Preliminary future projections for Pacific bluefin tuna stock based on the 2024 stock assessment base case.

Kirara Nishikawa, Hiromu Fukuda, Yohei Tsukahara and Shuya Nakatsuka

Highly Migratory Resources Division, Fisheries Resources Institute,
Japan Fisheries Research and Education Agency
2-12-4 Fukuura, Kanazawa, Yokohama, Kanagawa 236-8648, Japan

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1. Abstract

As the PBF future projection, 'ssfuture' has been used since 2012 stock assessment. Through some stock assessments, the future projection model was updated several times. This document provides the explanation of the latest projection setting, corresponding to the CMMs decided by WCPFC and IATTC commissions and future harvesting scenarios requested by the WCPFC Northern Committee – IATTC Joint Working Group. The dynamics has been able to be calculated from any year of the assessment period and the NAA at the year before the assessment terminal year, and FY 2021 is adopted as the beginning year of this projections by March 2024 meeting.

2. Introduction

The ISC PBFWG has assessed PBF stock condition and forecasted the future condition based on the stock assessment outputs. These projection results have been provided as the information to consider the conservation measure in the WCPFC and IATTC. The future projection platform for PBF was developed and compiled as an R-package 'ssfuture', and it was firstly introduced in the 2012 assessment (ISC 2012). This software can simulate quarterly age-structured population dynamics in a forward direction, which has a similar model structure with the Stock Synthesis (Methot and Wetzel 2013).

For the 2024 stock assessment of Pacific bluefin tuna, the WG developed the base case stock assessment model during the in-person meeting in March 2024 in Kaohsiung. This document provides the explanation of the latest projection setting and the results, corresponding to the requested scenarios by the joint working group of the IATTC and WCPFC NC for the PBF management.

3. Models and Methods

Base case assessment model

The 2024 PBF assessment base case model was developed using the stock synthesis version 3.30.22.1. The base case model files were shared among the attendees of the assessment meeting on March 9th, 2024. We used this base case model for all of the analyses in this document.

Bootstrap

Each projection is conducted based on the 300 bootstrap replicates of assessment followed by twenty stochastic simulations, thus 6000 runs in total are estimated for each scenario. From this assessment, the PBFWG updated the version of the stock synthesis from 3.30.14 to 3.30.22. This update included the change in the bootstrapping procedure for the size composition data, but we confirmed that the difference by this update for the estimated demography was not critical (Fig.). In Fukuda et al. (2020), biases of the output variables between the point estimates of the assessment base case and the median of bootstrap replicates were pointed out. These

biases were also confirmed in the 2024 assessment base case. Lee et al. (2021) identified possible sources of the biases during the bootstrapping procedure, and a method for bootstrapping procedure to reduce the biases were suggested. This method was applied in the current procedure of the bootstrapping for the 2024 assessment.

Grouping of the fleets

In the 'ssfuture', the fishery fleets in the assessment can be lumped into groups of fleets to apply a mutual catch upper limit for the group of fleets. Common age-based fishing mortality (F@Age from the assessment) and size-based catch quota are applied among the fleets in a group. Number of groups should be equal or smaller than number of fleets. The groups of the fishing fleet in the projection were defined as;

Group 1 (Japanese longline)	; Fleet 1,2
Group 2 (Japanese Purse seine)	: Fleet 5-10
Group 3 (Japanese coastal fisheries)	: Fleet 12-19
Group 4 (Korea)	: Fleet 11
Group 5 (Chinese-Taipei)	: Fleet 3,4
Group 6 (EPO commercial fisheries)	: Fleet 20,21
Group 7 (EPO Sport)	: Fleet 22,23
Group 8 (Unaccounted mortality)	: Fleet 24-26.

Projection time frame

In March 2024 stock assessment meeting, the WG agreed to start the projection from the beginning of 2021 fishing year (one year before the terminal year of assessment) ending in 2041. The reason for this procedure was that the recruitment in 2021 fishing year of the assessment had a large uncertainty mainly due to the lack of information in the input data. 20 years of future dynamics of PBF stock was simulated in this projection. Catch for 2021-2022 are based on reported catch. Catch for 2023 is based on the allocation.

