Performance of the HK5 management procedure under the new operating models.

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新しいオペレーティングモデルのもとでの管理方策 HK5 のパフォーマンス

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Abstract: I investigated performance of the HK5 management procedure under new operating models, whose configuration was determined at the technical meeting in Seattle. Behaviors of HK5 varied depending on values of its control parameters, even when being tuned to the same tuning levels. With a parameter set I regarded preferable (HK5_01), the HK5 was able to control TACs properly corresponding to stock status and inter-annual variation in catch was small at the same time. Furthermore the HK5 managed stock corresponding to change in recent trend of recruitment, and its performance in terms of safeguarding stock was high for robustness trials.

要旨: 新しいオペレーティングモデルのもとでの管理方策 HK5 のパフォーマンスを調べた。この新しいモデルはシアトルの技術会合で仕様が決められたものである。管理方策はパラメータ値によって、異なる挙動を示した。しかし、我々が最も好ましいと思うパラメータセットでは、漁獲量の変動が小さいにもかかわらず、資源状態に応じて、適切に TAC をコントロールすることが出来た。また近年の加入の動向に応じても、正しく管理を行うことが出来、ロバストネステストにおける資源の安全性も高かった。

Introduction

At the management procedure (MP) technical meeting held in Seattle, February 2005, configuration of new reference set and robustness trials as operating models (OM) for MP development for southern bluefin tuna (SBT) were specified (CCSBT, 2005). Under these new reference and robustness tests, I conducted tuning for the HK5 management procedure (Hiramatsu et al., 2004) and examined its performance.

The HK5 can be tuned to the same tuning levels with different combinations of control parameter values. Among these combinations, I considered ones which satisfied demands described below to be desirable and conducted tuning exercises with this idea. Further, considering uncertainty of OM, I thought it important to carefully examine not only performance for reference set but also that for robustness trials to develop more robust MPs. Preferable conditions are as follows:

- reference set
  - ✓ It is able to adaptively control TACs corresponding to stock status. It avoids extinction of stock, and increases catch when stock productivity is high.
  - ✓ Inter-annual variation in catch is small and catch does not largely fluctuate in short term.
  - ✓ Change in TAC is consistent with trend of stock status. TAC does not continue to decrease when stock trend becomes positive.
  - ✓ Long-term TAC levels are high.
- robustness trial
  - ✓ It is able to control TAC toward desirable directions under different OM scenarios for low recruitment in recent years.
  - ✓ In any circumstance, it manages to recover stock without extinction.

Simulation trials were conducted under the following specifications, which were agreed at the MP technical meeting in Seattle. Constant catch rule (CON) was tuned as well as HK5 for the purpose of reference (Table 1, Fig. 3).

- ✓ OM: reference set (Cfull2)
  robustness trial (full grid and single cell)
- ✓ tuning level (TL = median B_{2022}/B_{2004}): 0.9, 1.1, 1.3
- ✓ projection time horizon: 28 years
- ✓ the number of simulations: 2000 (reference and full grid robustness)
  500 (single cell robustness)
- ✓ first year for TAC change and frequency of change (TAC change option):
  Option A: 2006, every 3 year
  Option B: 2008, every 3 years
  Option C: 2008, every 5 years

This paper presents results of the following trials.

	TL=0.9 (1)	TL=1.1 (2)	TL=1.3 (3)
Option A		2a	
Option B	1b	2b	3b
Option C		2c	

<u>Description of HK5</u>

SBT are long-lived fish and fisheries target mainly younger fish before sexual maturation. Considering these actual situations for SBT, it might be better to utilize information of not only overall stock condition but also recruitment to determine TACs robustly. Such MPs can also quickly deal with sudden change in recruitment. HK5 ("Hiroyuki Kurota ver. 5") is an empirical decision rule depending on CPUE index of longline fisheries. This is a hybrid MP of the "HK1-dfl v2" and the "HK4-ag4 v1" (Tsuji et al., 2003) and TAC is set as a minimum of those determined by CPUE trend of age 4+ and CPUE level (absolute value) of age 4.

CPUE of age 4 in numbers ($CPUE_{age4}$) of Japanese longline is used as the index of recruitment before 2003 (Fig. 1). It is calculated from median CPUE of age 4+ among five series (nominal, ST window, Laslett, w0.8 and w0.5) and age-composition data of Japanese longline. In the projection, $CPUE_{age4}$ is also calculated from CPUE of age 4+ and age composition of LL1 fishery provided in the file "sbtOMdata":

$$CPUE_{age4} = \frac{catch_{age4}}{catch_{age4+}} \times CPUE_{age4+} \qquad (1)$$

It is chief characteristics of this MP to adopt the lower of TACs determined by the two different methods. TAC is specified by:

$$TAC_{y+1} = \begin{cases} TAC_y + max_{up} & if \quad TAC_{y+1} - TAC_y > max_{up} \\ \min\left(TAC_{y+1}^{trend4+},\ TAC_{y+1}^{level4}\right) & if \quad max_{down} < TAC_{y+1} - TAC_y < max_{up} \\ TAC_y - max_{down} & if \quad TAC_{y+1} - TAC_y < max_{down} \end{cases}$$

(2)

$$TAC_{y+1}^{trend\,4+} = TAC_y \times (1 + k\lambda) \quad (3)$$

where

λ: the slope of regression of ln($CPUE_{age4+}$) over years (from y - yrs_{cpue4+} to y - 1),

k: control parameter

$$TAC_{y+1}^{level4} = TAC_y \times f(CPUE_{age4,\,y-1}) \quad (4)$$

$$f(CPUE_{age4,\,y-1}) = \begin{cases} m_{\max} & if \quad CPUE_{age4,\,y-1} > l_{\max} \\ a \times CPUE_{age4,\,y-1} + b & if \quad l_{\min} \le CPUE_{age4,\,y-1} \le l_{\max} \\ m_{\min} & if \quad CPUE_{age4,\,y-1} < l_{\min} \end{cases} \quad (5)$$

where

$CPUE_{age4,y-1}$: average CPUE of age 4 over years (from $y - yrs_{cpue4}$ to $y - 1$),

m_{max}, m_{min}, l_{max}, l_{min}, a, b: control parameters

Fig. 2 shows an example of a relationship between $CPUE_{age4}$ and TAC change for HK5_01_2b.

Results and Discussion

I investigated performance of five variants of the HK5 (Table 2). Different combinations of the control parameter values were able to reach the same tuning level and the five variants showed different behaviors and performance. The following is a brief summery of the results:

- ✓ HK5_01 well satisfied demands for performance described in Introduction section above. HK5_01_2b controlled TACs appropriately for the reference set. It decreased catch in poor stock status and increased when stock was recovering (Fig. 4a). At the same time, catch fluctuation indicated by AAV was very small (Fig. 10). Maximum of TAC decrease and inconsistency of biomass and TAC changes were also low. I consider that this low variance in catch is one of strong points of the HK5_01.
- ✓ HK5_01 was able to change TACs to the right direction depending on assumptions of recent recruitment (Fig. 4b). There were few scenarios in the robustness trials, in which stock extinction was observed (Fig. 4c). Judging from these desirable results for the reference set and the robustness trials (also see Figs. 11, 12), I regard the

HK5_01 variant is the most preferable MP among five variants.

- ✓ There was a difference in early catch decrease depending on tuning levels (Fig. 4d). However, different tuning levels did not make a big difference in average catch over 20 years. This indicates that stock recovery is highly sensitive to change in catch. This is probably because estimated stock size is considerably small.
- ✓ There need some explanations concerning TAC change options. My exploratory analysis showed that TACs increased in 2006 and decreased substantially afterwards in some cases for the option A. These behaviors were observed in other HK5 variants. This is due to that adequate information of low recruitment is still not available in 2004, in which decision on TAC change in 2006 is made. Considering this, I changed a little the way of tuning MPs. This is why HK5 behaviors under option A differed from that under option B (Fig. 4e). I also fount that security against stock collapse was lowered in some degree under option C. TAC change of every five years might be inadequate to recover stock when it is declining.
- ✓ HK5_02 relaxes the upper limit of TAC change derived from information of recruitment. While fluctuation of catch becomes larger than HK5_01, this MP can set larger TAC if stock status is healthy (Fig. 5). Therefore I regard that this MP is as satisfactory as HK5_01.
- ✓ HK5_03 utilizes the average of age 4 CPUE over five years as the recruitment index, while HK5_01 uses the average over three years. Although this MP can manage stock safely, TAC decrease did not stop easily (Fig. 6). Security against stock collapse can be increased by adopting HK5_03. However, it may be too conservative from the viewpoint of long-term catch level.
- ✓ HK5_04 is designed to behave being sensitive to changes in CPUE for age 4+. While TAC reduction in 2008 was smaller, the magnitude of TAC decrease became larger afterwards (Fig. 7). Besides fluctuation of catch was much larger. For these reasons, I regard this MP to be not so preferable.
- ✓ HK5_05 has similar characteristics to HK5_02 (Fig. 8). Behaviors of the two MPs differed when comparing results between different tuning levels.
- ✓ HK5_06 is an exploratory trial. The purpose of this trial is to more realistically consider the situation we are facing. In this trial, TAC is reduced 20% of the current in 2006 as an emergent action, then TAC control with HK5 starts in 2009. Performance of this procedure was as satisfactory as that of HK5_01, and the final level of catch was higher (Fig. 9). This result suggests that early TAC reduction induces higher TACs in future.

