Further Exploration of the Operating Model for the Management Procedure Evaluation.

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Abstract

Specification of the Operating Model for the Management Procedure development is further explored. First, results of the core set specified as the basis for the final reference set are examined. They are highly dependent on the CPUE series used and the pessimistic result is considered to be related to low estimate of the omega parameter (CPUE-abundance relationship). Several sensitivity analyses regarding the tagging data weight and CPUE assumptions are also conducted. Finally, alternative model specifications are tested. Error structure and sample size for age and length composition data influence conditioning and future projection results significantly. It is necessary to determine the final reference set and the robustness trials in consideration of these results.

Introduction

The Stock Assessment Group (SAG) meeting in September 2004 determined that the Operating Model (OM) for the Management Procedure (MP) evaluation should be further developed, because all problems regarding the OM had not been solved in the meeting (CCSBT, 2004). Members are required to examine results of the core set specified as the basis for the final reference set and explore the impact of changes in the model assumptions and input data. This document refers to several important factors to determine the final reference set and the robustness trials, which will be finalized in February 2005 at the Seattle meeting.

The SAG adopted a new approach called the grid approach to integrate uncertainties of the OM into the reference set in place of the MCMC approach due to time constraints. The grid approach constructs the reference set from a large number of MPD results (scenarios) which cover the range of uncertainties in some fundamental parameters and input data: steepness, M0 (natural mortality at age 0), M10 (natural mortality over age 10), omega (CPUE-abundance relationship) and CPUE series, and the weight of scenarios is assigned based on priors (steepness and CPUE) or the combination of priors and likelihood (M0, M10 and omega). Following the grid approach, all analyses in this document were basically conducted with “main.tpl”, “sbtmod14.tpl” and “sample.tpl”, which were programs of the AD model builder (ADMB) distributed on 30 September 2004 by Ana Parma.

Future projections at the current catch (14930 mt) were also calculated to investigate model behaviors. It took over five hours to complete one grid integration, although the calculation time depended on model assumptions and machine power of PC.

<u>Consideration of the core set</u>

- *general feature and future projection result*

The core set is integrated across the five grid axes from 270 scenarios by the grid approach and it consists of 2000 stochastic realizations. Before examining results of the core set, I investigated numerical problems related to the local minima found for the previous versions (Panel, 2004). Several different initial values were set for the estimation. Converged estimates did not change from the originally estimated values in almost all cases where I had examined, although the maximum gradient component in convergence calculated by the ADMB was not so low (more than 10^{-4}). The core set would be more robust to the problem related to the local minima.

Figure 1 shows historical estimates of biomass and recruitment and future projections at the current catch for the core set. The projection result became more pessimistic than those with the previous OMs and the population would collapse in 30 years in many cases. I also conducted projections using different constant catches (Figure 2, Table 1). This pessimistic result would influence our choice of tuning levels for the MP evaluation.

- *strong interaction of CPUE and omega*

At first, I suspected that the pessimistic result of the core set was caused mainly by low recent recruitments in 2000 or later. However, population extinction was seen in many cases even without autocorrelation of future recruitments (noAC; Figure 3). This indicates that historical estimates of fundamental parameters of the population also become pessimistic.

The core set result was found to be highly dependent on CPUE series both in the conditioning and future projection (Figure 4). The result using the ST-window series was the most optimistic and biomass trend would be almost constant under the current catch. On the other hand, the w0.5 series produced very pessimistic result and the population would collapse around 2015 under the current catches. I found that these differences reflected differences in M0, M10 and omega estimates which are closely connected to each of CPUE series. Table 2 shows the number of realizations for each value of M0, M10, and omega by different CPUE series. The comparison between the ST-window and the w0.5 reveals a significant difference in distribution of omega values. The ST-window settled with the omega as 1.0 in much higher proportion than that for the w0.5. Figures 5 and 6 show conditioning results of “h2m2M2O2C4” (ST-window) and “h2m2M2O1C5” (w0.5), respectively, each of which is one of major scenarios in each CPUE. Likelihood components of the two are different mainly in CPUE and Indonesia CAA fittings (Table 3).

In all CPUE series except the ST-window and the Laslett, the omega parameter put higher weight to 0.75 than 1.0, although the prior weight of 0.75 was smaller (Table 2). I consider that this low omega is one of major reasons for the pessimistic result of the core set. It is necessary to pay more attention to omega values and their interaction to CPUE series as well as natural mortality.

- *low recruitment in 2000 and 2001 with low CVs*

Recruitment estimates before 2001 are used for the future projection without any modification. The narrow error bound on the recent recruitment estimates is one of issues to be further considered. Basson et al. (2004) indicated that CVs on recent recruitments in each scenario, which are approximated from the Hessian by the ADMB, are higher than those on past recruitments around 1960-1990. The same trend was observed when examining individual scenario independently as shown in Figure 7a as an example. This reflects limited amount of information on recent recruitment and it is quite natural.

However, the examination of CVs of recruitment obtained from all 2000 realizations of the core set (from Cfullnotag.s4) showed a different trend (Figure 7b). CVs were about 0.3 to 0.4 through all times except late 1970s and 1980s and they were almost constant from 1990 to 2001. This result shows that CVs in 2000 and 2001 are not lower compared to those in other years, but it also indicates that the time dependency is not strong. This difference in CV trends between each individual scenario and the core set must relate to the grid integration. If the grid approach is continued to be used, this issue would be needed for discussion.

I also investigated the reason for low recruitments in 2000 and 2001. In place of developing the program code for the retrospective analysis, I replaced the size composition data of LL1 catches in 2002 and 2003 with the average value of 1999-2001 data. This is an examination of what would be happened if no change were occurred in LL1 catch in 2002 and 2003, although there were few small fish in 2002 and 2003 in reality. Run using the new replaced data showed that recruitments were higher than those for the base case (core set) and that they were at almost the same level as those in the previous years (Figure 8). Therefore I consider that one of the reasons for the low recruitment estimate is lack of small fish in 2002 and 2003.

<u>Sensitivity test</u>

- *tagging data*

Further examination of tagging data was considered as a high priority for the analyses (CCSBT, 2004). New tagging data updated by Australian scientists were used in this analysis, but in general the conditioning results did not change significantly. The following is a brief summary of the results when incorporating new tagging data (Cfulltag):

1) B0 was lower than that for the core set and the decline rate (B2004/B0) was lower (Figure 9). Future projection was also more optimistic and the biomass was almost constant under the current catch (Figure 10, Table 4).
2) The error bounds on recent recruitments were narrower than those for the core set (Figure 7c).
3) Conditioning and projection results were highly dependent on CPUE series as in the core set (Figure 11, Table 5). B0 estimates were different among them. The ST-window had the most optimistic result and the w0.5 did the most pessimistic one. This difference is considered to reflect differences both in M10 and omega estimates.
4) Natural mortality was generally higher than that for the core set. Figures 12 and 13 are conditioning results of "h2m2M2O2C4_tag" and "h2m2M3O1C5_tag", each of which is one of major scenarios in each CPUE (also see Table 3). When M10 was higher, selectivity of the LL1 and the Indonesian fishery for older fish was higher. Comparison between "h2m2M2O1C5_notag" (Figure 6) and "h2m2M3O1C5_tag" (Figure 13) revealed that fitting to the tagging data was improved significantly when the weight for the tagging data increased. However, "h2m2M2O2C4_notag" (Figure 5) and "h2m2M2O2C4_tag" (Figure 12) did not show any major difference. Higher M0 and M10 values are preferred in all CPUE series except the ST-window (Table 5).
5) Omega values totally increased in all CPUE series compared to those for the core set. This is considered to be one of the reasons why the result is more optimistic when incorporating the tagging data.

As noted in previous meetings, one major problem in the way the model handles the tagging data is that reporting rates are assumed to be known (CCSBT, 2004). It is a key issue how the uncertainty could be incorporated to the model, if the tagging data were incorporated in the conditioning.

- *CPUE (median CPUE and age range for selectivity standardization)*

As noted earlier in the consideration of the core set, selection of CPUE series influences both conditioning and projection results substantially. Examination using the median of the five CPUE series showed that the general trend was similar to that for the core set, where the five different CPUE series were used individually (Figure 14, Table 6). However, the range of estimates was smaller. Especially the lower bound of biomass estimates in 2000 or later was close to the median, although the reason has not been clarified yet. The median CPUE could not cover enough uncertainties which the five different CPUE series involve.

I conducted the sensitivity analysis to the age range to standardize selectivity for CPUE predictions (Figure 15, Table 7). The age range was changed from 4-30 to 8-12. Results differed substantially, especially in selecting higher proportion of M10 and omega, and lower estimation of B0 and the current biomass. The future projection became much more pessimistic.

- *Indonesian fishery selectivity*

When the Indonesian fishery selectivity was assumed as constant over age 18, B0 and the current biomass were estimated to be lower and the future projection was more pessimistic (Figures 16, 17). It should be noted that the likelihood was much worse than for the base (Table 8).

Alternative model specifications

- *Sample size and error structure for age and length composition data*

The core set adopts the multinominal distribution as an error structure for age and length composition data. The sample size of each fishery was determined by the Panel in July 2004 by taking square of the old reference set times five to reduce the weight to the age and length composition data. I explored other alternatives for reducing the sample size and other error structures. The current program (sbtmod14.tpl) has additional two options for the error structure. One is the robust normal likelihood (Fournier et al., 1998) and the other is the log-normal distribution with variances based on the multinominal assumption and an additive variance term to consider additional process error (I called this “lognormal plus” approach). The additional process error was assumed to be the same among all fisheries.

Table 9 shows a summary of trials and results. I found that conditioning and future projection results depended on the error structure and the sample size significantly (Figures 18-25, Tables 10-17). Especially, the lognormal plus approach showed substantially different results. Although I have not examined each realization due to time constraints, this issue should be further examined. The following is a brief summary:

1) When using the old reference set as sample sizes, natural mortality, especially M10, had higher proportion in larger values than those for the core set irrespective of the error structure. B0 became lower. The projection results were more optimistic.
2) When the sample size was set as the half of the old reference set, the result was similar to that for the core set.

3) Runs using the robust normal distribution showed similar results as the default multinominal distribution.

4) The lognormal distribution resulted in higher M0 and omega values and more optimistic results. In addition, as the process error was assumed to be larger, the omega estimates became larger.

- *age-dependent natural mortality*

I explored different forms for age-dependency of natural mortality. Because the tagging data showed a strong interaction with natural mortality as noted earlier, the new modeling of natural mortality was applied both to "notag" and "tag" scenarios. Two alternatives were investigated to relax assumptions. First, the "m-slope", a curvilinear function to connect M0 and M10, was estimated instead of fixing it as 0.7. The range of m-slope was constrained from 0.3 to 1.2 in the estimation. Estimates of the slope were often different from the default value, but general form of age-dependency was not different significantly regardless of whether or not the tagging data was involved (Figures 26, 27) and the likelihood was not improved substantially enough to introduce the new parameter. Biomass and recruitment estimates also did not change (Figures 28, 29).

In some tuna species, natural mortality is considered to increase when fish is beyond a certain age (Hampton et al., 2003). If this is the case for SBT, it might influence not only natural mortality for young fish but also selectivity estimates. Therefore, in addition to M0 and M10, I introduced a new parameter "M20", which is natural mortality at age 20, by changing the program. I assumed that the mortality between age 10 and 20 changed linearly and it was constant beyond age 20. The range of M20 was set from 0.03 to 0.2. The results showed that average M10 estimates among all realizations were lower than those for the core set and M20 estimates were higher slightly than M10 (Figure 30). Historical biomass estimates generally did not change, but the recent trend of biomass was different especially when including the tagging data (Figures 31, 32). However, since the current projection program did not meet mortality change over age 10, the projection results were not able to be obtained.

<u>Reference</u>

Basson, M., Polacheck, T., Kolody, D., Preece A., and Hartog, J. 2004. Implications for management procedure evaluation: the mechanical update and further exploration of the operating model. CCSBT-ESC/0409/24.

CCSBT 2004. Report of the fifth meeting of the stock assessment group. Jeju, Republic of Korea, September 2004.

Fournier, D.A, Hampton, J., and Sibert, J.R. 1998. MULTIFAN-CL: a length-based, age-structured model for fisheries stock assessment, with applications to South Pacific albacore, *Thunnus* *alalunga*. Can. J. Fish. Aquat. Sci. 55:1-12.

Hampton, J., Kleiber, P., Takeuchi, Y., Kurota, H., and Maunder, M. 2003. Stock assessment of bigeye tuna in the western and central Pacific Ocean, with comparisons to the entire Pacific Ocean. SCTB16 Working Paper BET–1.

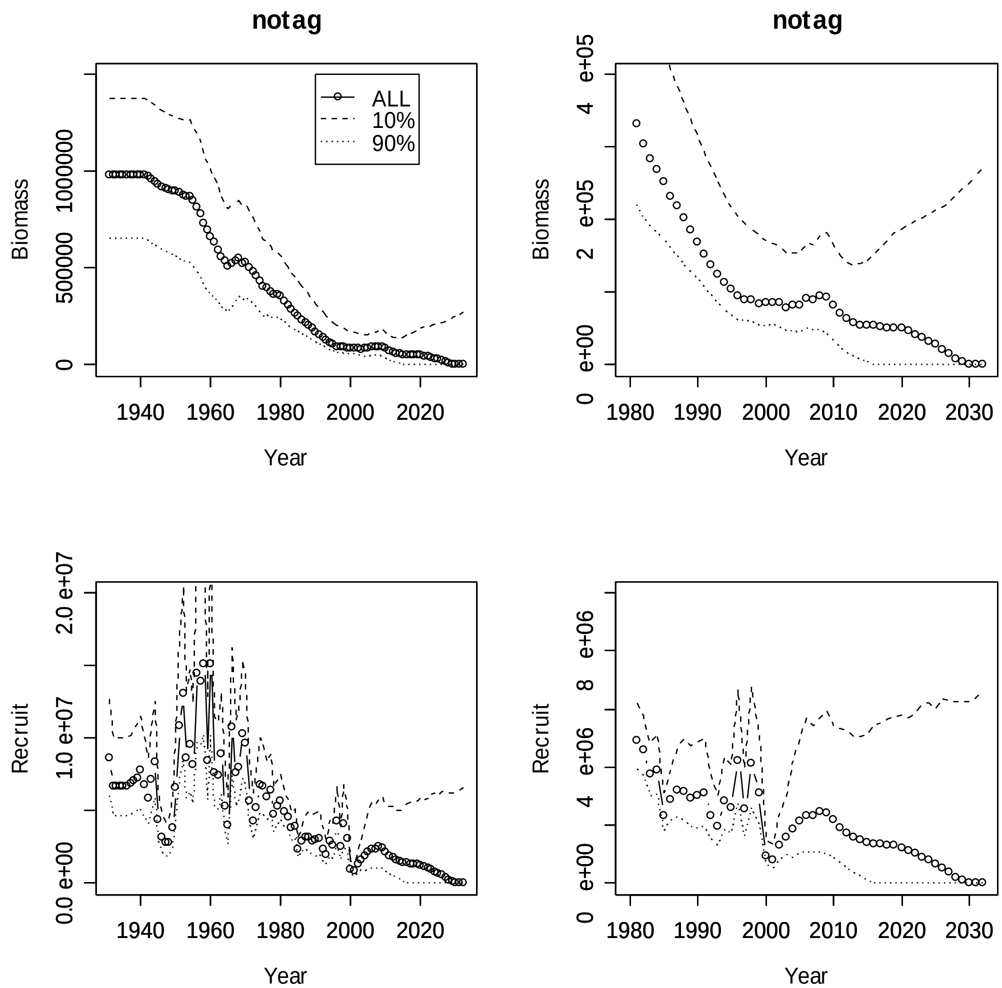


Figure 1. 10th, median and 90th percentiles of historical estimates of biomass (upper panels; left 1931-2032, right 1980-2032) and recruitment (lower panels; left 1931-2032, right 1980-2032) and future projections using the current catch for the core set. "ALL" represents the median of all 2000 realizations.

