

Simple variants of the SA hake Reference Case Operating Model (assessment) to take account of Namibian catches of *M. paradoxus*

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Summary

Variants of the SA hake Reference Case Operating Model (RC OM) which take account of Namibian catches in a manner that corresponds to the extreme scenario of demographic panmixia of *M. paradoxus* between the SA and Namibian regions are evaluated. These are based on the Namibian data currently available, and make a range of assumptions about, for example, the species split of the historical Namibian hake catches. A key result is that allowing for the possibility that there is sharing of the *M. paradoxus* resource between South Africa and Namibia results in an estimated status (current to pristine spawning biomass ratio) for that species which is (often considerably) **better** than indicated by the assessment of SA hake in isolation (in the RC OM). This result appears reasonably robust, given the panmictic assumption. For less complete mixing, similar results would be expected, though the quantitative improvement for the SA *M. paradoxus* “component” compared to the RC OM result would be less. These results indicate that the assumptions underlying the analyses of Butterworth and Rademeyer (2020) are conservative, and serve to strengthen their conclusion that the SA hake OMP2018 is sufficiently robust to secure avoidance of the adverse consequences (in resource conservation terms) which could result given a *M. paradoxus* stock which may be demographically shared (to some extent) with Namibia.

Background

The CAB for the SA hake MSC certification re-evaluation has requested an analysis of the impact on assessment outputs conducted by South Africa for the *M. paradoxus* resource under the assumption that this is shared with Namibia. While genetics data currently suggest a panmictic *M. paradoxus* stock for South Africa and Namibia as the most likely situation, the extent to which the resource is demographically shared between the two countries is unclear. The analysis that follows makes the assumption that there is demographic panmixia; this is extreme and likely unrealistic, but has been assumed with the intention of providing a bound to the range of possible results

Some information on the Namibian historical hake catches is available: catches up to 2012 were previously provided to R. Rademeyer by J. Kathena; the only further information that could be obtained was catches from 2013-2017 extracted from the FAO website. These catches have been incorporated into the South African Reference Case assessment model by assuming that the *M. paradoxus* component corresponds to 75% of the total Namibian catch, and this catch is then added to the *M. paradoxus* catch that is input into the South African assessment model (more specifically the Reference Case Operating Model (OM), see Ross-Gillespie and Butterworth 2019). These catches are listed in Table 1. Note that for this analysis the 2018 catch has been assumed to be the same as the 2017 catch, as no response to request to the Namibian client for this information has as yet been received. The assumption that 75% of the Namibian hake catch consists of *M. paradoxus* follows from catch information provided, for example, in Namboga *et al.* (2017).

Four runs have been considered in this document, namely the 2019 South African Reference Case (RC) and three variants.

- 1) The 2019 South African Reference Case Assessment model.
- 2) The run where the assumed Namibian *M. paradoxus* catches are included in (1).

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- 3) A variant of (2) where a penalty is added to ensure that $B_{MSY}/K^{sp} > 0.2$.
- 4) A variant on (2) where the *M. paradoxus* carrying capacity is reduced by 50% between 1970 and 1980, and remains at 50% thereafter.

The motivation for 4) is that the major collapse of the Namibian sardine resource that commenced at the end of the 1960s, and has shown little sign of recovery since the end of the 1970s, constituted a regime shift with a major source of food for hake removed from the Namibian ecosystem (Kircher *et al.* 2012). Note that the Namibian catches have been assumed to be governed by the same selectivity-at-length vector as estimated for the SA west coast offshore trawl fishery.

Results

Table 2 lists key assessment outputs, as well as parameter estimates for these four runs considered in this document, while Table 3 lists the negative log-likelihood components.

Figure 1 provides a graphical representation of the *M. paradoxus* catches, both for the South African catches and the combined South African and Namibian catches assumed for the variants of the 2019 SA RC OM/assessment. Figure 2 shows plots of the spawning biomass trajectories, while Figure 3 plots various recruitment outputs. Figure 4 and Figure 5 show the fits to the commercial and survey abundance indices, respectively.

When the model is run with these Namibian catches of *M. paradoxus* included, the estimate for B_{MSY}/K^{sp} is very low (around 0.11). As a result, two further variants were run: one where a penalty is added to ensure that $B_{MSY}/K^{sp} > 0.2$, and a second where the *M. paradoxus* carrying capacity is decreased linearly between 1970 and 1980 to 50% of the original value to account for the collapse of the sardine population over that period.

Discussion

Table 3 and Figures 4 and 5 indicate little change in the quality of the fits to the data for the model variants which include a Namibian *M. paradoxus* catch component. There is little deterioration in negative log likelihood if MSYL is forced to be at least 0.2, indicating that the data do not estimate that parameter very precisely.

A key result is that all three model variants indicate the *M. paradoxus* current spawning biomass to be over 50% of its pristine value, well above the 28% of the SA RC OM, when demographic panmixia of this species across South Africa and Namibia is assumed. Note that for the variant where *M. paradoxus* carrying capacity is assumed to have decreased, the current status is better still than indicated in the entry in Table 2 which refers to original rather than current carrying capacity.

