JOINT IATTC AND WCPFC-NC WORKING GROUP MEETING ON THE MANAGEMENT OF PACIFIC BLUEFIN TUNA
TENTH SESSION (JWG-10)

9 – 12 July 2025
Toyama, Japan (Hybrid)

Conversion factors for swapping catch quotas between Pacific bluefin tuna fishery sectors while maintaining the overall fishing intensity

IATTC-NC-JWG10-2025/IP-01

Pacific Bluefin Tuna Working Group
ISC[1]

[1] International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean

Conversion factors for swapping catch quotas between Pacific bluefin tuna fishery sectors while maintaining the overall fishing intensity

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April 2025

Working document submitted to the ISC Pacific bluefin tuna Working Group, International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean (ISC), from 14 to 18 April 2025, La Jolla, United States of America.

1 Introduction

The joint IATTC and WCPFC NC Working Group on the Management of Pacific Bluefin Tuna (JWG) requested in their meeting held in Monterey in 2025, that the ISC PBFWG provide the potential conversion factors for TACs (i) between WCPO small and WCPO large and (ii) between WCPO small/large and EPO, while maintaining the overall fishing intensity unchanged (JWGI01, 2025). Although a conversion factor for the swapping of TAC from the small PBF fishery to large PBF fishery was already agreed to and is currently in force in the WCPFC convention area, it only allows for the one-way conversion from small PBF (<30 kg in body weight ≈ age 2 and younger in the assessment model) to large PBF (≥30 kg). Also, the conversion factor itself was set based on a precautionary principle because the PBF stock was recovering at that time. The requested new conversion factor(s) seems to be intended for two-way conversions among the different fishing sectors and the wording "while maintaining the overall fishing intensity unchanged" explicitly indicates the JWG's intention to maintain the fishing intensity ($F_{\%SPR}$) at a target level, which might be adopted by the JWG through the MSE process in 2025.

Because of large differences in size selectivity by fishing gear (physical selectivity) as well as the size/age availability by area (e.g. migration pattern to the local fishing ground), the impact on the stock from catching a unit weight of PBF is very different among the different fishing sectors. It is important to consider those differences if the JWG or fishery managers of a country are considering a possible swap of a certain amount of catch from one fishing sector to another. Particularly, it should be considered that the impact on the stock will be higher when a certain amount of catch is swapped from a fishing sector catching very large PBF to those catching small PBF.

The current conversion factor was based on an analysis carried out by Maunder et al. (2014). Figure-20 in that document shows the impact on SSB of fishing a ton of fish at each different age up until age 5, the age at which all PBF are mature. Maunder et al (2014) defined impact as the equilibrium SSB that one ton of fish of that age would have produced if it was not fished relative to the equilibrium SSB that one ton of age 5 fish would have produced. It shows that taking 1 ton of age 0 fish is about 18 times the impact on SSB than taking a ton of 5 years old fish. The conversion factor currently used was calculated as the ratio of the age-specific impact of taking a ton of age-2.125 (middle of the 1st fishing quarter for 2-YO PBF; 18 kg of body weight) relative to taking a ton of age-2.875 (middle of the 4th fishing quarter for 2-YO PBF, when PBF biologically reaches to 30 kg of body weight on average). Since taking a ton of age-2.125 has an impact of 2.378 and taking a ton of age-2.875 has an impact of 1.623, we can take 1.465 times (2.378/1.623) the amount of age-2.875 PBF swapped from age-2.125 PBF with the same impact on the population. This conversion factor is currently used in the WCPFC convention area to swap the TAC from small to large PBF categories.

Because this conversion factor was calculated between "relatively older small PBF" and "relatively younger large PBF", the swap of the TAC from small to large PBF with this conversion factor would not reduce the chances of the stock rebuilding to the first and second rebuilding targets. If the swap had occurred from PBF catch any younger (age 0-1) to any older (age 3+) than that assumed for the conversion factor calculations (age-2.125 and age-2.875 respectively), the current conversion factor (1.46) would theoretically have resulted in the total fishing impact (the equilibrium SSB that a certain amount of removal would have produced if it was not fished) being lower, and thus, lead to higher chances of stock rebuilding. Technically, the inverse of the current conversion factor (1/1.46 = 0.68) can be used to swap the TAC of age-2.875 PBF to the TAC of age-2.125 PBF. However, in the current WCPFC CMM, the swap of the TAC is unidirectional and allowed only for converting TAC from small to large PBF. This is to avoid the potentially higher fishing impact of swapping the TAC from any larger PBF (older than age-2.875) to the smaller (younger than age-2.125) PBF using the inverse of the current conversion ratio.