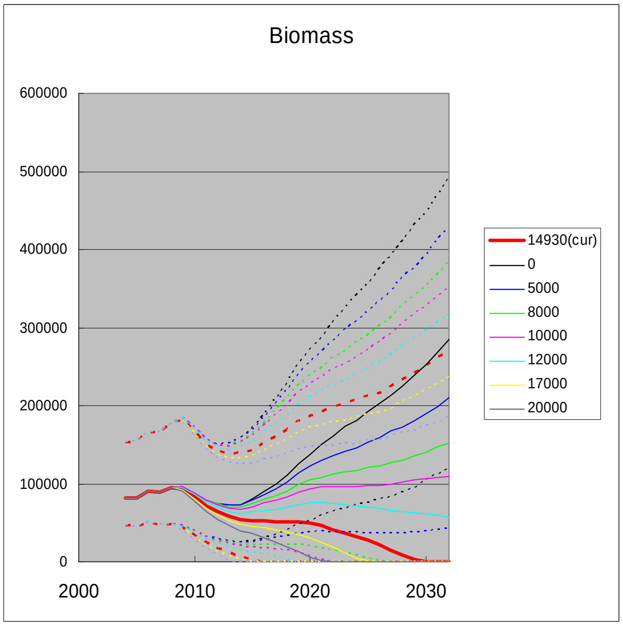


Figure 2. Future projection for the core set at different constant catches.

Table 1. B2022/B2004 for the core set at different constant catches.

Cfullnotag

constant catch level	B2022/B2004
14930	0.42
0	1.81
1000	1.74
2000	1.68
3000	1.62
4000	1.57
5000	1.50
6000	1.40
7000	1.29
8000	1.20
9000	1.11
10000	1.01
11000	0.88
12000	0.76
13000	0.64
14000	0.52
15000	0.42
16000	0.32
17000	0.21
18000	0.08
19000	0.01
20000	0.00

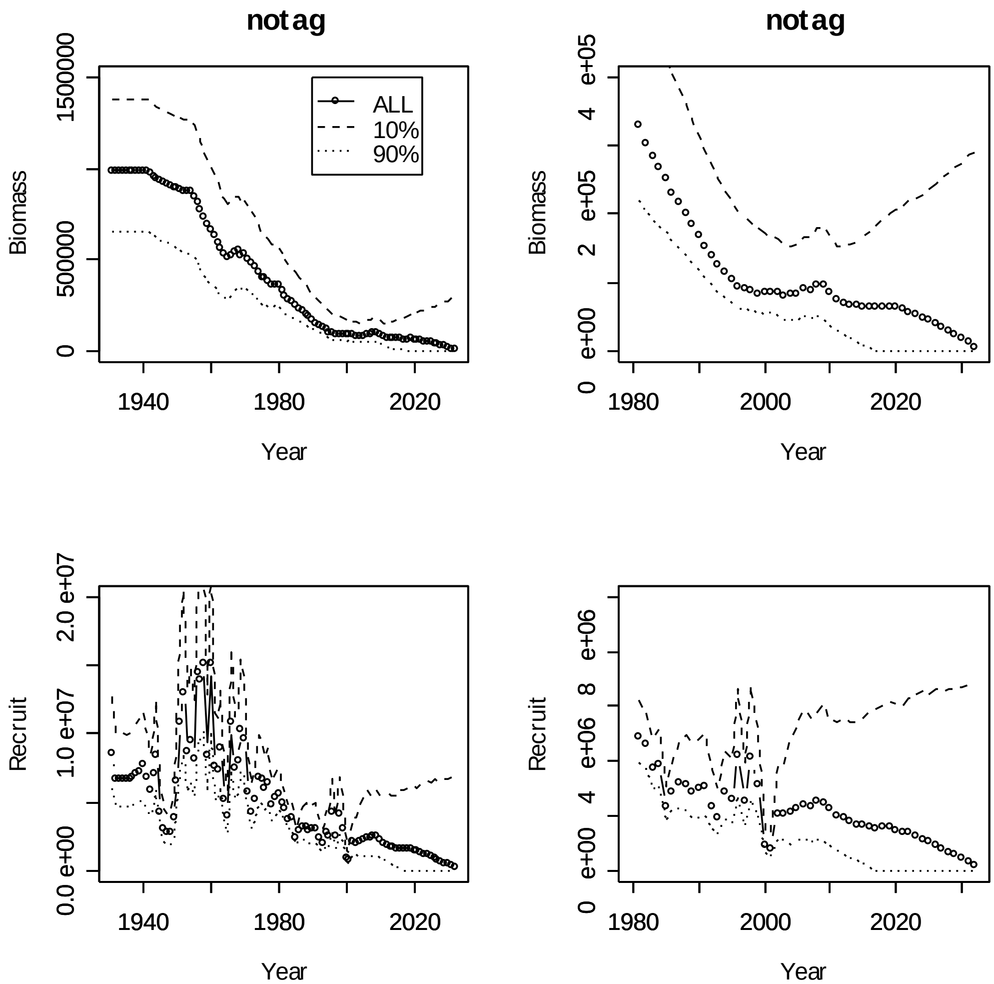


Figure 3. 10th, median and 90th percentiles of historical estimates of biomass (upper panels) and recruitment (lower panels) and future projections using the current catch for the noAC.

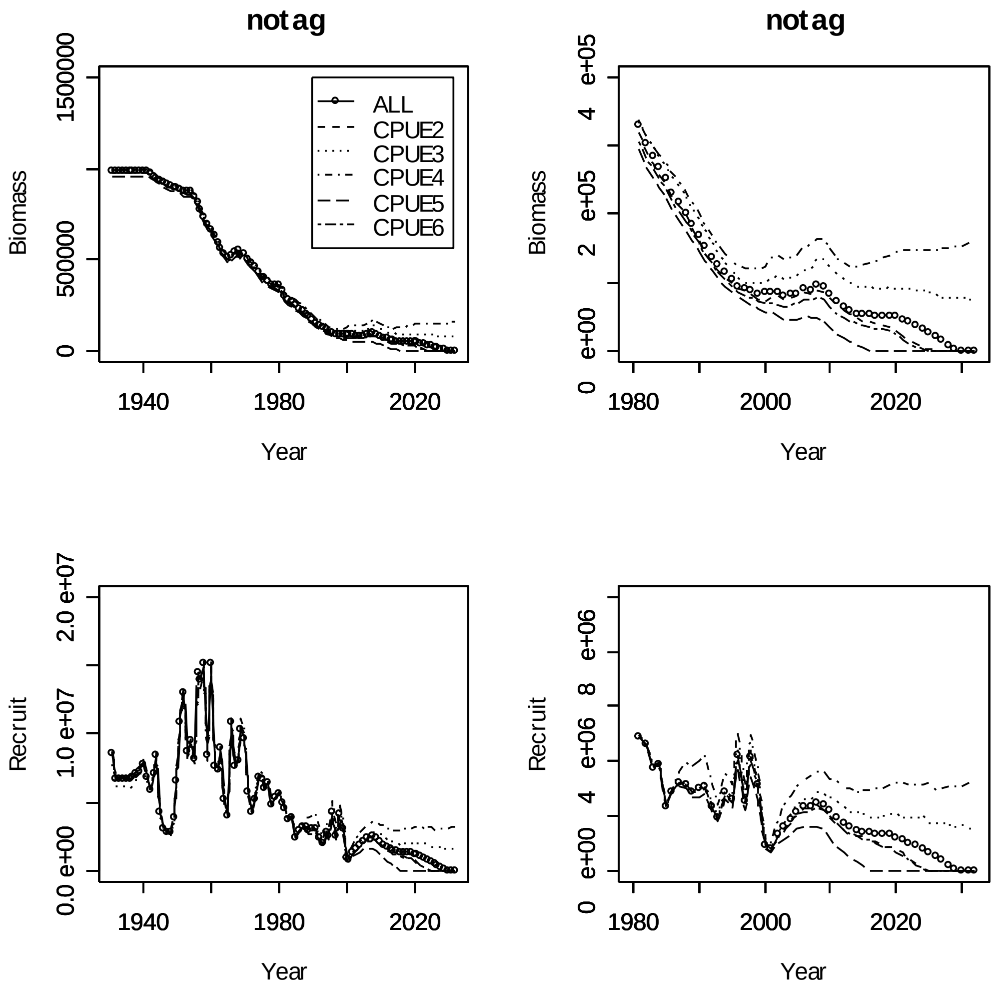


Figure 4. Comparison of the median of historical estimates of biomass (upper panels) and recruitment (lower panels) and future projections using the current catch for the core set among different CPUE series (ALL: all five CPUE series, CPUE2: nominal, CPUE3: Laslett, CPUE4: ST-window, CPUE5: w0.5, CPUE6: w0.8).

Table 2. The number of realizations in each level of M0, M10 and omega parameters in different CPUE series for the core set.

	m0			m10			omega	
cpue	0.3	0.4	0.5	0.07	0.1	0.13	0.75	1.0
nominal (2)	175	138	87	41	248	111	219	181
Laslett (3)	171	150	79	74	256	70	178	222
st-window (4)	169	138	93	88	202	110	48	352
w0.5 (5)	165	138	97	23	320	57	388	12
w0.8 (6)	165	144	91	48	282	70	376	24
all	845	708	447	274	1308	418	1209	791
average	0.380			0.102			0.849	

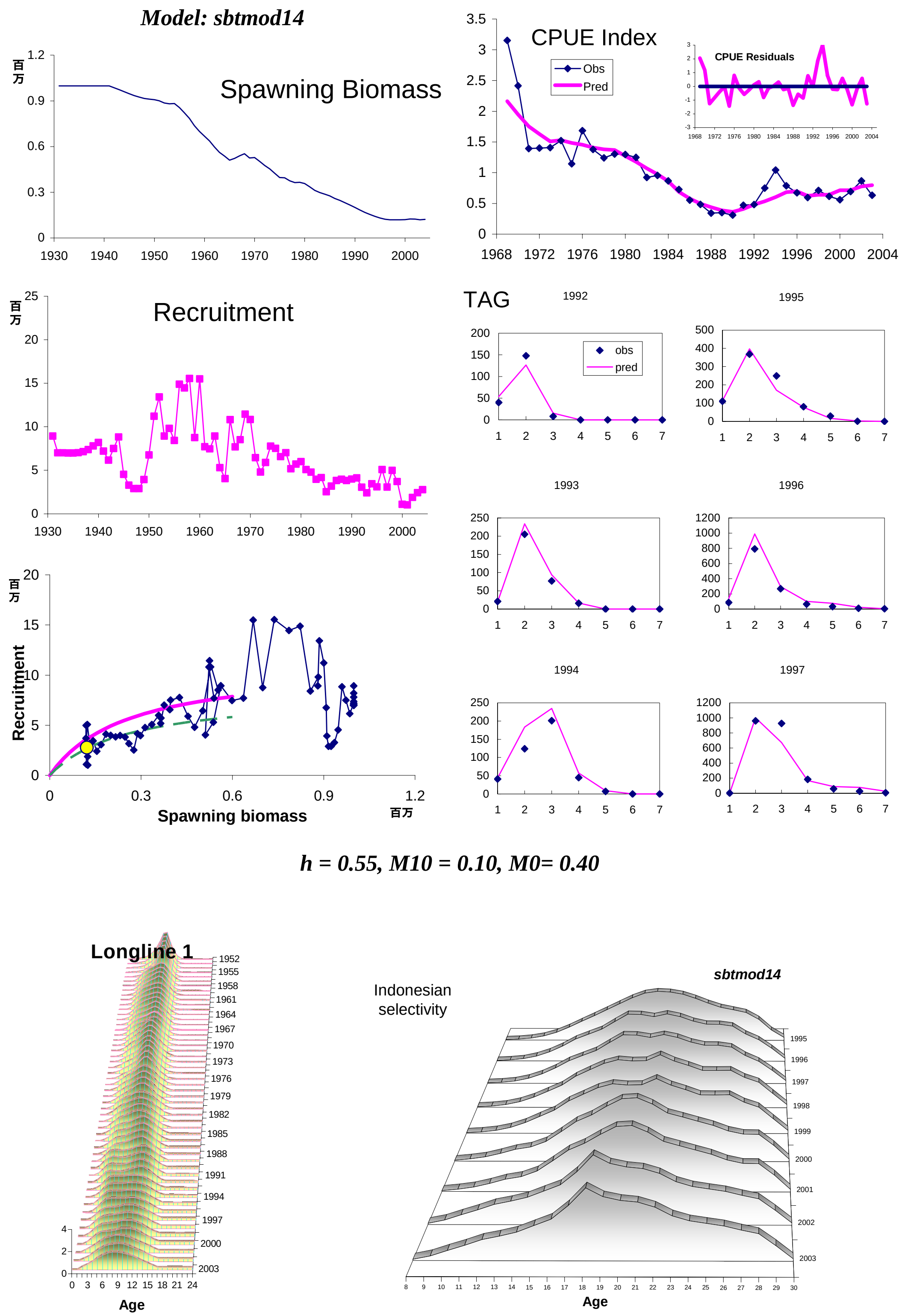


Figure 5. Conditioning results of h2m2M2O2C4_notag (core set).

