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Final improvement and performance evaluation of a candidate management procedure ("NT4") for southern bluefin tuna

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Abstract: This document provides results of final improvement and performance evaluation of a candidate management procedure (CMP) for southern bluefin tuna. A CMP considered is simple empirical one, called "NT4". NT4 utilizes CPUE, estimates from gene-tagging, and a close-kin mark recapture parent-offspring pairs (POP) index. Basic characteristics of NT4 are: i) until the tuning year of achieving the stock level target, NT4 suppresses increase of TAC, and after the tuning year, it tries to increase TAC as possible; ii) if recruitment level becomes declining to a very low level, then NT4 reduces TAC accordingly to avoid decrease of the stock. Comparisons of results between the reference set and associated robustness tests are presented. While projected median trends of both TAC and relative total reproductive output (TRO) under most of robustness scenarios tested are similar to ones for the reference set, median TAC and TRO trends under "reclow5" (also its combinations with "as2016" or "cpuew0") and "cpuew0" scenarios are different from the ones for the reference set reflecting reaction to assumptions of low recruitment or low productivity of stock.

ミナミマグロのための管理方式候補（"NT4"）の最終的な改良と性能評価

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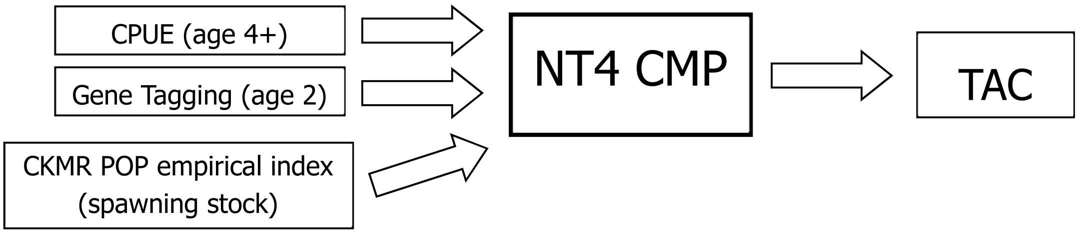
要旨：この文書ではミナミマグロのための管理方式候補（CMP）の最終的な改良と性能評価の結果を提供する。考えた CMP は単純で経験的なものであり、"NT4" と呼ばれる。NT4 は CPUE、遺伝標識からの推定値、および近縁遺伝標識再捕の親子ペア（POP）指数を利用している。NT4 の基本的特徴は以下；i) 資源水準目標を達成するチューニング年までは、NT4 は TAC の増加を抑え、チューニング年以降は可能な限り TAC を増やそうとする；ii) もし加入水準が非常に低水準まで低下した場合には、それに応じて NT4 は資源の減少を回避するために TAC を削減させる。リファレンスセットとそれに関連する頑健性試験との結果の比較を示す。試験したほとんどの頑健性シナリオの下での TAC と相対総再生産出力（TRO）両者の予測された中央値のトレンドはリファレンスセットのものと類似しているが、低加入または資源の低い生産性の仮定に対する反応を反映して、"reclow5"（また "as2016"あるいは"cpuew0"とのその組み合わせ）および"cpuew0"シナリオの下での TAC と TRO の中央値のトレンドはリファレンスセットのものとは異なっていた。

1. Introduction

Due to cessation of the CCSBT scientific aerial survey (AS) after 2017 for both budgetary and logistic reasons, to set TAC for the 2021-2023 fishing season in 2020, the CCSBT decided to develop a new management procedure (MP) which utilizes, in addition to longline CPUE index, recruitment estimates (age 2 fish abundance) obtained from the gene-tagging project (GT) and/or spawning stock indices from the close-kin mark recapture project (CKMR) in place of the current MP by 2019 (CCSBT 2017). At the 10th Operating Model and Management Procedure technical meeting (OMMP10), results of improvement and performance evaluation of a simple empirical candidate MP (CMP), "NT4", were presented (Takahashi 2019). This document provides results of final improvement and performance evaluation of NT4.

2. Description of the CMP ("NT4")



"NT4" CMP uses the following three indicators as inputs to evaluate the stock trend/level, and then specifies the next year's TAC:

(1) CPUE age 4+ series - Use as an indicator of change in the spawning stock biomass <u>trend</u> (the slope of log(CPUE age 4+) over the most recent t_{CPUE} years);

(2) Gene Tagging (GT) age 2 abundance estimate – Use as an indicator of the recruitment <u>level</u> (the most recent $t_{GTlimit}$ years average) of whether this level is below the prespecified lowest recruitment level (as the lowest limit);

(3) CKMR POP empirical index (Hillary et al. 2016) – Use as an indicator of the spawning stock <u>level</u> (the most recent t_{POP} years average) of whether this level is below or above the prespecified target spawning stock level.

