

Conditioning of the hake OMP2018 Reference Set models

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Summary

An associated brief background and the first set of results are presented for the conditioning of the OMP2018 Reference Set (RS) models.

Introduction

Results for the conditioning of the OMP2018 Reference Set (RS) of models are presented.

Following recommendations of the Panel for the 2017 International Stock Assessment Workshop (Cox *et al.* 2017), the RS consists officially of eight models spanning two axes of uncertainty: the central year in which the catch shifted from primarily *M. capensis* to *M. paradoxus*, and the form of the stock recruitment function. The Panel recommended that the natural mortality-at-age be removed as an axis of uncertainty in the RS and that the mortality-at-age vectors estimated in the hake predation model (Ross-Gillespie and Butterworth, 2018) be used (sensitivity to these mortality-at-age vectors will be tested at a later stage).

There are four options for the central year.

1. Centre of the shift occurred in 1952¹.
2. Centre of the shift occurred in 1958.
3. Centre of the shift occurred in 1963.
4. Start the model in 1978 (which is when the modern commercial CPUE data and some catch-at-length data series commence).

There are two options for the form of the stock-recruitment function.

1. Modified Ricker
2. Beverton-Holt

Each of the runs (except for the three starting in 1978) have undergone “jittering” whereby the starting parameters are jittered by a small percentage and the minimisation is restarted to try to ensure that a global minimum has been found.

When the Ricker Models were originally run, the stock recruitment h parameter was estimated at the upper bound of 1.5 for both species. The upper bound was then increased to 3 to see what the unconstrained estimate for h would be. While the *M. paradoxus* estimate for the stock recruitment h and γ parameters remained reasonable (h generally between 1.5 and 1.7 and γ between 0.3 and 0.5), the *M. capensis* estimates for h tended to increase to very high values (i.e. well above 2) and in some cases the γ estimate was extremely low (below 0.1), resulting in unrealistically domed plots of recruitment against spawning biomass. Jittering also yielded very different results with virtually the same negative log-likelihood, suggesting that the *M. capensis* stock recruitment parameters h and γ

¹ The central years tested for OMP2014 were 1950, 1958 and 1965. It was found, however, that the fits to the GLM CPUE data became markedly worse when the central year was later than 1963. Hence 1963 was taken as the third option instead of 1965, and 1950 was similarly adjusted to 1952 to maintain the symmetry of the previous set.

are not very well determined. Remembering that h is the proportion of pristine recruitment that occurs when the biomass is at 20% of K , an upper limit of 2 was imposed on h , which seemed to result in more stable estimation of the *M. capensis* h and γ parameters.

Input data

The input data assumed for these models are different to the OMP2014 input data in that (a) data are now available up to 2016/2017 and (b) the species-splitting algorithm from 2013 has been updated (OLRAC 2018). The new species-splitting algorithm impacts the catch series and the GLM CPUE series and had a greater impact on the assessment results than was anticipated (the *M. paradoxus* depletion changed from 25% to 31% with the new data -see Ross-Gillespie *et al.* 2018), primarily owing to a higher rate of increase indicated by the *M. paradoxus* South Coast CPUE series. There remains an ongoing investigation into the exact source of this difference, but for the results presented here the data from the new species-splitting algorithm have been used.

Model starting in 1978

The main differences between the model starting in 1917 and in 1978 are the assumptions around the population structure in the first year ($y0$) of the model. Under pristine equilibrium conditions (i.e. 1917) the assumption is made that the number of fish in age cohort $a+1$ can be calculated as $N_{y0,a+1} = N_{y0,a}e^{-M_a}$. Since the population would not have been at equilibrium conditions in 1978, some further assumptions have to be made.

The numbers in the first cohort of age zero are given by the stock recruitment relationship. For the 1978 runs presented in this document, the subsequent numbers-at-age are given by:

$$N_{1978,a+1} = N_{1978,a}e^{-(M_a+\varphi)} \quad (1)$$

where M_a is the natural at age a and φ is an additional mortality component to account for fishing mortality in preceding years.

Furthermore, the proportion of spawning biomass in 1978 relative to pristine values in 1917 is estimated, i.e. a parameter $\theta = B_{1978}^{sp}/K^{sp}$. The model can also be adjusted to allow $N_{1978,a+1}$ to be estimated for all ages up to some specific age a^* , but this has not yet been attempted at this stage.

When first implementing this model, serious issues were experienced with instability in the minimisation. In order to produce some results, several parameters had to be fixed. These parameters are:

- The offshore selectivity parameters (West coast and South Coast) - nine parameters
- The inshore selectivity parameters - three parameters
- The scaling factor for female paradoxus selectivity (south coast surveys only) - two parameters
- The sigma parameters for the age-length matrix variance - 12 parameters
- The growth curve parameters - 12 parameters

These parameters were fixed at the (best fitting) RS02 "Reference Case" run values. Additionally, the stock-recruitment parameters (h and γ) appeared to be very poorly estimated, so these were also fixed at the RS02 values.