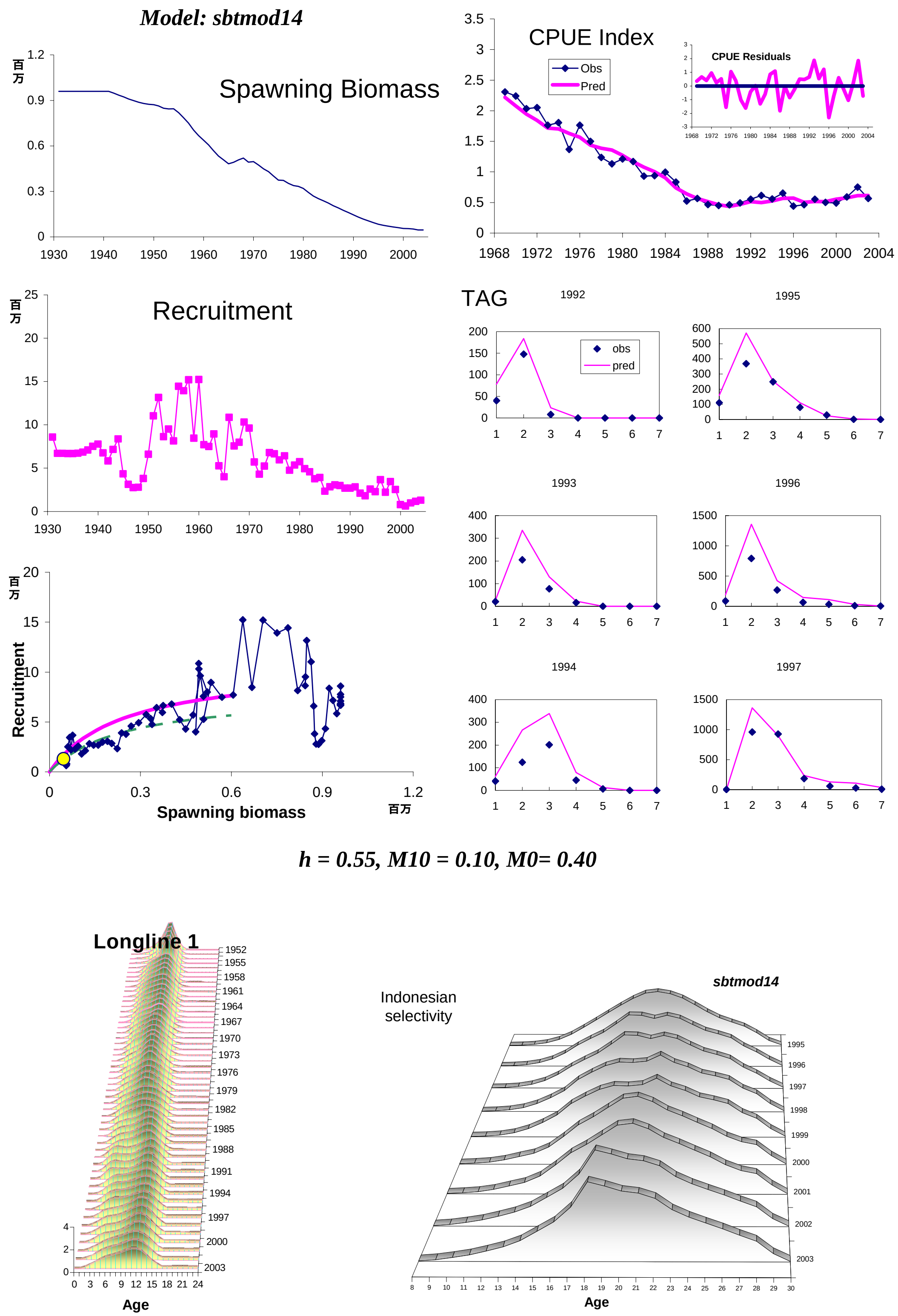
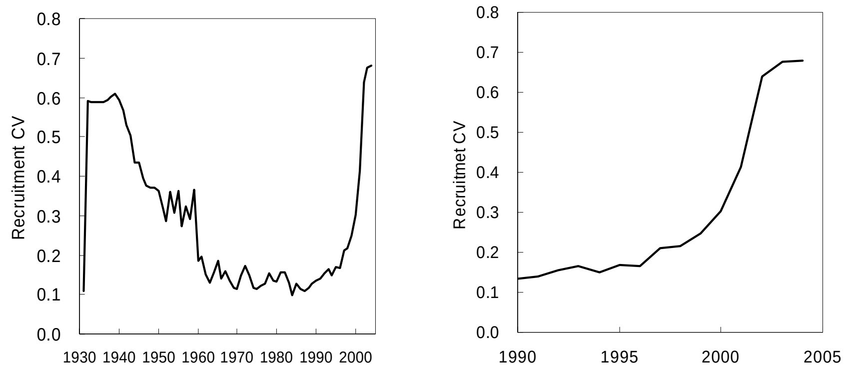


Figure 6. Conditioning results of h2m2M2O1C5_notag (core set).

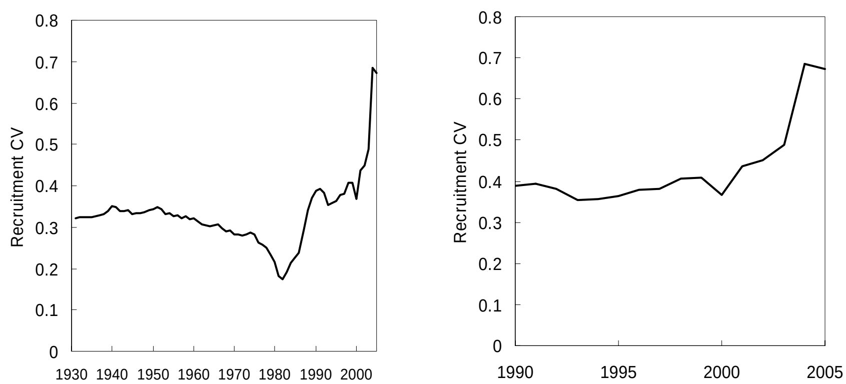
Table 3. MPD results for some selected runs in the core set and the Cfulltag set.

		core h2m2M2O2C4	core h2m2M2O1C5	tag h2m2M2O2C4	tag h2m2M3O2C5
	Steepness	0.55	0.55	0.55	0.55
	M(0)	0.4	0.4	0.4	0.4
	M(10)	0.1	0.1	0.1	0.14
	Omega	1	0.75	1	0.75
	Cpue	4	5	4	5
	Total	476.22	456.854	480.008	463.361
Likelihood	LL1	136.149	137.029	135.493	135.694
	LL2	48.7836	48.2802	48.9821	48.6387
	LL3	106.39	106.726	106.619	107.802
	LL4	137.134	136.321	136.662	134.92
	IND	25.0019	21.9282	25.0571	22.8974
	SURF	31.5918	32.3536	31.7465	32.3276
	CPUE	-43.0549	-59.108	-42.7398	-58.2362
	Tags	4.91138E-05	0.000183793	3.28236	3.67879
Penalties	Sel.Ch	33.729	32.1274	34.1524	34.0422
	Sel.sm	21.4515	22.7058	21.3757	21.0418
	Sg.R	-20.9554	-21.5098	-20.6228	-19.446
	M(0)	0	0	0	0
	M(10)	0	0	0	0
	Steepness	0	0	0	0
Ref. Pts	msy	24355.2	23619.1	24520.3	26999.5
	S(msy)	326222	313366	328643	219675
	S(msy)/B0	0.326836	0.326411	0.326858	0.329668
	S(2004)/S(0)	0.122235	0.0483025	0.134965	0.0778943
	S(2004)	122005	46372.1	135702	51904.9
Rho	1931-Y	0.639942	0.647788	0.648714	0.676686
	1965-1998	0.421413	0.455074	0.440245	0.541522
SigmaR	Model SigR	0.6	0.6	0.6	0.6
	1931-Y	0.406284	0.398922	0.410963	0.426972
	1965-1998	0.296121	0.302763	0.298487	0.331167
CPUE	1969-Y	0.310845	0.0337792	0.310741	0.0267222
Autocorr.	1990-2000	0.35318	0.133403	0.369771	0.0886183

(a) Example of h2m2M2O2C4_notag



(b) core set



(c) Cfulltag

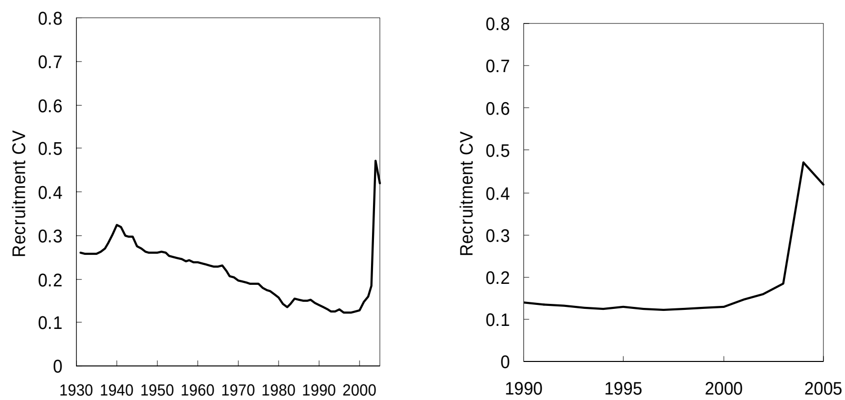


Figure 7. CVs of estimated recruitments.

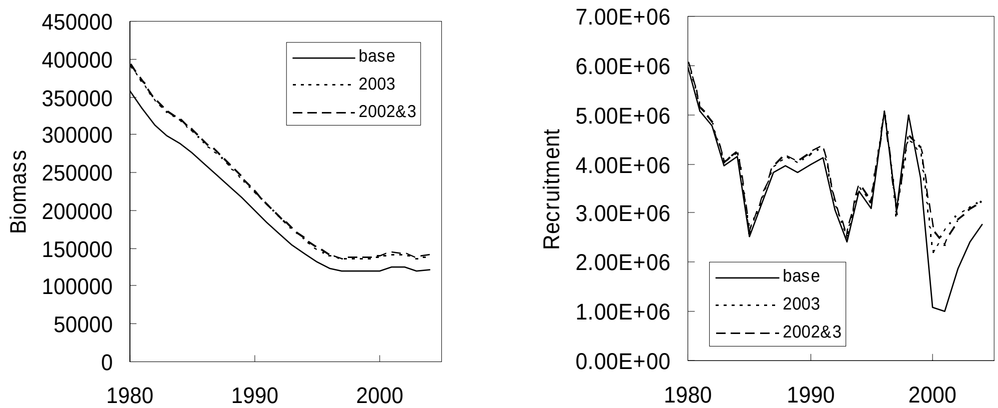


Figure 8. Biomass (left) and recruitment (right) estimates using catch-at-size data of LL1 in 2002 and 2003 replaced by the average of 1999-2001 data.

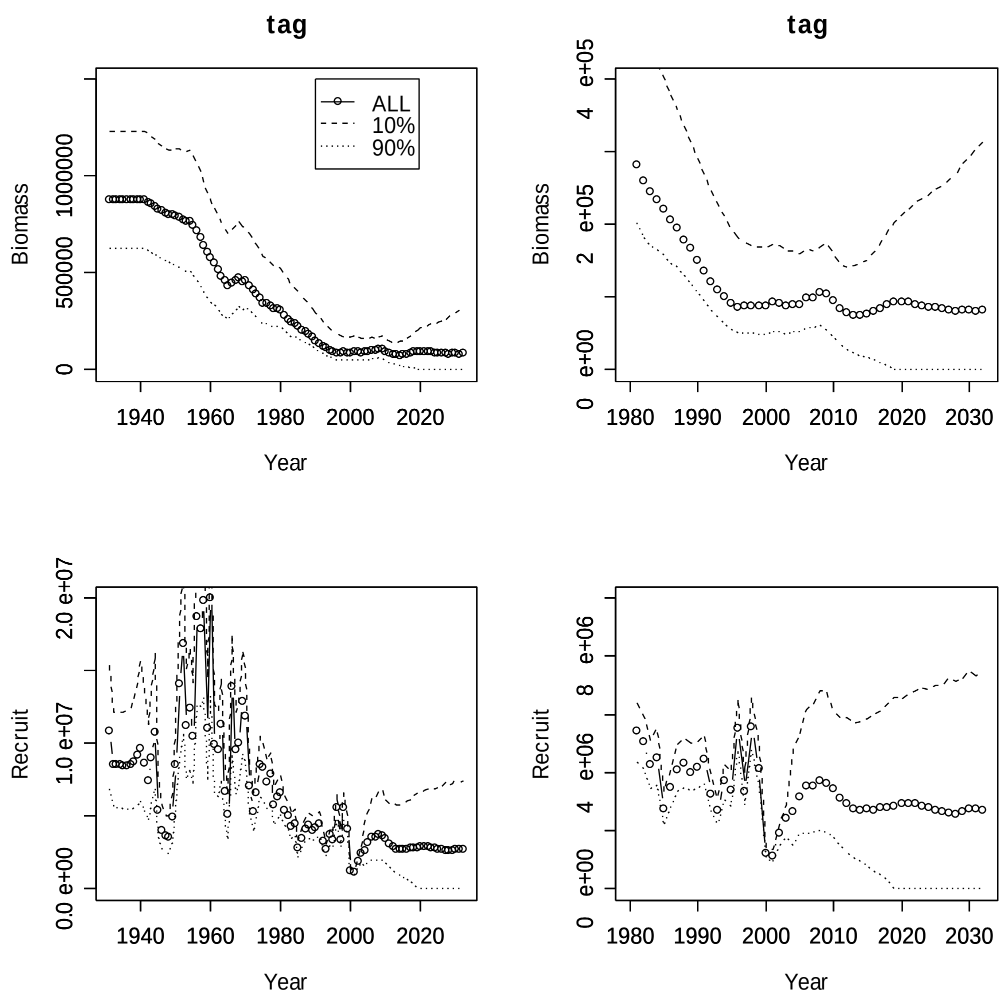


Figure 9. 10th, median and 90th percentiles of historical estimates of biomass (upper panels) and recruitment (lower panels) and future projections using the current catch for the Cfulltag set.

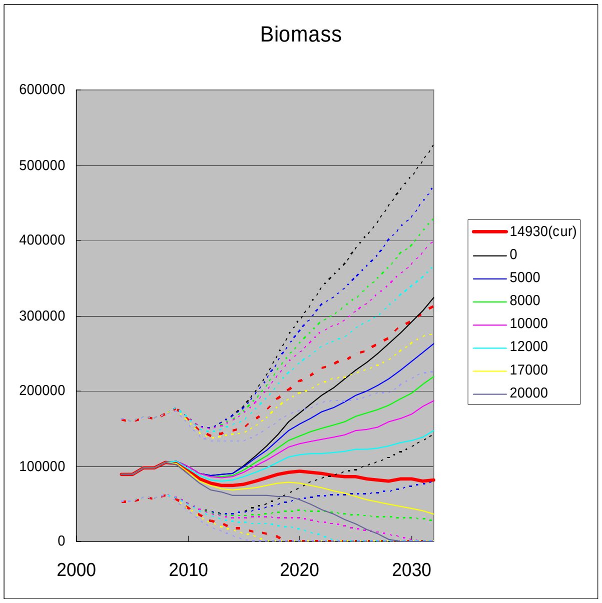


Figure 10. Future projection for the Cfulltag set at different constant catches.

Table 4. B2022/B2004 for the Cfulltag at different constant catches.