Equations of TAC calculation are:

For CPUE-based TAC,

If year y ≤ (2035 or 2040)[1], then use

$$TAC_{y+1}^{CPUE} = \begin{cases} TAC_y(1 + k1_{CPUE}S1_{CPUE}) & S1_{CPUE} < 0 \\ TAC_y(1 + k2_{CPUE}S1_{CPUE}) & S1_{CPUE} \geq 0 \end{cases} \quad \text{eq. 1}$$

Else if year y > (2035 or 2040) and $\mu_{POP} \leq \alpha_1 I_{target}^{POP}$, then use the same equations as eq. 1

$$TAC_{y+1}^{CPUE}(= TAC1_{y+1}^{CPUE}) = \begin{cases} TAC_y(1 + k1_{CPUE}S1_{CPUE}) & S1_{CPUE} < 0 \\ TAC_y(1 + k2_{CPUE}S1_{CPUE}) & S1_{CPUE} \geq 0 \end{cases} \quad \text{(same as eq. 1)}$$

Else if year y > (2035 or 2040) and $\mu_{POP} \geq \alpha_2 I_{target}^{POP}$, then use

$$TAC_{y+1}^{CPUE}(= TAC2_{y+1}^{CPUE}) = \begin{cases} TAC_y(1 + k3_{CPUE}S2_{CPUE}) & S2_{CPUE} < 0 \\ TAC_y(1 + k4_{CPUE}S2_{CPUE}) & S2_{CPUE} \geq 0 \end{cases} \quad \text{eq. 2}$$

Else if year y > (2035 or 2040) and $\alpha_1 I_{target}^{POP} < \mu_{POP} < \alpha_2 I_{target}^{POP}$, then use

$$TAC_{y+1}^{CPUE} = w^{CPUE} TAC2_{y+1}^{CPUE} + \left(1 - w^{CPUE}\right) TAC1_{y+1}^{CPUE} \quad \text{eq. 3}$$

$$w^{CPUE} = \frac{\mu_{POP}/I_{target}^{POP} - \alpha_1}{\alpha_2 - \alpha_1} \quad \text{eq. 4}$$

TAC_y: TAC for year *y*
TAC_{y+1}^{CPUE}: TAC calculated using log(CPUE (age 4+)) slope for *y*+1
μ_{POP}: the average POP index over the most recent t_{POP} years
I_{target}^{POP}: the prespecified target spawning stock level
$S1_{CPUE}$: the slope of log(CPUE age 4+) over the most recent $t1_{CPUE\_slope}$ years
$S2_{CPUE}$: the slope of log(CPUE age 4+) over the most recent $t2_{CPUE\_slope}$ years
$k1_{CPUE}$: a parameter for TAC calculation using log(CPUE (age 4+)) slope when $S1_{CPUE} < 0$
$k2_{CPUE}$: a parameter for TAC calculation using log(CPUE (age 4+)) slope when $S1_{CPUE} \geq 0$
$k3_{CPUE}$: a parameter for TAC calculation using log(CPUE (age 4+)) slope when $S2_{CPUE} < 0$
$k4_{CPUE}$: a parameter for TAC calculation using log(CPUE (age 4+)) slope when $S2_{CPUE} \geq 0$

[1] Year 2035 is used when the tuning target is 30%TRO by 2035, 2040 is applied when the target is 35%TRO by 2040.

For TAC based on GT age 2 abundance estimate,

$$TAC_{y+1}^{GTlimit} = \begin{cases} TAC_y k_{GT}^{limit} \left(\frac{\mu_{GT}}{N_{age2}^{limit}}\right)^2 & \mu_{GT} < N_{age2}^{limit} \\ Not\ used & \mu_{GT} \geq N_{age2}^{limit} \end{cases} \quad \text{eq. 5}$$

$TAC_{y+1}^{GTlimit}$: TAC calculated using the GT age 2 abundance estimate level
k_{GT}^{limit}: a gain parameter for TAC calculation using the GT age 2 abundance estimate level
μ_{GT}: the average GT age 2 abundance estimate over the most recent t_{GTlimt} years
N_{age2}^{limit}: the prespecified lowest limit of age 2 abundance below which TAC is reduced

Final TAC is specified as

$$TAC_{y+1} = \begin{cases} min\left(TAC_{y+1}^{GTlimit}, TAC_{y+1}^{CPUE}\right) & \mu_{GT} \leq \beta_1 N_{age2}^{limit} \\ TAC_{y+1}^{CPUE} & \mu_{GT} \geq \beta_2 N_{age2}^{limit} \\ wTAC_{y+1}^{CPUE} + (1-w) min\left(TAC_{y+1}^{GTlimit}, TAC_{y+1}^{CPUE}\right) & \beta_1 N_{age2}^{limit} < \mu_{GT} < \beta_2 N_{age2}^{limit} \end{cases} \quad \text{eq. 6}$$

$$w = \frac{\mu_{GT}/N_{age2}^{limit} - \beta_1}{\beta_2 - \beta_1} \quad \text{eq. 7}$$

3. Tuning of the CMP

At the OMMP10, the meeting agreed that, in further development of CMPs for the presentation to the Extended Scientific Committee for the 24th meeting of the Scientific Committee (ESC24), developers would continue to focus on the two combinations of target level and tuning year: i) 30% of the initial total reproductive output (TRO_0) by 2035 (30% by 2035); and ii) 35% of TRO_0 by 2040 (35% by 2040) (CCSBT 2019). As previously done, NT4 was tuned to these two combinations providing a 50% probability of reaching the tuning points with a maximum TAC change of 3000 t. In addition, according to the agreement at the OMMP10, NT4 was also tuned using maximum TAC changes of 2000 t and 4000 t in 30% by 2035 case only. The tunings were done based on the reference set operating model (OM) ("base18_UAM1.grid"). Then, associated robustness tests scenarios agreed at the OMMP10 ("as2016", "as2016cpue18", "as2016reclow5", "cpueom75", "cpueupq", "cpuew0", "cpuew0reclow5", "fis20", "h55", and "reclow5"; see Table 5 in CCSBT 2019) were run using the same tuning parameter values as the reference set case for the 30% by 2035 and 35% by 2040 combinations only. Briefly, "as2016", "cpue18", "cpueom75", "cpueupq", "cpuew0", "fis20", "h55", and "reclow5" respectively correspond to cases where: remove the high 2016 aerial survey data point; remove the high 2018 core vessels CPUE point;

power function for biomass-CPUE relationship with power=0.75; CPUE q increased by 25% permanently in 2008; Variable Square (VS) CPUE interpretation is assumed; Indonesian selectivity flat from age 20+; just check any estimation tweaks that might be required when h=0.55; reduce future recruitment by 50% during the first 5 years.

