Initial trials of new candidate management procedures for southern bluefin tuna

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Abstract : This document provides preliminary results of initial development and simulation trials of new candidate management procedures (MPs) for southern bluefin tuna. MPs considered are all simple empirical ones, called "NT1" and "NT2". The NT1 utilizes CPUE and gene-tagging (GT) indices in its harvest control rules (HCRs) for setting TAC. The NT2 has a HCR that utilizes a close-kin mark recapture parent-offspring pairs (POP) index in addition to the same HCRs as incorporated in the NT1. Major findings from the initial test trials are: the NT1 and NT2 could be tuned to all the tuning points tested; for both MPs, the tuning results were similar regardless of values used for maximum TAC change when comparing the results of tuning to the same stock level (30% or 35% of the initial total reproductive output, TRO_0); for both MPs, the tuning results were different between tunings to the stock levels of 30%TRO_0 and 35%TRO_0; when testing the NT1 and NT2 under the "lowR" (n=10 years) robustness scenario using the existing parameter values tuned based on the reference set, both MPs reacted to 10-year series of low recruitment accordingly.

ミナミマグロのための新たな管理方式候補の初期試験

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要旨：この文書はミナミマグロのための新たな管理方式（MP）候補の初期開発とシミュレーション試行の予備的な結果を提供する。検討された MP は全て単純で経験的なもので、“NT1” と “NT2” と呼ばれる。NT1 は CPUE および遺伝標識（GT）指数を TAC 設定のための漁獲制御ルール（HCR）において利用している。NT2 は、NT1 に組み込まれたものと同様の HCR に加え、近縁標識再捕の親子ペア（POP）指数も利用した HCR をもつ。この最初のテスト試行から分かった主な事柄は以下：NT1 および NT2 はテスト対象とした全てのチューニングポイントにチューニングすることができた；両 MP に関し、同じ資源水準（初期総再生産出力、TRO_0 の 30%または 35%）へチューニングした結果を比べると、用いた最大 TAC 変化幅の値によらず、チューニング結果は似ていた；両 MP に関し、チューニング結果は 30%TRO_0 と 35%TRO_0 のそれぞれの資源水準へのチューニングで異なっていた；リファレンスセットをベースにチューニングされた既存のパラメタ値を用いて “lowR”（n=10 年）頑健性シナリオの下で NT1 および NT2 をテストしたが、両 MP ともに 10 年間の低加入に応じて反応した。

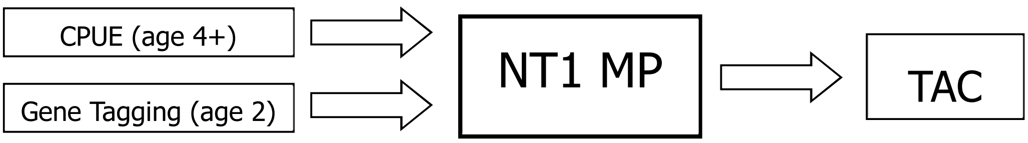
1. Introduction

Budgetary and logistic reasons combined make the CCSBT scientific aerial survey (AS) difficult to continue beyond 2018. One of the two required inputs (recruitment index) for the current CCSBT management procedure (MP), Bali procedure, has been obtained from the AS. Due to this cessation of the AS, to set TAC for the 2021-2023 fishing season in 2020, the CCSBT decided to develop a new 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).

This document provides preliminary results of initial development and simulation trials of new candidate management procedures (MPs) for southern bluefin tuna. MPs considered here are all simple empirical ones, not model-based.

2. Description of candidate MPs ("NT*")

2.1. NT1 MP



The "NT1" MP uses the following two 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 trend (the slope of log(CPUE age 4+) over the most recent t_{CPUE} years);

(2) Gene Tagging (GT) age 2 abundance estimate – (a) Use as an indicator of the recruitment level (the most recent $t_{GTlimit}$ years average) of whether this level is below the prespecified lowest recruitment level (as the lowest limit); (b) Use as an indicator of change in the recruitment trend (the slope of log(GT estimate) over the most recent t_{GT} years)

Equations of TAC calculation are:

$$TAC_{y+1}^{CPUE} = \begin{cases} TAC_y(1 + k1_{CPUE}S_{CPUE}) & S_{CPUE} < 0 \\ TAC_y(1 + k2_{CPUE}S_{CPUE}) & S_{CPUE} \geq 0 \end{cases}$$

TAC_y: TAC for year *y*

TAC_{y+1}^{CPUE}: TAC calculated using log(CPUE (age 4+)) slope for *y*+1

S_{CPUE}: the slope of log(CPUE age 4+) over the most recent t_{CPUE} years

$k1_{CPUE}$: a gain parameter for TAC calculation using log(CPUE (age 4+)) slope when $S_{CPUE}<0$

$k2_{CPUE}$: a gain parameter for TAC calculation using log(CPUE (age 4+)) slope when $S_{CPUE}>=0$

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

$TAC_{y+1}^{GTlimit}$: 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

$$TAC_{y+1}^{GT} = \begin{cases} TAC_y(1 + k1_{GT}S_{GT}) & S_{GT} < 0 \\ TAC_y(1 + k2_{GT}S_{GT}) & S_{GT} \geq 0 \end{cases}$$

TAC_{y+1}^{GT}: TAC calculated using log(GT age 2 abundance estimate) slope for *y*+1