Recruitment

In common with the stock assessment, the recruitment in the projection settled in July 1st in Calendar year. For 2024 stock assessment, recruitment in the projection period was assumed to be a historical average level (stochastic resampling from stock assessment period; 1983-2020). The terminal recruitments for 2021 and 2022 contained large uncertainty, thus those were not included. Although the past stock assessments used a longer time period starting 1952 for the resampling of historical recruitment since the assessment time period was longer than the current assessment, the PBFWG confirmed that the distribution of the historical recruitments was not critically different between the current assessment and the 2022 assessment.

Harvesting scenario for projection

The harvesting scenario for the projection basically followed the method conducted at the 2018 PBF stock assessment (ISC 2018). For scenarios 1-11, the harvesting is controlled based on the age specific fishing mortality in the average of 2002-2004 FY to reflect the effort management and catch limit for small and large PBF categories (i.e. <30kg or ≥30kg) for the fisheries in western Pacific except for the Korean purse seine fleet, which have a different fishing pattern in recent year. The average fishing mortality at age of 2014-2016 was applied to the Korean PS fleet.

Because there is no resolution for effort management in the CMM of IATTC, the same fishing pattern by eastern Pacific fisheries is simulated (e.g. F2002-04). Also, there has been a "bag limit" domestic regulation for US sports fishery, but the PBFWG do not have best way to address it for projection because of the difficulty to set explicit catch limit. Therefore, we continued the previous projection setting (using F2009-11) to simulate the harvesting by EPO sports fishery. The harvesting for scenario 12 (constant F30%SPR) is controlled based on the average fishing mortality in 2017-2019 to reflect the current fishing pattern.

The Joint Working group held on July 2023 discussed and requested harvesting scenarios (WCPFC 2023, Annex E) to the ISC for analysis. The new harvesting scenarios are listed in Table 1 and followings are the notes for each scenario. In all harvesting scenarios except scenario 12 (constant F30%SPR), annual catch limit was specified for the all fishery groups except the EPO sports fishery, and the catch allocations were renewed on January 1st of each calendar year in the projection.

Scenario 1: Status quo of the current CMM (WCPFC CMM 2023-02, IATTC Resolution 21-05);

Scenario 2: Based on #1, a part of quota for small PBF category (<30 kg in body weight, PBF younger than age 3) was transferred to the quota for large PBF category (≥ 30kg in body weight, PBF older than age 2.75) with conversion factor (1.47). (30% and 40% of quota for small PBF category for Japan and Korea, respectively);

Scenario 3: No fishing allowed;

Scenario 4: Based on #1, increasing PBF quotas in proportional among the WCPO and EPO fisheries to the level achieving 20%SSB0 at the last year of the projection in 60% of probability;

Scenario 5: Based on #1, increasing PBF quotas in proportional among the WCPO large PBF category and EPO fishery to the level achieving 20%SSB0 at the last year

of the projection in 60% of probability;

Scenario 6: Based on #4, increasing the PBF quota of the WCPO small fish category for 20%, while increased the PBF quota of the WCPO large fish category and EPO fishery to the level achieving 20%SSB0 at the last year of the projection in 60% of probability with maintaining the catch proportion between WCPO and EPO as status quo;

Scenario 7: Based on #4, increasing the PBF quota of the WCPO small fish category for 30%, while increased the PBF quota of the WCPO large fish category and EPO fishery to the level achieving 20%SSB0 at the last year of the projection in 60% of probability with maintaining the catch proportion between WCPO and EPO as status quo;

Scenario 8: Increasing the PBF quota of all fisheries to the level achieving 20%SSB0 in 60% of probability and the fishery impact ratio between WPO and EPO fisheries as 70:30 with maintaining the proportion between the quota of WCPO small and large fish category;