Additionally, robustness tests with an OM scenario including the grid-type trolling recruitment index (TRG) and with an assumption of future recruitment reduction by 90% during the first 5 years (named "TRG" and "reclow501", respectively) for consideration at the ESC24 were run.

4. Results

Values for the input parameters of NT4 used in simulation tests were summarized in Table 1. Tunings were done allowing the error range between -0.005 and +0.005 for the tuning probability (i.e., 0.495-0.505 when the tuning probability is 0.5). Results (trajectories of TAC and relative total reproductive output, TRO) for 30% by 2035 (with maximum TAC changes of 2000 t, 3000 t, and 4000 t) and 35% by 2040 (with a maximum TAC change of 3000 t) based on the reference set (base18_UAM1) are shown in Figs. 1a (TAC) and 1b (relative TRO). Results of robustness tests associated with 30% by 2035 (with a maximum TAC change of 3000 t) are shown in Figs. 2a and 2b along with the reference set case. Similarly, figures for robustness tests associated with 35% by 2040 (with a maximum TAC change of 3000 t) are shown in Figs. 3a and 3b. Results of additional robustness tests under different recruitment assumptions ("TRG" and "reclow501") are shown in Figs. 4a and 4b along with the reference set case. Representative performance statistics graphs are shown in Figs. 5 (30% by 2035 and 35% by 2040 for base18), 6 (robustness tests associated with 30% by 2035), and 7 (robustness tests associated with 35% by 2040).

Major findings from the tunings (for the reference set) and robustness tests are summarized below (these summaries are all explained with respect to median behaviors of TAC and relative TRO trends):

- Basic characteristics of NT4 are: i) until the tuning year of achieving the stock level target (2035 or 2040), NT4 suppresses increase of TAC, and after the tuning year, it tries to increase TAC as possible corresponding to increase of the stock (Figs. 1ab); ii) if recruitment level becomes declining to a low level, then NT4 reduces TAC accordingly to avoid decrease of the stock (Figs. 2ab, 3ab, and 4ab).
- When testing NT4 under "reclow5" robustness scenario and its combinations with "as2016" or "cpuew0" scenarios ("as2016reclow5" or "cpuew0reclow5"), NT4 reduces TAC accordingly reacting to the low recruitment to avoid decline of TRO (Figs. 2ab and 3ab). Such reaction is much stronger under an assumption of a 90% recruitment reduction ("reclow501" in Figs. 4ab).

- When testing NT4 under "as2016", "as2016cpue18", "cpue0m75", "cpueupq", "fis20", "h55", and "TRG" robustness scenarios, median behaviors of both TAC and relative TRO were similar to the reference set (base18), except the behavior of relative TRO under "h55" (Figs. 2ab, 3ab, and 4ab). However, the probability of reaching the tuning point under these robustness scenarios became less than 50%.

- When testing NT4 under "cpuew0" robustness scenario, it results in more pessimistic situation where TAC is not increased (is substantially reduced in some cases) reacting to low productive stock to avoid decline of TRO than under "reclow5" (Figs. 2ab and 3ab). The combination of "cpuew0" and "reclow5" results in the most pessimistic situation among the robustness scenarios tested.

・ Acknowledgements

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5. References

CCSBT (2017) Report of the Twenty Second Meeting of the Scientific Committee. 2 September 2017. Yogyakarta, Indonesia

CCSBT (2019) Report of the Tenth Operating Model and Management Procedure Technical Meeting. 24-28 June 2019. Seattle, USA

Hillary R, Preece A, Davies C (2016) Methods for data generation in projections. CCSBT-ESC/1609/BGD06 (*Previously* CCSBT-OMMP/1609/07)

Takahashi N (2019) Further improvement and performance evaluation of a candidate management procedure ("NT4") for southern bluefin tuna. CCSBT-ESC/1909/BGD06 (*Previously* CCSBT-OMMP/1906/10)

Table 1. Values for the input parameters of NT4

	maxTACchange_%TRO_0			
input parameter	2000_30	3000_30	4000_30	3000_35
I_{target}^{POP}	2500000	2500000	2500000	2500000
t_{POP}	3	3	3	3
$k1_{CPUE}$ (tuned)	0.20	0.20	0.20	0.20
$k2_{CPUE}$ (tuned)	1.45	1.30	1.30	0.68
$t1_{CPUE}$	10	10	10	10
$k3_{CPUE}$ (tuned)	0.10	0.10	0.10	0.10
$k4_{CPUE}$ (tuned)	3.00	3.00	3.00	3.00
$t2_{CPUE}$	5	5	5	5
k_{GT}^{limit} (tuned)	0.75	0.75	0.75	0.75
t_{GTlimt}	5	5	5	5
N_{age2}^{limit}	700000	700000	700000	700000
α_1	0.90	0.90	0.90	0.90
α_2	1.10	1.10	1.10	1.10
β_1	0.90	0.90	0.90	0.90
β_2	1.10	1.10	1.10	1.10
maximum TAC (capping)	32000	32000	32000	32000