Cfulltag

constant catch level	B2022/B2004
14930	0.87
0	2.07
1000	2.01
2000	1.96
3000	1.90
4000	1.84
5000	1.78
6000	1.71
7000	1.63
8000	1.55
9000	1.47
10000	1.39
11000	1.27
12000	1.16
13000	1.07
14000	0.97
15000	0.87
16000	0.77
17000	0.68
18000	0.57
19000	0.48
20000	0.40

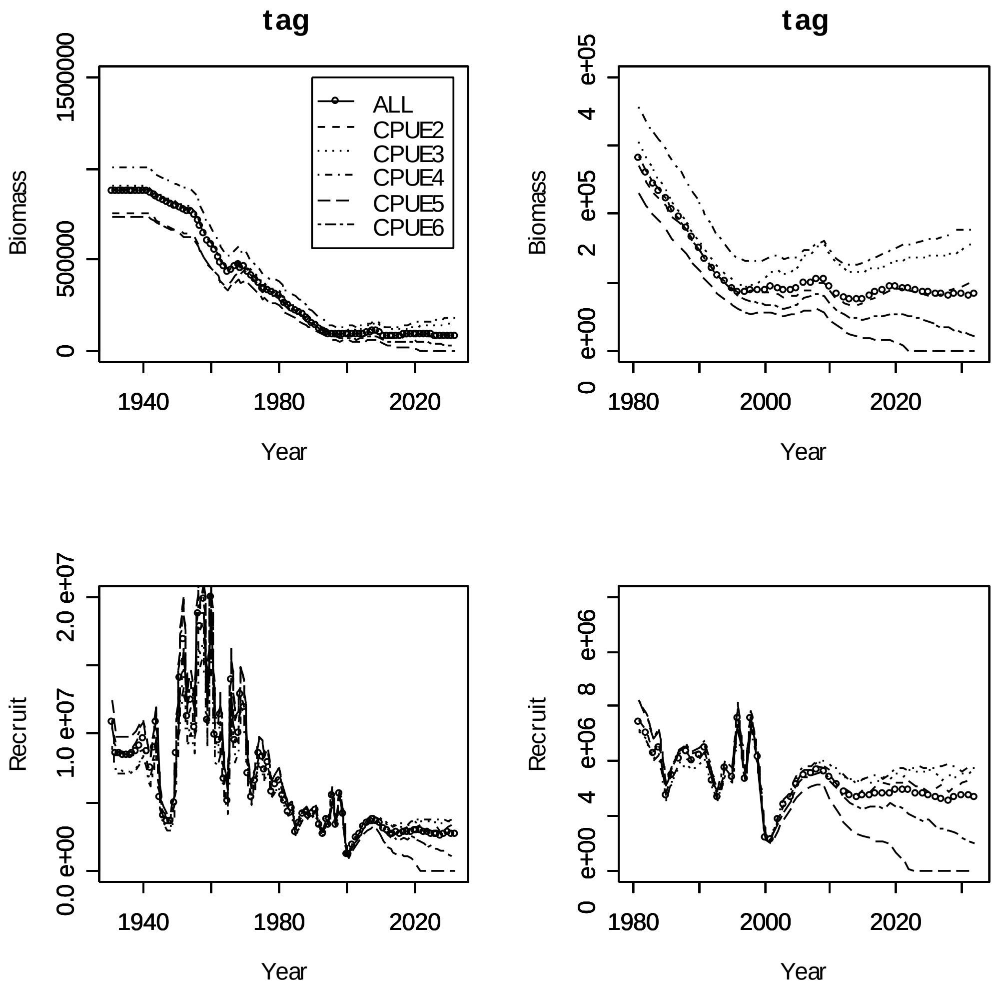


Figure 11. Comparison of historical estimates of biomass (upper panels) and recruitment (lower panels) and future projections using the current catch for the Cfulltag set among different CPUE series.

Table 5. The number of realizations in each level of M0, M10 and omega parameters in different CPUE series for the Cfulltag set.

	m0			m10			omega	
cpue	0.3	0.4	0.5	0.07	0.1	0.13	0.75	1.0
nominal (2)	119	119	162	6	170	224	65	335
Laslett (3)	119	133	148	53	205	142	76	324
st-window (4)	114	170	116	75	228	97	20	380
w0.5 (5)	21	146	233	0	171	229	346	54
w0.8 (6)	82	107	211	2	229	169	311	89
all	455	675	870	136	1003	861	818	1182
average	0.421			0.111			0.898	

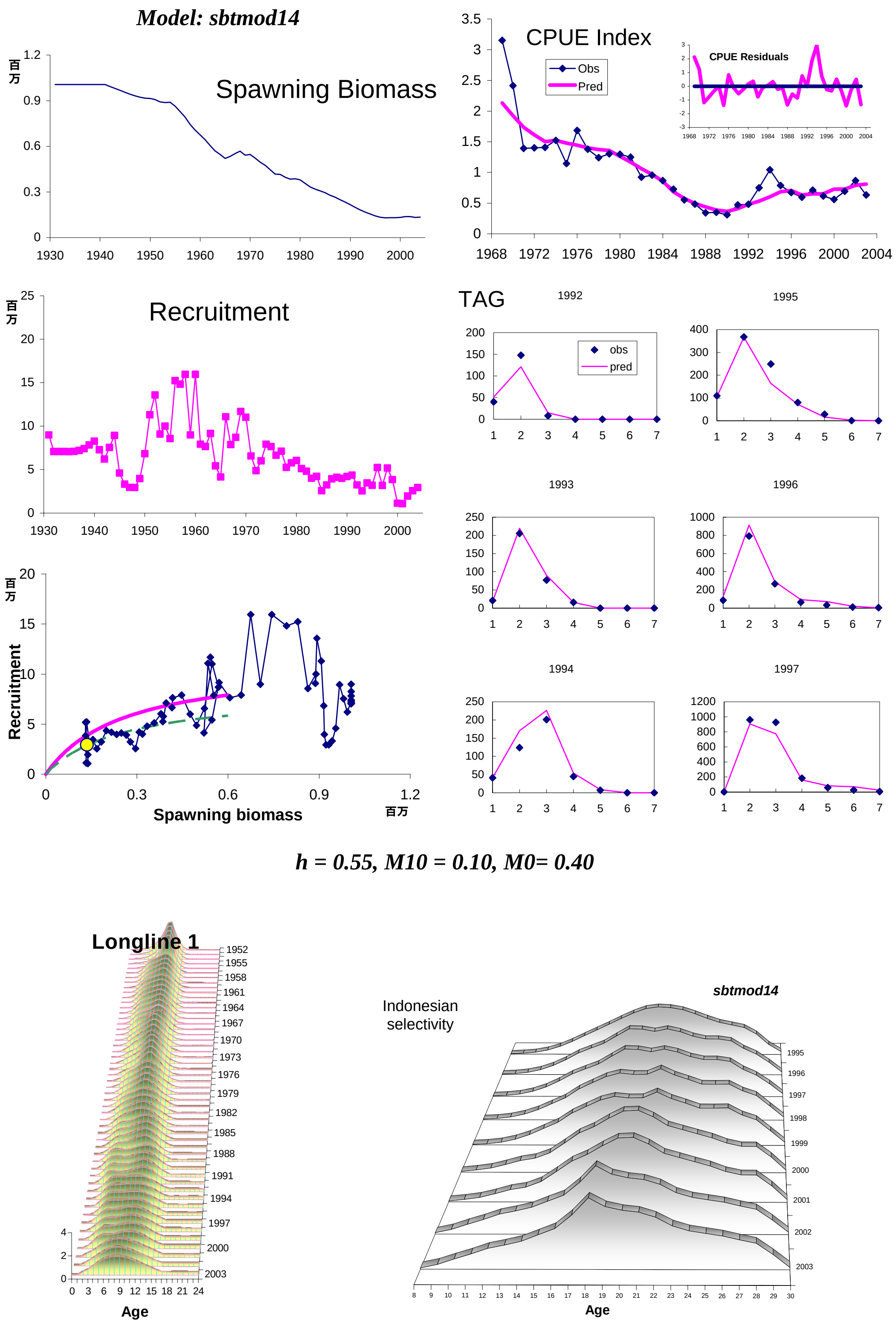


Figure 12. Conditioning results of h2m2M2O2C4_tag (Cfulltag).

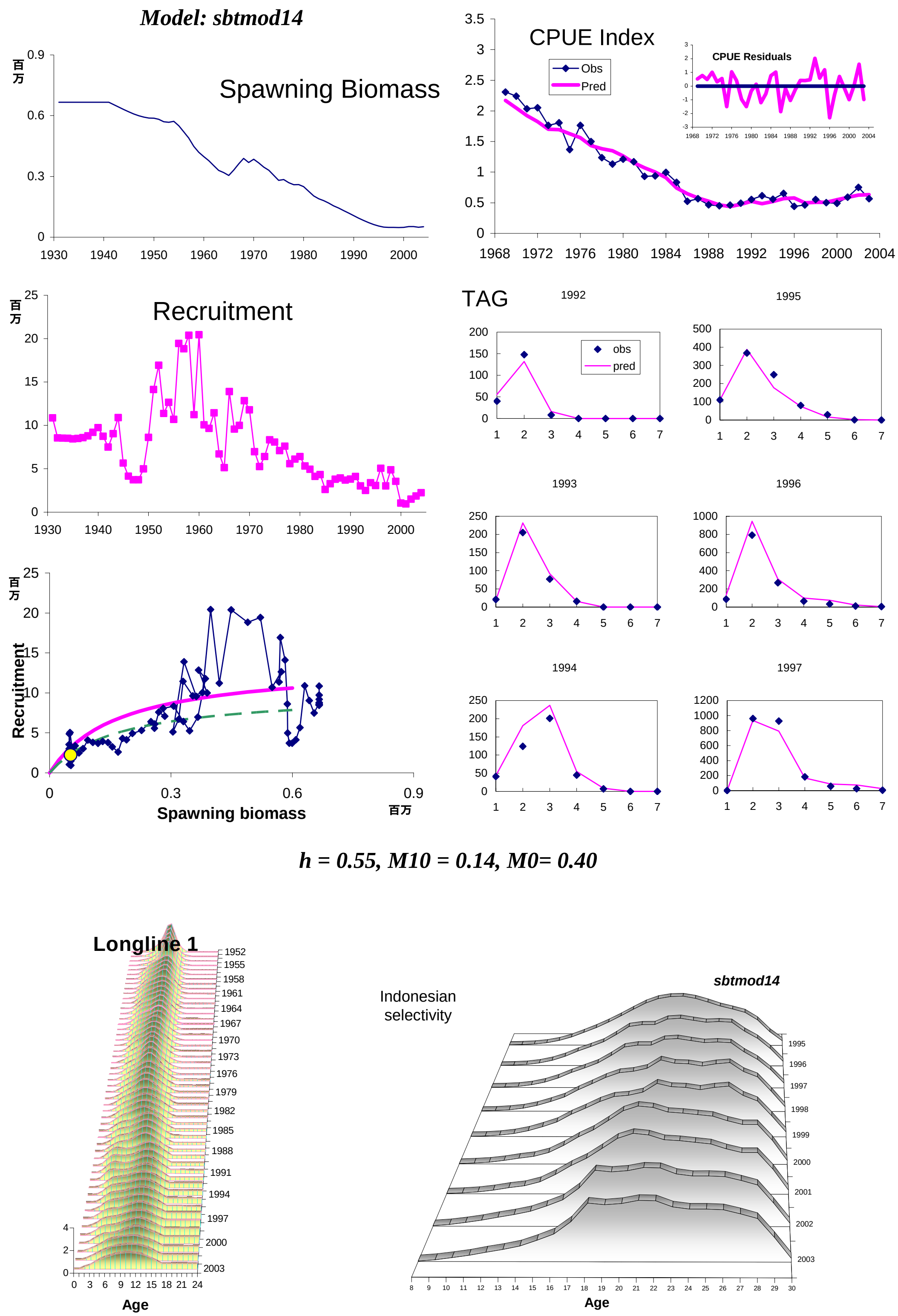


Figure 13. Conditioning results of h2m2M3O1C5_tag (Cfulltag).

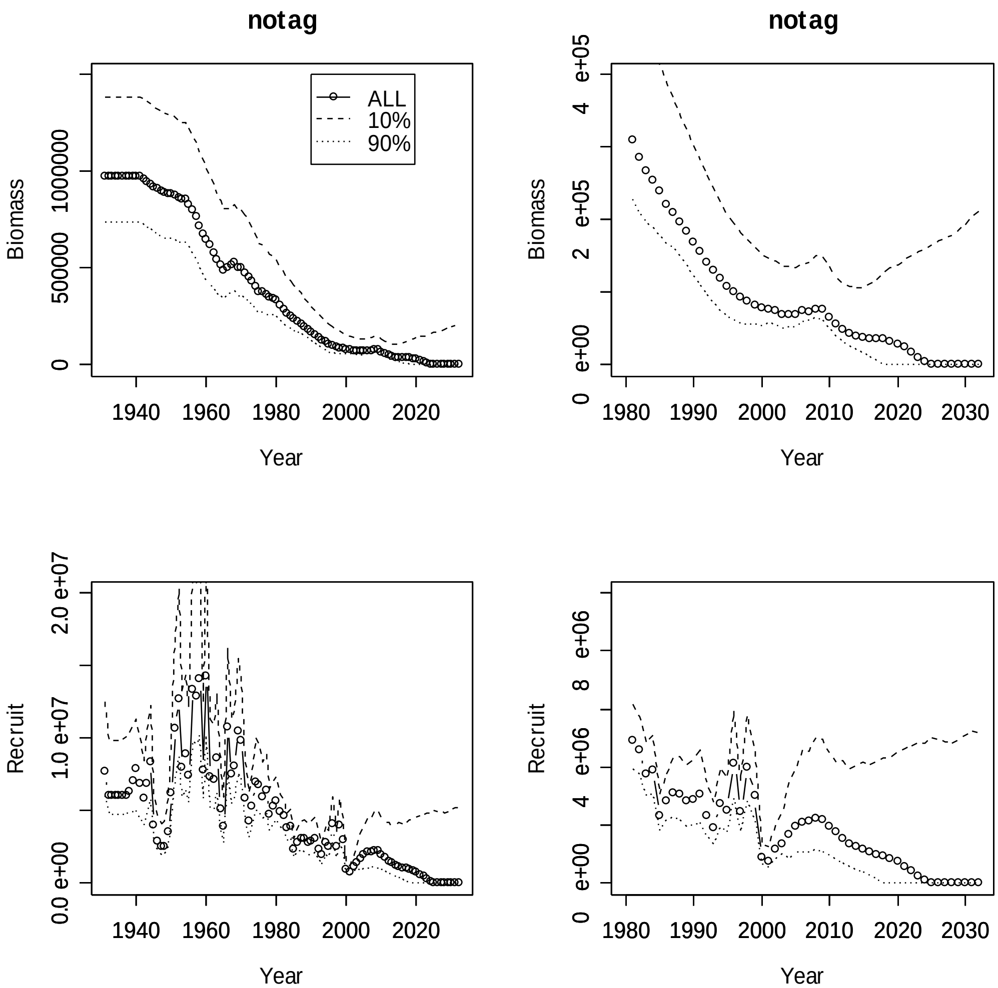


Figure 14. 10th, median and 90th percentiles of historical estimates of biomass (upper panels) and recruitment (lower panels) and future projections using the current catch for the sensitivity analysis using the median CPUE.

