Further examinations of the SBT operating model under overcatch scenarios to select critical uncertainty factors for the update

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Stock assessments and constant catch projections under several overcatch scenarios are conducted using the Operating Model (OM) developed by CCSBT ESC. The current analysis shows that (1) the existence of overcatch and (2) CPUE adjustments to longline overcatch are key factors as noted by the SAG/ESC meetings in 2006. In general, current stock status in both absolute and relative terms is somewhat better than past perceptions due to incorporating overcatch in the assessment model and to recruitment returning to its recent average level as indicated from recent fishing data. It is, however, noted that future projections become more pessimistic as the degree of CPUE adjustments increased. We consider that if these overcatch effects could be incorporated reasonably (likely as further uncertainty axes), the current framework of OM conditionings and projections based on the grid approach could be applied for the update of OMs used for the development of new management procedures.

Introduction

The CCSBT Extended Scientific Committee (ESC) meeting held in September 2007 decided to update the conditioning for the Operating Model (OM) over the next two years, instead of rapidly developing an interim Management Procedure (MP) (CCSBT, 2007a). While the OM was originally developed as a population dynamics model for the evaluation of first-generation MPs in the CCSBT, this would be used with constant-catch projections to provide the basis for advice on TACs in 2009. The Stock Assessment Group (SAG) recommended that members undertake work on the conditioning of the OM using a scenario approach, where model parameters are estimated under several pre-specified scenarios and assumptions, particularly regarding overcatch and CPUE adjustments (CCSBT, 2007b).

In this paper, we report the results of OM conditionings using data updated to 2007, and for future projections at the current catch level, to examine the impacts of several factors on SBT stock trends. The analysis concentrates mainly on effects of (1) overcatch by purse-seine and longline fisheries and (2) adjustments of Japanese longline CPUEs in relation to the longline overcatch, both of which are considered to be potentially major uncertainties for past and future stock trends. We also examine the effect of the extent of recruitment recovery from very low levels around 2000 in evaluating short-term risks of substantial stock declines, which has been a matter serious concern at recent CCSBT meetings.

Data and model specification

In this analysis, we used several programs and input files sequentially: "sbtmod20.exe" and "sbtdata8.dat" for the conditioning, "sample_v4.exe" for the grid sampling, and "sbtprojv116.exe" for the projection. The data file "sbtdata8.dat" used for this analysis was provided tentatively in the late June, but as a consequence of our modifications, this now includes almost the same dataset as the latest official version (distributed on 9 July) including CPUE series (the traditional w0.5 and w0.8), except Indonesian age composition data for 2007 (but this difference did not impact final results substantially). Though "sbtprojv116.exe" was originally developed in 2007 for conditioning results of "sbtmod19.exe", this projection program seemed to work properly for the sbtmod20.exe as well after a minor modification to the file "fixed_quants04". However, the projection results should be regarded only as a guide at this stage, because our modifications have not been checked sufficiently. We conducted constant catch projections at the current level (10,815t) over 24 years (from 2009 to 2032). This catch amount comes from a total of reported catch in 2007 for each fleet (LL1: 3508.20t, LL2: 840.65t, Indonesia 1123.57t, Australia 5342.19t). Catch for LL3 (328t) was not incorporated in the projections due to programming issues. The catch proportion of each fleet in the future was fixed at the current level.

In addition to fishery data distributed from the Secretariat, we used two new CPUE series provided by the CPUE working group (Itoh et al., 2008). One includes a factor of by-catch of yellowfin and bigeye tuna in the standardization (Itoh, 2008a), and the other does not (Itoh, 2008b). Each series consists of two subseries (w0.5 and w0.8) as the traditional method does. CPUEs in 2007 were tentatively assumed to equal to those in 2006. We also preliminarily incorporated two recruitment indices from Japanese trolling surveys (the trolling survey conducted with the acoustic survey for 1996-2006, and the new piston-line survey for 2006-2007; Itoh and Sakai, 2008). These indices were fitted separately to the abundance of age 1 using a lognormal likelihood.

We took two approaches to examine model behaviors: the grid approach (integrating over scenarios) and the specific scenario approach. In the grid approach, the following grid specification was used for the base case. This is the same configuration as the original grid used in the 2006 SAG/SC meetings.

	levels	value			prior			simulation weight
steepness	3	0.385	0.55	0.73	0.2	0.6	0.2	prior
M0	3	0.3	0.4	0.5		uniform		posterior
M10	3	0.07	0.1	0.14		uniform		posterior
omega	2	0.75	1		0.4	0.6		posterior
cpue	2	w0.5	w0.8			uniform		prior
q age-range	2	4-18	8-12		0.67	0.33		prior
sample size	2	sqrt	orig.5			uniform		prior

2000 scenarios used for projections in the grid approach were sampled from these 432 scenario combinations based on the posterior weights. In the specific scenario approach, parameters such as steepness and the *M*s were estimated directly in the conditioning process for several specific scenarios. This approach might also be valuable to ascertain some general features of model behavior in a situation of constraints on time. The original settings for priors on estimated parameters were not changed. 50 projections were conducted for a specific scenario to incorporate recruitment variations in the future.

Results and Discussion

Our current analysis shows that the existence of overcatch and CPUE adjustment are key factors as also noted at the SAG/ESC meetings in 2006. In general, current stock status in both absolute and relative terms is somewhat better than past perceptions due to incorporating overcatch in the assessment model and recruitment returning to its recent average level as indicated by recent fishing data. The two approaches (grid and specific scenario) showed similar results. Summary results regarding each factor are as follows:

1. Incorporating overcatch for surface and longline fisheries led to a greater current spawning biomass and more optimistic future projections (runs 1-4 in Table 1, Figs. 1a-d). In particular, the longline overcatch had larger impacts. The current catch level is sustainable for all the overcatch runs. Overcatch led to much lower "M0" and higher "omega" (which relates to the linearity of CPUE vs abundance relationship). Changes in the likelihood components for runs 2 and 17 in Table 2 compared to runs 1 and 16, respectively, indicate that overcatch has the potential to affect many factors considerably (also see Figs. 2a-b).
2. CPUE adjustment, the so-called *S* issue, had large impacts (runs 5-6 in Table 1, runs 3-5 and 16-19 in Table 2, Figs. 1e-f). As *S* is set larger, the current biomass becomes larger. Future projections, however, were more pessimistic as *S* increased for the grid runs. This is different from results obtained in 2006 (Kurota et al., 2006). This might be related to a fact that consideration was limited to two CPUE series (w0.5 and w0.8) in the present analysis. When *S* was set at 0.5 or more (the C2 and C3 scenarios), the model fits to CPUE were very poor in general with residuals that showed high autocorrelation (Figs. 2c-d).

3. The new CPUE series proposed by the CPUE working group led to more optimistic future projections (runs 7-10 in Table 1, Figs. 1g-j). Parameter distributions in the default grid configuration were not substantially different from those for the traditional CPUE series. In general, the model fits to CPUE and LL1 size composition data were worse (runs 24-27 in Table 2, Figs. 2e-f).
4. New recruitment indices from Australian fisheries hardly impacted the overall stock trends for the current model specification (runs 11-12 in Table 1). However, commercial spotting data led to a higher recruitment estimate for 2003 (Fig. 1k). Recruitment indices from Japanese trolling surveys also showed higher recent recruitment estimates (run 13 in Table 1). In particular, the recruitment estimates for 2005 and 2006 were very high (Fig. 1m). This is related to a fact that recent trolling indices are quite high and there is no other information as of 2008 to estimate the recruitments in 2005 and 2006.
5. Incorporating overcatch led to poor fits to tagging data at high M0 (0.4; run 2 in Table 2). This is likely to be a major reason why lower M0 was preferred in the grid sampling (e.g., Fig. 1d; also see runs 16 and 20 in Table 2). Interestingly, projection results were not different compared to cases when tagging data was incorporated (runs 14-15 in Table 1, Figs. 1n-o). It might be necessary to discuss tagging data availability again, including the validity of reporting rate estimates.
6. Previously (before 2004, if we recall correctly) steepness tended to be estimated low at around 0.4. In this analysis as well, when steepness sampling is based on likelihood, a no-overcatch run preferred lower steepness and led to very pessimistic results (run 16 in Table 1, run 16 in Table 2). However, overcatch scenarios reflected higher steepness, close to the original prefixed prior, even if the CPUE adjustment was not applied (Figs. 1q-t, also see runs 16-19 in Table 2).
7. Retrospective analysis indicated that data for recent two or four years did not change stock productivity estimates substantially (runs 6-9 in Table 2). However, the recent data do confirm that recruitments have increased since recruitment failures in 2000 and 2001.
8. Other uncertainty factors in the current grid were examined, though our analysis was limited to a small number of scenarios. CPUE w0.8 showed almost the same conditioning results as those for the w0.5 series in the current base case (runs 10-12 in Table 2). The reason why Omege=0.75 was hardly accepted for overcatch scenarios in the grid seemed to be worse fits to CPUE series (run 13 in Table2). When "q age range" was narrower, fitting to CPUE was better as expected, and the future projection showed more pessimistic results (run 14 in Table2). The "sqrt" scenario also led to more pessimistic results (run 15 in Table2).

