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ISC PBFWG - 2018 Pacific Bluefin Tuna Stock Assessment

EXECUTIVE SUMMARY MAY 2018

1. Stock Identification and Distribution

Pacific bluefin tuna (*Thunnus orientalis*) has a single Pacific-wide stock managed by both the Western and Central Pacific Fisheries Commission (WCPFC) and the Inter-American Tropical Tuna Commission (IATTC). Although found throughout the North Pacific Ocean, spawning grounds are recognized only in the western North Pacific Ocean (WPO). A portion of each cohort makes trans-Pacific migrations from the WPO to the eastern North Pacific Ocean (EPO), spending up to several years of its juvenile life stage in the EPO before returning to the WPO.

2. Catch History

While Pacific bluefin tuna (PBF) catch records prior to 1952 are incomplete, there are some PBF landings records dating back to 1804 from coastal Japan and to the early 1900s for U.S. fisheries operating in the EPO. Catch of PBF was estimated to be high from 1929 to 1940, with a peak catch of approximately 47,635 t (36,217 t in the WPO and 11,418 t in the EPO) in 1935; thereafter catches of PBF dropped precipitously due to World War II. PBF catches increased significantly in 1949 as Japanese fishing activities expanded across the North Pacific Ocean. By 1952, a more consistent catch reporting process was adopted by most fishing nations. Estimates of PBF annual catches fluctuated widely from 1952 to 2016 (Figure 1). During this period reported catches peaked at 40,383 t in 1956 and reached a low of 8,653 t in 1990. Catches in 2015 and 2016 were 11,194 t and 13,198 t, respectively, including non-ISC member countries. While a suite of fishing gears have been used to catch PBF, the majority is currently caught in purse seine fisheries (Figure 2). Catches during 1952-2016 were predominately composed of juvenile PBF, but since the early 1990s, the catch of age 0 PBF has increased significantly (Figure 3).

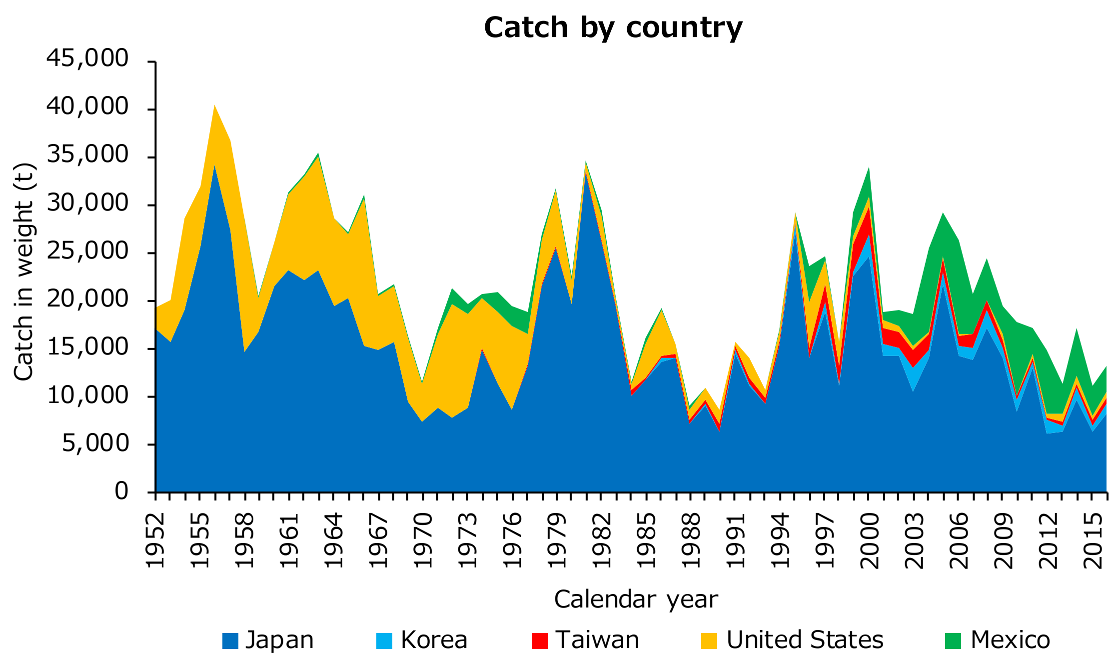

Figure 1. Annual catch of Pacific bluefin (*Thunnus orientalis*) tuna by country from 1952 through 2016 (calendar year).

