

## UPDATE TO THE $F_{0.1}$ BASED CANDIDATE MANAGEMENT PROCEDURE AND FINAL PERFORMANCE TUNING RESULTS

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### SUMMARY

*An updated description of the  $F_{0.1}$  management procedure is provided. The performance tuned results indicate that a phase-in period where TAC is consistent with current levels can be implemented with little effect on performance. Tuning to a PGK value of 0.7 rather than 0.6 resulted in a loss of yield regardless of the length of the management cycle (2 versus 3 year). However, when comparing performance for 2 versus 3-year cycles, it was observed that a 3-year cycle introduces more variability in yield. Implementing a scaler on the TAC change in log space effectively reduced the TAC variability with minor reductions in yield or safety.*

### RESUMEN

*Se proporciona una descripción actualizada del procedimiento de ordenación  $F_{0.1}$ . Los resultados de la calibración del desempeño indican que puede aplicarse un periodo de introducción progresiva en el que el TAC sea coherente con los niveles actuales sin apenas afectar al desempeño. La calibración a un valor PGK de 0,7 en lugar de a 0,6 produjo una pérdida de rendimiento independientemente de la duración del ciclo de ordenación (dos frente a tres años). Sin embargo, al comparar el desempeño de los ciclos de ordenación de dos y tres años, se observó que un ciclo de tres años introduce más variabilidad en el rendimiento. La implementación de una escala en el cambio de TAC en el espacio logarítmico redujo eficazmente la variabilidad de TAC con reducciones menores en el rendimiento o la seguridad.*

### RÉSUMÉ

*Une description actualisée de la procédure de gestion  $F_{0.1}$  est fournie dans le présent document. Les résultats du calibrage des performances indiquent qu'une période d'introduction progressive où le TAC est cohérent avec les niveaux actuels peut être mise en œuvre avec peu d'effet sur les performances. Le calibrage à une valeur de PGK de 0,7 plutôt que de 0,6 a entraîné une perte de production quelle que soit la durée du cycle de gestion (deux ou trois ans). Cependant, en comparant les performances pour des cycles de deux ans et de trois ans, il a été observé qu'un cycle de trois ans introduit plus de variabilité dans la production. La mise en œuvre d'une échelle dans le changement de TAC dans l'espace logarithmique a réduit efficacement la variabilité du TAC avec des réductions mineures de la production ou de la sécurité.*

### KEYWORDS

*Management Strategy Evaluation, operating models, CPUE*

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## 1. Introduction

This document provides a mathematical description of a candidate management procedure (cMP) tuned to a reference grid of 48 operating models (OM) that reflect alternate states of reality for the Atlantic Bluefin tuna population. The platform for cMP development and testing was provided by the ABTMSE package version 7.7.1 (Carruthers 2022).

The cMP is an updated version of a cMP presented at the July, 2022 MSE meeting. The major updates are:

- the range normalization now uses  $\max N = 1.0$  and  $\min N = 0.1$
- the *CAN\_SWNS* index is used as the biomass reference
- $q$ , previously a tuning parameter is now the same for both east and west ( $q = 1.875E-7$ ) and is simply a variable used as part of the abundance estimator calculation. The “tuning” parameters are now fully encapsulated in alpha and beta parameters defined below.
- as part of a “phase-in” adjustment of the TAC advice, a variance adjustment is implemented for the first 4 or 3 projected years for a 2 year and 3 year management cycle, respectively. (i.e., years 2023 to 2026 or 2023 to 2025)
- following the phase-in period, the maximum increase and decrease in TAC from one management period to the next has now been set at 20% and 30%, respectively. Except during the phase-in period when the maximum decrease in TAC is set to 10%.

## 2. Methods

### 2.1 F01 CMP mathematics

This cMP sets the TAC using an estimate of  $F_{0.1}$  and the current abundance of the stock. The  $F_{0.1}$  calculation depends on choosing 3 indicators from each management area that index the relative abundance of young, middle aged and older stock components (Table 1). Prior to use, these indicators are subjected to a range normalization, following which the average index value for the most recent 3 years is determined. A partial recruitment vector is developed from the age group means relative to the total. The calculations as described are as follows:

$$I'_{sm} = (((I_{sm} - \min(I_{sm})) * 0.9) / (\max(I_{sm}) - \min(I_{sm}))) + 0.1$$
$$I'_{md} = (((I_{md} - \min(I_{md})) * 0.9) / (\max(I_{md}) - \min(I_{md}))) + 0.1$$
$$I'_{lg} = (((I_{lg} - \min(I_{lg})) * 0.9) / (\max(I_{lg}) - \min(I_{lg}))) + 0.1$$

$$\overline{I'_{sm}} = \frac{1}{3} \sum_{N-2}^N I'_{sm}$$

$$\overline{I'_{md}} = \frac{1}{3} \sum_{N-2}^N I'_{md}$$

$$\overline{I'_{lg}} = \frac{1}{3} \sum_{N-2}^N I'_{lg}$$

$$I_{tot} = \overline{I'_{sm}} + \overline{I'_{md}} + \overline{I'_{lg}}$$

$F_{0.1}$  is a calculation based on a yield-per-recruit analysis from *fishmethods* (Nelson, 2019) that follows the modified Thompson-Bell algorithm :

$$\begin{aligned}
 Z_a &= M_i + PR_a * F_a \\
 N_{a+1} &= N_a * e^{-Z_a} \\
 \bar{N}_a &= (1 - e^{-Z_a}) * \frac{N_a}{Z_a} \\
 \bar{N}_{a+} &= \frac{N_{a+}}{Z_{a+}} \\
 C_a &= (N_a - N_{a+1}) * \frac{PR_a * F_a}{Z_a} \\
 Y_a &= \bar{W}_a C_a = PR_a * \bar{F}_a B_a
 \end{aligned}$$

where the ages  $a$  for each management area are as defined in the 2015 VPA,

$Y_a, C_a, N_a, B_a$  = Yield, Catch, Numbers and Biomass at age respectively,  
 $W_a$  = Weight at age is from the 2015 VPA for the west and 2017 VPA for the east,  
 $F_a$  = Fishing mortality at age,  
 $M_a$  = Natural mortality at age scaled to the Lorenzen function (Walter *et al.* 2018),  
 $Z_a$  = Total mortality at age ( $F_a + M_a$ ),  
 $PRE_{1:10}$  = the partial recruitment vector applied to fishing mortality (F) to obtain partial F-at-age is calculated from the east MP indicators,  
 $PRW_{1:16}$  = the partial recruitment vector applied to fishing mortality (F) to obtain partial F-at-age is calculated from the east MP indicators.

East values (**Table 2**)

$$\begin{aligned}
 a &= \{1,2,3,4,5,6,7,8,9,10\} \\
 W_{1:10} &= \{3.0, 10.0, 19.0, 35.0, 50.0, 69.0, 90.0, 113.0, 138.0, 205.0\} \\
 M_{1:10} &= \{0.40, 0.33, 0.27, 0.23, 0.20, 0.18, 0.16, 0.14, 0.13, 0.12\} \\
 PRE_{1:10} &= \left\{ \frac{\overline{I'_{sm}}}{\overline{I'_{tot1:4}}} \quad \frac{\overline{I'_{md}}}{\overline{I'_{tot5:6}}} \quad \frac{\overline{I'_{lg}}}{\overline{I'_{tot7:10}}} \right\} \\
 I_{sm,md,lg} &= \{ FR\_AER\_SUV2, JPN\_LL\_NEAtl2, MED\_LAR\_SUV \} \\
 I_{bm} &= \{ MED\_LAR\_SUV \} \\
 q &= 1.875E - 7
 \end{aligned}$$

West values (**Table 2**)

$$\begin{aligned}
 a &= \{1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16\} \\
 W_{1:16} &= \{3.1, 9.8, 15.1, 19.9, 43.3, 60.5, 89.9, 111.6, 144.8, 174, 201.1, 225.5, 247.7, 264, 283.5, 340\} \\
 M_{1:16} &= \{0.40, 0.33, 0.27, 0.23, 0.20, 0.18, 0.16, 0.14, 0.13, 0.12, 0.12, 0.11, 0.11, 0.11, 0.11, 0.11\}
 \end{aligned}$$

$$PRW_{1:16} = \left\{ \frac{\overline{I'_{sm}}}{\overline{I_{tot\ 1:4}}} \quad \frac{\overline{I'_{md}}}{\overline{I_{tot\ 5:6}}} \quad \frac{\overline{I'_{lg}}}{\overline{I_{tot\ 7:16}}} \right\}$$

$$I_{sm,md,lg} = \{ US\_RR\_66\_144, CAN\_SWNS, MEXUS\_GOM\_PLL \}$$

$$I_{bm} = \{ CAN\_SWNS \}$$

$$q = 1.875E - 7$$

The  $F_{0.1}$  estimate is based on yield-per-recruit calculation for  $F$  ranging from 0 to 10 in increments of 0.01. The last age in the  $a$  vector is a plus group and the oldest age in the plus group is 35. If an estimate of  $F_{0.1}$  can't be calculated because of missing index values or a failure of the YPR calculation, a default value of 0.2 is assumed.