In general, the goodness-of-fit to the new dataset including overcatch effects is not particularly bad for the current model specification. Therefore we consider that if overcatch effects could be incorporated reasonably by modifications such as adding new uncertainty axes, the current basic framework for OM conditioning and projections based on the grid approach could be applied for an update of OMs for new MP developments.

References

CCSBT 2007a. Report of the Extended Scientific Committee for the Twelfth Meeting of the Scientific Committee. 10-14 September 2007, Hobart, Australia.

CCSBT 2007b. Report of the Eighth Meeting of the Stock Assessment Group. 4-8 September 2007, Hobart, Australia.

Itoh, T. 2008a. Candidate for the final standardized CPUE for MP. CPUE analysis in intersessional period. Working Paper 19.1.

Itoh, T. 2008b. Data remake and revised GLM runs. CPUE analysis in intercessional period. Working Paper 15.1.

Itoh, T., Lawrence, E., and Pope, J.G. The development of new agreed CPUE series for use in future MP work. CCSBT-ESC/0809/xx.

Itoh, T., and Sakai, O. Report on the piston-line trolling survey in 2007/2008. CCSBT-ESC/0809/41.

Kurota, H., Butterworth, D.S., and Sakai, O. 2006. SBT stock assessment and projection under overcatch scenarios using the operating model. CCSBT-ESC/0609/42.

Table 1. Summary results for grid simulations. A value in round parenthesis represents a difference from that of a base case set indicated at the last line for each column. Projections assume a constant future catch at the current TAC level. B is spawning biomass.

		overcatch			CPUE adjustment		new CPUE series				new recruit index			no tagging data		steepness weighting based on likelihood				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	C0S0L0	C0S0L1	C0S1L0	C0S1L1	C1S1L1	C2S1L1	C0S1L1_cpue1	C1S1L1_cpue1	C0S1L1_cpue2	C1S1L1_cpue2	C1S1L1_rec01	C1S1L1_rec10	C1S1L1_troll	C0S1L1_notag	C1S1L1_notag	C0S0L0_hlike	C0S1L1_hlike	C1S1L1_hlike	C0S1L1_notag_hlike	C1S1L1_notag_hlike
CPUE:S=0.25(1),0.5(2)					1	2		1		1	1	1	1		1			1		1
surface overcatch			1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1
longline overcatch		1		1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1
new CPUE (without bycatch)							1	1												
new CPUE (with bycatch)									1	1										
Aus commercial spotting											1									
Aus aerial survey												1								
Jpn troll survey													1							
steepness: weighting based on likelihood																1	1	1	1	1
no use of tag data														1	1				1	1
B2008	47889	73139 (25250)	51803 (3914)	75354 (27466)	76897 (1543)	99212 (23858)	69673 (-5681)	68738 (-8159)	81795 (6441)	80307 (3409)	77817 (920)	76756 (-142)	90406 (13508)	73409 (-1946)	76789 (-109)	56122 (8233)	75354 (0)	73435 (-3462)	77483 (4074)	76789 (0)
B2032/B2008	0.64	1.45 (0.81)	1.10 (0.47)	1.80 (1.17)	1.42 (-0.38)	1.29 (-0.51)	2.21 (0.41)	1.87 (0.45)	2.18 (0.38)	1.86 (0.44)	1.49 (0.07)	1.51 (0.09)	3.08 (1.66)	1.94 (0.14)	1.56 (0.14)	0.02 (-0.61)	1.85 (0.05)	1.35 (-0.07)	1.76 (-0.18)	1.37 (-0.19)
B2014/B2008	0.77	0.93 (0.16)	0.79 (0.02)	0.93 (0.16)	0.85 (-0.08)	0.83 (-0.10)	1.09 (0.15)	0.99 (0.14)	1.06 (0.13)	0.97 (0.12)	0.86 (0.01)	0.89 (0.04)	1.06 (0.21)	0.94 (0.01)	0.86 (0.01)	0.73 (-0.04)	0.94 (0.01)	0.85 (-0.00)	0.93 (-0.00)	0.85 (-0.01)
R2003&4/R1990s	0.78	0.71 (-0.07)	0.81 (0.02)	0.71 (-0.07)	0.66 (-0.06)	0.63 (-0.08)	0.85 (0.13)	0.76 (0.10)	0.83 (0.12)	0.75 (0.09)	0.72 (0.07)	0.70 (0.04)	0.82 (0.17)	0.70 (-0.01)	0.63 (-0.02)	0.74 (-0.04)	0.73 (0.01)	0.66 (0.00)	0.70 (-0.00)	0.63 (-0.00)
B2008/B0	0.074	0.088 (0.014)	0.080 (0.006)	0.091 (0.017)	0.094 (0.003)	0.099 (0.008)	0.088 (-0.003)	0.088 (-0.006)	0.097 (0.006)	0.095 (0.001)	0.092 (-0.002)	0.093 (-0.002)	0.102 (0.008)	0.097 (0.006)	0.097 (0.003)	0.074 (0.000)	0.091 (0.000)	0.094 (0.000)	0.096 (-0.001)	0.099 (0.001)
compared to		C0S0L0	C0S0L0	C0S0L0	C0S1L1	C0S1L1	C0S1L1	C1S1L1	C0S1L1	C1S1L1	C1S1L1	C1S1L1	C1S1L1	C0S1L1	C1S1L1	C0S0L0	C0S1L1	C1S1L1	C0S1L1_notag	C1S1L1_notag

Table 2. Summary results for specific scenario runs. Values in bold indicate that they are estimated. The base case is set as “steepness: estimate, M0=0.4, M10=0.14, cpue= w0.5 (traditional), omega=1.0, q age range=4-18, sample size=orig.5”. Conventions are as for Table 1; values in square parentheses are Hessian-based standard errors.

			overcatch	CPUE adjustment			retrospective analysis				cpue w0.8		
		1	2	3	4	5	6	7	8	9	10	11	12
		C0S0L0	C0S1L1	C1S1L1	C2S1L1	C3S1L1	C0S1L1_2003	C0S1L1_2005	C1S1L1_2003	C1S1L1_2005	C0S1L1_w0.8	C1S1L1_w0.8	C2S1L1_w0.8
	Steepness	**0.538**	**0.586**	**0.576**	**0.585**	**0.616**	**0.546**	**0.598**	**0.568**	**0.609**	**0.610**	**0.598**	**0.615**
	[se]	[0.073]	[0.074]	[0.073]	[0.077]	[0.079]	[0.077]	[0.078]	[0.080]	[0.078]	[0.076]	[0.077]	[0.082]
			(0.047)	(-0.010)	(-0.001)	(0.030)	(-0.040)	(0.012)	(-0.008)	(0.033)	(0.024)	(0.022)	(0.030)
	M(0)	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
	[se]												
	M(10)	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
	[se]												
Ref. Pts	B2008	48487	63471	64513	66598	66707					69695	72238	73979
			(14985)	(1042)	(3127)	(3236)					(6224)	(7725)	(7381)
	B2032/B2008	0.85	2.79	2.09	2.34	3.01					3.35	2.78	3.09
			(1.94)	(-0.71)	(-0.46)	(0.21)					(0.55)	(0.69)	(0.75)
	B2014/B2008	0.79	1.02	0.91	0.91	0.98					1.11	1.01	1.03
			(0.23)	(-0.11)	(-0.11)	(-0.04)					(0.09)	(0.11)	(0.12)
	R2003&4/R1990s	0.84	0.77	0.69	0.70	0.75					0.83	0.76	0.78
			(-0.07)	(-0.08)	(-0.07)	(-0.01)					(0.06)	(0.07)	(0.08)
	B2008/B0	0.074	0.092	0.094	0.099	0.103					0.104	0.108	0.114
			(0.019)	(0.002)	(0.007)	(0.011)					(0.012)	(0.014)	(0.015)
Likelihood	Total	465.40	469.75	475.36	486.56	496.37	399.77	424.05	403.94	427.10	471.67	480.78	492.40
			(4.35)	(5.61)	(16.82)	(26.62)					(1.92)	(5.42)	(5.83)
	LL1	187.58	188.23	187.93	187.29	186.33	155.08	165.28	154.99	165.27	187.91	187.69	186.82
			(0.65)	(-0.30)	(-0.94)	(-1.90)					(-0.32)	(-0.24)	(-0.47)
	LL2	64.41	65.62	66.50	66.87	66.78	39.40	47.81	39.72	48.36	65.70	66.43	66.61
			(1.21)	(0.89)	(1.25)	(1.16)					(0.09)	(-0.08)	(-0.26)
	LL3	52.69	53.16	53.03	52.86	52.61	52.80	52.94	52.73	52.83	53.02	52.89	52.69
			(0.47)	(-0.13)	(-0.30)	(-0.55)					(-0.14)	(-0.13)	(-0.17)
	LL4	103.74	101.99	102.71	103.21	103.61	102.47	101.96	102.77	102.45	102.19	102.86	103.38
			(-1.75)	(0.72)	(1.22)	(1.63)					(0.20)	(0.16)	(0.17)
	IND	47.00	46.31	46.99	47.47	47.27	32.11	39.40	33.51	40.02	46.62	47.42	47.63
			(-0.68)	(0.67)	(1.15)	(0.96)					(0.31)	(0.43)	(0.16)
	SURF	28.20	29.14	29.38	29.31	29.14	27.93	28.44	28.11	28.64	29.01	29.15	29.07
			(0.94)	(0.24)	(0.17)	(-0.01)					(-0.13)	(-0.23)	(-0.25)
	CPUE	-64.11	-64.61	-61.53	-51.27	-39.22	-57.44	-62.80	-57.42	-62.57	-62.75	-56.83	-45.20
			(-0.49)	(3.08)	(13.34)	(25.39)					(1.86)	(4.71)	(6.07)
	Tags	3.65	9.00	9.34	9.63	9.60	7.76	9.00	9.22	10.01	9.76	10.26	10.52
			(5.35)	(0.33)	(0.63)	(0.60)					(0.76)	(0.92)	(0.89)
Priors	Sel.Ch	42.54	41.94	42.28	42.35	41.33	34.60	36.86	35.17	37.14	41.41	42.13	41.95
			(-0.60)	(0.34)	(0.41)	(-0.60)					(-0.52)	(-0.15)	(-0.40)
	Sel.sm	24.14	22.28	22.46	22.57	22.59	19.04	20.01	19.15	20.25	22.24	22.44	22.53
			(-1.86)	(0.18)	(0.30)	(0.31)					(-0.04)	(-0.02)	(-0.04)
	Sg.R	-24.43	-23.31	-23.72	-23.73	-23.70	-20.39	-22.61	-20.41	-22.95	-23.46	-23.68	-23.62
			(1.12)	(-0.41)	(-0.42)	(-0.39)					(-0.15)	(0.04)	(0.11)
	M(0)	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)
	M(10)	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)
	Steepness	0.00	0.01	0.00	0.01	0.02	0.00	0.01	0.00	0.02	0.02	0.01	0.02
			(0.01)	(-0.00)	(-0.00)	(0.02)					(0.01)	(0.01)	(0.02)
	compared to		C0S0L0	C0S1L1	C0S1L1	C0S1L1	C0S1L1	C0S1L1	C1S1L1	C1S1L1	C0S1L1	C1S1L1	C2S1L1

