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ISC'S RESPONSE TO NC9'S INFORMATION REQUEST S REGARDING NORTH PACIFIC ALBACORE TUNA AND PACIFIC BLUEFIN TUNA

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

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ISC'S RESPONSE TO NC9'S INFORMATION REQUESTS REGARDING NORTH PACIFIC ALBACORE TUNA AND PACIFIC BLUEFIN TUNA[1]

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ISC'S RESPONSE TO NC9'S INFORMATION REQUESTS REGARDING NORTH PACIFIC ALBACORE TUNA AND PACIFIC BLUEFIN TUNA

TAIPEI, JULY 2014

The International Scientific Committee for Tuna and Tuna-Like Species provides the following information to the Northern Committee in response to their requests stemming from NC9 on North Pacific albacore tuna (section A) and Pacific bluefin tuna (section B).

A. ALBACORE TUNA

The Northern Committee (NC) of the Western and Central Pacific Fisheries Committee (WCPFC) sought information on a list of potential limit reference points (LRPs) for north Pacific albacore tuna (*Thunnus alalunga*) during its Eight Regular Session and requested that the ISC update its responses based on the 2014 stock assessment results during its Ninth Regular Session in September 2013. The WG discussed the request and developed the updated responses, including new calculations of reference points and depletion probabilities, shown in *ISC/14/ANNEX10/ATTACHMENT7*

ATTACHMENT 7 (from *ISC14/Annex 10*)

INFORMATION AND ADVICE ON BIOLOGICAL REFERENCE POINTS FOR NORTH PACIFIC ALBACORE UPDATED WITH 2014 STOCK ASSESSMENT RESULTS

This document updates the information and advice requested by the Eighth Regular Session of the Northern Committee (NC8) using the 2014 stock assessment results (Appendix 1). These updates were developed by the Albacore Working Group (WG) during the assessment workshop, April 14-28, 2014 in La Jolla, USA. The organization of this document follows the questions posed by NC8.

1.0 ASSESSMENT MODEL PARAMETERS

1.1 Stock-recruitment Relationship and Steepness Parameter

The 2014 stock assessment assumed that a Beverton-Holt stock recruitment relationship was representative of stock-recruitment dynamics in the north Pacific albacore stock and that the value of the steepness parameter (h) in this relationship is 0.9. The assumption of a Beverton-Holt stock-recruitment relationship is considered plausible, although the relationship may be weak. Two separate estimates of the steepness parameter based on life history theory provide evidence that plausible values of h are in the range $0.6 < h < 1.0$, with separate estimates reporting peak frequency distribution values of 0.84 and 0.95, respectively (Brodziak et al. 2011; Iwata et al. 2011). The steepness value assumed in the 2014 assessment is the median between these estimates ($h = 0.9$) and is considered reasonable by the WG based on its knowledge of albacore stock productivity relative to other highly migratory species. However, the WG notes that there are likely long-term environmental trends affecting recruitment in addition to the stock recruitment relationship.

1.2 Biological and Fishery Parameters

The age-based maturity schedule used in the 2014 stock assessment is identical to the schedule used in the 2011 assessment: 50% of albacore at age-5 are assumed to be sexually mature and all fish age-6 and older are mature. This age-based maturity schedule is considered reasonable, but it is based on maturity data that are more than 40 years old and there is a need to develop a better description of maturity at age or length for north Pacific albacore since existing information does not capture spatial variation in maturity across the range of the adult component of this stock.

Natural mortality, M, was not estimated in the 2014 assessment model, but was fixed at 0.3 yr^{-1} for all ages. The assumed value was taken from assessments of Atlantic albacore (e.g., ICCAT 2010) and was used in previous assessments. The WG recognizes the need to develop estimates of sex-specific natural mortality for north Pacific albacore because a two sex model was used for the 2014 assessment and there are clear differences in sex ratio with increasing size.

Given the data inputs and model structure, the WG concludes that fishery selectivity for north Pacific albacore is well estimated for the eight fleets for which size composition data are available. Selectivity of fleets for which no size data were available was assumed to be identical to one of the eight fleets based on similarities in operating characteristics.

2.0 CANDIDATE REFERENCE POINTS

2.1 Estimated Yields and Probabilities

Advice on expected future yields and variability under low, average, and high historical recruitment scenarios over a 10-yr projection period was requested by NC8 and NC9 to assist in determining the suitability of candidate reference points. Additional information in the form of the estimated probability of breaching the Interim Management Objective (average of the 10 historical lowest years of SSB) and several biomass depletion levels for each candidate reference point harvest scenario was also requested. The WG developed separate tables to provide these estimates for low, average, and high historical recruitment scenarios (Tables 1 to 3). These estimates are based on the 2014 assessment model, which includes data through 2012.

Methods - Biomass depletion levels are calculated relative to $SSB_{F=0}$, which is estimated as the mean spawning biomass ($N = 100$) at the terminal year of a 30-yr projection with F=0 for a given level of low, average, or high recruitment, i.e., the mean SSB at 2041. Thus, a different average value of $SSB_{F=0}$ was calculated for each recruitment scenario and applied to the nine harvest scenarios. Estimating $SSB_{F=0}$ was a first and separate step from the projections described below.

A second set of projections to derive estimates of future yield and probabilities that biomass will fall below depletion levels in at least one year of the projection period was performed with the R package "ssfuture" (Ichinokawa 2012,) which was also used for future projections in the 2014 stock assessment. Biological parameter values and initial population number were estimated for 2011 and recruitment was estimated by random resampling of the low, average, or high historical recruitment period data from the 2014 base case model. Projections were conducted for 27 combinations of recruitment (three scenarios) and constant harvests strategies (nine scenarios corresponding to candidate reference points $F_{SSB\text{-}ATHL}$, F_{MSY}, $F_{0.1}$, F_{MED}, $F_{10\%}$, $F_{20\%}$, $F_{30\%}$, $F_{40\%}$ and $F_{50\%}$). One hundred (100) bootstrap replicates were used to estimate the mean expected yield (±CV) and the probability that SSB would fall below biomass depletion levels at a constant fishing mortality equivalent to the candidate reference points for each recruitment-harvest combination projection. Mean expected yield is calculated as average harvest at the terminal year of the projection, which is 2021 for 10-year and 2036 for the 25-year projections.

Results - Expected yield for all harvest scenarios increases with increasing recruitment level and the differences between yield in the low and high recruitment scenarios ranges between 50,000 and 72,000 t, depending on the harvest scenario used (Tables 1 to 3). The

F_{MSY}, $F_{10\%}$, and $F_{20\%}$ harvest scenarios produce similar large expected yields and while the $F_{SSB-ATHL}$ scenario produces the lowest expected yield regardless of the length of the projection period 10 or 25 years) . Expected yield increases approximately 33% between the minimum and maximum values in all recruitment scenarios.