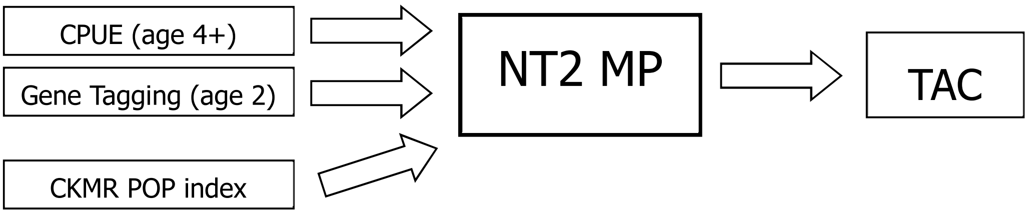
S_{GT}: the slope of log(GT age 2 abundance estimate) over the most recent t_{GT} years

$k1_{GT}$: a gain parameter for TAC calculation using log(GT estimate) slope when $S_{GT}<0$

$k2_{GT}$: a gain parameter for TAC calculation using log(GT estimate) slope when $S_{GT}>=0$

$$TAC_{y+1} = \begin{cases} minimum\left(TAC_{y+1}^{GTlimit}, \frac{TAC_{y+1}^{CPUE} + TAC_{y+1}^{GT}}{2}\right) & \mu_{GT} < N_{age2}^{limit} \\ \frac{TAC_{y+1}^{CPUE} + TAC_{y+1}^{GT}}{2} & \mu_{GT} \geq N_{age2}^{limit} \end{cases}$$

2.2. NT2 MP



In addition to the two (CPUE and GT) indicators which the "NT1" MP uses, the "NT2" MP utilizes a spawning stock index derived from parent-offspring pairs (POP) data of the CKMR as an input to evaluate the stock 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 trend (the slope of log(CPUE age 4+) over the most recent t_{CPUE} years);

(2) Gene Tagging (GT) age 2 abundance estimate – (a) Use as an indicator of the recruitment level (the most recent $t_{GTlimit}$ years average) of whether this level is below the prespecified lowest recruitment level (as the lowest limit); (b) Use as an indicator of change in the recruitment trend (the slope of log(GT estimate) over the most recent t_{GT} years)

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

For the CPUE and GT parts of harvest control rule (HCR), equations of TAC calculation are same as the ones incorporated in the NT1 MP. Additional equations of the TAC calculation for the POP part of HCR in the NT2 MP are:

$$TAC_{y+1}^{POP} = \begin{cases} TAC_y\left(1 + k1_{POP}\dfrac{I_{target}^{POP} - \mu_{POP}}{\mu_{POP}}\right) & \mu_{POP} > I_{target}^{POP} \\ TAC_y\left(1 + k2_{POP}\dfrac{I_{target}^{POP} - \mu_{POP}}{\mu_{POP}}\right) & \mu_{POP} \leq I_{target}^{POP} \end{cases}$$

TAC_{y+1}^{POP}: TAC calculated using the POP index level 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

$k1_{POP}$: a gain parameter for TAC calculation using the POP index when $\mu_{POP} > I_{target}^{POP}$
$k2_{POP}$: a gain parameter for TAC calculation using the POP index when $\mu_{POP} \leq I_{target}^{POP}$

$$TAC_{y+1} = \begin{cases} minimum\left(TAC_{y+1}^{GTlimit}, \dfrac{TAC_{y+1}^{CPUE} + TAC_{y+1}^{GT} + TAC_{y+1}^{POP}}{3}\right) & \mu_{GT} < N_{age2}^{limit} \\ \dfrac{TAC_{y+1}^{CPUE} + TAC_{y+1}^{GT} + TAC_{y+1}^{POP}}{3} & \mu_{GT} \geq N_{age2}^{limit} \end{cases}$$

3. Tuning points tested

At the fifth meeting of the Strategy and Fisheries Management Working Group (SFMWG5), the meeting agreed the tuning points of providing a 50% probability of reaching 25%, 30%, 35%, and 40% of the initial total reproductive output (TRO_0) by 2035 with maximum TAC changes of 2000 t, 3000 t, and 4000 t (5000 t in some scenarios if needed) (CCSBT 2018). Tuning points considered and tried for the OMMP9 meeting are indicated in Table 1 and 2 for the NT1 and NT2 MPs, respectively. Simulation tests focused on tunings based on the reference set operating model (OM) ("base16.grid"). Then, additionally, only "lowR" robustness test (the option switch in "mycontrol*.dat" was set to 10, meaning recruitment reduction for first 10 years) was run using the same tuning parameter values as the reference set case (for the tuning point of providing a 50% probability of reaching 30% of TRO_0 by 2035 with maximum TAC changes of 3000 t) to check whether the NT1 and NT2 MPs can adequately respond to a period of low recruitment.

4. Preliminary Results

Values for the tuning parameters of the NT1 and NT2 MPs used in simulation tests were summarized in Table 3 and 4, respectively. Tuning exercises were done allowing the error range between -0.5% and +0.5% for the tuning probability (e.g., 49.5%-50.5% when the tuning probability is 50%). Tuning results (trajectories of TAC and spawning stock size in total reproductive output, TRO) based on the reference set are shown in Figs. 1 and 2 (NT1) and Figs. 4 and 5 (NT2). Results based on the "lowR" robustness test using the parameter values for the tuning point of providing a 50% probability of reaching 30% of TRO_0 by 2035 with maximum TAC changes of 3000 t with the reference set are shown in Figs . 3 (NT1) and 6 (NT2). Comparisons of performance statistics with respect to TRO between NT1 and NT2 for the tuning levels of 30% and 35% of TRO_0 are summarized in Fig. 7 (3000 t max TAC change) and Fig. 8 (4000 t max TAC change). Comparisons of performance statistics with respect to TAC are summarized in Fig. 9 (3000 t max TAC change) and Fig. 10 (4000 t max TAC change).

