

Examination of the southern bluefin tuna (SBT) operating model and preliminary projections for the 2014 assessment

2014年の資源評価のための
オペレーティングモデルの解析と暫定的な将来予測

Osamu SAKAI¹, Norio TAKAHASHI¹, Hiroyuki KUROTA^{1,2} and Doug S Butterworth³

境 磨 ・ 高橋紀夫 ・ 黒田啓行 ・ ダグ バタワース

¹National Research Institute of Far Seas Fisheries, Fisheries Research Agency, JAPAN

国際水産資源研究所

²Seikai National Research Institute, Fisheries Research Agency, JAPAN

西海区水産研究所

³University of Cape Town

ケープタウン大学

Summary

The impacts of updates of the SBT operating Model (OM) and input data are examined. Preliminary results from the stock assessments and from projections using Bali Procedure (MP3) are compared to earlier results from the stock assessment conducted in 2011. The analyses show that:

- (1) for the new base case, there is a great upward trend in biomass for age 10+ SBT, and biomass is greater in absolute terms, compared to the previous stock assessment; but the stock's status in 2013 remains low ($B_{2013}/B_0=0.07$);
- (2) for the projection results for base case, the expected catch (TAC) under the MP and the abundance indices (CPUE and aerial survey index) are very similar to those for the previous results calculated in the MP evaluation in 2011, and the stock rebuilding probability is a little more optimistic ($P[B_{2035} > 20\%B_0]=75.6\%$);
- (3) past unaccounted catch mortality would have a low impact on estimates of recent stock status, if those amounts were in the range of 1-10% of the LL1 catch;
- (4) the sensitivity trials indicate no danger of stock collapsing if managed under the MP, even for the most pessimistic scenario ("upq2008") considered;
- (5) these results suggest that the Bali Procedure (MP3) as currently specified can manage SBT stock adequately, so that there is no need for re-tuning at this time.

要約

オペレーティングモデル (OM) と入力データの更新の影響を検討した。暫定的な資源評価とバリ方式を使用した将来予測の結果を前回 (2011 年) の資源評価結果と比較した。得られた結果は以下の通り :

- (1) 前回の資源評価と比較して、OM によるベースケースシナリオでの評価結果では全体的に高いバイオマスが推定されるものの、その B_0 に対する資源状態は未だ低い水準である ($B_{2013}/B_0=0.07$) ;
- (2) ベースケースシナリオでの将来予測結果では、2011 年の MP 性能評価における将来予測結果に非常に類似した TAC と資源指数の予測値が示される。また、資源回復確率はより楽観的になる ($P[B_{2035}> 20\%B_0]=75.6\%$) ;
- (3) 過去の考慮されていない死亡量が、もし LL1 漁業での漁獲量の 1~10%程度であったならば最近の資源水準への影響は小さいであろう ;
- (4) 感度試験の結果、たとえ最も悲観的なシナリオの下での評価 (upq2008 シナリオ) においても、管理方式での資源管理によって資源が崩壊する危険が無い事が示された ;
- (5) これらの結果は、現在のところバリ方式 (MP3) を再チューニングせずに使用しても、ミナマガロ資源を適切に管理できることを示唆している。

1. Introduction

The Operating Model (OM) for stock assessment has been updated since the previous model-based stock assessment developed during 16th CCSBT Extended Scientific Committee (ESC) meeting. There are three primary aspects of this update:

- (1) the usual update of the input data (e.g. total catch, catch at size, abundance indices),
- (2) inclusion of the Close-Kin data, and
- (3) changing the maturity schedule assumed (CCSBT 2013a).

As these aspects of the update may impact the result of stock assessment, they need to be examined carefully to check their influence and the reasonability of the results to which they lead.

The 4th Operating Model and Management Procedure technical meeting (OMMP4) (CCSBT 2013b) and 18th ESC (CCSBT 2013a) determined certain specifications for the OM to be used for following stock assessment which is scheduled for 2014, but there was inadequate time to conduct all the analyses needed to finalize sensitivity scenarios relating to model assumptions, and projection specifications were not fully examined. These matters are important issues to consider in the stock assessment setting.

The 2014 stock assessment is first to be conducted after the implementation of the management procedure (MP) as the basis to recommend future TACs. Thus, one important task for this new assessment will be to check that continued management under the MP remains appropriate. This will require a comparison between the new assessment results and earlier simulated stock trajectories considered in the MP evaluations in 2011. If the assessment results fall substantially outside of these earlier simulations from the OMs used in testing and selecting this MP, the ESC will have to discuss whether “exceptional circumstances” apply under the “meta-rule” process.

In this document, we report OM examination and projection results for the recent tentative base case and for some candidates for sensitivity trials that were specified at the previous ESC. In particular this report covers:

- (1) the impact on results arising from the recent data updates,
- (2) the influence of additional allowance for unaccounted catch for both the conditioning and the projection, and
- (3) the differences from the previous stock assessment results.

2. Methods

Updates of data and model

The version of program codes and data files used in this analysis is controlled by “GitHub”. This is a web-based hosting service for software development project, and CCSBT have a repository to

manage, improve, and share the OM and projection program code¹. We modified several program codes and data files which were downloaded from GitHub repository in May 2014. The major points that we changed was as follows.

- Data file “sbtdata2012_newLambda0.dat” (input data for OM)

- Update of the recent piston-line trolling index (to 2013) for a sensitivity trial to the OM.
- Addition of a tentative assumption of unaccounted mortality using an LL1 overcatch adjustment option in the OM. The new scenarios we added were a 1%, 5%, or 10% increase of LL1 catch from 2006 onwards to take account of discards and recreational fishing mortality.

- OM code “sbtmod.tpl” (program code of conditioning)

- Modification to output the “Historical biomass of age 10+ fish” into the “.grid” file.
- Modification to control the additional LL1 overcatch scenarios to include the unaccounted mortality.

- MP code “sbtproj.tpl” (program code of projection)

- Modification to handle age 10+ fish biomass from “.grid” file.
- Addition of “.s9” output code for age 10+ fish biomass from 1931 and including the years for which the TAC is projected.
- Addition of some options to include the unaccounted mortality and 20% surface overcatch assumption.

All of modified files were re-uploaded into GitHub repository to share among the CCSBT members in advance of the 5th Operating Model and Management Procedure Technical Meeting (OMMP5). The grid sampling code “sample.tpl” was not modified.

Model specification

In this analysis, input data up to 2012 were used for OM conditioning (the Aerial survey (AS) index extended over 1993–2013). The projection period was the following 27 years (from 2013 to 2040), although the TACs for the first 5 years were fixed to correspond to information provided in the 2014 data exchange and the TAC determination at the 12th annual Commission meeting (CCSBT 2013c): 11029.34t in 2013 (actual catch), 12449t in 2014, and 14647t in 2015–2017 (TAC based on the MP). After 2018, TACs were simulated using the Bali procedure (MP3) every three years with a one year time lag. The control file of MP3 included the LL1 CPUE (1969–2012) and AS index (1993–2013), which are the same input data as used for the last MP calculation during the 18th ESC (the catchability ratio for AS vs CPUE = 849.843). This MP was tuned in 2011. Quota allocations by

¹ <https://github.com/CCSBT-DM/sbtmod>

fleet were based on the “nominal allocations”: LL1: 0.5099, LL2: 0.0732, Indonesia: 0.0648, Australia: 0.3522.

The default grid specification which was agreed at the 18th ESC was used for this analysis (Table 1). The difference between the previous grid structure and new one is as follows:

- (1) Steepness: using uniform weight to sample instead of the likelihood-based weight,
- (2) M0 (=M1): high value “0.50” was added instead of low value “0.30”,
- (3) M10: values were changed to “0.05, 0.075, 0.1, 0.125” from “0.07, 0.10, 0.13, 0.16” (Table 2).

For the base case and some sensitivity analyses, we also examined results for an alternative grid structure which has an extended range of M0 and M10 values (M0: “0.30, 0.35, 0.40, 0.45, 0.50, 0.54”; M10: “0.03, 0.06, 0.09, 0.12, 0.15, 0.18”: - see Table 3).

Base case and sensitivity runs

We examined the base case run and some of the sensitivity trials which were specified at the 18th ESC (CCSBT 2013a). Details of the specification of each run are summarized in Table 4.

Comparison with previous assessment result

The base case run was compared to the previous assessment result which is the “base case” run for the MP tuning in 2011. Based on the “base.grid” calculated in 16th ESC, the “MP3_2035_3000_inc” scenario was re-run using the previous projection program (sbtprojv120) and the Bali procedure (MP3). The input file is the same as used for the MP evaluation in 2011 (catchability ratio AS vs CPUE = 838.2094).

3. Results and Discussion

Base case

When the default grid structure is used, the middle M0 values (0.40 and 0.45) and lower M10 values are preferred (Fig. 1a). Negative log-likelihood profiles show that the likelihood component for the tag data results in higher objective-function weights which are assigned to lower M10 values (Fig. 2). There are no results that would support the necessity for changing the default grid specification; the grid values which are outside of the default grid are rarely sampled in the extended grid run (Fig. 1b).

The current OM calculates an “index” of the spawning populations which involves weighting by the relative spawning contribution potential-at-age (we call this the “SSB index” in this document), instead of the absolute spawning stock biomass (CCSBT 2013b). However, the OMMP4 meeting agreed to use 10+ year-old biomass for reporting on stock status for consistency (CCSBT 2013b). Accordingly we show the trajectories of both age 10+ biomass and the SSB index in this

document. Compared to the age 10+ biomass, the SSB index already indicates an upward trend in the most recent year, possibly due to the new maturity schedule (that now starts at age 7) which was used to calculate the SSB index (Fig. 3).

-Comparison with the previous assessment in 2011:

In the base case analysis, the median value of age 10+ biomass in 2013 is 78,729 t, which is 70% greater than for the previous assessment/projection results (Table 5). This higher biomass value is not only for 2013, but for the whole historical trajectory for the age 10+ biomass (Fig. 3b). The stock status in 2013 remains low at 0.07 B_0 , but this is a little higher than for previous assessment/projection (0.05 B_0). Current 90%-ile intervals are larger than for the previous assessment. This is a consequence of the different grid specification: e.g. the current assessment uses prefixed equal-weights for steepness instead of a likelihood-based weight (Table 2).

The base case projections using the Bali Procedure (MP3) indicate that the age 10+ biomass will reach the interim rebuilding target of 0.20 B_0 with 75.6% probability by 2035 (Table 5). This probability is larger than for the previous assessment, which suggests that recent stock rebuilding has been more optimistic than was expected. In a comparison of projection results between the current base case and the previous assessment, the current base case indicated higher absolute values of age 10+ biomass: however the distributions of the future catch (TAC) and predicted abundance indices (CPUE and Aerial survey index) fully overlap each other (Figs. 3 and 4). These results indicate that current OM update essentially affects only the estimation of the absolute values of biomass, and has a low impact on TAC calculations which are based on abundance indices and use the MP. According we conclude that the Bali Procedure (MP3) as currently specified can manage the SBT stock adequately, so that there is no need for re-tuning at this time.