The WG notes that improvements implemented in the 2014 assessment model affect the $F_{SSB-ATHL}$ reference point. The biomass trajectory in the current assessment has changed relative to the 2011 model, with a low biomass period occurring at the end of the modeled time frame. Because of this change, the estimated SSB–ATHL threshold differs from the previous assessment and now includes several recent years (2007-2010) in its calculation. However, the WG also notes that the point estimate of this threshold is 117,835 t, which is more than twice the SSB_{MSY} level (49,680 t) estimated by the 2014 base case model. Consideration should be given to determining whether it is appropriate to include recent years in the calculation of this threshold since the threshold is used to evaluate the current status of the stock based on those recent years.

The probability of depleting spawning biomass (SSB) to various levels varies with the harvest scenarios, but in general the probabilities for a given harvest scenario are higher when low recruitment is assumed than high recruitment (Tables 1 and 3). Probabilities are highest for the high yield harvest scenarios (F_{MSY}, $F_{10\%}$, $F_{20\%}$) and lowest for the $F_{SSB-ATHL}$ harvest scenario. The probability of depletion decreases as the depletion level increases from $SSB_{40\%}$ to $SSB_{10\%}$ in all recruitment scenarios (Tables 1-3).

2.3 Harvest Scenarios Relative to Reference Points

Estimated F-ratios of candidate reference points for two different constant harvest scenarios ($F_{2002-2004}$, $F_{2010-2012}$) are shown in Table 4 to determine if reference point levels are exceeded. It is important to note that the WG used selectivity for $F_{2002-2004}$ and $F_{2010-2012}$, respectively, for these calculations. The WG also notes that all reference point ratios were calculated by SS except $F_{0.1}$, which was based on yield-per-recruit (YPR) analysis because SS has no calculation option for this reference point. This means that the quantitative basis for the $F_{0.1}$ calculation differs from the other reference points.

$F_{2002-2004}/F_{RP}$ ratios are consistently higher than $F_{2010-2012}/F_{RP}$ ratios with a maximum difference of 46% for F_{MSY}. The $F_{50\%}$ and F_{MED} reference point ratios exceeded 1.0 under an F-current ($F_{2010-2012}$) harvest scenario, the remaining ratios were less than 1.0 for Fcurrent.

2.4 Environmental Influences on Candidate Reference Points

The north Pacific albacore stock is modeled as an recruitment-driven stock in 2014 since there is little evidence at present that fishing has reduced SSB below thresholds associated with the majority of biomass-based reference points that might be chosen. The WG suspects but does not have strong evidence at present supporting the hypothesis that recruitment is "environmentally driven" in addition to the stock-recruitment effect implicit in the assumption of a steepness parameter of h=0.9. Kiyofuji (2013) presented a working paper that provides evidence of cyclic changes in albacore recruitment levels (high, low, average) that seems to fit regime shifts in productivity of the North Pacific Ocean in the 1970s and 1980s. Zhang et al. (2013) showed that stock productivity, when modeled with a logistic surplus production model, was positively affected by the North Pacific Gyre Oscillation (NPGO) and negatively affected by the multi-variate ENSO index (MEI) at a lag period of four years. Hokimoto and Kiyofuji (2013) demonstrated that changes in phytoplankton concentration impact the migration behavior of albacore based on the in-situ data and were able to develop a model to predict albacore location depending on the chlorophyll-a concentration of phytoplankton. Although it is not clear what population process is impacted by large scale climate forcing represented by the

NPGO and MEI, Zhang et al. (2013) and the WG speculate that these results could be a latent recruitment effect.

A preliminary assessment of the effects of regime shifts on values of F_{SPR}s can be accomplished by comparing the results for the low and high recruitment scenarios in Tables 1 and 3. The probability of SSB breaching the Interim Management Objective and other depletion levels when harvesting at F_{MSY}, $F_{10\%}$ and $F_{20\%}$ was higher than the other harvests scenarios for both high and low recruitment assumptions. Depletion probabilities were always higher in the low recruitment scenario relative to those of high recruitment scenario and these differences range from 20 to 60%.

3.0 Literature Cited

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Zhang, Z., Holmes, J., and Teo, S.L.H. 2013. A Study on Effects of Climatic Variables on the Production of the North Pacific Albacore Tuna Population. Working paper ISC/13/ALBWG-01/04 presented at the ISC Albacore Working Group Meeting, 19-25 March 2013, Shanghai Ocean University, Shanghai, China.

Table 1. Expected future yield at the end of the projection period (± CV) and estimated probabilities that SSB will be lower than several biomass depletion level thresholds in at least one year of the projection period under nine constant harvest scenarios corresponding to candidate reference points and the low historical recruitment scenario. $SSB_{F=0\ xx\%}$ refers to spawning biomass depletion relative to the unfished state. Probabilities highlighted in bold are ≥ 0.50.

Low Historical Recruitment Scenario

				Biomass Depletion Level				
Reference Point	Projection Period (yr)	Future* Yield (mt)	CV	SSB-ATHL	$SSB_{F=0\ 10\%}$	$SSB_{F=0\ 20\%}$	$SSB_{F=0\ 30\%}$	$SSB_{F=0\ 40\%}$
$F_{SSB\text{-}ATHL}$	25	63,111	(0.08)	**0.84**	0.00	0.00	0.15	**0.60**
$F_{SSB\text{-}ATHL}$	10	68,987	(0.07)	**0.71**	0.00	0.01	0.16	0.46
F_{MSY}	10	90,956	(0.10)	**0.92**	**0.51**	**0.69**	**0.79**	**0.86**
$F_{0.1}$	10	74,663	(0.08)	**0.78**	0.00	0.06	0.35	**0.60**
F_{MED}	10	70,294	(0.08)	**0.73**	0.00	0.01	0.19	**0.50**
$F_{10\%}$	10	91,910	(0.11)	**0.95**	**0.68**	**0.79**	**0.85**	**0.91**
$F_{20\%}$	10	90,570	(0.09)	**0.92**	0.47	**0.67**	**0.78**	**0.86**
$F_{30\%}$	10	86,158	(0.09)	**0.88**	0.12	**0.52**	**0.68**	**0.79**
$F_{40\%}$	10	80,337	(0.08)	**0.83**	0.00	0.22	**0.53**	**0.70**
$F_{50\%}$	10	72,115	(0.08)	**0.75**	0.00	0.03	0.25	**0.55**

*Future yield is estimated for females and doubled to account for males.