- ✓ HK5 specifies TAC using information of CPUE and age compositions in catch, and thus error in CPUE and sample size may affect performance of the procedure. I examined robustness of the performance to changes in error in CPUE (0.6 and 0.9) and sample size (25% and 50% of the original) (Fig. 13). The MP performance almost unchanged even when sample size was reduced to one fourth. In contrast, as observation error in CPUE increased, variance in catch increased and average catch in turn decreased. This tendency was conspicuous, especially for HK5_01, compared with HK5_02 and HK5_03. The results imply that there is a trade-off between MP sensitivity to CPUE change and robustness to error in CPUE. This also relates to that HK5 specifies TAC as minimum of TAC values independently calculated from two information sources (CPUE level for age 4 and CPUE trend for age 4+). However, for even HK5_01, because bias always tends to reducing catch, safeguarding of stock is not fatally spoiled.

References

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Hiramatsu, K., Kurota, H., Shono, H., Takahashi, N. 2004. Behaviors of CPUE-based management procedures examined through the CCSBT final trial specifications. CCSBT-MP/0404/08.

Tsuji, S., Takahashi, N., Shono, H., Kurota, H., Hiramatsu, K. 2003. Further exploration of CPUE-based management procedures. CCSBT-ESC/0309/38.

Table 1. Results under constant catch strategies.

MP name	TL&TAC option	*target level*	max_{up}	max_{down}	B_{2022}/B_{2004}	ave C_{20yrs}
CON_01	2b	8650	5000	5000	1.099	10098
	1b	10100	5000	5000	0.901	11066
	3b	7200	5000	5000	1.299	9156
	2a	10250	5000	5000	1.096	10718
	2c	9000	8000	8000	1.104	10186
	4b	0	5000	5000	0.053	14231
	5b	14930	5000	5000	2.019	5215

Table 2. Parameter values and B_{2022}/B_{2004} and average catch over 20 years for each HK5 variant.

MP name	TL&TAC option	*k*	l_{max}	l_{min}	m_{max}	m_{min}	max_{up}	max_{down}	yrs_{cpue4+}	yrs_{cpue4}	B_{2022}/B_{2004}	ave C_{20yrs}
HK5_01	2b	**2.5**	**0.065**	**0.025**	**1.10**	**0.7500**	**5000**	**5000**	**10**	**3**	1.097	9634
	1b	2.5	0.065	0.025	1.10	0.8250	5000	5000	10	3	0.901	10396
	3b	2.5	0.065	0.025	1.10	0.6650	5000	5000	10	3	1.303	8628
	2a	2.5	0.150	0.055	1.10	0.8000	5000	5000	10	3	1.098	9521
	2c	2.5	0.065	0.025	1.10	0.6400	8000	8000	10	3	1.098	9844
HK5_02	2b	2.5	0.100	0.025	**1.25**	0.7575	5000	5000	10	3	1.097	9670
	1b	2.5	0.100	0.025	1.25	0.8325	5000	5000	10	3	0.898	10454
	3b	2.5	0.100	0.025	1.25	0.6850	5000	5000	10	3	1.299	8803
	2a	2.5	0.150	0.077	1.25	0.8000	5000	5000	10	3	1.100	9434
	2c	2.5	0.100	0.025	1.25	0.6620	8000	8000	10	3	1.101	9938
HK5_03	2b	2.5	0.150	0.050	1.25	0.7500	5000	5000	10	**5**	1.095	9339
	1b	2.5	0.150	0.025	1.25	0.7500	5000	5000	10	5	0.896	10187
	3b	2.5	0.150	0.070	1.25	0.7500	5000	5000	10	5	1.304	8501
	2a	2.5	0.150	0.035	1.10	0.7500	5000	5000	10	5	1.100	9434
	2c	2.5	0.150	0.050	1.25	0.6400	8000	8000	10	5	1.100	9416
HK5_04	2b	**5.0**	0.150	0.021	1.25	0.7500	5000	5000	10	5	1.101	8872
	1b	5.0	0.125	0.000	1.25	0.7500	5000	5000	10	5	0.897	9703
	3b	5.0	0.150	0.046	1.25	0.7500	5000	5000	10	5	1.297	8272
	2a	5.0	0.150	0.005	1.10	0.7500	5000	5000	10	5	1.107	8925
	2c	5.0	0.150	0.051	1.25	0.7500	8000	8000	10	5	1.103	9198
HK5_05	2b	2.5	0.150	0.017	**1.25**	0.7500	5000	5000	10	3	1.104	9543
	1b	2.5	0.130	0.000	1.25	0.7500	5000	5000	10	3	0.904	10391
	3b	2.5	0.150	0.070	1.25	0.7500	5000	5000	10	3	1.303	8546
	2a	2.5	0.150	0.017	1.10	0.7500	5000	5000	10	3	1.095	9481
	2c	2.5	0.150	0.017	1.25	0.6550	8000	8000	10	3	1.099	9814
HK5_06	2a	2.5	0.065	0.025	1.10	0.9600	5000	5000	10	3	1.102	10113

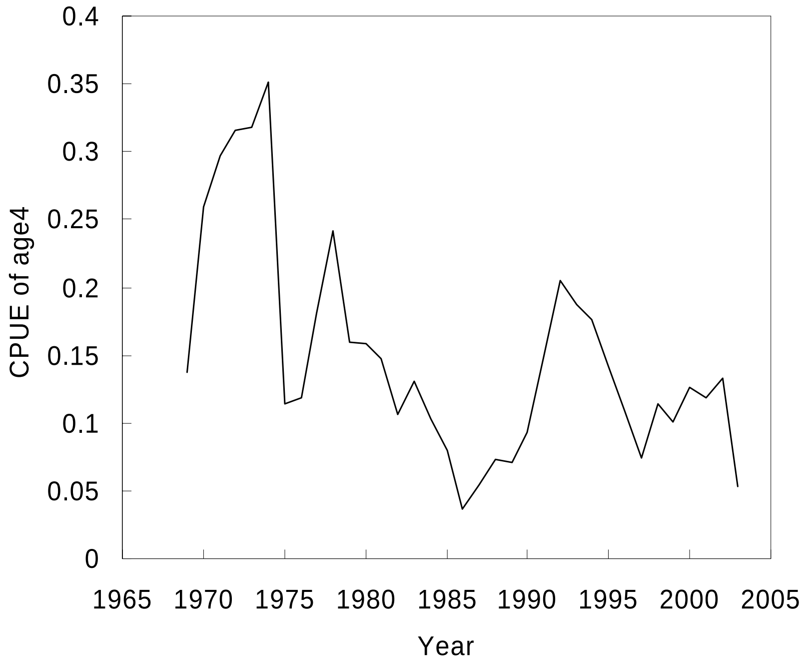


Fig. 1. CPUE of age 4 fish used as recruitment information.