Sensitivity run

-“CK off” and “IS20”:

For the “CKoff” and “IS20” sensitivity scenarios, the examinations were conducted using not only the default grid but also the extended grid. For the “CKoff” scenario, for which we excluded the CK data from input data set, higher M10 values are preferred compared to the base case run. Nevertheless the highest M10 value (0.18) is rarely sampled for the run with the extended grid (Fig. 5). The “CKoff” scenario gives rise to very similar results to previous assessment: the new age 10+ biomass is only some 10% higher (compared to the 70% for the base case), the stock status in 2013 is 0.06 B_0 and the rebuilding probability ($P[B_{2035} > 20\%B_0]$) is 69.9% (Table 5).

In the “IS20” scenario, the maximum age at which flat selectivity commences is changed from age 25 to age 20 for Indonesian LL fishery. This scenario also shows a preference for higher M10 values, but the highest M10 value (0.18) is not sampled for the run with the extended grid run (Fig. 6). This scenario leads to lower B_0 values compared to the other scenarios; thus the results for stock

status and rebuilding probability are somewhat more optimistic ($B_{2013}/B_0 = 0.08$, and $P[B_{2035} > 20\%B_0] = 85.1\%$; see Table 5).

-Unaccounted mortality:

This document reports some sensitivity scenarios related to unaccounted catch mortality (UAM). In these scenarios, three cases of extra catch are assumed in LL1 fishery from 2006 onwards (increases in the LL1 catch of 1%, 5%, and 10%) in order to examine the impact of recent UAM (from discards and recreational fishing mortality) for conditioning and projections. In addition, the impact of a continued 20% over-catch by the surface fishery is also examined in the projections.

The results show that there is not very much difference for the distributions of M0 and M10 values that are sampled in the grid between the base case run and the LL1 extra catch scenarios, regardless of the extent of these extra catches (the “AddedC1p”, “AddedC5p”, and “AddedC10p” scenarios; see Fig. 7h, i, and j). The estimates of stock status are almost same amongst these scenarios ($B_{2013}/B_0 = 0.07$ – see Table 5); this suggests that past UAM would have a low impact on the estimation of recent stock status, if the extent was the range of 1–10% of the LL1 catch. These UAM would reduce the probability of stock rebuilding ($P[B_{2035} > 20\%B_0] = 70.0–74.9\%$), but they would be not sufficient to preclude reaching the rebuilding target of 20% B_0 with a 70% probability (Table 5). In contrast, the impact of a continued 20% surface over-catch has strong impact on stock rebuilding; it would make it more difficult for the SBT stock to reach the rebuilding target in 2035 (e.g. for the “SV_overC” scenario: $P[B_{2035} > 20\%B_0] = 68.9\%$). However, even if these UAM and over-catches are fully included in the OM, there is no danger of the stock collapsing if management continues under the MP (“C10p_overC” scenario: see Table 5 and Fig. 8-P).

-The other sensitivity trials:

We also examined the other seven sensitivity trials which were specified at the 18th ESC (CCSBT 2013a). Almost all these scenarios indicate similar distributions for the M0 and M10 values sampled in the grid, and estimated stock statuses (B_{2013}/B_0) are in the range of 0.06–0.08. There is no result which indicates any potential danger of stock collapsing under the MP management. The most optimistic scenario is “Include Troll”; incorporating the troll survey data increases recent recruitment estimates, particularly for 2010 (Fig. 8-I). This would lead to particularly rapid recovery of the spawning stock biomass in projections, and reflects the highest stock rebuilding probability amongst the sensitivity scenarios ($P[B_{2035} > 20\%B_0] = 88.1\%$). In contrast, the most pessimistic scenario is “upq2008”; which assumes a step-function increase in catchability of 0.35 from 2008 onwards. This scenario suggests a lower stock status ($B_{2013}/B_0 = 0.06$) and rebuilding probability ($P[B_{2035} > 20\%B_0] = 56.2\%$); however the plausibility of this scenario is questionable because the high 2008 LL1 CPUE point may simply be part of general increasing trend (Pope 2014). This increasing trend probably reflects the existence of some strong year-classes in the late 2000s (Sakai 2014).

4. Further works

These analysis have not used the dataset from the most recent fishing year (2013FY). In advance of the next stock assessment at the 19th ESC, the fully updated dataset should be used as input data for OM to examine the model behavior for the base case and sensitivity runs. In addition, further discussion about the fleet and catch-at-size related to UAM will be required, which we tentatively included in LL1 without making any change in the associated for catch-at-size data.

5. Reference

CCSBT (2013a) Report of the Eighteenth Meeting of the Scientific Committee. 7 September 2013. Canberra, Australia.

CCSBT (2013b) Report of the Fourth Operating Model and Management Procedure Technical Meeting. 23-26 July 2013. Portland, Maine, USA.

CCSBT (2013c) Report of the Twentieth Annual Meeting of Commission. 14-17 October 2013. Adelaide, Australia.

Pope, J. G. (2014) A note on the Shepherd-Nicholson fit to CPUE at age data with extensions to examine any 2008 anomaly. CCSBT/CPUE2014/05 8p.

Sakai O. (2014) Examining the reasonability of “upq2008” sensitivity scenario using historical fluctuation of nominal Japanese CPUE by age. CCSBT-OMMP/1406/12 5p.

Table 1. The default grid structure which was specified at the 18th ESC.

	Levels	Cumulate	Values	Prior	Simulation
		Number			weight
Steepness	5	5	0.55, 0.64, 0.73, 0.82, 0.90	Uniform	Prior
M ₁	4	20	0.35, 0.40, 0.45, 0.50	Uniform	Likelihood
M ₁₀	4	80	0.050, 0.075, 0.100, 0.125	Uniform	Likelihood
Omega	1	80	1	NA	NA
CPUE series	2	160	w0.5, w0.8	Uniform	Prior
q-age-range	2	320	4-18, 8-12	0.67, 0.33	Prior
Sample size	1	320	Sqrt	NA	NA

Table 2. The old grid structure which was used for previous stock assessment (16th ESC). The shading indicates specifications which are not included in the new default.

	Levels	Cumulate	Values	Prior	Simulation
		Number			weight
Steepness	5	5	0.55, 0.64, 0.73, 0.82, 0.90	Uniform	Likelihood
M ₁	4	20	0.30 , 0.35, 0.40, 0.45	Uniform	Likelihood
M ₁₀	4	80	0.070 , 0.100, 0.130 , 0.160	Uniform	Likelihood
Omega	1	80	1	NA	NA
CPUE series	2	160	w0.5, w0.8	Uniform	Prior
q-age-range	2	320	4-18, 8-12	0.67, 0.33	Prior
Sample size	1	320	Sqrt	NA	NA

Table 2. The extended grid structure which is used for the base case trial. The shading indicates specifications which differ from those for the default.

	Levels	Cumulate	Values	Prior	Simulation
		Number			weight
Steepness	5	5	0.55, 0.64, 0.73, 0.82, 0.90	Uniform	Prior
M ₁	6	30	0.30 , 0.35, 0.40, 0.45, 0.50, 0.54	Uniform	Likelihood
M ₁₀	6	180	0.03 , 0.06 , 0.09 , 0.12 , 0.15 , 0.18	Uniform	Likelihood
Omega	1	180	1	NA	NA
CPUE series	2	360	w0.5, w0.8	Uniform	Prior
q-age-range	2	720	4-18, 8-12	0.67, 0.33	Prior
Sample size	1	720	Sqrt	NA	NA

Table 4. The list of base case and sensitivity run specifications

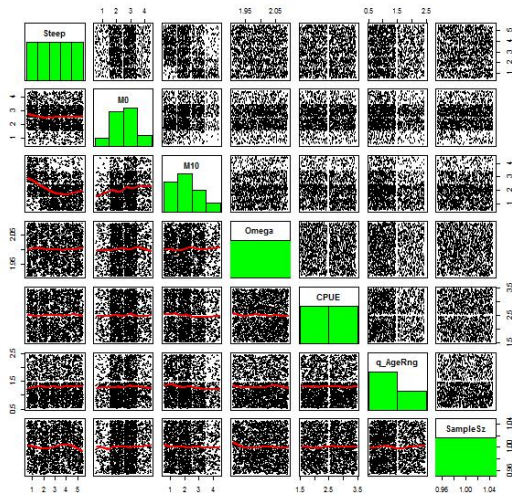
Scenario	Description
[Base_case]	<ul style="list-style-type: none"> ➤ Tentative base case setting which was agreed in 18th ESC. ➤ Including the Close-Kin (CK) data and new maturity schedule and fecundity assumption (CCSBT 2013b).
[CKoff]	<ul style="list-style-type: none"> ➤ Excluding the CK data. <ul style="list-style-type: none"> - Replace “ck_sw” from “1” to “0” in sqrt.dat file line 60.
[IS20]	<ul style="list-style-type: none"> ➤ Change of the maximum age from 25 to 20 starting the flat selectivity in Indonesian LL fishery. <ul style="list-style-type: none"> - Replace fifth “max age (I35)” value from “25” to “20” in sqrt.dat file line 90.
[upq2008]	<ul style="list-style-type: none"> ➤ An increase in catchability of 0.35, using a step function, from 2008 onwards. <ul style="list-style-type: none"> - A 35% increase in “catchability parameters (I16)” at 2008 in sqrt.dat file line36.
[constantq]	<ul style="list-style-type: none"> ➤ Excluding the linear increment in catchability over time. <ul style="list-style-type: none"> - Replace all “catchability parameters (I16)” to “1” in sqrt.dat file line 33-36.
[Omega75]	<ul style="list-style-type: none"> ➤ Relationship between biomass and CPUE with power=0.75. <ul style="list-style-type: none"> - Replace “Omega (I19) of CPUE parameter” from “1.0” to “0.75” in sqrt.dat file line 44. - Replace “omega value” from “1.0” to “0.75” in base.dat file line 16.
[TagFmixing]	<ul style="list-style-type: none"> ➤ Increasing the fishing mortality of tagged SBT by 50% relative to the F applied to the whole population. <ul style="list-style-type: none"> - Replace “tag_H_factor” from “1.00” to “1.50” in sqrt.dat file line 58 (second value).
[C0S1L1]	<ul style="list-style-type: none"> ➤ Past longline overcatch had no impact on LL1 CPUE. <ul style="list-style-type: none"> - Select “0” scenario option for the “cpue_case” in base.dat file line 21.
[C2S1L1]	<ul style="list-style-type: none"> ➤ 50% of lonline overcatch associated with reported effort for LL1 CPUE <ul style="list-style-type: none"> - Select “2” scenario option for the “cpue_case” in base.dat file line 21.
[IncludeTroll]	<ul style="list-style-type: none"> ➤ Including the piston-line troll survey index. <ul style="list-style-type: none"> - Replace “troll_sw” from “0” to “1”, and “phase_tautroll” from “0” to “1” in sqrt.dat file line 62 and 64, respectively.