In this document, we provide a calculation of new conversion factors to swap a certain amount of catch across the different fishing sectors while maintaining the total SPR. Also, we conducted some forward simulations (e.g. projections) to confirm if this conversion factor could maintain the total SPR and equilibrium SSB relatively unchanged, given the current assumptions.

2 Materials and Method

2.1 Data

Quarterly catch at age during 2015-2022, quarterly natural mortality, body weight at age in the middle of each fishing quarter, and maturity at age were extracted from the base-case model of the 2024 ISC PBF stock assessment. Detailed information of the model and input data (the catch, discard, abundance index, and size composition) were described in the stock assessment report (ISC 2024).

2.2 Fleet Group

In this analysis, we defined 5 groups of fishing sectors based on the estimated selectivities of the fleets, namely;

- Group 1. WCPO small PBF group: Fleets 8-10 (Japanese Purse seiners targeting small PBF), Fleets 12-15 (Japanese troll and Pole&line);
- Group 2. WCPO mix PBF group: Fleets 11 & 16-19 (Korean Purse seine, Japanese set-net, Japan other fisheries);
- Group 3. WCPO large PBF group: Fleets 1-7 (Japanese and Taiwanese longliners, Japanese purse seiners targeting large PBF);
- Group 4. EPO fisheries group: Fleets 20-23 (EPO commercial fisheries, EPO recreational fishery);
- Group 5. Unseen mortality group: Fleets 24-26 (WCPO and EPO unaccounted mortality fleets).

2.3 Conversion factor

To compute the age-specific fishing impact, relative impact on the spawning biomass of a catch of a metric ton of fish, by age (Figure-20 of Maunder et al. 2014) was first reproduced using the biological parameters from the latest stock assessment (ISC 2024). It was further expanded to show the impact of 1 metric ton of removal at each quarterly age up to age 20 (Figure 1). Teo et al. (2024) also used a similar method to calculate the age-specific fishing impact of North Pacific albacore as the SSB equivalent (mt) removed if 1 mt of albacore at specific ages were removed from the population. For PBF, we calculated the SSB equivalent of removing 1 metric ton of fish at each age in quarters from population (Table 1). The calculation was carried out by quarter since PBF fisheries have caught large amounts of age 0-1 fish, which grow rapidly within a year, and the fishery impact of these fisheries can vary significantly depending on the season in which PBF are caught.

If a fleet caught a specific proportion of ages in a certain year, it would be relatively straightforward to find the total impact on SSB of that fleet in the certain year by multiplying the catch at age in weight from that year and the age-specific impact, and subsequently summing up across all the ages. For PBF, we calculated total fishing impact of specific fleet groups (see above) by multiplying the quarterly catch at age in weight from a fleet group during 2015-2022 with the quarterly age specific relative impact shown in Table 1 (Table 3), and subsequently dividing by the annual catch of the fleet group (Table 2) to calculate the average fishing impact (units of SSB equivalent in mt) per unit catch of the fleet group during 2015-2022 (Table 4). Then, conversion factors were computed by taking the ratio of the average 2015-2022 fishing impact per unit catch by each fleet group for each potential pair of fleet groups (Table 5).

Importantly, the fishing impact per unit catch of each fleet group is sensitive to changes in the selectivity of the fleet group, especially for the groups catching small PBF, and selectivity at age can change over time. Therefore, the conversion factors would have to be recalculated if the selectivities for the fleet groups changed drastically.

2.4 Simulation test

To determine if the conversion factors could maintain the total SPR and the equilibrium SSB at relatively unchanged levels, if a swap of TACs between two fishing sectors occurred, future projection under several catch scenarios were performed. We used the exact same method of forward projections, including initial conditions, future recruitment, assumption of fishing intensity, and fleet groups, as the 2024 stock assessment, as well as Nishikawa et al. (2024). Six catch scenarios, which included some swaps of TAC between WCPO large and small PBF categories, or WCPO large and EPO, in different magnitudes were compared (Table 6). Scenarios tested are;

Scenario 1: WCPFC CMM 2024-01, IATTC Resolution C-24-02 (no swap);

Scenario 2: From scenario 1, swap WCPO large PBF of -1,000 tons for WCPO small PBF of +160 tons using the conversion factor of 0.16;
Scenario 3: From scenario 1, swap WCPO large PBF of -1,000 tons for EPO PBF of +660 tons using the conversion factor of 0.66;
Scenario 4: From scenario 1, swap WCPO large PBF of -3,000 tons for WCPO small PBF of +480 tons using the conversion factor of 0.16;
Scenario 5: From scenario 1, swap WCPO large PBF of -3,000 tons for EPO PBF of +1,980 tons using the conversion factor of 0.66;
Scenario 6: From scenario 1, swap WCPO large PBF of -6,250 tons for WCPO small PBF of +1,000 tons using the conversion factor of 0.16.