Scenario 9: Increasing the PBF quota of all fisheries to the level achieving 20%SSB0 in 60% of probability and the fishery impact ratio between WPO and EPO fisheries as 80:20 with maintaining the proportion between the quota of WCPO small and large fish category;

Scenario 10: Based on #8, increasing the PBF quota of all fisheries to the level achieving 20%SSB0 in 60% of probability and the fishery impact ratio between WPO and EPO fisheries as 70:30 with changing the proportion between the quota of WCPO small fish category smaller than that for large fish category;

Scenario 11: Based on #9, increasing the PBF quota of all fisheries to the level achieving 20%SSB0 in 60% of probability and the fishery impact ratio between WPO and EPO fisheries as 80:20 with changing the proportion between the quota of WCPO small fish category smaller than that for large fish category;

Scenario 12: Constant F30%SPR scenario

About the scenarios 4-11, there is a specified biomass target (e.g. 20% SSB0 with 60% probability), so that the harvesting scenario to achieve this target in the last year of the projection (i.e. 2041 FY) was explored. The scenarios 8-11 also have a specified future impact ratio between the WCPO and EPO fisheries in 2034 FY (80:20 or 70:30). Among those scenarios, scenarios 8 and 9 specified the catch proportion between the WCPO small PBF fishery and large PBF fishery as pro rata, so those were explored by changing the allocated quota between WCPO fishery and EPO fishery or allocated quota for WCPO small PBF fishery

and WCPO large PBF fishery. The scenarios 10 and 11 mentioned the proportion of catch limit increases for the WCPO small PBF fishery and that for the large PBF fishery to be "SMALL < LARGE", a part of the quota increments for the WCPO small PBF category in the scenarios 8 and 9 were moved to the WCPO large PBF category in scenarios 10 and 11 with adjustment to achieve the biomass target and E-W fishery impact ratio.

The scenario 12 was conducted to project the stock and fishery with the constant fishing mortality of F30%SPR, which was listed in the HCR for the PBF MSE as one of the target reference points. For this scenario, the average fishing mortality at age during 2017-2019 was used as a basic exploitation pattern in recent years (Tommasi and Lee, 2022), and a multiplier for Fs at each age was applied to maintain F30%SPR.

For all of the scenarios, catch by the unseen mortality fleets (Fleets 24-26 in the assessment) was not accounted for the projection period since this could be treated as a compliance issue.

Performance indicators

Since the PBF stock achieved the initial rebuilding target and 2nd rebuilding target already in the assessment period, some performance indicators used in the 2022 stock assessment are outdated (e.g. The fishing year expected to achieve the 2nd rebuilding target with 60% probability, Probability of achieving the 2nd rebuilding target at 10 years after achieving initial rebuilding target). Also, the SSB_{loss} (the historical lowest biomass), which was used as a reference biomass to calculate the risk of the stock is considered not suitable as a performance metrics since the stock level is recovered to a historic high level and the tested harvesting scenarios would not be a severe for the stock to breach that level. Thus the WG agreed to change to 7.7% SSB_0.

In addition to those performance indicators, the JWG requested the ISC to explore at least one harvesting scenario that satisfies those matters simultaneously; 1) Stock meets the second rebuilding target (20%SSB_0) in 60 % of probability; 2) Achieving the future fishery impact ratio between the WPO and EPO being 70%:30% and 80%:20% in 2034. For this kind of the request, we calculated the future fishery impact ratio (Fukuda et al., 2020) between the WPO and EPO at 2034 FY.

4. Results

The results were shown in the Tables x-x and Figures y-y. Because of the accumulation of young fish in the base-case model, the stock was projected to increase much higher SSB than 20%SSB0 in all scenarios. The scenarios 1 and 2 (status quo and status quo plus conversion) showed a continuation of the SSB increase and the scenario 2 showed a higher asymptotic SSB

(Fig. 1). Some of the scenarios, which were specified to maintain the 20%SSB_0, showed a decreasing trend from a peak of the biomass at the late 2020's to the end year of the projection by its nation of the harvest scenario. The scenario 12 (constant F30%SPR) showed a gradual increase in the SSB.