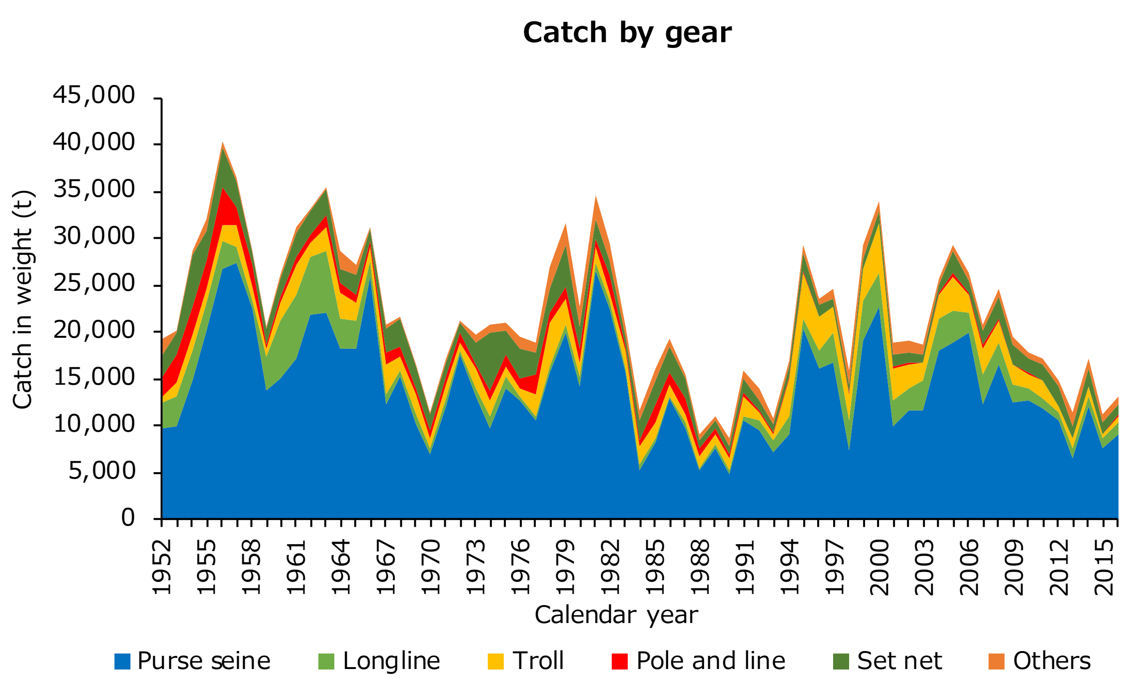

Figure 2. Annual catch of Pacific bluefin tuna (*Thunnus orientalis*) by gear type from 1952 through 2016 (calendar year).

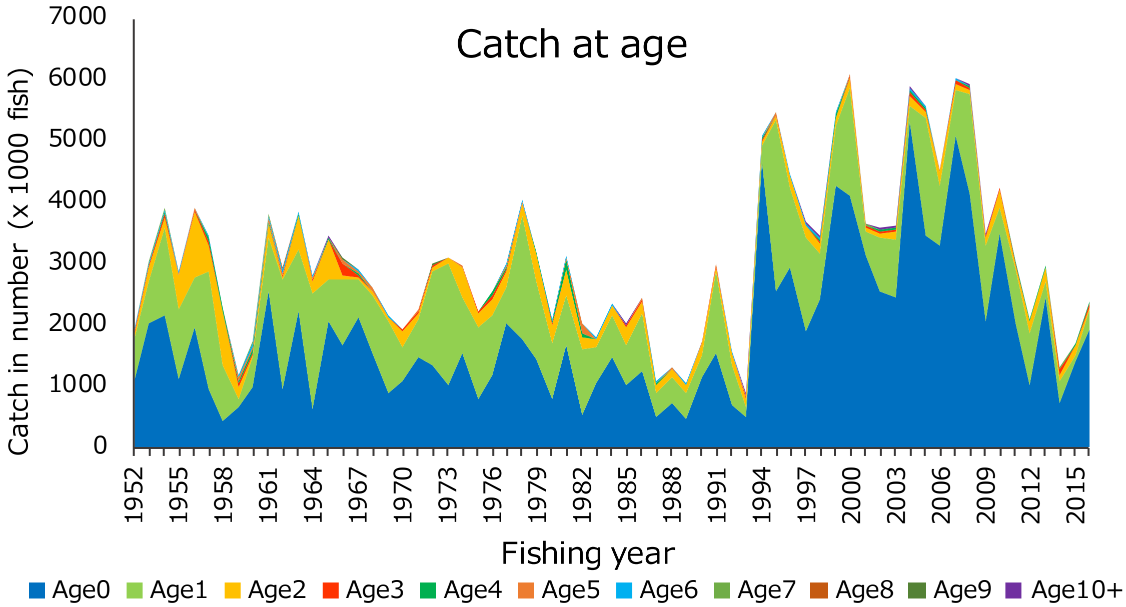

Figure 3. Estimated annual catch-at-age of Pacific bluefin tuna (*Thunnus orientalis*) by fishing year[1] (1952-2016; data for 1952 are incomplete).

3. Data and Assessment

As the 2018 assessment was an update, the basic model construction is the same as used for the 2016 assessment with up-to-date data. Population dynamics were estimated using a fully integrated age-structured model (Stock Synthesis (SS) v3.24f) fitted to catch, size-composition and catch-per-unit effort (CPUE) data from 1952 to 2016 (fishing year), provided by Members of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC), Pacific Bluefin Tuna Working Group (PBFWG) and non-ISC countries. Life history parameters included a length-at-age relationship from otolith-derived ages, and natural mortality estimates from a tag-recapture study and empirical-life history methods.

Nineteen fleets were defined for use in the stock assessment model based on country/gear/season/region stratification. Quarterly observations of catch and size compositions, when available, were used as inputs to the model to describe the removal processes. Annual estimates of standardized CPUE from the Japanese distant water, off-shore and coastal longline, the Taiwanese longline and the Japanese troll fleets were used as measures of the relative abundance of the population. The Japanese and Taiwanese longline CPUEs (used to inform the

[1] To better describe PBF biology, the fishing year (from July 1 to June 30 of the following calendar year) was used instead calendar year in the modelling context.

trend of adult abundance) showed gradually increasing trends in the updated years while the Japanese troll CPUE (used to inform recruitment) has been higher than the low level in 2014.

The assessment model was fitted to the input data in a likelihood-based statistical framework. Maximum likelihood estimates of model parameters, derived outputs and their variances were used to characterize stock status and to develop stock projections.

4. Stock Status and Conservation Information

Stock Status

The 2018 base-case model was constructed with minimal modifications relative to the 2016 base-case model. Based on the diagnostic analyses, the model represents the data sufficiently and results were consistent with the 2016 assessment. The 2018 assessment results considered the best available science information and appropriate for developing advice on stock status and conservation for the PBF.

The base-case model results show that: (1) spawning stock biomass (SSB) fluctuated throughout the assessment period, (2) the SSB steadily declined from 1996 to 2010; and (3) the slow increase of the stock continues since 2011 including the most recent two years. Based on the model diagnostics, the estimated biomass trend for the last 30 years is considered robust although SSB prior to the 1980s is uncertain due to data limitations. Using the base-case model, the 2016 SSB (terminal year) was estimated to be around 21,000 t in the 2018 assessment, which is an increased from 19,000 t in 2014 (Table 1 and Figure 4).