		other grid axes			h & m: full estimate				no tagging data				new CPUE series			
		13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
		C1S1L1_omega0.75	C1S1L1_qrange8-12	C1S1L1_sqrt	C0S0L0_free	C0S1L1_free	C1S1L1_free	C2S1L1_free	C0S0L0_notag_free	C0S1L1_notag_free	C1S1L1_notag_free	C2S1L1_notag_free	C0S1L1_cpue1_free	C1S1L1_cpue1_free	C0S1L1_cpue2_free	C1S1L1_cpue2_free
	Steepness	**0.526**	**0.549**	**0.569**	**0.533**	**0.620**	**0.646**	**0.639**	**0.527**	**0.574**	**0.598**	**0.573**	**0.709**	**0.723**	**0.638**	**0.665**
	[se]	[0.073]	[0.066]	[0.077]	[0.077]	[0.083]	[0.086]	[0.108]	[0.091]	[0.089]	[0.097]	[0.125]	[0.080]	[0.080]	[0.084]	[0.082]
		(-0.050)	(-0.028)	(-0.007)	(-0.005)	(0.087)	(0.026)	(0.019)	(-0.006)	(-0.046)	(-0.047)	(-0.066)	(0.089)	(0.077)	(0.017)	(0.020)
	M(0)	0.40	0.40	0.40	**0.395**	**0.346**	**0.362**	**0.366**	**0.403**	**0.393**	**0.401**	**0.404**	**0.348**	**0.361**	**0.340**	**0.357**
	[se]				[0.035]	[0.033]	[0.032]	[0.033]	[0.039]	[0.039]	[0.039]	[0.039]	[0.032]	[0.032]	[0.033]	[0.032]
					(-0.005)	(-0.049)	(0.016)	(0.020)	(0.008)	(0.047)	(0.040)	(0.038)	(0.003)	(-0.001)	(-0.005)	(-0.005)
	M(10)	0.14	0.14	0.14	**0.143**	**0.128**	**0.114**	**0.107**	**0.144**	**0.140**	**0.123**	**0.117**	**0.124**	**0.114**	**0.130**	**0.118**
	[se]				[0.014]	[0.012]	[0.012]	[0.012]	[0.018]	[0.015]	[0.014]	[0.015]	[0.012]	[0.012]	[0.013]	[0.012]
					(0.003)	(-0.015)	(-0.013)	(-0.021)	(0.001)	(0.012)	(0.009)	(0.009)	(-0.004)	(-0.001)	(0.002)	(0.003)
Ref. Pts	B2008	47347	44278	63634	47612	60885	58016	65134	48291	65995	62987	75265	66154	63713	66080	60863
		(-17167)	(-20235)	(-880)	(-874)	(13273)	(-2869)	(4249)	(679)	(5110)	(4970)	(10131)	(5269)	(5697)	(5195)	(2846)
	B2032/B2008	0.74	1.07	1.72	0.86	2.95	2.38	2.22	0.95	2.60	2.00	1.65	NA	NA	NA	NA
		(-1.35)	(-1.02)	(-0.37)	(0.01)	(2.09)	(-0.57)	(-0.73)	(0.09)	(-0.35)	(-0.38)	(-0.57)				
	B2014/B2008	0.82	0.81	0.83	0.81	1.06	0.95	0.90	0.82	1.03	0.93	0.87	NA	NA	NA	NA
		(-0.09)	(-0.09)	(-0.08)	(0.02)	(0.26)	(-0.11)	(-0.16)	(0.01)	(-0.04)	(-0.03)	(-0.03)				
	R2003&4/R1990s	0.66	0.64	0.55	0.84	0.79	0.70	0.67	0.83	0.76	0.68	0.64	1.02	0.92	0.94	0.84
		(-0.04)	(-0.05)	(-0.14)	(0.00)	(-0.05)	(-0.09)	(-0.12)	(-0.01)	(-0.02)	(-0.02)	(-0.03)	(0.23)	(0.22)	(0.15)	(0.14)
	B2008/B0	0.064	0.063	0.093	0.073	0.079	0.070	0.073	0.075	0.094	0.081	0.089	0.089	0.081	0.086	0.075
		(-0.030)	(-0.031)	(-0.001)	(-0.000)	(0.005)	(-0.009)	(-0.006)	(0.002)	(0.015)	(0.012)	(0.016)	(0.011)	(0.012)	(0.007)	(0.006)
Likelihood	Total	478.98	469.57	539.67	465.60	467.04	470.90	481.00	461.27	459.54	464.51	474.60	471.09	477.98	469.30	471.53
		(3.62)	(-5.79)	(64.32)	(0.20)	(1.44)	(3.86)	(13.96)	(-4.34)	(-7.50)	(-6.39)	(-6.40)	(4.05)	(7.07)	(2.26)	(0.62)
	LL1	188.61	190.53	154.25	187.48	188.93	188.92	188.49	187.44	188.20	188.34	187.60	191.26	190.73	191.57	191.35
		(0.69)	(2.60)	(-33.68)	(-0.10)	(1.45)	(-0.01)	(-0.44)	(-0.04)	(-0.73)	(-0.58)	(-0.89)	(2.33)	(1.81)	(2.64)	(2.44)
	LL2	66.97	66.89	84.11	64.42	65.76	66.91	67.58	64.41	65.58	66.71	67.32	65.27	65.97	64.84	65.70
		(0.46)	(0.39)	(17.61)	(0.01)	(1.34)	(1.15)	(1.81)	(-0.01)	(-0.18)	(-0.21)	(-0.25)	(-0.50)	(-0.94)	(-0.93)	(-1.22)
	LL3	53.59	53.28	110.18	52.75	53.10	52.65	52.49	52.77	53.21	52.85	52.80	52.81	52.42	53.33	52.89
		(0.56)	(0.26)	(57.15)	(0.06)	(0.35)	(-0.44)	(-0.61)	(0.02)	(0.11)	(0.20)	(0.31)	(-0.29)	(-0.23)	(0.24)	(0.24)
	LL4	101.51	102.11	135.93	103.71	102.09	103.02	103.57	103.66	101.94	102.73	103.13	102.34	103.30	101.58	102.42
		(-1.20)	(-0.60)	(33.23)	(-0.03)	(-1.62)	(0.94)	(1.48)	(-0.05)	(-0.15)	(-0.29)	(-0.44)	(0.26)	(0.28)	(-0.51)	(-0.60)
	IND	46.56	46.08	32.89	47.02	46.08	46.62	47.53	46.66	45.84	46.46	47.43	45.39	46.02	45.57	45.84
		(-0.43)	(-0.91)	(-14.10)	(0.03)	(-0.94)	(0.54)	(1.45)	(-0.36)	(-0.24)	(-0.16)	(-0.10)	(-0.69)	(-0.60)	(-0.51)	(-0.77)
	SURF	29.32	29.53	34.66	28.19	29.28	29.75	29.84	28.05	28.33	28.75	28.76	29.13	29.36	29.03	29.40
		(-0.06)	(0.15)	(5.28)	(-0.01)	(1.09)	(0.47)	(0.57)	(-0.14)	(-0.95)	(-0.99)	(-1.09)	(-0.15)	(-0.38)	(-0.25)	(-0.35)
	CPUE	-57.04	-66.91	-63.29	-64.08	-64.85	-63.43	-56.40	-64.06	-64.94	-63.08	-55.92	-60.06	-54.99	-63.35	-61.51
		(4.49)	(-5.38)	(-1.75)	(0.04)	(-0.78)	(1.42)	(8.45)	(0.02)	(-0.09)	(0.35)	(0.48)	(4.79)	(8.44)	(1.50)	(1.92)
	Tags	7.57	7.49	9.47	3.64	5.00	4.77	4.73	0.00	0.00	0.00	0.00	5.04	4.90	5.01	4.81
		(-1.77)	(-1.84)	(0.13)	(-0.02)	(1.36)	(-0.23)	(-0.27)	(-3.64)	(-5.00)	(-4.77)	(-4.73)	(0.05)	(0.14)	(0.01)	(0.05)
Priors	Sel.Ch	42.29	41.48	42.69	42.55	42.27	42.68	43.93	42.31	42.46	43.10	44.75	40.59	40.76	41.62	41.32
		(0.01)	(-0.80)	(0.42)	(0.01)	(-0.27)	(0.40)	(1.65)	(-0.24)	(0.19)	(0.42)	(0.82)	(-1.68)	(-1.92)	(-0.65)	(-1.36)
	Sel.sm	22.45	22.75	23.52	24.08	22.74	23.29	23.56	24.05	21.98	22.91	23.03	22.14	23.34	22.11	23.12
		(-0.01)	(0.29)	(1.07)	(-0.06)	(-1.34)	(0.56)	(0.82)	(-0.03)	(-0.76)	(-0.38)	(-0.53)	(-0.59)	(0.05)	(-0.63)	(-0.17)
	Sg.R	-22.84	-23.67	-24.75	-24.41	-24.41	-24.81	-24.72	-24.29	-23.29	-24.35	-24.35	-23.89	-24.52	-23.28	-24.52
		(0.88)	(0.05)	(-1.03)	(0.01)	(0.00)	(-0.40)	(-0.31)	(0.12)	(1.12)	(0.46)	(0.38)	(0.53)	(0.30)	(1.13)	(0.30)
	M(0)	0.00	0.00	0.00	0.01	0.93	0.46	0.37	0.00	0.02	0.00	0.00	0.83	0.48	1.11	0.58
		(0.00)	(0.00)	(0.00)	(0.01)	(0.92)	(-0.47)	(-0.56)	(-0.01)	(-0.91)	(-0.46)	(-0.36)	(-0.09)	(0.02)	(0.18)	(0.12)
	M(10)	0.00	0.00	0.00	0.25	0.11	0.03	0.01	0.27	0.22	0.08	0.04	0.08	0.03	0.12	0.04
		(0.00)	(0.00)	(0.00)	(0.25)	(-0.15)	(-0.08)	(-0.10)	(0.02)	(0.12)	(0.05)	(0.03)	(-0.03)	(-0.00)	(0.02)	(0.01)
	Steepness	0.00	0.00	0.00	0.00	0.03	0.05	0.04	0.00	0.00	0.01	0.00	0.14	0.17	0.04	0.07
		(-0.00)	(-0.00)	(-0.00)	(0.00)	(0.03)	(0.02)	(0.02)	(0.00)	(-0.02)	(-0.04)	(-0.04)	(0.11)	(0.12)	(0.02)	(0.02)
	compared to	C1S1L1	C1S1L1	C1S1L1	C0S0L0	C0S0L0_free	C0S1L1_free	C0S1L1_free	C0S0L0_free	C0S1L1_free	C1S1L1_free	C2S1L1_free	C0S0L0_free	C1S1L1_free	C0S0L0_free	C1S1L1_free