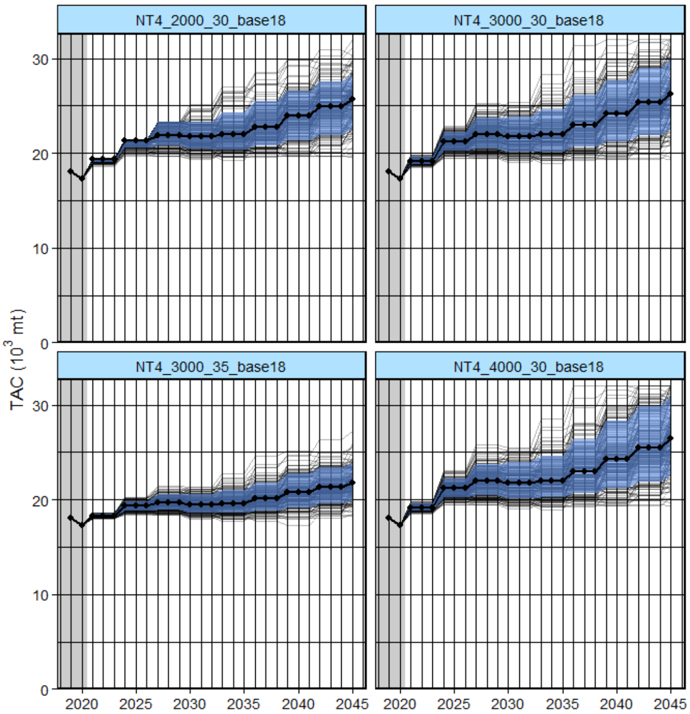

Fig. 1a. Trajectories of TAC for 30% by 2035 (with max TAC changes of 2000t, 3000t, and 4000t) and 35% by 2040 (with a max TAC change of 3000t) based on the reference set (base18_UAM1).

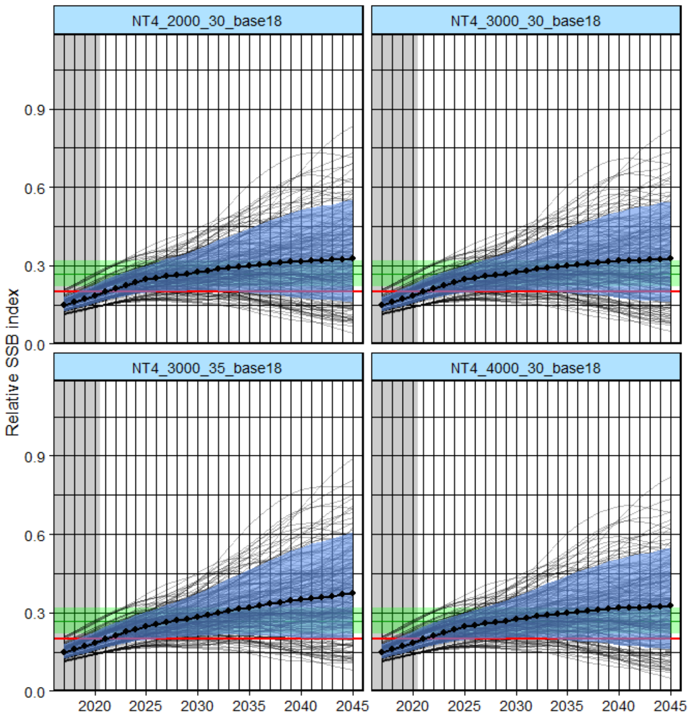

Fig. 1b. Trajectories of relative TRO for 30% by 2035 (with max TAC changes of 2000t, 3000t, and 4000t) and 35% by 2040 (with a max TAC change of 3000t) based on the reference set (base18_UAM1).

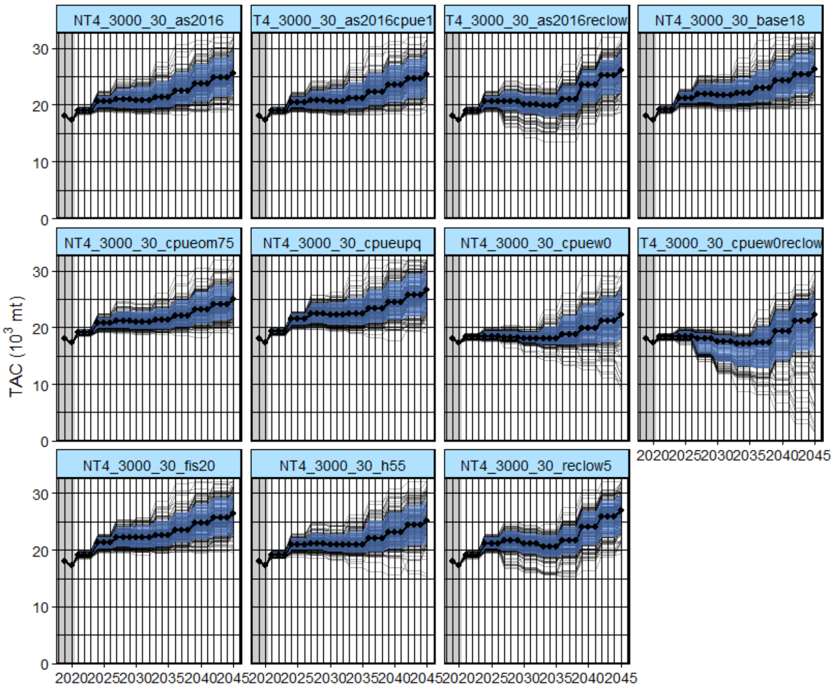

Fig. 2a. Trajectories of TAC for 30% by 2035 (base18 with a max TAC change of 3000t) and associated robustness tests.