Major findings from the initial test trials are summarized below:

- The NT1 and NT2 could be tuned to all the tuning points tested (Tables 1 and 2).
- For all tuning exercises conducted, both NT1 and NT2 achieved the current management objective of providing at least 70% probability of reaching 20% of TRO_0 by 2035 with probabilities of higher than 80% (the leftmost panels in Figs. 7a and 8a).
- For both NT1 and NT2, the results (trajectories of TAC and spawning stock size in total reproductive output, TRO) of tuning to the stock level of 30%TRO_0 were similar regardless of values used for maximum TAC change (the median trajectories of both TAC and TRO continued to increase) (Figs. 1 and 4).
- For both NT1 and NT2, the results of tuning to the stock level of 35%TRO_0 were similar regardless of values used for maximum TAC change (the median trajectory of TRO continued to increase whereas that of TAC was consistently reduced) (Figs. 2 and 5).
- For both NT1 and NT2, the patterns of median trajectory of TAC were different between results of tuning to the stock levels of 30%TRO_0 (increasing trend) and 35%TRO_0 (deceasing trend) (compare Figs. 1 and 2, and Figs. 4 and 5).
- When testing the NT1 and NT2 based on the "lowR" (n=10 years) robustness scenario using the parameter values for the tuning point of providing a 50% probability of reaching 30%TRO_0 by 2035 with maximum TAC changes of 3000 t with the reference set, both

MPs reacted to 10-year series of low recruitment accordingly (with a given set of the tuned parameter values for both MPs, the median TAC trajectory was not reduced very much and so consequently the future TRO level declined as trade-off) (Figs. 3 and 6).

- Results of testing the NT1 and NT2 were similar (compare Figs. 1 and 4, Figs. 2 and 5, and Figs. 3 and 6). Reasons of this would be that both MPs are structurally similar (the NT2 consists of the same HCR parts using CPUE and GT indices as the NT1 and plus the HCR using the POP index, in other words, the NT2 structurally includes the NT1), and that the POP index may provide an information signal about the spawning stock which is consistent with the other signals from CPUE and GT indices.

・ Acknowledgements

The author thanks Dr. Richard Hillary for all efforts to modify the OM projection code and for kindly sharing his example MP code using POP index and his R graphics code.

5. References

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

CCSBT (2018) Report of the Fifth Meeting of the Strategy and Fisheries Management Working Group. 6-8 March 2018. Canberra, Australia

Hillary R, Preece A, Davies C (2016) Methods for data generation in projections. CCSBT-OMMP/1609/07 (CCSBT-ESC/1609/BGD 06)

Table 1. Tuning points tested for the NT1 MP

		%TRO_0			
		25	30	35	40
maximum TAC change	2000		O		
	3000		O	O	
	4000		O	O	
	(5000)				

Table 2. Tuning points tested for the NT2 MP

		%TRO_0			
		25	30	35	40
maximum TAC change	2000		O		
	3000		O	O	
	4000		O	O	
	(5000)				

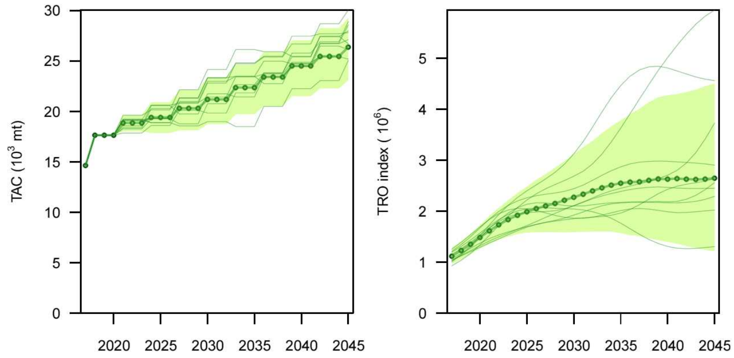
Table 3. Values for the tuning parameters of the NT1 MP

	maxTACchange_%TRO_0				
Tuning parameter	2000_30	3000_30	4000_30	3000_35	4000_35
$k1_{CPUE}$	0.40	0.40	0.40	1.85	1.85
$k2_{CPUE}$	0.98	0.95	0.88	0.10	0.10
t_{CPUE}	5	5	5	5	5
k_{GT}^{limit}	0.90	0.90	0.90	0.90	0.90
t_{GTlimt}	2	2	2	2	2
N_{age2}^{limit}	840000	840000	840000	840000	840000
$k1_{GT}$	0.10	0.10	0.10	1.70	1.35
$k2_{GT}$	2.20	2.00	2.00	0.10	0.10
t_{GT}	5	5	5	5	5

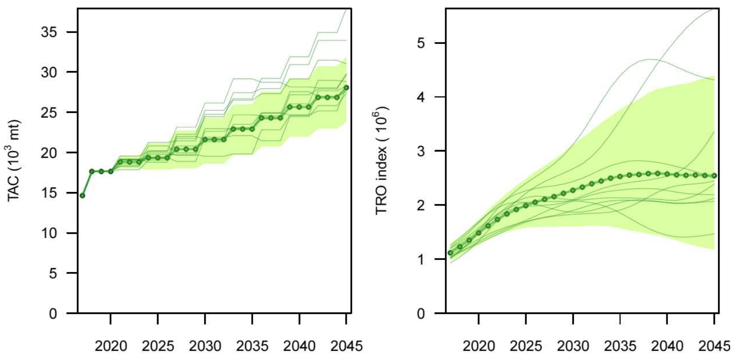
Table 4. Values for the tuning parameters of the NT2 MP