Table 2. Expected future yield at the end of the projection period (± CV) and estimated probabilities that SSB will be lower than several biomass depletion level thresholds in at least one year of the projection period under nine constant harvest scenarios corresponding to candidate reference points and the average historical recruitment scenario. $SSB_{F=0\ xx\%}$ refers to spawning biomass depletion relative to the unfished state. Probabilities highlighted in bold are ≥ 0.50.

Average Historical Recruitment Scenario

				Biomass Depletion Level				
Reference Point	Projection Period (yr)	Future* Yield (mt)	CV	SSB-ATHL	$SSB_{F=0\ 10\%}$	$SSB_{F=0\ 20\%}$	$SSB_{F=0\ 30\%}$	$SSB_{F=0\ 40\%}$
$F_{SSB\text{-}ATHL}$	25	90,467	(0.09)	**0.50**	0.00	0.00	0.23	**0.72**
$F_{SSB\text{-}ATHL}$	10	97,869	(0.09)	**0.55**	0.00	0.01	0.30	**0.74**
F_{MSY}	10	130,623	(0.12)	**0.92**	**0.57**	**0.78**	**0.88**	**0.96**
$F_{0.1}$	10	106,636	(0.10)	**0.73**	0.00	0.11	**0.53**	**0.84**
F_{MED}	10	99,887	(0.09)	**0.61**	0.00	0.03	0.35	**0.78**
$F_{10\%}$	10	132,641	(0.14)	**0.95**	**0.73**	**0.85**	**0.92**	**0.97**
$F_{20\%}$	10	129,028	(0.12)	**0.92**	**0.53**	**0.76**	**0.88**	**0.95**
$F_{30\%}$	10	123,664	(0.11)	**0.88**	0.16	**0.62**	**0.81**	**0.90**
$F_{40\%}$	10	114,441	(0.10)	**0.81**	0.00	0.31	**0.69**	**0.89**
$F_{50\%}$	10	102,666	(0.09)	**0.66**	0.00	0.05	0.42	**0.81**

*Future yield is estimated for females and doubled to account for males.

Table 3. Expected future yield at the end of the projection period (± CV) and estimated probabilities that SSB will be lower than several biomass depletion level thresholds in at least one year of the projection period under nine constant harvest scenarios corresponding to candidate reference points and the high historical recruitment scenario. $SSB_{F=0\ xx\%}$ refers to spawning biomass depletion relative to the unfished state. Probabilities highlighted in bold are ≥ 0.50.

High Historical Recruitment Scenario

				Biomass Depletion Level				
Reference Point	Projection Period (yr)	Future* Yield (mt)	CV	SSB-ATHL	$SSB_{F=0\ 10\%}$	$SSB_{F=0\ 20\%}$	$SSB_{F=0\ 30\%}$	$SSB_{F=0\ 40\%}$
$F_{SSB\text{-}ATHL}$	25	113,178	0.07	0.20	0.00	0.00	0.27	**0.82**
$F_{SSB\text{-}ATHL}$	10	121,006	0.07	0.38	0.00	0.02	0.45	**0.92**
F_{MSY}	10	162,487	0.09	**0.92**	**0.62**	**0.83**	**0.94**	**0.99**
$F_{0.1}$	10	132,120	0.07	**0.63**	0.00	0.15	**0.71**	**0.94**
F_{MED}	10	123,643	0.07	0.43	0.00	0.03	**0.51**	**0.92**
$F_{10\%}$	10	163,931	0.09	**0.95**	**0.77**	**0.88**	**0.96**	**0.99**
$F_{20\%}$	10	161,209	0.08	**0.92**	**0.58**	**0.82**	**0.93**	**0.99**
$F_{30\%}$	10	153,149	0.08	**0.88**	0.17	**0.70**	**0.90**	**0.99**
$F_{40\%}$	10	142,139	0.07	**0.79**	0.00	0.39	**0.83**	**0.97**
$F_{50\%}$	10	126,947	0.07	**0.51**	0.00	0.07	**0.60**	**0.93**

*Future yield is estimated for females and doubled to account for males.

Table 4. Potential reference points and estimated F-ratios using Fcurrent ($F_{2010-2012}$) and $F_{2002-2004}$ (current F in the 2006 assessment that lead to the implementation of CMMs). Ratios ≥ 1.0 are highlighted in bold.

Reference Point	$F_{2010-2012}/F_{RP}$	$F_{2002-2004}/F_{RP}$
$F_{SSB-ATHL}$	0.72	0.85
F_{MSY}	0.52	0.76
$F_{0.1}$	0.51	0.56
F_{MED}	**1.30**	**1.34**
$F_{10\%}$	0.63	0.71
$F_{20\%}$	0.71	0.80
$F_{30\%}$	0.81	0.92
$F_{40\%}$	0.94	**1.07**
$F_{50\%}$	**1.13**	**1.29**

B. PACIFIC BLUEFIN TUNA

In response to NC9's request (Attachment 1) for information on (B.1) the probability of reaching SSB benchmarks given certain harvest levels, (B.2) the range of historical variation in recruitment and (B.3) catch and effort data of juvenile and adult PBF for 1994 – present, ISC prepared the following. The analyses where B.1 and B.2 are addressed can be found in the ISC PBFWG working papers ISC14/PBFWG1-06 and ISC14/PBFWG-1/10rev. This document summarizes and consolidates the information.

B.1. Probabilities of reaching SSB benchmarks

(From *ISC/IM14/Annex 4*)

Table A summarizes the results of the future projections requested by NC9. Figures A, B, and C compare expected outcomes using combinations of seven harvest scenarios and three future recruitment scenarios. In relation to the projections requested by NC9, only Scenario 6[2], the strictest one, results in an increase in SSB even if the current low recruitment continues (Figures A-C). Given the result of Scenario 6, further substantial reductions in fishing mortality and juvenile catch over the whole range of juvenile ages should be considered to reduce the risk of SSB falling below its historically lowest level.

If the low recruitment of recent years continues, the risk of SSB falling below its historically lowest level observed would increase. This risk can be reduced with implementation of more conservative management measures.

Based on the results of future projections requested at NC9, unless the historical average level (1952-2011) of recruitment is realized, an increase of SSB cannot be expected under the current WCPFC and IATTC conservation and management measures[3], even under full implementation (Scenario 1)[4].

If the specifications of the harvest control rules used in the projections were modified to include a definition of juveniles that is more consistent with the maturity ogive[5] used in

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[2] For the WCPO, a 50% reduction of juvenile catches from the 2002-2004 average level and F no greater than *F2002-2004*. For the EPO, a 50% reduction of catches from 5,500 t. From the scientific point of view, juvenile catches were not completely represented in the reductions modeled under Scenario 6 for some fisheries although these reductions comply with the definition applied by the NC9.