Table 6. The number of realizations in each level of M0, M10 and omega parameters for the sensitivity analysis using the median CPUE.

	m0			m10			omega	
cpue median	0.3	0.4	0.5	0.07	0.1	0.13	0.75	1.0
all	847	713	440	296	1339	365	1354	646
average	0.380			0.101			0.831	

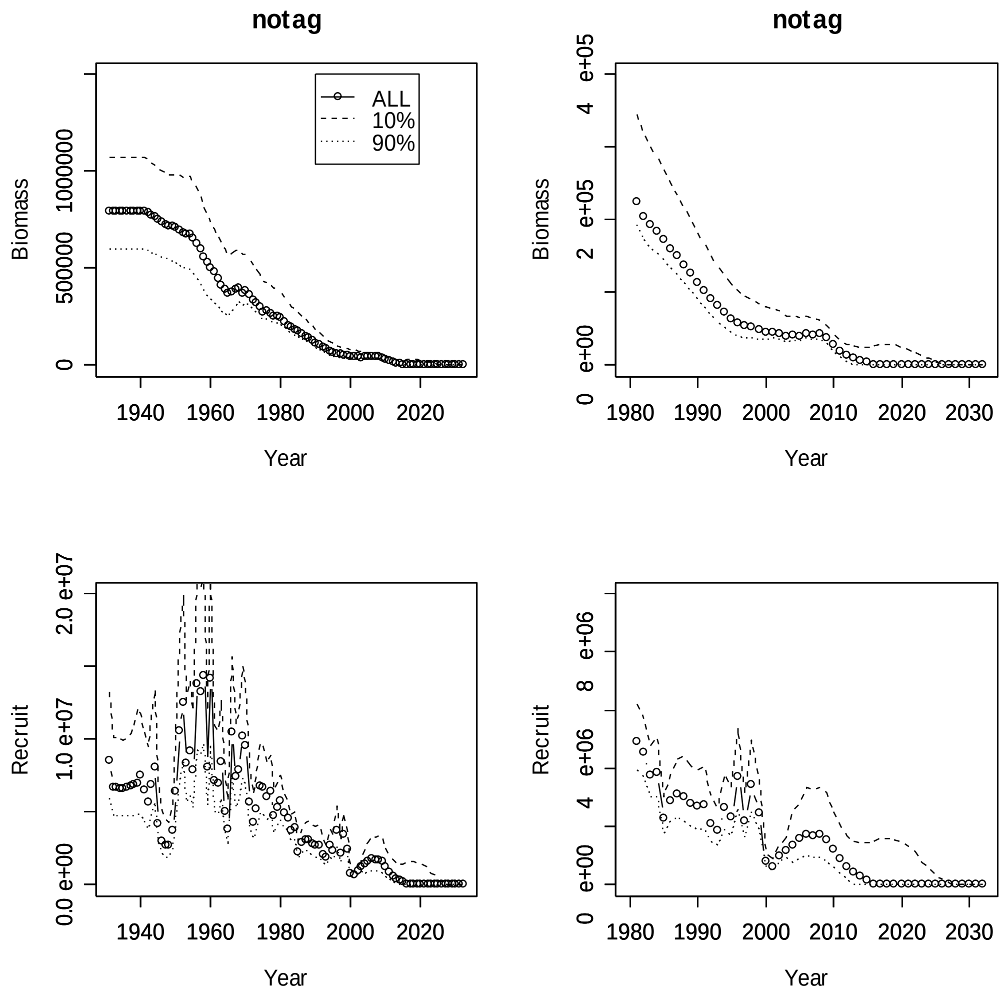
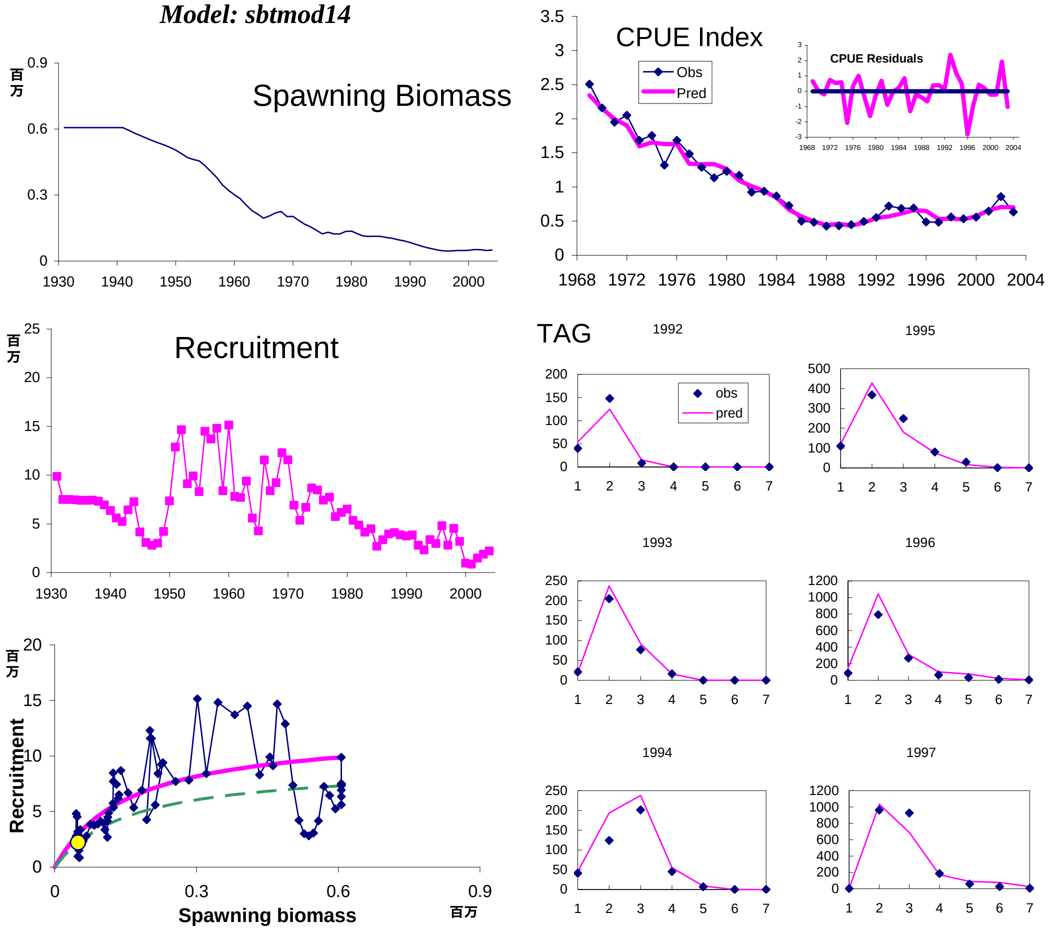


Figure 15. 10th, median and 90th percentiles of historical estimates of biomass (upper panels) and recruitment (lower panels) and future projections using the current catch when for the sensitivity analysis to the age range for selectivity standardization for CPUE prediction (CPUE age range 8-12).

Table 7. The number of realizations in each level of M0, M10 and omega parameters for the sensitivity analysis to the age range for selectivity standardization for CPUE prediction (CPUE age range 8-12).

	m0			m10			omega	
cpue median	0.3	0.4	0.5	0.07	0.1	0.13	0.75	1.0
all	944	686	370	41	875	1084	57	1943
average	0.371			0.116			0.993	

Model: sbtmod14



h = 0.55, M10 = 0.14, M0= 0.40

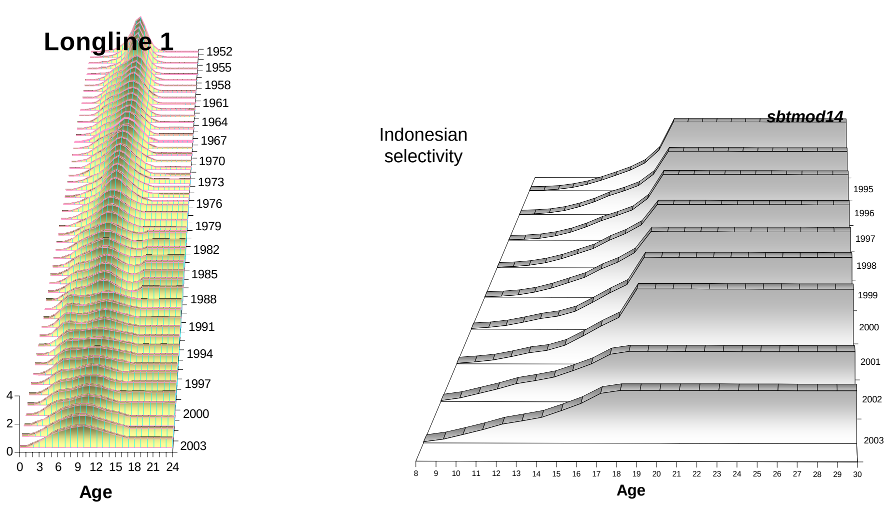


Figure 16. Conditioning results of h2m2M3O2 when Indonesia selectivity is constant over age 18.

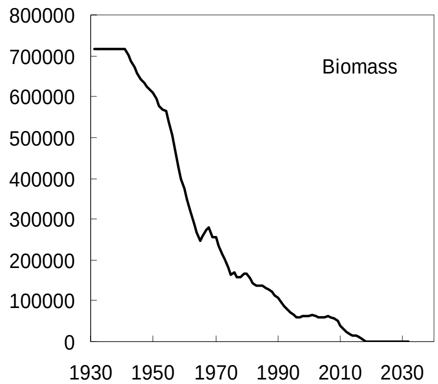


Figure 17. Projection results of h2m2M3O2 at the current catch when Indonesia selectivity is assumed to be constant over age 18.

Table 8. MPD results for sensitivity tests to Indonesian fishery selectivity.

		base h1m2M3O2	Indo18 h1m2M3O2	base h2m2M3O2	Indo18 h2m2M3O2
	Steepness	0.385	0.385	0.55	0.55
	M(0)	0.4	0.4	0.4	0.4
	M(10)	0.14	0.14	0.14	0.14
	Omega	1	1	1	1
	Cpue	1	1	1	1
	Total	464.007	485.839	464.211	476.824
Likelihood	LL1	136.869	141.469	137.584	141.337
	LL2	48.6888	48.2111	48.7638	48.358
	LL3	108.155	105.794	107.221	105.403
	LL4	136.323	141.285	136.291	140.525
	IND	25.1971	36.6995	24.7691	33.0298
	SURF	32.0806	32.1604	32.0735	32.0478
	CPUE	-59.7215	-62.361	-59.0241	-62.2476
	Tags	6.32677E-05	4.94273E-05	5.68439E-05	5.40181E-05
Penalties	Sel.Ch	36.7591	35.9219	36.0817	35.0044
	Sel.sm	20.6836	20.9524	20.5111	20.6734
	Sg.R	-21.0275	-14.2932	-20.0598	-17.3067
	M(0)	0	0	0	0
	M(10)	0	0	0	0
	Steepness	0	0	0	0
Ref. Pts	msy	21579.5	18138	27230	24538.6
	S(msy)	356101	299277	221967	200066
	S(msy)/B0	0.41688	0.417168	0.329563	0.329864
	S(2004)/S(0)	0.134441	0.083325	0.140363	0.081919
	S(2004)	114840	59777.5	94537.4	49684.7
Rho	1931-Y	0.631824	0.718777	0.655112	0.707721
	1965-1998	0.447061	0.351059	0.446395	0.465627
SigmaR	Model SigR	0.6	0.6	0.6	0.6
	1931-Y	0.405374	0.458608	0.41777	0.447453
	1965-1998	0.308475	0.285441	0.303347	0.306416
CPUE	1969-Y	0.121398	0.0566797	0.0966185	0.0232437
Autocorr.	1990-2000	0.383489	0.339954	0.32519	0.281126

Table 9. A summary of trials and results on the error structure and the sample size for age and length composition data.

option	Fig	Table	error structure	sample size*	M0	M10	omega	projection (median of B2032)
base	3	2	multinominal	core set	0.380	0.102	0.849	extinction
a	18	10	multinominal	old reference set	0.404	0.122	0.859	almost current level
b	19	11	multinominal	old reference set / 2	0.381	0.114	0.837	extinction
c	20	12	robust normal	old reference set	0.406	0.122	0.849	slight decline trend
d	21	13	robust normal	core set	0.400	0.109	0.868	decline trend
e	22	14	lognormal plus	old reference set + process error (0.0)	0.377	0.126	0.887	almost current level
f	23	15	lognormal plus	core set + process error (0.0)	0.365	0.110	0.910	slight decline trend
g	24	16	lognormal plus	core set + process error (0.05)	0.370	0.110	0.922	slight decline trend
h	25	17	lognormal plus	core set + process error (0.2)	0.366	0.114	0.955	almost current level

* core set = 5×(old reference set ^ 0.5)

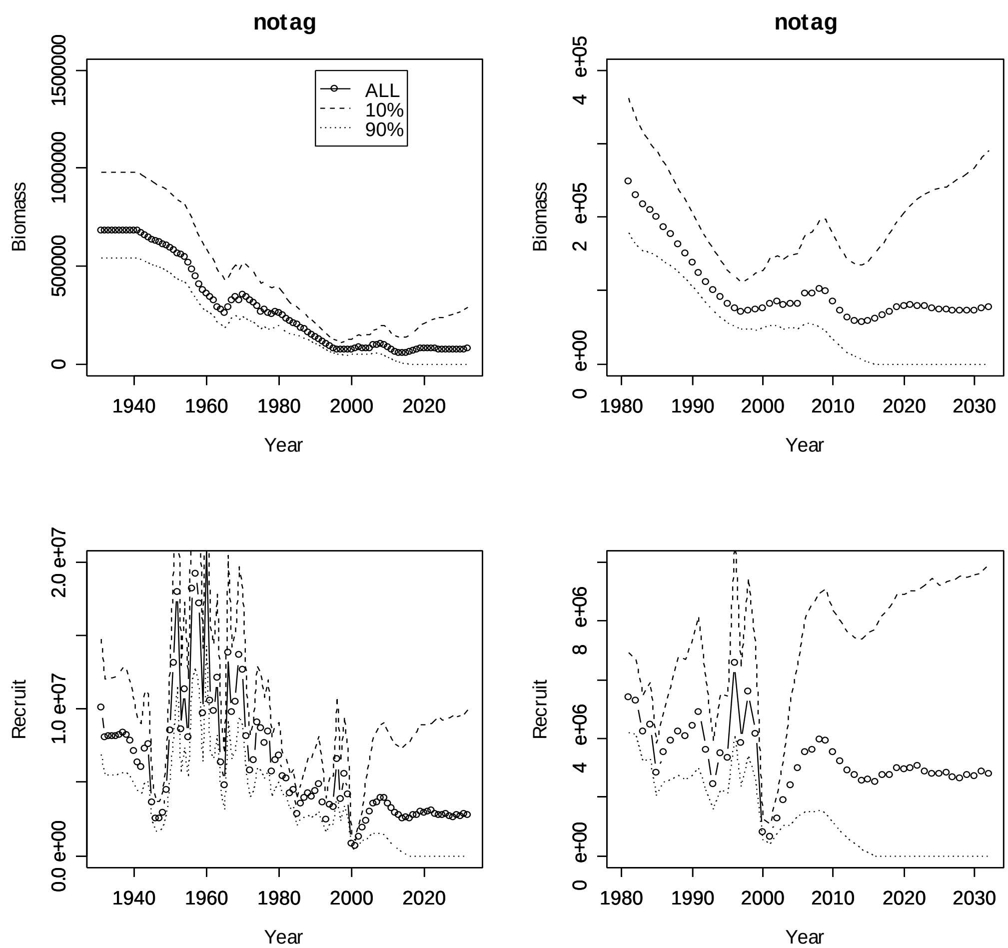


Figure 18. 10th, median and 90th percentiles of historical estimates of biomass (upper panels) and recruitment (lower panels) and future projections using the current catch when error structure for age- and size-composition data is multinominal and sample size is old reference set (option a).