The next step involves estimating the current biomass for each stock or region. The stock or region-specific biomass is based on the value of an index assumed to reference either the biomass of the stock or the biomass of fish in a region and is scaled by the change in stock to the component indices relative to a reference period (2016 to 2021) as follows:

$$\overline{I'_{sm\_cur}} = \frac{1}{3} \sum_{N-2}^N I'_{sm}$$

$$\overline{I'_{md\_cur}} = \frac{1}{3} \sum_{N-2}^N I'_{md}$$

$$\overline{I'_{lg\_cur}} = \frac{1}{3} \sum_{N-2}^N I'_{lg}$$

$$I_{total\_current} = \overline{I'_{sm\_cur}} + \overline{I'_{md\_cur}} + \overline{I'_{lg\_cur}}$$

$$\overline{I'_{sm\_ref}} = \frac{1}{6} \sum_{2016}^{2021} I'_{sm}$$

$$\overline{I'_{md\_ref}} = \frac{1}{6} \sum_{2016}^{2021} I'_{md}$$

$$\overline{I'_{lg\_ref}} = \frac{1}{6} \sum_{2016}^{2021} I'_{lg}$$

$$I_{total\_ref} = \overline{I'_{sm\_ref}} + \overline{I'_{md\_ref}} + \overline{I'_{lg\_ref}}$$

$$B = \left( \frac{1}{6} \sum_{2016}^{2021} I_{bm} \right) * \frac{I_{total\_current}}{I_{total\_ref}}$$

A TAC proposal for the Eastern and Western area during the phase-in period (years 2023-2024 and 2025-2026 when using a two-year management period or years 2023-2025 when using a three-year management cycle) was calculated as follows:

$$pTAC_{N+1} = \begin{cases} \alpha * F_{0.1} * \frac{B}{q}, I_{tot} > 0 \\ \alpha * 0.2 * \frac{B}{q}, I_{tot} = 0 \end{cases}$$

Similarly, following the phase-in (years later than 2026 for a 2-year management cycle or 2025 for a 3-year management cycle) the proposed TAC was:

$$pTAC_{N+1} = \begin{cases} \beta * F_{0.1} * \frac{B}{q}, I_{tot} > 0 \\ \beta * 0.2 * \frac{B}{q}, I_{tot} = 0 \end{cases}$$

where the  $\alpha$  and  $\beta$  values are given in Table 3 and were used in performance tuning.

The TAC during the phase-in period was modified in order to minimize variability as follows:

$$TAC_{N+1} = TAC_N * \exp(\log(pTAC_{N+1}/TAC_N)*0.1)$$

and  $TAC_{N+1}$  was constrained to be  $\geq 0.9 * TAC_N$  and  $\leq 1.2 * TAC_N$ . If  $TAC_{N+1}$  was less than  $0.9 * TAC_N$  then  $TAC_{N+1} = 0.9 * TAC_N$ ; if  $TAC_{N+1}$  was greater than  $1.2 * TAC_N$  then  $TAC_{N+1} = 1.2 * TAC_N$ .

The TAC after the phase-in period was modified so that if  $pTAC_{N+1}$  was  $\leq 0.7 * TAC_N$  or  $\geq 1.2 * TAC_N$ , then the TAC was set to the maximum  $1.2 * TAC_N$ , or minimum  $0.7 * TAC_N$ .

The R script for the above procedure is provided in Appendix I along with code to calculate catch in year one based on the indicator time series.

## 2.2 Performance tuning

Panel 2 requested that cMPS be performance tuned to a target PGK = 0.60 (PGK60) and PGK = 0.70 (PGK70). That is, the probability of the stock being in the green quadrant of the Kobe matrix in the 30th projected year must be close 0.6 and 0.7, respectively. These target tunings were requested for a 2 and 3 year management cycle and for each of the 4 scenarios the cMP must implement a phase-in of the cMP's TAC for the first 2 and 1 cycles, respectively.

Additionally, it was requested to explore the effect on performance of applying the formula  $TAC_{N+1} = TAC_N * \exp(\log(pTAC_{N+1}/TAC_N)*0.4)$  to all projected years after the phase-in period (note that the scaler has changed from 0.1 to 0.4). This modification to the TAC was applied to the PGK60\_2y scenario.

Except for one scenario (which incorporates variance reduction in TAC for all projected years), the FO cMP only differed with respect to the  $\alpha$  and  $\beta$  tuning parameter values. The  $\alpha$  and  $\beta$  tuning parameter values for these 5 different runs are given in **Table 3**.

It should be noted that when tuning to a target PGK value, it was not possible to use the reduced stochastic simulation reference set (4 sims per OM) as when tuning to a Br30 target. All performance tunings had to be done using the full stochastic simulation reference set (48 sims per OM).

### 2.3 Results

The FO2a version of the Fzero1 cMP was selected for performance tuning and the FO CMP was successfully tuned to PGK = 0.60 (PGK60) and PGK = 0.70 (PGK70) for both east and west using both 2-year and 3-year management cycles. The requirement for implementing a phase-in of the TAC resulted in the testing of several alternative phase-in strategies which were assessed based on their effect on PGK and Br30 performance metrics relative to each other and a base no phase-in strategy (Table 4). Only a 2 year management cycle was tested.

The alternatives considered were a) maintaining the 2021 TAC for 2 and 3 management cycles, b) limiting TAC change to a 20% increase and a 10% decrease for 2 cycles, and c) rescaling the TAC change where the percent change was based on the calculation  $\exp(\log(\text{TAC}_{\text{new}}/\text{TAC}_{\text{old}}) \times \theta)$  but also subject to the 20/10 rule.

Overall, the PGK values were very similar to the base for all phase-in strategies whereas maximum safety was achieved using either the status quo TAC for 2 cycles or a variance reduction with  $\theta=0.1$  (Table 4). Rather than fixing the TAC, the variance reduction approach was adopted for further performance tuning on the full stochastic OM reference set.

#### Status

Table 3 provides the Br30 values for each of the FO cMP variants and indicates that all the values are well above 1.2 for each stock-cMP combination. Tuning to exactly PGK60 and PGK70 for both stocks at the same time was relatively successful (Table 3), however the Br30s for each variant do vary between the two stocks ranging from 1.240 – 1.383 for the west and 1.398 – 1.586 in the east with distributions at the extremes also being slightly different between cMP variants (**Figure 1**).

#### Safety

When PGK70 was used as the performance tuning target both FO2b and FO2d had the highest LD median and lower 5<sup>th</sup> percentile values (LD15) in the east and the west; the difference between using a 2-yr or 3-yr management cycle was minor on the LD statistics (Table 5). PGK60 performance tuning did result in lower median LD values for east and west; however, in the west they did not have very different LD15 values compared to PGK70 variants in the west. There were larger differences noted in the east (Table 5). The LD15 statistics for the east using FO2c (PGK70/3-yr cycle) failed to meet the limit reference point (LRP) established by the BFT MSE (LRP = 0.40; Table 5).

Tuning to PGK60 or PGK70 led the LD10 values for east and west to go below the LRP, except for FO2b in the east (**Table 5**).

Overall there appears to be a slightly larger reduction in east safety (LD) using a 3-year management cycle compared with west values. There are improvements to safety for both east and west when using PGK70 as the performance tuning target. If the safety objective is to simply have LD15 be above 0.40 then only FO2c (PGK60/3-yr) failed to achieve this and only in the east (Table 5). Should Panel 2 focus on LD10 as the performance statistic used to satisfy their objectives for safety then none of the FO variants would meet those objectives.

#### Yield

Overall the differences between the 5 variants of the FO cMP followed an expected pattern of reduced yield when increasing PGK tuning target from 0.60 to 0.70, with smaller differences in yield between 2-year and 3-year cycle lengths.

Tuning to PGK70 led to lower yields across all the yield performance indicators for both east and west (**Figure 3, 4, 5**). The yield difference between PGK60 and PGK70 tunings for C10, C20, AvC30 are substantial, while differences in yield between 2-yr and 3-yr management cycles (for the same PGK target) are much smaller (**Figure 4, 5**).

The median yield in C1 was not impacted by the 4 different tuning scenarios (**Figure 3**) because the tuning parameter during the phase-in period was identical in an effort to maintain provide a TAC more similar to the 2021 TACs (west = 2,726 t and east = 36,000 t). The 90% whiskers on C1 (**Figure 3**) exist due to several indices (CAN\_SWNS, MEXUS\_GOM\_PLL, JPN\_LL\_NEAt12, and MED\_LAR) used in the FO cMP that did not have their 2021 values incorporated in the MSE data-series.

## Stability

TAC stability was evaluated using the VarC performance metric which characterizes the variation in TAC between management periods. The VarC metric for PGK60 variants was very similar as were the VarC values for the PGK70 variants (Figure 6). Changing from a 2-year management cycle to a 3-year management cycle had the largest impact on the VarC metric with a 3-year cycle having higher VarC and therefore lower stability than a 2-year cycle. This increase in the VarC metric for 3-year cycles does follow the logic that allowing fewer opportunities for the TAC to be updated does not allow the TAC to respond to “rapid” changes in biomass as promptly as would a 2 year cycle. The variability in biomass fluctuations would need to be small to ensure stable TACs under a 3 year management cycle.