Historical recruitment estimates have fluctuated since 1952 without an apparent trend. The low recruitment levels estimated in 2010-2014 were a concern in the 2016 assessment. The 2018 assessment estimate of 2015 recruitment is low and similar to estimates from previous years while the 2016 recruitment estimate is higher than the historical average (Figure 4). The uncertainty of the 2016 recruitment estimate is higher than in previous years because it occurs in the terminal year of the assessment model and is mainly informed by one observation from the troll age-0 CPUE index. The troll CPUE series has been shown to be a good predictor of recruitment, with no apparent retrospective error in the recruitment estimates of the terminal year given the current model construction. As the 2016 recruits grow and are observed by other fleets, the magnitude of this year class will be more precisely estimated in the next stock assessment. The estimated magnitude of the 2016 year class had a positive impact on the projection results.

Table 1. Total biomass, spawning stock biomass and recruitment of Pacific bluefin tuna (*Thunnus orientalis*) estimated by the base-case model, where Coefficient of Variation (CV) measures relative variability defined as the ratio of the standard deviation to the mean.

Fishing year	Total biomass (t)	Spawning stock biomass (t)	CV for SSB	Recruitment (x1000 fish)	CV for R
1952	150825	114227	0.51	9305	
1953	146228	107201	0.49	21843	0.17
1954	147385	96239	0.49	34556	0.15
1955	152230	83288	0.50	14106	0.19
1956	169501	76742	0.49	34261	0.11
1957	188830	82975	0.46	12574	0.15
1958	208078	108677	0.41	3436	0.30
1959	214898	147004	0.39	7963	0.22
1960	218055	155183	0.39	7745	0.21
1961	211262	168125	0.39	23323	0.10
1962	197361	151993	0.42	10794	0.18
1963	181329	129755	0.45	27615	0.10
1964	169581	114448	0.45	5827	0.32
1965	159109	100628	0.46	11584	0.35
1966	144866	95839	0.44	8645	0.44
1967	121987	89204	0.44	10803	0.38
1968	107216	83374	0.45	13656	0.24
1969	93223	69074	0.47	6413	0.30
1970	81816	57958	0.48	7120	0.40
1971	71900	49980	0.48	12596	0.34
1972	67819	43035	0.46	22742	0.17
1973	65474	37205	0.44	11058	0.27
1974	65059	29896	0.44	13570	0.17
1975	63515	27733	0.38	11011	0.18
1976	66532	30485	0.30	9171	0.32
1977	64320	36220	0.25	25078	0.17
1978	69199	33382	0.25	15057	0.26
1979	69609	28007	0.29	11509	0.20
1980	71313	30757	0.25	7584	0.27
1981	72109	28867	0.21	11703	0.13
1982	53715	25408	0.21	6965	0.21
1983	31185	15086	0.29	10078	0.15
1984	33147	12813	0.31	9231	0.20
1985	36319	12846	0.28	9601	0.19
1986	35877	15358	0.23	7857	0.19
1987	31609	14632	0.25	6224	0.22
1988	33868	15709	0.25	8796	0.14
1989	38189	15519	0.25	4682	0.28
1990	46388	19468	0.23	18462	0.09
1991	61501	25373	0.21	11803	0.11
1992	70077	32022	0.20	4426	0.17
1993	79910	43691	0.18	4365	0.18
1994	90135	51924	0.19	28350	0.04
1995	103322	67152	0.18	17414	0.09
1996	98854	66841	0.18	17564	0.06
1997	99196	61069	0.19	10919	0.10
1998	95373	60293	0.19	15014	0.08
1999	91963	56113	0.20	23450	0.05
2000	87384	53835	0.21	14335	0.06
2001	76182	50222	0.21	15786	0.05
2002	77727	47992	0.20	13509	0.06
2003	74204	47569	0.19	7769	0.09
2004	68407	40707	0.20	26116	0.04
2005	63042	33820	0.21	14659	0.06
2006	50197	27669	0.23	11645	0.06
2007	43558	22044	0.24	21744	0.04
2008	41169	16754	0.27	20371	0.04
2009	35677	13011	0.27	8810	0.07
2010	33831	12188	0.25	15948	0.05
2011	34983	13261	0.23	13043	0.06
2012	37451	15892	0.20	6284	0.09
2013	39113	18107	0.20	11874	0.06
2014	38918	19031	0.19	3561	0.14
2015	38322	19695	0.20	7765	0.13
2016	41191	21331	0.22	15988	0.21