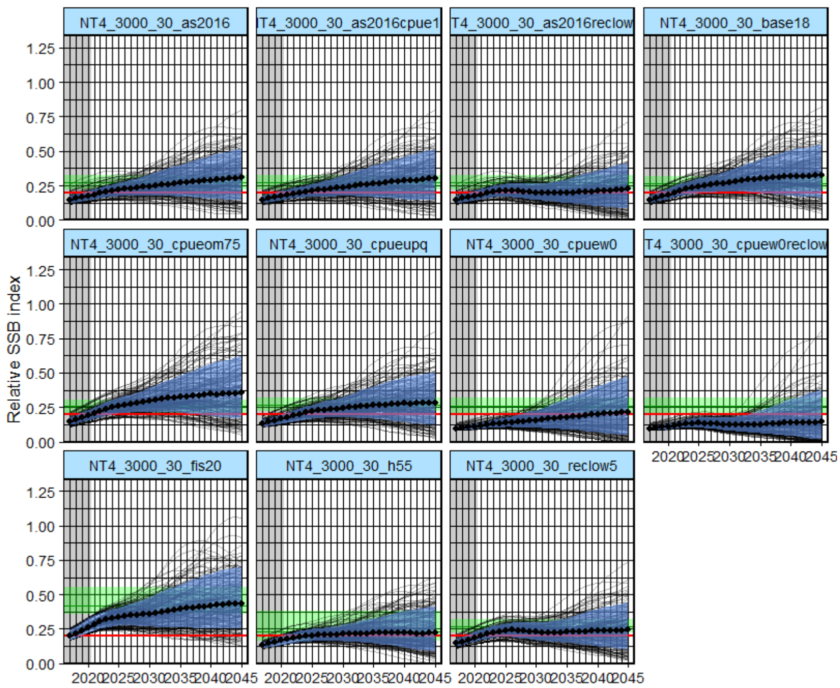

Fig. 2b. Trajectories of relative TRO for 30% by 2035 (base18 with a max TAC change of 3000t) and associated robustness tests.

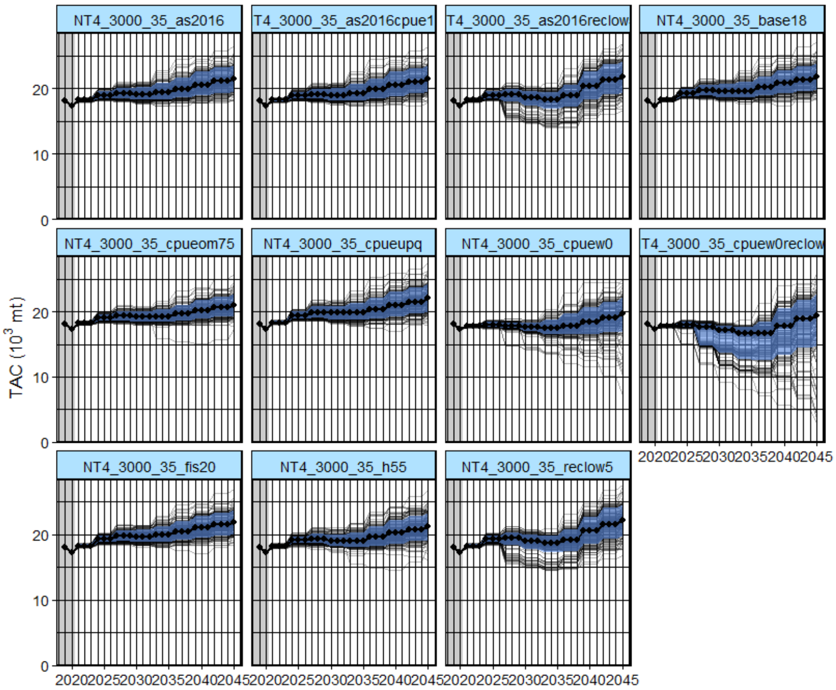

Fig. 3a. Trajectories of TAC for 35% by 2040 (base18 with a max TAC change of 3000t) and associated robustness tests.

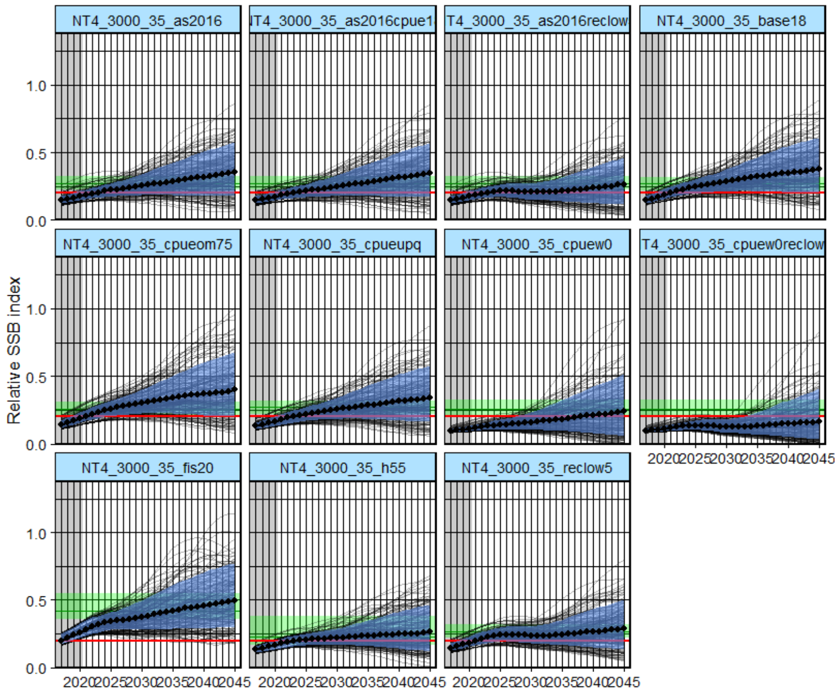

Fig. 3b. Trajectories of relative TRO for 35% by 2040 (base18 with a max TAC change of 3000t) and associated robustness tests.