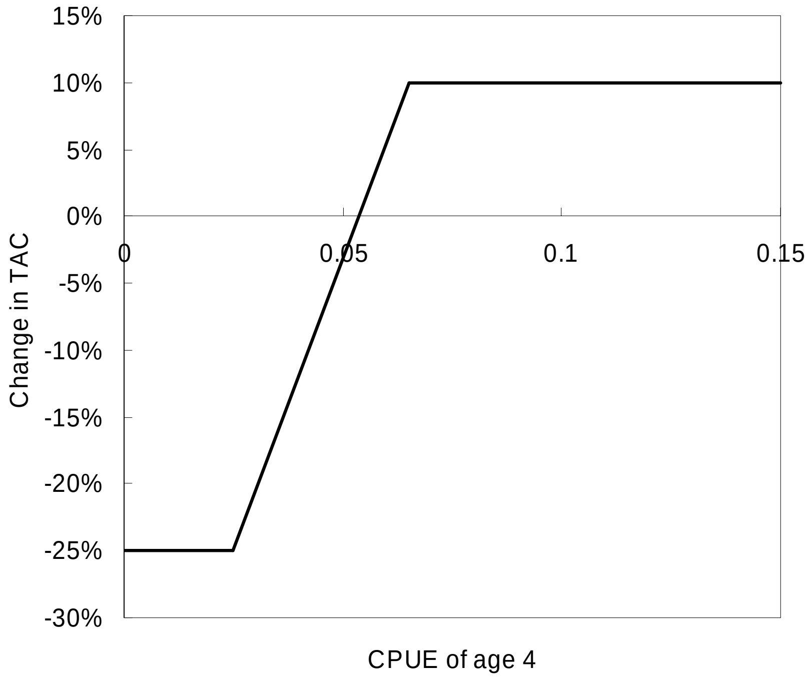


Fig. 2. Example of relationship between average CPUE of age 4 and change in TAC for HK5_01_2b.

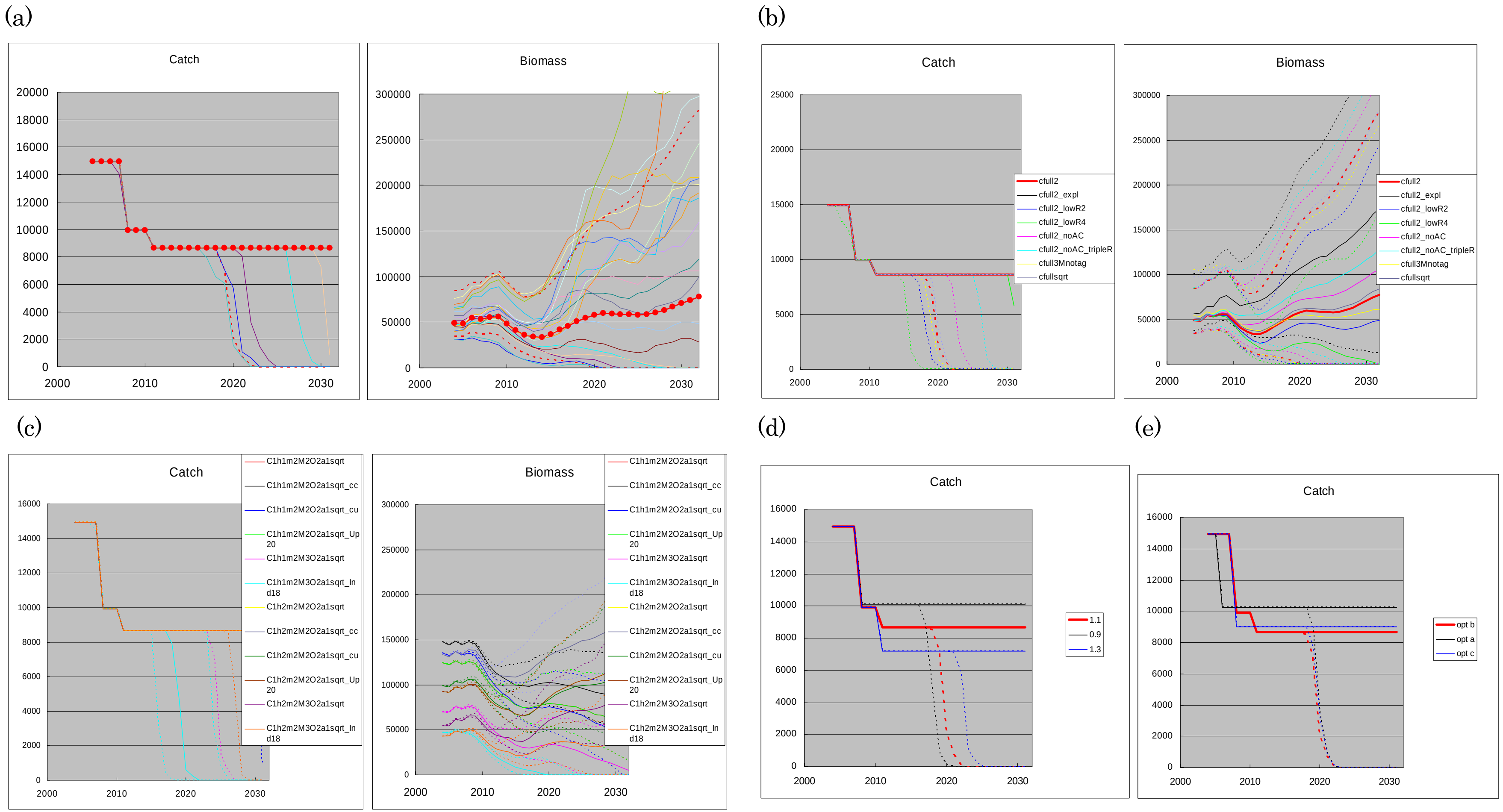


Fig. 3. Results of CON_01 for (a) the Cfull2 reference set (median, 10th and 90th percentiles with worm plots, TL=1.1, TAC option B), (b) the full grid robustness trials, (c) the single-cell robustness trials, (d) different tuning levels (TL=1.1, 0.9, 1.3) and (e) different TAC change options (option B, option A, option C).