[SV_OverC]	<ul style="list-style-type: none"> ➤ Continual 20% overcatch by Australian surface fishery in projection. - Set “1.2” as the UAM option of Aus surface fishery in mycontrol.dat file under the base case grid run.
[AddedC1p]	<ul style="list-style-type: none"> ➤ Incorporation of unaccounted mortality (assuming the extra 1% catch in LL1 as the discard mortality from 2006). - Select new LL1 overcatch scenario “Case1b” which was added in sbtdata.dat line 693-722, using base.dat line 24. - Set “1.01” as the UAM option of LL1 in mycontrol.dat file.
[C1p_OverC]	<ul style="list-style-type: none"> ➤ Combined scenario of “AddedC1p” and “SV_OverC”
[AddedC5p]	<ul style="list-style-type: none"> ➤ Incorporation of unaccounted mortality (assuming the extra 5% catch in LL1 as the discard and recreational fishing mortality from 2006). - Select new LL1 overcatch scenario “Case1c” which was added in sbtdata.dat line 693-722, using base.dat line 24. - Set “1.05” as the UAM option of LL1 in mycontrol.dat file.
[C5p_OverC]	<ul style="list-style-type: none"> ➤ Combined scenario of “AddedC5p” and “SV_OverC”
[AddedC10p]	<ul style="list-style-type: none"> ➤ Incorporation of unaccounted catch (assuming the extra 10% catch in LL1 as the discard and recreational fishing mortality from 2006). - Select new LL1 overcatch scenario “Case1c” which was added in sbtdata.dat line 693-722, using base.dat line 24. - Set “1.10” as the UAM option of LL1 in mycontrol.dat file.
[C10p_OverC]	<ul style="list-style-type: none"> ➤ Combined scenario of “AddedC10p” and “SV_OverC”

Table 5. Summary results of conditioning and projection results under the Bali Procedure (which was tuned at 2011 ESC) for the base case and sensitivity trials.

Scenario	Absolute biomass (t) of age 10+ (Median)					Stock status based on the biomass of age 10+					Probability of reaching the target by 2035
	B ₂₀₁₁	B ₂₀₁₂	B ₂₀₁₃	B ₂₀₁₄	B ₂₀₁₅	B ₂₀₁₁ /B ₀	B ₂₀₁₂ /B ₀	B ₂₀₁₃ /B ₀	B ₂₀₁₄ /B ₀	B ₂₀₁₅ /B ₀	P[B ₂₀₃₅ > 20%B ₀]
Previous assessment	45,422	44,471	45,158	50,498	67,016	0.05	0.05	0.05	0.06	0.08	70.3%
Base case (default grid)	80,286	78,293	78,729	92,797	109,418	0.07	0.07	0.07	0.08	0.10	75.6%
CKoff	50,427	49,195	51,106	62,103	77,916	0.06	0.06	0.06	0.07	0.08	69.9%
IS20	67,939	65,118	64,702	75,555	91,743	0.09	0.08	0.08	0.10	0.12	85.1%
upq2008	74,716	72,163	71,765	83,050	95,977	0.07	0.06	0.06	0.07	0.09	56.2%
constantq	85,526	82,925	83,822	98,901	116,146	0.08	0.08	0.08	0.09	0.11	81.4%
Omega75	72,639	70,125	69,996	81,043	95,339	0.06	0.06	0.06	0.07	0.08	69.7%
TagFmixing	80,587	78,795	79,250	93,505	109,985	0.07	0.07	0.07	0.09	0.10	77.4%
C0S1L1	81,010	79,178	80,350	94,358	114,282	0.08	0.07	0.07	0.09	0.11	82.3%
C2S1L1	80,923	78,155	77,898	91,395	106,291	0.07	0.07	0.07	0.08	0.09	69.5%
IncludeTroll	79,893	77,978	78,859	93,316	111,608	0.08	0.07	0.07	0.09	0.11	88.1%
SV_overC	80,286	78,293	78,729	92,795	109,396	0.07	0.07	0.07	0.08	0.10	68.9%
AddedC1p	80,232	78,082	78,636	92,659	109,188	0.07	0.07	0.07	0.08	0.10	74.9%
C1p_overC	80,232	78,082	78,636	92,656	109,170	0.07	0.07	0.07	0.08	0.10	68.3%
AddedC5p	80,160	77,988	78,062	92,014	108,465	0.07	0.07	0.07	0.08	0.10	72.6%
C5p_overC	80,160	77,988	78,062	92,010	108,446	0.07	0.07	0.07	0.08	0.10	65.7%
AddedC10p	79,573	77,193	77,470	91,151	107,429	0.07	0.07	0.07	0.08	0.10	70.0%
C10p_overC	79,573	77,193	77,470	91,147	107,408	0.07	0.07	0.07	0.08	0.10	63.4%

a) Base case (default)



b) Base case (extended grid)

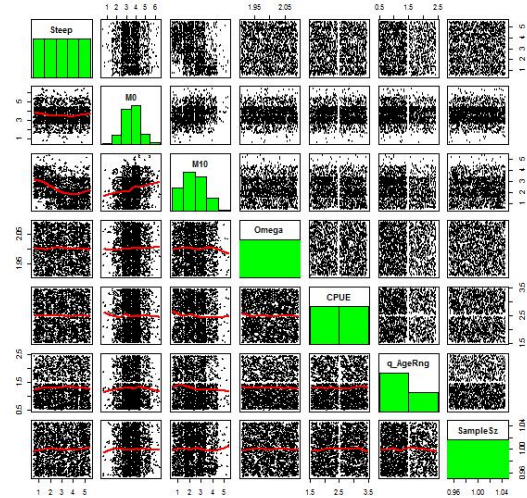


Fig. 1. Shad plots for the “Base case” run.

The grid structure was examined using the default setting (left) and the extended setting (right). Six levels were used for both M0 (=M1) and M10 in the extended setting, but additional M0 and M10 values were rarely sampled (the highest value of M10 was not sampled).

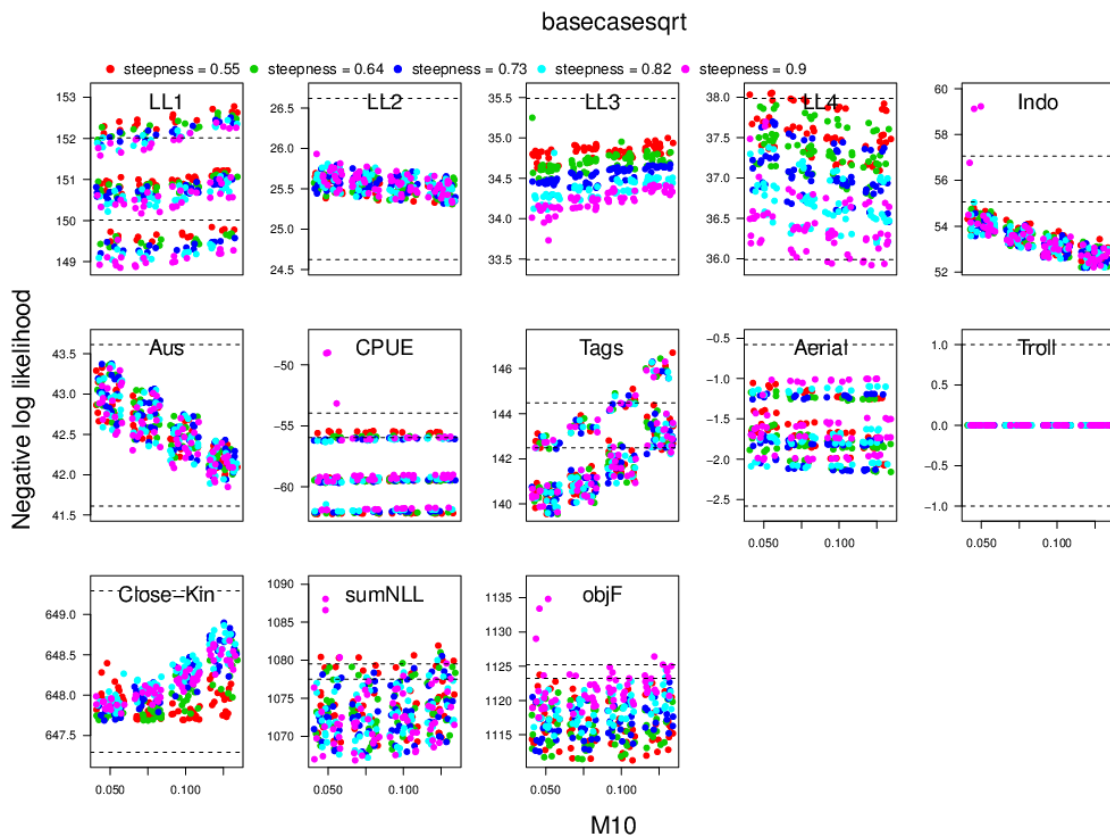


Fig. 2. Negative log-likelihood profiles for the base case (default grid).

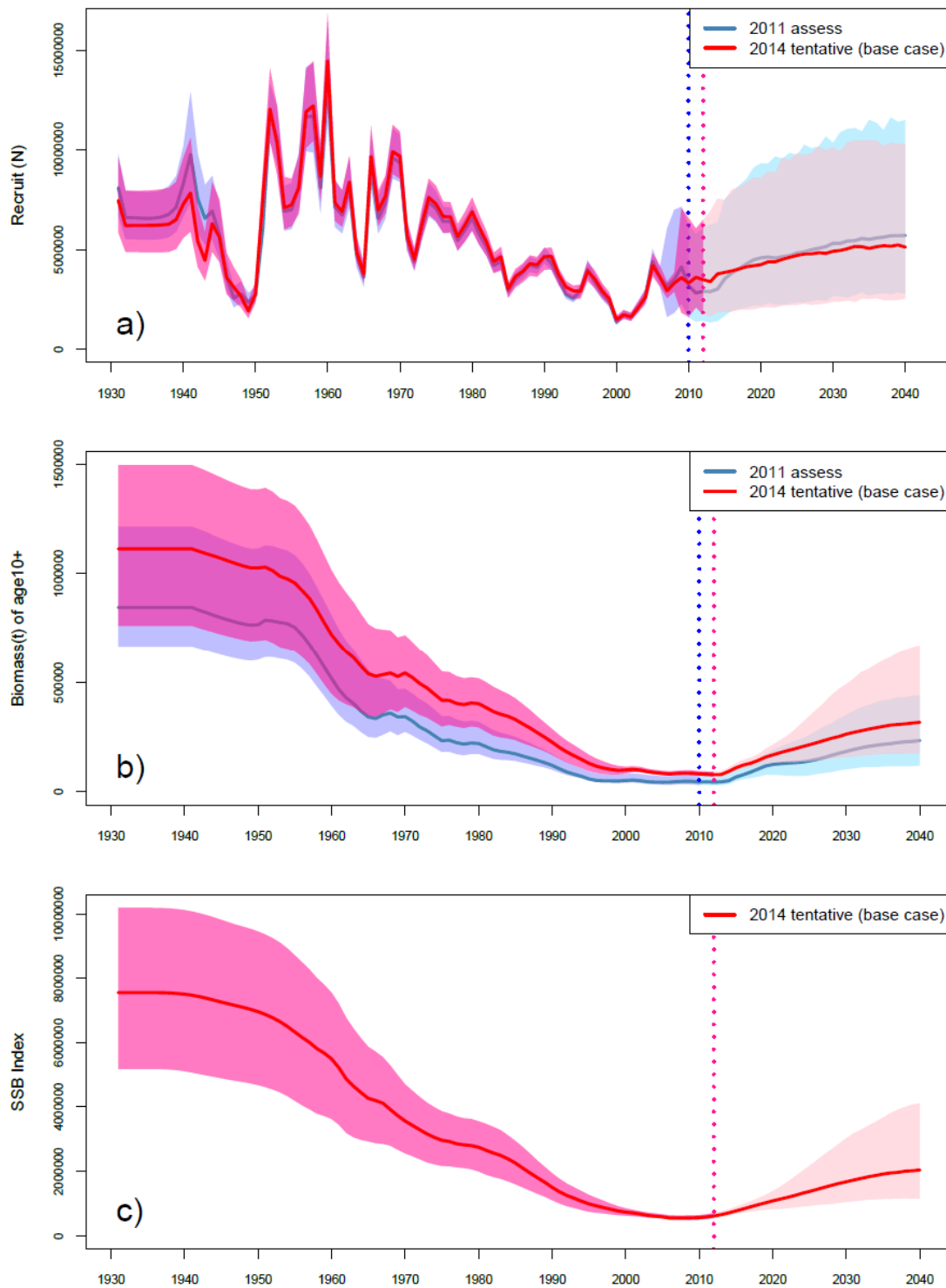


Fig. 3. Trajectories for a) recruitment, b) biomass of age 10+ fish, and c) “SSB index”.

