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Updated future projections of Pacific bluefin tuna with draft results to answer the requests from NC9.

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Summary

This working paper reports the enhancements of future projection software used for ISC PBF stock assessment in terms of both its functionalities and performance as well as the results of future projection calculations from the current version of representative run of Fukuda et al (2014) in response to the requests made by Northern Committee of WCPFC in Sept. 2013. The results clearly indicated that unless future recruitments remain historical average range of variation, continuation of perfect implementation of management measure in 2014 by both WCPFC and IATTC is not strong enough to increase the spawning stock from current historical very low level. Among 6 additional alternative candidate of management measure from 2015, scenario 6 performed best in terms of expected increase of the spawning stock size within 10 or 15 years from 2014 and probability declining spawning stock biomass bellow historically lowest observed, in particular, under increased risk of low recruitment in coming years. This working paper also introduced the preliminary results using alternative formulation of future recruitments for consideration to use at the next full stock assessment it as one of alternative scenario of future recruitments.

1. Introduction

Since 2008 (ISC 2008) Stock Synthesis (Methot and Wetzel 2012) has been used for the main stock assessment platform of ISC Pacific bluefin tuna stock assessments. Also from 2008 stock assessment future projection of Pacific bluefin tuna has been done using software written in R (R core team 2013)

Future projections in 2012 stock assessment

At the last stock assessment PBF in 2012, ISC PBF WG conducted four future projection calculations from the representative run with four future harvesting scenarios listed below and future recruitments which were randomly resampled from the whole stock assessment period (1952-2009), without any spawner-recruitment relationship. (ISC2012a).

I. Constant fishing mortality at current F (F2007 - 2009)
II. Constant fishing mortality during 2002 - 2004 (F2002 - 2004)

III. Constant fishing mortality of F2007 - 2009 with catch limitations on purse seine fleets in the EPO and northwestern Pacific.
IV. Constant fishing mortality of F2002 - 2004 with catch limitations on purse seine fleets in the EPO and northwestern Pacific

The WG picked up these four scenarios, in particular the scenarios I and IV to represent the status quo before WCPFC and IATTC started the regulations on PBF and "regulations currently implemented by IATTC (since 2012 fishing season) and Japan (since 2011 fishing season). The first and second scenarios were used to evaluate effects of only fishing mortality restrictions" (p35 of ISC2012a)

ISC (2012a) summarized the results of future projection calculations as follows,
"The four harvest scenarios … showed clear differences in their expected future stock trajectories…. At the current F level (F2007 - 2009), the SSB was expected to decline slightly to about 22,000 mt. If the fishing mortality is at the 2002 - 2004 level, SSB was expected to increase, with median SSB in 2030 expected to be around 40,000 mt. The effect of catch limits for the purse seine fisheries in the WCPO and EPO were substantial. Regardless of underlying fishing mortality scenarios, the future median SSB should increase substantially (50,000 mt for F2007 - 2009 and 83,000 mt for F2002 - 2004)."

At the intercessional ISC plenary which adopted the results of 2012 PBF stock assessment requested additional future projections with "recruitment levels consistent with the lower values estimated in the 1980s" (p9 of ISC 2012b)

Later in July 2013, at the plenary session of ISC13, the results of "additional projection scenarios with recruitment levels consistent with the lower values estimated 1980s" were presented. "Two types of future recruitment scenarios were considered: i) future recruitment levels will continue at the level of 1980-1989 i.e. average recruitment was 10 million fish per year, ii) future recruitment for the first 10 years will be at the level of 1980-1989, but will subsequently recover to an average levels calculated from values from 1952-2009" (P28 of ISC 2013b). Because of the difficulty of predicting the duration of low recruitment period, the WG noted "the two alternative scenarios provide some useful insight into the implications for varying duration of the low recruitment period".(p 29 of ISC 2013b)

There was also a discussion that "the F levels at 2002-2004 and 2007-2009 in

combination with catch limits assumed in the projections may or may not reflect the current implementation of either the WCPFC or IATTC management measures"(p29 of ISC 2013b). In essence, there was a discussion whether one of or both regulations by WCPFC and IATTC are catch capping or catch quota.

In September 2013, NC9 provided seven future harvest scenarios requesting ISC to answer the results of future projections with those scenarios at NC10 in 2014 (attachment F[1] of NC9's summary report (WCPFC 2013).

This working paper provides the interpretations of attachment F of NC9 summary report to implement what NC9 requested ISC and results of future projections based on it. Descriptions of the enhancements of future projection software to implement the future harvest scenarios and future recruitment scenarios of the attachment F are also presented in Appendix 3.

2. Materials and methods

2.1 NC9's requests

Core of NC9's requests is that

"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."

2.2 Future recruitment scenarios

From 2008 stock assessment to 2012 stock assessment, PBFWG used resampling of recruitment time series from whole stock assessment period, while the need for some alternatives including cyclic pattern of future recruitment. ISC (2013b) picked up the period, 1980-1989 to represent the low recruitment period. Ishida et al (2014) analyzed the patterns of estimated recruitments of the "preliminary updated" representative run of Fukuda et al (2014). They found that the recruitment in 1980-1993 is significantly

[1] Also included as appendix 1 of this working paper

lower (P=0.0275) than the historically average recruitments in 1952-2012. As they demonstrated, the period in 1980-1993 can be an alternative candidate representing low recruitment period. Nevertheless, the authors continue to pick up the period 1980-1989 to represent the low recruitment period. This is because the 1990 year class was estimated as the second strongest year class since 1960. Excluding the 1990 year class by limiting the low recruitment period by 1989 may be useful, in particular for presentation to stake holders.