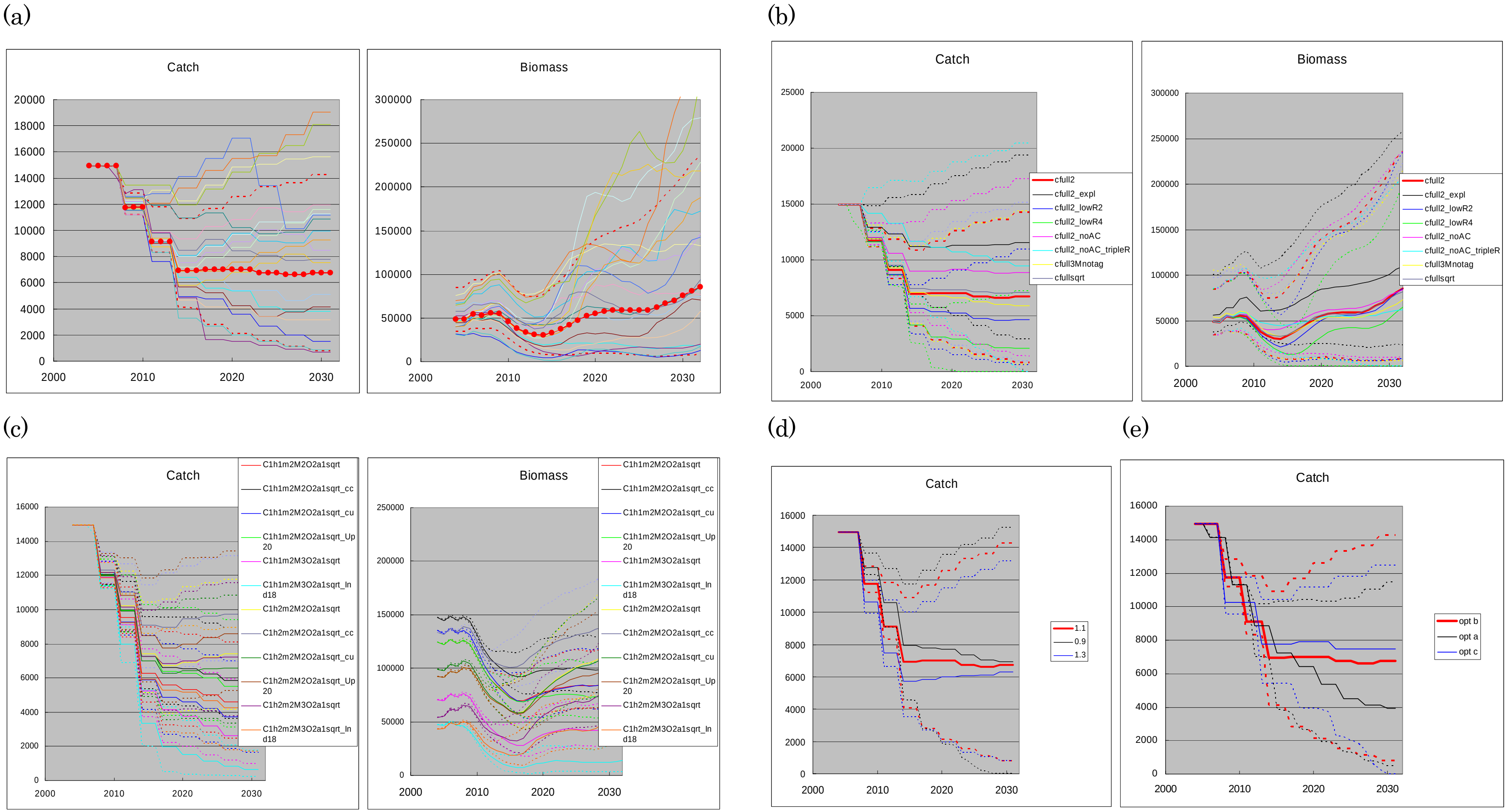


Fig. 4. Results of HK5_01 for (a) the Cfull2 reference set (median, 10th and 90th percentiles with worm plots, TL=1.1, TAC option B), (b) the full grid robustness trials, (c) the single-cell robustness trials, (d) different tuning levels (TL=1.1, 0.9, 1.3) and (e) different TAC change options (option B, option A, option C).

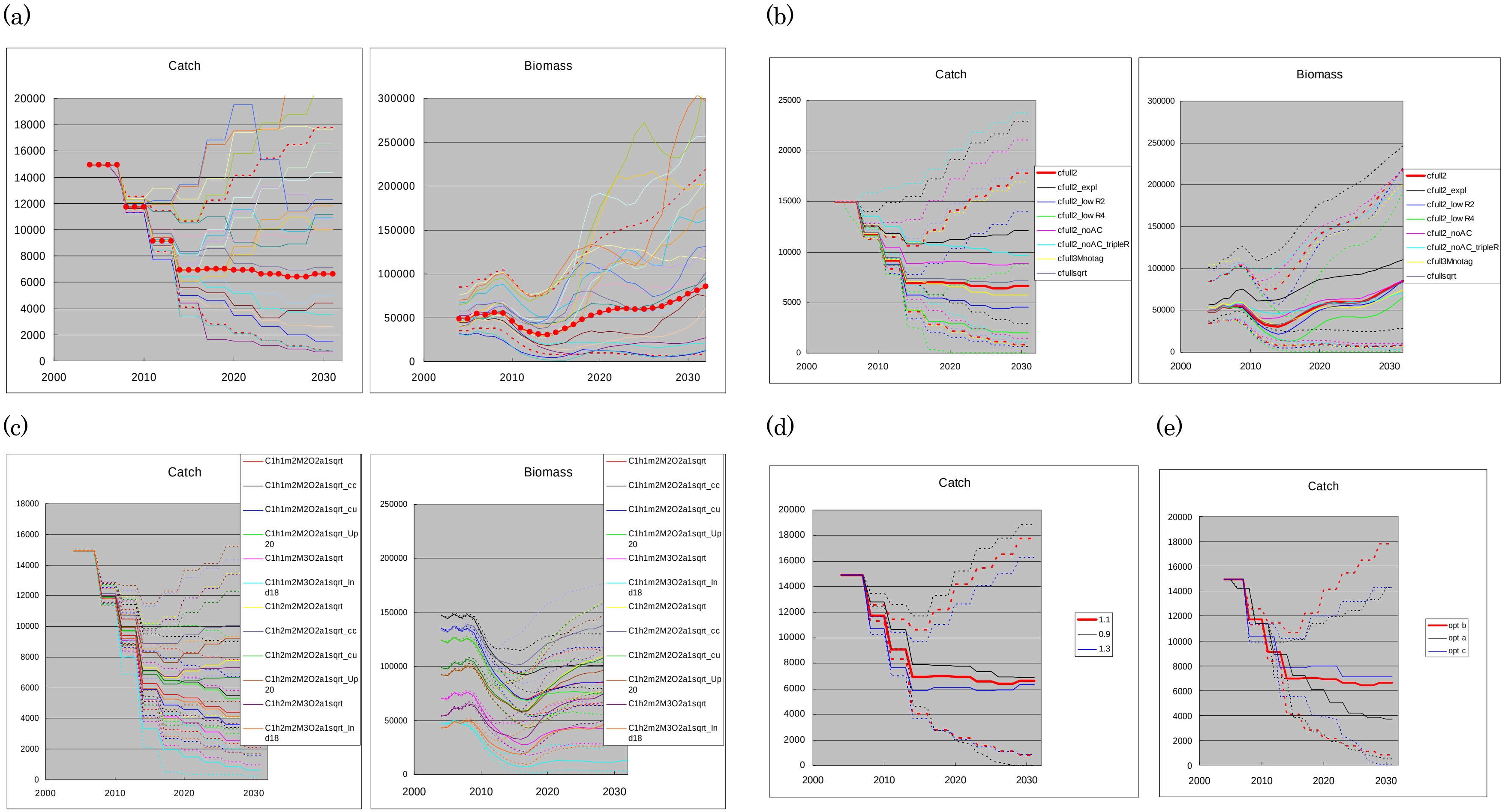


Fig. 5. Results of HK5_02 for (a) the Cfull2 reference set (median, 10th and 90th percentiles with worm plots, TL=1.1, TAC option B), (b) the full grid robustness trials, (c) the single-cell robustness trials, (d) different tuning levels (TL=1.1, 0.9, 1.3) and (e) different TAC change options (option B, option A, option C).