The red line with the pink region shows the median and 90% intervals of the current base case. The blue line with the light-blue region shows those for the previous assessment which was calculated in 2011. The dotted line shows the boundaries of the conditioning and projections.

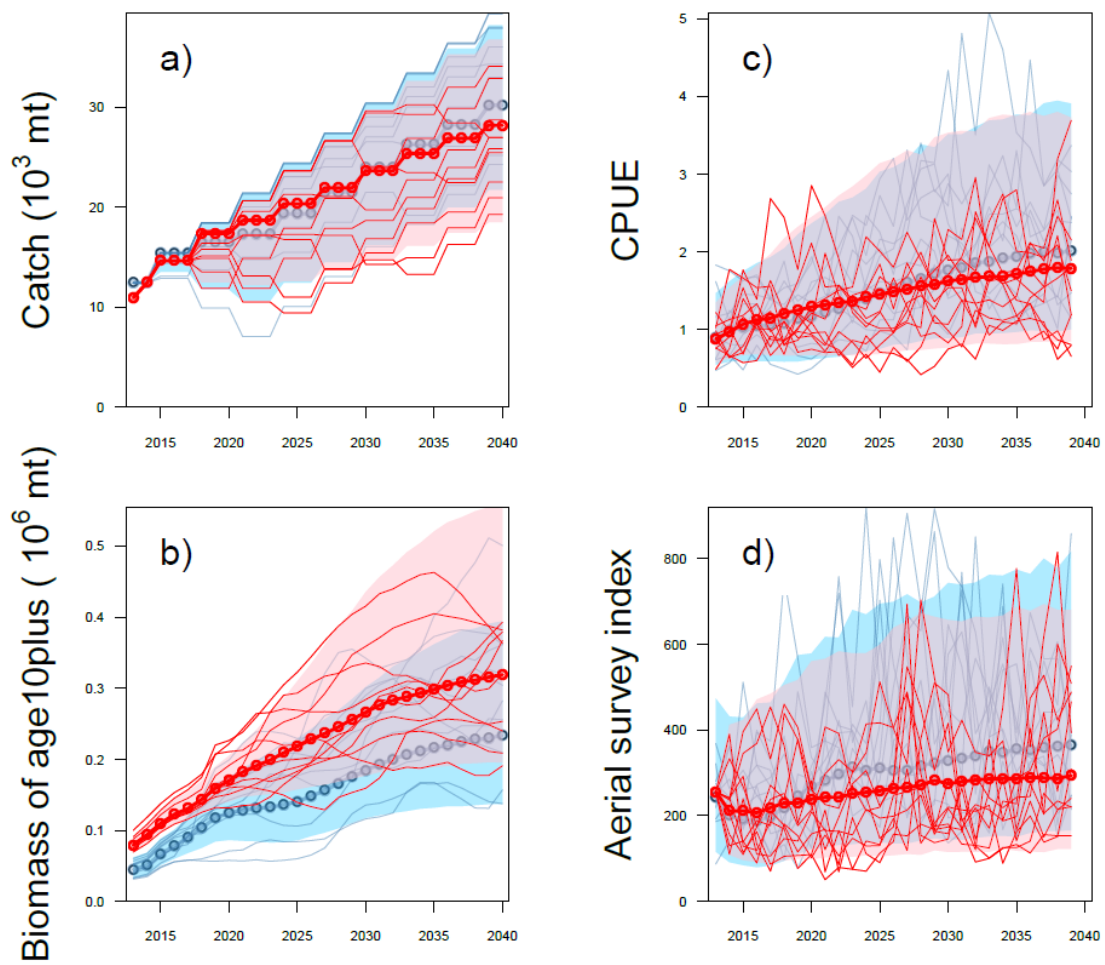
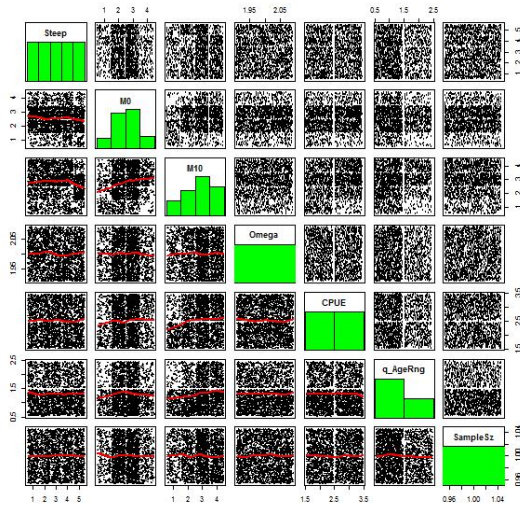


Fig. 4. Predicted values under the Bali Procedure; a) catch (10^3 tonnes), b) biomass of age 10+ fish (10^6 tonnes), c) CPUE of LL1, and d) Aerial survey index.

The red points with the pink regions show the median and 90% intervals of the current base case. The blue points with the light-blue regions show those for the previous assessment which was calculated in 2011.

a) CK off (default grid)



b) CK off (extended grid)

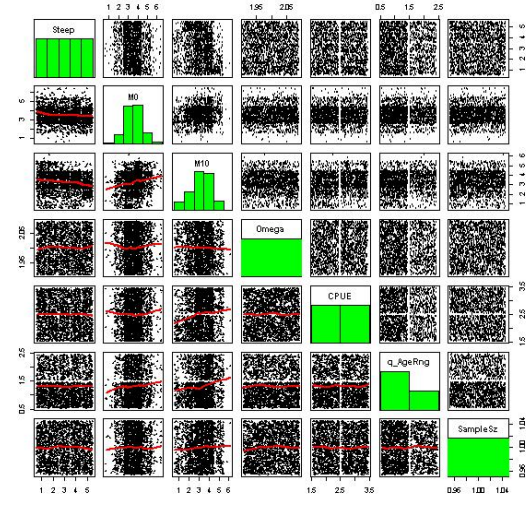
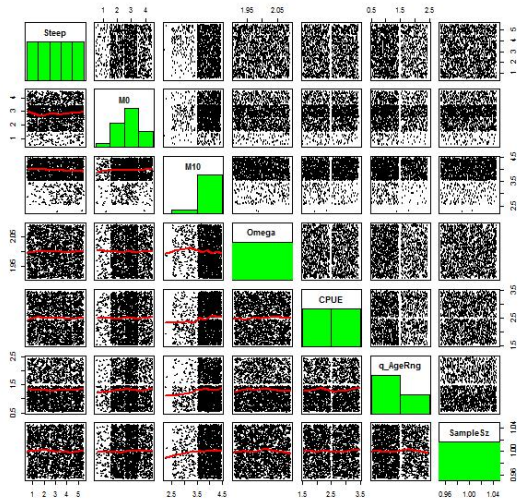


Fig. 5. Shaded plots for “CK off” run.

The grid structure was examined using the default setting (left) and the extended setting (right). Six levels were used for both M0 (=M1) and M10 in the extended setting, but additional M0 and highest M10 values were rarely sampled.

a) IS20 (default grid)



b) IS20 (extended grid)

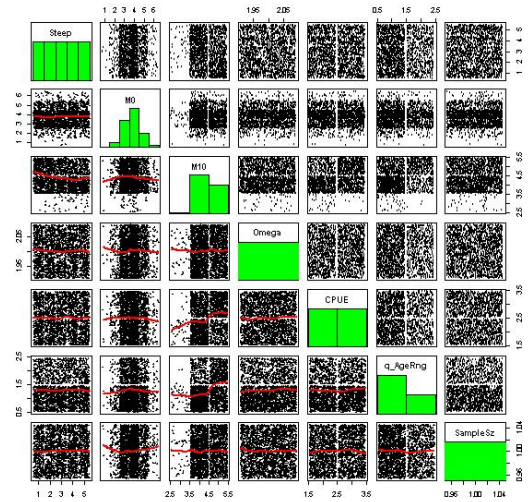
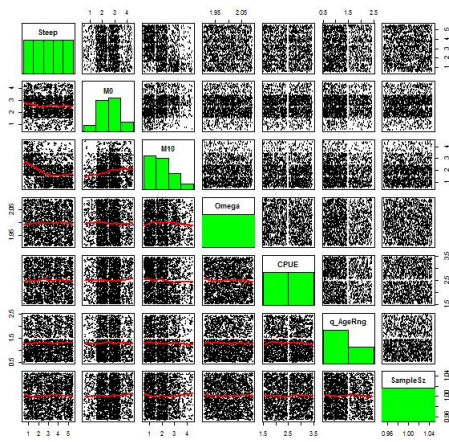


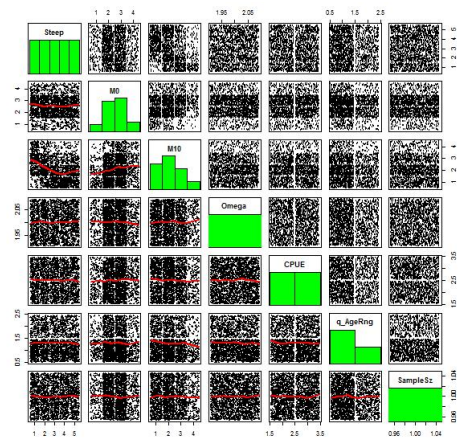
Fig. 6. Shaded plots for “IS20” run.

The grid structure was examined using the default setting (left) and the extended setting (right). Six levels were used for both M0 (=M1) and M10 in the extended setting. In default grid, only two higher M10 values (0.100 and 0.125) were sampled (mainly 0.125). In contrast, the middle M10 values (0.09, 0.12, and 0.15) were sampled in the extended grid run.