As for the duration of low recruitment period, Ishida et al (2014) found that recruitment in 1980-1993 was significantly lower (P=0.040), than the level of recruitment of later period in 1994-2008. They also found that the recruitment in 2009-2012 was significantly lower (P=0.0278) than the recruitments in 1994-2008 (table 5 of Ishida et al 2014). They also applied sequential t-test (Rodionov and Overland 2005) to the same time series of estimated recruitments and found two break points; between 1993 and 1994 year classes and 2008 and 2009 year classes with significant level of 0.2. Their founding suggests that the duration of different productivity phase (regime) might be about 14 or 15 years. Based on these observations, two scenarios of low recruitments were chosen; 1) low recruitment level similar to the period 1980-1989 continue, 2) 10 years of low recruitment from 2014 assuming low recruitment period actually started from 2009 following historical average level of recruitment. In addition to the low recruitment scenario resampling of whole recruitment time series

2.3 Recruitment scenarios of "future" recruitment that was already born in the real world

The latest year of 2014 stock assessment is 2012 fishing year (July 1, 2012-June 30, 2013 in calendar year). The latest recruitment estimate available from the Stock Synthesis is 2012-year class. As has been done in the past stock assessment, since the latest recruitment estimate is likely imprecise, the authors propose to use estimated recruitment till 2011 but replace it with randomly resampled recruitment in appropriate period as future recruitment. However year classes 2012 and 2013 were already born. In particular ISC 13 plenary paid a special attention to the possible very weak 2012 year class. As for 2013 year class currently available information from fishery targeting age 0 PBF is suggesting possible weak 2013 year class while its strength might be stronger compared to the 2012 year class. Based on these consideration, authors propose to assume 2012 and 2013 year class (recruitment) may be very weak. This is implemented by generating recruitments in 2012 and 2013 from resampling of estimated recruitments in 1986-1988 which are three lowest year classes in 1980-1989.

2.4 How to calculate the $SSB_{recent,F=0}$

$SSB_{recent,F=0}$ can roughly be defined as theoretical spawning stock biomass size without fishing assuming recent level recruitment. There are two approaches to determine recent level of recruitment; 1) fixed size moving window approach which uses fixed number of years of recent recruitment, 2) STARS approach (Punt and …) which uses the level of recruitment of current productivity phase (regime). As discussed in 2.2, average level of recruitment may be lowered from 2009. In this particular calculation, in order to make sure the projected population to have steady state, 60 years from 2012 forward projection calculation was done. This WP tested these two approaches. 1st approach gave mean $SSB_{recent,F=0}$ =620,116 ton, (median=616,625 ton, sd=70,586 ton) in 2072, 2nd approach gave mean $SSB_{recent,F=0}$=438,241 ton, (median=437,617,sd=37,721 ton) in 2072.

2.5 Harvest scenarios

NC9 defined 7 candidates of harvest scenarios from 2015. Scenario 1 is continuation of management measure in 2014 by both WCPFC and IATTC, while the others listed alternative measures (see table in appendix 1). In principle, the harvest scenario is combination of constant effort strategy and catch capping to juvenile and/or adult catch for WPO fisheries, constant catch strategy for EPO commercial fisheries and no regulation to EPO sport fishery. Also it is necessary to note that for WPO fisheries specific level of fishing for each scenario with specific percentage of catch reduction of only juvenile or juvenile plus adult from the average juvenile (and/or adult) catch. This means it need an additional condition how to realize these reduction. This working paper took following approach.

i. Fishing effort is interpreted as fishing mortality, i.e., e.g. fishing effort of 2002-2004 level is translated into average F in 2002-2004.
ii. 14 fisheries in the stock assessment model reorganized into 6 fleets, approximately each fishery represent a country's fishery.
iii. If reduction of juvenile catch is required to certain level, F of ages 0-2 is assumed to be reduced to meet necessary juvenile catch reduction requirement.
iv. If, in addition, reduction of adult catch is required, F of ages 3 and older is assumed to be reduced.

For EPO commercial fishery (fleet 12 of the representative run), NC9 requested to apply

a type of constant catch strategy with maximum F level as twice of that in 2002-2004 in order to realize constant catch strategy. There is no distinction in between juvenile and adult catch, while the results of 2012 stock assessment and 2014 representative run of Fukuda et al 2014 suggests their majority of fishing mortality covers ages 1-3. This was implemented as applying twice of partial F of all ages in 2002-2004 for future partial F of EPO commercial fishery with capping of specified amount. This effectively has same effect of constant catch with maximum F of twice of that in 2002-2004. For EPO sport fishery (Fleet 13 of SS model), this working paper simply applied average partial F in 2002-2004, since IATTC's resolution (C-13-02) as well as NC9's requests ignores EPO sport fishery.

Since catch capping or constant catch is annual basis, while actual population dynamic model used in the future projection is quarterly basis, actual implementations are a bit complicated. They are described in technical appendix (appendix 3)

2.6 Benchmarks

NC9 requested to report "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" and "expected average yield over the final three years of the projection". To accomplish this, this working paper calculated the probability of future SSB excessing the listed reference levels of SSB at least one year from 2014 to 2023 (10 years) or from 2014 to 2028 (15 years). Average expected yield in 2026-2028 was also calculated. In addition, we also calculated the probability of SSB falling below the historical lowest observed level of SSB (about 18,300ton) at least once within 15 years.

3. Results

Table 2[2] summarized the benchmarks listed in section 2.5 with $SSB_{recent,F=0}$ from fixed moving window approach. Figure 3[3] compared expected performance of seven harvest scenarios by three future recruitment scenario. Within 10 years any scenario can only be expected very limited chance to reach the reference levels of SSB which NC9 picked up except for the case when future recruitment is middle (historical average, resampling from whole assessment period). Scenario 6 can be expected to increase future SSB to

[2] Revised versions of table 2 based on the final base case SS run is shown in Appendix 2

[3] Revised version of figure 3 based on the final base case run is shown in appendix 2.

10% of $SSB_{recent,F=0}$ if fixed moving window approach is used and historical median with very high probability of recovery (more than 80% in each recruitment scenario) within 15 years. Scenario 7 performed better next to the scenario 6, in particular when future recruitment is middle (historical average level), however expected increase of SSB is limited and lower than that by scenario 6. In addition, if future recruitment is low, scenario 7 performs very poor in the sense that SSB can only have 10% chance to reach 10% of $SSB_{recent,F=0}$ if fixed moving window approach.