Given the limited availability of data from Namibia, the sensitivity of these results to assumptions made needs to be carefully considered. If the 2018 Namibian hake catch assumed is increased from the 2017 value to the largest annual Namibian catch made this century, the ratio of the current to pristine spawning biomass would decrease by only 0.1% of the pristine abundance. Hence, such results are not greatly sensitive to recent catch levels. However, there is a change if the assumption about the historical species split of the Namibian hake catch is altered. When Namibia took direct control of the fishery, strict limitations to shallower water fishing were imposed to reduce the catch of smaller fish. This would have tended to reduce the amount of *M. capensis* that might otherwise have been taken. If then, prior to 1990, the assumption is made that *M. capensis* constituted 50% of the catch rather than the 25% subsequently, the current to pristine ratio of the spawning biomass drops to 37%; this does though still remain well above the 28% for the SA RC OM. This analysis has not taken account of any abundance index information from the Namibian region. However, under the assumption made of demographic panmixia, the associated trend information would simply reinforce that provided by the indices available for the SA region, so that while this absence of such index information from Namibia would result in some loss of precision, it would not have led to the introduction of bias in the estimates (at least to first order).

The *M. paradoxus* MSY estimates shown in Table 2 may seem surprisingly high for the model variants which take account of Namibian catches. But it is important to stress that the assumption of demographic panmixia made here is an extreme. In reality any mixing is likely to be less, which would reduce these estimates. But those lower

values would then apply only to the “SA component” of the shared stock, with the effective Namibian catch taken from that stock being less, and hence having a lesser impact.

In conclusion

The key message from this analysis is that allowing for the possibility that there is sharing of the *M. paradoxus* resource between South Africa and Namibia results in an estimated status (current to pristine spawning biomass ratio) for that species which is **better** than indicated in the assessment of SA hake in isolation (the SA RC OM). Though some relatively far reaching assumptions have been made for these analyses (and indeed would in the main, e.g. historical species splits of the catch, need to be made for **any** such analyses), this conclusion does appear reasonably robust.

Concerning then the analysis by Butterworth and Ross-Gillespie (2020) related to the robustness of SA hake OMP2018 to an increased Namibian catch of *M. paradoxus*, which assumed demographic panmixia but no corresponding improvement in stock status or productivity, these results show those assumptions to be conservative. Accordingly, they serve to strengthen the conclusion of that paper that that the SA hake OMP2018 is sufficiently robust to secure avoidance of the adverse consequences (in resource conservation terms) which could result given a *M. paradoxus* stock which may be demographically shared (to some extent) with Namibia.

References

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- Kirchner C., Kainge, P. and Kathena, J. 2012. Evaluation of the status of the Namibian hake resource (*Merluccius* spp.) using Statistical Catch-at-Age analysis. Environment for Development Initiative.
- Namboga A. et al. 2017. Hake size structure from commercial trawlers off the coast of Namibia 2015 -2016. NATMIRC DWG/HK/2017/doc05a.
- Ross-Gillespie, A., and Butterworth, D.S. 2019. Update to the hake Reference Case model incorporating the 2018 commercial and 2019 survey data. DEA Fisheries document: FISHERIES/2019/OCT/SWG-DEM/22rev.

Table 1: Namibian hake catches (species combined) in '000 tons as provided to R. Rademeyer by J. Kathena (up to 2012) and as extracted from the FAO website (2013-2017). In the interest of simplicity and alacrity, the 2018 catch has been assumed to be the same as the 2017 catch. For the various assessments described in this document, 75% of the catches listed in the table below have been added to the SA West Coast offshore trawl catches of *M. paradoxus* for the variants of the current SA hake Reference Case Operating Model considered (see text for rationale).

Year	Catch	Year	Catch
1964	47.852	1992	87.497
1965	193.200	1993	108.000
1966	334.627	1994	112.206
1967	394.445	1995	130.362
1968	630.392	1996	129.102
1969	526.657	1997	116.593
1970	627.198	1998	106.788
1971	595.215	1999	157.897
1972	820.110	2000	171.468
1973	667.965	2001	174.126
1974	514.558	2002	156.451
1975	488.208	2003	189.308
1976	601.045	2004	173.902
1977	431.483	2005	158.060
1978	379.390	2006	136.770
1979	310.175	2007	125.500
1980	171.848	2008	126.300
1981	211.534	2009	130.000
1982	307.078	2010	135.000
1983	339.590	2011	140.000
1984	364.993	2012	138.000
1985	386.184	2013	146.936
1986	381.189	2014	121.764
1987	300.249	2015	142.877
1988	336.000	2016	155.737
1989	309.329	2017	157.196
1990	132.379	2018	157.196
1991	56.135		

Table 2: The top section lists key assessment outputs for the four runs considered in this document (dark blue for the 2019 SA RC, light blue with dashed line for the variant that includes the Namibian catch, purple for the associated variant that restricts $\frac{B_{MSY}}{K^{SP}} > 0.2$ and dark green with dashed lines for the associated variant where the carrying capacity is decreased). The bottom section lists the actual parameter estimates. Note that for the fourth run (where K^{SP} is reduced by 50% between 1970 and 1980), the estimates reported for K^{SP} and B_{2017}^{SP}/K^{SP} correspond to the initial K , i.e. the values have not been adjusted to reflect the reduced K .

