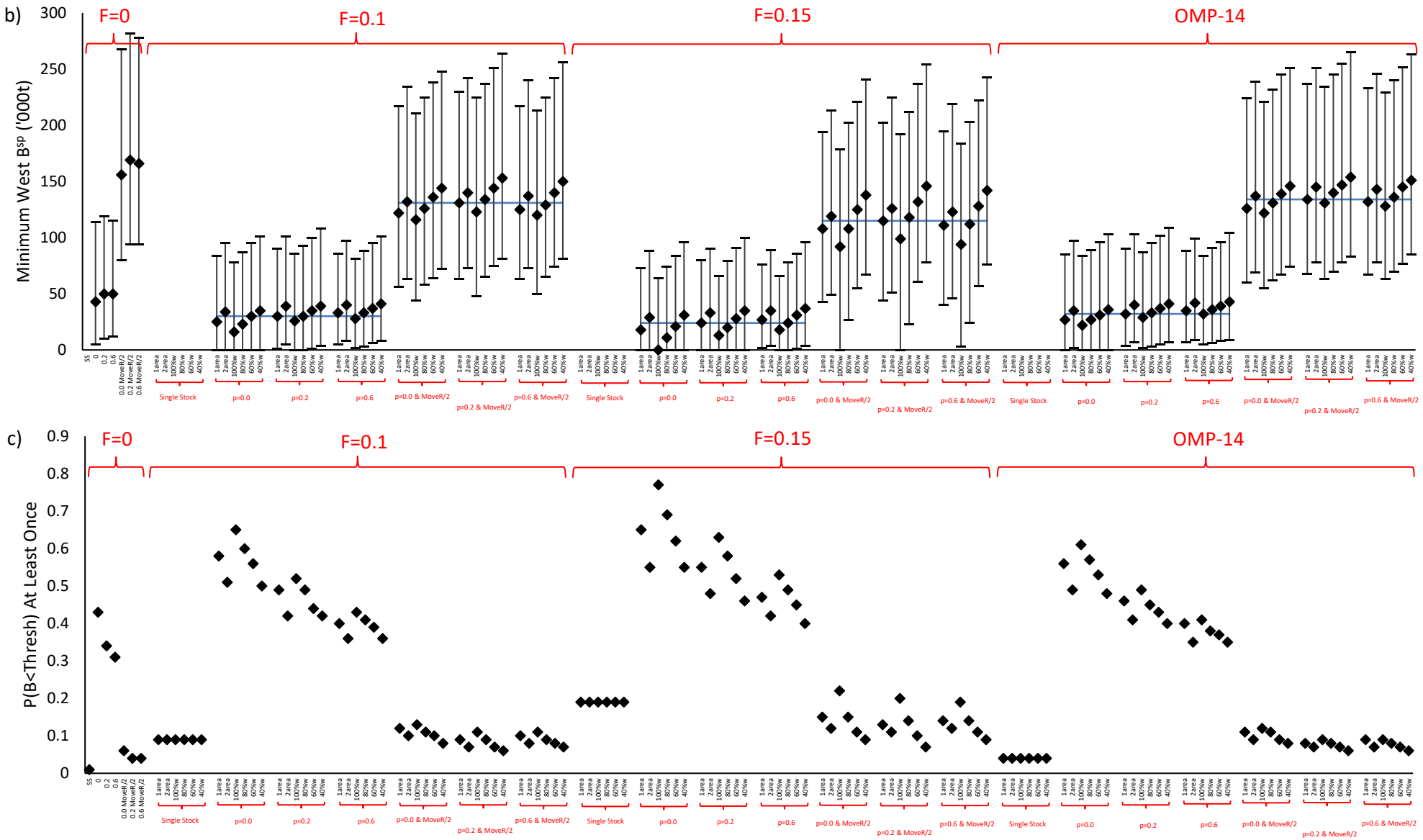

Figure 1 (continued).