	maxTACchange_%TRO_0				
Tuning parameter	2000_30	3000_30	4000_30	3000_35	4000_35
$k1_{CPUE}$	0.40	0.40	0.40	1.85	1.85
$k2_{CPUE}$	0.85	0.85	0.85	0.1	0.1
t_{CPUE}	5	5	5	5	5
k_{GT}^{limit}	0.90	0.90	0.90	0.90	0.90
t_{GTlimt}	2	2	2	2	2
N_{age2}^{limit}	840000	840000	840000	840000	840000
$k1_{GT}$	0.10	0.10	0.10	1.35	1.35
$k2_{GT}$	2.00	2.00	2.00	0.10	0.10
t_{GT}	5	5	5	5	5
I_{target}^{POP}	2500000	2500000	2500000	1800000	1800000
t_{POP}	3	3	3	3	3
$k1_{POP}$	0.10	0.10	0.10	0.50	0.50
$k2_{POP}$	0.085	0.080	0.080	0.045	0.045

(a) NT1, 30%TRO_0, maxTACchange = 2000 t, Reference set



(b) NT1, 30%TRO_0, maxTACchange = 3000 t, Reference set



(c) NT1, 30%TRO_0, maxTACchange = 4000 t, Reference set

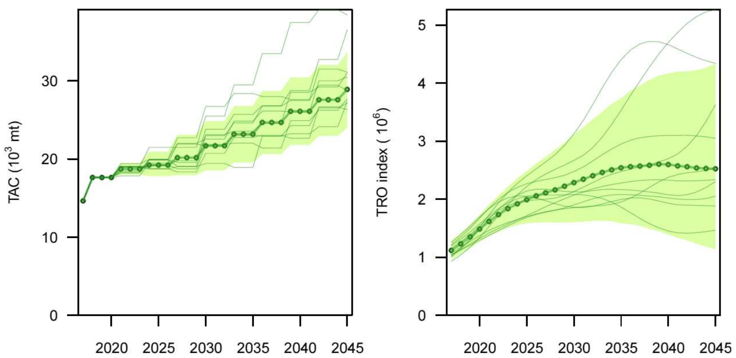
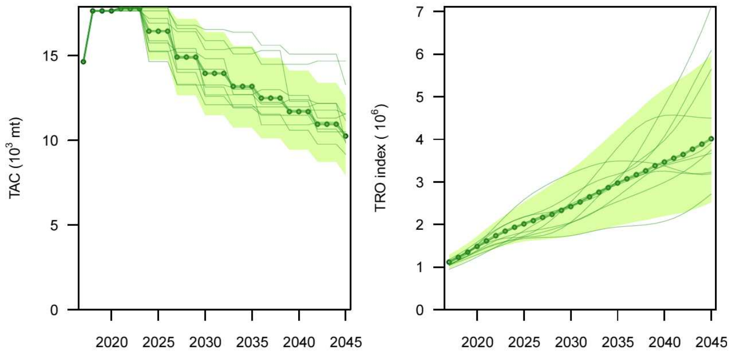


Fig. 1. Trajectories of TAC and spawning stock size in total reproductive output (TRO) for the tuning point of providing a 50% probability of reaching 30% of TRO_0 by 2035 with maximum TAC changes of (a) 2000 t, (b) 3000 t, and (c) 4000 t from simulation test results of NT1 MP based on the reference set OM.

(a) NT1, 35%TRO_0, maxTACchange = 3000 t, Reference set



(b) NT1, 35%TRO_0, maxTACchange = 4000 t, Reference set

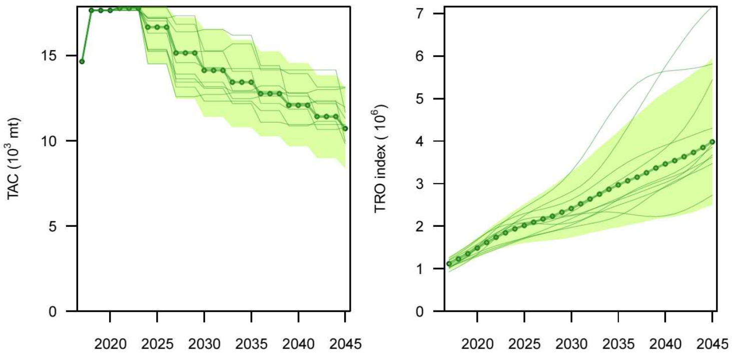


Fig. 2. Trajectories of TAC and spawning stock size in total reproductive output (TRO) for the tuning point of providing a 50% probability of reaching 35% of TRO_0 by 2035 with maximum TAC changes of (a) 3000 t and (b) 4000 t from simulation test results of NT1 MP based on the reference set OM.

NT1, 30%TRO_0, maxTACchange = 3000 t, "lowR" (n=10 years)