Results and Discussion

For the Beverton-Holt models (aside from those starting in 1978), the estimate of the steepness parameter h tended to reach whatever upper bound was placed on it. Consequently, these models

were run for two different fixed values of h , namely $h=0.90$ and $h=0.70$. Results are therefore presented in this document for 12 RS models (four for the central year assumption multiplied by three for Ricker, Beverton-Holt with $h=0.90$ and Beverton-Holt with $h=0.70$).

Table 1a and b list key parameter outputs for the 12 RS models, while Table 2 lists the negative log-likelihood components of the models.

Figure 1 shows the female spawning biomass trajectories for all 12 RS models in blue (solid lines for Ricker models, dashed lines for Beverton-Holt models), contrasted against the Oct 2017 model in black. Figure 2a and b also show the spawning biomass trajectories, but broken into smaller groups.

Figure 3a and b show the recruitment plots for *M. paradoxus* and *M. capensis* respectively, while Figure 4 shows the fits to the CPUE data.

A few initial discussion points of note are listed below.

- Depletion for *M. paradoxus* ranges from 0.26 to 0.41 for (generalised) Ricker and from 0.13 to 0.37 for Beverton Holt stock-recruitment models.
- Depletion for *M. capensis* ranges from 0.63 to 0.74 for Ricker and from 0.08 to 0.74 for Beverton-Holt models (note the very wide range in this case).
- The Beverton-Holt based OMs are generally worse than Ricker-based OMs in terms of the negative log-likelihood and many of the Beverton-Holt models show little effect of changes in spawning biomass on expected recruitment.
- Beverton-Holt models with $h=0.9$ result in B_{MSY}/K^{sp} estimates that are very low ($\sim 10\%$ for *M. paradoxus*). Fixing h at 0.7 has the effect of increasing these estimates (to $\sim 20\%$). Beverton-Holt with $h=0.9$ is generally better in total negative log-likelihood points, but $h=0.7$ is better when considering only the negative log-likelihood components that are comparable across the 12 RS models (i.e. for the years from 1978 onwards only).
- *M. paradoxus* is consistently estimated above B_{MSY} (except for one of the models starting in 1978). *M. capensis* is above B_{MSY} except for the runs Beverton-Holt that produce a very flat biomass trajectory where biomass has little impact on recruitment.
- Caution should be taken when interpreting results from the models starting in 1978 as these are not as robust as those for the other models. Interestingly, the models tend to estimate a B_{1978}^{sp}/K^{sp} value that is low for *M. paradoxus* and the B_{1978}^{sp}/K^{sp} estimate for both species is similar to those estimated by the Ricker models starting in 1917. When the θ parameter (where θ is the estimate of B_{1978}^{sp}/K^{sp}) is forced higher, fits to GLM CPUE and catch-at-length data become markedly worse (thus current estimates of often appreciable resource depletion are not a consequence of catches prior to the mid-1970s alone).
- Models RS02 (the Ricker model with central year 1958) and RS03 (the Ricker model with central year 1963) are the best in terms of the total negative log-likelihood. When considering only the comparable negative log-likelihood components, Model RS08b (Beverton-Holt with $h=0.7$, starting in 1978) performs the best, but the results of that model are not entirely reliable at this stage given the issues that were experienced with estimation instability.

References

- Cox, S., Howell, D. and Punt, A.E. 2017. International Review Panel Report for the 2017 International Fisheries Stock Assessment Workshop, 27 November – 1 December 2017, University of Cape Town.
- OLRAC SPS. 2018. A hake species splitting model using (a) weight proportion rather than number proportion as the target variable, (b) survey + observer data, and (c) size class interactions. Fisheries Branch document FISHERIES/2018/FEB/SWG-DEM/07.
- Ross-Gillespie, A. and Butterworth, D.s. 2018. Update on the MARAM hake predation model, focusing on the natural mortality-at-age vectors to be used for the Reference Set of Operating Models for the 2018 Hake OMP review. Fisheries Branch document FISHERIES/2018/MAR/SWG-DEM/11.
- Ross-Gillespie, A., Butterworth, D.S. and Durholtz, D. 2018. Bridge-building between the 2017 and 2018 hake RC assessment models. Fisheries Branch document FISHERIES/2018/MAY/SWG-DEM/20.

Table 1a: Key parameter estimates for the RS models (biomass units are thousand tons). Cases where the current spawning biomass is below its MSY value are bold font, marked with an asterisk.