[3] WCPFC: Reduce all catches of juveniles (age 0 to 3-(less than 30 kg)) by at least 15% below the 2002-2004 annual average levels, and maintain the total fishing effort below the 2002-2004 annual average levels. IATTC: Catch limit of 5000 t with an additional 500 t for commercial fisheries for countries with catch history. (1. In the IATTC Convention Area, the commercial catches of bluefin tuna by all the CPCs during 2014 shall not exceed 5,000 metric tons. 2. Notwithstanding paragraph 1, any CPC with a historical record of eastern Pacific bluefin catches may take a commercial catch of up to 500 metric tons of eastern Pacific bluefin tuna annually. (C-13-02), see https://www.iattc.org/PDFFiles2/Resolutions/C-13-02-Pacific-bluefin-tuna.pdf)

[4] Athough these measures assume *F* be kept below *F2002-2004*, *F2009-2011* was higher than *F2002-2004*

[5] 20% at age 3; 50% at age 4; 100% at age 5 and older.

the stock assessment, projection results could be different; for example, rebuilding may be faster. While no projection with a consistent definition of juvenile in any harvest scenario was conducted, any proposed reductions in juvenile catch should consider all non-mature individuals.

Given the low level of SSB, uncertainty in future recruitment, and importance of recruitment in influencing stock biomass, monitoring of recruitment should be strengthened to allow the trend of recruitment to be understood in a timely manner.

Table A. (from *ISC/IM14/Annex 4*). Results for the future projections requested by NC9 under seven harvest scenarios and assuming three future recruitment conditions where $SSB_{recent,F=0}$ is calculated using the most recent ten year's recruitment (2002-2011).

[dark shading] The harvest scenario will result in less than a 50% probability of archieving the reference level.
[light shading] 51-79% probability of archieving the reference level
[no shading] 80-100% probability of archieving the reference level.

NC9`s scenarios	Future recruit level		Within 10 years from 2014					Within 15 years from 2014					Mean yield in 2026 - 2028
			Probability achieving reference level at least one year					Probability achieving reference level at least one year					
	2014 - 2023 (10years)	From 2024	62KT (10%SSB0)	93KT (15%SSB0)	124KT (20%SSB0)	155KT (25%SSB0)	Historical Median(43KT)	62KT (10%SSB0)	93KT (15%SSB0)	124KT (20%SSB0)	155KT (25%SSB0)	Historical Median(43KT)	
No.1	Low	Low	0%	0%	0%	0%	4%	1%	0%	0%	0%	7%	13664.7
	Low	Middle	0%	0%	0%	0%	4%	3%	0%	0%	0%	14%	16320.9
	Middle	Middle	48%	24%	10%	4%	69%	76%	50%	29%	15%	90%	22932.5
No.2	Low	Low	1%	0%	0%	0%	5%	2%	0%	0%	0%	9%	13455.7
	Low	Middle	1%	0%	0%	0%	5%	4%	0%	0%	0%	17%	15817.9
	Middle	Middle	53%	30%	16%	8%	72%	80%	59%	40%	26%	92%	17572.0
No.3	Low	Low	1%	0%	0%	0%	9%	4%	0%	0%	0%	18%	13380.1
	Low	Middle	1%	0%	0%	0%	9%	8%	1%	0%	0%	29%	15447.2
	Middle	Middle	60%	36%	20%	10%	79%	87%	67%	48%	31%	96%	17019.4
No.4	Low	Low	1%	0%	0%	0%	2%	1%	0%	0%	0%	5%	13186.2
	Low	Middle	1%	0%	0%	0%	2%	2%	0%	0%	0%	9%	15834.0
	Middle	Middle	48%	27%	13%	5%	64%	77%	57%	37%	20%	87%	23565.0
No.5	Low	Low	3%	0%	0%	0%	16%	8%	1%	0%	0%	32%	14195.6
	Low	Middle	3%	0%	0%	0%	16%	16%	2%	0%	0%	46%	16225.3
	Middle	Middle	70%	43%	22%	10%	87%	92%	75%	52%	32%	98%	24219.0
No.6	Low	Low	51%	12%	2%	0%	85%	84%	39%	9%	2%	98%	17055.8
	Low	Middle	51%	12%	2%	0%	85%	90%	51%	17%	4%	99%	18767.5
	Middle	Middle	96%	83%	61%	38%	99%	100%	98%	91%	77%	100%	27453.9
No.7	Low	Low	6%	1%	0%	0%	31%	18%	2%	0%	0%	59%	14453.7
	Low	Middle	6%	1%	0%	0%	31%	30%	4%	0%	0%	73%	16502.3
	Middle	Middle	77%	49%	26%	13%	92%	96%	81%	59%	38%	99%	23316.9

Table B. Amount of Pacific bluefin tuna (*Thunnus orientalis*) catch reduction and catch limit by country by scenario.

			WPO : Catch limit (left) and amount of catch reduction(right) of juvenile by country						EPO : Quota by scenario			
	juvenile catch	adult catch	Japan		Korea		Taiwan		EPO Comm		EPO SPORT	
no1	85% of 2002-2004 average		6549	1156	1220	215	-	-	5500	-	-	-
no2	85% of 2002-2004 average	85% of 2002-2004 average	6549	1156	1220	215	-	-	5500	-	-	-
no3	85% of 2002-2004 average	85% of 2002-2004 average	6549	1156	1220	215	-	-	4675	-	-	-
no4	85% of 2002-2004 average		6549	1156	1220	215	-	-	4675	-	-	-
no5	75% of 2002-2004 average		5778	2004	1077	359	-	-	4125	-	-	-
no6	50% of 2002-2004 average		3852	3852	718	718	-	-	2750	-	-	-
no7	75% of 2002-2004 average		5778	2004	1077	359	-	-	4125	-	-	-