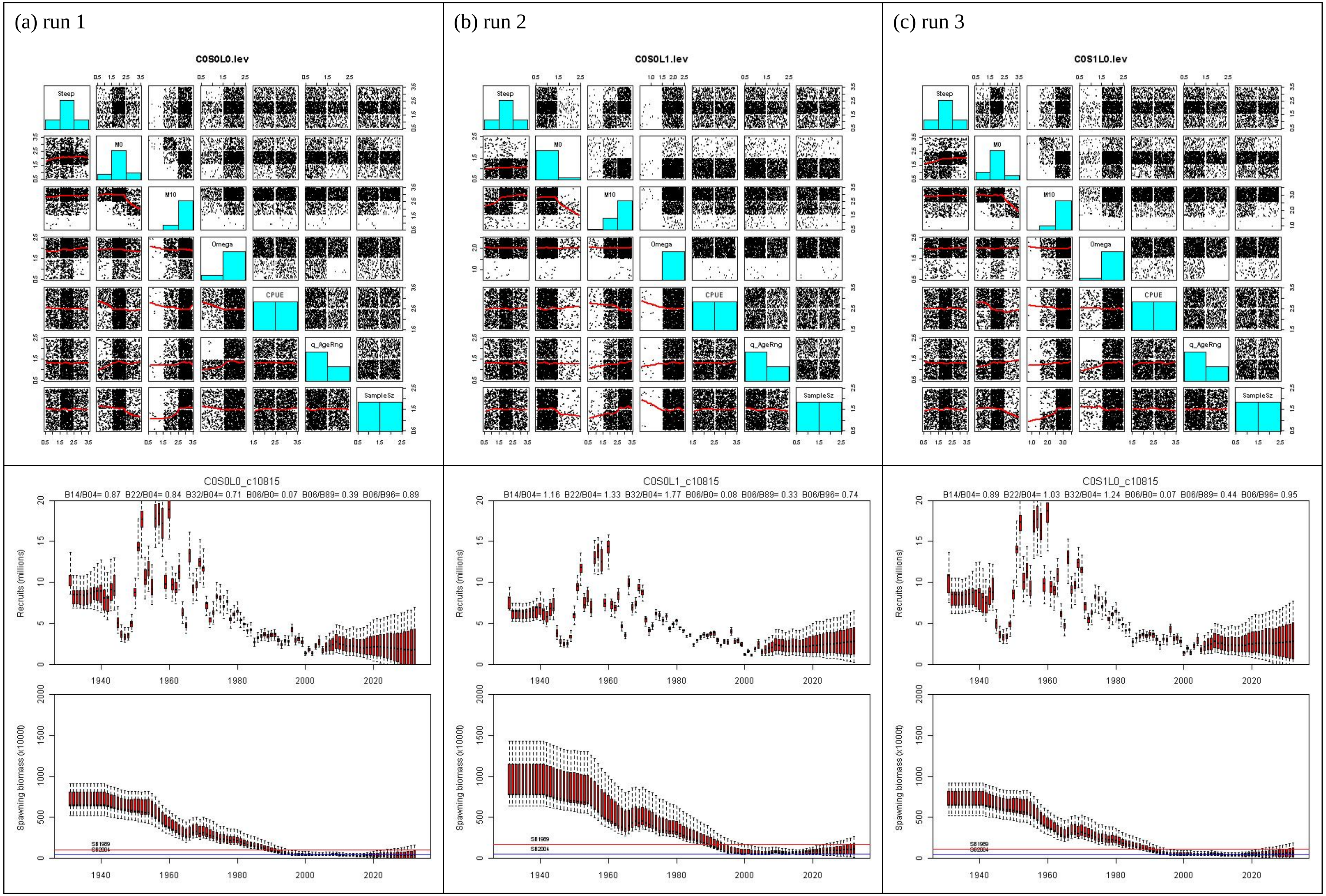


Fig. 1. Estimated distributions for each uncertainty axis (upper panels), and recruitment and biomass trajectories of 2000 scenarios (lower panels).