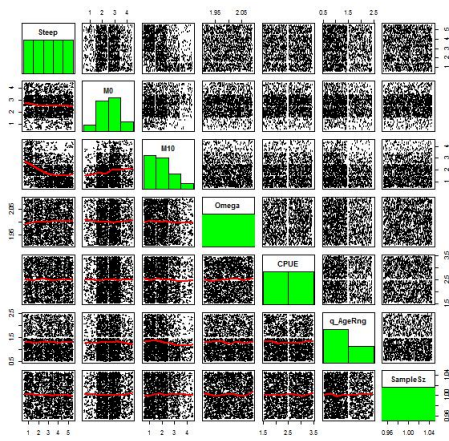
a) upq2008



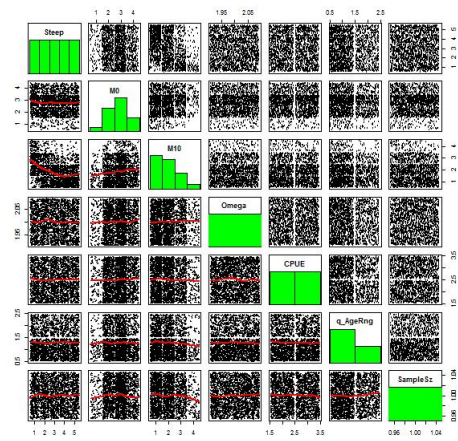
b) constantq



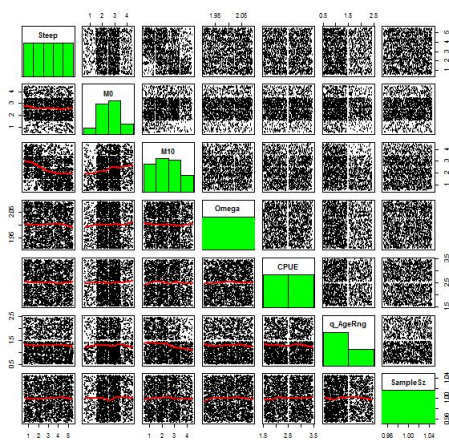
c) Omega75



d) TagFmixing



e) C0S1L1



f) C2S1L1

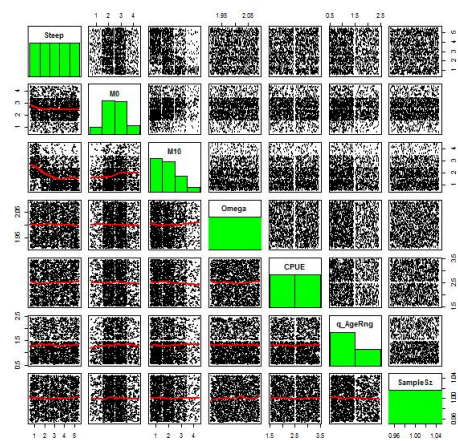
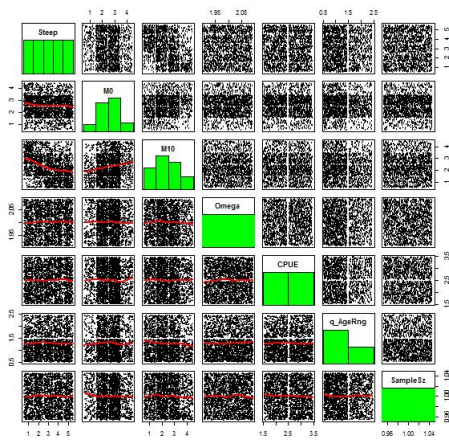


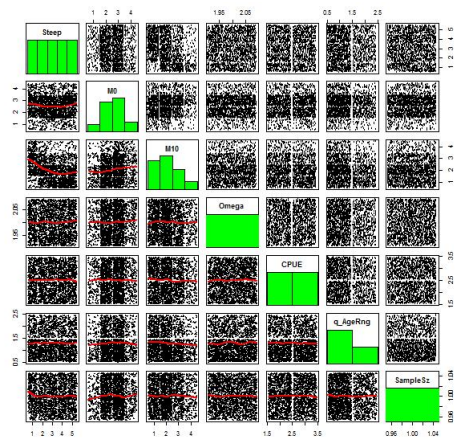
Fig. 7. Shaded plots for the other sensitivity runs.

The grid structure was examined using the default setting. Almost all scenarios indicate similar distributions of M0 and M10 values sampled in the grid.

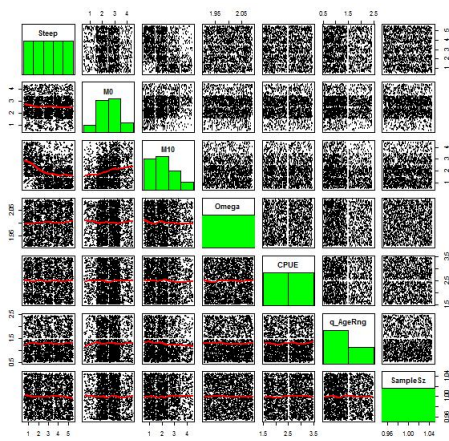
g) IncludeTroll



h) Added_C1p



i) Added_C5p



j) Added_C10p

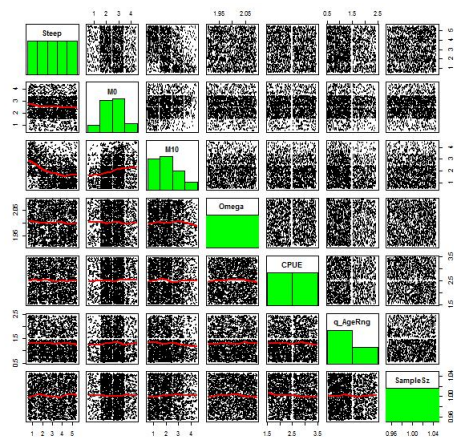
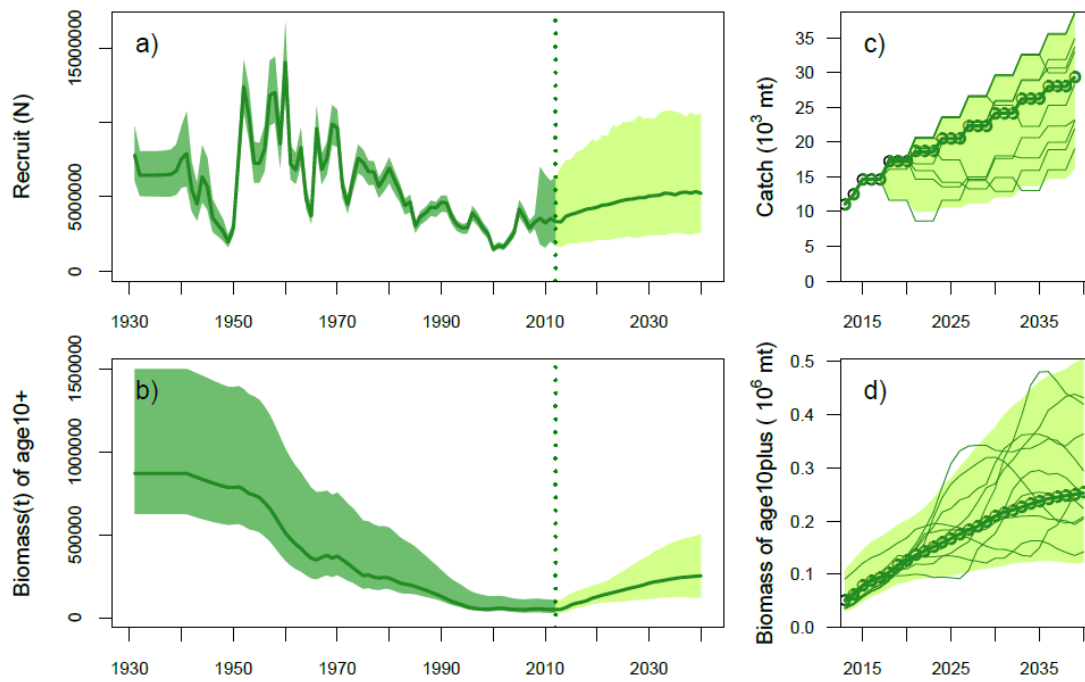


Fig. 7. (cont.) Shaded plots for the other sensitivity runs.

The grid structure was examined using the default setting. Almost all scenarios indicate similar distributions of M0 and M10 values sampled in the grid.

A) CKoff



B) IS20

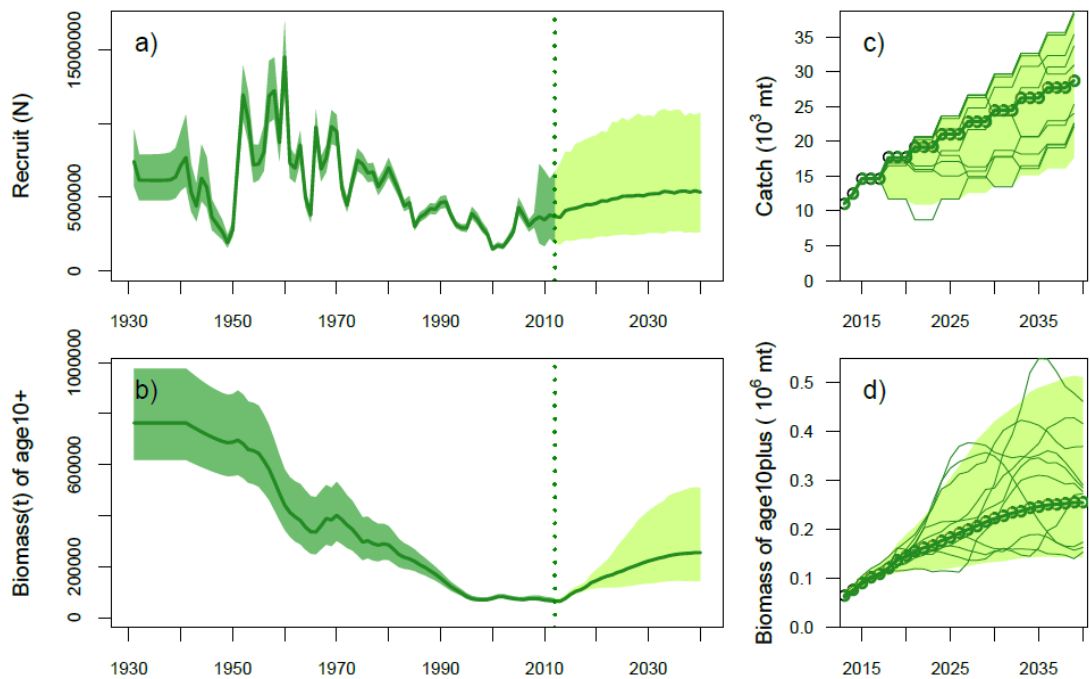
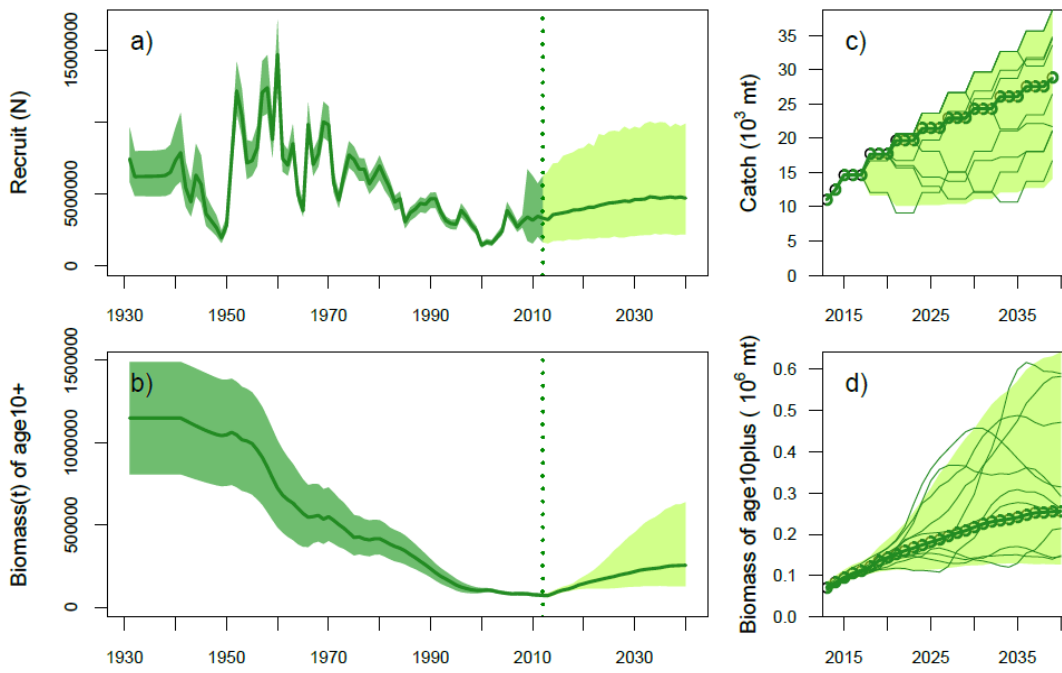