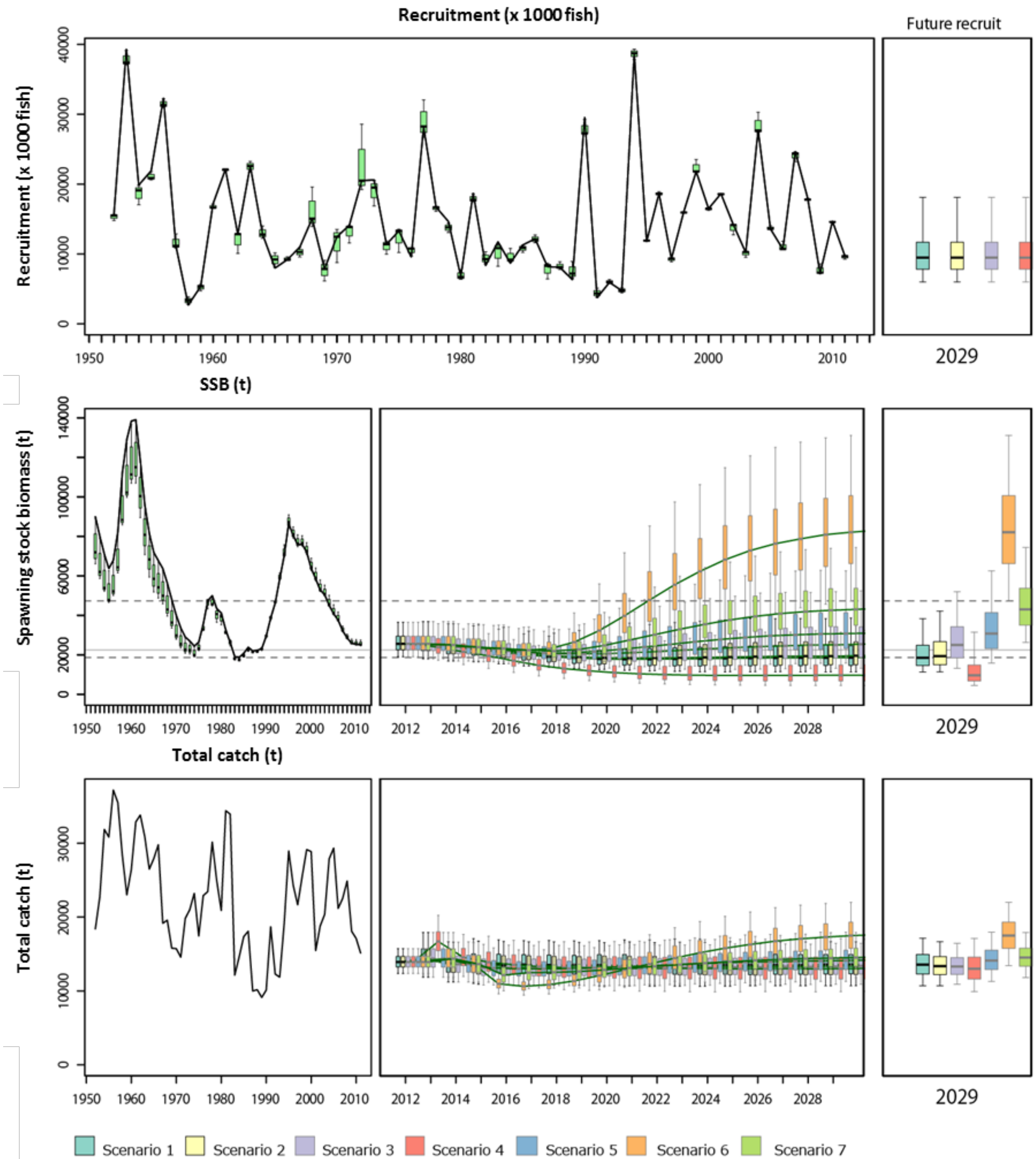

Figure A. Comparison of future Pacific bluefin tuna (*Thunnus orientalis*) SSB trajectories in seven harvest scenarios (see full text for scenario definitions) under low recruitment conditions. Error bars represent 90% confidence limits.

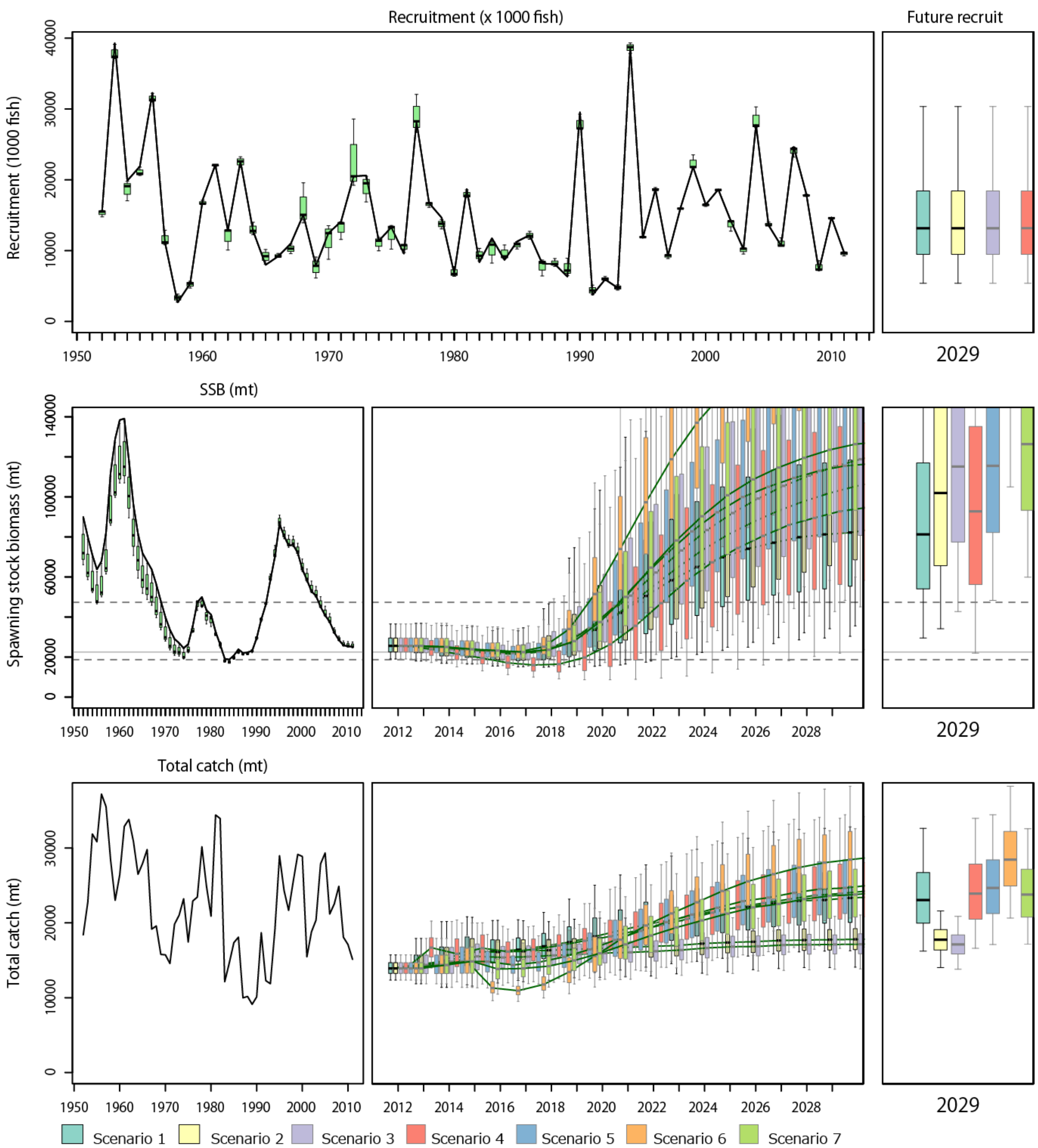

Figure B. Comparison of future Pacific bluefin tuna (*Thunnus orientalis*) SSB trajectories in seven harvest scenarios (see full text for scenario definitions) under average recruitment conditions (resampling from recruitment in 1952-2011). Error bars represent 90% confidence limits.