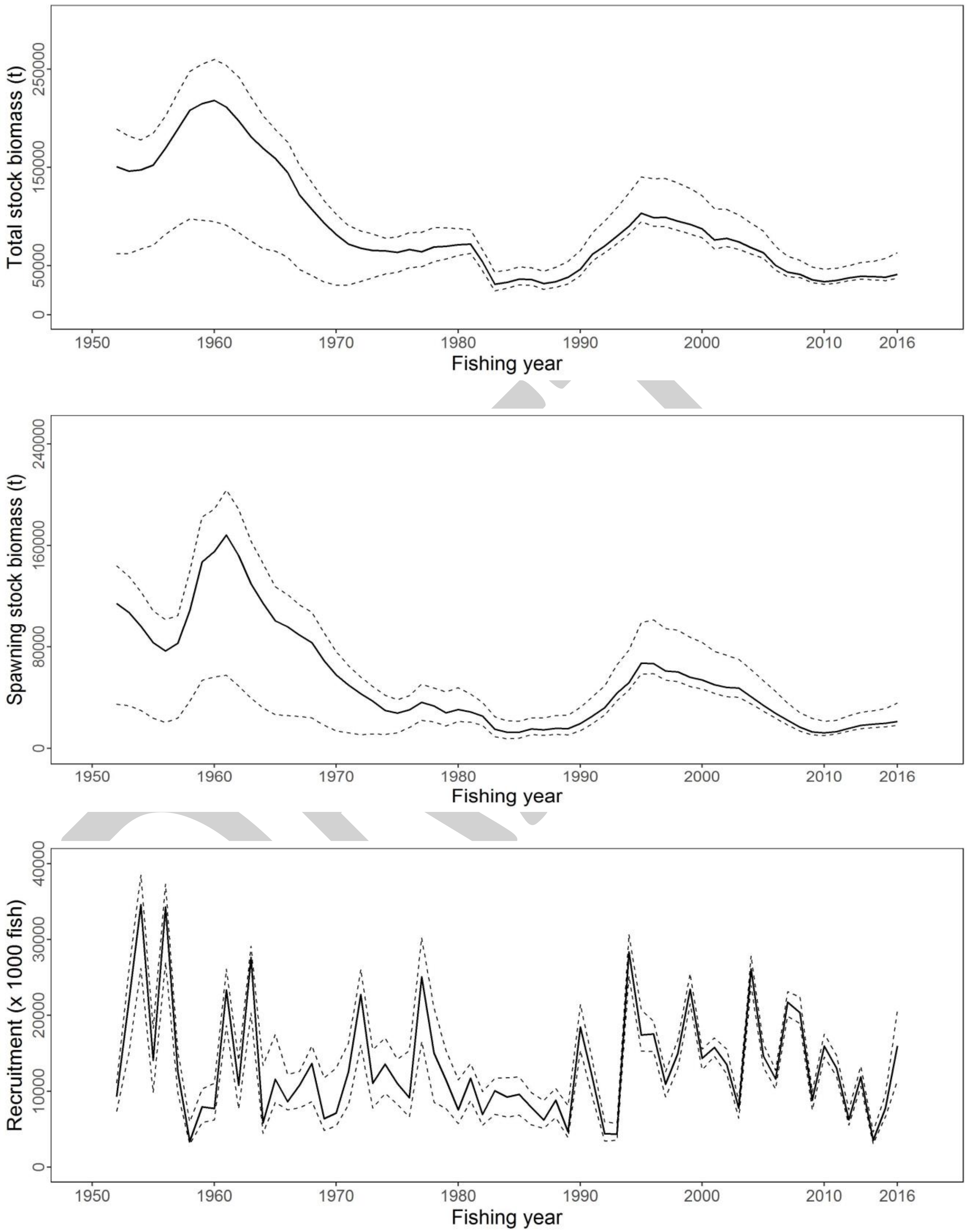

Figure 4. Total stock biomass (top), spawning stock biomass (middle) and recruitment (bottom) of Pacific bluefin tuna (*Thunnus orientalis*) from the base-case model. The solid lines indicate point estimates and the dashed lines indicate the 90% confidence intervals.

Comparison of estimated age-specific fishing mortalities (F) on the stock during 2012-2014, 2015-2016, and 2002-2004 (the base period for the WCPFC Conservation and Management Measure) are presented in Table 2 and Figure 5. A substantial decrease in estimated F is observed in ages 0-2 in 2015-2016. Note that stricter management measures in WCPFC and IATTC have been in place since 2015.

Table 2. Changes of estimated age-specific *F*s of Pacific bluefin tuna (*Thunnus orientalis*) from 2002-2004 to 2012-2014 and 2015-2016.

	Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Change from	F2012-14	-9%	-42%	24%	-10%	-11%	-25%	-35%	-7%	-3%	-23%	0%	7%	11%	13%	15%	16%	17%	18%	19%	19%	20%
F2002-04 to	F2015-16	-49%	-57%	-21%	25%	56%	34%	18%	-3%	-15%	-24%	-13%	-11%	-8%	-7%	-5%	-4%	-3%	-3%	-2%	-2%	-1%

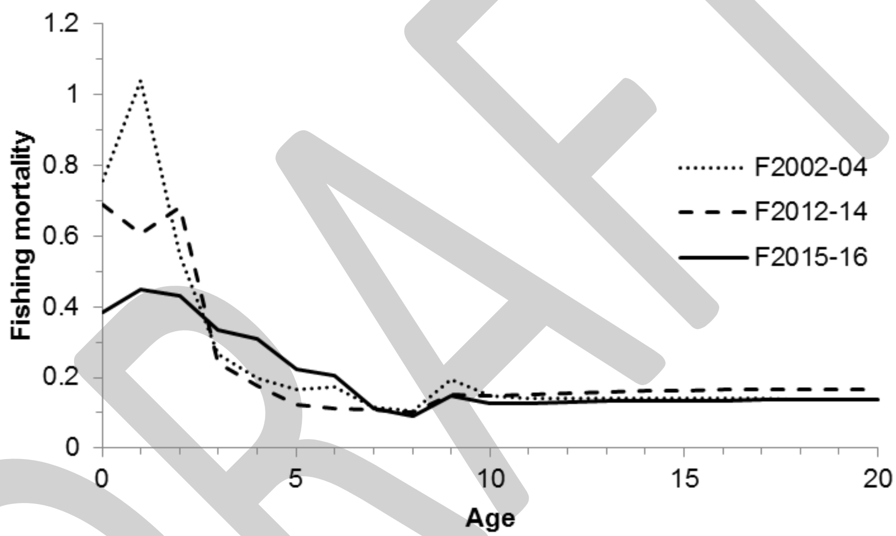

Figure 5. Geometric means of annual age-specific fishing mortalities of Pacific bluefin tuna (*Thunnus orientalis*) in 2002-2004 (dotted line), 2012-2014 (dashed line), and 2015-2016 (solid line).