## TAC change statistics

A 20/10 limit on the change in TAC during the phase-in period and a 20/30 limit for all the TAC changes thereafter was requested by Panel 2. The TAC change should be checked for all cMPs in order to provide assurance to Panel 2 that the cMPs function as requested but the check can also demonstrate how often TAC advice is driven by the TAC change constraints. Both Table 6 and Figure 8 indicate that the cMPs hit the limits more often with recruitment scenario 2 OMs with a maximum of 25% of the time. Recruitment scenario 1 results in cMPs hitting the limits no more than 7% of the time and recruitment scenario 2 is midway at no more than 13%. Considering the simulations within OMs, the percentage never exceeded 35%.

The FO2e cMP, which incorporates variance reduction, hit the limits the least number of times regardless of the recruitment scenario. The second best cMP tended to be FO2b, the performance varied by recruitment regime and stock.

## 3. Interpretation

Since Panel 2 had requested that cMPS be performance tuned to a target  $PGK = 0.60$  (PGK60) and  $PGK = 0.70$  (PGK70), the status of the two stocks have been tuned to the status objective (with Panel 2 still to determine if probability of being in the green part of the Kobe plot will be set at 60% or 70%).

## What does it all mean

Overall the differences between the 5 FO cMP variants was not huge when tuning to a stock status objective (i.e., PGK). The safety objective of LD15 was met by FO2a, FO2b, FO2d, FO2e and was also met in the west for FO2c but failed to reach 0.40 for FO2c (Table 5). Variation in TAC (VarC) was under 20 for all variants and while the variation was higher for 3-year management cycles, the difference between 2-yr and 3-yr cycles was only ~3% (Figure 6).

Yield provided the most change across the 4 objective categories (Status, Safety, Yield, and Stability). There were clear trade offs when choosing between scenarios tuned to PGK60 vs PGK70. Yield declined when higher PGK targets were chosen. The choice of management cycle length also resulted in differing yields, 2-year cycles led to slightly more yield in the west and slightly less yield in the east and vice versa for the selection of a 3-yr management cycle length (Figure 4 and 5). This could prove to be a challenging choice for Panel 2 as the different cycle lengths lead to better yields for one stock compared to another.

Overall four variants passed enough thresholds to continue to be considered as cMPs, while one (FO2c) failed to meet the LRP threshold and the BFT species group should discuss if it should continue to be considered.

A final consideration was the frequency with which a cMP hit the TAC change limits imposed by Panel 2. cMPs which do not hit the limits as often while showing good performance should be preferred.

## 4. Acknowledgements

Thanks to the GPSS section and PED Division for supporting cMP development by providing funds for a virtual machine.

## References

- Carruthers Tom (2022). ABTMSE: Atlantic Bluefin Tuna Management Strategy Evaluation. R package version 7.7.1.
- Nelson, Gary A. (2019). fishmethods: Fishery Science Methods and Models. R package version 1.11-1.  
<https://CRAN.R-project.org/package=fishmethods>

**Table 1.** List of indicators used by the CMP for each age class bin for the east and west TAC calculations.

	West Indicator	East Indicator
Young fish age 1-4	US_RR_66_144	FR_AER_SUV2
Middle aged fish age 5-6	CAN_SWNS	JPN_LL_NEAtl2
Older fish age 7-10+ east and 7-16+ west	MEXUS_GOM_PLL	MED_LAR_SUV
Index used for biomass of stock or region	CAN_SWNS	MED_LAR_SUV

**Table 2.** Values for  $W_a$  and  $M_a$  for each of the ages used in the “Fishmethods” yield-per-recruit analysis.

	WEST	EAST
Ages	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16+	1, 2, 3, 4, 5, 6, 7, 8, 9, 10+
$W_a$ (weight-at-age)	3.1, 9.8, 15.1, 19.9, 43.3, 60.5, 89.9, 111.6, 144.8, 174.0, 201.1, 225.5, 247.7, 264.0, 283.5, 340.0	3.0, 10.0, 19.0, 35.0, 50.0, 69.0, 90.0, 113.0, 138.0, 205.0
$M_a$ (natural mortality at age)	0.40, 0.33, 0.27, 0.23, 0.20, 0.18, 0.16, 0.14, 0.13, 0.12, 0.12, 0.11, 0.11, 0.11, 0.11, 0.11	0.40, 0.33, 0.27, 0.23, 0.20, 0.18, 0.16, 0.14, 0.13, 0.12

**Table 3.** A summary of the performance tuning results (PGK and Br30) with the respective  $\alpha$  and  $\beta$  tuning parameter values for 5 different runs of the FO cMP. FO2e incorporates the variance reduction method following the phase-in period using a  $\theta$  of 0.4.

	PGK		Br30		$\alpha$		$\beta$	
Tuning Scenario	West	East	West	East	West	East	West	East
FO2a: PGK60/2y	0.5998	0.6016	1.240	1.399	0.85	0.82	0.84	0.90
FO2b: PGK70/2y	0.6923	0.7014	1.369	1.586	0.85	0.82	0.75	0.73
FO2c: PGK60/3y	0.6020	0.6085	1.250	1.398	0.85	0.82	0.83	0.91
FO2d: PGK70/3y	0.7014	0.6949	1.383	1.575	0.85	0.82	0.74	0.75
FO2e: PGK60/2y	0.592	0.62	1.254	1.451	0.85	0.82	0.81	0.82

**Table 4.** A summary of the performance metrics (PGK and Br30) for different phase-in strategies under a 2 year management cycle. The phase-in period is 4 years except where noted. “Status quo” refers to maintaining the 2021 TAC; “20/10” limits TAC change to a 20% increase and 10% decrease, and “variance reduction” refers to a rescaling ( $\theta$ ) of the TAC change in log space. The transformed value is still subject to the 20/10 rule.

	PGK		Br30	
Phase-in Strategy	West	East	West	East
None	0.65	0.67	1.25	1.50
Status quo	0.64	0.69	1.26	1.52
Status quo (6 year)	0.62	0.68	1.25	1.50
20/10 rule	0.64	0.67	1.25	1.50
Variance reduction, $\theta=\{0.4 \text{ west}, 0.2 \text{ east}\}$	0.64	0.68	1.25	1.51
Variance reduction, $\theta=\{0.1 \text{ west}, 0.1 \text{ east}\}$	0.64	0.68	1.26	1.52

**Table 5.** Lowest depletion (LD) values for the 5 FO cMP variants. FO2a (PGK60/2-yr cycle), FO2b (PGK70/2-yr cycle), FO2c (PGK60/3-yr cycle), FO2d (PGK70/3-yr cycle), FO2e (PGK60/2-yr cycle with variance reduction). 15% CI (LD15) and 10% CI (LD10) are the lower bound of the 15% and 10% confidence interval of LD, respectively. A limit reference point of LD=0.40 was established by the BFT MSE.

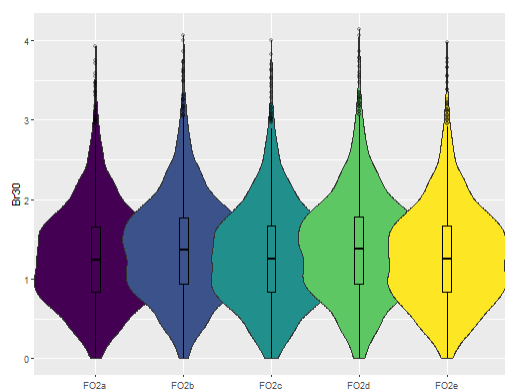
Variant of FO	West			East		
	Median LD	15% CI (LD15)	10% CI (LD10)	Median LD	15% CI (LD15)	10% CI (LD10)
FO2a (PGK60/2-yr)	1.11	0.44	0.29	1.25	0.40	0.31
FO2b (PGK70/2-yr)	1.21	0.45	0.29	1.39	0.50	0.41
FO2c (PGK60/3-yr)	1.12	0.43	0.28	1.21	0.37	0.28
FO2d (PGK70/3-yr)	1.22	0.45	0.29	1.37	0.48	0.38
FO2e (PGK60/2-yr)	1.13	0.41	0.27	1.24	0.39	0.29

**Table 6.** A summary of the percentage times that the TAC advice is at the limit dictated by the 20/10 and 20/30 rules a cMP must follow for phase-in and post-phase-in periods. Results are provided for the 5 FO cMPs, for each OM and stock and are based on a 30 year projection period and 48 simulations per OM (n=1440). FO2a (PGK60/2-yr cycle), FO2b (PGK70/2-yr cycle), FO2c (PGK60/3-yr cycle), FO2d (PGK70/3-yr cycle), FO2e (PGK60/2-yr cycle with variance reduction).