The authors DO NOT have specific recommendations for the above scenarios or any other allocation proposals. These projections were only used to determine if the calculated conversion factors could be used to swap TACs between the fleet groups while maintaining the equilibrium SSB and total SPR relatively unchanged.

The future projection platform, which was compiled as an R-package 'ssfuture', was used. This software can simulate quarterly age-structured population dynamics in a forward direction, and allows depiction of fishing intensity-based management and catch upper limit-based management simultaneously (Akita et al., 2016).

3 Results

Figure 1 showed the fishery impact by quarterly age in SSB equivalent units for 1 ton of PBF removed from the population at the specific ages and quarters, relative to that for 1 ton of age 5 PBF removed in the 4th quarter (first quarterly age when all PBF are assumed to be mature). It showed that the relative impact is about 19 times higher when 1 ton of age-0 PBF was removed in the 1st quarter than when 1 ton of age-5 PBF was removed in the 4th quarter. Because of rapid growth during age 0-1, the number of fish in 1-ton of fish decreases substantially during this time, which in turn leads to a rapid decrease in the fishery impact during the age 0-1. It is notable that the impact of an age-0 fishery can be decreased substantially if it can wait for even a half-year before catching PBF. In other words, they can catch more tons of fish if they can wait a half year, with the same impact on the population.

As shown in Table 2, the WCPO large PBF fleet group has the largest share in terms of the amount of catch in weight, followed by the EPO fleet group and WCPO mix PBF fleet group. The WCPO small PBF fleet group has the lowest share among those 4 groups now. However, because of the size (age) of fish caught, the WCPO small PBF fleet group still has the largest impact on the population among those fleet groups, followed by the WCPO mix PBF fleet group, and the EPO fleet (Table 3). The WCPO large PBF fleet has the lowest impact on the stock even though the largest amount of PBF in weight was caught by this fleet group during the same period. The relative impact per unit catch averaged over 2015-2022 was used to calculate the conversion ratio (Table 5).

The forward simulation tests showed that although there are some differences in the trajectories of relative SSB and SPR, all scenarios ended at similar relative biomasses of 38-39% SSB0 and SPRs of 0.34-0.35 in 2041 (Figure 2). This indicated that the conversion factors could work reasonably well for swaps of TACs between these fleet groups, while maintaining the SPR and equilibrium SSBs relatively unchanged.

However, it should be noted that the results could be varied if conditions are different from those assumed here. In particular, this conversion factors assumes that the selectivity of subject fleet groups will not change from the average selectivity during 2015-2022, but actual fishery selectivities are expected to vary over year. Furthermore, if the swap of TAC occurred from a part of fleet group (e.g. a fleet only catching very large fish) to a part of another fleet group (e.g. a fleet only catching age-0 fish), it will lead to a different result from the simulations. Also, the age-specific SSB equivalent to the 1 metric ton of removal (Table 1) was calculated using the current natural mortality assumption, which is one of the influential uncertain parameters in the stock assessment of this species. Therefore, the conversion factors might not work well for swapping TACs if the true natural mortality were substantially different from this assumption. If these conversion factors are used in the future management, it will be important that the selectivities of the fisheries be estimated periodically to determine if any drastic changes have occurred.

Furthermore, it should be noted that the candidate management procedures put forward by the JWG and evaluated in the MSE specify the use of WCPO:EPO allocations that would result in a WCPO:EPO proportional fishery impact of 80:20 or 70:30. Thus, the ISC has developed for the MSE a method to modify the TAC between the EPO and WCPO to obtain the prescribed EPO:WCPO fishery impact ratio (Tommasi and Lee 2024). The fishery impact ratio depends on a measure of the impact of a particular fleet group on SSB, as does the impact described in this paper, but it is calculated without assuming equilibrium. It is computed by simulating what the SSB would have been in the absence of catches from the fleet group under consideration (Wang et al. 2009). The fishery impact is then turned into a proportional fishery impact by calculating the fishery impact of a particular fleet group relative to the impact of all the fleet groups combined. As for the impact measure presented here, it differs for fleets with different selectivity and it is higher for fleets catching small PBF. Also, it was calculated for the WCPO as a whole, across all its different fleet groups. Transfers of TAC between the EPO and WCPO based on a prescribed fishery impact ratio would be more consistent with how the impact between EPO and WCPO was calculated for the MSE.