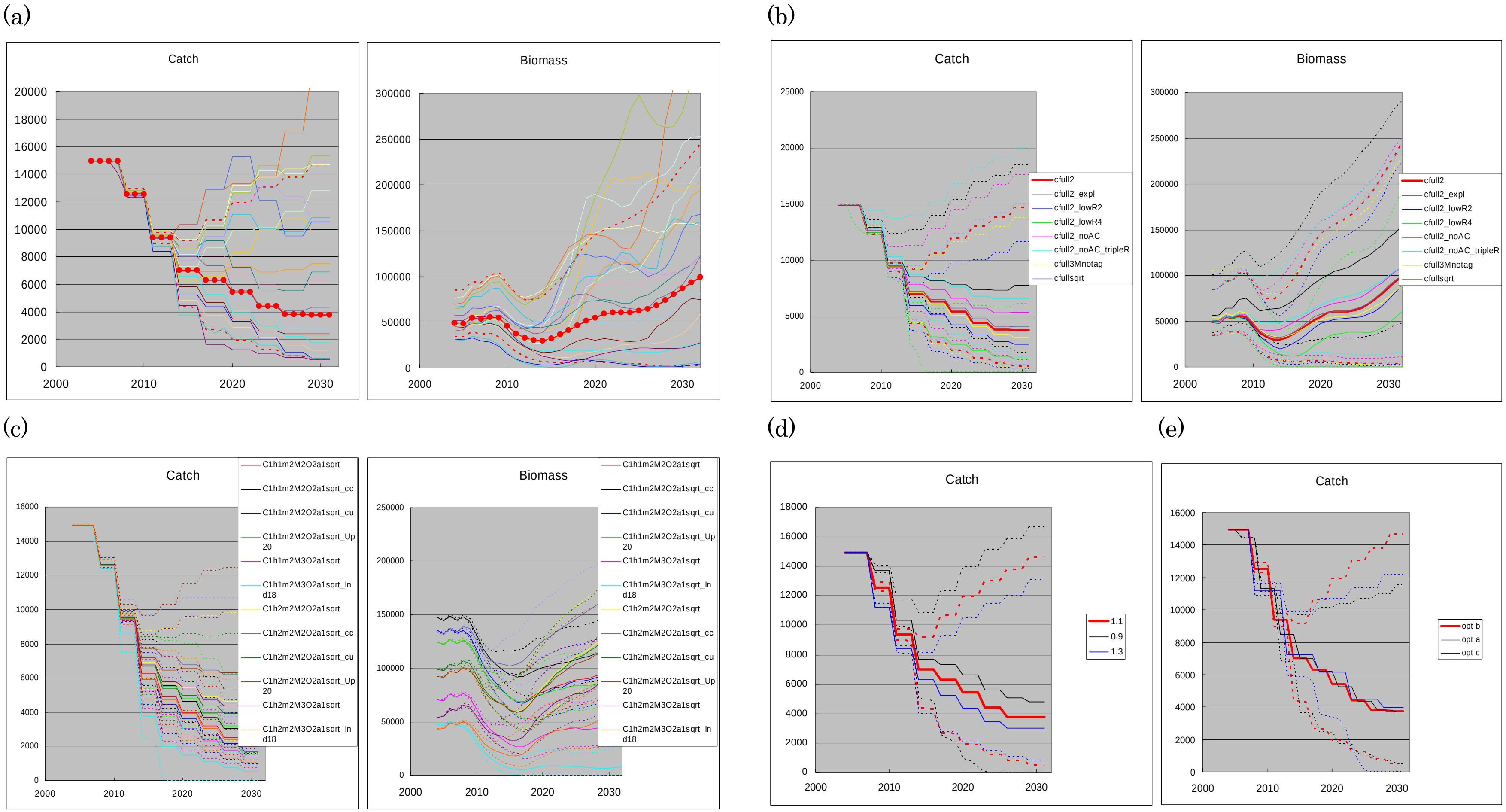


Fig. 6. Results of HK5_03 for (a) the Cfull2 reference set (median, 10th and 90th percentiles with worm plots, TL=1.1, TAC option B), (b) the full grid robustness trials, (c) the single-cell robustness trials, (d) different tuning levels (TL=1.1, 0.9, 1.3) and (e) different TAC change options (option B, option A, option C).

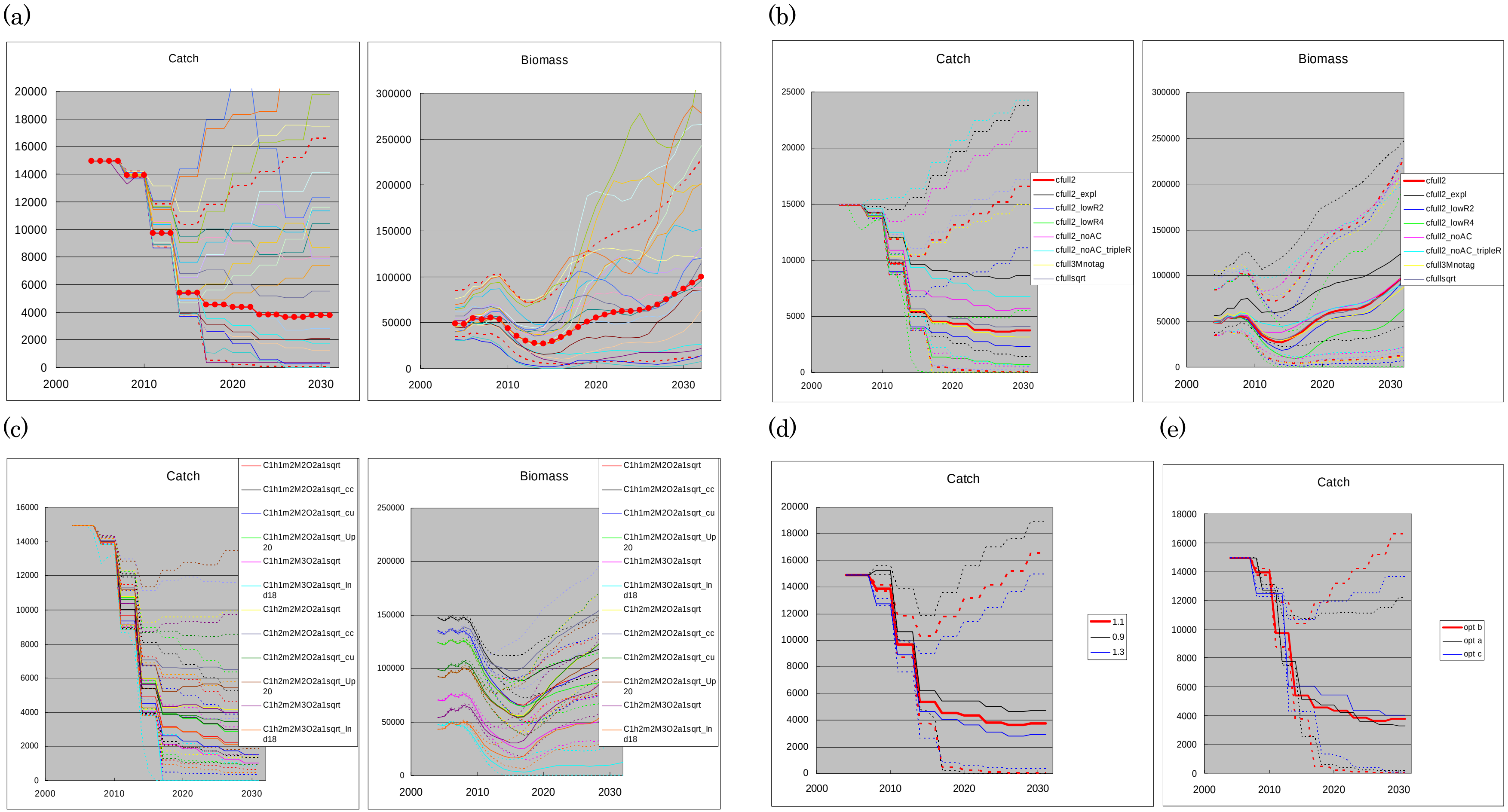


Fig. 7. Results of HK5_04 for (a) the Cfull2 reference set (median, 10th and 90th percentiles with worm plots, TL=1.1, TAC option B), (b) the full grid robustness trials, (c) the single-cell robustness trials, (d) different tuning levels (TL=1.1, 0.9, 1.3) and (e) different TAC change options (option B, option A, option C).