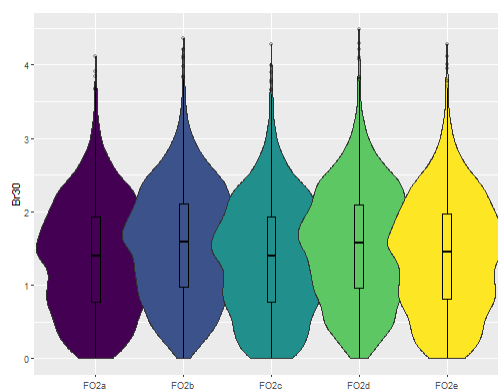
OM	FO2a		FO2b		FO2c		FO2d		FO2e	
	East	West	East	West	East	West	East	West	East	West
1	3.4	5.7	4.1	5	2.5	5	2.4	4.5	0.1	0.8
2	18.2	21.3	15.4	16.9	19.5	21.5	15.9	17.1	8.5	14.1
3	4.7	5.9	7.7	6.6	4.4	5.5	6.6	6	0.1	0.3
4	3.3	5.3	4	5.7	2.3	5	2.6	4	0.1	0.4
5	8.6	13.1	8.2	13.5	10.3	15	8.6	14.1	0.7	4.5
6	4.9	4.4	8	5.1	3.5	4.1	5.9	4.6	0.1	0.6
7	3.6	5.2	3.8	5	3.9	5.2	3.9	5.4	0.1	0.6
8	16.5	20.5	14.4	15.8	18.9	20.4	15.6	15.9	8.7	12.5
9	4	5.5	5.7	5.1	4	4.2	5.7	5.2	0	0.6
10	5	4.8	5.3	5.6	4.2	4.7	4.7	4.2	0.1	0.3
11	6.2	15.8	6.7	13.1	9.6	15.8	7.4	13.8	1.1	6.1
12	6.5	5.1	9.7	5.9	6.2	4.7	8	5.1	0.4	0.2
13	4.4	2.8	4.8	3.7	3.5	2.9	3.1	3.7	0.9	0.2
14	11.6	13.4	10.7	12.9	14.5	13.6	12.2	13.5	2.2	3.9
15	6.1	5.7	12.1	6.4	3.6	5.6	7.9	5.6	0.8	0.3
16	3.5	4.7	4.3	4.2	2.6	4.4	3.2	3.9	0.1	0.5
17	7.2	12.1	7.3	11.5	10.1	13.1	8.4	13.2	1.1	3
18	5.2	5.7	7	5.5	3.1	5	5.4	5.6	0.1	0.1
19	4.5	4.7	4.9	3.9	4.4	4.3	4.6	4.1	0.1	0.2
20	15.6	16.1	13.5	15.7	18.3	17	15.9	16.5	8.7	7.6
21	4.2	4.4	5.4	4.3	4.2	4.1	5.9	4.9	0	0.1
22	5.6	3.3	6.5	3.4	6.9	3.1	5.6	3.9	0.4	0
23	5.3	11.3	8.1	11.3	4.7	12.7	6.2	12.4	0.3	3.1
24	8.7	4.5	11.1	4.8	8.1	3.6	9.8	4.3	0.4	0
25	2.7	5.1	3.8	4.8	2.2	4.5	2.9	3.3	0	0.3
26	12.1	12.9	10.9	11.7	15.4	14.1	13.6	13.4	2.9	3.7
27	4.1	6.1	5.4	5.7	3.4	4.2	4	4.8	0	0.6
28	3.8	5.3	4.2	4.9	2.7	5.4	3.1	5	0	1.3
29	12.8	14.2	11	13.1	14.2	15.1	11.9	14.7	2.8	4.4
30	3.8	6	4.8	5.9	2.6	4.8	4	4.6	0.1	1.2
31	3.4	4.6	3.5	5.1	3	4.6	2.3	4.2	0.1	0.6
32	13.8	8.9	11.2	8.7	16.3	11.3	13	9.7	3.9	1
33	2.6	4.9	3.9	5.6	2.1	4.4	3.3	4.7	0	0.4
34	4	5.5	4.1	5.2	2.3	4.5	2.5	4.5	0	0.7
35	11.6	9.6	11.8	8.5	13.1	10.8	12.1	10.3	3.4	1.5

36	4.6	5.6	5.5	5.6	3	4.7	4.5	4.9	0.1	0.8
37	3	4.5	3.4	4.8	2.3	3.2	2.3	4.3	0	0.6
38	9.6	12.5	10.5	11.1	12.5	12.2	11	12.3	1.2	3
39	3.1	4.3	3.6	5.6	2.5	4.1	3.9	4.8	0	0.1
40	3.5	4.2	4.2	4.5	2.6	3.3	3.6	3.6	0.2	0
41	10.3	5.7	8.7	5.6	12.3	6.3	10.8	7.3	0.9	0
42	3.4	4.7	5.9	4.6	2.7	3.8	4.4	4.3	0	0.2
43	3.1	4.1	4	4.2	2.1	3.6	3.1	4.1	0	0.3
44	9.8	11	11	10.6	13.1	12.5	10.1	11.4	1	2.2
45	3.2	4.6	5.3	5.2	2.6	4.5	4.7	4.7	0	0.2
46	2.6	3.6	3.3	4.4	2.4	3.3	2.2	3.9	0	0
47	6.8	8.1	7	7.3	8.8	8.6	8.3	8.8	0.9	0.7
48	3.4	5.6	6.4	4.5	2.6	4.1	4.8	4	0	0.3

West

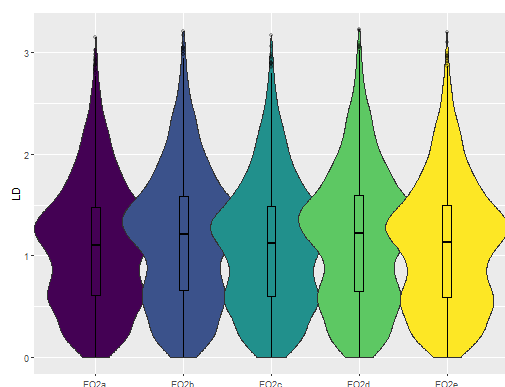


East

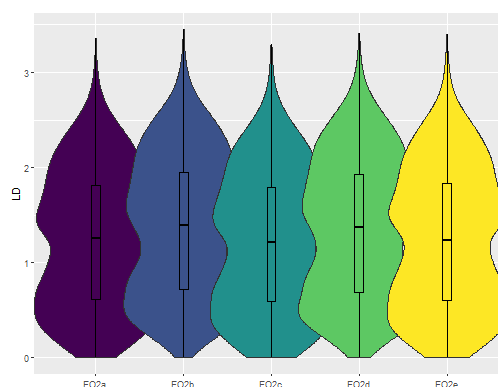


**Figure 1.** Violin plots of spawning stock biomass (SSB) relative to dynamic  $SSB_{MSY}$  in projection year 30 (Br30) for 5 FO cMP variants within each management area. FO2a (PGK60/2-yr cycle), FO2b (PGK70/2-yr cycle), FO2c (PGK60/3-yr cycle), FO2d (PGK70/3-yr cycle), FO2e (PGK60/2-yr cycle with variance reduction).