4. Discussion and conclusion

4.1 Performance of seven harvest scenarios provided by NC9

Scenario 1 which can be called as a "status quo" in the sense regulations in 2014 is assumed to continue in both WPO and EPO can probably be compared with the harvest scenario IV at 2012 stock assessment which assumes perfect implementation of WCPFC and IATTC's regulation as well as Japanese domestic additional measure. Although there are several differences in the details of regulations, general conclusion of those two harvest scenarios is same. If future recruitment is at the historical average level of variation, spawning stock can be expected to increase steadily. SSB is likely increase more than 15% of $SSB_{recent,F=0}$,whichever definition of it is used, with about 50% chance.

On the other hand, if future recruitment is at low recruitment level as experienced in 1980s, SSB is likely to stay at around current very low level. Even worse it is very likely (87% chance) that SSB decline below the historically lowest observed. Among six remaining harvest scenarios (2-7), scenarios 2-4 have very poor performance at low recruitment. Rest of three harvest scenario (5-7) can be expected to increase SSB to some extent. But degree of increase is different by each harvest scenario. Roughly speaking scenario 6 performs best across the three recruitment scenarios, scenario 7 is the next to scenario6 but its performance is not enough from both expected increase of SSB and risk of further decline of SSB, if future recruitment remains low.

As discussed in 2.2, average level of recruitment may be lowered from 2009 until 2012 and possibly in 2013 as well compared to the recruitments before 2009. The importance to consider the real risk of low recruitment in the coming decade increased more than before. ISC may need to advice or make a warning to stakeholders on the increased risk of entering low recruitment phase and also need to make a conservation advice based on

the increased risk of low recruitment in coming years. If it is the case, i.e., if future recruitment is likely be low as experienced in 1980s, there is no other choice than scenario 6 among the seven harvest scenarios NC9 listed.

4.2 Related issues

The choice of $SSB_{recent,F=0}$ has another aspects to evaluate harvest scenario. If ISC and NC prefer consistency to the biomass reference points based on "B0" listed by NC9 and the future recruitment level, use of different $SSB_{recent,F=0}$ by different recruitment level is very attractive idea. This is particularly true, if change of regime is timely detected. It is still not yet clear if this idea is applicable to the recruitment dynamics of PBF. It may be worth to consider this idea.

Lastly, although, generally speaking, PBF is likely to have very high steepness or its recruitments is close to environmentally driven, it may be worth to conduct an additional future projection calculation as sensitivity analysis using a kind of stock recruitment relationship (e.g. Beaverton-Holt or Ricker type one). One of the difficulty of this type of trial is that estimated recruitments in stock assessment period (1952-2012) had been stayed to similar level to the estimated unfished recruitment until very recent years although SSB has already declined to very low level compared to the calculated SSB0 before apparent decline of recruitment detected in 2009. This leads to some doubts on the biological parameters, in particular older adult which can have substantial effect to the estimation of 100% spawners per recruit ($SPR_{100\%}$), but can have limited effects to the stock biomass during stock assessment period since PBF stock has already been heavily exploited since 1950s based on the results of 2012 stock assessment (ISC 2012a) and preliminary "representative run" of Fukuda et al (2014). This can also affects the calculation of $SSB_{recent,F=0}$. ISC PBF WG may need to critically re-examine reproductive parameters which are the basis of important management benchmarks of the stock.

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Tables and figures

Table 1 Probability densities of t and F values for recruitment between three periods in 1980-1993, 1994-2008, 2009-2012 and long term periods in 1952-2012 and 1980-2012. (Table 5 of Ishida et al 2014)

Recruitment	1952-2012	1980-2012	1980-1993	1994-2008	2009-2012
1952-2012		0.2731	0.0275*	0.0792	0.1057
1980-2012	0.9542		0.0795	0.0425**	0.1598
1980-1993	0.4961	0.5455		0.0040**	0.4323
1994-2008	0.9826	0.9852	0.5892		0.0278*
2009-2012	0.2077	0.2161	0.3275	0.2234	

Table 2 Summary of benchmarks calculated by seven harvest scenarios in section 2.5 and three future recruitment scenarios in section 2.2. SSBrecent,F=0 in this table used mean of SSBrecent,F=0 with recent recruitment taken from 2002-2011.

			Within 10years from 2014					Within 15 years from 2014						
			Probability achieving reference level at least one year					Probability achieving reference level at least one year					Probabilty declining SSB bellow historically lowest observed	Mean yield in 2026-2028
NC9 's scenarios	Future recruit level		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)		
	2014-2023 (10 years)	From 2024												
No1	Low	Low	0%	0%	0%	0%	2%	1%	0%	0%	0%	4%	87%	13581.2
	Low	Middle	0%	0%	0%	0%	2%	2%	0%	0%	0%	10%	85%	16305.4
	Middle	Middle	45%	23%	10%	4%	67%	75%	49%	28%	13%	89%	36%	22945.6
No2	Low	Low	0%	0%	0%	0%	2%	1%	0%	0%	0%	5%	83%	13413.3
	Low	Middle	0%	0%	0%	0%	2%	3%	0%	0%	0%	13%	81%	15849.3
	Middle	Middle	50%	29%	15%	8%	70%	79%	58%	39%	25%	91%	32%	17644.2
No3	Low	Low	0%	0%	0%	0%	2%	1%	0%	0%	0%	5%	83%	13413.3
	Low	Middle	0%	0%	0%	0%	2%	3%	0%	0%	0%	13%	81%	15849.3
	Middle	Middle	50%	29%	15%	8%	70%	79%	58%	39%	25%	91%	32%	17644.2
No4	Low	Low	0%	0%	0%	0%	1%	1%	0%	0%	0%	3%	99%	13030.7
	Low	Middle	0%	0%	0%	0%	1%	1%	0%	0%	0%	6%	99%	15767.9
	Middle	Middle	46%	25%	12%	5%	61%	76%	56%	36%	20%	86%	88%	23529.6
No5	Low	Low	2%	0%	0%	0%	12%	6%	0%	0%	0%	25%	48%	14101.7
	Low	Middle	2%	0%	0%	0%	12%	13%	1%	0%	0%	39%	47%	16178.9
	Middle	Middle	69%	41%	21%	9%	86%	92%	74%	51%	31%	98%	21%	24268.3
No6	Low	Low	49%	9%	1%	0%	84%	84%	35%	7%	1%	98%	10%	17009.9
	Low	Middle	49%	9%	1%	0%	84%	91%	49%	13%	2%	99%	10%	18781.2
	Middle	Middle	97%	83%	60%	36%	99%	100%	99%	92%	77%	100%	8%	27546.3
No7	Low	Low	4%	0%	0%	0%	26%	13%	1%	0%	0%	54%	19%	14396.9
	Low	Middle	4%	0%	0%	0%	26%	25%	3%	0%	0%	70%	19%	16504.7
	Middle	Middle	76%	47%	25%	12%	93%	96%	80%	57%	36%	100%	12%	23375.6