Basically, the allocated quota for each fishery group were consumed within a year in all scenarios, so that the expected catches were similar with their quota. However, because Korean purse seine fleet caught PBF of both small and large size categories using their quota in the small PBF category, the expected catch in the WCPO small PBF category looked like lower than their quota while their catch in the large PBF category was higher than their quota. The expected catch by EPO sports fishery was correlated with the stock size due to the nature of the F control though, the expected catches were around 1,000 tons if the stock size was maintained around 20%SSB_0 (scenarios 4-11). In scenario 12, because of the exploitation patten of Fishing year 2017-2019 in the 2024 stock assessment base case, the expected catch by EPO sports fishery remained relatively low. It might be beneficial for the WG to revisit about the reference years to represent the recent exploitation pattern for the PBF MSE.

Overall, the requested projection scenarios were performed, and there were consistencies between the previous and current projections. Since a catch for age 0 to 1 PBF has a larger impact on the future SSB than the same amount of catch for large PBF (> 30 kg), the expected total catch was larger if the ratio of the small PBF quota was moderate.

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Table 1. The scenario list based on NC request.

Harvesting scenarios												
Reference No	Scenarios				Catch limit in the projection				Specified fishery impact at 2034		Specified SSB at 2041 of projection	Note
	WCPO		EPO		WCPO		EPO					
	Small	Large	Small	Large	Small	Large	Small	Large	WCPO	EPO		
1	Status quo (WCPFC CMM2023-02, IATTC Resolution 21-05)				4,475	7,859	3,995		-	-	-	JWG's request 1(NC19 Summary Report, Attachment E; Maintaining the current CMM)
2	Maintaining the current CMM assuming maximum transfer utilizing the conversion factor				3,236	9,799	3,995		-	-	-	JWG's request 02 (Maximum utilization of transfer from small fish catch limit to large fish catch limit using the conversion factor).
3	No fishing allowed				0	0	0		-	-	-	JWG's request 03 (No fishing)
4	Status quo +60%	Status quo +60%	Status quo +60%		7,310	12,424	6,392		-	-	20%SSB0 with 60% of probability	JWG's request 04-1 (scenario achieving 20%SSB0 with 60%probability by pro-rata change in catch).
5	Status quo	Status quo +180%	Status quo +180%		4,475	21,555	11,186		-	-	20%SSB0 with 60% of probability	JWG's request 04-2 (scenario achieving 20%SSB0 with 60%probability by proportional change in catch among the WCPO large fish catch limit and EPO total catch limit).
6	Status quo +20%	1.3*(Status quo +60% +(WCPO_small_SQ* (60%-20%)) ton)	1.3*(Status quo +60%)		5,420	20,235	8,310		-	-	20%SSB0 with 60% of probability	JWG's request 04-3 (scenario achieving 20%SSB0 with 60% probability by maintaining the total catch proportion between WCPO and EPO as status quo while limiting the catch limit increase for WCPO small fish as 20% of its original catch limit).
7	Status quo +30%	1.2*(Status quo +60% +(WCPO_small_SQ* (60%-30%)) ton)	1.2*(Status quo +60%)		5,893	17,789	7,670		-	-	20%SSB0 with 60% of probability	JWG's request 04-4 (scenario achieving 20%SSB0 with 60% probability by maintaining the total catch proportion between WCPO and EPO as status quo while limiting the catch limit increase for WCPO small fish as 30% of its original catch limit).
8	Status quo +30%	Status quo +30%	Status quo +190%		5,893	10,142	11,586		70	30	20%SSB0 with 60% of probability	JWG's request 05-1 (explored constant catch scenario achieving fishery impact ratio between WCPO and EPO as 70% and 30% while maintaining the catch proportion of small and large fish in WCPO as status quo).
9	Status quo +55% (i<a)	Status quo +55% (j>a)	Status quo +80%		7,074	12,044	7,191		80	20	20%SSB0 with 60% of probability	JWG's request 05-1 (explored constant catch scenario achieving fishery impact ratio between WCPO and EPO as 80% and 20% while maintaining the catch proportion of small and large fish in WCPO as status quo).
10	Status quo +10% (g<e)	Status quo +130% (h>e)	Status quo +190%		4,948	17,751	11,586		70	30	20%SSB0 with 60% of probability	JWG's request 05-2 (explored constant catch scenario achieving fishery impact ratio between WCPO and EPO as 70% and 30% while maintaining the catch proportion of small fish in WCPO lower than that of status quo).
11	Status quo +40% (i<a)	Status quo +120% (j>a)	Status quo +80%		6,015	17,540	7,191		80	20	20%SSB0 with 60% of probability	JWG's request 05-3 (explored constant catch scenario achieving fishery impact ratio between WCPO and EPO as 80% and 20% while maintaining the catch proportion of small fish in WCPO lower than that of status quo).
12	No limit	No limit	No limit		NA				-	-	-	SPR30% Scenario F1719 multiplied 1.4