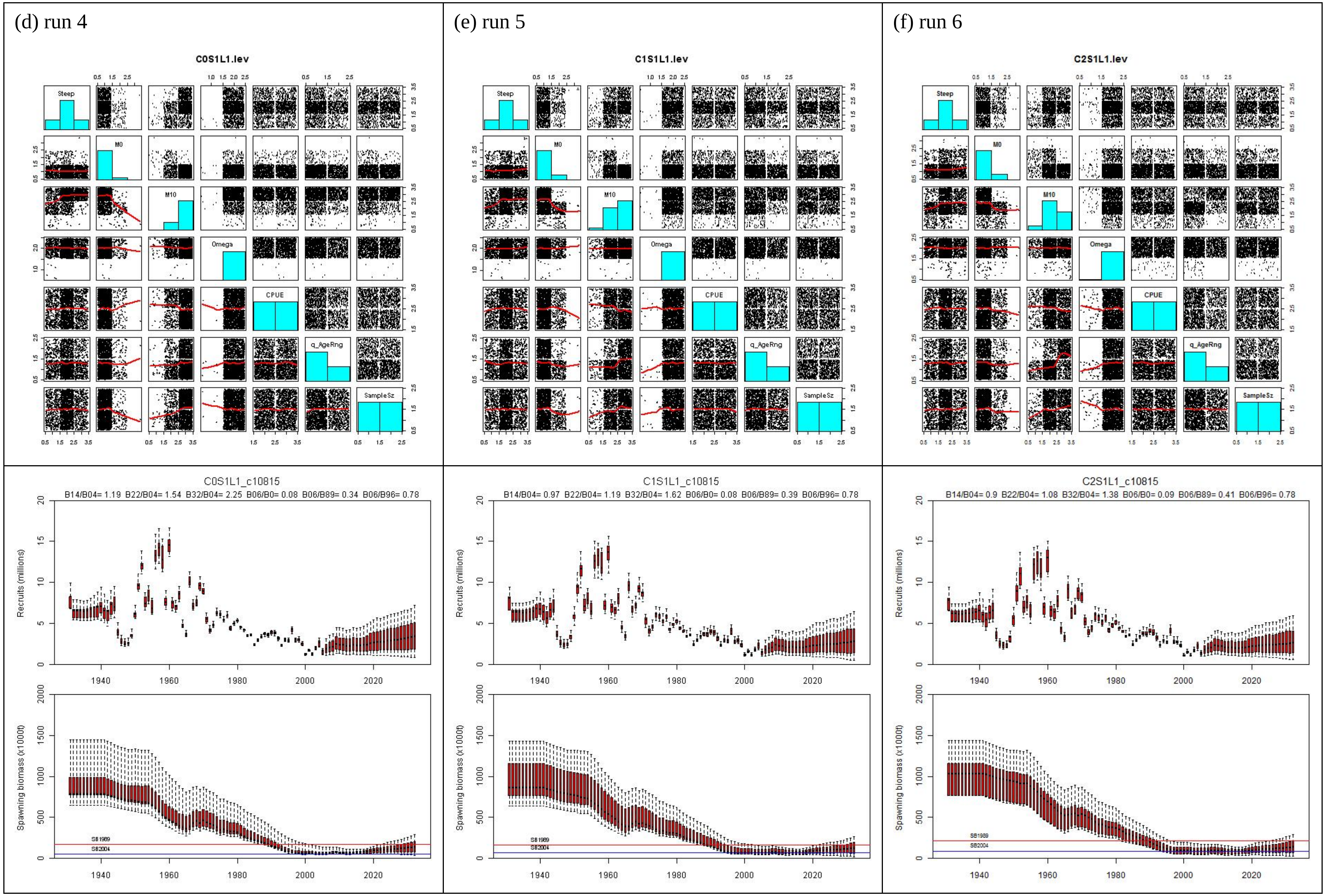


Fig. 1. (continued)

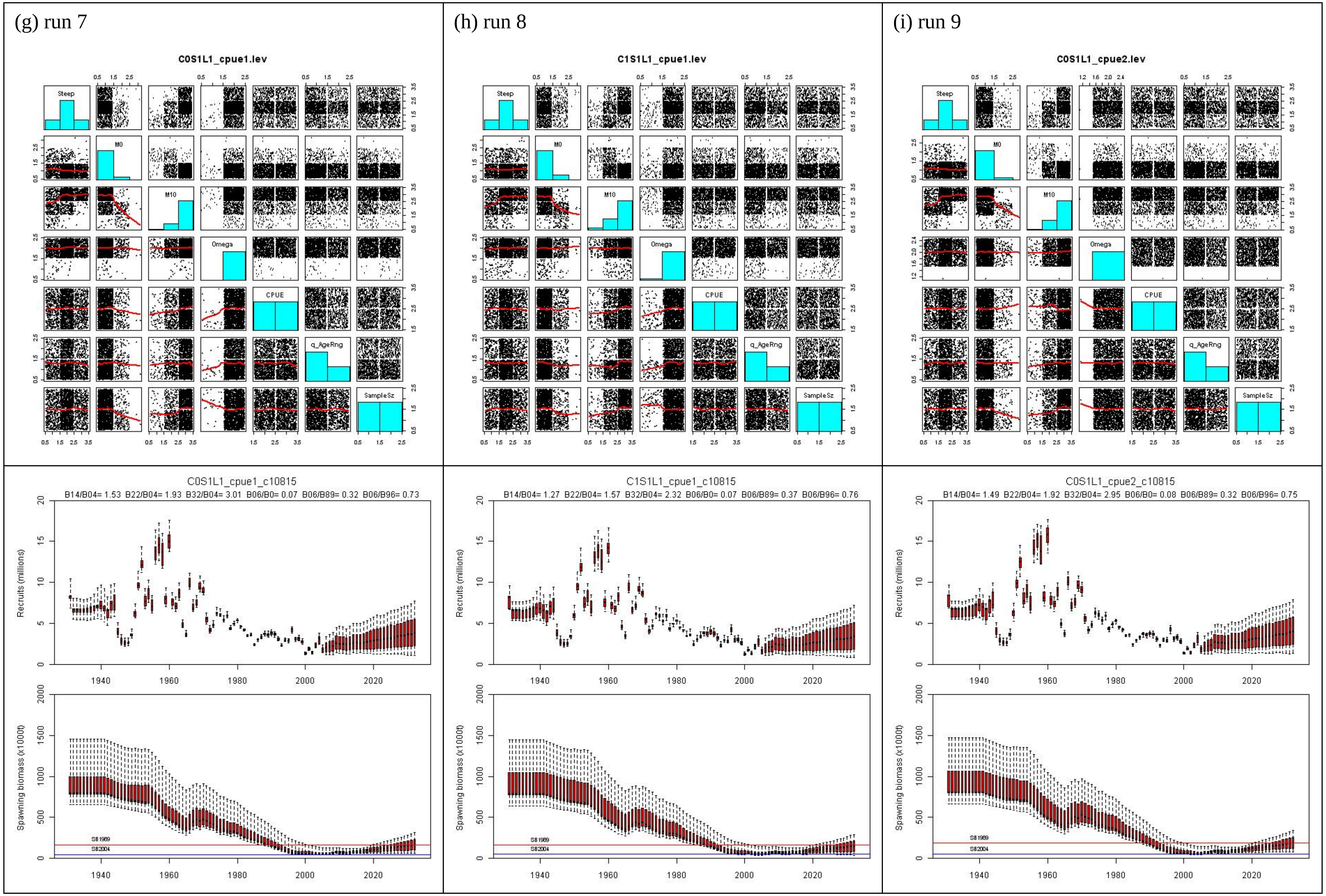


Fig. 1. (continued)

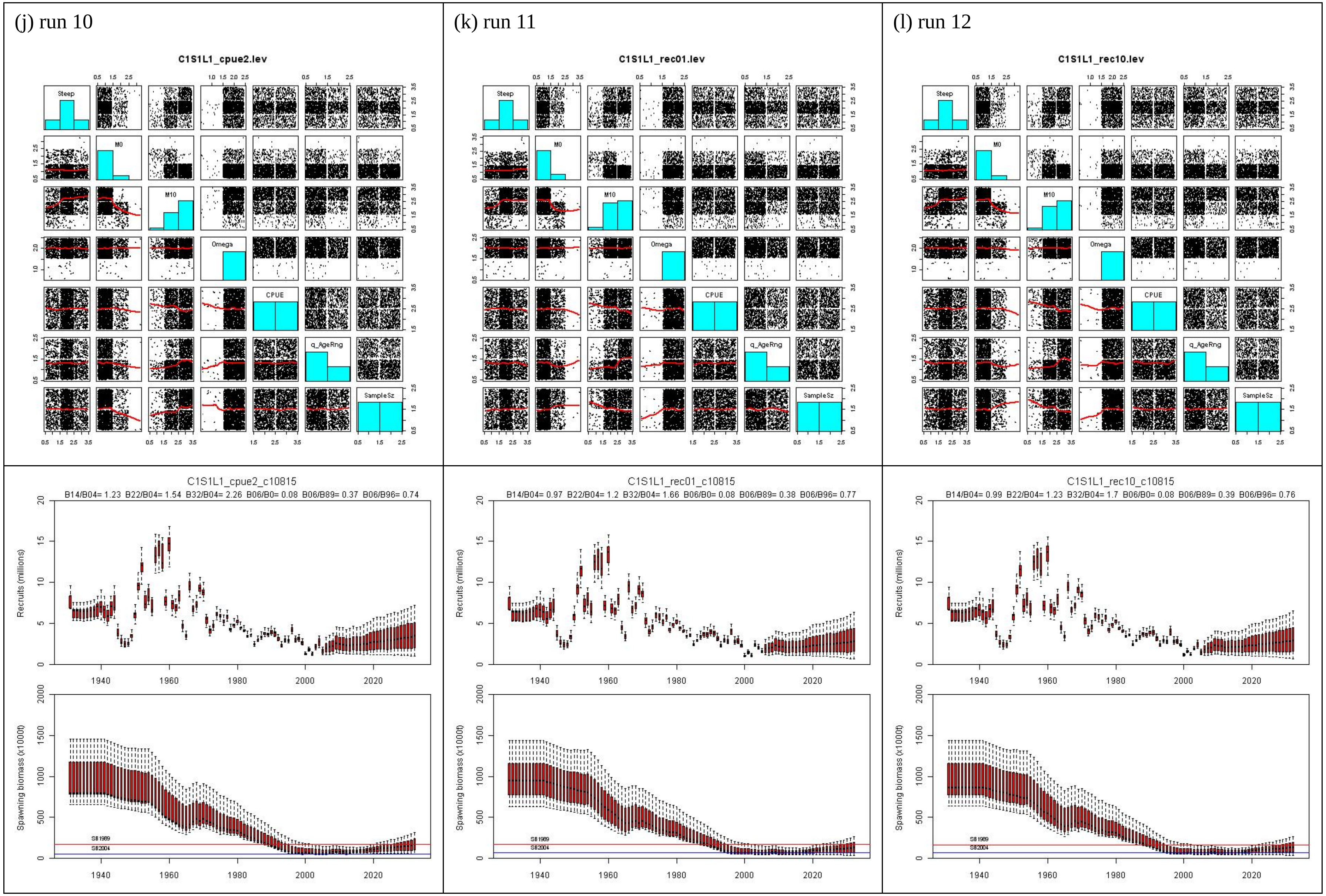


Fig. 1. (continued)