With respect to reference points, the WCPFC adopted an initial rebuilding target (the median SSB estimated for the period 1952 through 2014) and a second rebuilding target (20%$SSB_{F=0}$ under average recruitment), without specifying a fishing mortality reference level. The 2018 assessment estimated the initial rebuilding target to be 6.7%$SSB_{F=0}$ and the corresponding fishing mortality expressed as spawning potential ratio (SPR) to be $F_{6.7\%SPR}$ (Table 3). Spawning potential ratio (SPR) is the ratio of cumulative spawning biomass that an average recruit is expected to produce over its lifetime when the stock is fished at the current intensity to the cumulative spawning biomass that could be produced by a recruit over its lifetime when the stock is unfished. Spawning potential ratio is often used as a measure of fishing intensity when selectivity changes substantially over time, as is the case with Pacific bluefin tuna. $F_{6.7\%SPR}$ describes a fishing mortality and aggregate fishery selectivity pattern that is expected to produce 6.7% of the cumulative unfished spawning biomass; a low number is consistent with high fishing mortality on the stock. Because the projections contain catch limits, fishing mortality is expected to decline, i.e., $Fx_{\%SPR}$ will increase, as biomass increases. The Kobe plot shows that the point estimate of the 2016 SSB was 3.3%$SSB_{F=0}$ and the 2016 fishing mortality corresponds to $F_{6.7\%SPR}$ (Figure 6). Table 3bis provides the evaluation of the stock status of PBF against common reference points. It shows that the PBF stock is overfished relative to biomass-based limit reference points adopted for other species in WCPFC (20%$SSB_{F=0}$) and is subject to overfishing relative to most of the common fishing intensity-based reference points.

Table 3. Comparison of spawning stock biomass and fishing intensity of Pacific bluefin tuna (*Thunnus orientalis*) in 1995 (recent high biomass), 2002-2004 (WCPFC reference year), 2011 (5 years ago), and 2016 (latest) to those of the rebuilding targets. SPR refers to spawning potential ratio, which is used as a measure of fishing intensity.

	initial rebuilding target	second rebuilding target	1995 (recent high)	2002-2004 (reference year)	2011 (5 years ago)	2016 (latest)
Biomass (%$SSB_{F=0}$)	SSB median 1952-2014 = 6.7%	20%	10.4%	7.1%	2.1%	3.3%
Fishing intensity (SPR)	6.7%	20%	5.1%	3.4%	4.9%	6.7%

Table 3bis. Ratios of the estimated fishing mortalities F2002-2004, F2012-2014 and F2015-2016 relative to computed fishing intensity-based biological reference points and SSB (t) and depletion ratio for the terminal year of the reference period for PBF.

	F_{max}	$F_{0.1}$	F_{med}	F_{loss}	$F_{10\%}$	$F_{20\%}$	$F_{30\%}$	$F_{40\%}$	Estiamted SSB for terminal year of each reference period	Depletion ratio for terminal year of each reference period
2002-2004	1.77	2.47	1.04	0.78	1.25	1.80	2.41	3.18	40,707	6.3%
2012-2014	1.47	2.04	0.86	0.65	1.03	1.49	2.00	2.63	19,031	3.0%
2015-2016	1.32	1.85	0.78	0.58	0.93	1.35	1.81	2.38	21,331	3.3%