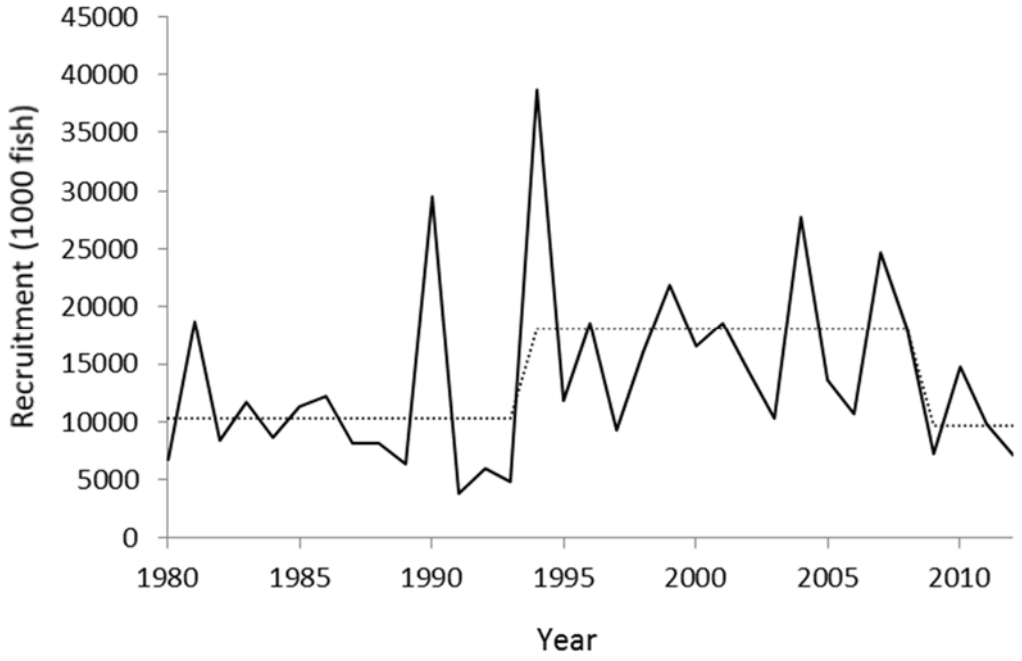


Figure 1 Time series of estimated recruitment (1000 fish) of the "updated" representative run of Fukuda et al (2014). With dotted line indicating the means and shifts detected by a sequential regime shift detection method. The first shift was detected in 1994, and the second shift was found in 2009 using significant level=0.2. (Fig. 2 of Ishida et al 2014)

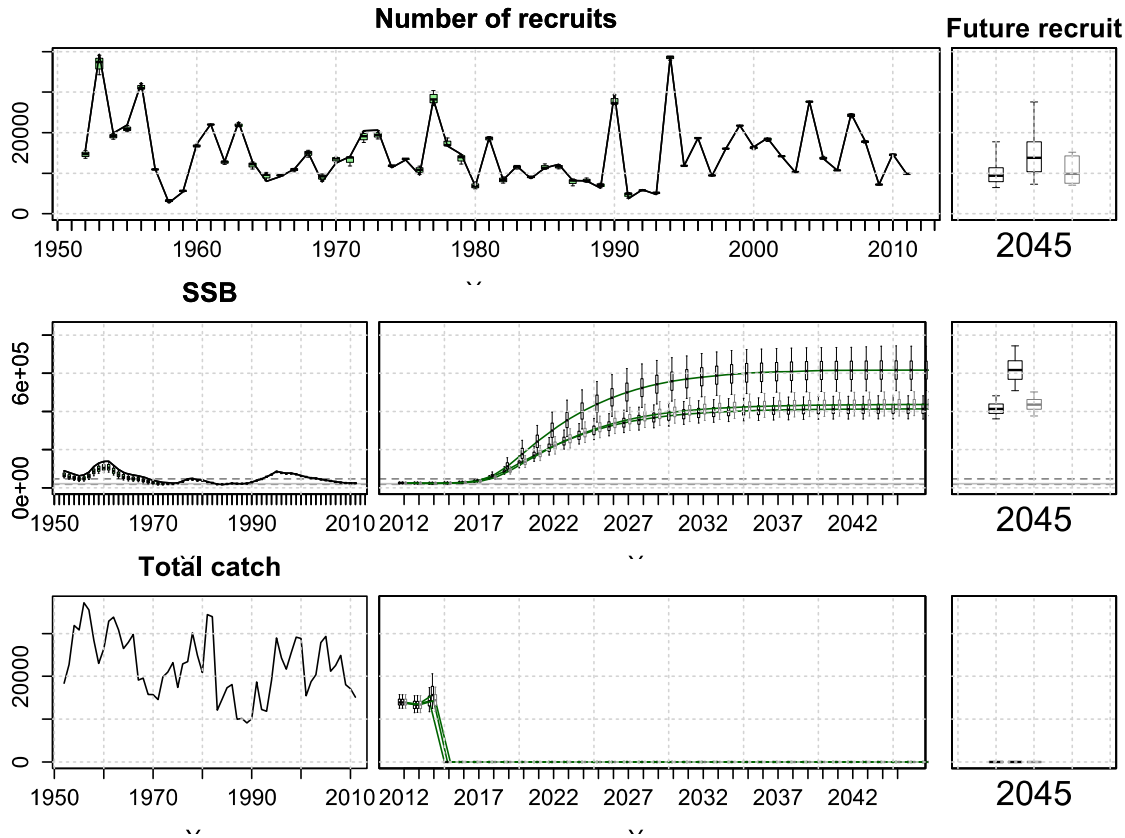


Figure 2 Future projection results with no fishing mortality after 2015 under different future recruitment scenarios to obtain SSBreent,F=0 with different recruitment scenarios. Future recruitment scenarios used are 1) resampling from recruitments in 1980-1989, 2) resampling of recruitments in recent 10 years (2002-2011), 3) resampling of recruitments in most recent 3 years (2009-2011). Fishing mortality of all fleets and age classes are set to 0 from 2015 and onward.