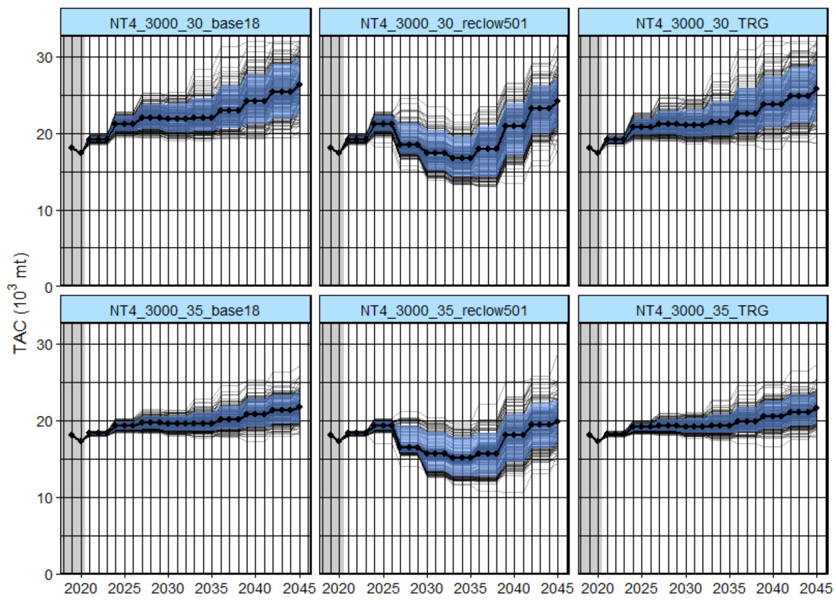

Fig. 4a. Trajectories of TAC for 30% by 2035 and 35% by 2040 (base18 with a max TAC change of 3000t) and additional robustness tests under different recruitment assumptions ("TRG" and "reclow501").

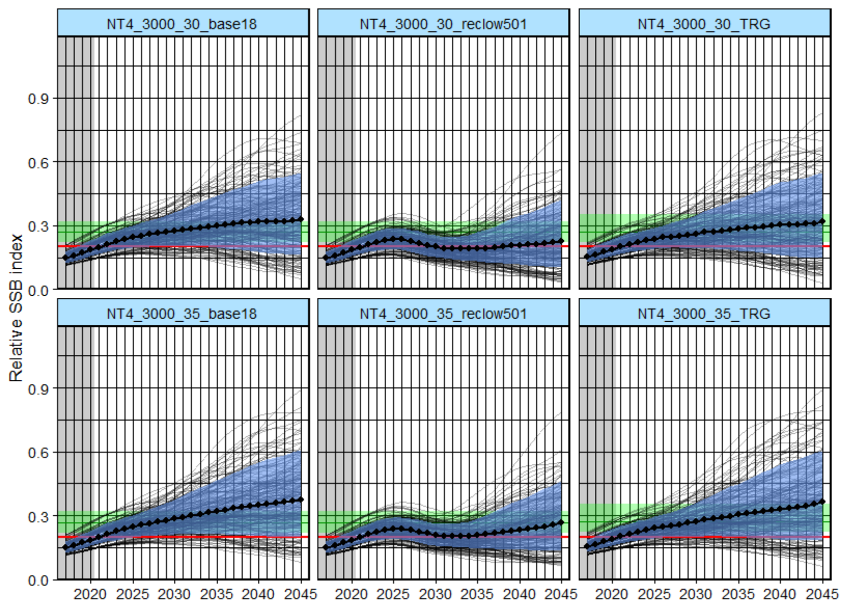

Fig. 4b. Trajectories of relative TRO for 30% by 2035 and 35% by 2040 (base18 with a max TAC change of 3000t) and additional robustness tests under different recruitment assumptions ("TRG" and "reclow501").