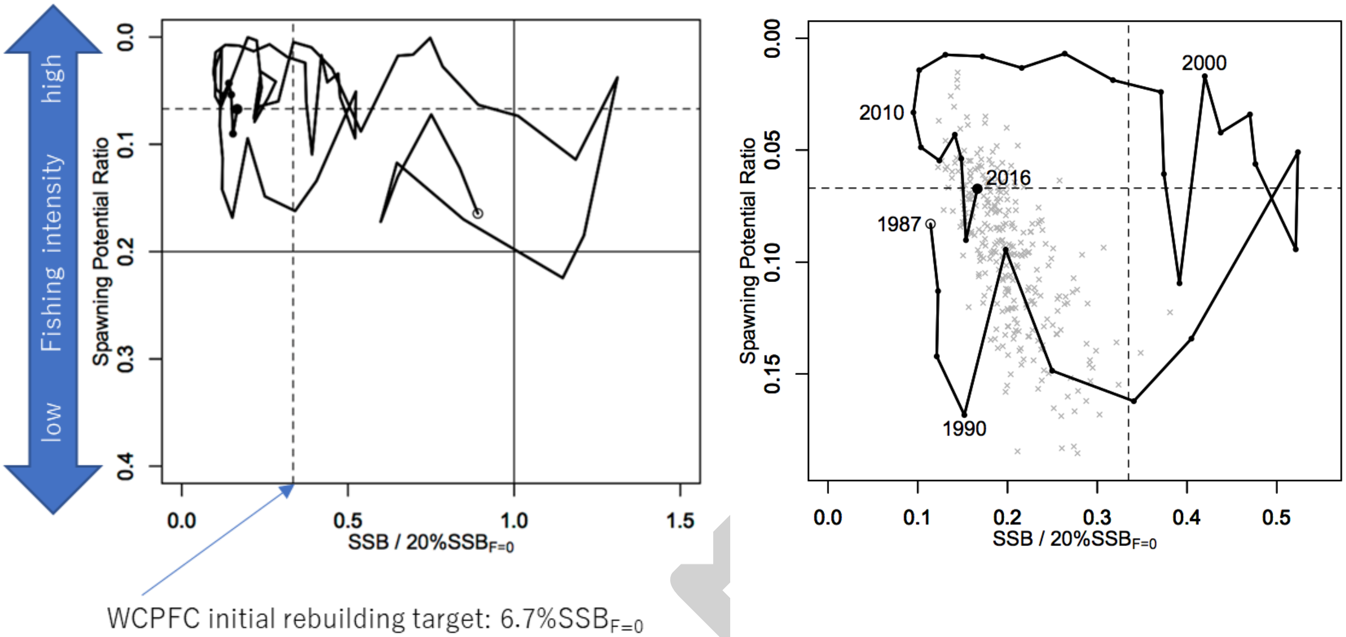

Figure 6. Kobe plots for Pacific bluefin tuna (*Thunnus orientalis*). X axis shows the annual SSB relative to 20%$SSB_{F=0}$ and the Y axis shows the spawning potential ratio as a measure of fishing intensity. Solid vertical and horizontal lines in the left figure show 20%$SSB_{F=0}$ and the corresponding fishing intensity, respectively (which also corresponds to the second rebuilding target). Dashed vertical and horizontal lines in both figures show the initial rebuilding target (SSB_{MED} = 6.7%$SSB_{F=0}$) and the corresponding fishing intensity, respectively. SSB_{MED} is calculated as the median of estimated SSB over 1952-2014. The left figure shows the historical trajectory, where the open circle indicates the first year of the assessment (1952) while solid circles indicate the last five years of the assessment (2012-2016). The right figure shows the trajectory of the last 30 years, where grey crosses indicate the uncertainty of the terminal year.

Figure 7 depicts the historical impacts of the fleets on the PBF stock, showing the estimated biomass when fishing mortality from respective fleets is zero. Historically, the WPO coastal fisheries group has had the greatest impact on the PBF stock, but since about the early 1990s the WPO purse seine fleets, in particular those targeting small fish (ages 0-1), have had a greater impact, and the effect of these fleets in 2016 was greater than any of the other fishery groups. The impact of the EPO fishery was large before the mid-1980s, decreasing significantly thereafter. The WPO longline fleet has had a limited effect on the stock throughout the analysis period because the impact of a fishery on a stock depends on both the number and size of the fish caught by each fleet; i.e., catching a high number of smaller juvenile fish can have a greater impact on future spawning stock biomass than catching the same weight of larger mature fish.

Based on these findings, the following information on the status of the Pacific bluefin tuna stock is provided:

1. No biomass-based limit or target reference points have been adopted to evaluate overfished status for PBF. However, the PBF stock is overfished relative to biomass-based reference points adopted by WCPFC for other species (Table 3bis).
2. No fishing intensity-based limit or target reference points have been adopted to evaluate overfishing for PBF. However, the PBF stock is subject to overfishing relative to most of commonly adopted fishing intensity-based reference points (Table 3bis).

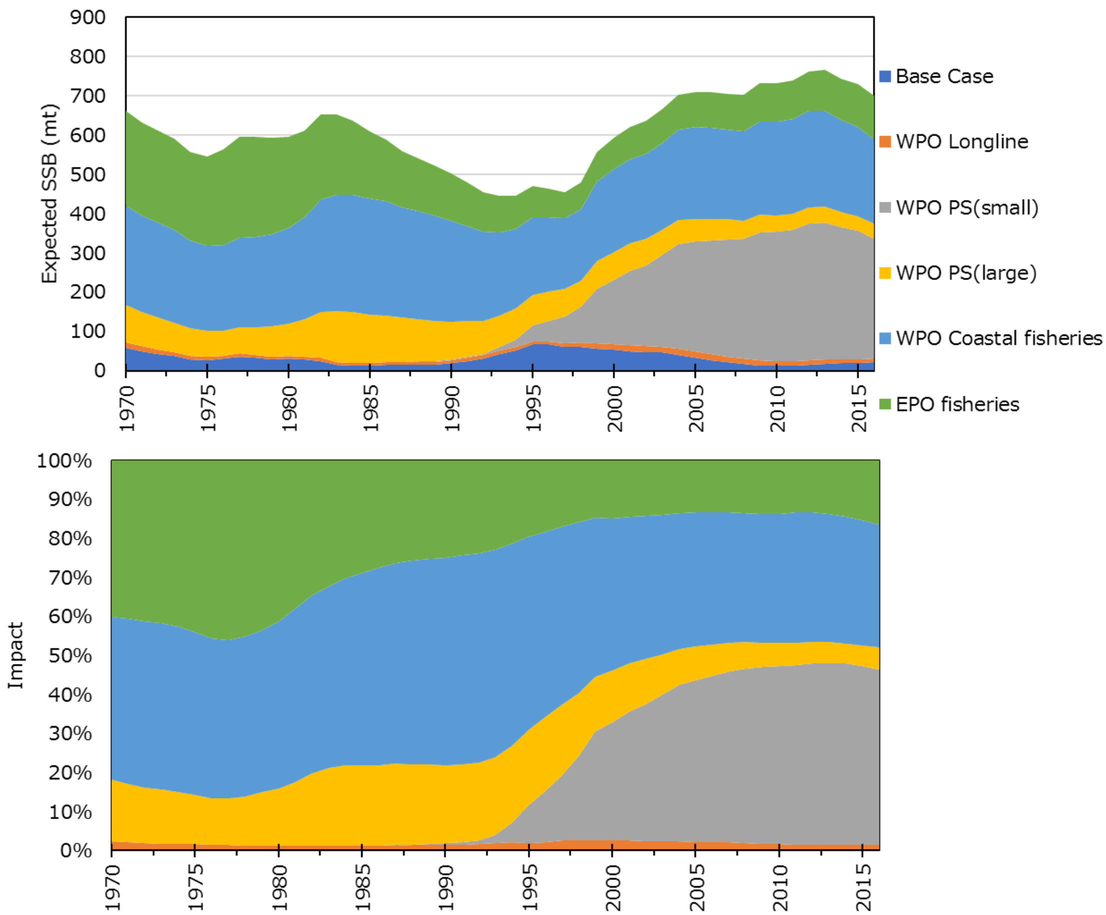

Figure 7. Trajectory of the spawning stock biomass of a simulated population of Pacific bluefin tuna (*Thunnus orientalis*) when zero fishing mortality is assumed, estimated by the base-case model. (top: absolute impact, bottom: relative impact). Fleet definition; WPO longline: F1, F12, F17. WPO purse seine for small fish: F2, F3, F18. WPO purse seine: F4, F5. WPO coastal fisheries: F6-11, F16, F19. EPO fisheries: F13, F14, F15.