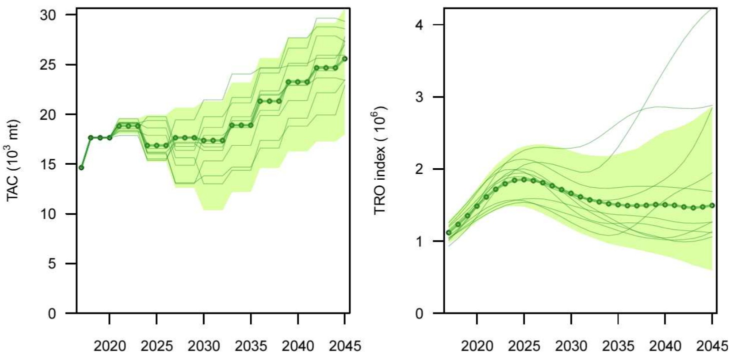
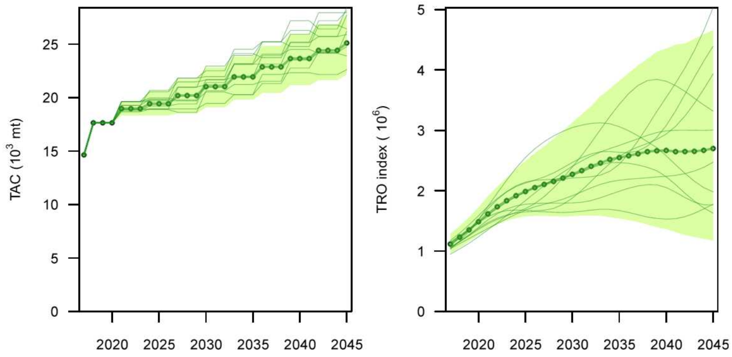
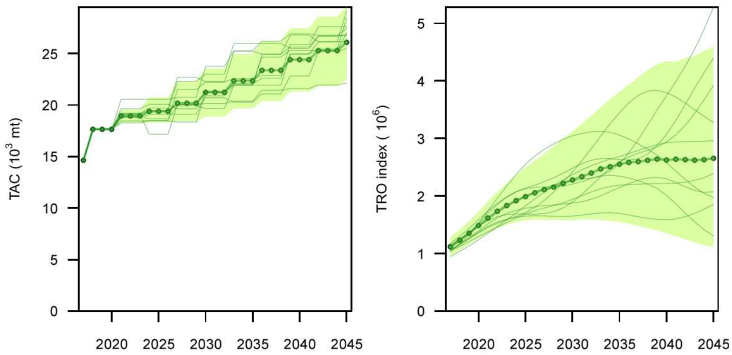


Fig. 3. Trajectories of TAC and spawning stock size in total reproductive output (TRO) from simulation test results of NT1 MP based on the "lowR" (n=10 years) robustness test using the parameter values for the tuning point of providing a 50% probability of reaching 30% of TRO_0 by 2035 with maximum TAC changes of 3000 t with the reference set OM.

(a) NT2, 30%TRO$_0$, maxTACchange = 2000 t, Reference set



(b) NT2, 30%TRO$_0$, maxTACchange = 3000 t, Reference set



(c) NT2, 30%TRO$_0$, maxTACchange = 4000 t, Reference set

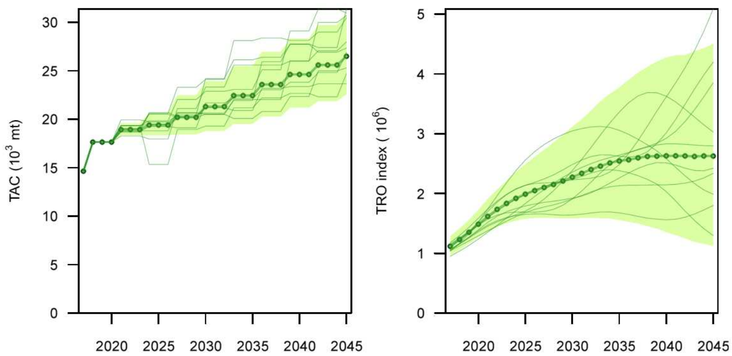
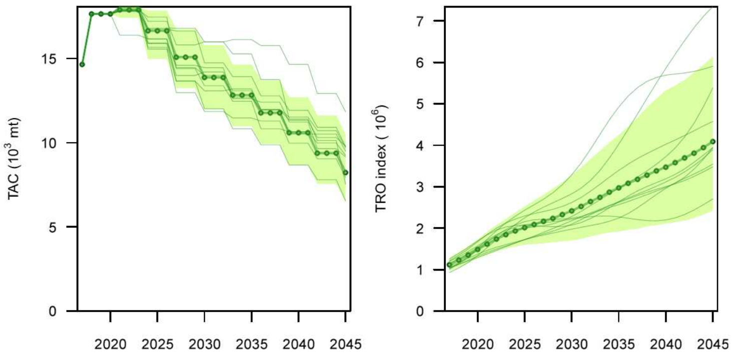


Fig. 4. Trajectories of TAC and spawning stock size in total reproductive output (TRO) for the tuning point of providing a 50% probability of reaching 30% of TRO$_0$ by 2035 with maximum TAC changes of (a) 2000 t, (b) 3000 t, and (c) 4000 t from simulation test results of NT2 MP based on the reference set OM.

(a) NT2, 35%TRO_0, maxTACchange = 3000 t, Reference set



(b) NT2, 35%TRO_0, maxTACchange = 4000 t, Reference set

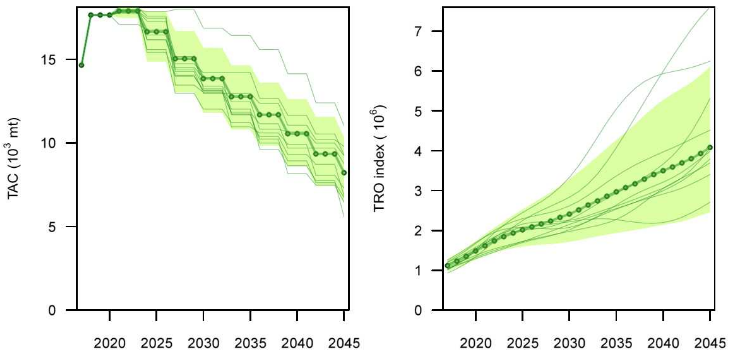


Fig. 5. Trajectories of TAC and spawning stock size in total reproductive output (TRO) for the tuning point of providing a 50% probability of reaching 35% of TRO_0 by 2035 with maximum TAC changes of (a) 3000 t and (b) 4000 t from simulation test results of NT2 MP based on the reference set OM.