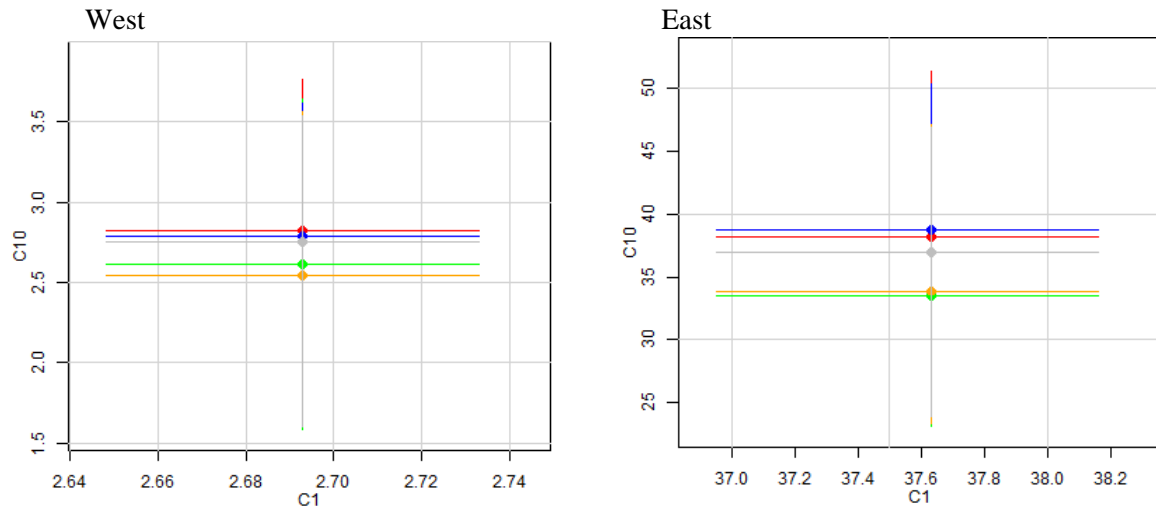
West



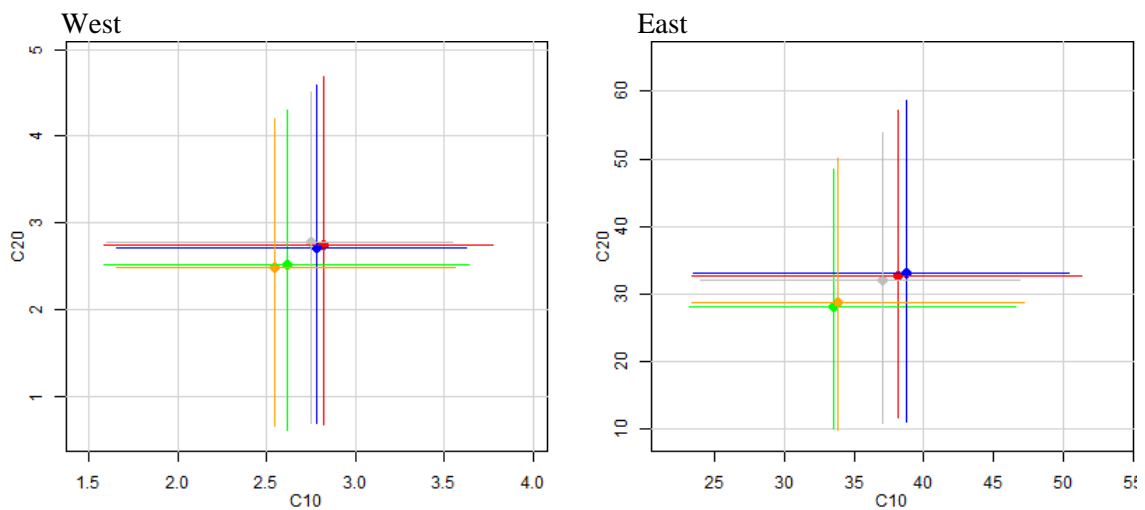
East



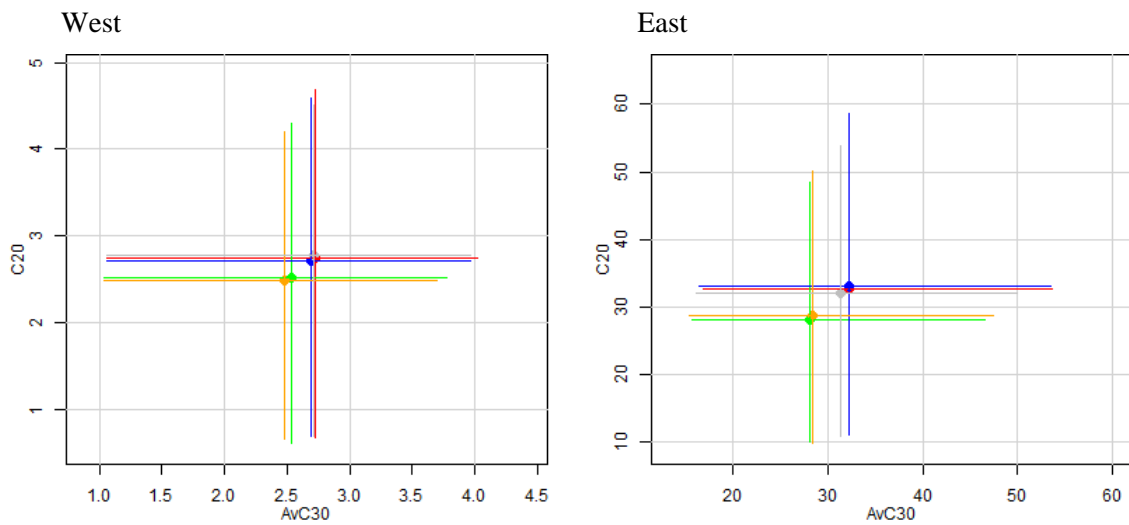
**Figure 2.** Violin plots of lowest depletion (LD) for the FO cMP variants within each management area. FO2a (PGK60/2-yr cycle), FO2b (PGK70/2-yr cycle), FO2c (PGK60/3-yr cycle), FO2d (PGK70/3-yr cycle), FO2e (PGK60/2-yr cycle with variance reduction).



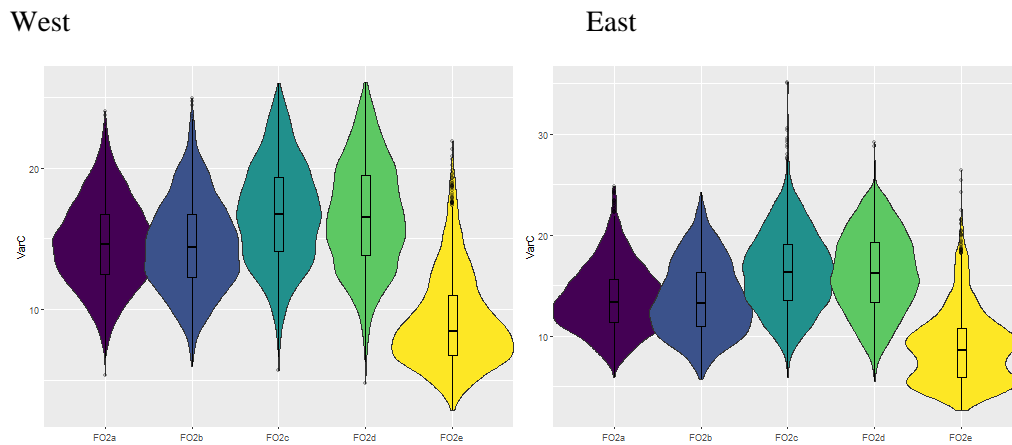
**Figure 3.** Median and 90<sup>th</sup> percentiles for C1 (TAC for the first cycle of the management procedure) and C10 (mean TAC over the first 10 years of the management period) within each management area. FO2a (red; PGK60/2-yr cycle), FO2b (green; PGK70/2-yr cycle), FO2c (blue; PGK60/3-yr cycle), FO2d (orange; PGK70/3-yr cycle), FO2e (grey; PGK60/2-yr cycle with variance reduction).



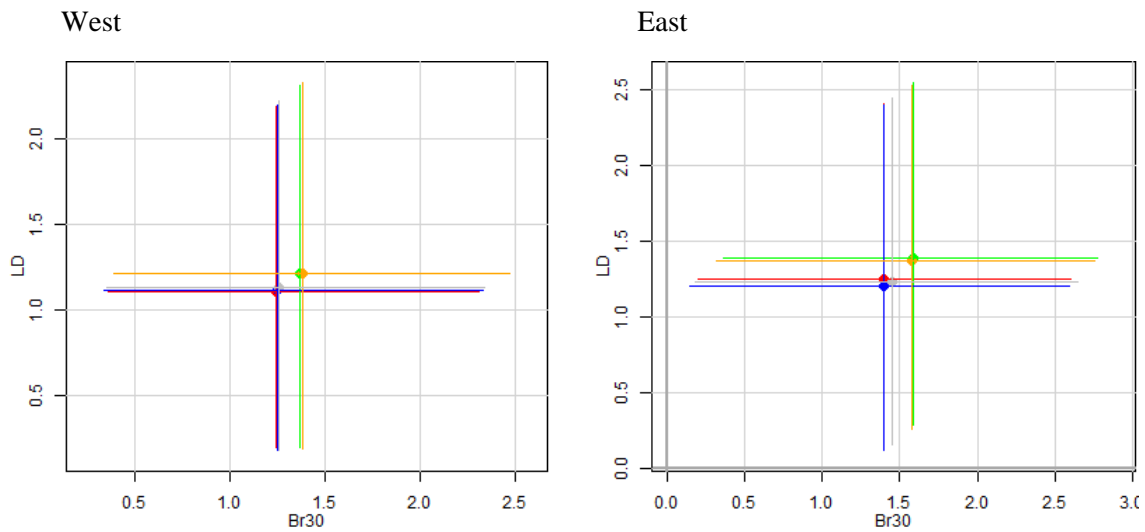
**Figure 4.** Median and 90<sup>th</sup> percentiles for C20 (mean TAC over years 11 to 20 of the management period) and C10 (mean TAC over the first 10 years of the management period) within each management area. FO2a (red; PGK60/2-yr cycle), FO2b (green; PGK70/2-yr cycle), FO2c (blue; PGK60/3-yr cycle), FO2d (orange; PGK70/3-yr cycle), FO2e (grey; PGK60/2-yr cycle with variance reduction).