Table 10. The number of realizations in each level of M0, M10 and omega parameters in different CPUE series when error structure for age- and size-composition data is multinominal and sample size is old reference set (option a).

	m0			m10			omega	
cpue	0.3	0.4	0.5	0.07	0.1	0.13	0.75	1.0
nominal (2)	106	109	185	1	120	279	205	195
Laslett (3)	122	164	114	3	83	314	106	294
st-window (4)	127	167	106	1	69	330	80	320
w0.5 (5)	112	126	162	1	157	242	374	26
w0.8 (6)	142	127	131	1	78	321	363	37
all	609	693	698	7	507	1486	1128	872
average	0.404			0.122			0.859	

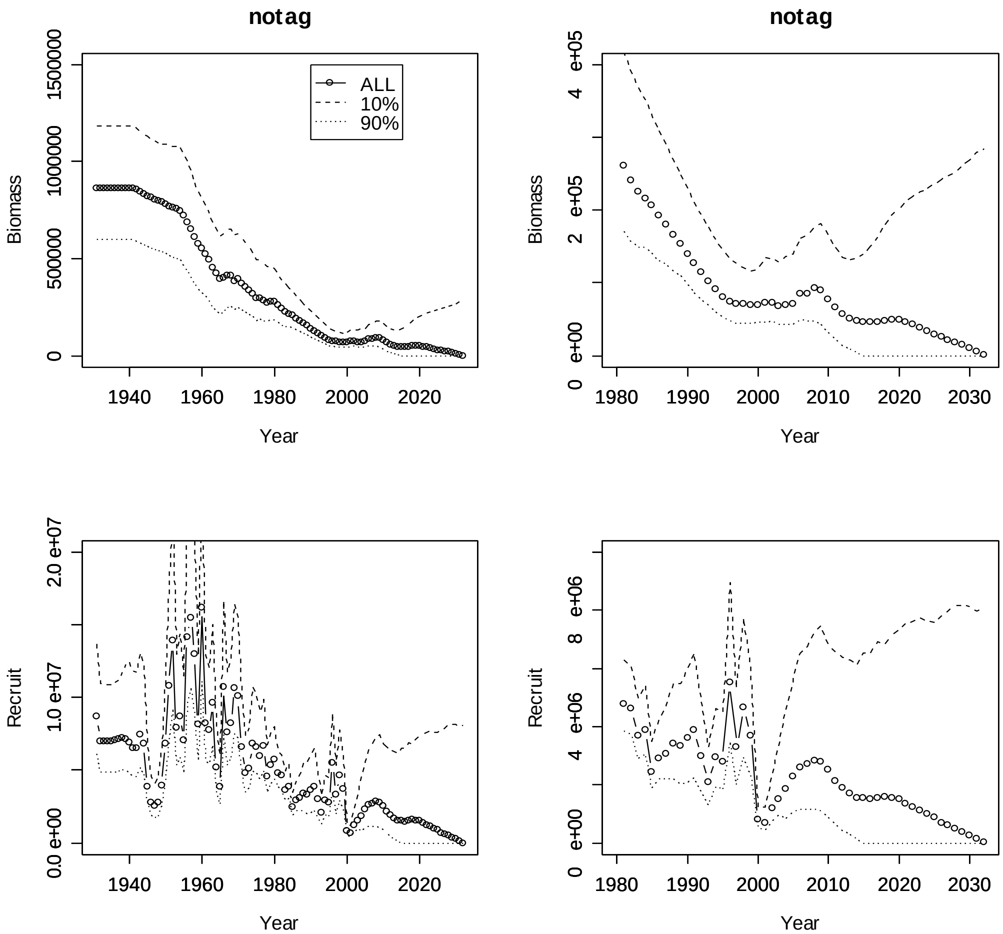


Figure 19. 10th, median and 90th percentiles of historical estimates of biomass (upper panels) and recruitment (lower panels) and future projections using the current catch when error structure for age- and size-composition data is multinominal and sample size is old reference set / 2 (option b).

Table 11. The number of realizations in each level of M0, M10 and omega parameters in different CPUE series when error structure for age- and size-composition data is multinominal and sample size is old reference set / 2 (option b).

	m0			m10			omega	
cpue	0.3	0.4	0.5	0.07	0.1	0.13	0.75	1.0
nominal (2)	167	138	95	6	219	175	283	117
Laslett (3)	180	139	81	15	188	197	215	185
st-window (4)	170	141	89	14	151	235	64	336
w0.5 (5)	163	126	111	2	191	207	384	16
w0.8 (6)	165	143	92	5	210	185	355	45
all	845	687	468	42	959	999	1301	699
average	0.381			0.114			0.837	

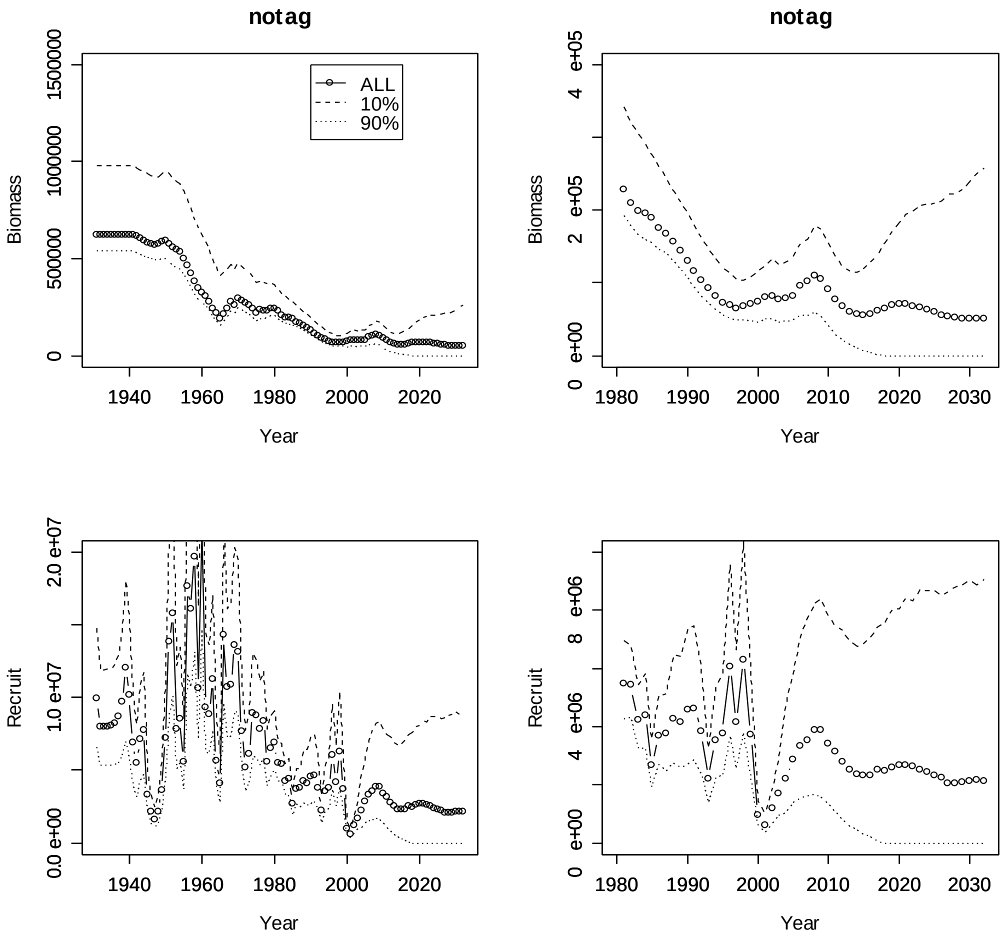


Figure 20. 10th, median and 90th percentiles of historical estimates of biomass (upper panels) and recruitment (lower panels) and future projections using the current catch when error structure for age- and size-composition data is robust normal and sample size is old reference set (option c).

Table 12. The number of realizations in each level of M0, M10 and omega parameters in different CPUE series when error structure for age- and size-composition data is robust normal and sample size is old reference set (option c).

	m0			m10			omega	
cpue	0.3	0.4	0.5	0.07	0.1	0.13	0.75	1.0
nominal (2)	113	160	127	23	64	313	167	233
Laslett (3)	75	231	94	18	93	289	183	217
st-window (4)	61	196	143	9	70	321	111	289
w0.5 (5)	91	151	158	1	74	325	391	9
w0.8 (6)	157	143	100	27	93	280	358	42
all	497	881	622	78	394	1528	1210	790
average	0.406			0.122			0.849	

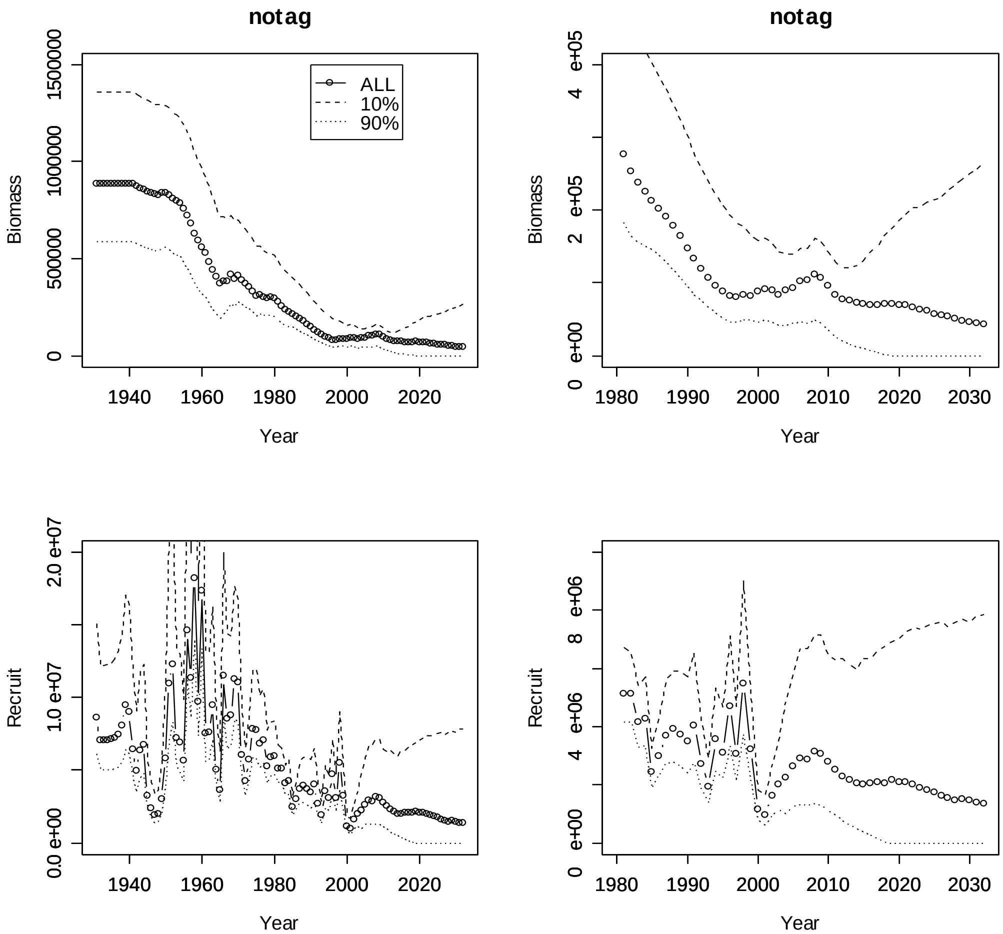


Figure 21. 10th, median and 90th percentiles of historical estimates of biomass (upper panels) and recruitment (lower panels) and future projections using the current catch when error structure for age- and size-composition data is robust normal and sample size is core set (option d).

Table 13. The number of realizations in each level of M0, M10 and omega parameters in different CPUE series when error structure for age- and size-composition data is robust normal and sample size is core set (option d).

	m0			m10			omega	
cpue	0.3	0.4	0.5	0.07	0.1	0.13	0.75	1.0
nominal (2)	174	126	100	69	133	198	199	201
Laslett (3)	113	173	114	54	216	130	126	274
st-window (4)	69	213	118	17	285	98	32	368
w0.5 (5)	70	155	175	40	154	206	356	44
w0.8 (6)	183	106	111	88	85	227	346	54
all	609	773	618	268	873	859	1059	941
average	0.400			0.109			0.868	

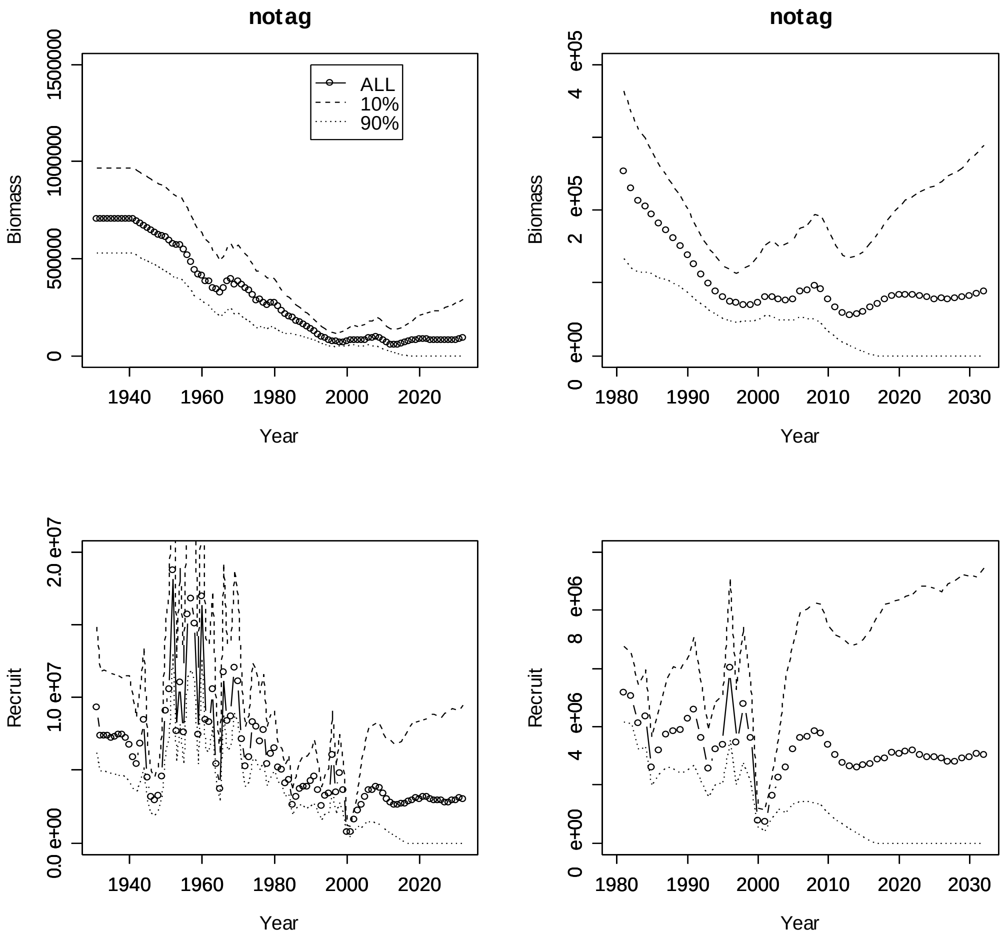


Figure 22. 10th, median and 90th percentiles of historical estimates of biomass (upper panels) and recruitment (lower panels) and future projections using the current catch when error structure for age- and size-composition data is lognormal plus and sample size is old reference set (option e).