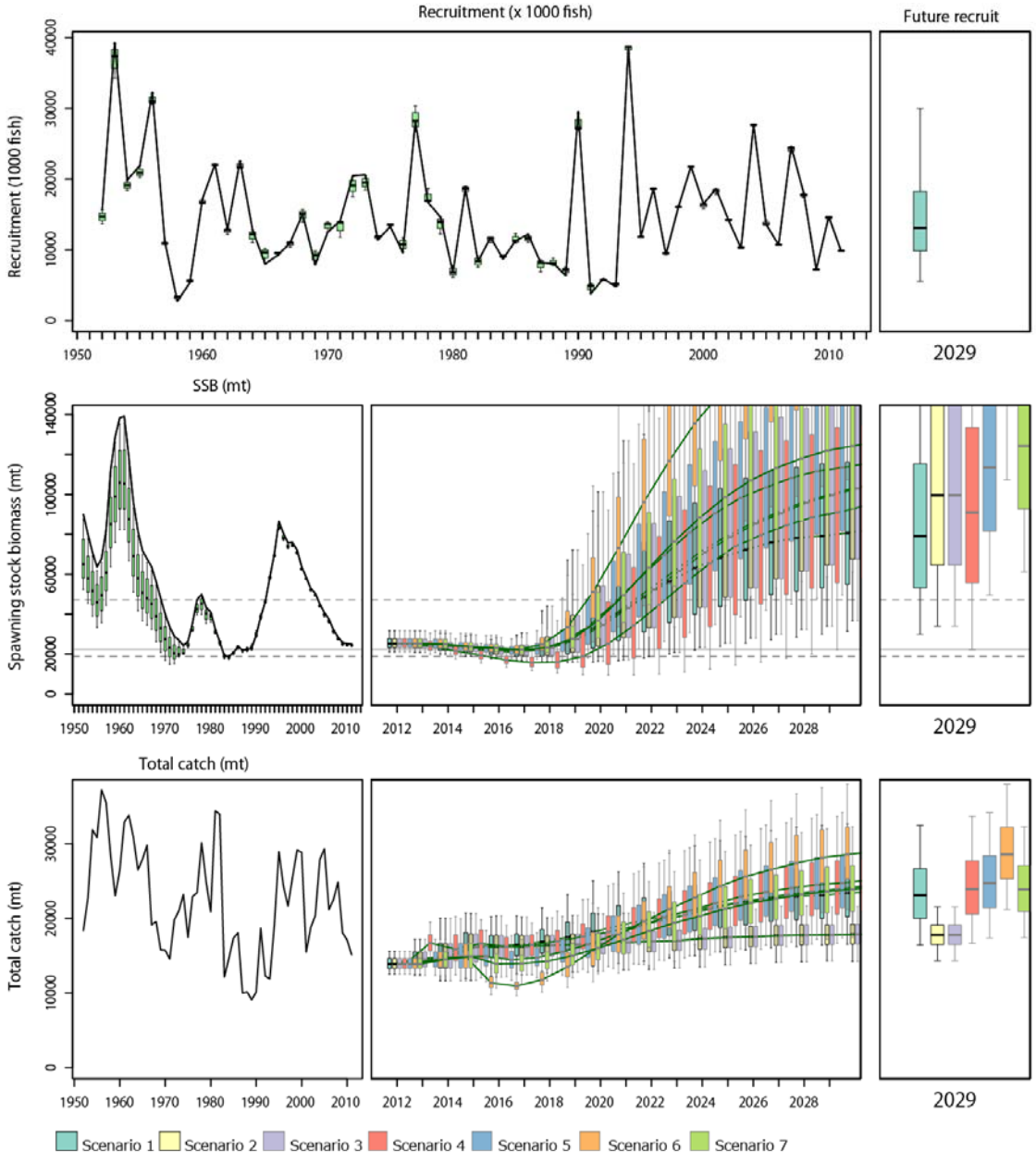


Figure 3a Comparison of future SSB trajectories by seven harvest scenarios with middle recruitment level (resampling from recruits in 1952-2011)