Model name	Central Year	Stock Recruit	<i>M. paradoxus</i>							<i>M. capensis</i>								
			K^{sp}	B_{MSY}^{sp}	B_{2017}^{sp}	B_{2017}^{tot}	B_{2017}^{sp}/K^{sp}	$B_{2017}^{sp}/B_{MSY}^{sp}$	B_{MSY}^{sp}/K^{sp}	MSY	K^{sp}	B_{MSY}^{sp}	B_{2017}^{sp}	B_{2017}^{tot}	B_{2017}^{sp}/K^{sp}	$B_{2017}^{sp}/B_{MSY}^{sp}$	B_{MSY}^{sp}/K^{sp}	MSY
(0) Oct 2017	1958	Ricker	515	115	127	245	0.25	1.11	0.22	137	196	63	141	334	0.72	2.23	0.32	81
(1) RS01	1952	Ricker	350	57	92	204	0.26	1.63	0.16	144	414	117	301	660	0.73	2.58	0.28	103
(2) RS02	1958		321	63	101	222	0.31	1.62	0.19	146	290	83	199	447	0.69	2.39	0.29	83
(3) RS03	1963		267	69	111	239	0.41	1.60	0.26	148	466	140	345	752	0.74	2.46	0.30	105
(4) RS07	Start `78		313	61	88	197	0.28	1.45	0.19	144	231	66	145	333	0.63	2.18	0.29	66
(5) RS04a	1952	Beverton-Holt (h=0.9)	512	51	76	178	0.15	1.48	0.10	140	417	84	35	103	0.08	0.42*	0.20	52
(6) RS05a	1958		537	52	86	200	0.16	1.66	0.10	142	1148	202	824	1760	0.72	4.07	0.18	126
(7) RS06a	1963		551	52	98	226	0.18	1.87	0.10	144	1344	236	999	2127	0.74	4.23	0.18	148
(8) RS08a	Start `78		613	80	95	211	0.15	1.19	0.13	139	424	78	163	370	0.38	2.10	0.18	48
(9) RS04b	1952	Beverton-Holt (h=0.7)	70	14	24	160	0.35	1.69	0.20	151	522	150	86	209	0.17	0.58*	0.29	47
(10) RS05b	1958		77	16	29	183	0.37	1.83	0.20	158	592	172	70	174	0.12	0.41*	0.29	54
(11) RS06b	1963		831	190	287	510	0.35	1.51	0.23	130	1371	378	984	2103	0.72	2.61	0.28	114
(12) RS08b	Start `78		1100	270	145	319	0.13	0.54*	0.25	169	489	138	148	340	0.30	1.08	0.28	42

Table 1b: Some further parameter estimates. Note that B_{1978}^{sp}/K^{sp} is a model output for the first three models in each group and an estimable parameter (θ) for the last in each group where the assessment starts in 1978.

Model name	Central Year	Stock Recruit	<i>M. paradoxus</i>					<i>M. capensis</i>				
			K^{sp}	h	γ	B_{1978}^{sp}/K^{sp}	φ	K^{sp}	h	γ	B_{1978}^{sp}/K^{sp}	φ
(0) Oct 2017	1958	Ricker	515	1.26	0.38	0.11	NA	196.03	1.34	0.86	0.34	NA
(1) RS01	1952	Ricker	349	1.48	0.36	0.08	NA	416.08	1.79	0.73	0.42	NA
(2) RS02	1958		321	1.63	0.48	0.10	NA	290.21	2.00	0.81	0.36	NA
(3) RS03	1963		267	1.90	0.80	0.14	NA	465.71	1.59	0.77	0.41	NA
(4) RS07	Start `78		313	1.63	0.48	0.13	0.40	230.54	2.00	0.81	0.39	0.25
(5) RS04a	1952	Beverton-Holt (h=0.9)	512	0.90	NA	0.13	NA	416.65	0.90	NA	0.08	NA
(6) RS05a	1958		537	0.90	NA	0.18	NA	1147.91	0.90	NA	0.65	NA
(7) RS06a	1963		551	0.90	NA	0.27	NA	1343.95	0.90	NA	0.66	NA
(8) RS08a	Start `78		613	0.90	NA	0.09	0.41	423.85	0.90	NA	0.24	0.30
(9) RS04b	1952	Beverton-Holt (h=0.7)	70	0.70	NA	0.30	NA	522.23	0.70	NA	0.19	NA
(10) RS05b	1958		77	0.70	NA	0.36	NA	591.99	0.70	NA	0.12	NA
(11) RS06b	1963		831	0.70	NA	0.49	NA	1371.21	0.70	NA	0.62	NA
(12) RS08b	Start `78		1100	0.70	NA	0.07	0.34	489.36	0.70	NA	0.23	0.26

Table 2: Negative log-likelihood components are shown for the RS models. For the models starting in 1978, the historical CPUE data are not relevant as they end in 1978, neither are the Age-length key as the growth curve parameters have been fixed for these models. Additionally, three years' of South Coast offshore catch-at-length data are ignored in the 1978 model, as this series starts in 1975 – hence the commercial catch-at-length value is also not comparable with the other RS models. Grey font and italics have been used to show values that are not comparable across the models. For the Oct 2017 model the incomparability is as a result of the old treatment of the catch-at-length data. The “comparable -lnL” column contains the total of the negative log-likelihood components that are comparable across the RS Models 1-12 (columns marked with a star have been excluded from this total). The values in brackets indicate the difference between the comparable -lnL for a given run with the minimum across the RS.