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Table 1 Age-specific SSB equivalent in mt, if 1 metric ton of PBF at specific ages and quarters are removed from the population. For example, if 1 mt of age-3 fish are removed in the 1st quarter, (reading down the vertical band) this will be equivalent to 12.1 mt of PBF SSB.

Age	Body weight (kg)	fish/ton	SSB equiv (mt)	relative to age5
0.125	0.34	2932	140.9	18.8
0.375	0.96	1045	74.9	10.0
0.625	1.99	502	53.6	7.2
0.875	3.49	287	45.7	6.1
1.125	5.46	183	43.6	5.8
1.375	7.90	127	33.2	4.4
1.625	10.8	92.4	26.7	3.6
1.875	14.2	70.4	22.4	3.0
2.125	18.0	55.5	19.4	2.6
2.375	22.2	45.0	16.8	2.2
2.625	26.9	37.2	14.8	2.0
2.875	31.8	31.4	13.3	1.8
3.125	37.2	26.9	12.1	1.6
3.375	43.0	23.3	11.1	1.5
3.625	49.0	20.4	10.4	1.4
3.875	55.2	18.1	9.8	1.3
4.125	61.7	16.2	9.1	1.2
4.375	68.3	14.6	8.8	1.2
4.625	75.0	13.3	8.5	1.1
4.875	81.8	12.2	8.3	1.1
5.125	88.6	11.3	7.7	1.0
5.375	95.6	10.5	7.6	1.0
5.625	102	9.8	7.5	1.0
5.875	109	9.1	7.5	1.0
6.125	116	8.6	6.5	0.87
6.375	123	8.1	6.5	0.87
6.625	130	7.7	6.6	0.88
6.875	136	7.3	6.7	0.89
7.125	143	7.0	5.8	0.77
7.375	150	6.7	5.9	0.78
7.625	156	6.4	6.0	0.80
7.875	162	6.2	6.1	0.82
8.125	168	5.9	5.3	0.70
8.375	174	5.7	5.4	0.72
8.625	180	5.6	5.6	0.75
8.875	186	5.4	5.8	0.77
9.125	191	5.2	4.9	0.66
9.375	196	5.1	5.1	0.68
9.625	202	5.0	5.3	0.71
9.875	207	4.8	5.5	0.73
10.125	212	4.7	4.7	0.62
10.375	216	4.6	4.9	0.65
10.625	221	4.5	5.1	0.68
10.875	225	4.4	5.3	0.71

Age	Body weight (kg)	fish/ton	SSB equiv (ton)	relative to age5
11.125	230	4.4	4.5	0.60
11.375	234	4.3	4.7	0.62
11.625	238	4.2	4.9	0.65
11.875	242	4.1	5.1	0.68
12.125	245	4.1	4.3	0.58
12.375	249	4.0	4.5	0.61
12.625	253	4.0	4.8	0.64
12.875	256	3.9	5.0	0.67
13.125	259	3.9	4.2	0.56
13.375	262	3.8	4.4	0.59
13.625	265	3.8	4.7	0.62
13.875	268	3.7	4.9	0.66
14.125	271	3.7	4.1	0.55
14.375	273	3.7	4.3	0.58
14.625	276	3.6	4.6	0.61
14.875	278	3.6	4.8	0.65
15.125	281	3.6	4.0	0.54
15.375	283	3.5	4.3	0.57
15.625	285	3.5	4.5	0.60
15.875	287	3.5	4.8	0.64
16.125	289	3.5	4.0	0.53
16.375	291	3.4	4.2	0.56
16.625	293	3.4	4.5	0.60
16.875	294	3.4	4.7	0.63
17.125	296	3.4	3.9	0.53
17.375	298	3.4	4.2	0.56
17.625	299	3.3	4.4	0.59
17.875	301	3.3	4.7	0.62
18.125	302	3.3	3.9	0.52
18.375	303	3.3	4.1	0.55
18.625	305	3.3	4.4	0.58
18.875	306	3.3	4.6	0.62
19.125	307	3.3	3.9	0.52
19.375	308	3.2	4.1	0.55
19.625	309	3.2	4.3	0.58
19.875	310	3.2	4.6	0.62
20.125	316	3.2	3.8	0.50
20.375	316	3.2	4.0	0.54
20.625	317	3.2	4.3	0.57
20.875	318	3.1	4.5	0.60

Table 2. Annual catch in weight (mt) by fleet group estimated by the ISC 2024 stock assessment base case.