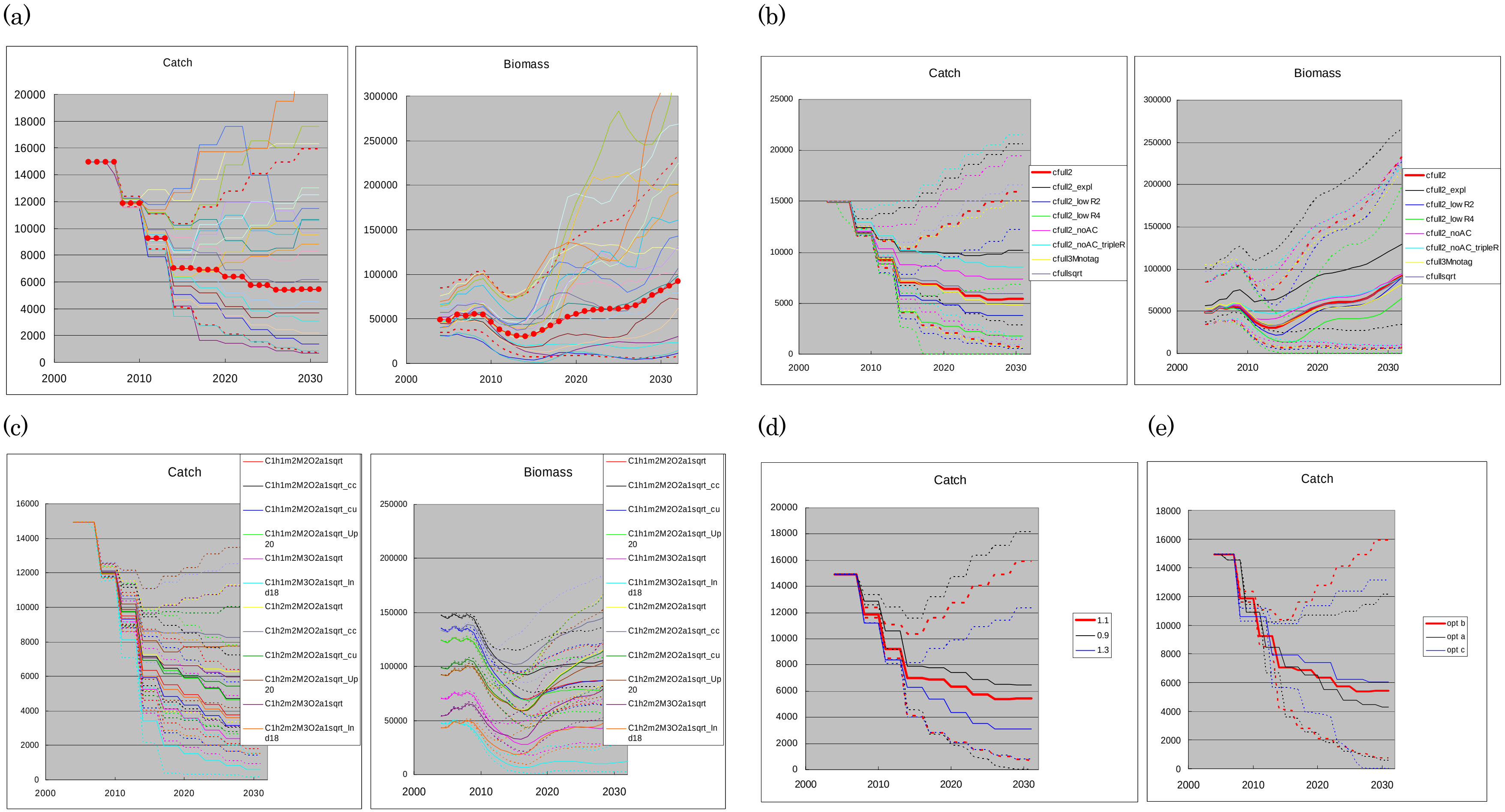


Fig. 8. Results of HK5_05 for (a) the Cfull2 reference set (median, 10th and 90th percentiles with worm plots, TL=1.1, TAC option B), (b) the full grid robustness trials, (c) the single-cell robustness trials, (d) different tuning levels (TL=1.1, 0.9, 1.3) and (e) different TAC change options (option B, option A, option C).

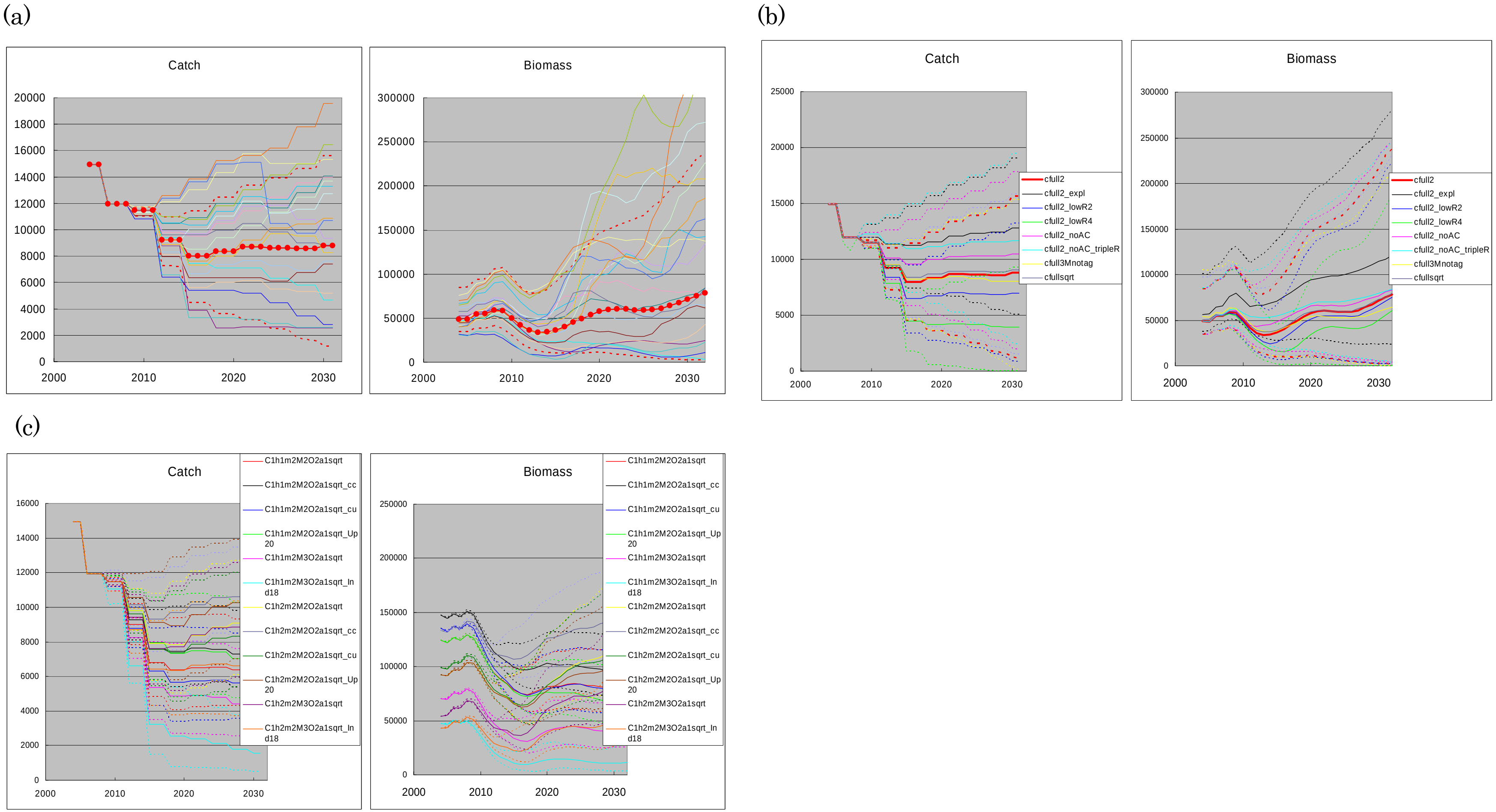


Fig. 9. Results of HK5_06 for (a) the Cfull2 reference set (median, 10th and 90th percentiles with worm plots, TL=1.1, TAC option A), (b) the full grid robustness trials, and (c) the single-cell robustness trials.

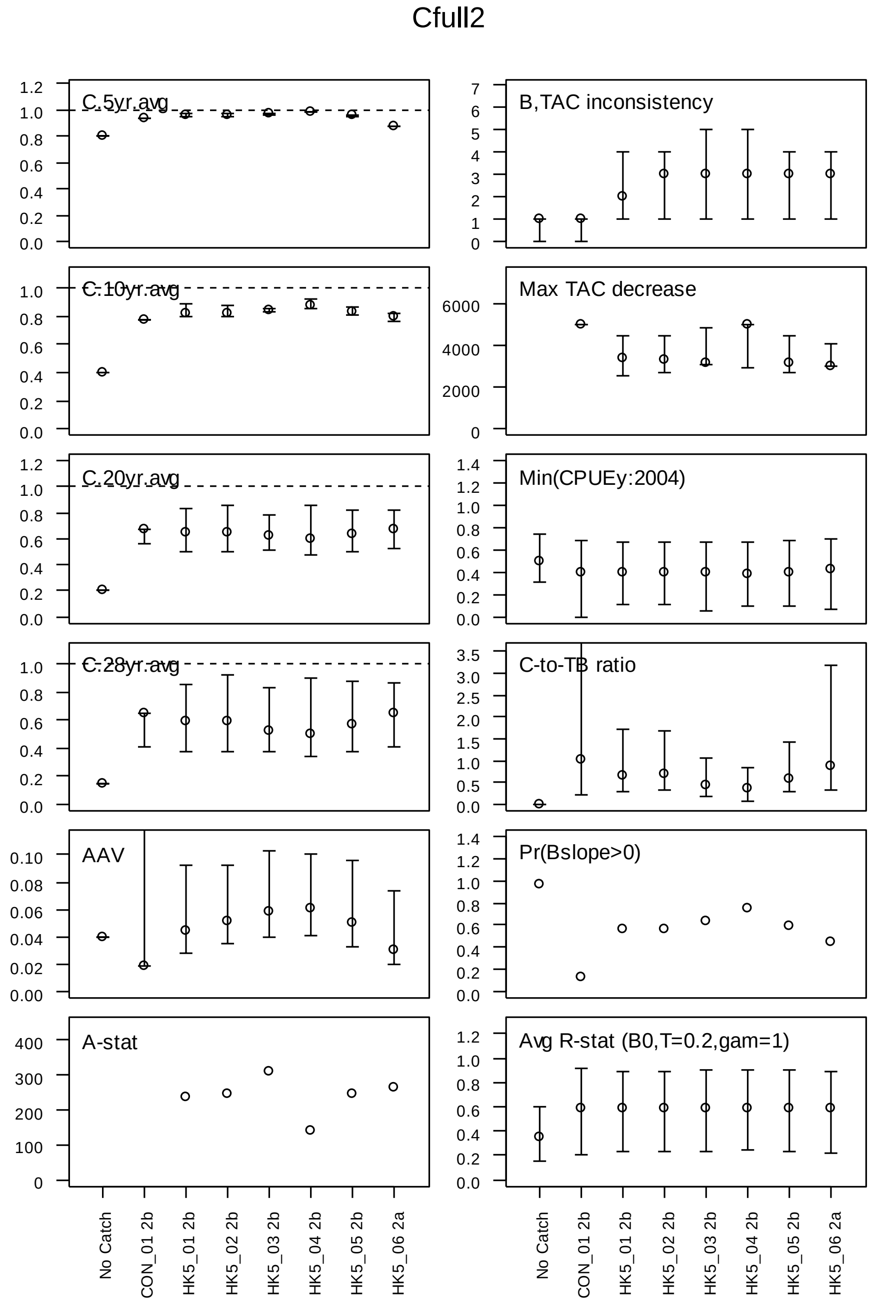


Fig. 10. Performance statistics for the HK5 MPs for the reference set (TL=1.1, TAC option B except HK5_06).