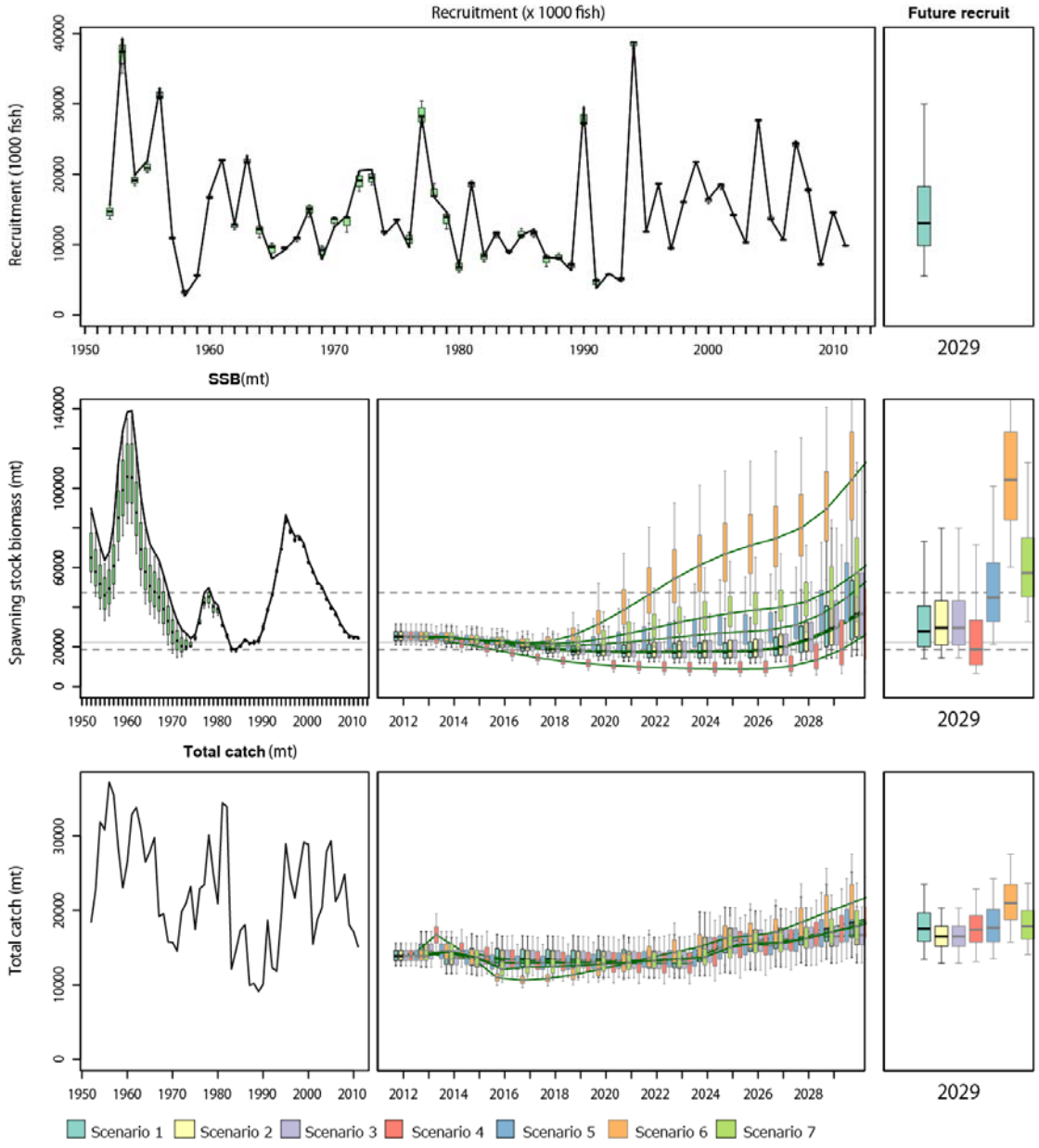


Figure 3b. Comparison of future SSB trajectories by seven harvest scenarios with 10 years (2014-2023) low recruitment following middle recruitment level (resampling from recruits in 1952-2011) since 2024

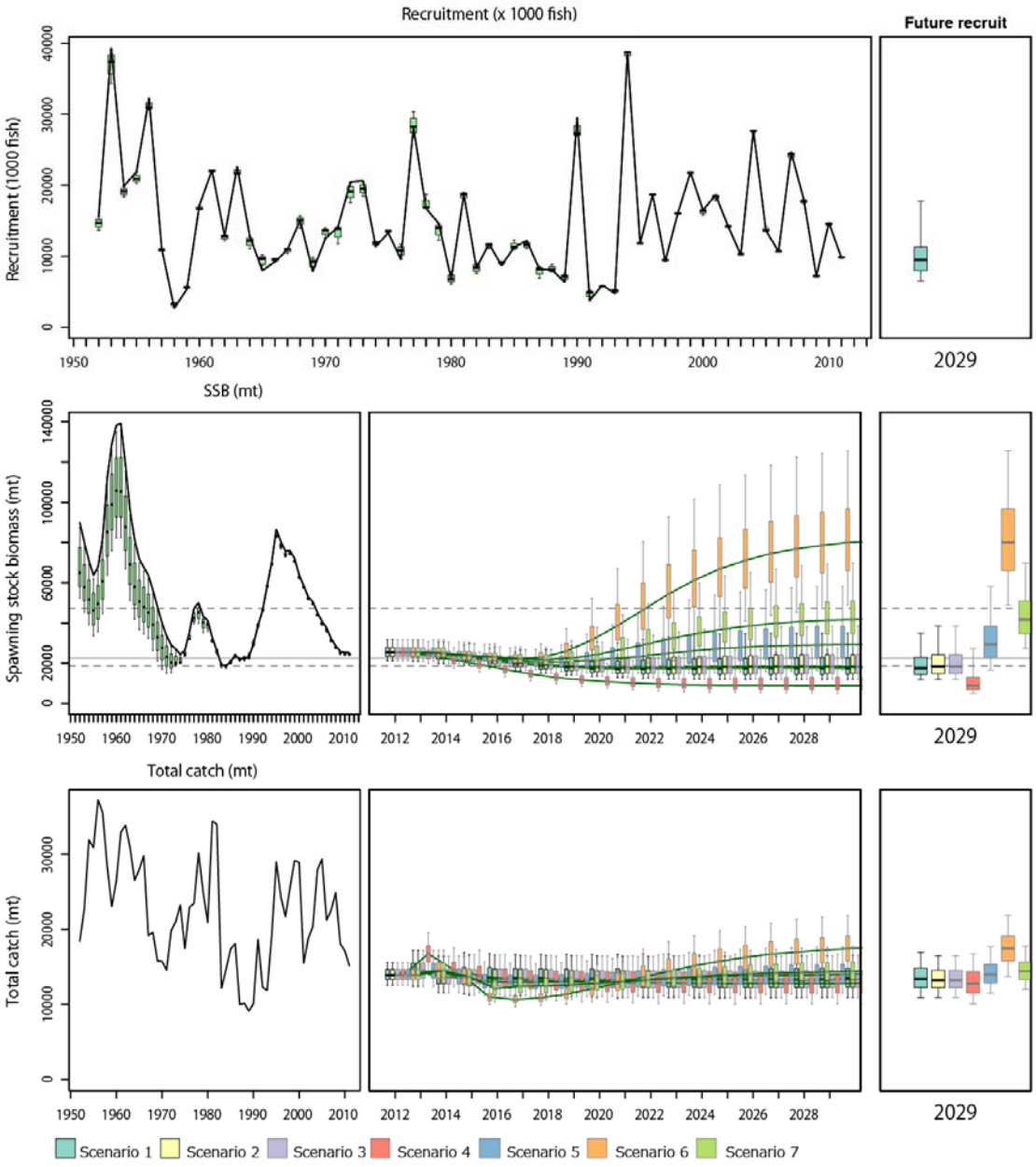


Figure 3c. Comparison of future SSB trajectories by seven harvest scenarios with low recruitments

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 request to the 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 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.