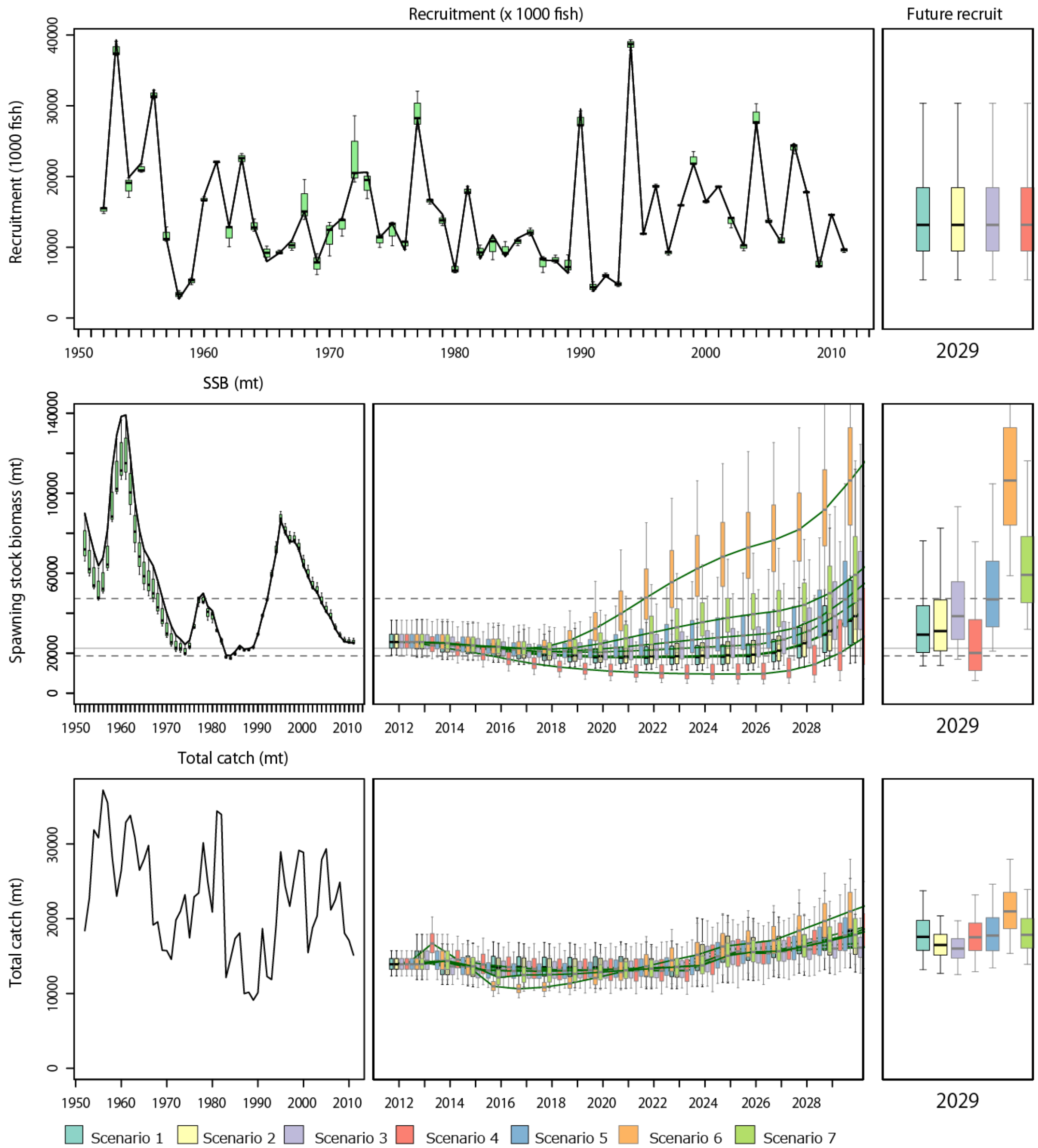

Figure C. Comparison of future Pacific bluefin tuna (*Thunnus orientalis*) SSB trajectories in seven harvest scenarios (see full text for scenario definitions) assuming 10 years (2014-2023) of low recruitment followed by average recruitment after 2024 (resampling from recruitment in 1952-2011). Error bars represent 90% confidence limits.

B.2. Range of Historical Variation in Recruitment

Regarding the range of historical variation in recruitment, such as in terms of standardized CPUEs for particular fisheries, or other appropriate measures, specifically; information for the low recruitment period during the 1980s, and for the last 10 years the PBFWG noted that (from *ISC14/Annex 16*):

i) shifts in recruitment were detected in 1994 and 2009 by a sequential regime shift detection method and the following three periods were defined: 1980-1993, 1994-2008 and 2009-2012;
ii) the recruitment of PBF was significantly lower in 1980-1993 and 2009-2012 than in 1994-2008; and
iii) significant positive relationships were found between the recruitment and CPUE in Nagasaki (R^2=0.581), Kochi (R^2=0.206) and Wakayama (R^2=0.288), and the recruitment forecasts using these relationships were thought to be promising.

The PBFWG also provide Figure D of recruitment estimated by the base case model and standardized CPUE in Nagasaki, Kochi and Wakayama from 1980 to 2012 and Table C of Recruitment (in thousands of fish) from the base case model and standardized CPUE from 1980 to 2012 in response to NC9's request (from *ISC/14/ANNEX/16*):