Fig. 8. Trajectories of a) recruitment, b) biomass of age 10+ fish, c) predicted TAC, and d) biomass for the sensitivity trials.

The green line with the greenish yellow region shows the median and 90% intervals.

C) upq2008



D) constantq

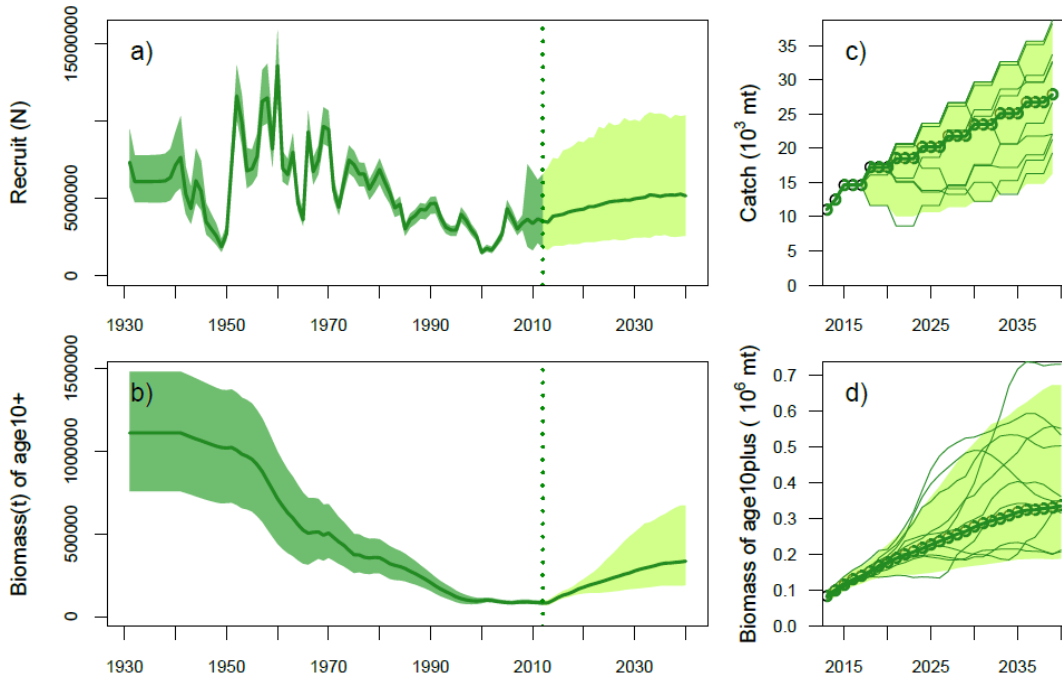
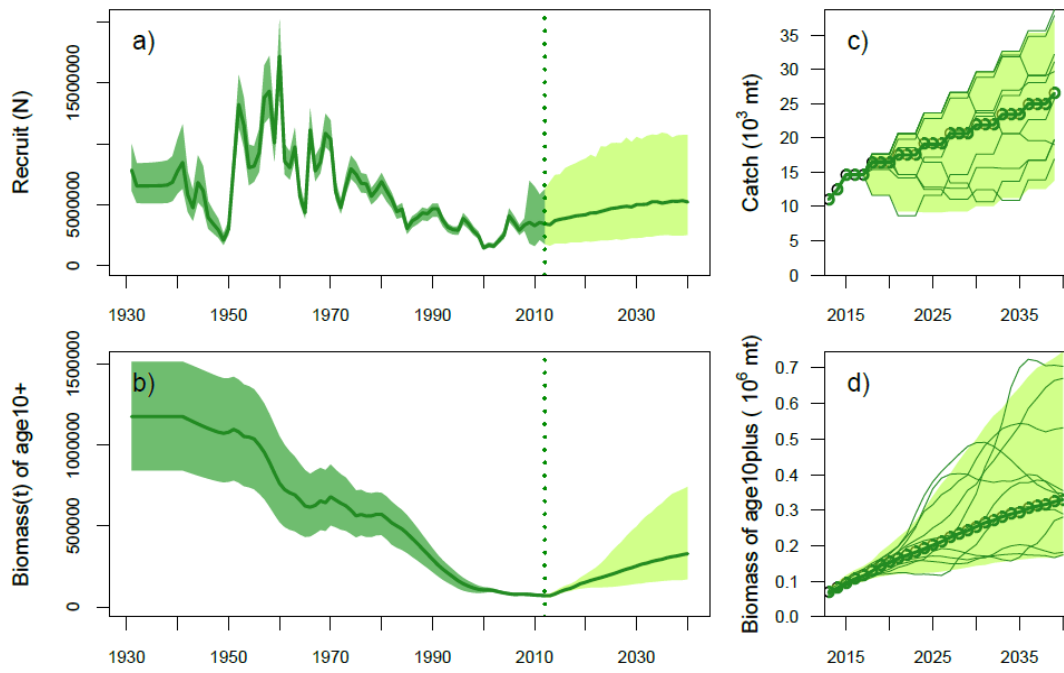


Fig. 8. (cont.)

E) Omega75



F) TagFmixing

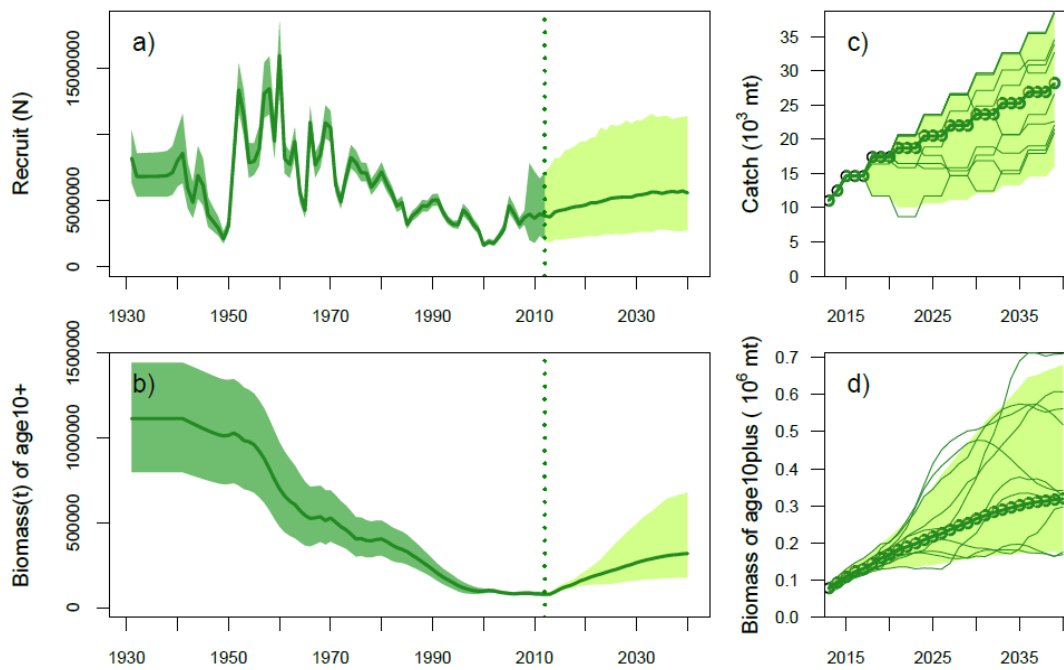
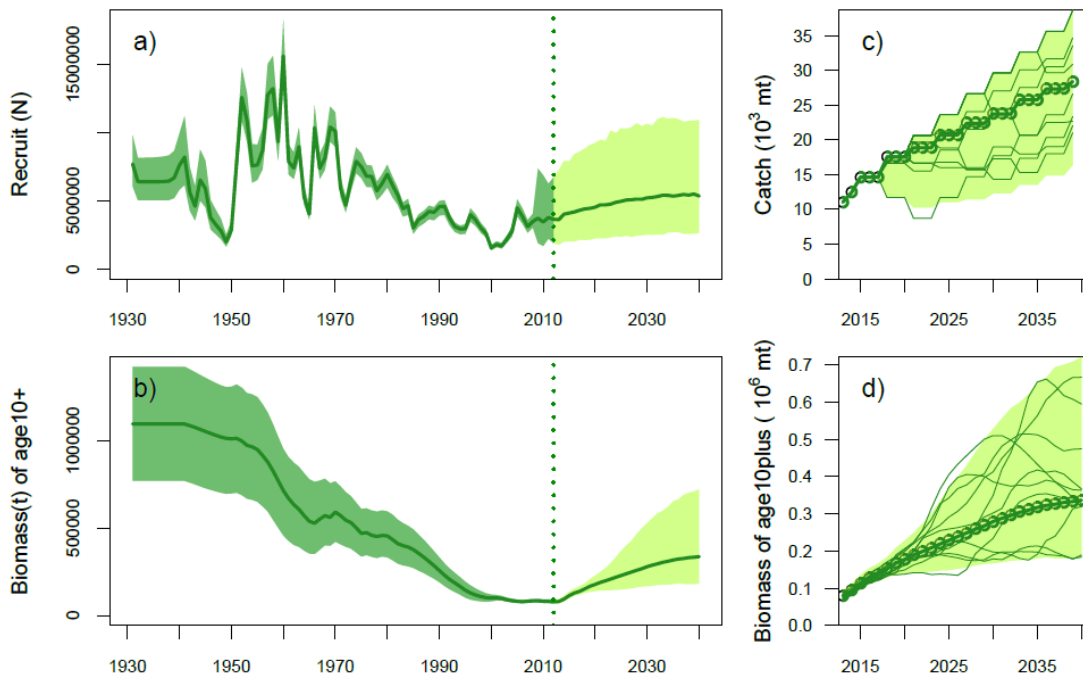


Fig. 8. (cont.)