Include in the projections results table a metric that calculates the probability of overfishing compared to candidate target reference points.

Table 2. The performance indicators

Performance indicators					
Median SSB at 10 years after achieving initial rebuilding target [2029]	Median SSB at 2034	Probability of achiving the 2nd rebuilding target at 2041 of projection	Risk to breach $SSB_{7.7\%F=0}$ at least once by 2041	Fishery impact ratio of WPO fishery at 2034	Fishery impact ratio of EPO fishery at 2034

Table 3. The result of Future projections.

Harvesting scenarios												Performance indicators					
Reference No	Scenarios				Catch limit in the projection				Specified fishery impact at 2034		Specified SSB at 2041 of projection	Median SSB at 10 years after achieving initial rebuilding target [2029]	Median SSB at 2034	Probability of achiving the 2nd rebuilding target at 2041 of projection	Risk to breach $SSB_{7.7\%F=0}$ at least once by 2041	Fishery impact ratio of WPO fishery at 2034	Fishery impact ratio of EPO fishery at 2034
	WCPO		EPO		WCPO		EPO										
	Small	Large	Small	Large	Small	Large	Small	Large	WCPO	EPO							
1	Status quo (WCPFC CMM2023-02, IATTC Resolution 21-05)				4,475	7,859	3,995		-	-	-	235531	287844	100%	0%	78%	22%
2	Maintaining the current CMM assuming maximum transfer utilizing				3,236	9,799	3,995		-	-	-	245444	308868	100%	0%	77%	23%
3	No fishing allowed				0	0	0		-	-	-	397437	536653	100%	0%	86%	14%
4	Status quo +60%	Status quo +60%	Status quo +60%		7,310	12,424	6,392		-	-	20%SSB0 with 60% of probability	175639	158658	61%	8%	82%	18%
5	Status quo	Status quo +180%	Status quo +180%		4,475	21,555	11,186		-	-	20%SSB0 with 60% of probability	142895	143211	60%	19%	71%	29%
6	Status quo +20%	1.3*(Status quo +60% +(WCPO_small_SQ* (60%-20%)) ton)	1.3*(Status quo +60%)		5,420	20,235	8,310		-	-	20%SSB0 with 60% of probability	151085	148332	60%	18%	78%	22%
7	Status quo +30%	1.2*(Status quo +60% +(WCPO_small_SQ* (60%-30%)) ton)	1.2*(Status quo +60%)		5,893	17,789	7,670		-	-	20%SSB0 with 60% of probability	161024	156324	63%	14%	80%	20%
8	Status quo +30%	Status quo +30%	Status quo +190%		5,893	10,142	11,586		70	30	20%SSB0 with 60% of probability	169537	158245	61%	14%	69%	31%
9	Status quo +55% (i<a)	Status quo +55% (j>a)	Status quo +80%		7,074	12,044	7,191		80	20	20%SSB0 with 60% of probability	175494	162242	63%	9%	79%	21%
10	Status quo +10% (g<e)	Status quo +130% (h>e)	Status quo +190%		4,948	17,751	11,586		70	30	20%SSB0 with 60% of probability	150681	147825	60%	19%	70%	30%
11	Status quo +40% (i<a)	Status quo +120% (j>a)	Status quo +80%		6,015	17,540	7,191		80	20	20%SSB0 with 60% of probability	163103	153985	61%	14%	80%	20%
12	No limit	No limit	No limit		NA				-	-	-	180016	190088	99%	0%	77%	23%