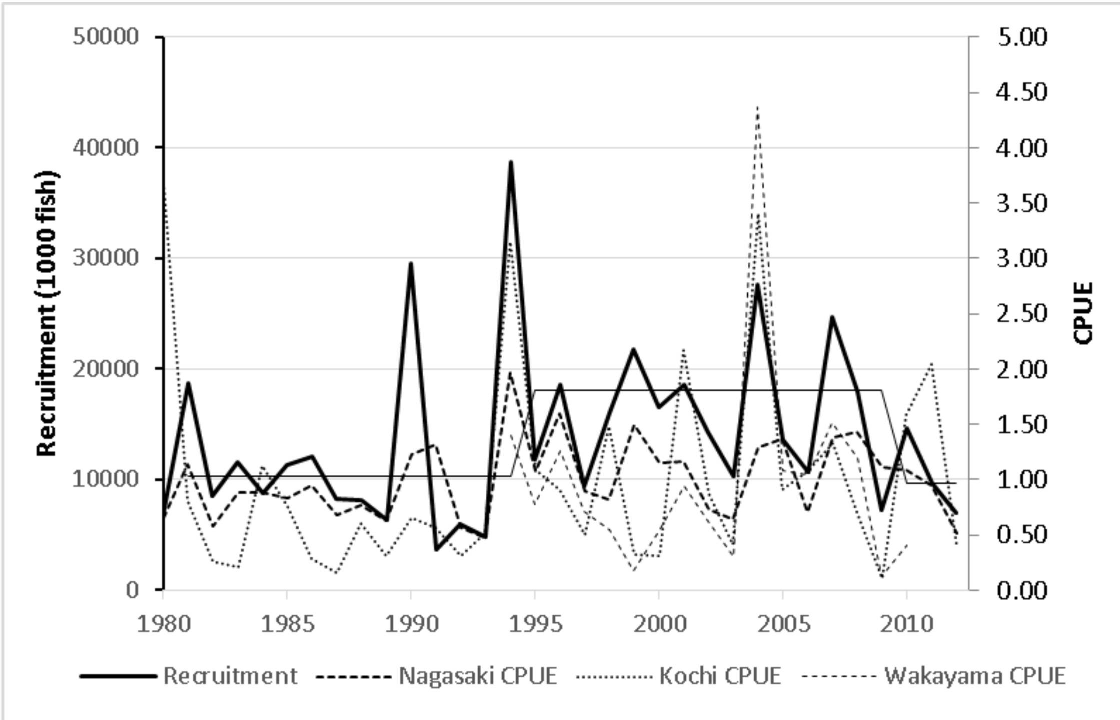

Figure D. Pacific bluefin tuna (*Thunnus orientalis*) ecruitment estimated by the base case model and standardized CPUE in Nagasaki, Kochi and Wakayama from 1980 to 2012. The thin line indicates the means and shifts in recruitment detected by a sequential regime shift detection method. The first shift was detected in 1994, and the second shift was found in 2009.

Table C. Pacific bluefin tuna (*Thunnus orientalis*) recruitment (in thousands of fish) from the base case model and standardized CPUE from 1980 to 2012.

Year	Recruitment	Nagasaki CPUE	Kochi CPUE	Wakayama CPUE
1980	6715	0.66	3.69	
1981	18681	1.14	0.81	
1982	8473	0.58	0.25	
1983	11591	0.89	0.20	
1984	8791	0.89	1.13	
1985	11306	0.83	0.76	
1986	12062	0.95	0.29	
1987	8317	0.68	0.16	
1988	8125	0.77	0.60	
1989	6413	0.62	0.31	
1990	29494	1.23	0.65	
1991	3718	1.32	0.57	
1992	5955	0.57	0.31	
1993	4798	0.47	0.51	
1994	38732	1.97	3.16	1.40
1995	11822	1.07	1.09	0.78
1996	18584	1.60	0.91	1.26
1997	9362	0.90	0.50	0.71
1998	16022	0.82	1.48	0.55
1999	21816	1.49	0.33	0.18
2000	16558	1.15	0.31	0.53
2001	18579	1.16	2.17	0.94
2002	14190	0.73	0.86	0.62
2003	10292	0.65	0.41	0.30
2004	27678	1.29	3.41	4.37
2005	13598	1.36	0.92	1.08
2006	10700	0.71	1.07	1.04
2007	24642	1.38	1.33	1.51
2008	18001	1.44	0.71	1.20
2009	7200	1.11	0.10	0.13
2010	14679	1.09	1.58	0.40
2011	9701	0.94	2.05	
2012	7015	0.52	0.39	

2.3 Catch and effort data tables of juvenile and adult PBF

NC9 requested that ISC produce a catch and effort data table of juvenile and adult Pacific bluefin tuna for the reference year (2002–2004). The two tables below respond to this request.

Annual catch in metric tons of Pacific bluefin tuna (*Thunnus orientalis*) in the Convention Area

The indicated figures are sourced from the ISC's report of ISC14.

Unit = metric ton

CCM	Fisheries			1994			1995			1996			1997			1998			1999			2000			2001			2002			2003		
	Category	Subcategory	Targeting PBT? (Y/N)	<30kg inBW	>=30kg inBW	total	<30kg inBW	>=30kg inBW	total	<30kg inBW	>=30kg inBW	total	<30kg inBW	>=30kg inBW	total	<30kg inBW	>=30kg inBW	total	<30kg inBW	>=30kg inBW	total	<30kg inBW	>=30kg inBW	total	<30kg inBW	>=30kg inBW	total	<30kg inBW	>=30kg inBW	total	<30kg inBW	>=30kg inBW	total
Canada	Total																									0	0	0	0	0	0
China	Purse seine																														
	Long Line																														
	Others																														
	Total																									0	0	0	0	0	0
Cook Island	Total																									0	0	0	0	0	0
Japan[*1]	Total			6,165	9,021	15,186	20,740	6,350	27,091	9,480	4,527	14,008	13,610	5,242	18,852	7,049	4,142	11,191	10,624	12,004	22,628	15,445	9,132	24,577	10,251	3,960	14,212	9,309	4,877	14,186	7,951	2,455	10,407
Korea	Purse seine		Y																									932	0	932	2,601	0	2,601
	Troll		Y																														
	Total																									932	0	932	2,601	0	2,601
Chinese Taipei	Long Line		Y																										1,523	1,523		1,863	1,863
	Others		N																										4	4		21	21
	Total																									0	1,527	1,527	0	1,884	1,884
USA	Purse seine[*2]		N																									0	0	0	0	0	0
	Sport[*2]		N																									0	0	0	0	0	0
	Others		N																									0	0	0	0	0	0
	Longline		N																									0	2	2	0	1	1
	Total																									0	2	2	0	1	1
Vanuatu	Total																									0	0	0	0	0	0
Belize	Total																									0	0	0	0	0	0
Mexico	Purse seine																														
	Others																														
	Total																									0	0	0	0	0	0

***1; Catch in Japan is North and South Pacific, but catch in other countries is North Pacific.**
***2; US purse seine and sport catches occur outside of the WCPFC convention area and are therefore not included here. US longline catches are assumed to be all adults based on the average weight of PBF landed by the fishery.**

Annual catch in metric tons of Pacific bluefin tuna (*Thunnus orientalis*) in the Convention Area (continued)

The indicated figures are sourced from the ISC's report of ISC14.