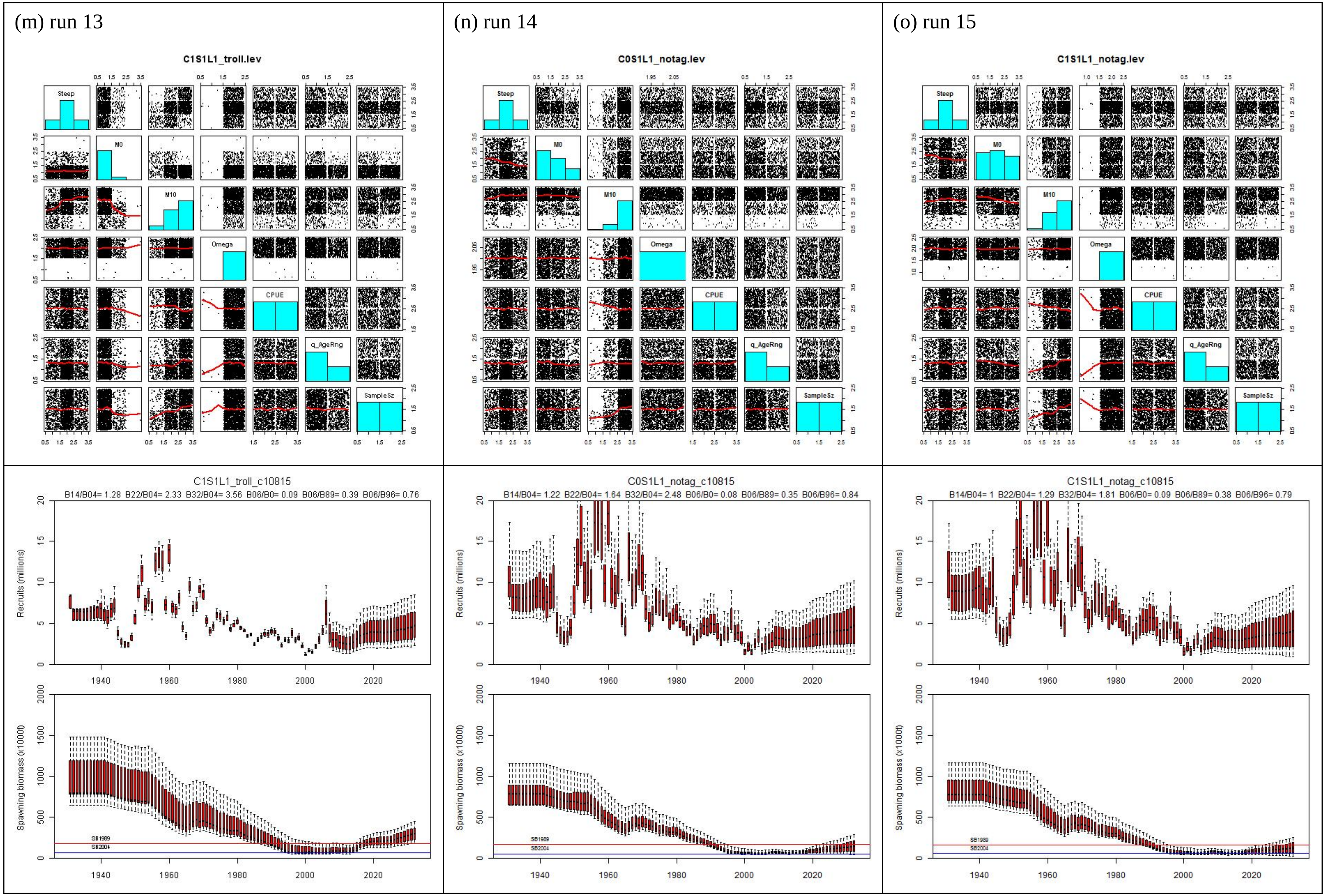
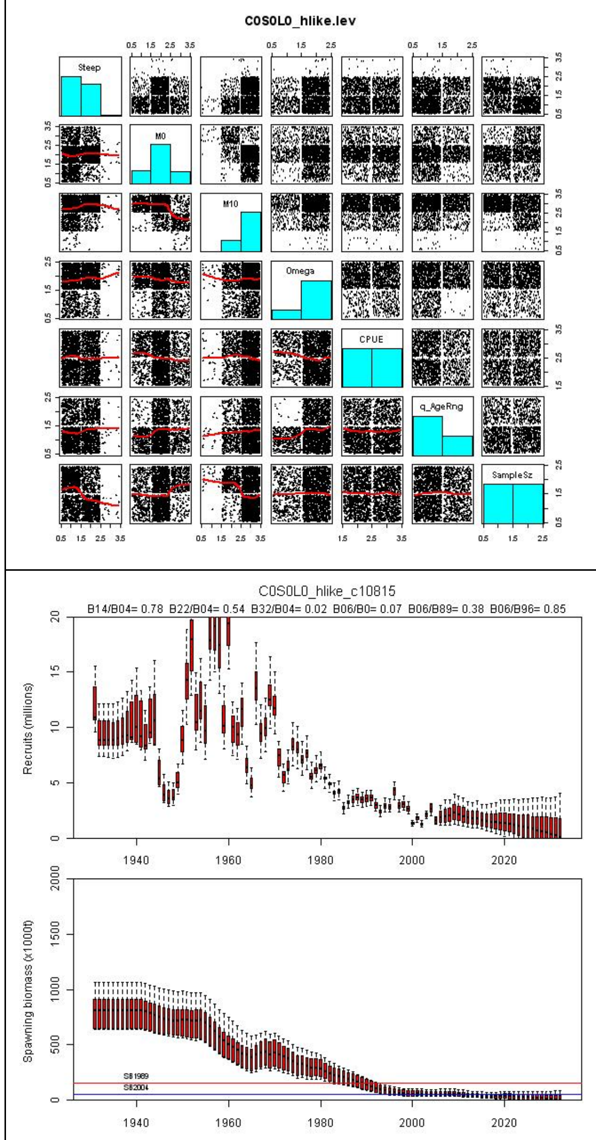
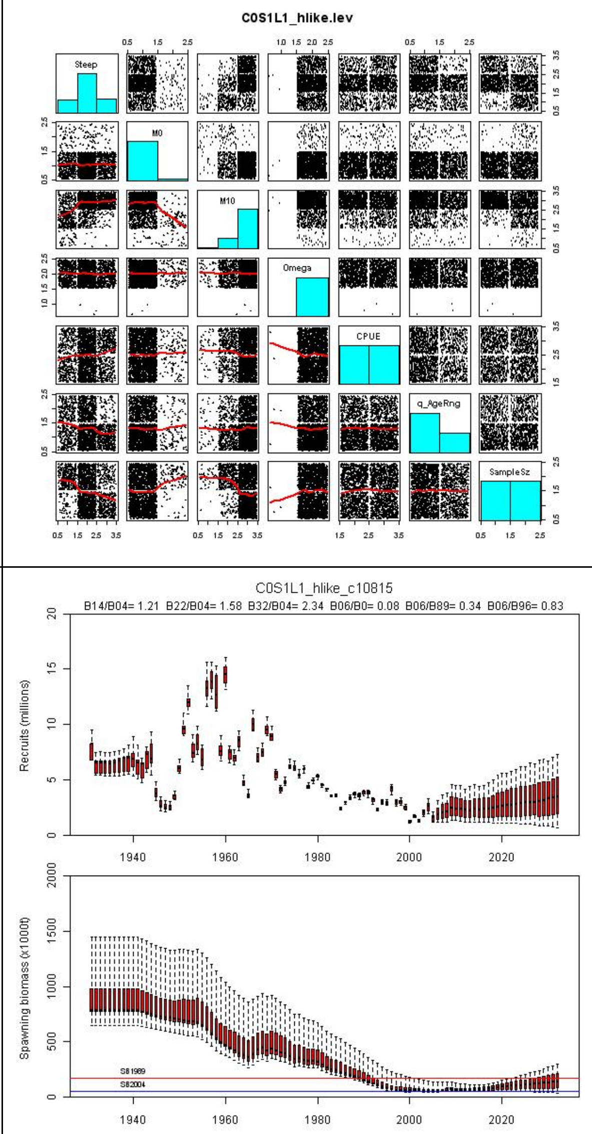


Fig. 1. (continued)