G) C0S1L1



H) C2S1L1

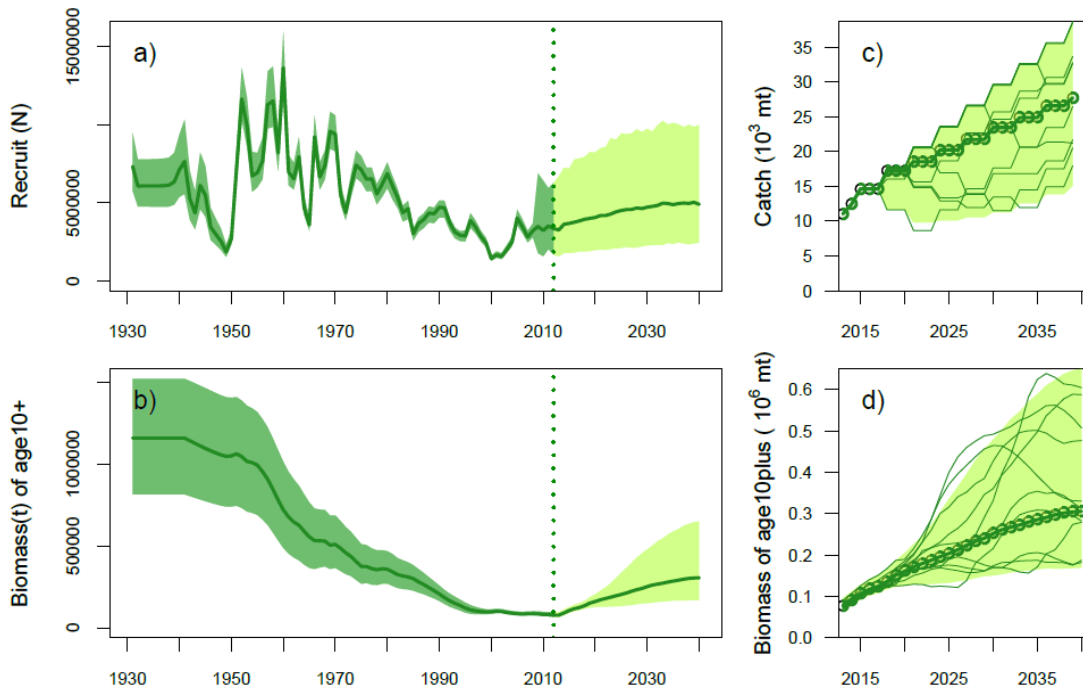
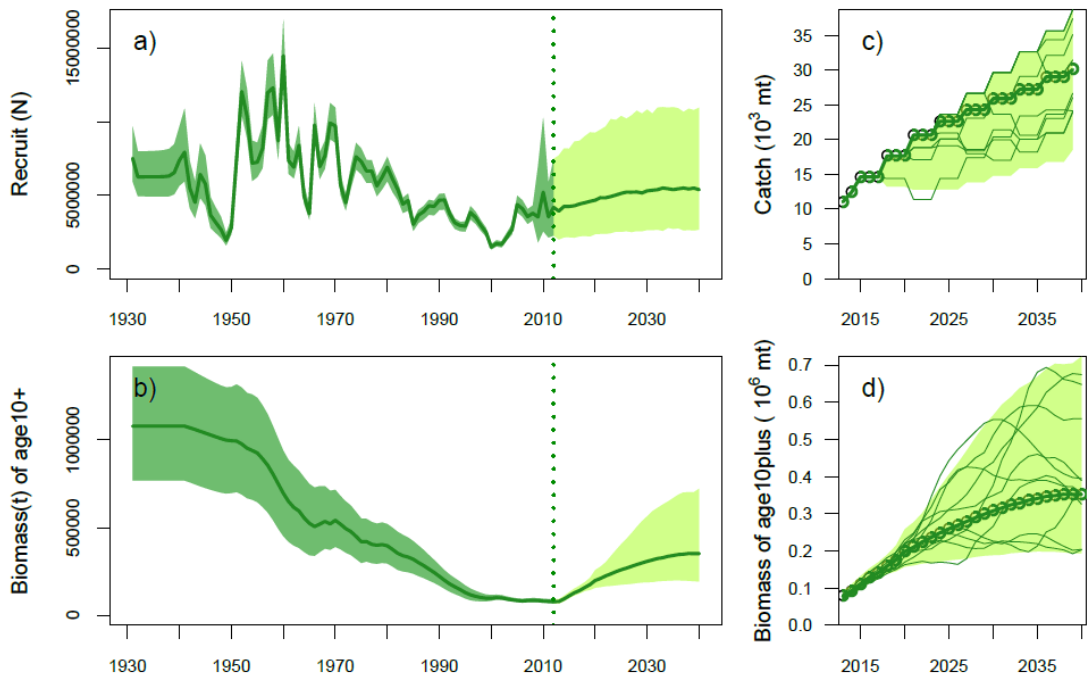


Fig. 8. (cont.)

I) Include Troll



J) SV_overC

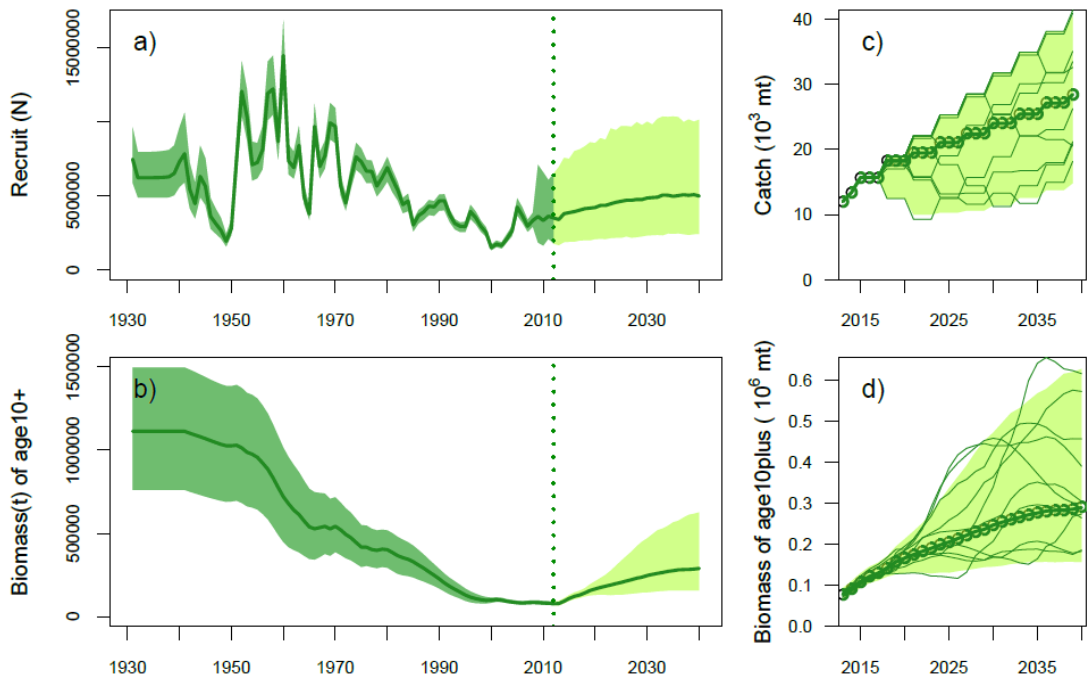
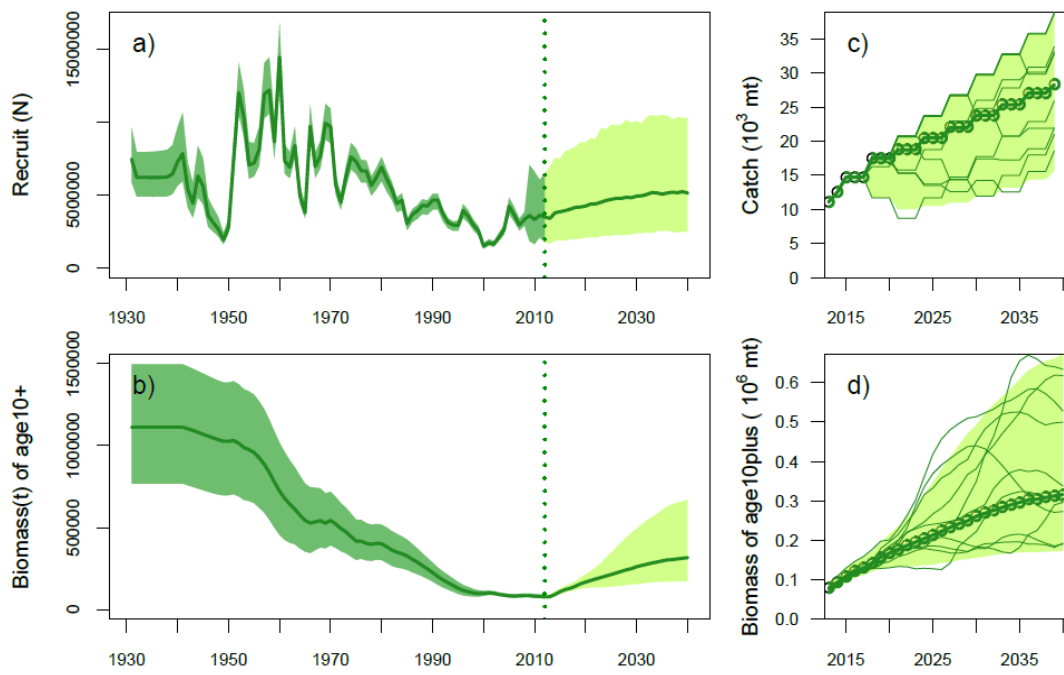


Fig. 8. (cont.)