NT2, 30%TRO_0, maxTACchange = 3000 t, "lowR" (n=10 years)

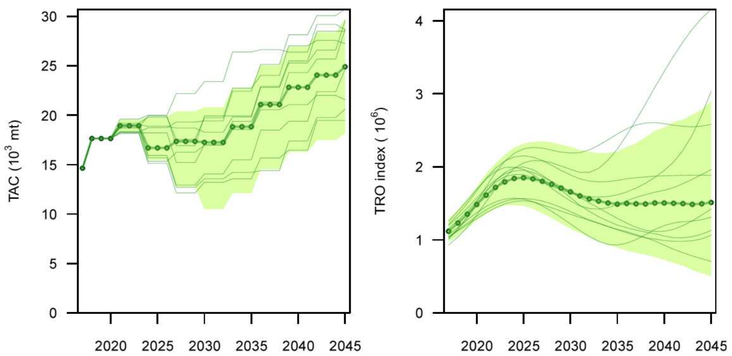
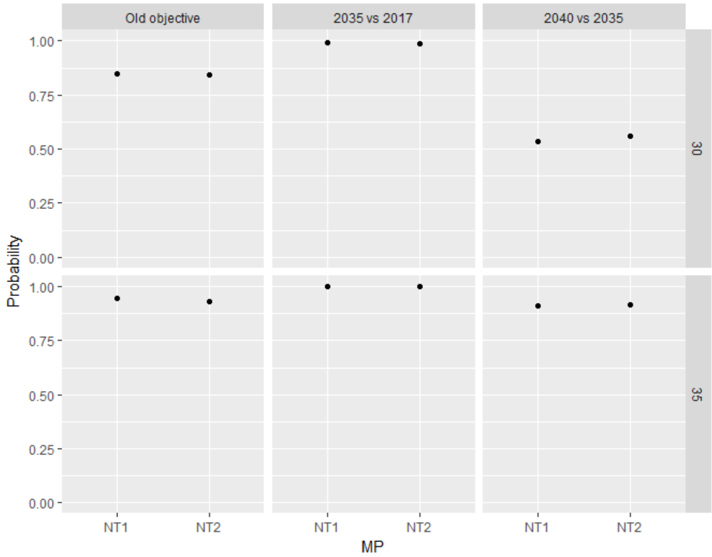


Fig. 6. Trajectories of TAC and spawning stock size in total reproductive output (TRO) from simulation test results of NT2 MP based on the "lowR" (n=10 years) robustness test using the parameter values for the tuning point of providing a 50% probability of reaching 30% of TRO_0 by 2035 with maximum TAC changes of 3000 t with the reference set OM.

(a) P(TRO_{2035} > $0.2TRO_0$), P(TRO_{2035} > TRO_{2017}), P(TRO_{2040} > TRO_{2035})



(b) Log-linear trend (2021 to 2035)

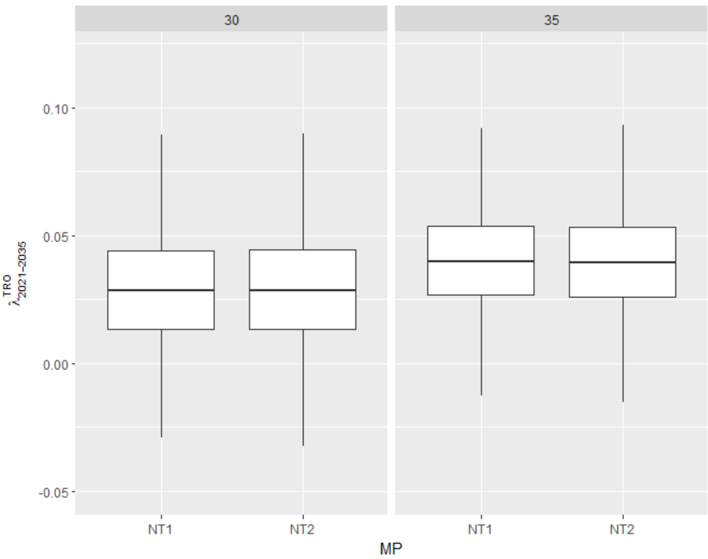
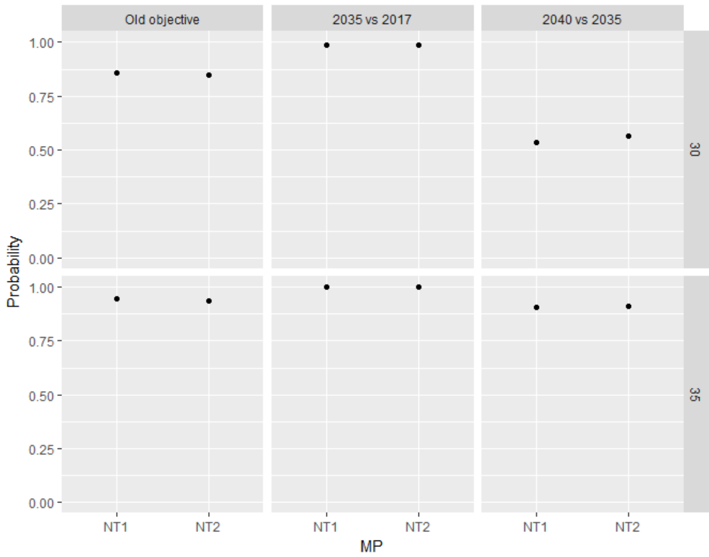


Fig. 7. Comparisons of performance statistics with respect to spawning stock (TRO) between NT1 and NT2 for the tuning levels of 30% and 35% of TRO_0 in the case of <u>3000 t</u> maximum TAC change.