(p) run 16



(q) run 17



(r) run 18

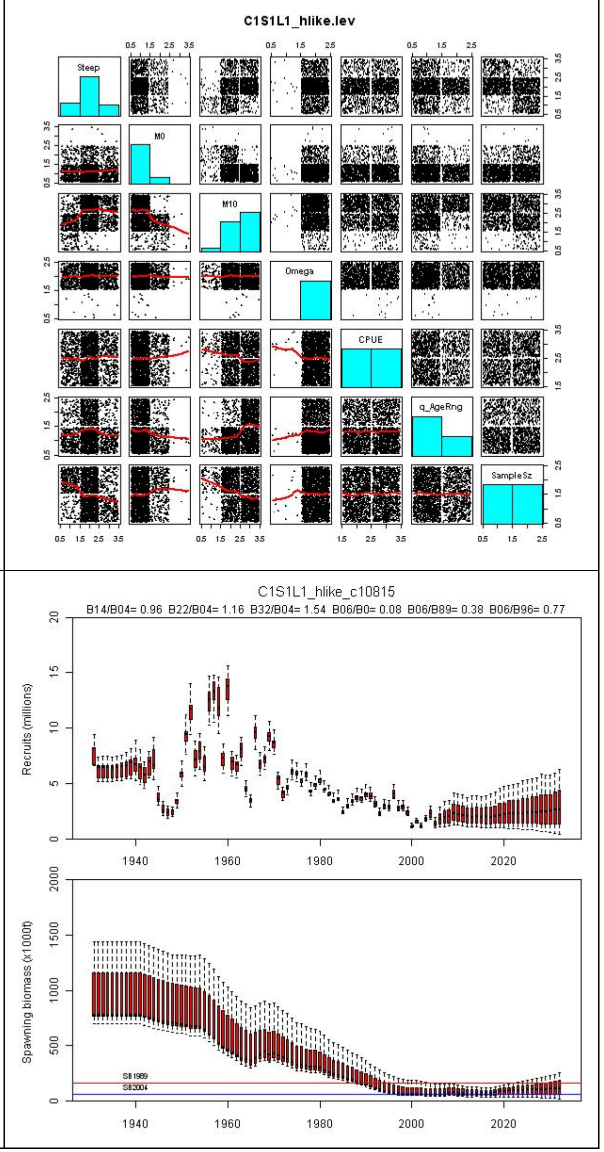
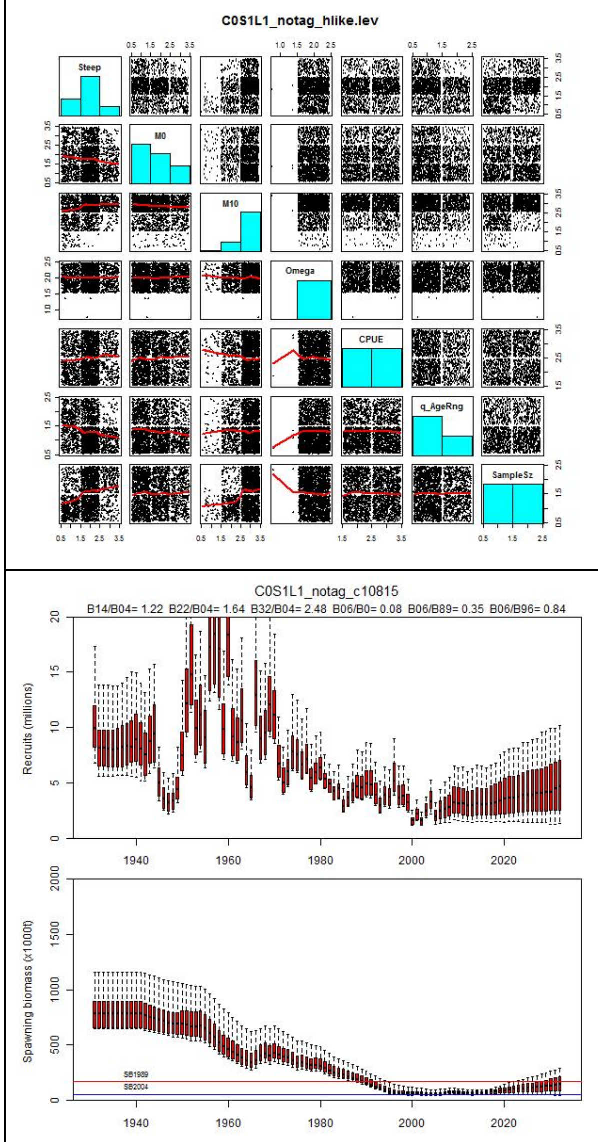


Fig. 1. (continued)

(s) run 19



(t) run 20

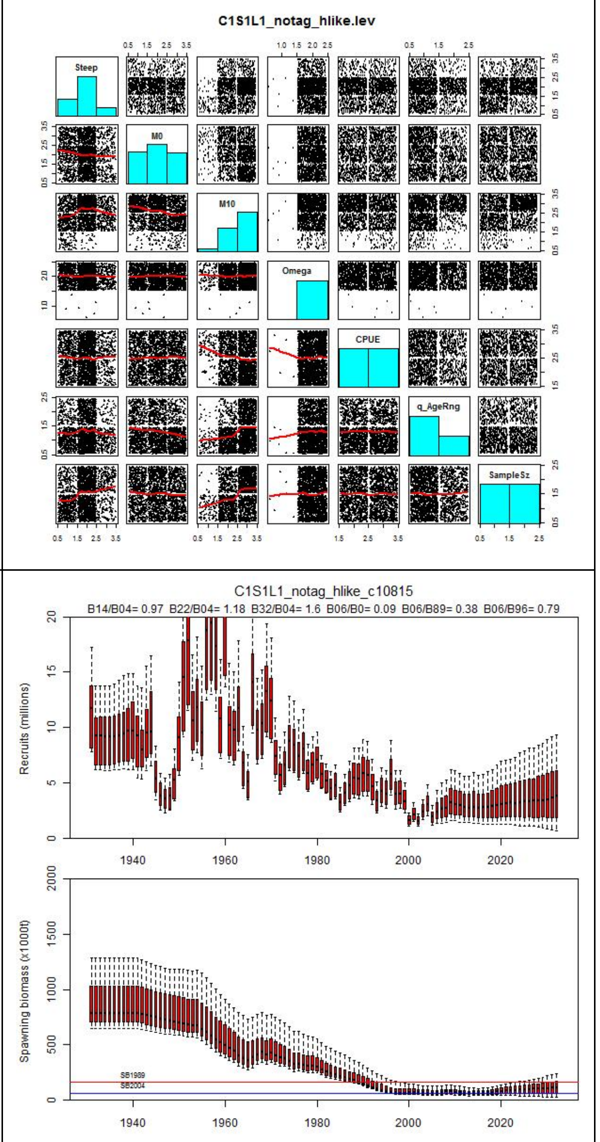


Fig. 1. (continued)

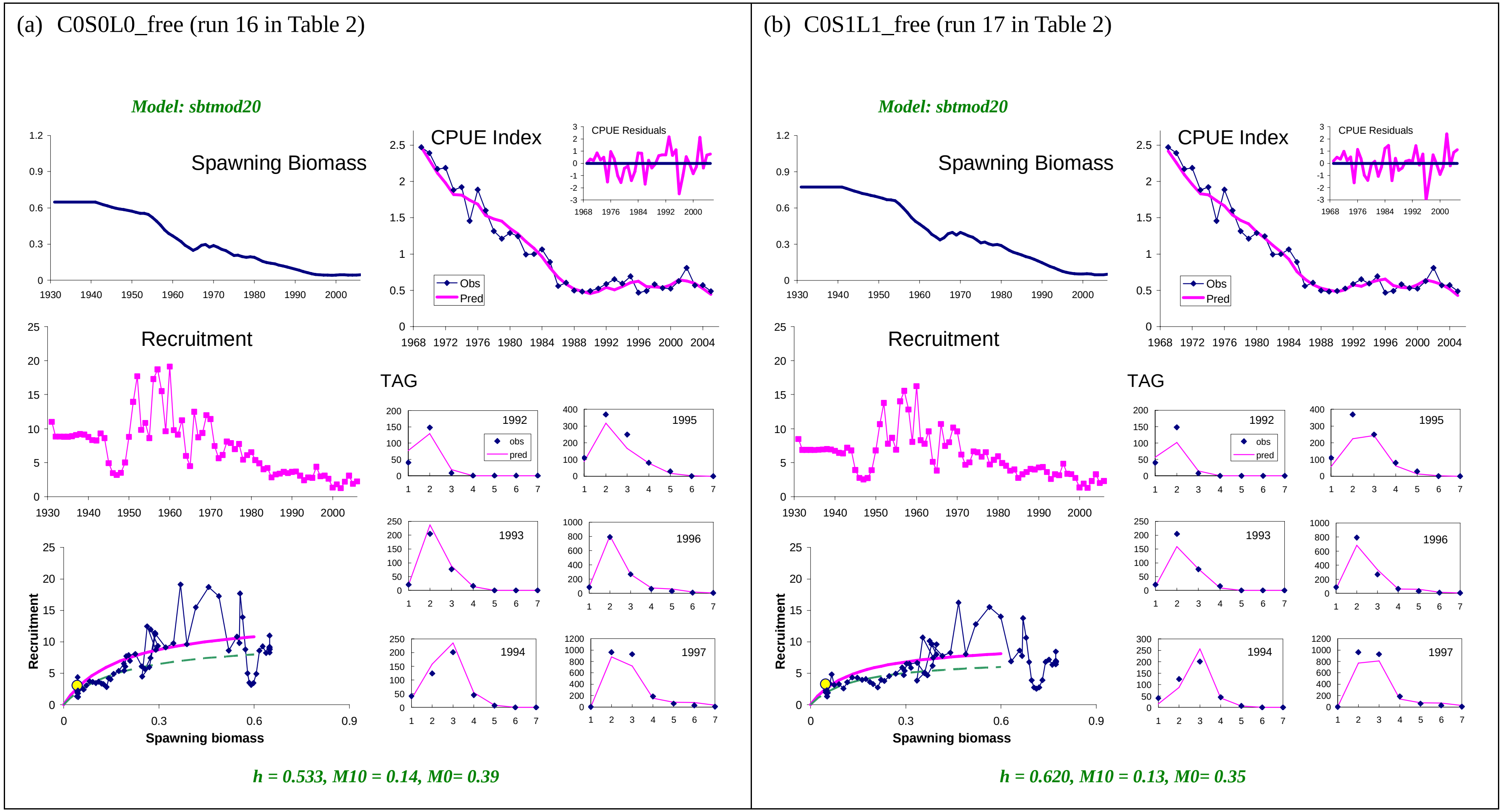
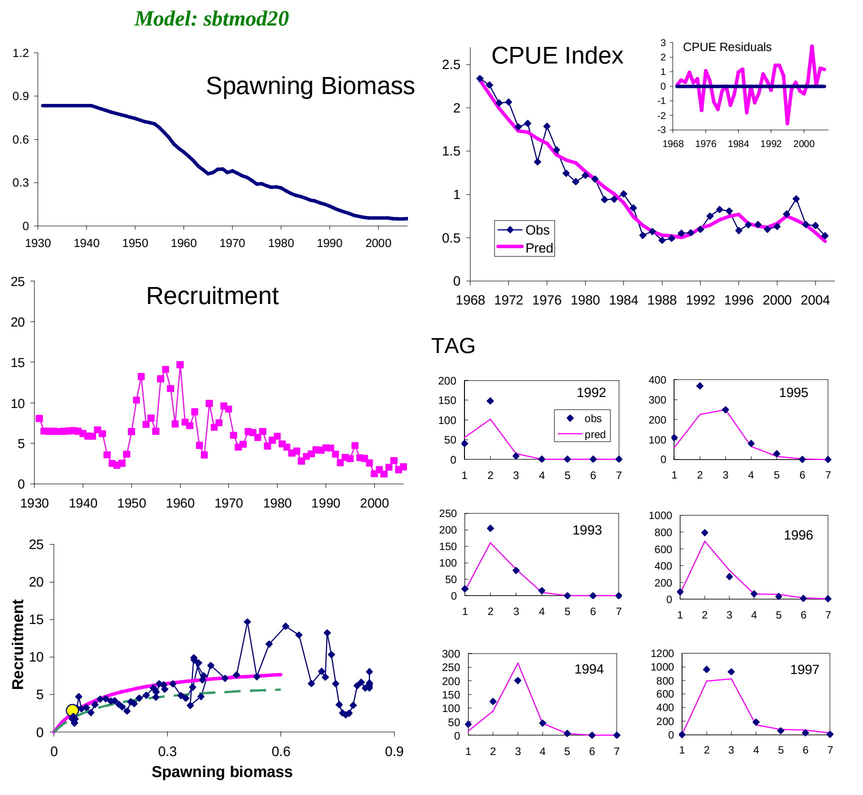