	WCPO			**EPO**
	Fishing effort in PBF fisheries	**Juvenile catches**	**Adult catches**	**Catches**
1	2002-04 ave	15% reduction from 2002-04 ave		5,500 mt/yr
2	2002-04 ave	15% reduction from 2002-04 ave	15% reduction from 2002-04 ave	5,500 mt/yr
3	2002-04 ave	15% reduction from 2002-04 ave	15% reduction from 2002-04 ave	4,675 mt/yr
4	2007-09 ave	15% reduction from 2002-04 ave		4,675 mt/yr
5	2002-04 ave	25% reduction from 2002-04 ave		4,125 mt/yr
6	2002-04 ave	50% reduction from 2002-04		2,750 mt/yr

		ave		
7	15% reduction from 2002-04 ave	25% reduction from 2002-04 ave		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, the ISC is requested to run the 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, the 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 ten years, is requested.

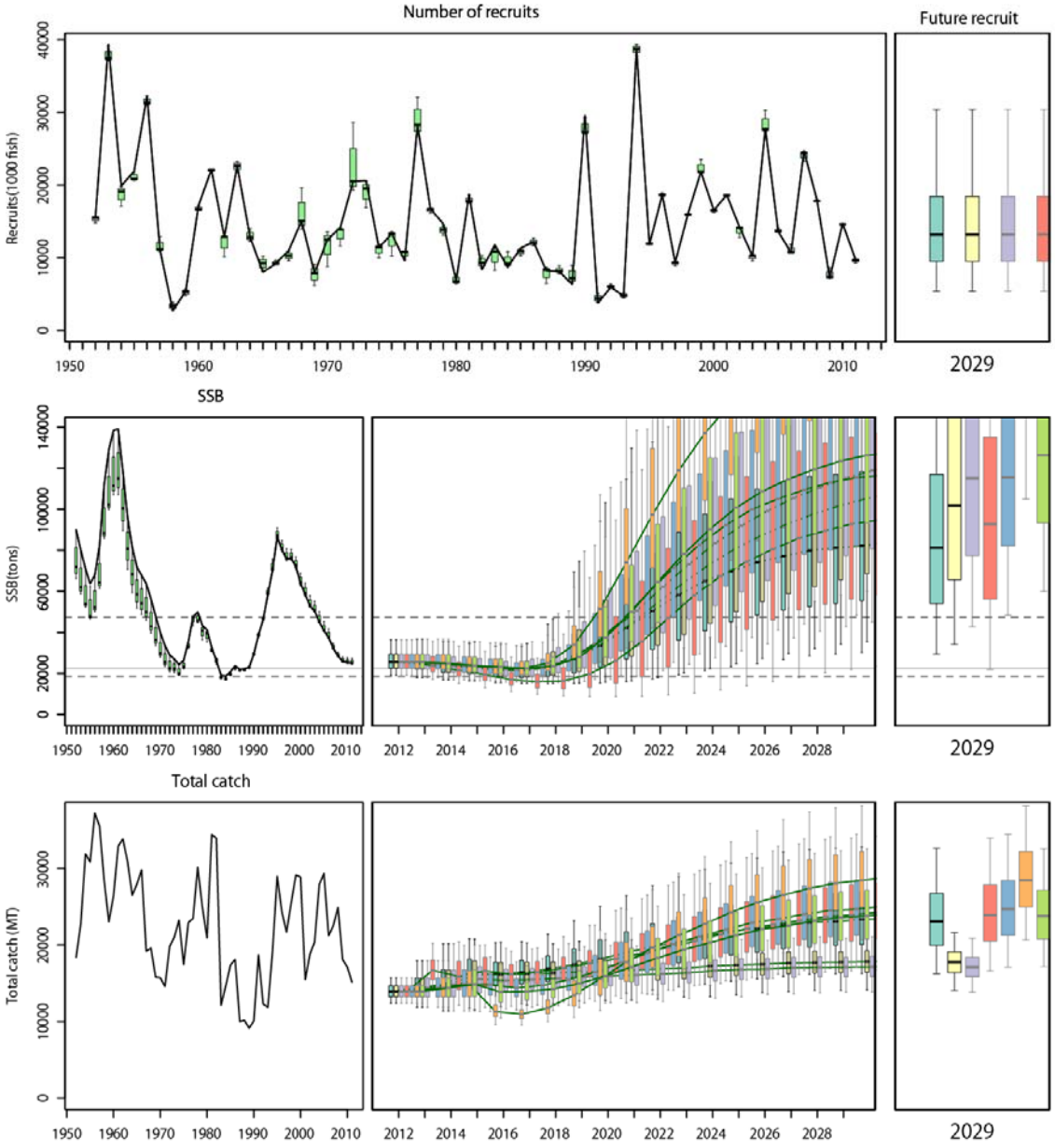
Appendix 2 Revised results based on the final base case run(representative run) finalized during workshop.

During the stock assessment workshop Japanese troll CPUE which is used as one of abundance indices of PBF stock assessment was revised from what presented before WS(see Fujioka et al 2014). Since the final base case SS run was revised using revised troll CPUE, future projection calculations and table 2 were revised during the workshop. This appendix presents the revised table 2 with alternative version of table 2 based on the $SSB_{recent,F=0}$ based on recent low recruitments (2009-2011). Revised version of figure 3 was also presented. The results was not so different from original tables and figures. In the stock assessment report.