The catch limit includes 250t transfer of Japanese puese seines from small fish to large fish.

Table 4. The expected catch

Reference No	Harvesting scenarios								Expected catch							
	Scenarios				Catch limit in the projection				2029				2034			
	WCPO		EPO		WCPO		EPO		WPO		EPO		WPO		EPO	
	Small	Large	Small	Large	Small	Large	Small	Large	Small	Large	Commercial	Sport	Small	Large	Commercial	Sport
1	Status quo (WCPFC CMM2023-02, IATTC Resolution 21-05)				4,475	7,859	3,995		4,184	8,219	4,010	1,797	4,179	8,232	4,011	2,005
2	Maintaining the current CMM assuming maximum transfer utilizing				3,236	9,799	3,995		3,256	9,884	4,016	1,933	3,256	9,895	4,018	2,189
3	No fishing allowed				0	0	0		0	0	0	0	0	0	0	0
4	Status quo +60%	Status quo +60%	Status quo +60%		7,310	12,424	6,392		6,509	13,111	6,348	996	6,540	12,969	6,332	926
5	Status quo	Status quo +180%	Status quo +180%		4,475	21,555	11,186		4,386	21,718	11,223	1,033	4,383	20,799	11,224	1,055
6	Status quo +20%	1.3*(Status quo +60% +(WCPO_small_SQ* (60%-20%)) ton)	1.3*(Status quo +60%)		5,420	20,235	8,310		5,388	20,361	8,321	1,030	5,394	19,989	8,330	1,035
7	Status quo +30%	1.2*(Status quo +60% +(WCPO_small_SQ* (60%-30%)) ton)	1.2*(Status quo +60%)		5,893	17,789	7,670		5,727	17,911	7,669	1,035	5,739	17,717	7,673	1,026
8	Status quo +30%	Status quo +30%	Status quo +190%		5,893	10,142	11,586		5,488	10,540	11,562	993	5,508	10,420	11,556	950
9	Status quo +55% (i<a)	Status quo +55% (j>a)	Status quo +80%		7,074	12,044	7,191		6,594	12,521	7,194	1,011	6,620	12,456	7,196	953
10	Status quo +10% (g<e)	Status quo +130% (h>e)	Status quo +190%		4,948	17,751	11,586		4,704	18,017	11,581	1,020	4,707	17,667	11,589	1,025
11	Status quo +40% (i<a)	Status quo +120% (j>a)	Status quo +80%		6,015	17,540	7,191		5,991	17,424	7,197	1,027	6,006	17,233	7,205	1,000
12	No limit	No limit	No limit		NA				4,820	18,091	5,607	715	4,812	19,436	5,668	733

Korean catch reflects recent catch proportion for small and large, thus expected catches do not match with catch allocations completely.