Catch (mt)	WCPO_S	WCPO_M	WCPO_L	EPO
2015	1,751	2,971	3,876	3,150
2016	3,563	3,107	4,423	4,317
2017	2,285	3,154	4,205	3,653
2018	2,106	1,936	4,180	2,571
2019	2,488	2,461	5,038	3,887
2020	2,114	3,082	5,496	4,616
2021	2,709	3,811	6,167	5,458
2022	2,430	3,672	6,136	5,242

Table 3. Annual total fishing impact (SSB equivalent mt) by fleet group estimated from catch at age and age-specific relative impact.

Total impact	WCPO_S	WCPO_M	WCPO_L	EPO
2015	11,914	7,304	4,134	5,962
2016	23,804	9,671	4,614	5,727
2017	14,277	9,468	4,218	4,782
2018	13,251	4,749	4,729	3,446
2019	14,923	5,514	4,951	5,867
2020	12,956	6,775	5,290	6,631
2021	16,735	8,131	5,600	8,540
2022	15,487	8,434	5,315	8,584

Table 4. Annual and average impact per unit catch calculated as the annual total fishing impact (table 3) divided by the annual catch in weight (Table 2).

Impact/ton	WCPO_S	WCPO_M	WCPO_L	EPO
2015	6.80	2.46	1.07	1.89
2016	6.68	3.11	1.04	1.33
2017	6.25	3.00	1.00	1.31
2018	6.29	2.45	1.13	1.34
2019	6.00	2.24	0.98	1.51
2020	6.13	2.20	0.96	1.44
2021	6.18	2.13	0.91	1.56
2022	6.37	2.30	0.87	1.64
Average	6.34	2.49	1.00	1.50

Table 5. Estimated conversion factors across the fleet groups. The values in upper triangle can be used when you swap the TAC from a fleet group in the left column to a fleet group in the top row. The values in lower triangle can be used to swap the TAC from a fleet group in the top row to a fleet group in the left column.

Conversion factor	WCPO_S	WCPO_M	WCPO_L	EPO
WCPO_S	1	2.55	6.37	4.22
WCPO_M	0.39	1	2.50	1.66
WCPO_L	0.16	0.40	1	0.66
EPO	0.24	0.60	1.51	1

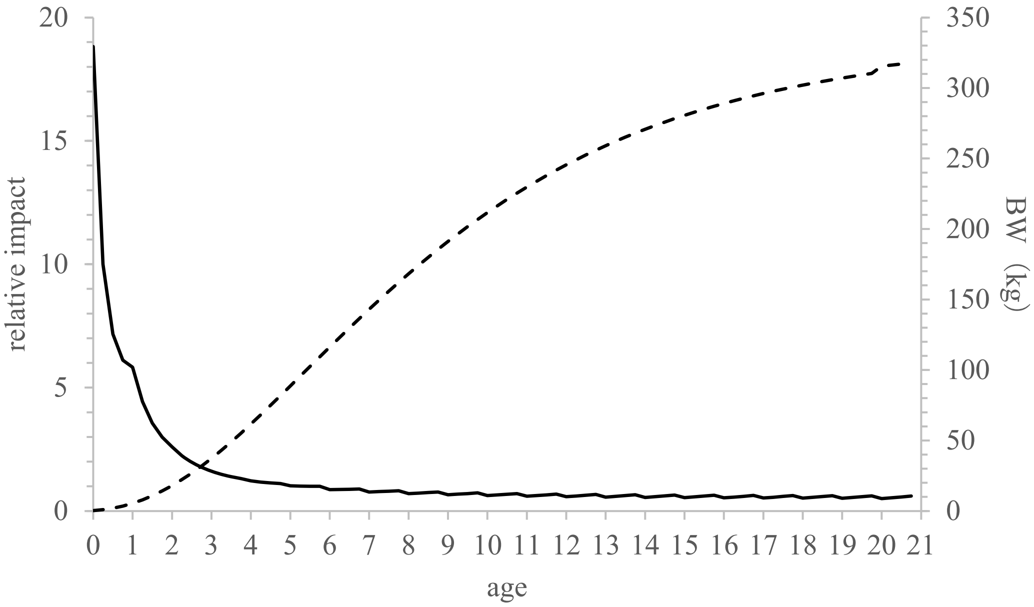

Figure 1 Age specific fishery impact relative to age 5 in 4th quarter (bold line) and body weight of the individual PBF (dashed line).