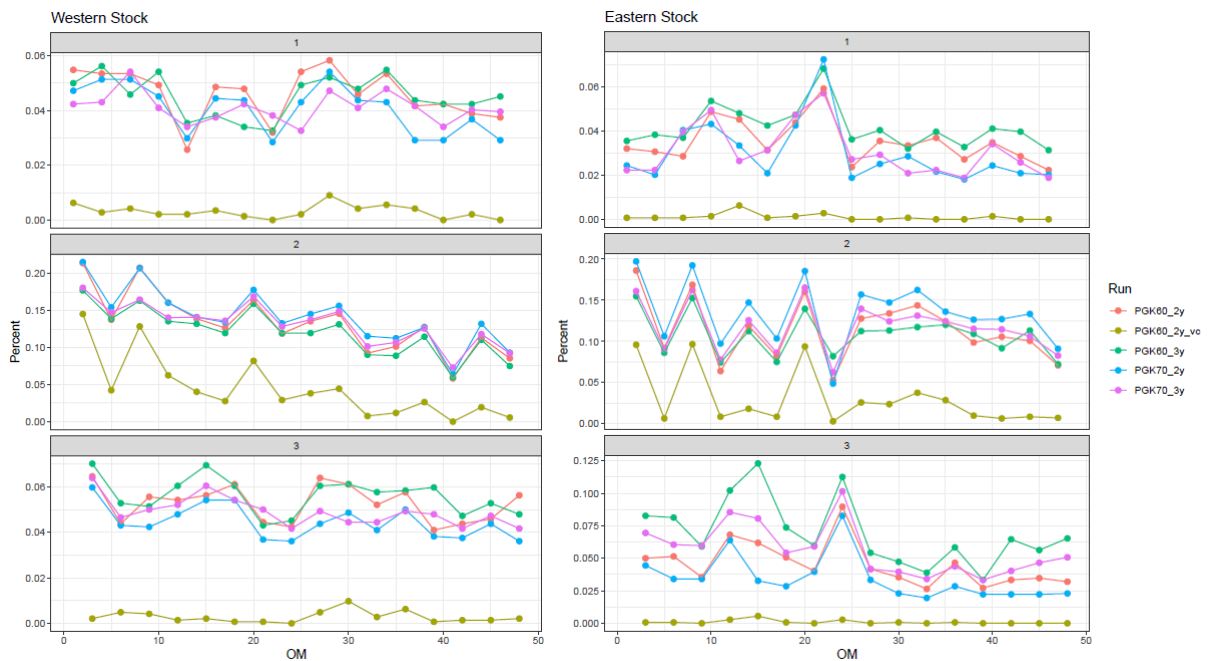
**Figure 5.** Median and 90<sup>th</sup> percentiles for AvC30 (average catch for the first 30 years of the management procedure) and C10 (mean TAC over the first 10 years of using the management procedure) within each management area. FO2a (red; PGK60/2-yr cycle), FO2b (green; PGK70/2-yr cycle), FO2c (blue; PGK60/3-yr cycle), FO2d (orange; PGK70/3-yr cycle), FO2e (grey; PGK60/2-yr cycle with variance reduction).



**Figure 6.** Violin plots of variation in catch (VarC) for the 5 FO cMP variants within each management area. FO2a (PGK60/2-yr cycle), FO2b (PGK70/2-yr cycle), FO2c (PGK60/3-yr cycle), FO2d (PGK70/3-yr cycle), FO2e (PGK60/2-yr cycle with variance reduction).



**Figure 7.** Median and 90<sup>th</sup> percentiles for LD (lowest depletion) and Br30 (dynamic biomass ratio at year 30) within each management area. FO2a (red; PGK60/2-yr cycle), FO2b (green; PGK70/2-yr cycle), FO2c (blue; PGK60/3-yr cycle), FO2d (orange; PGK70/3-yr cycle), FO2e (grey; PGK60/2-yr cycle with variance reduction).



**Figure 8.** Plots of the percentage of times that the TAC advice is at the limit dictated by the 20/10 and 20/30 rules a cMP must follow for phase-in and post-phase-in periods. Results are provided for the 5 FO cMPs, for each OM and stock and are based on a 30 year projection period and 48 simulations per OM ( $n=1440$ ). FO2a (PGK60/2-yr cycle), FO2b (PGK70/2-yr cycle), FO2c (PGK60/3-yr cycle), FO2d (PGK70/3-yr cycle), FO2e (PGK60/2-yr cycle with variance reduction).

## Appendix I

```
#####
# Updates Fzero1 with new features
# Limit change to 20/30
# Scale reference biomass using change in 3 indicators
#####
EHIWb_1 =
function (x, dset, yrsmth = 3, DOWN= .7, UP=1.2, VarCadj=.1,
          IndexID_y = 13, IndexID_m = 12, IndexID_o = 14,
          IndexID_bio = 14, F=1.11, RefYrs = 52:56, PI = 1.11 )
{#dset=dset
#####
# required packages #
if(!require(fishmethods)){
  install.packages('fishmethods')
}
library(fishmethods)

# required functions
# Range Normalization
RangeNorm = function(x,maxN=1,minN=0.1){
  maxD = max(x, na.rm=T)
  minD = min(x, na.rm=T)
  (( (x-minD)*(maxN-minN))/(maxD-minD)) + minN
}

# YPR where
# wgt is the weight at age in 2015 from west VPA
# M is scaled to the Lorenzen function SCRS/2017/176
# age is as defined in the 2015 West VPA
# partial is calculated from indicators

BFT_yprW = function(Small=1,Med=1,Large=1){
  wgt=c(3.1,      9.8,      15.1,      19.9,      43.3,      60.5,      89.9,      111.6,      144.8,      174,      201.1,      225.5,
        247.7,      264,      283.5,      340)
  M = c(0.40, 0.33, 0.27, 0.23, 0.20, 0.18, 0.16, 0.14, 0.13, 0.12, 0.12, 0.11,
        0.11, 0.11, 0.11, 0.11)
  age = c(1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16)
  partial = c(rep(Small,4), rep(Med,2),rep(Large,10))
  if(sum(is.na(c(Small,Med,Large)))==0) {
    ypr(age=age, wgt = wgt, partial = partial, M = M, plus=TRUE,
        oldest = 35, maxF = 10, incrF=0.01, graph=F)$Reference_Points[1,1]
  } else {0}
}
#####
```

```

# index for F01 calculation
#ny <- 58 #length(dset[[1]]$Cobs[x, ])
ny <- length(dset$Cobs[x, ]) # number of years of data
ind_a <- (ny - (yrsmth - 1)):ny # subset of years used in YPR calc

# Range normalization of indicators indexing young, medium and old fish
# Keeping mean of most recent 3 years
Small = mean(RangeNorm(dset$Iobs[x,IndexID_y,])[ind_a], na.rm=T)
Med = mean(RangeNorm(dset$Iobs[x,IndexID_m,])[ind_a], na.rm=T)
Large = mean(RangeNorm(dset$Iobs[x,IndexID_o,])[ind_a], na.rm=T)
Total = Small + Med + Large

# Fraction at age
fSmall = (Small/Total)
fMed = (Med/Total)
fLarge = (Large/Total)

# Calculate F01
if(!is.na(Total)==T){
  F01 = BFT_yprW(Small=fSmall,Med=fMed,Large=fLarge)
}else{F01 = .2}

# if(is.na(F01)==T | F01>.1) {F01 = .1}

# New TAC is F01*B/q
q = 1.875E-7 #0.25E-6 # from 2015 VPA continuity run

# Calculate change in indicators relative to current period
CurB = mean(RangeNorm(dset$Iobs[x,IndexID_y,])[ind_a], na.rm=T) +
  mean(RangeNorm(dset$Iobs[x,IndexID_m,])[ind_a], na.rm=T) +
  mean(RangeNorm(dset$Iobs[x,IndexID_o,])[ind_a], na.rm=T)
# RefYrs = 52:57 currently refers to 2016 to 2021
RefB = mean(RangeNorm(dset$Iobs[x,IndexID_y,])[RefYrs], na.rm=T) +
  mean(RangeNorm(dset$Iobs[x,IndexID_m,])[RefYrs], na.rm=T) +
  mean(RangeNorm(dset$Iobs[x,IndexID_o,])[RefYrs], na.rm=T)
deltaB = CurB/RefB

SSB = mean(dset$Iobs[x,IndexID_bio,])[RefYrs], na.rm=T)*deltaB

# fix F during phase in at tuned values
TAC_pi = F01*(SSB/q)*PI
TAC = F01*(SSB/q)*F

# Constraint on TAC change
T_dat = dset$TAC[x, ]
pTAC = T_dat[length(T_dat)]

```

```

#TAC = pTAC*(DOWN + (1/(UP + exp(-8*((TAC-pTAC)/pTAC) )))) ) # <- version used in Sept. 2021
if(ny<61){
  #TAC = pTAC # this is status quo for 4 years
  TAC_change <- TAC_pi/pTAC # the implied ratio of the new to old advice
  new_TAC_change <- exp(log(TAC_change)*VarCadj) # multiple log of TAC change by VarCadj

  if(new_TAC_change>(UP)) new_TAC_change=(UP) # apply 20% max upward TAC change constraint
  if(new_TAC_change<(0.9)) new_TAC_change=(0.9) # apply 20% max downward TAC change constraint

  TAC <- pTAC * new_TAC_change
  # TAC = if(((TAC-pTAC)/pTAC > UP-1)|((TAC-pTAC)/pTAC < 0.9-1)) {
  # TAC = pTAC*ifelse((TAC-pTAC)/pTAC > .2, UP, 0.9)
  # }else{TAC = pTAC*(1+((TAC-pTAC)/pTAC))}
}else{
  TAC = if(((TAC-pTAC)/pTAC > UP-1)|((TAC-pTAC)/pTAC < DOWN-1)) {
    TAC = pTAC*ifelse((TAC-pTAC)/pTAC > .2, UP, DOWN)
  }else{TAC = pTAC*(1+((TAC-pTAC)/pTAC))}
}

TAC}

class(EH1Wb_1) = 'MP'
environment(EH1Wb_1) <- asNamespace('ABTMSE')

#$$#$
#####
# Updates Fzero1b with new features
# Limit change to 20/30
# Scale reference biomass using change in 3 indicators
#####
EH1Eb_1 =
function (x, dset, yrsnth = 3, DOWN = .7, UP=1.2, VarCadj=.1,
          IndexID_y = 1, IndexID_m = 6, IndexID_o = 2,
          IndexID_bio = 2, F=0.80, RefYrs = 52:56, PI=0.80 )
{ #dset=dset
  #####
  # required packages #
  if(!require(fishmethods)){
    install.packages('fishmethods')
  }
  library(fishmethods)

  # required functions
  # Range Normalization