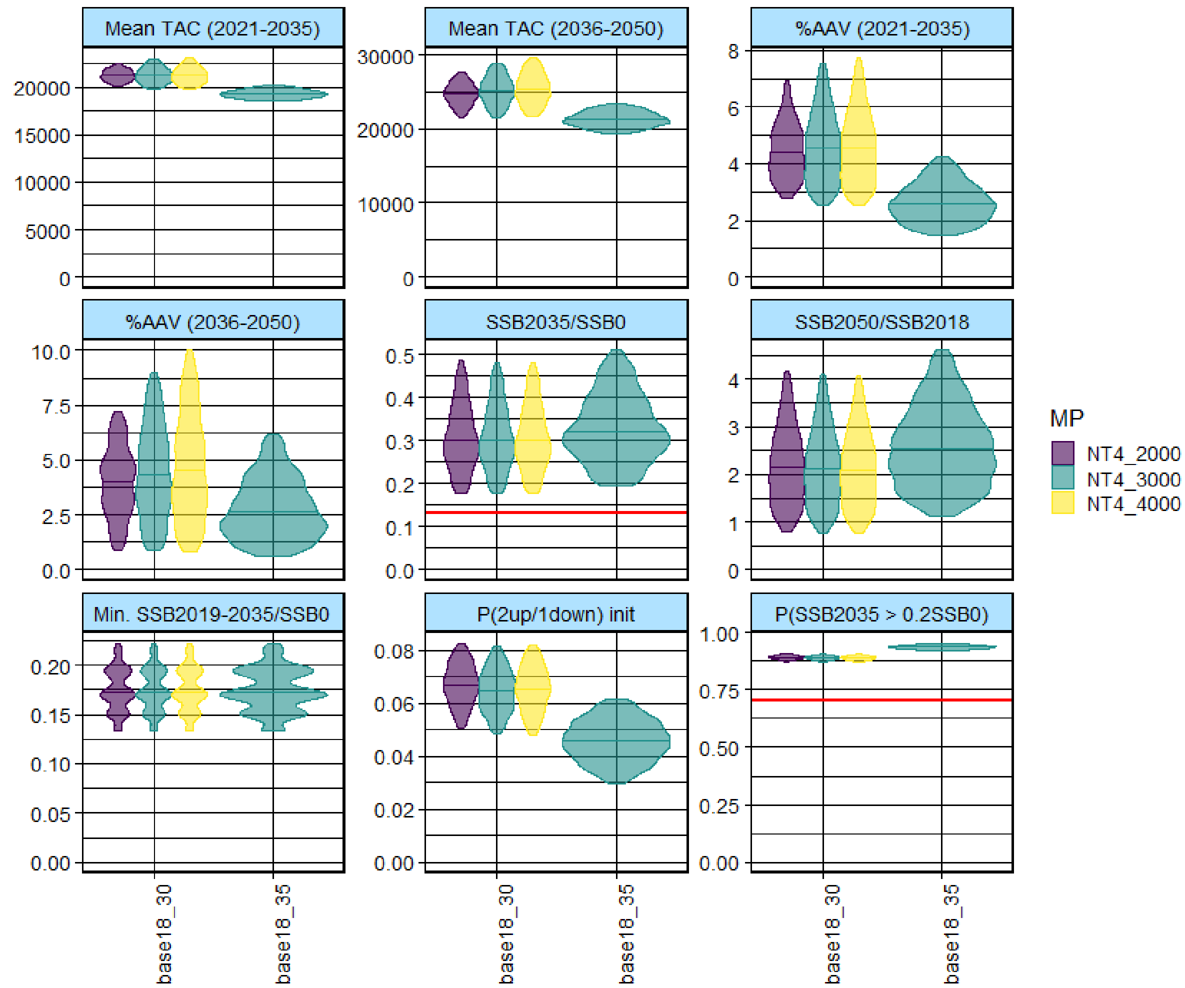

Fig. 5. Representative performance statistics graphs for the reference set (base18) tuned to 30% by 2035 and 35% by 2040.