Model name	Central Year	Stock Recruit	Total -lnL	Comparable lnL	historical CPUE*	GLM CPUE	Survey	Comm. CAL*	Comm. Sex-disagg CAL	Survey CAL	Survey sex-disagg CAL	Age-length Keys*	Rec. Resid.
(0) Oct 2017	1958	Ricker	<i>-5251.52</i> (-)	- -	-40.8	-191.4	-35.1	<i>-1330.6</i>	<i>-1110.6</i>	<i>-709.7</i>	<i>-1968.3</i>	124.5	10.4
(1) RS01	1952	Ricker	-3138.8 (2.9)	-2400.1 (5.0)	-36.9	-187.8	-34.6	-824.4	-682.2	-413.6	-1091.1	122.6	9.2
(2) RS02	1958		-3141.6 (0.0)	-2401.5 (3.5)	-36.8	-190.7	-34.8	-825.5	-681.8	-413.4	-1090.3	122.2	9.5
(3) RS03	1963		-3140.8 (0.8)	-2403.3 (1.8)	-36.1	-190.4	-34.7	-823.7	-682.3	-413.4	-1091.1	122.0	8.6
(4) RS07	Start `78		- -	-2394.2 (10.8)	NA	-182.8	-36.4	<i>-804.1</i>	-681.9	-412.1	-1090.6	NA	9.6
(5) RS04a	1952	BH (h=0.9)	-3122.0 (19.6)	-2376.6 (28.5)	-40.4	-172.5	-33.6	-828.1	-680.7	-416.0	-1087.0	123.0	13.3
(6) RS05a	1958		-3114.4 (27.3)	-2381.1 (23.9)	-35.6	-162.9	-32.6	-821.7	-686.2	-416.8	-1094.4	124.1	11.8
(7) RS06a	1963		-3111.8 (29.8)	-2377.8 (27.3)	-36.6	-159.1	-32.0	-821.6	-685.6	-417.0	-1094.7	124.2	10.5
(8) RS08a	Start `78		- -	-2399.4 (5.7)	NA	-187.0	-36.2	<i>-799.6</i>	-681.9	-412.1	-1090.9	NA	8.7
(9) RS04b	1952	BH (h=0.7)	-3112.8 (28.8)	-2387.1 (18.0)	-37.9	-175.7	-34.8	-826.9	-680.0	-417.1	-1092.3	139.0	12.8
(10) RS05b	1958		-3111.4 (30.2)	-2385.5 (19.6)	-37.4	-174.3	-34.5	-828.3	-679.1	-417.8	-1091.8	139.7	12.1
(11) RS06b	1963		-3098.7 (43.0)	-2367.4 (37.7)	-32.1	-158.0	-30.7	-825.2	-678.2	-416.4	-1094.4	125.8	10.3
(12) RS08b	Start `78		- -	-2405.1 (0.0)	NA	-196.3	-37.2	<i>-793.9</i>	-680.8	-409.0	-1090.7	NA	8.8