<i>M. paradoxus</i>					<i>M. capensis</i>					
	-lnL	-3254.19	-3252.50	-3251.70	-3258.98					
K^{SP} (f)	329	1853	1580	1510		K^{SP} (f)	342	341	335	346
K^{SP} (m)	352	1600	1379	1320		K^{SP} (m)	343	334	332	339
B_{MSY}	55	199	315	373		B_{MSY}	96	97	97	105
MSY	142	493	508	546		MSY	82	82	83	82
B_{2017}^{SP}	91	1017	1036	769		B_{2017}^{SP}	218	218	215	224
B_{2017}^{tot}	205	1964	2010	1502		B_{2017}^{tot}	475	468	466	481
B_{2017}^{SP}/K^{SP}	0.28	0.55	0.66	0.51		B_{2017}^{SP}/K^{SP}	0.64	0.64	0.64	0.65
B_{2017}^{SP}/B_{MSY}	1.64	5.10	3.28	2.06		B_{2017}^{SP}/B_{MSY}	2.26	2.25	2.21	2.13
B_{MSY}/K^{SP}	0.17	0.11	0.20	0.25		B_{MSY}/K^{SP}	0.28	0.28	0.29	0.30

<i>M. paradoxus</i>					<i>M. capensis</i>									
	(3.50,10.00)		5.80	7.52	7.37	7.32		5.83	5.83	5.81	5.85			
ln(K)	(0.50,2.00)		1.76	1.12	1.36	0.91		2.00	2.00	1.98	1.91			
h	(0.00,2.00)		0.46	0.17	0.46	1.87		0.80	0.81	0.84	0.89			
gamma	(-5.00,5.00)													
Zeta		1985	-0.38	-0.23	-0.34	-0.48		-0.20	-0.19	-0.18	-0.20			
		1986	-0.17	0.04	-0.03	-0.18		0.08	0.08	0.07	0.08			
		1987	0.30	0.36	0.29	0.13		0.43	0.44	0.45	0.43			
		1988	0.05	0.10	0.03	-0.15		0.47	0.47	0.46	0.47			
		1989	0.09	0.06	0.00	-0.21		0.49	0.48	0.49	0.49			
		1990	0.08	0.06	0.01	-0.22		0.35	0.34	0.34	0.34			
		1991	0.09	0.04	-0.01	-0.24		0.15	0.16	0.16	0.16			
		1992	-0.10	0.01	-0.02	-0.21		0.06	0.05	0.05	0.06			
		1993	0.23	0.22	0.20	0.10		0.27	0.27	0.27	0.27			
		1994	0.21	0.22	0.23	0.19		0.18	0.19	0.19	0.19			
		1995	0.32	0.05	0.07	0.11		-0.04	-0.05	-0.05	-0.05			
		1996	-0.22	-0.15	-0.13	-0.04		0.09	0.10	0.10	0.10			
		1997	-0.07	-0.24	-0.21	0.01		0.09	0.09	0.09	0.09			
		1998	-0.24	-0.29	-0.24	0.06		-0.12	-0.12	-0.13	-0.12			
		1999	-0.28	-0.38	-0.34	0.01		-0.14	-0.14	-0.13	-0.14			
		2000	0.02	-0.08	-0.04	0.30		0.07	0.06	0.07	0.06			
		2001	0.16	-0.02	0.04	0.28		-0.15	-0.15	-0.16	-0.16			
		2002	-0.38	-0.41	-0.39	-0.27		-0.32	-0.32	-0.32	-0.33			
		2003	-0.18	-0.28	-0.27	-0.23		-0.06	-0.06	-0.05	-0.06			
		2004	0.31	0.32	0.34	0.30		0.01	-0.01	-0.02	-0.01			
		2005	0.13	0.07	0.08	0.02		0.00	-0.00	-0.00	-0.01			
		2006	-0.04	0.00	0.00	-0.11		-0.15	-0.17	-0.17	-0.17			
		2007	-0.08	-0.23	-0.24	-0.33		-0.19	-0.19	-0.18	-0.19			
		2008	0.21	0.29	0.31	0.20		-0.24	-0.24	-0.23	-0.24			
		2009	-0.19	-0.12	-0.12	-0.15		-0.57	-0.57	-0.58	-0.57			
		2010	0.02	-0.07	-0.05	-0.05		-0.44	-0.45	-0.44	-0.44			
		2011	-0.13	-0.05	-0.03	-0.01		-0.40	-0.38	-0.39	-0.38			
		2012	0.10	-0.07	-0.05	0.02		-0.35	-0.36	-0.39	-0.36			
		2013	0.14	0.23	0.25	0.33		0.09	0.11	0.12	0.11			
		2014	0.33	0.32	0.35	0.44		-0.04	-0.05	-0.08	-0.05			
		2015	-0.06	0.18	0.22	0.26		0.22	0.21	0.22	0.21			
		2016	-0.15	-0.02	0.00	0.02		0.38	0.44	0.46	0.44			
		2017	-0.14	0.08	0.09	0.10		-0.02	-0.03	-0.03	-0.03			
sig_add	(0.00,0.50)		0.17	0.20	0.20	0.21		0.15	0.14	0.14	0.14			
sig_ICSEAF	(0.25,1.00)	0.25												
sig_ICSEAF	(0.25,1.00)	0.25												
sig_GLM	(0.15,1.00)		0.15	0.15	0.15	0.15		0.16	0.16	0.16	0.16			
sig_GLM	(0.15,1.00)		0.16	0.18	0.17	0.17		0.22	0.22	0.22	0.22			
qWCz1	(0.00,10.00)							0.11	0.12	0.11	0.11			
qWCz2	(0.00,10.00)							10.00	3.69	9.44	1.01			
qWCpar	(0.00,10.00)		0.03	0.00	0.01	0.01								
r	(0.00,10.00)		0.07	0.06	0.06	0.06								
gamma	(0.00,1.00)							0.00	0.01	0.00	0.05			
lnq WC sum	(-5.00,2.00)		Old gear		New gear			Old gear		New gear				
lnq WC win	(-5.00,2.00)		0.58	-1.08	-1.09	-0.89	0.46	-1.20	-1.21	-1.01	0.10	0.09	0.10	0.08
lnq SC spr	(-5.00,2.00)		0.13	-1.59	-1.60	-1.48	-0.16	-2.08	-2.09	-1.86	0.16	0.17	0.18	0.16
lnq SC aut	(-5.00,2.00)		-0.10	-2.06	-2.06	-1.88	-0.18	-2.15	-2.15	-1.97	-0.06	-0.06	-0.08	-0.07
			0.00	-1.92	-1.93	-1.71	0.00	-1.92	-1.93	-1.71	0.20	0.19	0.18	0.17
AL theta0	(0.10,100.00)		Males		Females			Males		Females				
theta1	(0.01,20.00)		2.38	2.38	2.38	2.38	0.10	0.10	0.10	0.10	2.64	2.01	2.01	2.06
theta14	(0.01,20.00)		4.33	4.65	4.68	4.65	4.34	4.72	4.72	4.70	4.54	4.57	4.59	4.57
L2	(5.00,50.00)		10.8	4.58	2.84	0.11	11.9	9.91	9.90	10.3	7.17	6.85	6.82	6.86
L4	(20.00,70.00)		24.0	25.7	25.8	25.7	20.2	23.3	23.3	22.9	26.8	27.2	27.3	27.2
X	(0.00,1.00)		43.3	41.9	42.1	42.2	40.5	42.2	42.3	42.1	44.9	45.0	45.0	45.0
			0.50	0.50	0.50	0.50					0.50	0.50	0.50	0.50