Unit = metric ton

CCM	Fisheries			2004			2005			2006			2007			2008			2009			2010			2011			2012		
	Category	Subcategory	Targeting PBT? (Y/N)	<30kg inBW	>=30kg inBW	total	<30kg inBW	>=30kg inBW	total	<30kg inBW	>=30kg inBW	total	<30kg inBW	>=30kg inBW	total	<30kg inBW	>=30kg inBW	total	<30kg inBW	>=30kg inBW	total	<30kg inBW	>=30kg inBW	total	<30kg inBW	>=30kg inBW	total	<30kg inBW	>=30kg inBW	total
Canada																														
	Total			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
China	Purse seine																													
	Long Line																													
	Others																													
	Total			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Cook Island																														
	Total			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Japan[*1]	**Total**			**6,785**	**7,314**	**14,099**	**14,796**	**6,872**	**21,668**	**9,828**	**4,350**	**14,178**	**8,515**	**6,191**	**14,706**	**11,879**	**5,836**	**17,715**	**9,701**	**4,896**	**14,598**	**5,500**	**2,787**	**8,287**	**9,127**	**4,659**	**13,786**	**3,815**	**2,468**	**6,283**
Korea	Purse seine		Y	773	0	773	1,318	0	1,318	1,012	0	1,012	1,281	0	1,281	1,743	123	1,866	901	34	935	1,128	68	1,196	670	1	671	1,405	16	1,421
	Troll		Y																						0		0	1		1
	Total			**773**	**0**	**773**	**1,318**	**0**	**1,318**	**1,012**	**0**	**1,012**	**1,281**	**0**	**1,281**	**1,743**	**123**	**1,866**	**901**	**34**	**935**	**1,128**	**68**	**1,196**	**670**	**1**	**671**	**1,406**	**16**	**1,422**
Chinese Taipei	Long Line		Y		1,714	1,714		1,368	1,368		1,149	1,149		1,401	1,401		979	979		877	877		373	373		292	292		210	210
	Others		N		3	3		2	2		1	1		10	10		2	2		11	11		36	36		24	24		3	3
	Total			**0**	**1,717**	**1,717**	**0**	**1,370**	**1,370**	**0**	**1,150**	**1,150**	**0**	**1,411**	**1,411**	**0**	**981**	**981**	**0**	**888**	**888**	**0**	**409**	**409**	**0**	**316**	**316**	**0**	**213**	**213**
USA	Purse seine[*2]		N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sport[*2]		N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Others		N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Longline		N	0	1	1	0	0	1	0	1	1	0	2	2	0	1	1	0	2	2	0	3	3	0	2	2	0	7	7
	Total			**0**	**1**	**1**	**0**	**0**	**1**	**0**	**1**	**1**	**0**	**2**	**2**	**0**	**1**	**1**	**0**	**2**	**2**	**0**	**3**	**3**	**0**	**2**	**2**	**0**	**7**	**7**
Vanuatu																														
	Total			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Belize																														
	Total			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Mexico	Purse seine																													
	Others																													
	Total			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

*1; Catch in Japan is North and South Pacific, but catch in other countries is North Pacific.

*2; US purse seine and sport catches occur outside of the WCPFC convention area and are therefore not included here. US longline catches are assumed to be all adults based on the average weight of PBF landed by the fishery.

Annual Fishing fishing effort for Pacific bluefin tuna (*Thunnus orientalis*) in the Convention

CCM	Fisheries		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
	Category	Subcategory											
Canada													
China													
Cook Island													
Japan	Purse Seine		69	60	59	57	57	56	56	56	56	56	55
	Dist.&Off. Longline		654	632	613	591	538	494	480	361	342	330	304
	Coastal Longline		399	422	386	369	369	370	333	347	361	379	381
	Pole and Line		146	140	137	134	125	106	104	104	101	98	90
	Artisanal fisheries*[1]												11,615
	Set Net		1,876	1,956	1,956	1,956	1,956	1,956	1,888	1,888	1,888	1,888	1,888
	Others												
Korea	Purse senine		32	29	29	29	29	29	29	27	25	25	24
	Troll*2											14	34
Chinese Taipei	Longliner		684	659	632	619	522	489	484	490	557	590	530
	Others*3												
USA*4	N/A	N/A	0	0	0	0	0	0	0	0	0	0	0
Vanuatu													
Belize													
Mexico													

*1; Mostly Troll and Handline which registrated as fishing vessel to catch PBF.
*2; Catching PBT vessel.
*3; Most of catch from set-net.
*4;US do not have any PBF targeted effort in the WCPFC convention area.
Number of vessels that fished Pacific Bulefin Tuna as taget in the Convention Area north of 20 N

ATTACHMENT 1

Attachment F

The Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean

Northern Committee
Ninth Regular Session

Fukuoka, Japan
2–5 September 2013

NORTHERN COMMITTEE'S REQUEST TO ISC REGARDING PACIFIC BLUEFIN TUNA

For the purpose of evaluating the performance of various management scenarios with respect to rebuilding the stock of Pacific bluefin tuna, the Northern Committee requests advice from the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) on the following.

Under an appropriate range of future recruitment scenarios (for example, but not necessarily limited to: high, low, historical average), the probability of achieving each of five particular SSB levels (10%, 15%, 20%, and 25% $SSB_{recent,F=0}$, and historical median SSB) within 10 and 15 years under each of the harvest scenarios listed below. For each scenario, expected average yield over the final three years of the projection is also requested.

	Western and Central Pacific Ocean			**Eastern Pacific Ocean**
	Fishing effort in Pacific bluefin tuna fisheries	**Juvenile catches**	**Adult catches**	**Catches**
1	2002–2004 avg.	15% reduction from 2002–2004 avg.		5,500 mt/yr
2	2002–2004 avg.	15% reduction from 2002–2004 avg.	15% reduction from 2002–2004 avg.	5,500 mt/yr
3	2002–2004 avg.	15% reduction from 2002–2004 avg.	15% reduction from 2002–2004 avg.	4,675 mt/yr
4	2007–2009 avg.	15% reduction from 2002–2004 avg.		4,675 mt/yr
5	2002–2004 avg.	25% reduction from 2002–2004 avg.		4,125 mt/yr
6	2002–2004 avg.	50% reduction from 2002–2004 avg.		2,750 mt/yr
7	15% reduction from 2002–2004 avg.	25% reduction from 2002–2004 avg.		4,125 mt/yr

For those scenarios in which, for at least some fisheries, catches are limited but fishing effort (and thus F) is not, ISC is requested to run projections such that F in those fisheries is constrained to no greater than double the 2002–2004 average level.

For the purpose of developing a mechanism that establishes specific rules for CCMs in the event of a drastic drop in recruitment, ISC is requested to provide information regarding the range of historical variation in recruitment, such as in terms of standardized CPUEs for particular fisheries, or other appropriate measures. Specifically, information for the low recruitment period during the 1980s, and for the last 10 years, is requested.