```

```

RangeNorm = function(x,maxN=1,minN=0.1){
  maxD = max(x, na.rm=T)
  minD = min(x, na.rm=T)
  (( (x-minD)*(maxN-minN))/(maxD-minD)) + minN
}

# YPR where
# wgt is the weight at age in 2017 from east VPA
# M is scaled to the Lorenzen function SCRS/2017/176
# age is as defined in the 2015 East VPA
# partial is calculated from indicators

BFT_ypre = function(Small=1,Med=1,Large=1){
  wgt=c(3., 10., 19., 35., 50., 69., 90., 113., 138., 205.)
  M = c(0.40, 0.33, 0.27, 0.23, 0.20, 0.18, 0.16, 0.14, 0.13, 0.12)
  age = c(1,2,3,4,5,6,7,8,9,10)
  partial = c(rep(Small,4), rep(Med,2),rep(Large,4))
  if(sum(is.na(c(Small,Med,Large)))==0) {
    ypr(age=age, wgt = wgt, partial = partial, M = M, plus=TRUE,
      oldest = 35, maxF = 10, incrF=0.01, graph=F)$Reference_Points[1,1]
  } else {0}
}

#####

# index for F01 calculation
ny <- 57 #length(dset[[1]]$Cobs[x, ])-1
ny <- length(dset$Cobs[x, ]) # number of years of data
ind_a <- (ny - (yrsmth - 1)):ny # subset of years used in YPR calc

# Range normalization of indicators indexing young, medium and old fish
# Keeping mean of most recent 3 years
Small = mean(RangeNorm(dset$Iobs[x,IndexID_y,])[ind_a], na.rm=T)
Med = mean(RangeNorm(dset$Iobs[x,IndexID_m,])[ind_a], na.rm=T)
Large = mean(RangeNorm(dset$Iobs[x,IndexID_o,])[ind_a], na.rm=T)
Total = Small + Med + Large

# Fraction at age
fSmall = (Small/Total)
fMed = (Med/Total)
fLarge = (Large/Total)

# Calculate F01
if(!is.na(Total)==T){
  F01 = BFT_ypre(Small=fSmall,Med=fMed,Large=fLarge)
}else{F01 = .2}

```

```

# if(is.na(F01)==T | F01>.1) { F01 = .1 }

# New TAC is F01*B/q
q = 1.875E-7 #0.25E-6 # from 2015 VPA continuity run

# Calculate change in indicators relative to current period
CurB = mean(RangeNorm(dset$Iobs[x,IndexID_y,])[ind_a], na.rm=T) +
  mean(RangeNorm(dset$Iobs[x,IndexID_m,])[ind_a], na.rm=T) +
  mean(RangeNorm(dset$Iobs[x,IndexID_o,])[ind_a], na.rm=T)
# RefYrs = 52:56 currently refers to 2016 to 2021
RefB = mean(RangeNorm(dset$Iobs[x,IndexID_y,])[RefYrs], na.rm=T) +
  mean(RangeNorm(dset$Iobs[x,IndexID_m,])[RefYrs], na.rm=T) +
  mean(RangeNorm(dset$Iobs[x,IndexID_o,])[RefYrs], na.rm=T)
deltaB = CurB/RefB

SSB = mean(dset$Iobs[x,IndexID_bio,][RefYrs], na.rm=T)*deltaB

# fix F during phase in at tuned values
TAC_pi = F01*(SSB/q)*PI
TAC = F01*(SSB/q)*F

# Constraint on TAC change
T_dat = dset$TAC[x, ]
pTAC = T_dat[length(T_dat)]

#TAC = pTAC*(DOWN + (1/(UP + exp(-8*(((TAC-pTAC)/pTAC)))))) # <- version used in Sept. 2021
if(ny<61){
  #TAC = pTAC # this is status quo for 4 years
  TAC_change <- TAC_pi/pTAC # the implied ratio of the new to old advice
  new_TAC_change <- exp(log(TAC_change)*VarCadj) # multiple log of TAC change by VarCadj

  if(new_TAC_change>(UP)) new_TAC_change=(UP) # apply 20% max upward TAC change constraint
  if(new_TAC_change<(0.9)) new_TAC_change=(0.9) # apply 20% max downward TAC change constraint

  TAC <- pTAC * new_TAC_change
  # TAC = if(((TAC-pTAC)/pTAC > UP-1)((TAC-pTAC)/pTAC < 0.9-1)) {
  # TAC = pTAC*ifelse((TAC-pTAC)/pTAC > .2, UP, 0.9)
  # }else{ TAC = pTAC*(1+((TAC-pTAC)/pTAC))}
}else{
  TAC = if(((TAC-pTAC)/pTAC > UP-1)((TAC-pTAC)/pTAC < DOWN-1)) {
    TAC = pTAC*ifelse((TAC-pTAC)/pTAC > .2, UP, DOWN)
  }else{ TAC = pTAC*(1+((TAC-pTAC)/pTAC))}
}

TAC}

```

```

class(EH1Eb_1) = 'MP'
environment(EH1Eb_1) <- asNamespace('ABTMSE')
#####
#####
# Limit change to 20/30 and swap "MEXUS_GOM_PLL" for "CAN SWNS"

EH1Wb_5 = EH1Wb_1
formals(EH1Wb_5)$RefYrs = 52:57
formals(EH1Wb_5)$DOWN = .7
formals(EH1Wb_5)$UP = 1.2
formals(EH1Wb_5)$PI = .85
#formals(EH1Wb_5)$F = .92 # .91, .90, .89, .87, .85 # tuning for run 5 PGK60
#formals(EH1Wb_5)$F = .84 #.85, .77 # PGK60 for full stochastic tuning
#formals(EH1Wb_5)$F = .75 #.75, .755, .75, .76, .80 # tuning for run 5 PGK70
formals(EH1Wb_5)$F = .75 #.70, .68 # PGK70 for full stochastic tuning
formals(EH1Wb_5)$IndexID_bio = 12
class(EH1Wb_5) = 'MP'
environment(EH1Wb_5) <- asNamespace('ABTMSE')

EH1Eb_5 = EH1Eb_1
formals(EH1Eb_5)$RefYrs = 52:57
formals(EH1Eb_5)$DOWN = .7
formals(EH1Eb_5)$UP = 1.2
formals(EH1Eb_5)$PI = .82
#formals(EH1Eb_5)$F = .9075 #.905, .90, .89, .87, .85, .82 # tuning for run 5 PGK60
#formals(EH1Eb_5)$F = .90 #.91
#formals(EH1Eb_5)$F = .75 #.755, .76, .765, .77, .78, .80 # tuning for run 5 PGK70
formals(EH1Eb_5)$F = .73 #.735, .74 # PGK70 for full stochastic tuning
class(EH1Eb_5) = 'MP'
environment(EH1Eb_5) <- asNamespace('ABTMSE')
=====
#=====
# create dset or load from file
#=====

File = "Run5_VarCadjPhaseIn_sto"

DIR = paste0("C:\\Users\\HankeA\\Documents\\My_Projects\\MSE\\BFT\\Results2\\",File)
MSEobjs = dir(path=DIR,pattern = "MSE")[1:48]
MSEobjs = MSEobjs[order(sapply(strsplit(MSEobjs,"[_.]"), function(x) as.numeric(x[2])))]

dset = readRDS(paste(DIR,MSEobjs[2],sep="/"))

Inames = dset@Inames

```

```

dset = data.table(t(dset@Iobs[2,1,,]))
names(dset) = Inames
dset[, Year := 1964+(1:N)]

write.csv(dset, "Index_data_2.csv", row.names = F)

#=====
# cMP developed for the ABTMSE package 7.5; April 5, 2022

# Packages
require(data.table)
require(readit)

# Read the the index data. There should be 14 indicators
# followed by a year column

dset = data.table(readit(.data = "C:\\Users\\HankeA\\Documents\\My_Projects\\MSE\\BFT/Index_data_2.csv"))
if(names(dset)[1]=="FR_AER_SUV2"&names(dset)[15]=="Year") {
  c("THE dest LOOKS GOOD!!")
}else{c("WARNING: dset must only have columns for the 14 indices in the proper order followed by Year ")}

#####
# This script is based on the August 2022, Fzero cMP
# Limit change to 20/30, 2 y cycle
# You must provide the dset dataframe,
# the previous or current TAC (pTAC)
# and the year for which the TAC is estimated (ny).
# All other arguments can be changed.
#####

#####
# The Western MP
#####

Fzero1Wb_1 =
function (ny, dset, yrsmth = 3, DOWN= .7, UP=1.2, pTAC=2726000, RefYrs = 52:57,
          IndexID_y = 13, IndexID_m = 12, IndexID_o = 14,
          IndexID_bio = 12, F=0.84, PI=.85, VarCadj=.1)
{
  #####
  # required packages #
  if(!require(fishmethods)){
    install.packages('fishmethods')
  }
  library(fishmethods)

  # required functions