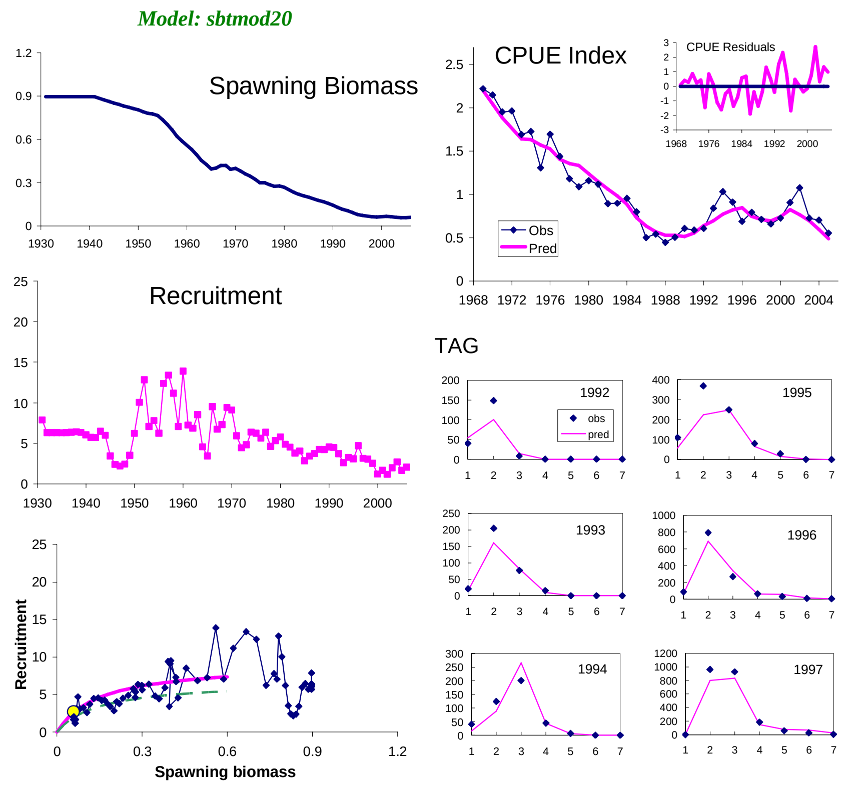
Fig. 2. Summary conditioning results for certain specific scenarios.

(c) C1S1L1_free (run 18 in Table 2)



h = 0.646, M10 = 0.11, M0= 0.36

(d) C2S1L1_free (run 19 in Table 2)



h = 0.639, M10 = 0.11, M0= 0.37

Fig. 2. (continued)

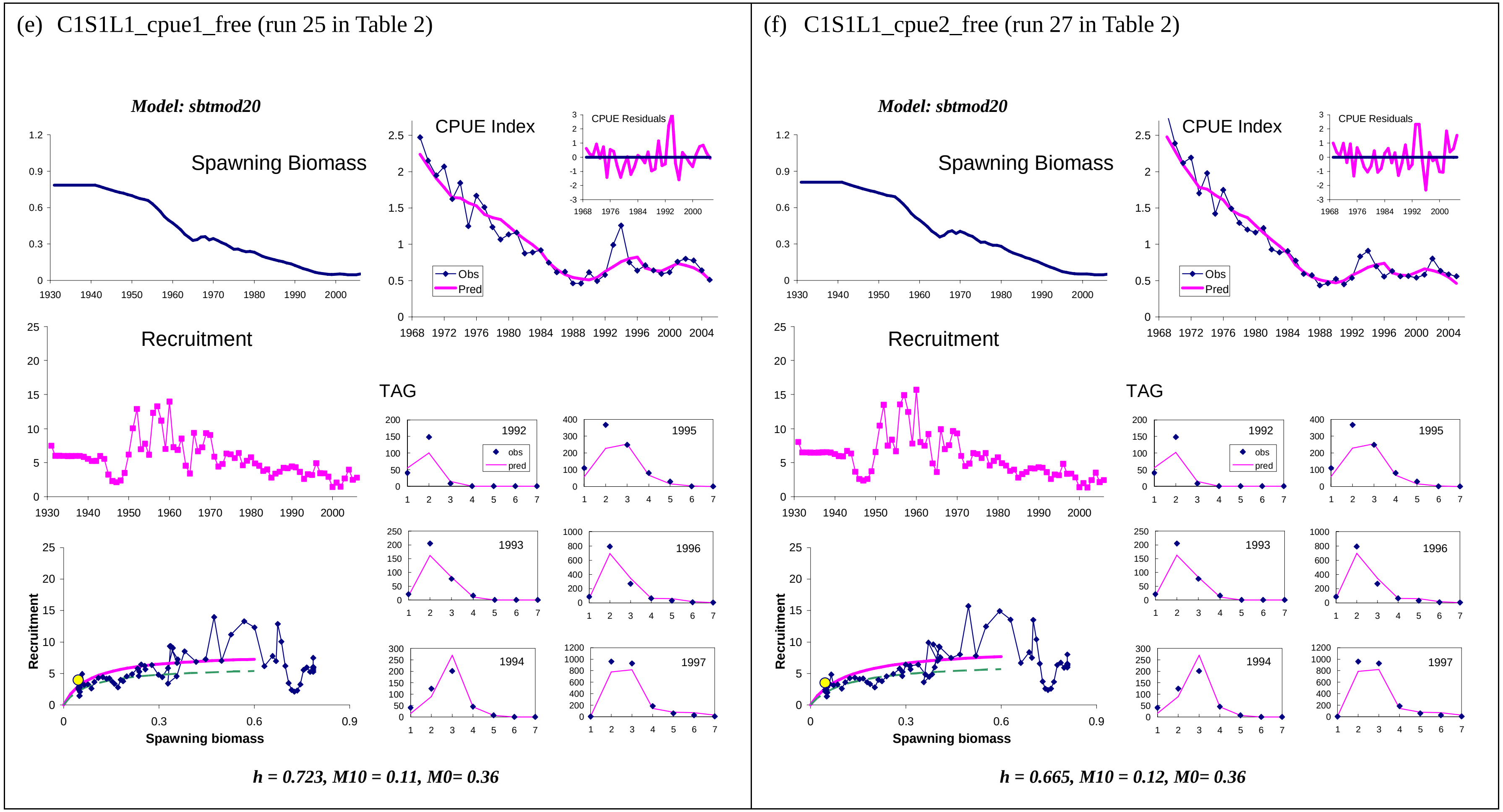


Fig. 2. (continued)