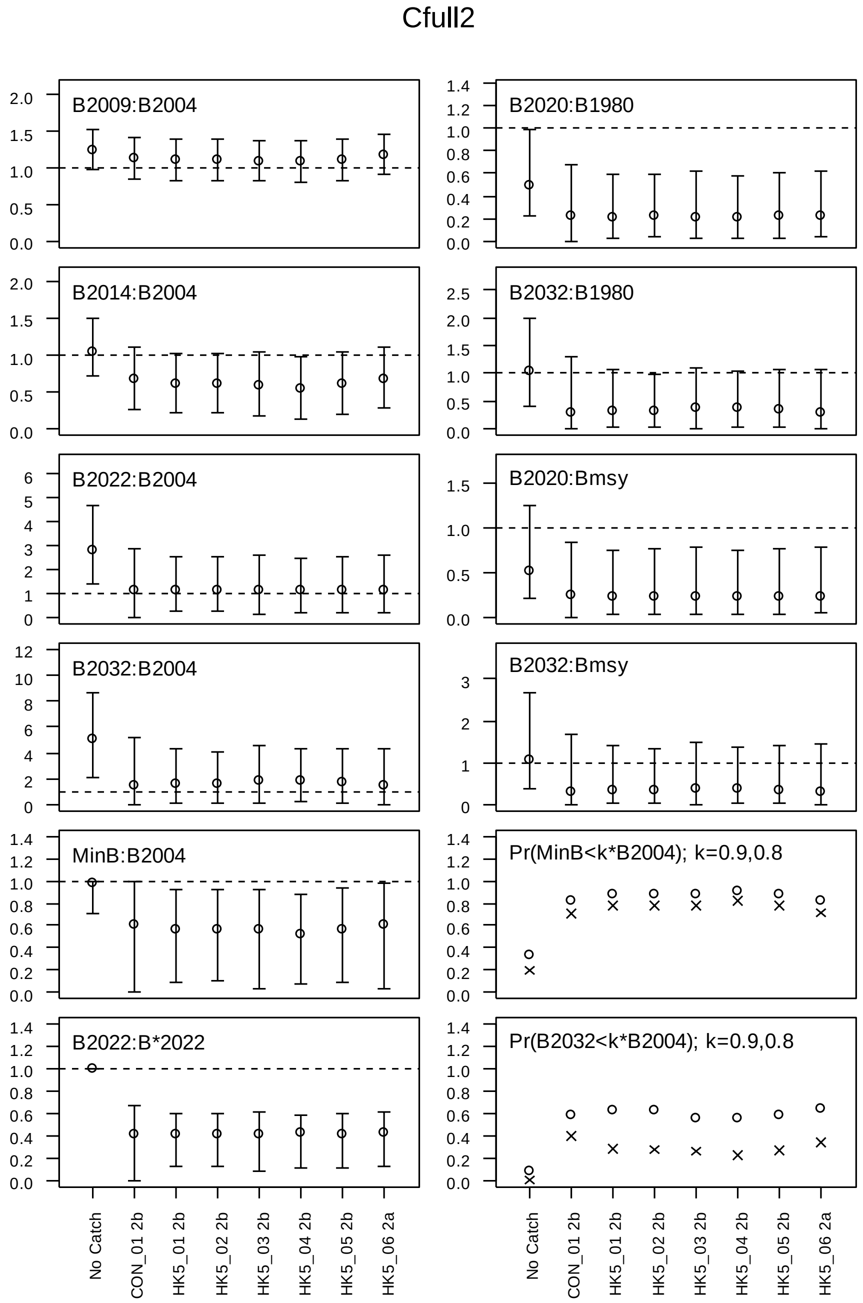
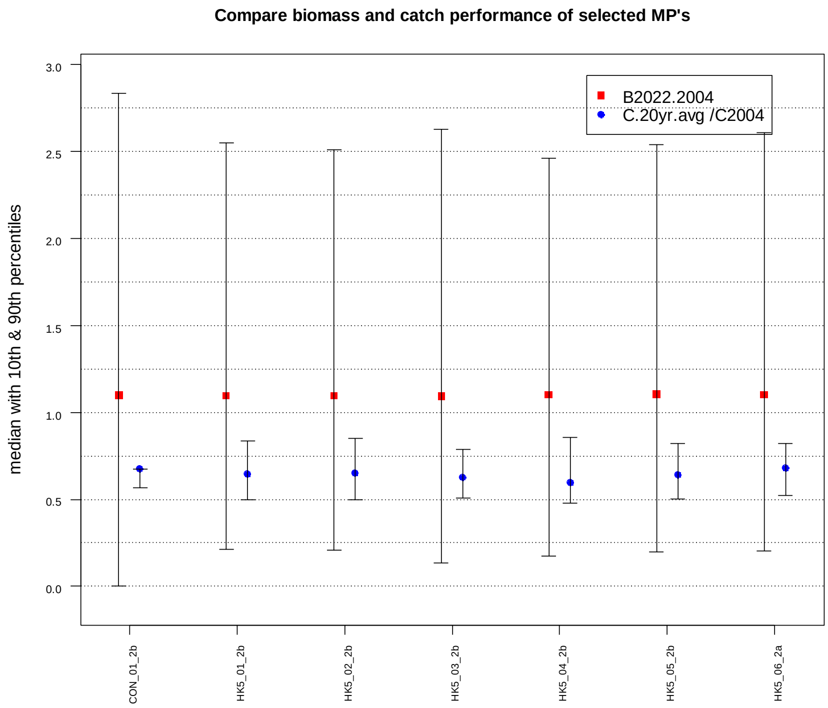


Fig. 10. continued.

(a)



(b)