(a) $P(TRO_{2035} > 0.2TRO_0)$, $P(TRO_{2035} > TRO_{2017})$, $P(TRO_{2040} > TRO_{2035})$



(b) Log-linear trend (2021 to 2035)

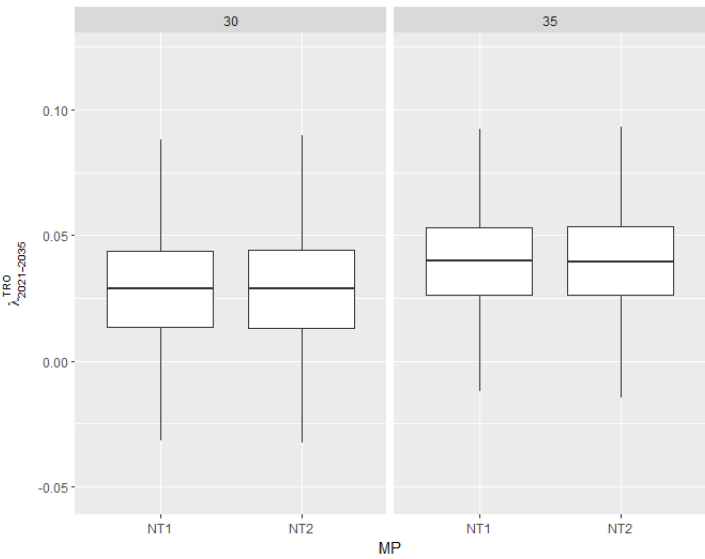
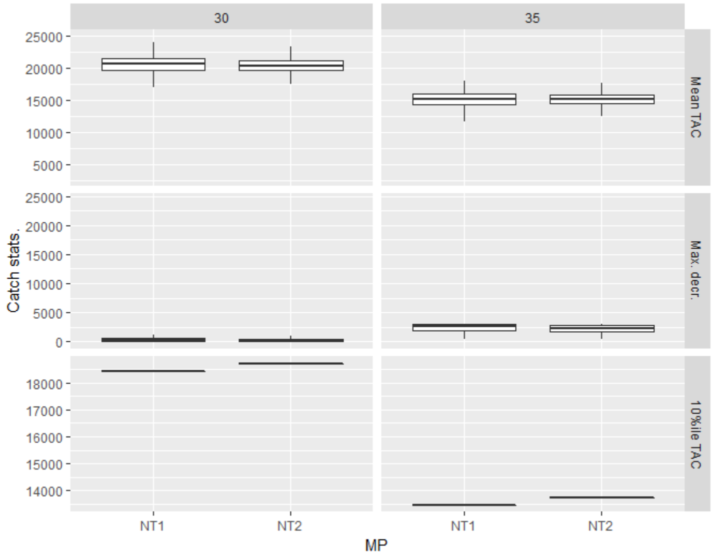


Fig. 8. Comparisons of performance statistics with respect to spawning stock (TRO) between NT1 and NT2 for the tuning levels of 30% and 35% of TRO_0 in the case of 4000 t maximum TAC change.

(a) Mean TAC (2021 to 2035), Max TAC decrease (2021 to 2035), 10%ile TAC (2021 to 2035)



(b) AAV (2021 to 2035)

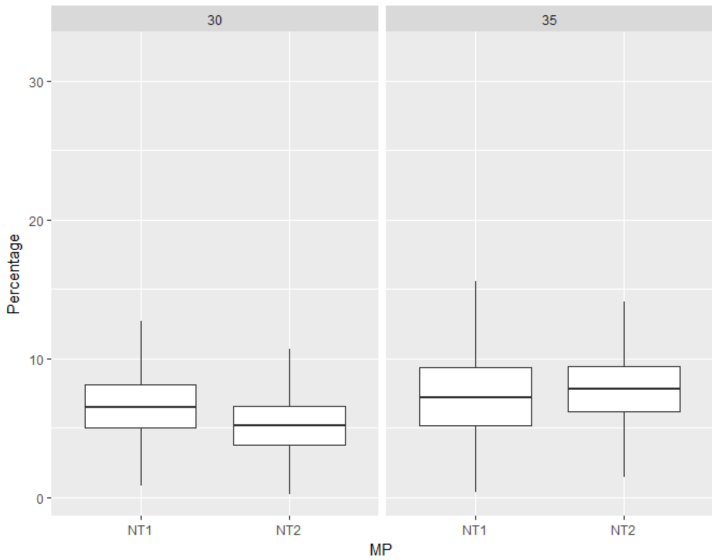


Fig. 9. Comparisons of performance statistics with respect to TAC between NT1 and NT2 for the tuning levels of 30% and 35% of TRO_0 in the case of 3000 t maximum TAC change. AAV is the average annual variation in TAC.