Conservation Information

After the steady decline in SSB from 1995 to the historical low level in 2010, the PBF stock appears to have started recovering slowly. The stock biomass is below the two rebuilding targets adopted by the WCPFC while the fishing intensity (spawning potential ratio) is at a level corresponding to the initial rebuilding target.

The Harvest Strategy proposed at the Joint WCPFC NC-IATTC WG meeting and adopted by the WCPFC (Harvest Strategy 2017-02) guided projections conducted by the ISC to provide catch reduction options if the projection results show that the initial rebuilding target will not be achieved at least with 60% by 2024 or to provide relevant information for a potential increase in catch if the probability of achieving the initial rebuilding target exceeds 75% by 2024.

The 2018 base case assessment results are consistent with the 2016 model results. However, the 2018 projection results are more optimistic than the 2016 projections, mainly due to the inclusion of the relatively good recruitment in 2016, which is twice as high as the median of assumed low recruitment scenario (1980-1989). Based on the performance analyses of the recruitment estimates using an age-structured production model and the retrospective diagnostics, terminal year recruitment estimates were included in the projections. The magnitude of terminal year recruitment is generally more uncertain than those of other years because it is based on one observation in 2016. As this 2016 year-class are observed in more fisheries in subsequent years, the uncertainty concerning the magnitude of this recruitment will be reduced and the estimated recruitment may differ, which will influence the projections and the probabilities of achieving both rebuilding targets.

The projection based on the base-case model mimicking the current management measures by the WCPFC (CMM 2017-08) and IATTC (C-16-08) under the low recruitment scenario resulted in an estimated 98% probability of achieving the initial rebuilding target by 2024. This estimated probability is above the threshold (75% or above in 2024) prescribed by the WCPFC Harvest Strategy (Harvest Strategy 2017-02) (scenario 0 of Table 4-6; Table 4: list of catch scenarios, Table 5: performance of the scenarios, Table 6: expected yield of the scenarios. See also Figure 8). The low recruitment scenario is more precautionary than the recent 10 years recruitment scenario. In the Harvest Strategy, the recruitment scenario is switched from the low recruitment to the average recruitment scenario beginning in the year after achieving the initial rebuilding target. The estimated probability to achieve the second rebuilding target was evaluated 10 years after the achievement of the initial rebuilding target or by 2034, whichever is earlier, is 96% (scenario 1 of Table 4-6; Figure 8 & 9). This estimate is above the threshold (60% or above in 2034) prescribed by the WCPFC Harvest Strategy. However, it should be recognized that these projection results are strongly influenced by the inclusion of the relatively high, but uncertain recruitment estimate for 2016.

Given the low SSB, the uncertainty in future recruitment, and the influence of recruitment on stock biomass, monitoring recruitment and SSB should be strengthened so that the recruitment trends can to be understood in a timely manner.

Table 4. Future projection scenarios for Pacific bluefin tuna (*Thunnus orientalis*).

Scenario #	Fishing mortality*1	WPO Catch limit Japan*2 Small	WPO Catch limit Japan*2 Large	WPO Catch limit Korea Small, Large	WPO Catch limit Taiwan Large	EPO*3 Catch limit Commercial Small, Large	EPO*3 Catch limit Sports	Catch limit Increase WPO Small, Large	Catch limit Increase EPO Small, Large
0[*4]	F	4,007	4,882	718	1,700	3,300	-	0%	0%
1	F	4,007	4,882	718	1,700	3,300	−	0%	0%

*1 F indicated the geometric mean values of quartaly age-specific fishing mortality during 2002-2004.
*2 The Japanese unilateral measure (transfering 250 mt of catch upper limit from that for small PBF to that for large PBF during 2017-2020) would be reflected.
*3 Fishing mortality for the EPO commercial fishery was asssumed to be enough high to fullfill its catch upper limit (F multiplied by two). The fishing mortality for the EPO recreational fishery was assumed to be F2009-11 average level.
*4 In scenario 0, the future recrutment were assumed to be the low recruitment (1980-1989 level) forever. In other scenarios, recruitment was switched from low recruitemnt to average recruitment from the next year of achieving the initial rebuilding target.

Table 5. Future projection scenarios for Pacific bluefin tuna (*Thunnus orientalis*) and their probability of achieving various target levels by various time schedules based on the base-case model.

Scenario #	Catch limit Increase WPO Small, Large	Catch limit Increase EPO Small, Large	Initial rebuilding target: The year expected to achieve the target with >60% probability	Initial rebuilding target: Probability of achiving the target at 2024	Initial rebuilding target: Probability of SSB is below the target at 2024 under the low recruitment	Second rebuilding target: The year expected to achieve the target with >60% probability	Second rebuilding target: Probability of achiving the target at 2034	Median SSB (mt) at 2034
0[*1]	0%	0%	2020	98%	2%	N/A	3%	74,789
1	0%	0%	2020	99%	2%	2028	96%	263,465

*1 In scenario 0, the future recrutment were assumed to be the low recruitment (1980-1989 level) forever. In other scenarios, recruitment was switched from low recruitemnt to average recruitment from the next year of achieving the initial rebuilding target.

Table 6. Expected yield for Pacific bluefin tuna (*Thunnus orientalis*) under various harvesting scenarios based on the base-case model.