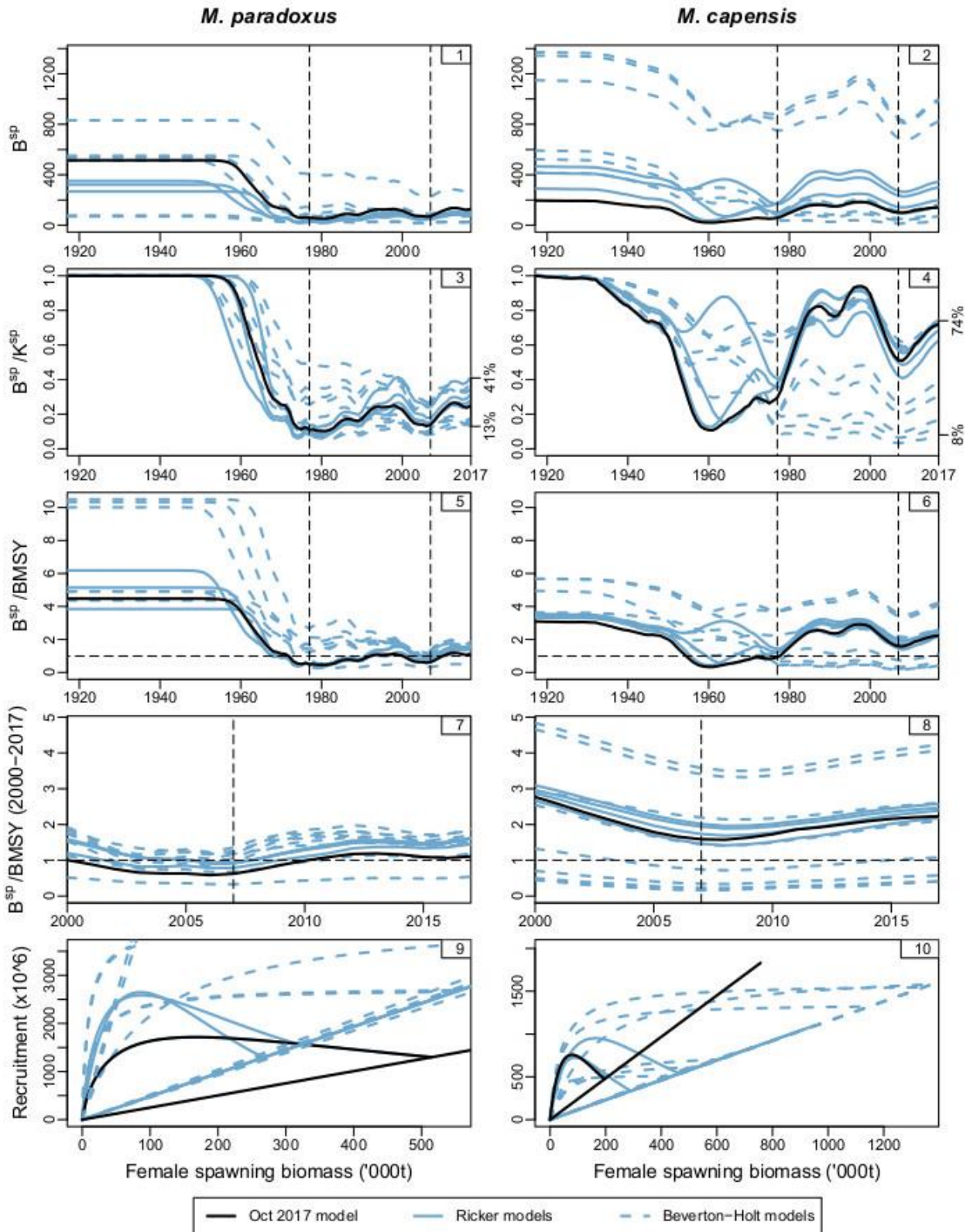


Figure 1: Female spawning biomass trajectories are shown for all the models with the purpose of comparing the 2017 model (black curves) with the 2018 RS models (blue curves). Recruitment plotted against spawning biomass is also shown.