Table 14. The number of realizations in each level of M0, M10 and omega parameters in different CPUE series when error structure for age- and size-composition data is lognormal plus and sample size is old reference set (option e).

	m0			m10			omega	
cpue	0.3	0.4	0.5	0.07	0.1	0.13	0.75	1.0
nominal (2)	122	127	151	2	20	378	114	286
Laslett (3)	189	129	82	1	52	347	89	311
st-window (4)	195	143	62	0	33	367	61	339
w0.5 (5)	217	101	82	0	142	258	328	72
w0.8 (6)	191	125	84	0	32	368	314	86
all	914	625	461	3	279	1718	906	1094
average	0.377			0.126			0.887	

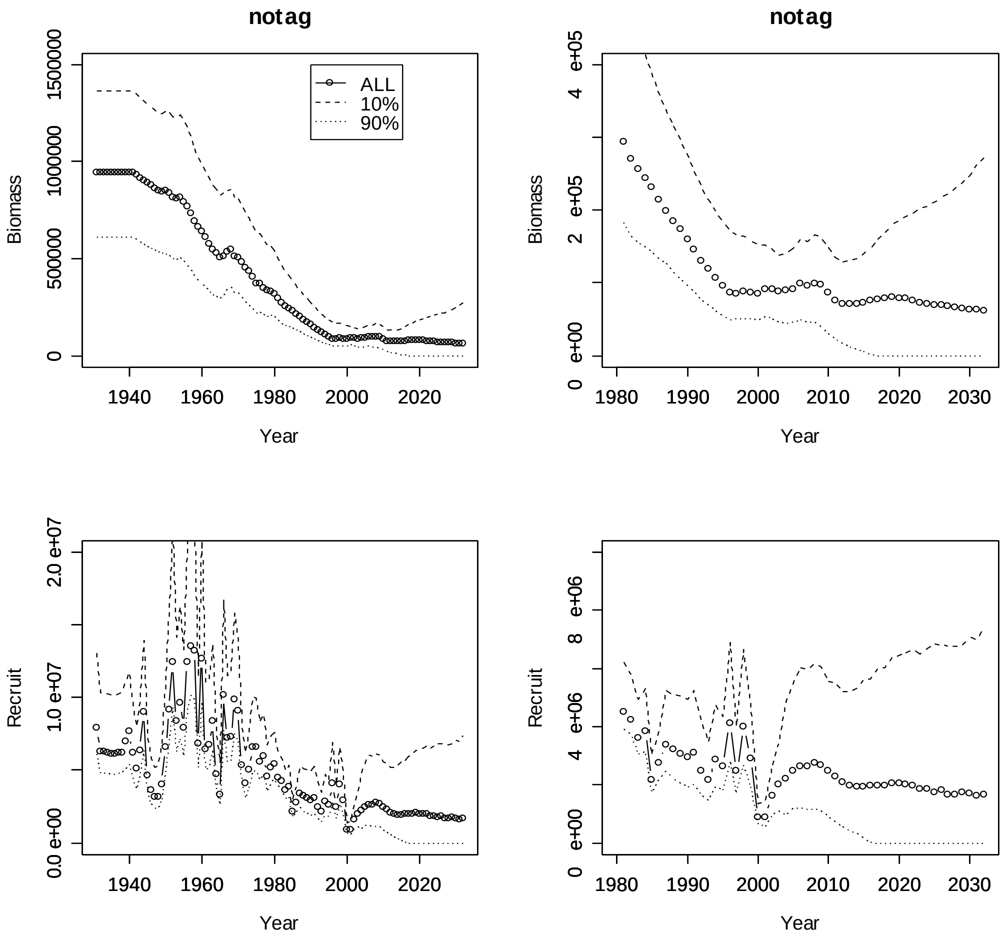


Figure 23. 10th, median and 90th percentiles of historical estimates of biomass (upper panels) and recruitment (lower panels) and future projections using the current catch when error structure for age- and size-composition data is lognormal plus and sample size is core set (option f).

Table 15. The number of realizations in each level of M0, M10 and omega parameters in different CPUE series when error structure for age- and size-composition data is lognormal plus and sample size is core set (option f).

	m0			m10			omega	
cpue	0.3	0.4	0.5	0.07	0.1	0.13	0.75	1.0
nominal (2)	176	142	82	20	131	249	41	359
Laslett (3)	207	129	64	40	230	130	53	347
st-window (4)	211	141	48	45	241	114	21	379
w0.5 (5)	198	138	64	7	230	163	327	73
w0.8 (6)	218	121	61	22	238	140	275	125
all	1010	671	319	134	1070	796	717	1283
average	0.365			0.110			0.910	

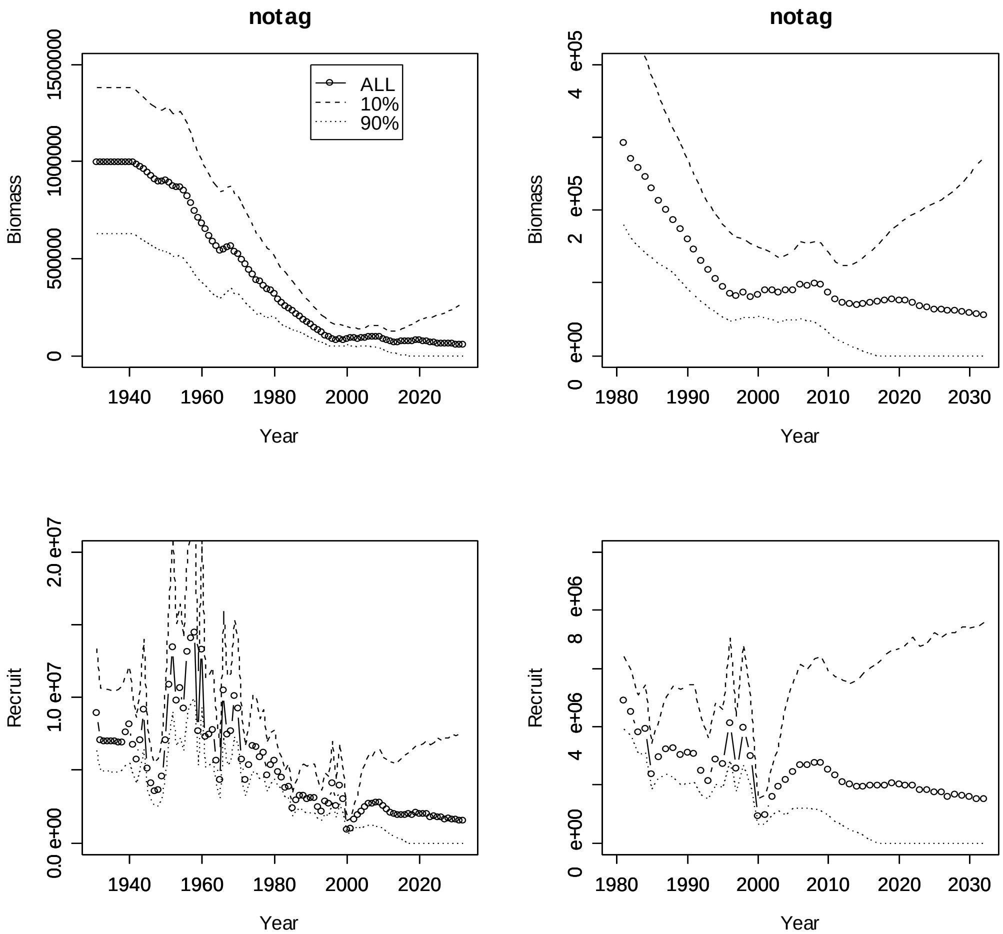


Figure 24. 10th, median and 90th percentiles of historical estimates of biomass (upper panels) and recruitment (lower panels) and future projections when error structure for age- and size-composition data is lognormal plus, sample size is core set and process error is 0.05 (option g).

Table 16. The number of realizations in each level of M0, M10 and omega parameters in different CPUE series when error structure for age- and size-composition data is lognormal plus, sample size is core set and process error is 0.05 (option g).

	m0			m10			omega	
cpue	0.3	0.4	0.5	0.07	0.1	0.13	0.75	1.0
nominal (2)	177	139	84	13	117	270	20	380
Laslett (3)	179	151	70	34	246	120	46	354
st-window (4)	192	153	55	37	262	101	14	386
w0.5 (5)	195	145	60	7	231	162	290	110
w0.8 (6)	189	141	70	29	245	126	251	149
all	932	729	339	120	1101	779	621	1379
average	0.370			0.110			0.922	

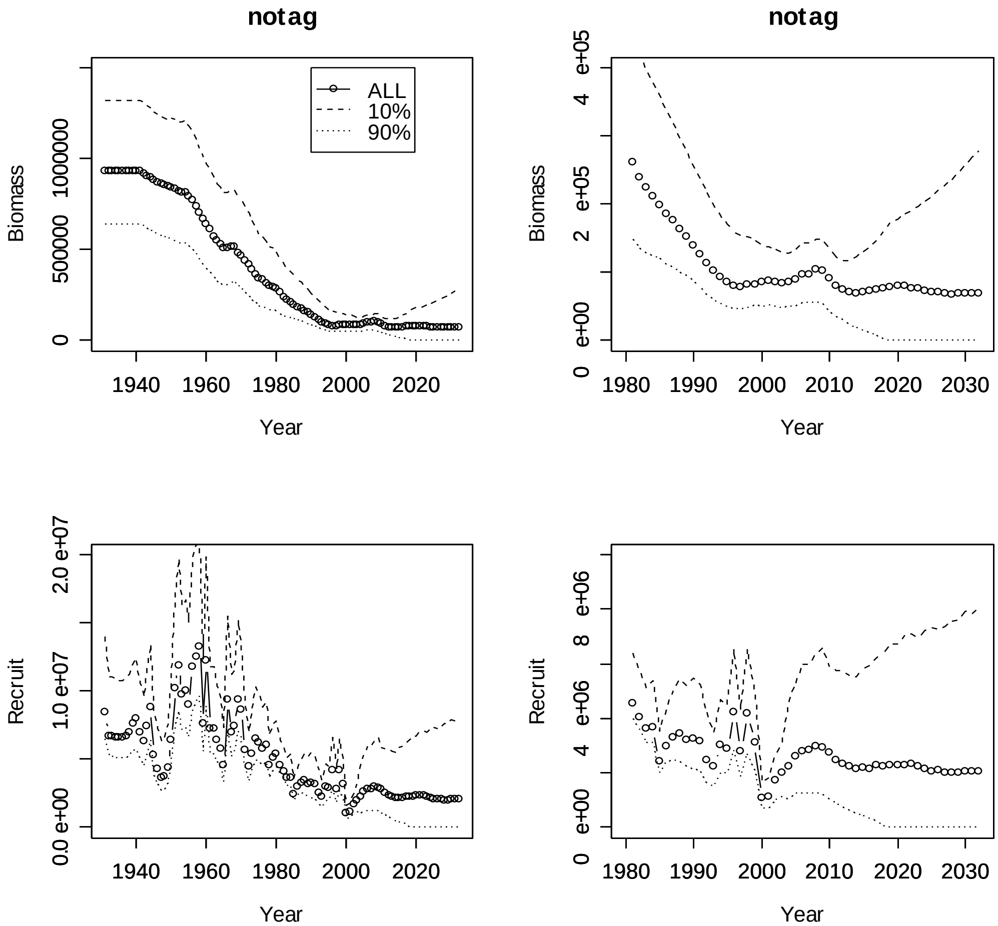


Figure 25. 10th, median and 90th percentiles of historical estimates of biomass (upper panels) and recruitment (lower panels) and future projections when error structure for age- and size-composition data is lognormal plus, sample size is core set and process error is 0.2 (option h).

Table 17. The number of realizations in each level of M0, M10 and omega parameters in different CPUE series when error structure for age- and size-composition data is lognormal plus, sample size is core set and process error is 0.2 (option h).

	m0			m10			omega	
cpue	0.3	0.4	0.5	0.07	0.1	0.13	0.75	1.0
nominal (2)	176	136	88	10	94	296	3	397
Laslett (3)	201	131	68	36	199	165	22	378
st-window (4)	217	137	46	30	219	151	3	397
w0.5 (5)	198	133	69	5	192	203	186	214
w0.8 (6)	226	111	63	19	192	189	144	256
ALL	1018	648	334	100	896	1004	358	1642
average	0.366			0.114			0.955	

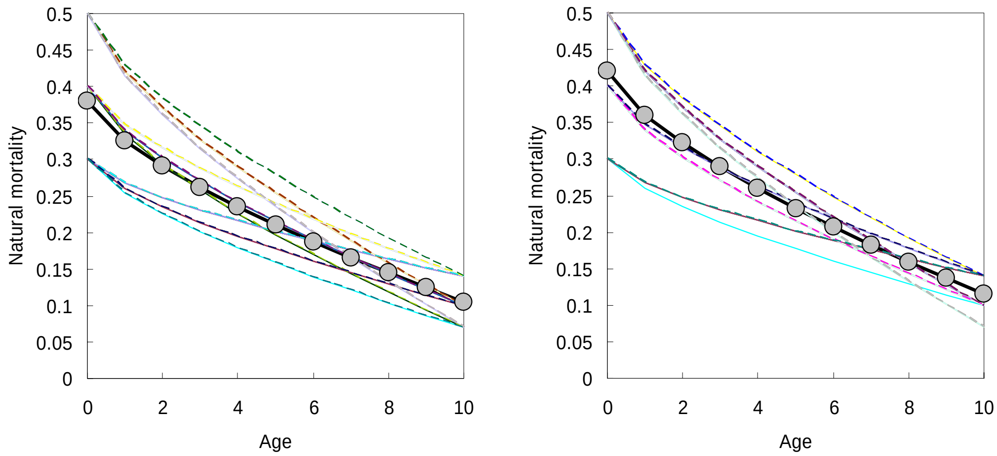


Figure 26. Average natural mortality as default cases (left: core set, right: tag).

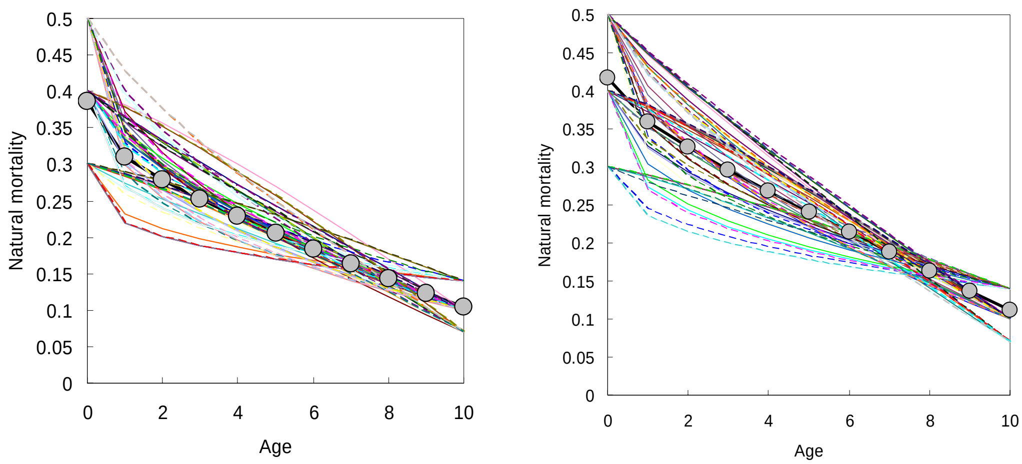


Figure 27. Average natural mortality with 100 representative examples when mslope is estimated (left: notag, right: tag).