Table 3: Negative log-likelihood components are listed for the four runs considered. Table (a) shows the values in absolute terms, while Table (b) shows the values relative to the first run, the 2019 SA RC.

(a) Negative log-likelihood components for various runs.

Run	GLM CPUE	ICSEAF CPUE	Survey abun.	Comm. CAL	Survey CAL	Recruit. resid.	ALKs	Penalties	Total (w/o pen.)
(1) 2019 SA RC	-215.47	-36.87	-35.65	-1514.99	-1591.17	9.04	130.80	0.12	-3254.31
(2) With Namibian Catch	-214.16	-39.02	-33.37	-1511.60	-1593.75	9.27	130.09	0.03	-3252.53
(3) BMSY/Ksp>0.2	-214.50	-38.05	-32.90	-1511.89	-1594.41	9.37	130.61	0.06	-3251.76
(4) Decrease K	-217.53	-39.33	-32.22	-1516.03	-1593.47	9.73	129.77	0.09	-3259.07

(b) Negative log-likelihood components relative to the first row (grey highlight indicates a worse nll).

Run	GLM CPUE	ICSEAF CPUE	Survey abun.	Comm. CAL	Survey CAL	Recruit. resid.	ALKs	Penalties	Total (w/o pen.)
(1) 2019 SA RC	-215.47	-36.87	-35.65	-1514.99	-1591.17	9.04	130.80	0.12	-3254.31
(2) With Namibian Catch	1.31	-2.15	2.28	3.39	-2.58	0.23	-0.71	-0.09	1.78
(3) BMSY/Ksp>0.2	0.96	-1.18	2.76	3.10	-3.23	0.34	-0.19	-0.06	2.55
(4) Decrease K	-2.06	-2.46	3.44	-1.03	-2.30	0.69	-1.03	-0.03	-4.76