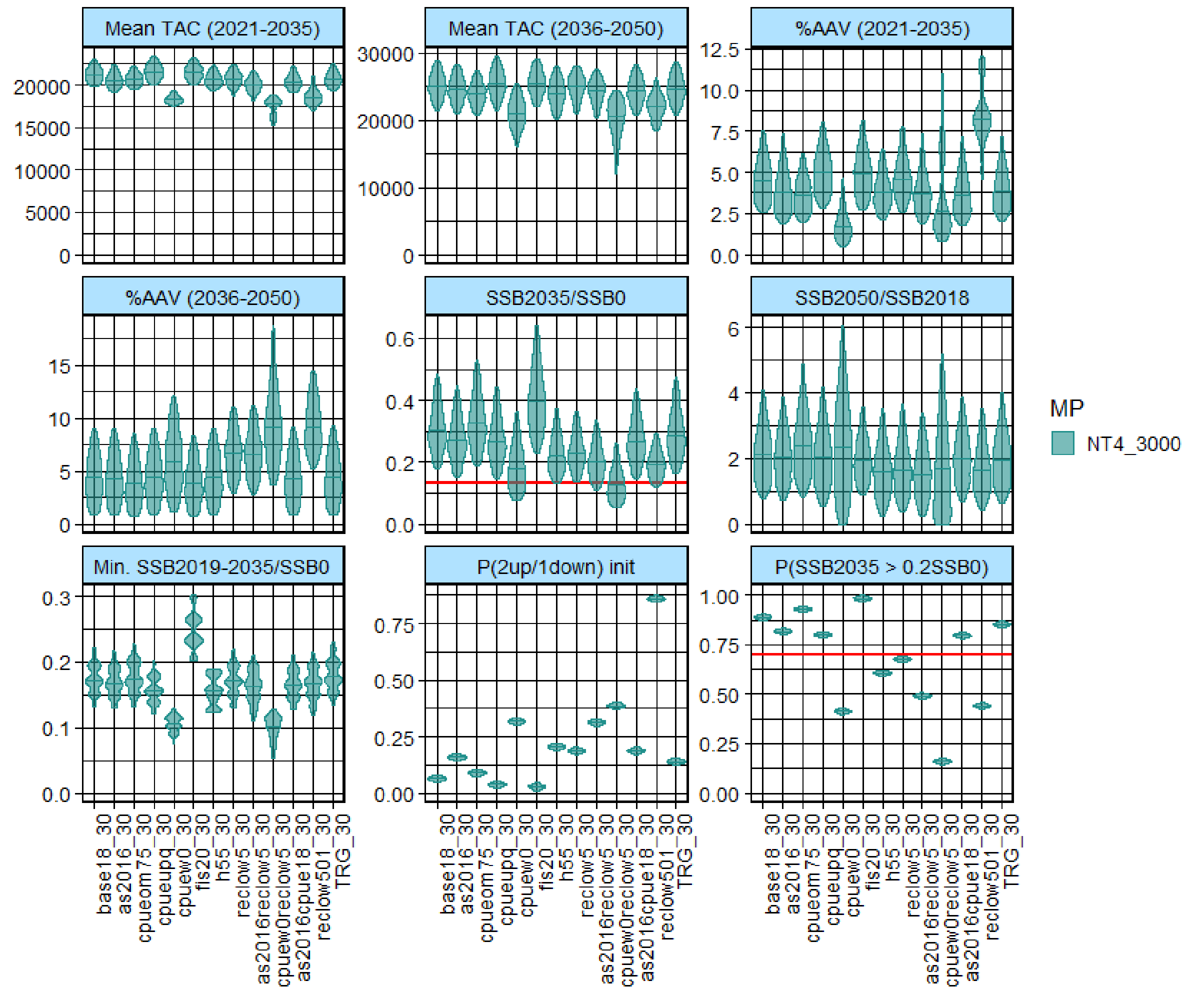

Fig. 6. Representative performance statistics graphs for robustness tests associated with the reference set (base18) tuned to 30% by 2035.

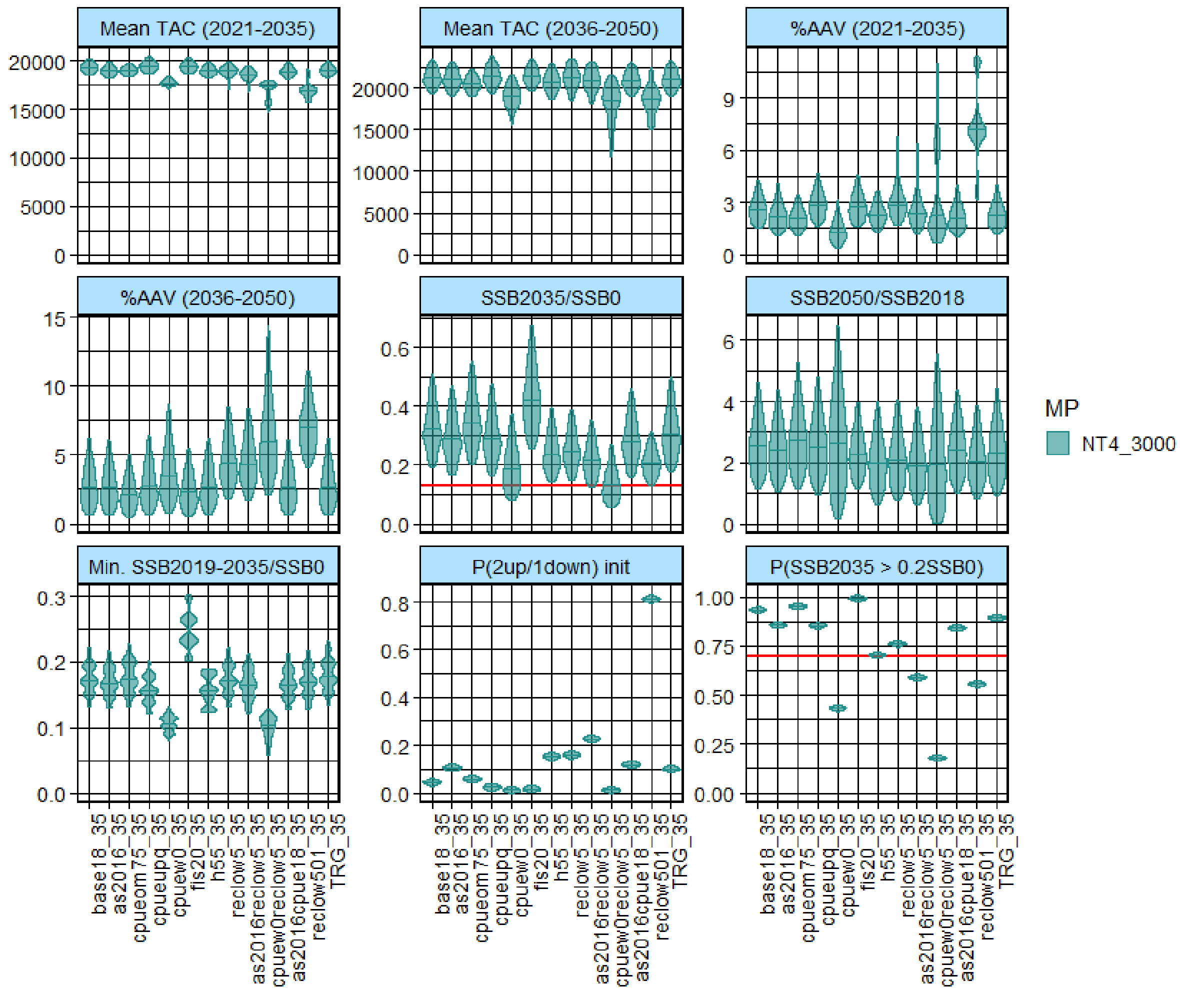

Fig. 7. Representative performance statistics graphs for robustness tests associated with the reference set (base18) tuned to 35% by 2040.