K) AddedC1p



L) C1p_overC

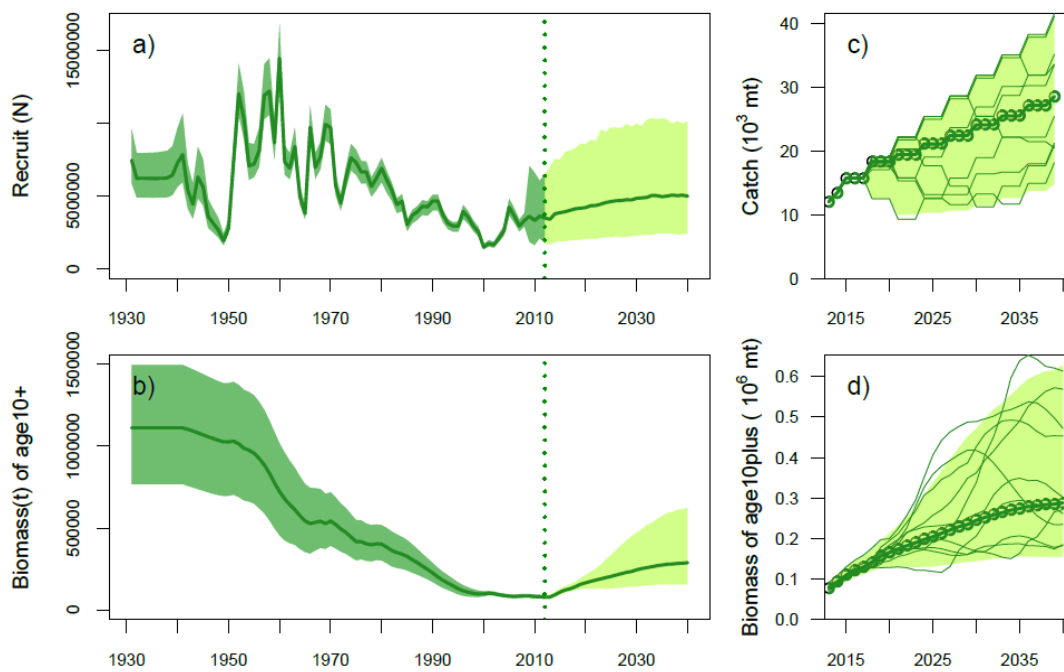
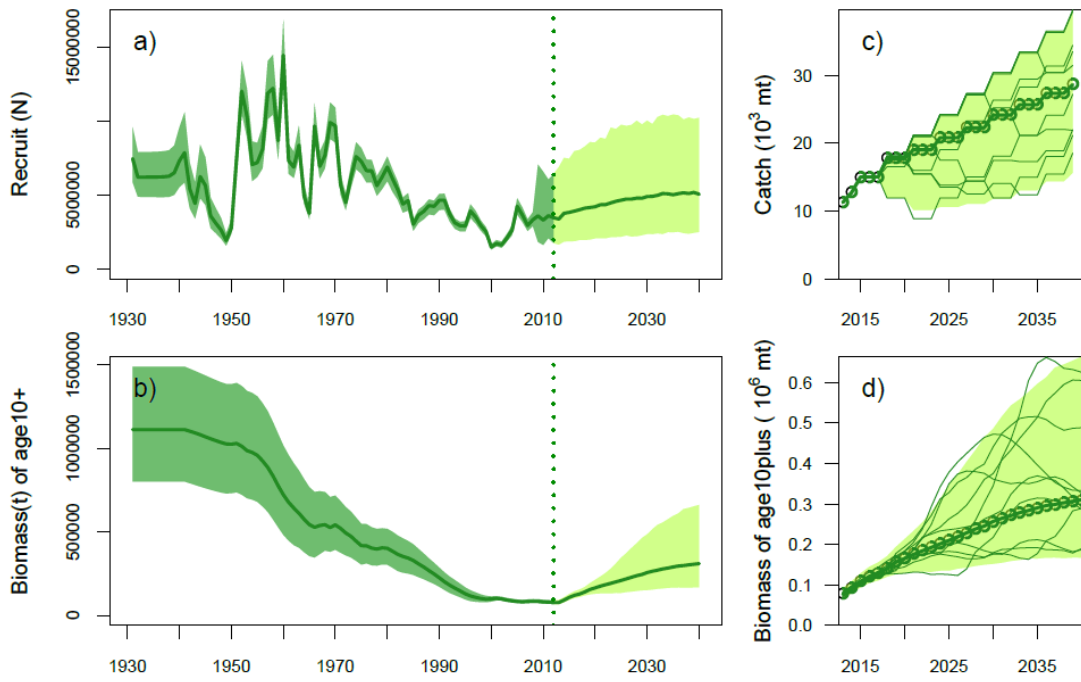


Fig. 8. (cont.)

M) AddedC5p



N) C5p_overC

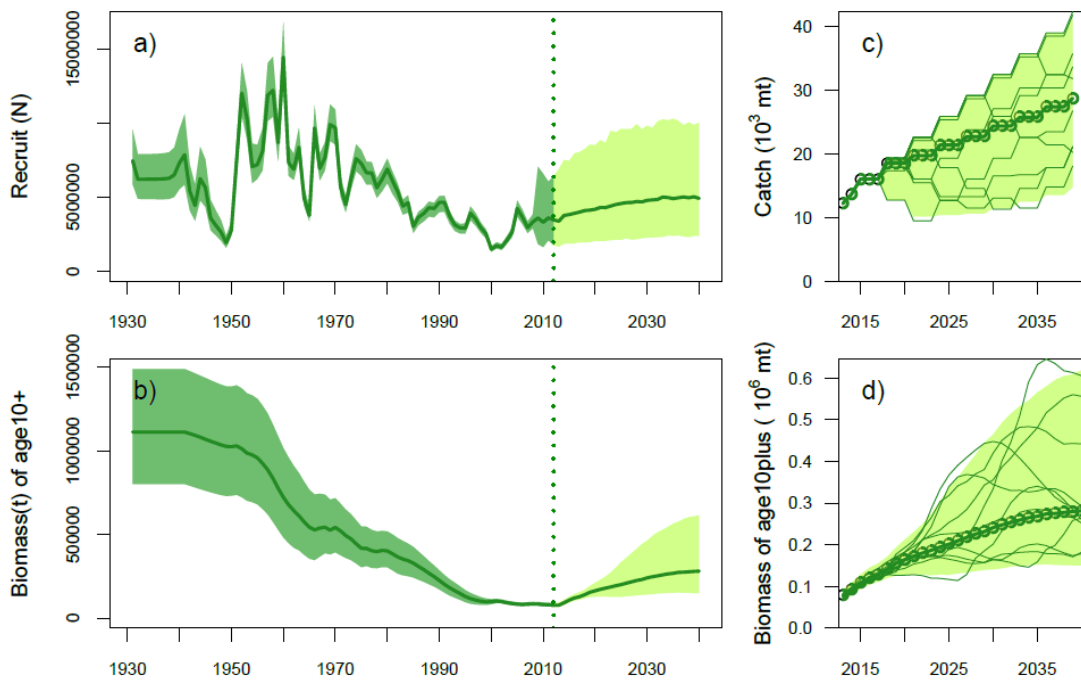
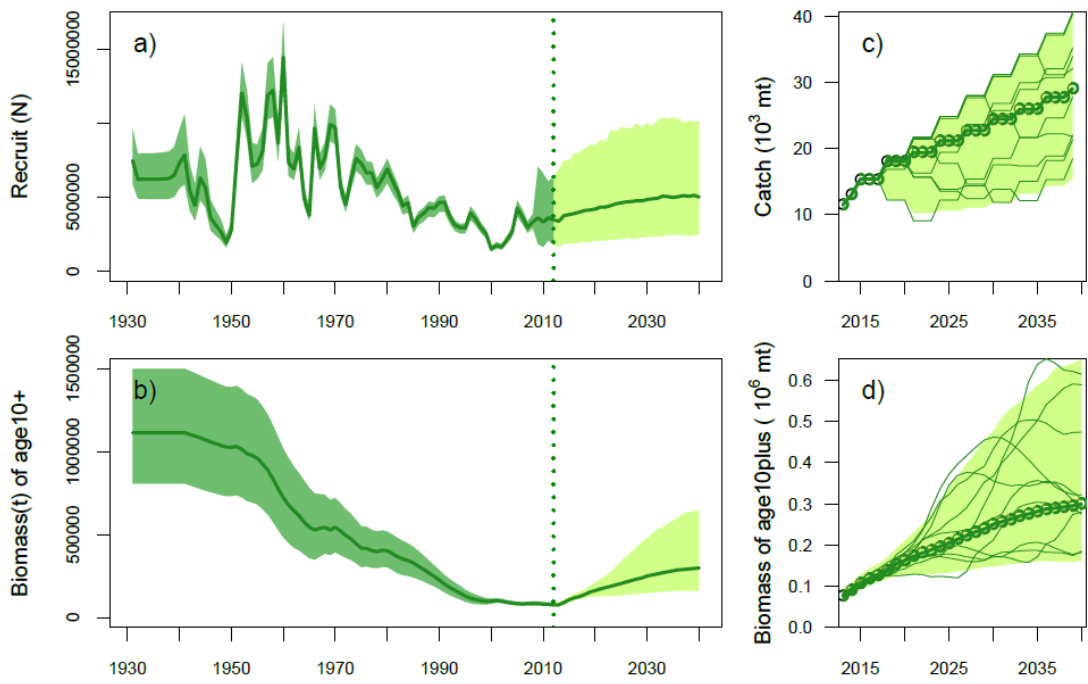


Fig. 8. (cont.)

O) AddedC10p



P) C10p_overC

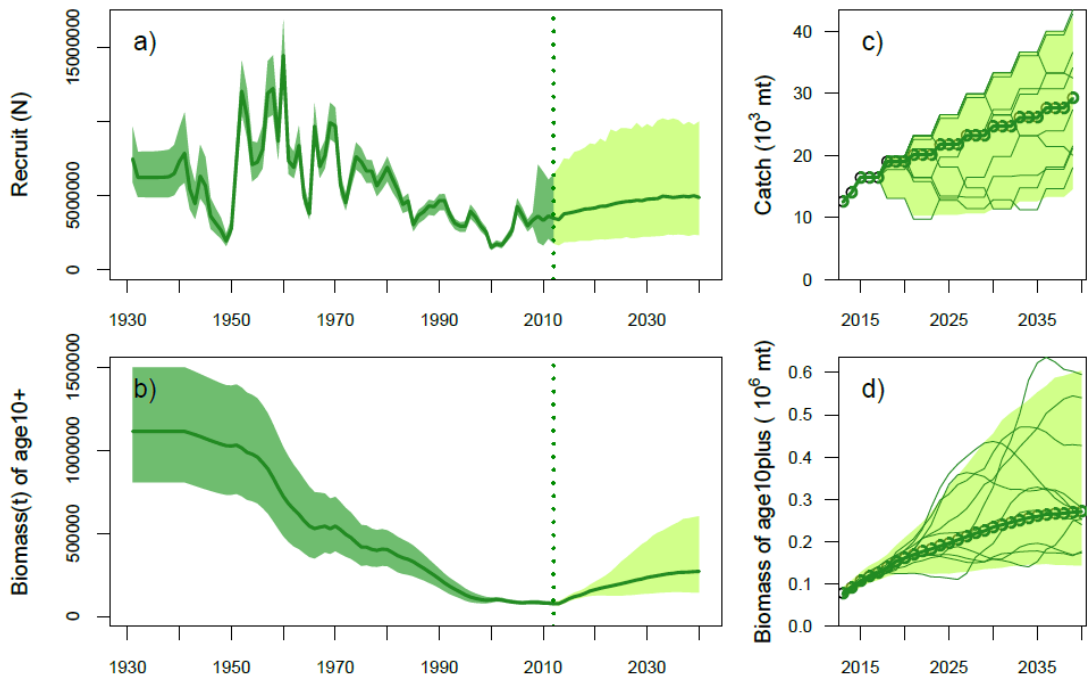


Fig. 8. (cont.)