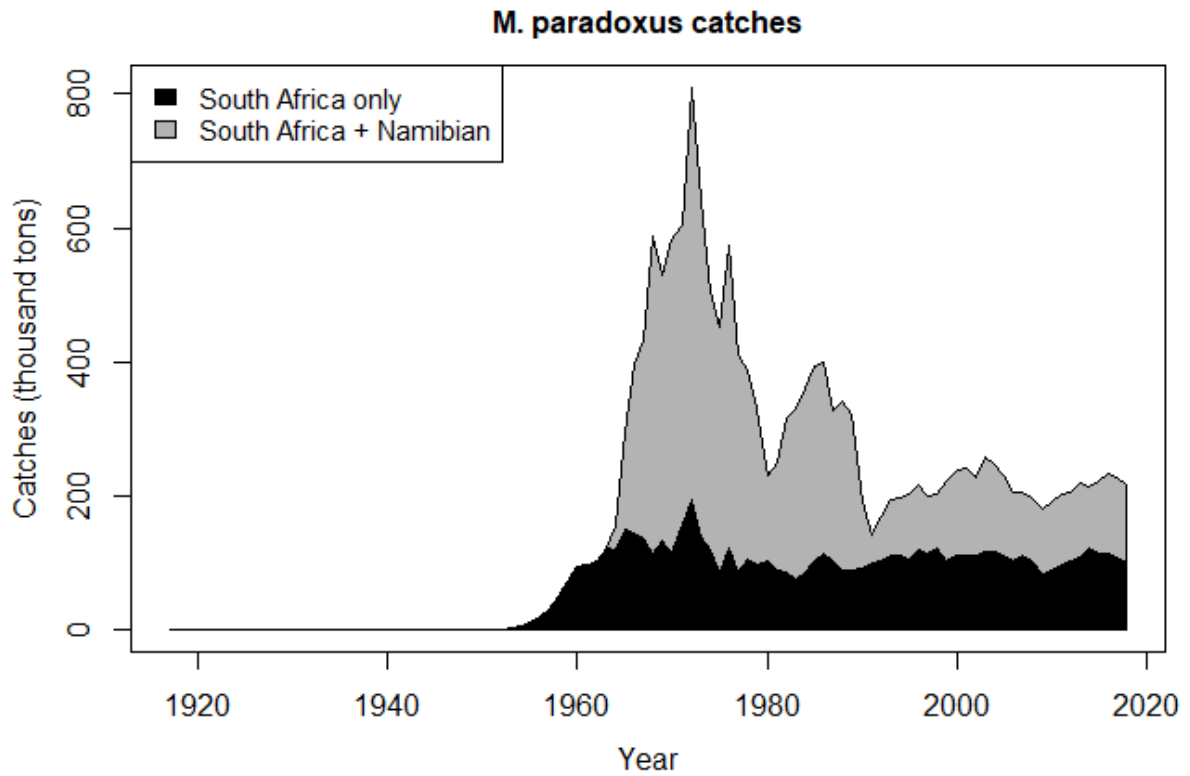


Figure 1: The total *M. paradoxus* catches are shown. The black shaded region shows the South African catches used in the standard SA Reference Case OM/stock assessment model. The grey shaded area shows the South African and Namibian catches combined, where the Namibian *M. paradoxus* catches are taken to be 75% of the total catches reported in Table 1.