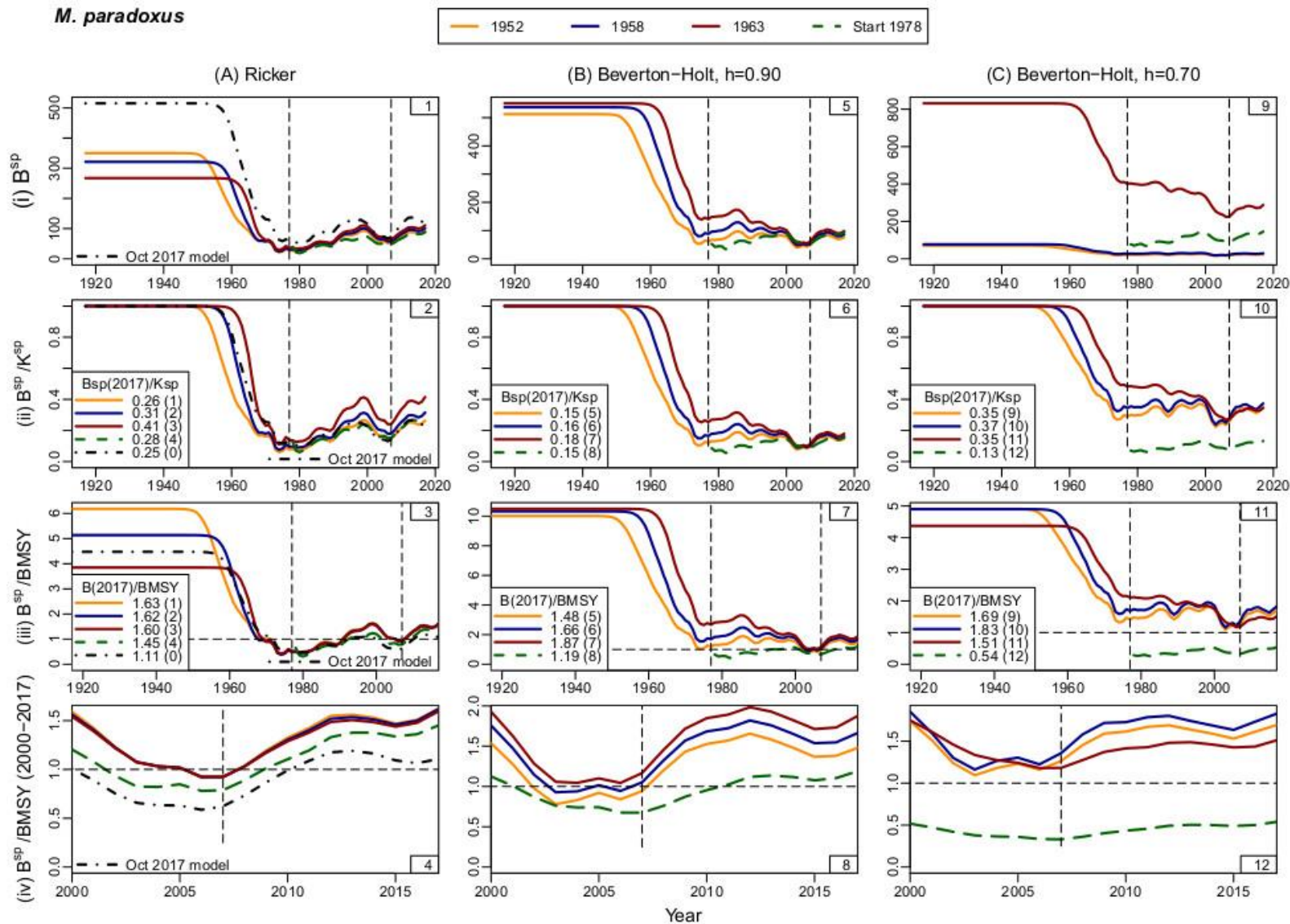


Figure 2a: Female spawning biomass trajectories are shown for *M. paradoxus* for smaller groupings of models. In the plots, yellow lines have been used for the models with the central year of shift occurring in 1952, blue lines for the 1958 models and red lines for the 1963 models. Dashed green lines have been used for the model starting in 1978. The Oct 2017 model has been included in the first column with the RS Ricker models (black dash-dot lines).