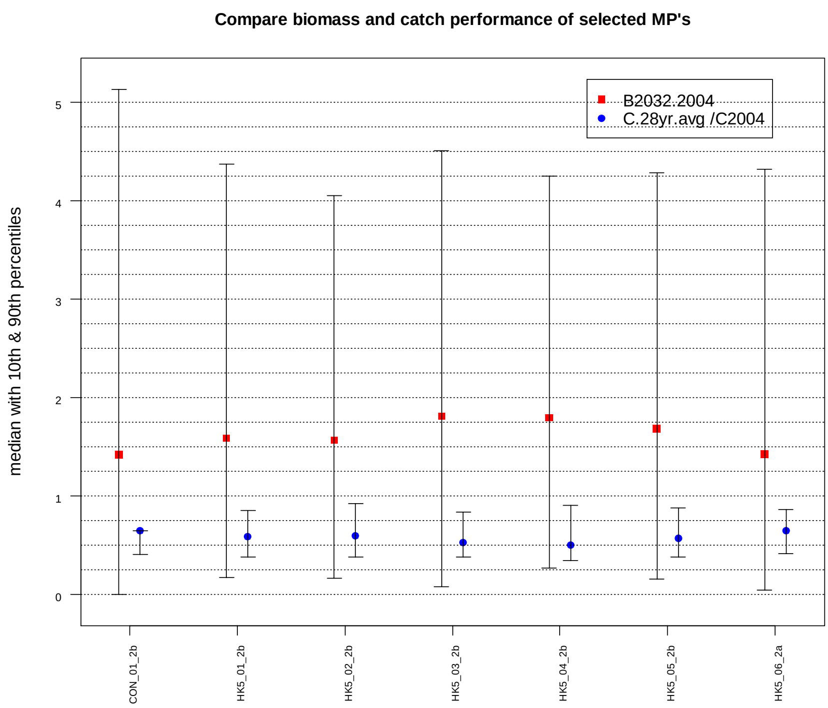
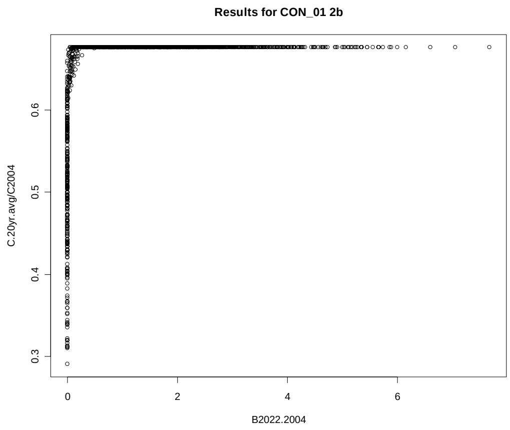
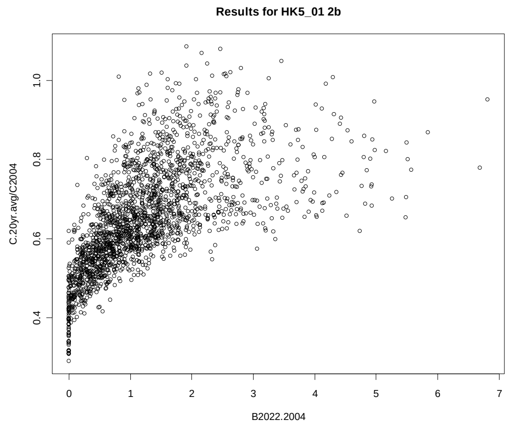


Fig. 11. Comparison of (a) B2022 and C20years and (b) B2032 and C28years among the HK5 variants for the reference set (TL=1.1, TAC option B except HK5_06).

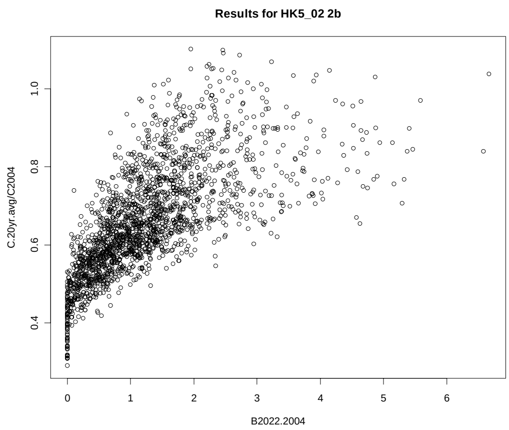
(a) CON_01_2b



(b) HK5_01_2b



(c) HK5_02_2b



(d) HK5_03_2b

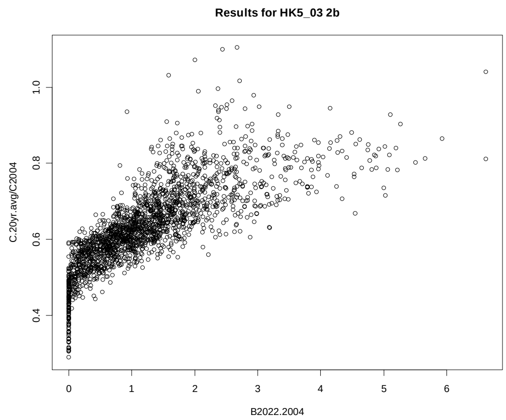
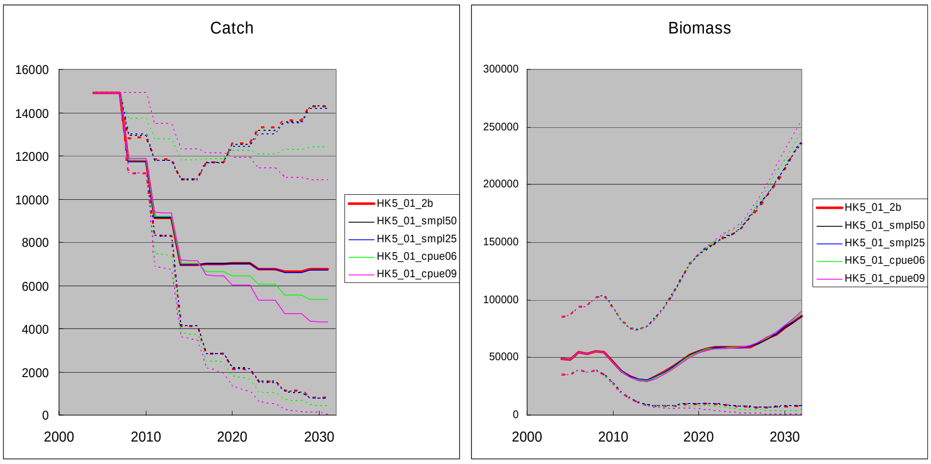
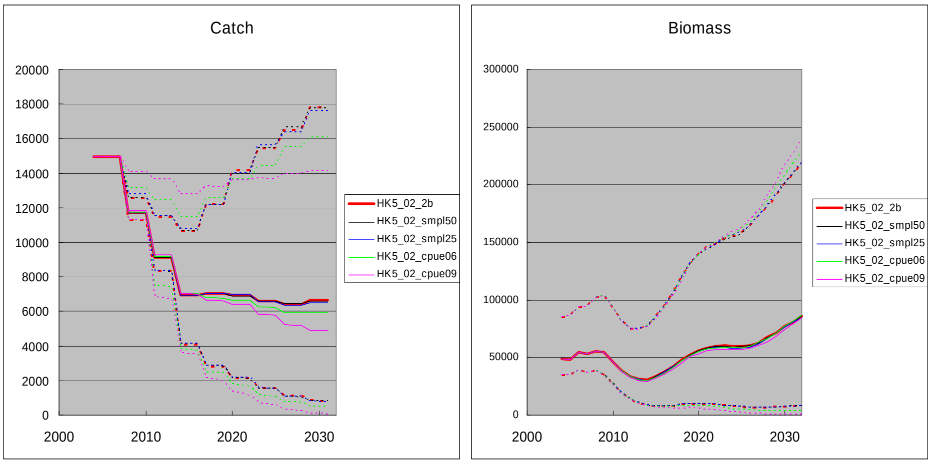


Fig. 12. Scatter plot of all 2000 biomass (B2022.2004) and catch (C20yr.avg) performance (TL=1.1, TAC option B).

(a) HK5_01



(b) HK5_02



(c) HK5_03

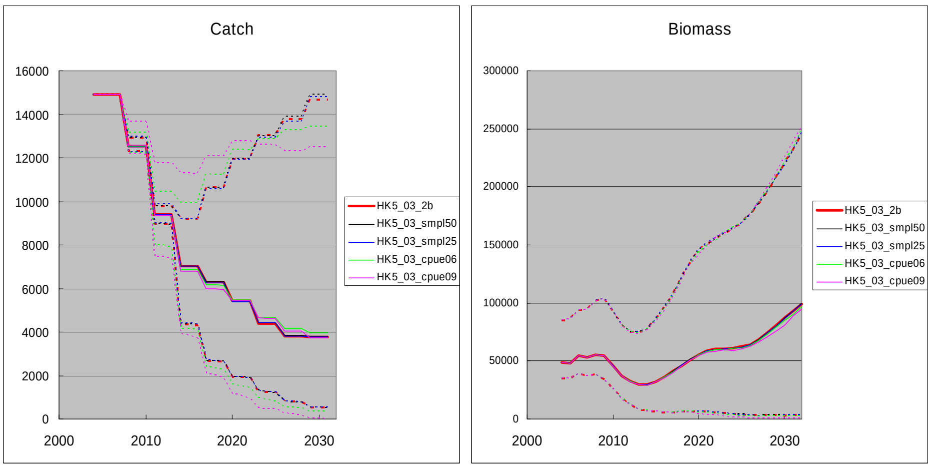


Fig. 13. Influences of sample sizes for age composition data (50% and 25% of the original) and CPUE index residuals (0.6 and 0.9) (TL=1.1, TAC option B).