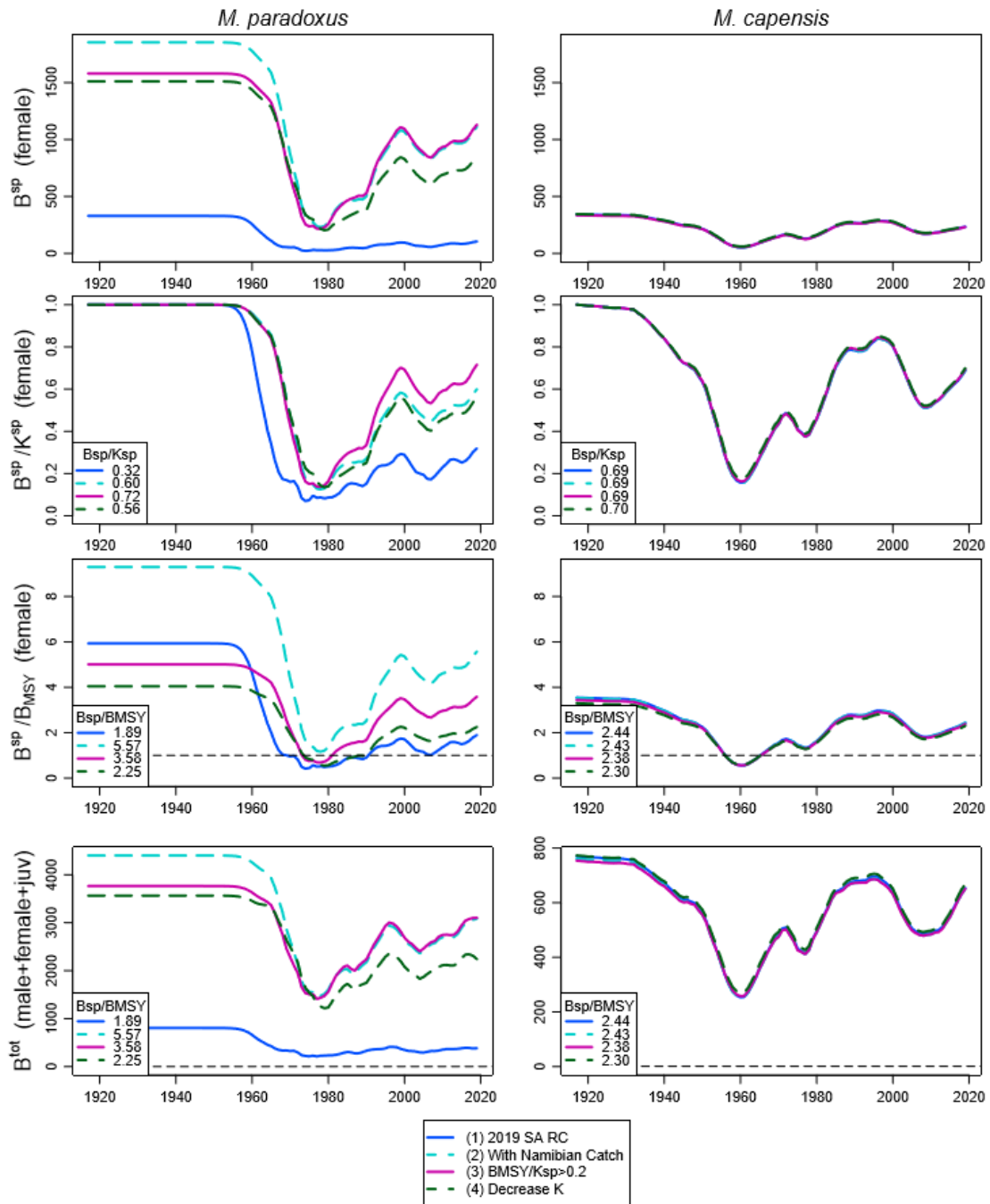


Figure 2: Female spawning biomass trajectories are shown for the four runs considered. The top row shows the spawning biomass in absolute terms, the second row relative to pristine spawning biomass and the third row relative to B_{MSY} . The bottom row shows the trajectories for the total biomass (including females, males and juveniles). Note that for run (4) where the carrying capacity is decreased by 50% between 1970 and 1980, the K^{SP} value referred to in the B^{SP}/K^{SP} plot (second row) corresponds to the original unreduced carrying capacity.