```

```

# Range Normalization
RangeNorm = function(x,maxN=1,minN=0.1){
  maxD = max(x, na.rm=T)
  minD = min(x, na.rm=T)
  (( (x-minD)*(maxN-minN))/(maxD-minD)) + minN
}

# YPR where
# wgt is the weight at age in 2015 from west VPA
# M is scaled to the Lorenzen function SCRS/2017/176
# age is as defined in the 2015 West VPA
# partial is calculated from indicators

BFT_ypw = function(Small=1,Med=1,Large=1){
  wgt=c(3.1,      9.8,      15.1,      19.9,      43.3,      60.5,      89.9,      111.6,      144.8,      174,      201.1,      225.5,
        247.7,      264,      283.5,      340)
  M = c(0.40, 0.33, 0.27, 0.23, 0.20, 0.18, 0.16, 0.14, 0.13, 0.12, 0.12, 0.11,
        0.11, 0.11, 0.11, 0.11)
  age = c(1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16)
  partial = c(rep(Small,4), rep(Med,2),rep(Large,10))
  if(sum(is.na(c(Small,Med,Large)))==0) {
    ypr(age=age, wgt = wgt, partial = partial, M = M, plus=TRUE,
        oldest = 35, maxF = 10, incrF=0.01, graph=F)$Reference_Points[1,1]
  } else {0}
}

#####

# index for F01 calculation
ny=ny-1
ind_a <- (ny - (yrsmth - 1)):ny # subset of years used in YPR calc

# Range normalization of indicators indexing young, medium and old fish
# Keeping mean of most recent 3 years
Small = mean(unlist(RangeNorm(dset[1:ny,...IndexID_y])[ind_a]), na.rm=T)
Med = mean(unlist(RangeNorm(dset[1:ny,...IndexID_m])[ind_a]), na.rm=T)
Large = mean(unlist(RangeNorm(dset[1:ny,...IndexID_o])[ind_a]), na.rm=T)
Total = Small + Med + Large

# Fraction at age
fSmall = (Small/Total)
fMed = (Med/Total)
fLarge = (Large/Total)

# Calculate F01
if(!is.na(Total)==T){
  F01 = BFT_ypw(Small=fSmall,Med=fMed,Large=fLarge)
}

```

```

}else{F01 = .2}

# if(is.na(F01)==T | F01>.1) {F01 = .1}

# New TAC is F01*I/q
q = 1.875E-7 #2.136444e-07#1.672e-07#1.14e-07#0.608E-6 # from 2015 VPA continuity run

# Calculate change in indicators relative to current period
CurB = apply(RangeNorm(dset[1:ny,..IndexID_y])[ind_a],2,mean,na.rm=T) +
  apply(RangeNorm(dset[1:ny,..IndexID_m])[ind_a],2,mean,na.rm=T) +
  apply(RangeNorm(dset[1:ny,..IndexID_o])[ind_a],2,mean,na.rm=T)
# RefYrs = 52:57 currently refers to 2016 to 2021
RefB =apply(RangeNorm(dset[1:ny,..IndexID_y])[RefYrs],2,mean,na.rm=T) +
  apply(RangeNorm(dset[1:ny,..IndexID_m])[RefYrs],2,mean,na.rm=T) +
  apply(RangeNorm(dset[1:ny,..IndexID_o])[RefYrs],2,mean,na.rm=T)
deltaB = CurB/RefB

SSB = apply(dset[1:ny,..IndexID_bio][RefYrs],2,mean,na.rm=T)*deltaB

# fix F during phase in at tuned values
TAC_pi = F01*(SSB/q)*PI
TAC = F01*(SSB/q)*F

if(ny<61){
  TAC_change <- TAC_pi/pTAC # the implied ratio of the new to old advice
  new_TAC_change <- exp(log(TAC_change)*VarCadj) # multiple log of TAC change by VarCadj

  if(new_TAC_change>(UP)) new_TAC_change=(UP) # apply 20% max upward TAC change constraint
  if(new_TAC_change<(0.9)) new_TAC_change=(0.9) # apply 10% max downward TAC change constraint

  TAC <- pTAC * new_TAC_change
}else{
  TAC = if(((TAC-pTAC)/pTAC > UP-1))((TAC-pTAC)/pTAC < DOWN-1)) {
    TAC = pTAC*ifelse((TAC-pTAC)/pTAC > .2, UP, DOWN)
  }else{ TAC = pTAC*(1+((TAC-pTAC)/pTAC))}
}
return(c(TAC,F01))}

#####
# The Eastern MP
#####
Fzero1Eb_1 =
function (ny, dset, yrsnth = 3, DOWN = .7, UP=1.2, pTAC=36000000, RefYrs = 52:57,
  IndexID_y = 1, IndexID_m = 6, IndexID_o = 2, VarCadj=.1,
  IndexID_bio = 2, F=0.90, PI=.82)
{

```

```
#####

# required packages #
if(!require(fishmethods)){
  install.packages('fishmethods')
}
library(fishmethods)

# required functions
# Range Normalization
RangeNorm = function(x,maxN=1,minN=0.1){
  maxD = max(x, na.rm=T)
  minD = min(x, na.rm=T)
  (( (x-minD)*(maxN-minN))/(maxD-minD)) + minN
}

# YPR where
# wgt is the weight at age in 2017 from east VPA
# M is scaled to the Lorenzen function SCRS/2017/176
# age is as defined in the 2015 East VPA
# partial is calculated from indicators

BFT_ypre = function(Small=1,Med=1,Large=1){
  wgt=c(3., 10., 19., 35., 50., 69., 90., 113., 138., 205.)
  M = c(0.40, 0.33, 0.27, 0.23, 0.20, 0.18, 0.16, 0.14, 0.13, 0.12)
  age = c(1,2,3,4,5,6,7,8,9,10)
  partial = c(rep(Small,4), rep(Med,2),rep(Large,4))
  if(sum(is.na(c(Small,Med,Large)))==0) {
    ypr(age=age, wgt = wgt, partial = partial, M = M, plus=TRUE,
      oldest = 35, maxF = 10, incrF=0.01, graph=F)$Reference_Points[1,1]
  } else {0}
}

#####

# index for F01 calculation
ny=ny-1
ind_a <- (ny - (yrsmth - 1)):ny # subset of years used in YPR calc

# Range normalization of indicators indexing young, medium and old fish
# Keeping mean of most recent 3 years
Small = mean(unlist(RangeNorm(dset[1:ny,...IndexID_y])[ind_a]), na.rm=T)
Med = mean(unlist(RangeNorm(dset[1:ny,...IndexID_m])[ind_a]), na.rm=T)
Large = mean(unlist(RangeNorm(dset[1:ny,...IndexID_o])[ind_a]), na.rm=T)
Total = Small + Med + Large

# Fraction at age
fSmall = (Small/Total)
```

```

fMed = (Med/Total)
fLarge = (Large/Total)

# Calculate F01
if(!is.na(Total)==T){
  F01 = BFT_ypRE(Small=fSmall,Med=fMed,Large=fLarge)
}else{F01 = .2}

# New TAC is F01*I/q
q = 1.875E-7 #0.25E-6 # from 2015 VPA continuity run
# Calculate change in indicators relative to current period
CurB = mean(unlist(RangeNorm(dset[1:ny,..IndexID_y])[ind_a]), na.rm=T) +
  mean(unlist(RangeNorm(dset[1:ny,..IndexID_m])[ind_a]), na.rm=T) +
  mean(unlist(RangeNorm(dset[1:ny,..IndexID_o])[ind_a]), na.rm=T)
# RefYrs = 52:57 currently refers to 2016 to 2021
RefB = mean(unlist(RangeNorm(dset[1:ny,..IndexID_y])[RefYrs]), na.rm=T) +
  mean(unlist(RangeNorm(dset[1:ny,..IndexID_m])[RefYrs]), na.rm=T) +
  mean(unlist(RangeNorm(dset[1:ny,..IndexID_o])[RefYrs]), na.rm=T)
deltaB = CurB/RefB

SSB = mean(unlist(dset[1:ny,..IndexID_bio][RefYrs]), na.rm=T)*deltaB

# fix F during phase in at tuned values
TAC_pi = F01*(SSB/q)*PI
TAC = F01*(SSB/q)*F

if(ny<61){
  TAC_change <- TAC_pi/pTAC # the implied ratio of the new to old advice
  new_TAC_change <- exp(log(TAC_change)*VarCadj) # multiple log of TAC change by VarCadj

  if(new_TAC_change>(UP)) new_TAC_change=(UP) # apply 20% max upward TAC change constraint
  if(new_TAC_change<(0.9)) new_TAC_change=(0.9) # apply 20% max downward TAC change constraint

  TAC <- pTAC * new_TAC_change
}else{
  TAC = if(((TAC-pTAC)/pTAC > UP-1)|((TAC-pTAC)/pTAC < DOWN-1)) {
    TAC = pTAC*ifelse((TAC-pTAC)/pTAC > .2, UP, DOWN)
  }else{TAC = pTAC*(1+((TAC-pTAC)/pTAC))}
}
return(c(TAC,F01))}

#####
## Provide TAC advice for the interval
## after year ny where current TAC is pTAC
#####

```

Fzero1Wb\_1(ny=58,pTAC=2760000,dset=dset,IndexID\_bio = 14)

Fzero1Wb\_1(ny=58,pTAC=2760000,dset=dset,IndexID\_bio = 12)

Fzero1Wb\_1(ny=58,pTAC=2760000,dset=dset,IndexID\_bio = 13)

Fzero1Eb\_1(ny=57,pTAC=33000000,dset=dset)