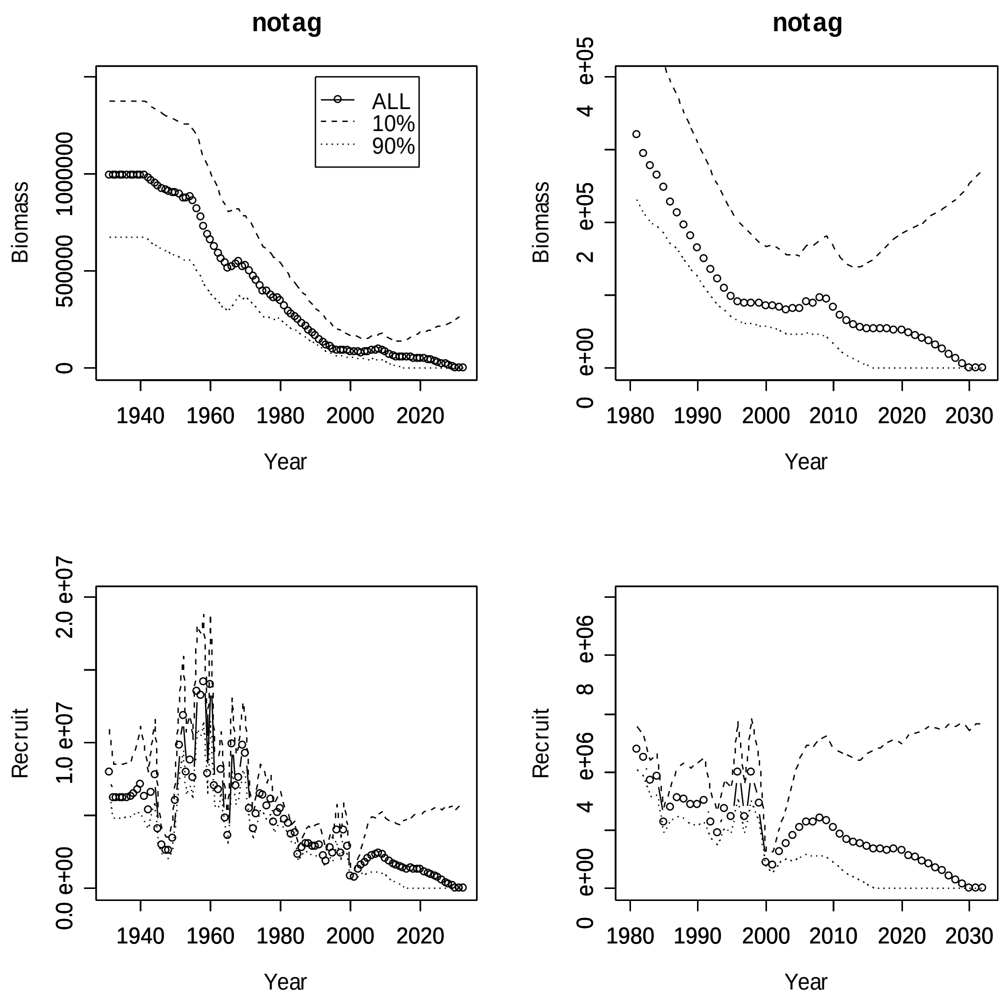


Figure 28. 10th, median and 90th percentiles of historical estimates of biomass (upper panels) and recruitment (lower panels) and future projections using the current catch when m-slope is estimated (notag).

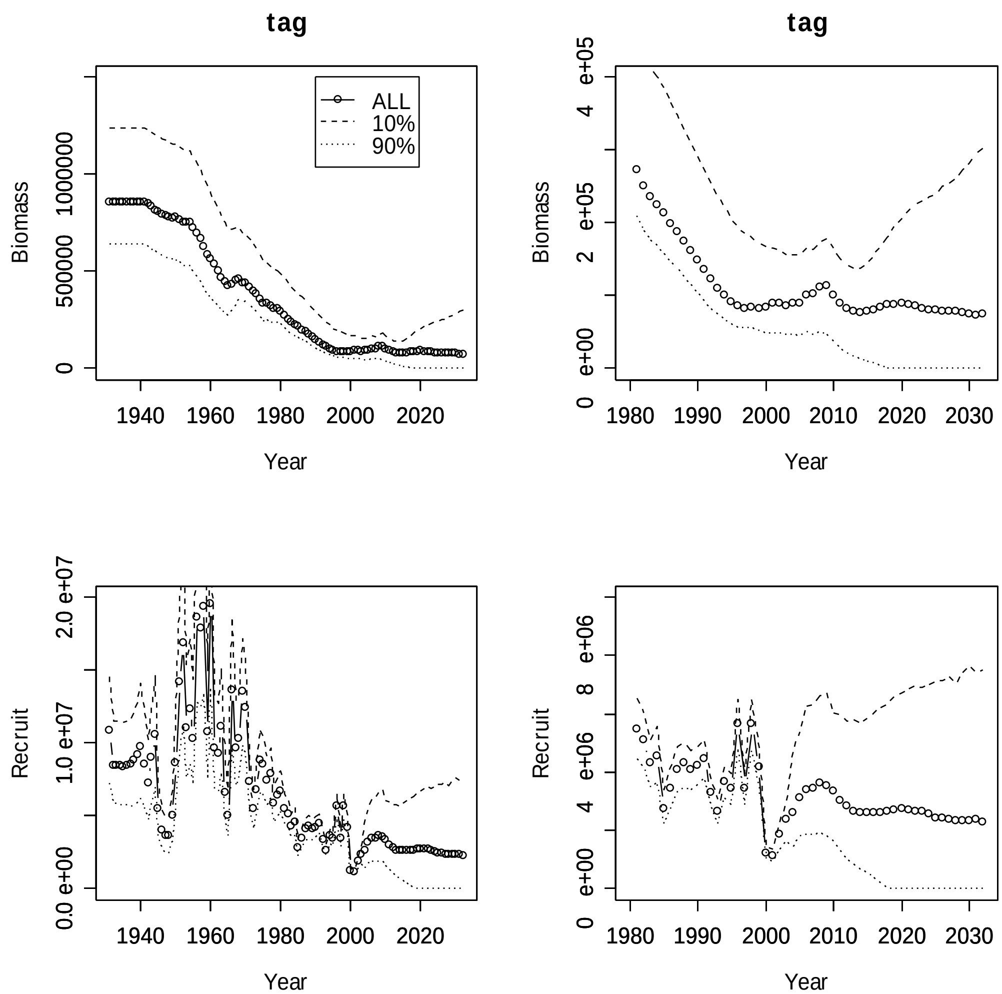


Figure 29. 10th, median and 90th percentiles of historical estimates of biomass (upper panels) and recruitment (lower panels) and future projections using the current catch when m-slope is estimated (tag).

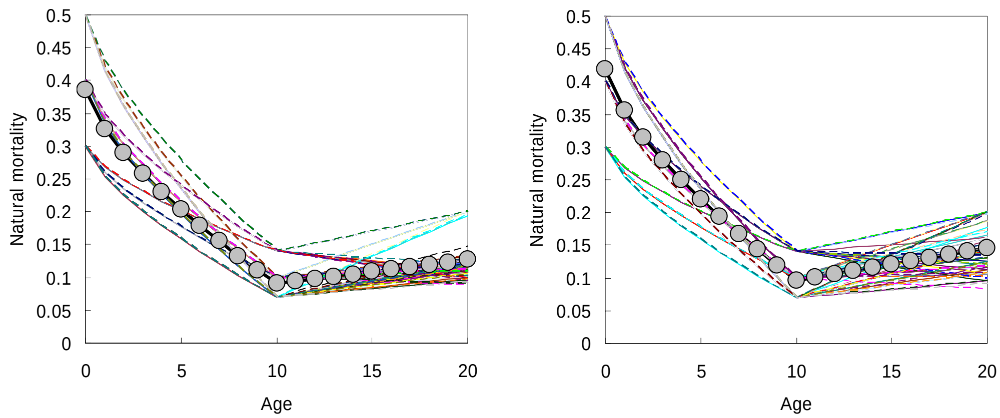


Figure 30. Average natural mortality with 100 representative examples when M20 is introduced (left: notag, right: tag).

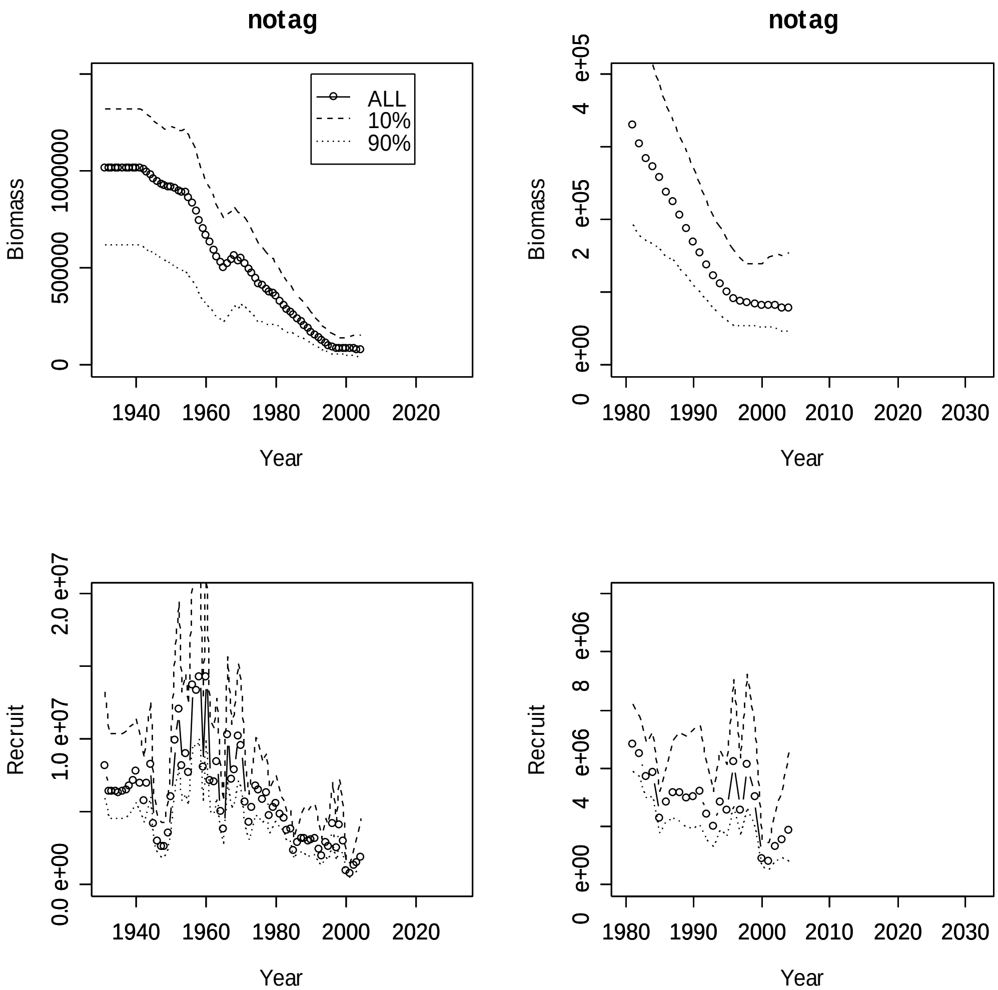


Figure 31. 10th, median and 90th percentiles of historical estimates of biomass (upper panels) and recruitment (lower panels) and future projections using the current catch when M20 is estimated (notag).

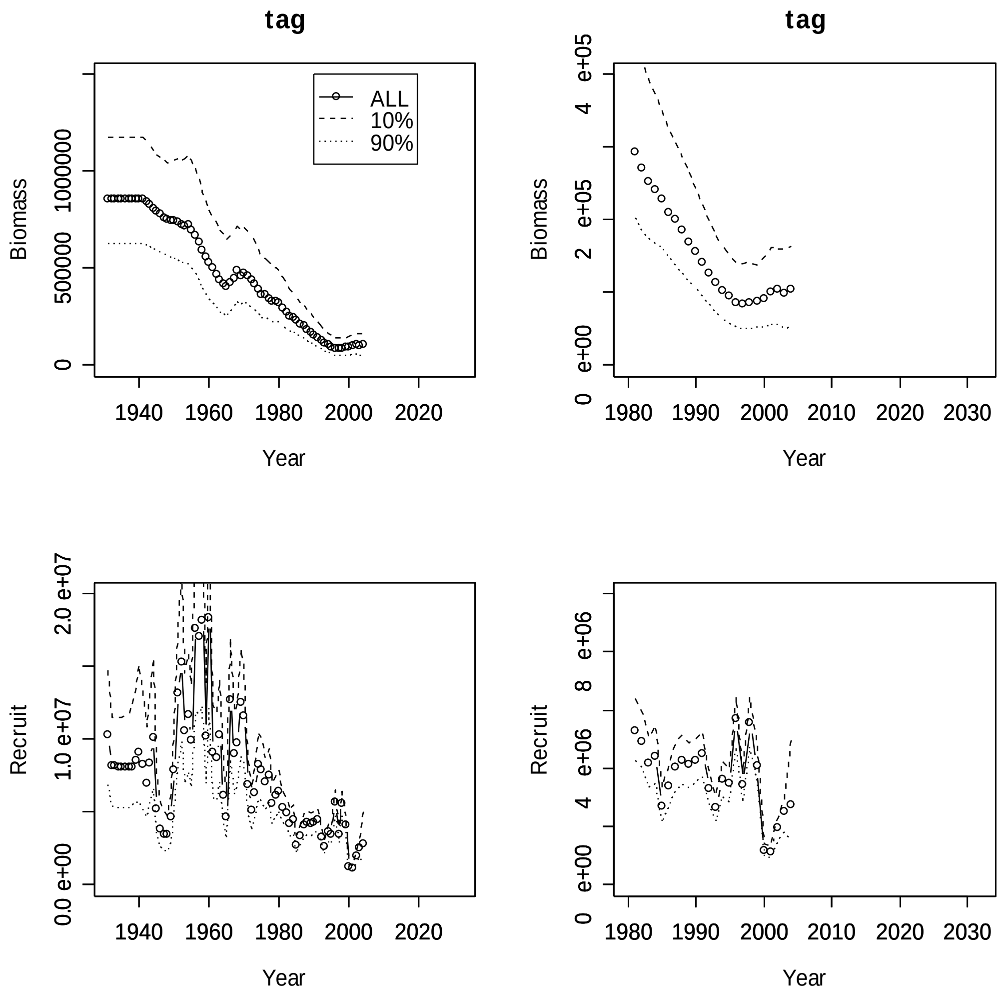


Figure 32. 10th, median and 90th percentiles of historical estimates of biomass (upper panels) and recruitment (lower panels) and future projections using the current catch when M20 is estimated (tag).