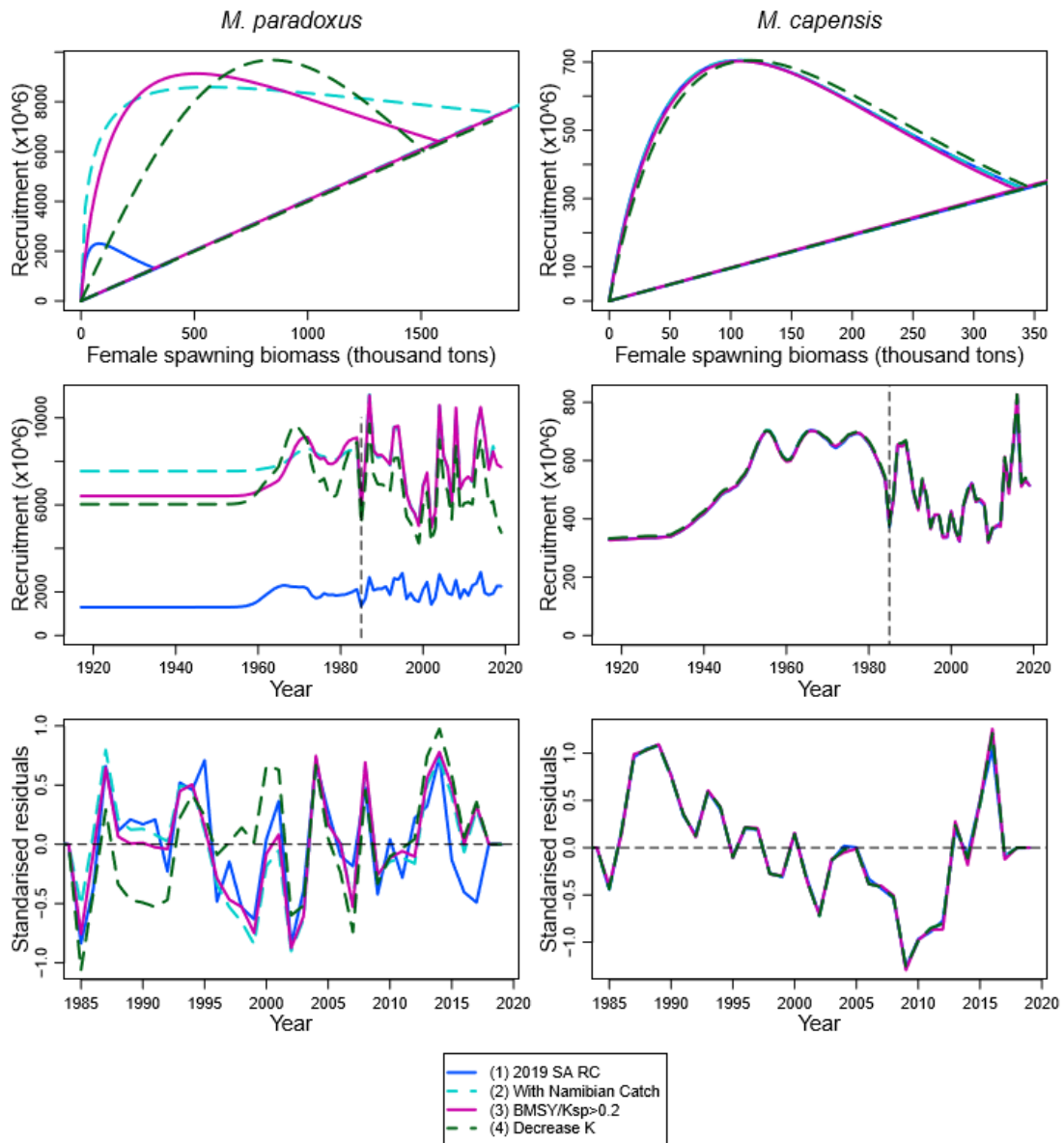


Figure 3: Recruitment is shown against female spawning biomass (top row) and against time (second row). The bottom row shows the estimated standardised stock recruitment residuals. Note that for the *M. paradoxus* recruitment plot in the first row, the stock recruitment curve for run (4) is for the original, unreduced K^{sp} .