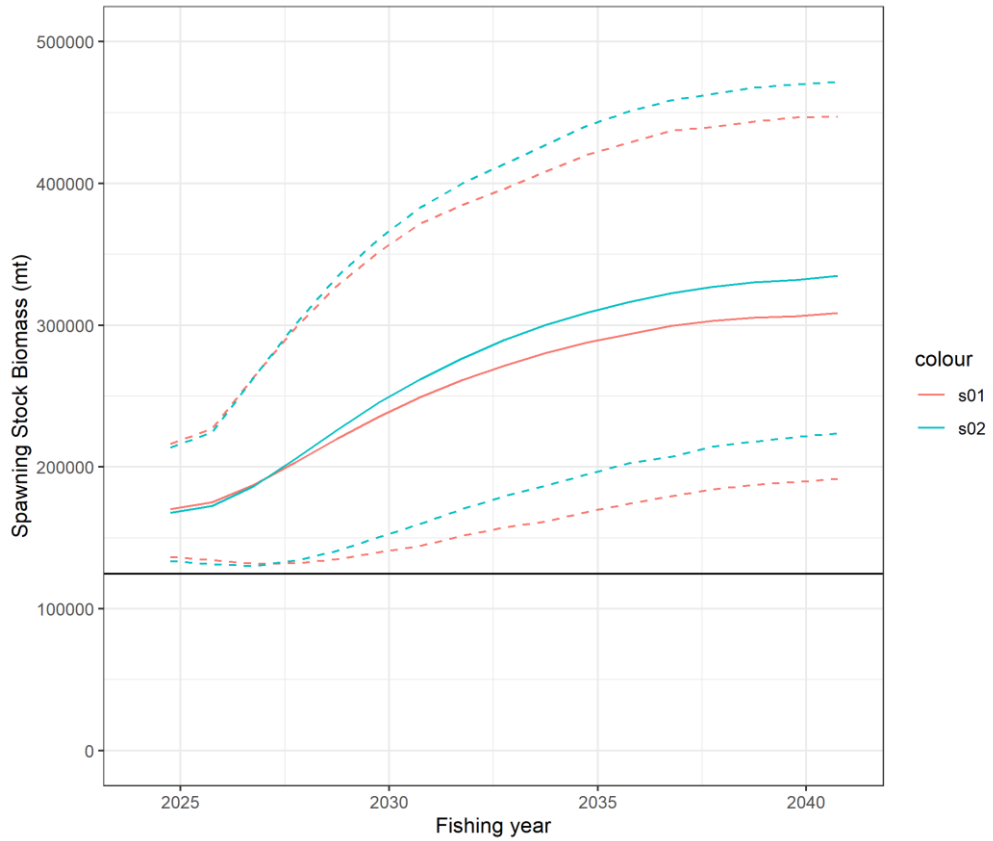

Figure 1. The projected SSB for scenario 1 and 2.