(c) P(TAC_{r+3}<TAC_{r+2}) IF TAC_{r+1}>TAC_r & TAC_{r+2}>TAC_{r+1} (default: r = 1)

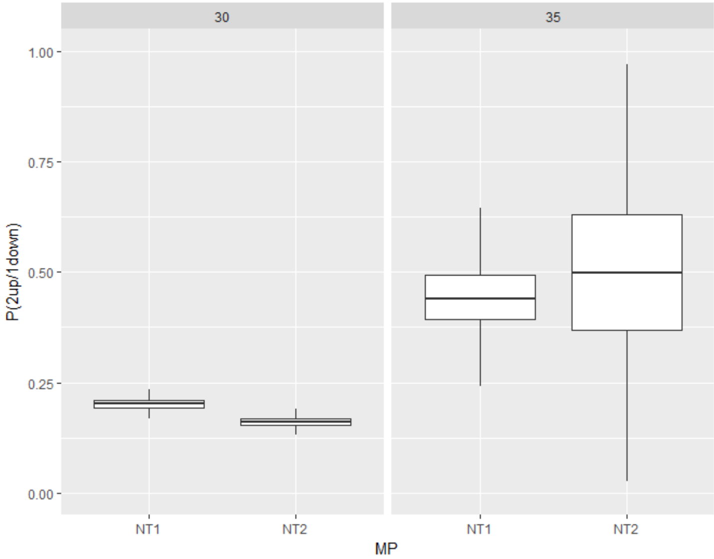
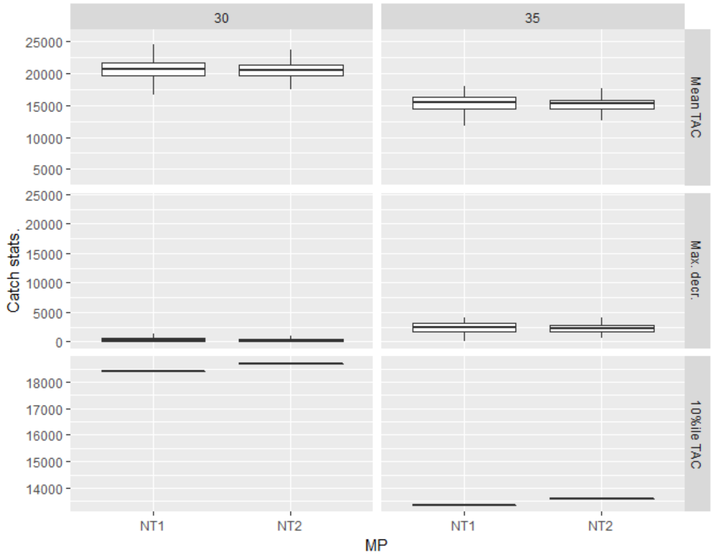


Fig. 9. (cont'd)

(a) Mean TAC (2021 to 2035), Max TAC decrease (2021 to 2035), 10%ile TAC (2021 to 2035)



(b) AAV (2021 to 2035)

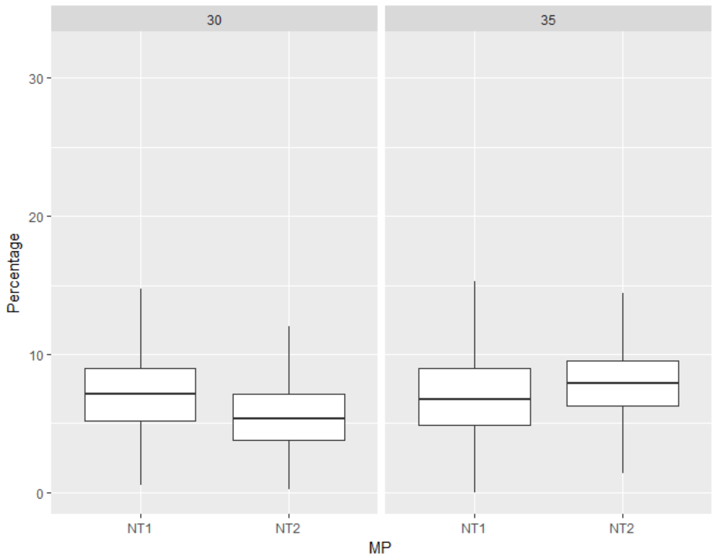


Fig. 10. Comparisons of performance statistics with respect to TAC between NT1 and NT2 for the tuning levels of 30% and 35% of TRO_0 in the case of <u>4000 t</u> maximum TAC change. AAV is the average annual variation in TAC.

(c) $P(TAC_{r+3}<TAC_{r+2})$ IF $TAC_{r+1}>TAC_r$ & $TAC_{r+2}>TAC_{r+1}$ (default: r = 1)

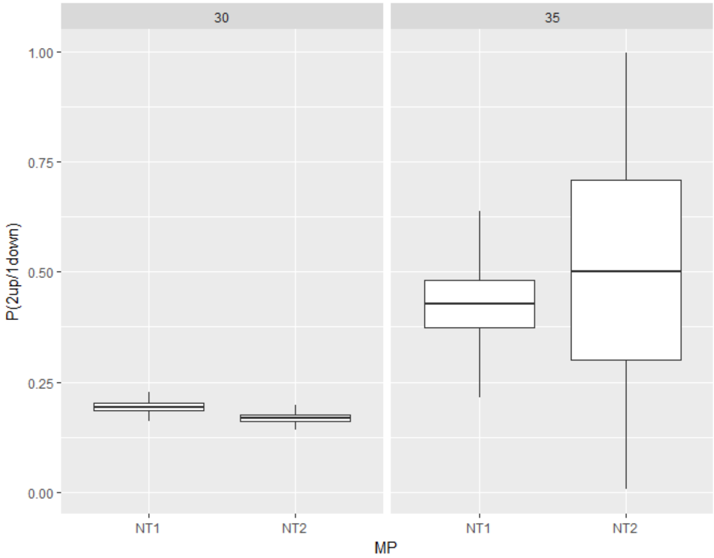


Fig. 10. (cont'd)