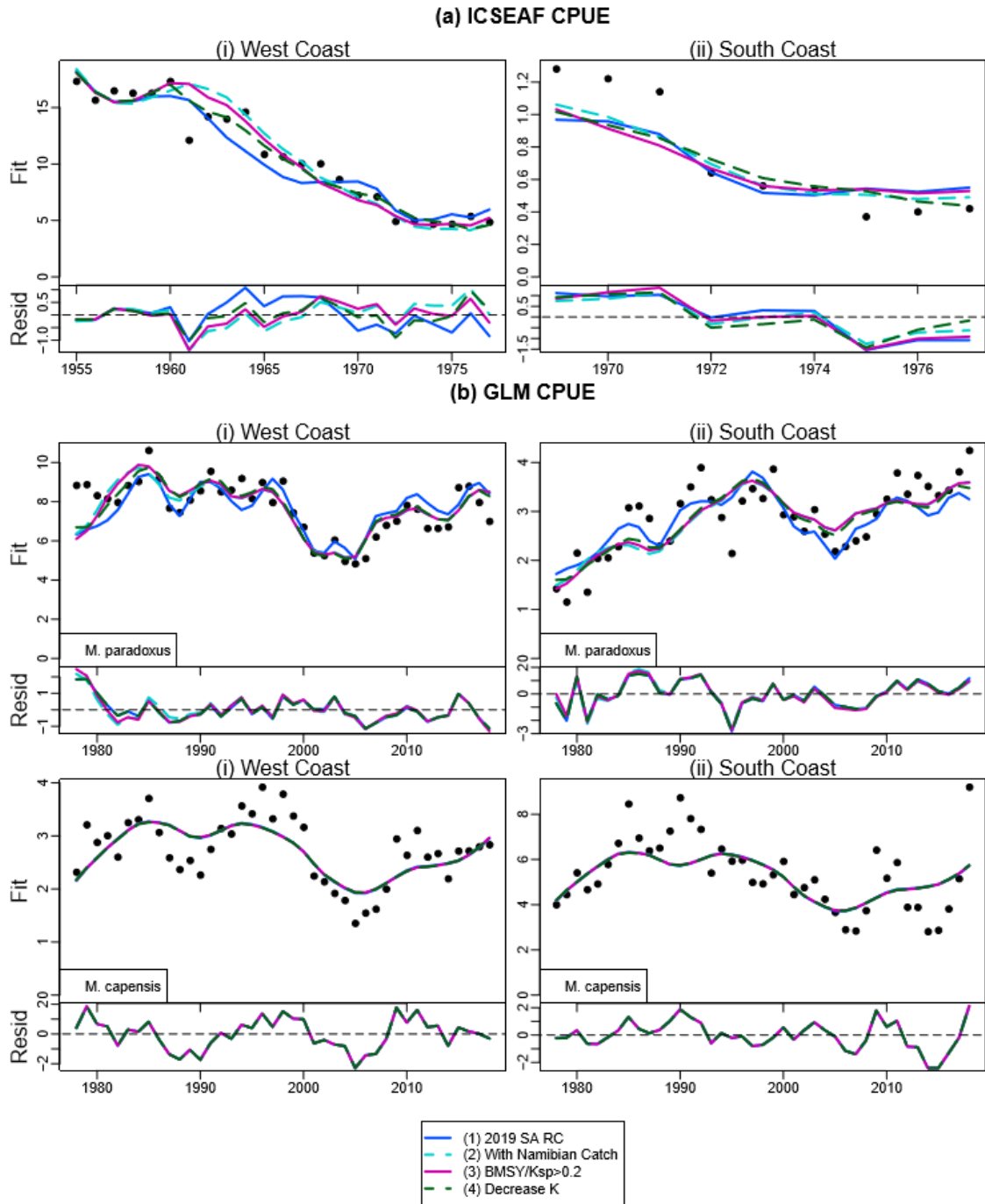


Figure 4: Fits to the historical CPUE data are shown (along with residuals) in the top section of the plot. The bottom section shows fits and residuals for the commercial GLM-standardised SA CPUE series for both species and SA coasts.

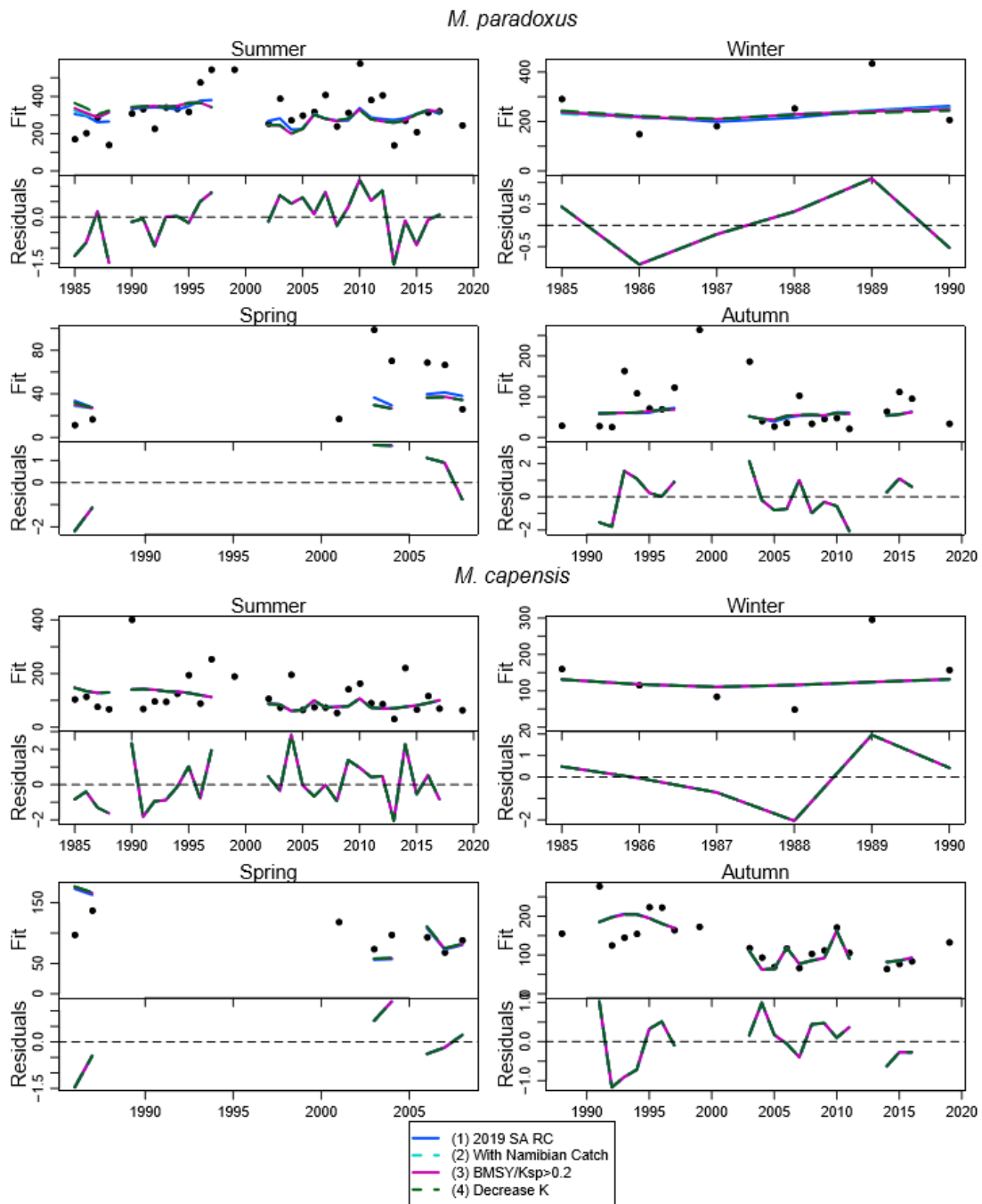


Figure 5: Fits to the SA survey abundance indices are shown for the four runs considered in this document.