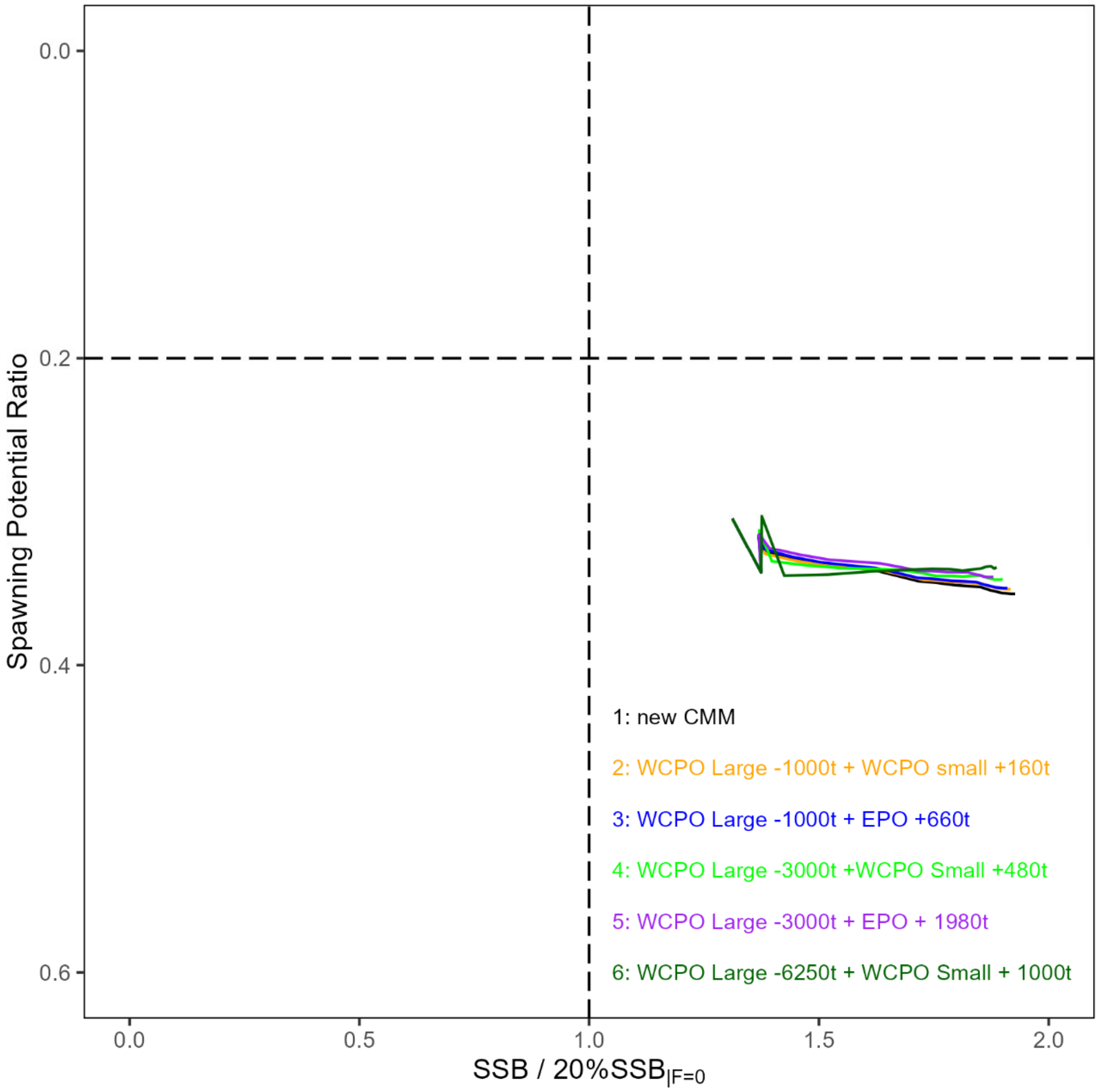

Figure 2 The phase plot for future projections.