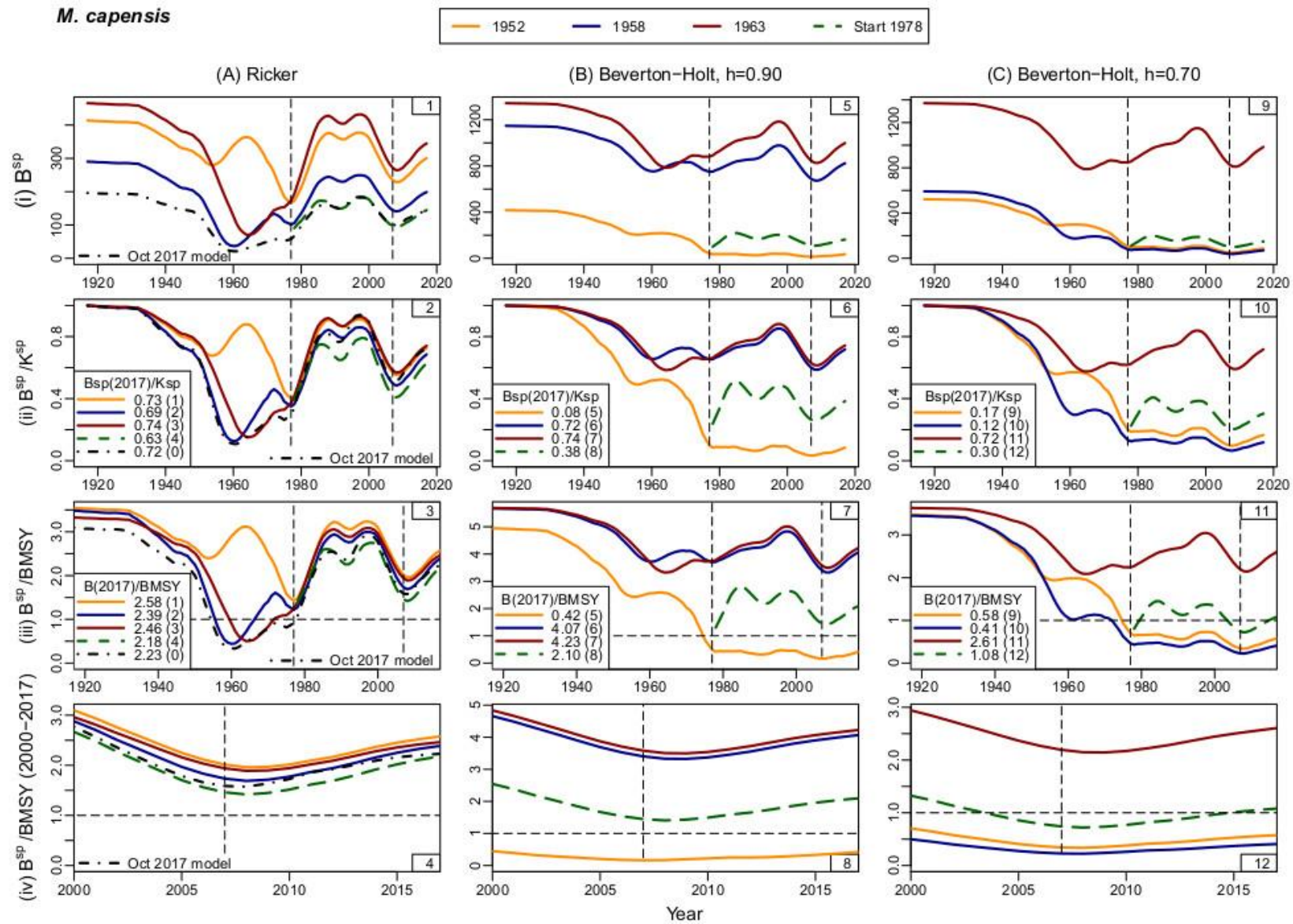


Figure 2b: Female spawning biomass trajectories are shown for *M. capensis* for the smaller groupings of models (as in Figure 2a).