Scenario #	Catch limit Increase				Expected annual yield in 2019, by area and size category (mt)				Expected annual yield in 2024, by area and size category (mt)				Expected annual yield in 2034, by area and size category (mt)			
	WPO		EPO		WPO		EPO		WPO		EPO		WPO		EPO	
	Small	Large	Small	Large	Small	Large	Small	Large	Small	Large	Small	Large	Small	Large	Small	Large
0	0%	0%	0%		4,477	4,384	3,530		4,704	6,133	3,457		4,704	6,211	3,451	
1	0%	0%	0%		4,477	4,384	3,530		4,745	6,202	3,665		4,747	6,640	3,703	

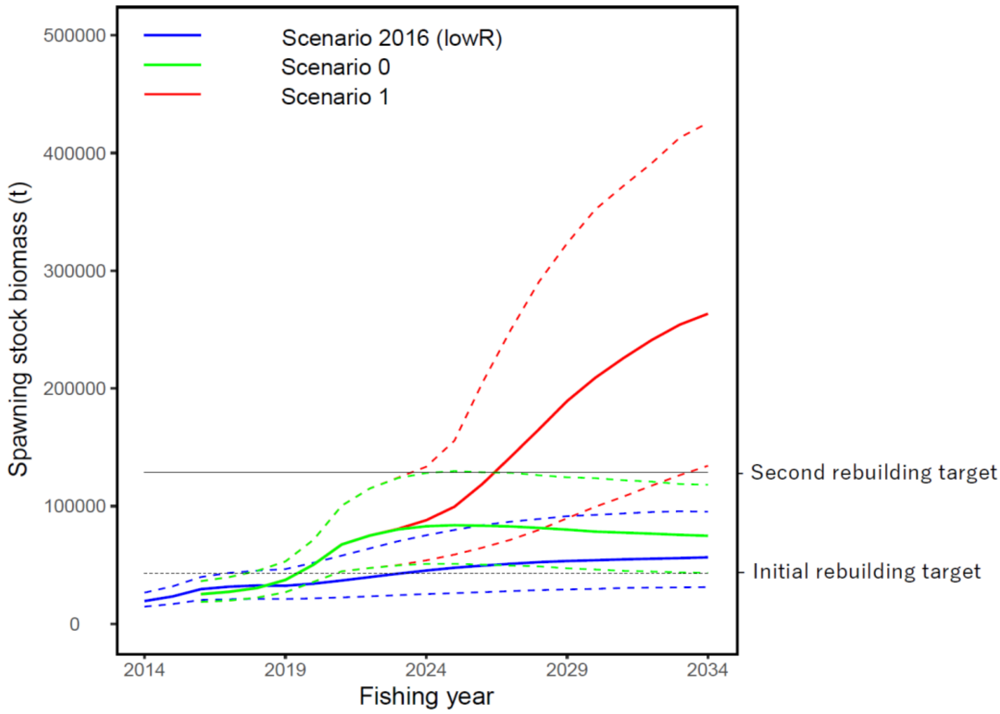

Figure 8. Comparison of future SSB under the current measures by assuming low recruitement using the 2016 assessment (scenario 2016 lowR), assuming low recruitment using the 2018 assessment (scenario 0), and assuming a shift of the recruitment scenario from low to average after achieving the initial rebuilding target using the 2018 assessment (scenario 1).

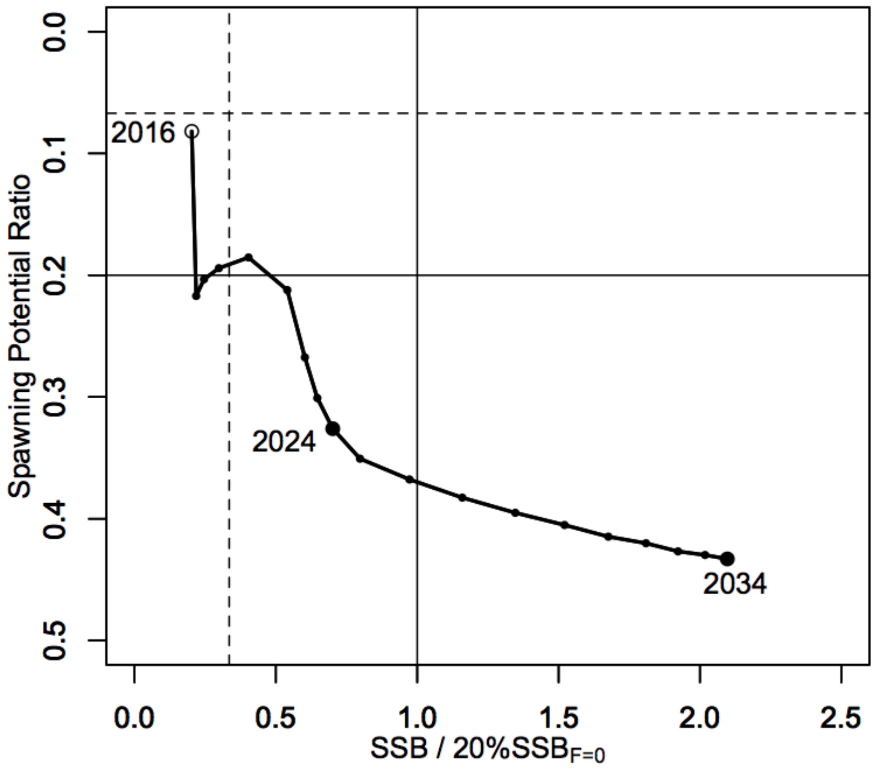

Figure 9. A projection result (scenario 1 from Table 4) for Pacific bluefin tuna (*Thunnus orientalis*) in a form of Kobe plot. X axis shows the relative SSB value to 20%$SSB_{F=0}$ (second rebuilding target) and Y axis shows the spawning potential ratio as a measure of fishing intensity. Vertical and horizontal solid lines indicate the second rebuilding target (20%$SSB_{F=0}$) and the corresponding fishing intensity, respectively, while vertical and horizontal dashed lines indicate the initial rebuilding target (SSB_{MED} = 6.7%$SSB_{F=0}$) and the corresponding fishing intensity, respectively.