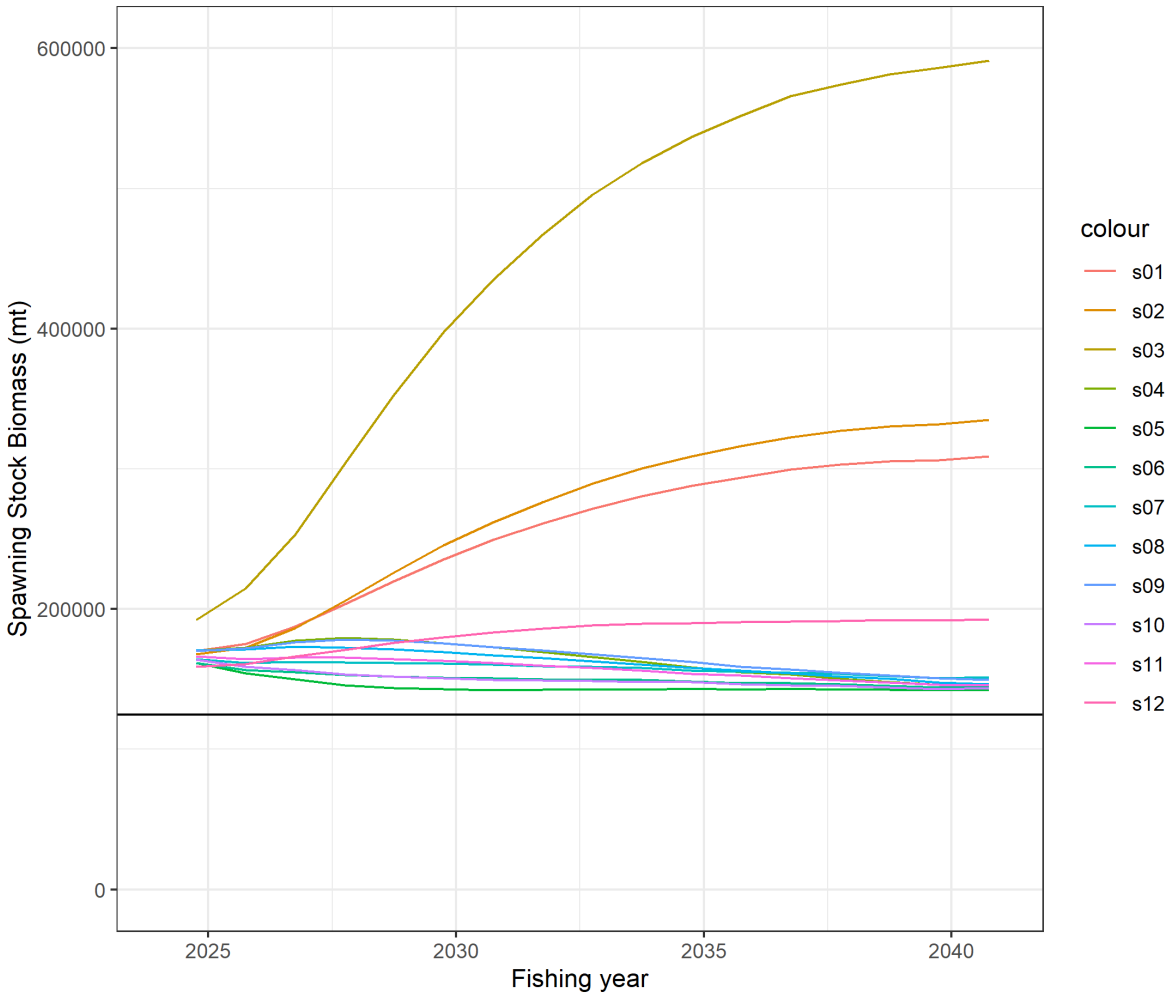

Figure 2. The projected SSB median for all scenarios.

Appendix A

Annex E

JOINT IATTC AND WCPFC-NC WORKING GROUP MEETING ON THE MANAGEMENT OF PACIFIC BLUEFIN TUNA
EIGHTH SESSION (JWG-08)

Fukuoka, Japan
3 – 5 July 2023

ISC'S PROJECTION SCENARIOS REQUESTED BY THE JWG08

JWG8 requests the ISC perform projections on the following scenarios in the 2024 assessment:

1. Maintaining the current CMM

2. Maintaining the current CMM assuming maximum transfers utilizing the conversion factor

3. No fishing allowed

4. Four scenarios as described below that result in the stock maintained above 20%SSB0 with a probability of 60%.
    - A scenario where increases are proportional between WCPO small/large fish catch limit and EPO catch limits
    - A scenario where increases are proportional between WCPO large fish catch limit and EPO catch limit
    - Scenarios of WCPO small fish catch limit increase by 20% and 30% respectively, while maintaining the proportion between WCPO total (small/large) catch limit and EPO catch limit

5. At least two scenarios that will result in each of 70:30 and 80:20 WCPO:EPO fishery impact by 2034 that maintain the stock above the second rebuilding target. The exact % increase can be determined by the ISC to meet the each of 70:30 and 80:20 fishery impact.
    - A scenario where increases are proportional for WCPO large and small fish
    - A scenario where increases are higher for WCPO large fish as compared to small fish.

Additionally, JWG8 has the following requests for ISC related to projections:

1. Once there is confirmation of meeting the second rebuilding target, the ISC shall recommend and provide information on the appropriate recruitment scenario(s) for use in the above projections.

2. Include in the projections results table a metric that calculates the probability of overfishing compared to candidate target reference points.