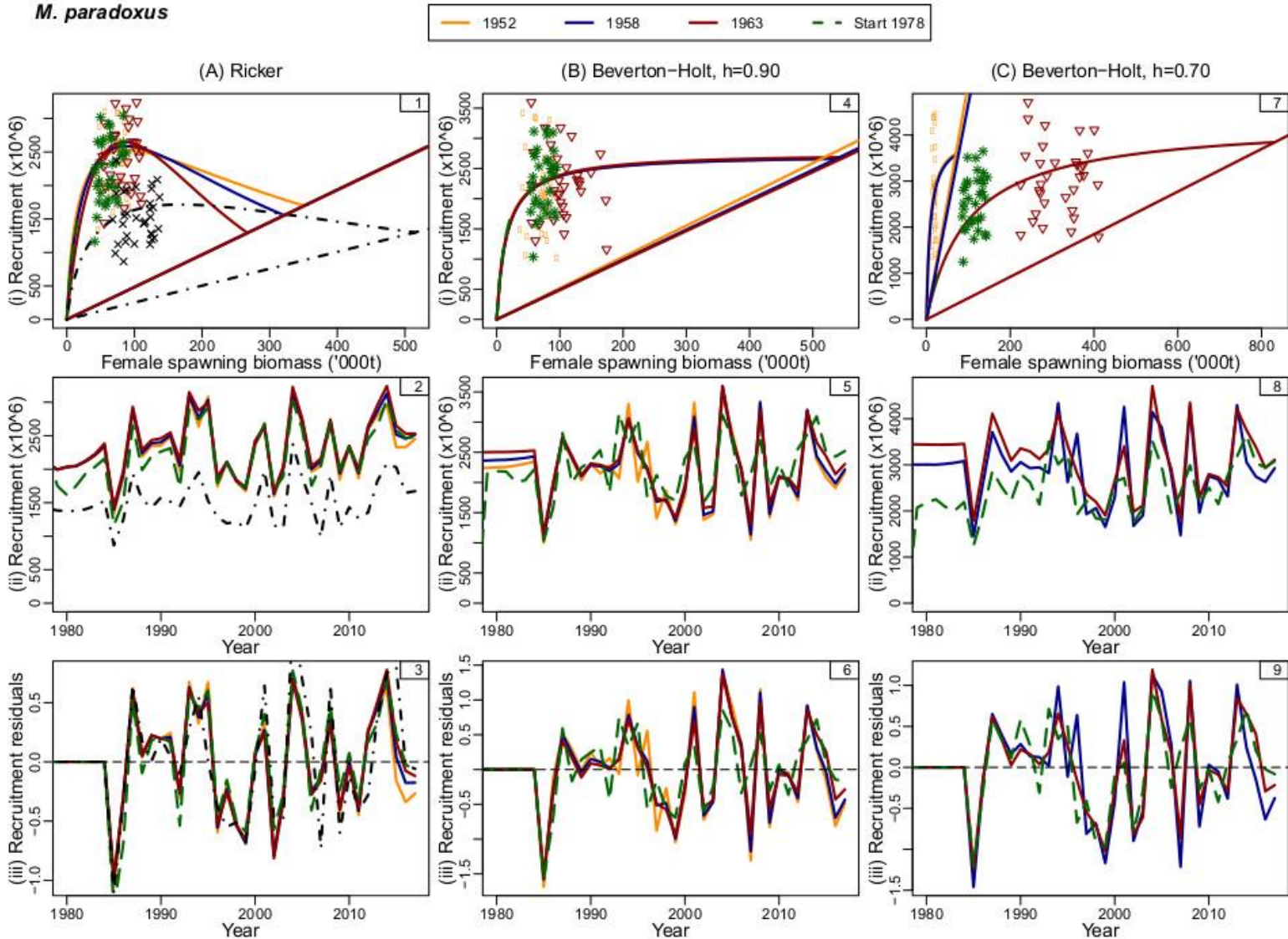


Figure 3a: Stock-recruitment plots together with recruitment time series and residuals about the stock-recruitment curves are shown for *M. paradoxus* for the smaller groupings of models. In the interest of clarity, the “data” are shown for a selection of models only. The straight lines through the origin in the stock-recruitment plots are replacement lines.

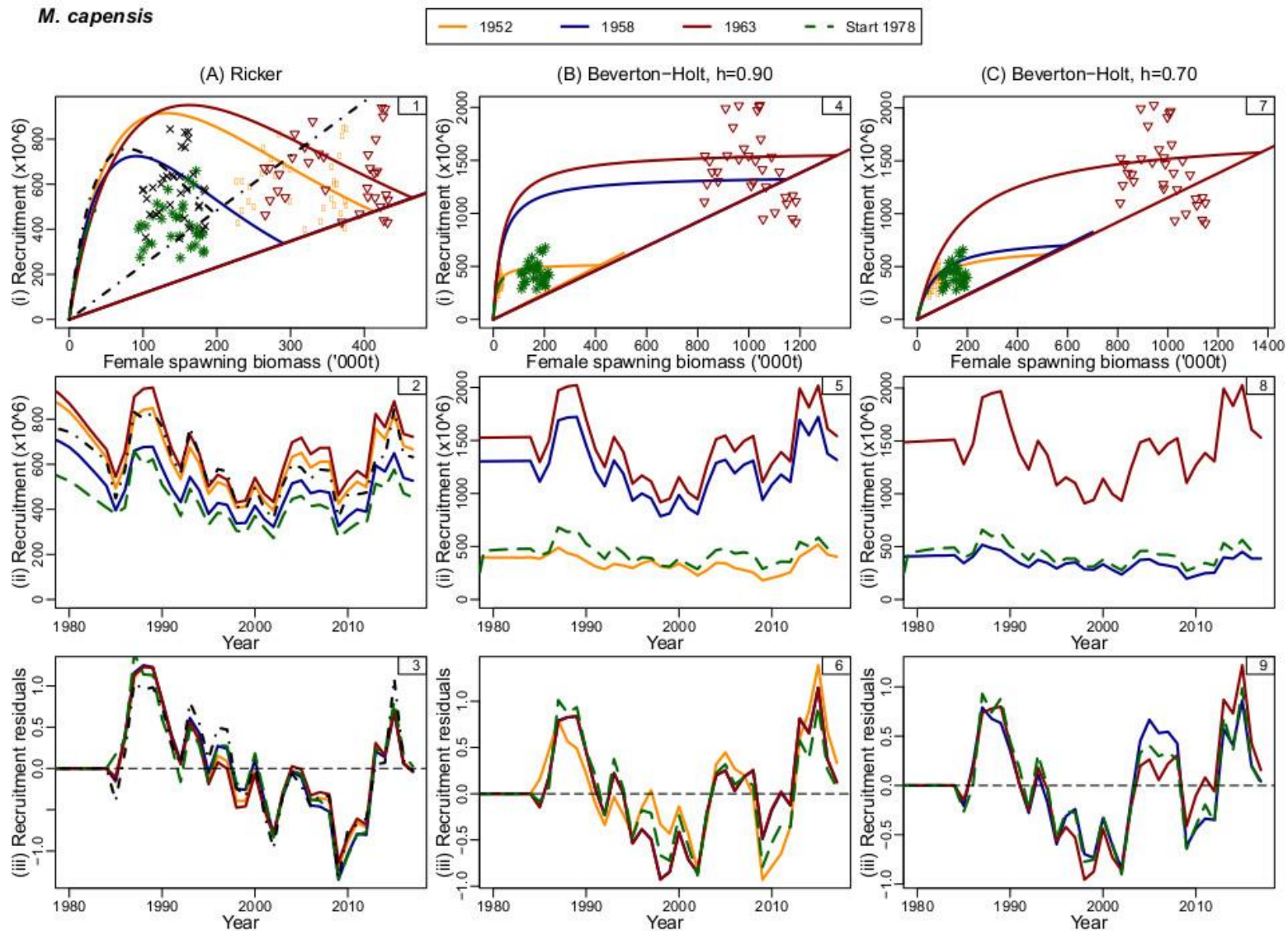


Figure 3b: Stock recruitment plots are shown for *M. capensis* for the smaller groupings of models (as in Figure 3a).