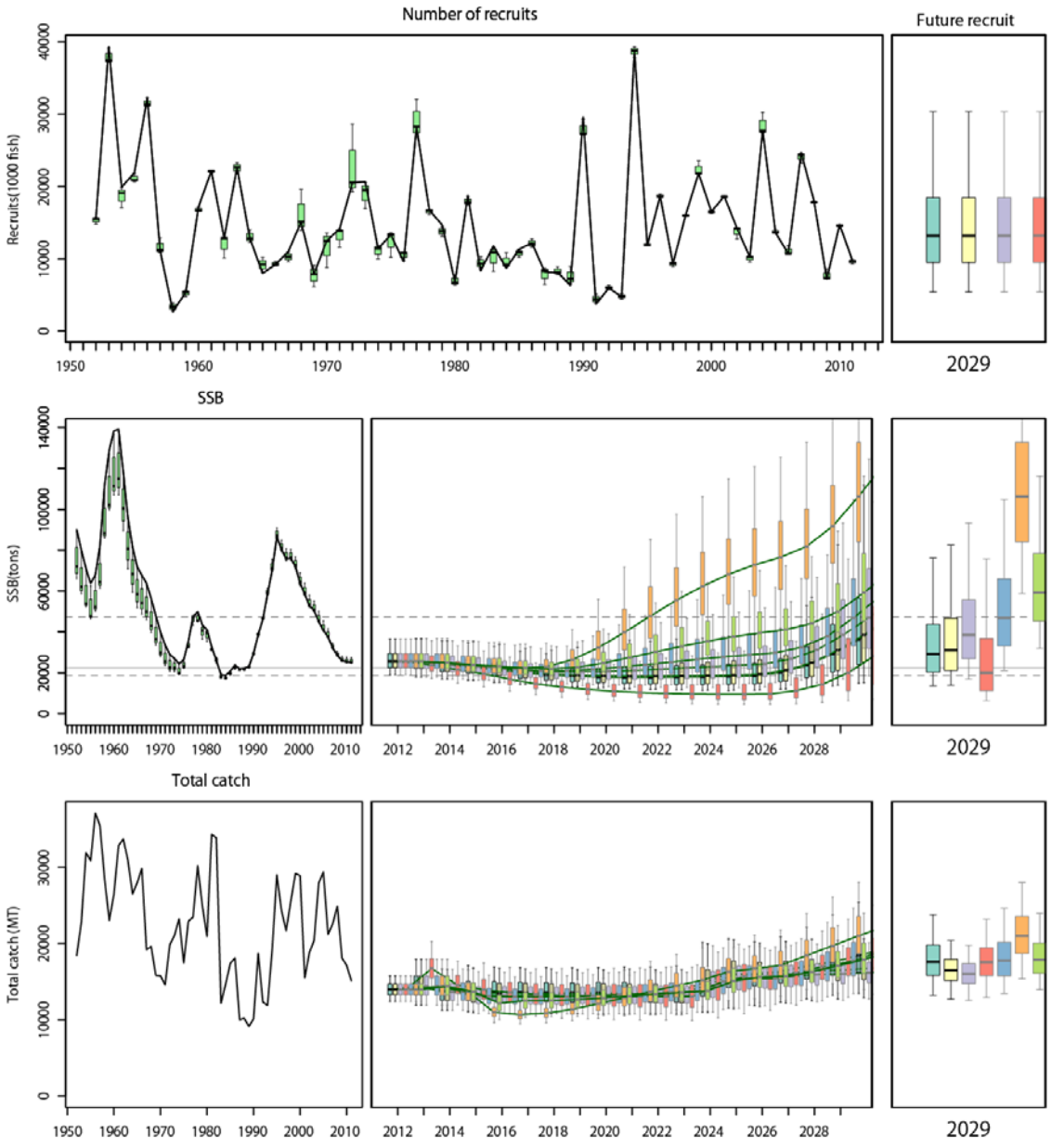
Appendix 2-Table 1 Revised version of table 2 in the main text and alternative version which used SSBrecent,F=0 using more recent recruitments from 2009-2011. Summary of benchmarks calculated by seven harvest scenarios in section 2.5 and three future recruitment scenarios in section 2.2. SSBrecent,F=0 in the top table used mean of SSBrecent,F=0 with recent recruitment taken from 2002-2011 and the mean of SSBrecent,F=0 with more recent recruitments taken from 2009-2011.

NC9`s scenarios	Future recruit level		Within 10 years from 2014					Within 15 years from 2014					Probability declining SSB bellow historically lowest observed	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%	79%	13664.7
	Low	Middle	0%	0%	0%	0%	4%	3%	0%	0%	0%	14%	78%	16320.9
	Middle	Middle	48%	24%	10%	4%	69%	76%	50%	29%	15%	90%	42%	22932.5
No.2	Low	Low	1%	0%	0%	0%	5%	2%	0%	0%	0%	9%	76%	13455.7
	Low	Middle	1%	0%	0%	0%	5%	4%	0%	0%	0%	17%	75%	15817.9
	Middle	Middle	53%	30%	16%	8%	72%	80%	59%	40%	26%	92%	39%	17572.0
No.3	Low	Low	1%	0%	0%	0%	9%	4%	0%	0%	0%	18%	62%	13380.1
	Low	Middle	1%	0%	0%	0%	9%	8%	1%	0%	0%	29%	61%	15447.2
	Middle	Middle	60%	36%	20%	10%	79%	87%	67%	48%	31%	96%	34%	17019.4
No.4	Low	Low	1%	0%	0%	0%	2%	1%	0%	0%	0%	5%	98%	13186.2
	Low	Middle	1%	0%	0%	0%	2%	2%	0%	0%	0%	9%	97%	15834.0
	Middle	Middle	48%	27%	13%	5%	64%	77%	57%	37%	20%	87%	80%	23565.0
No.5	Low	Low	3%	0%	0%	0%	16%	8%	1%	0%	0%	32%	51%	14195.6
	Low	Middle	3%	0%	0%	0%	16%	16%	2%	0%	0%	46%	51%	16225.3
	Middle	Middle	70%	43%	22%	10%	87%	92%	75%	52%	32%	98%	32%	24219.0
No.6	Low	Low	51%	12%	2%	0%	85%	84%	39%	9%	2%	98%	24%	17055.8
	Low	Middle	51%	12%	2%	0%	85%	90%	51%	17%	4%	99%	24%	18767.5
	Middle	Middle	96%	83%	61%	38%	99%	100%	98%	91%	77%	100%	22%	27453.9
No.7	Low	Low	6%	1%	0%	0%	31%	18%	2%	0%	0%	59%	31%	14453.7
	Low	Middle	6%	1%	0%	0%	31%	30%	4%	0%	0%	73%	31%	16502.3
	Middle	Middle	77%	49%	26%	13%	92%	96%	81%	59%	38%	99%	24%	23316.9

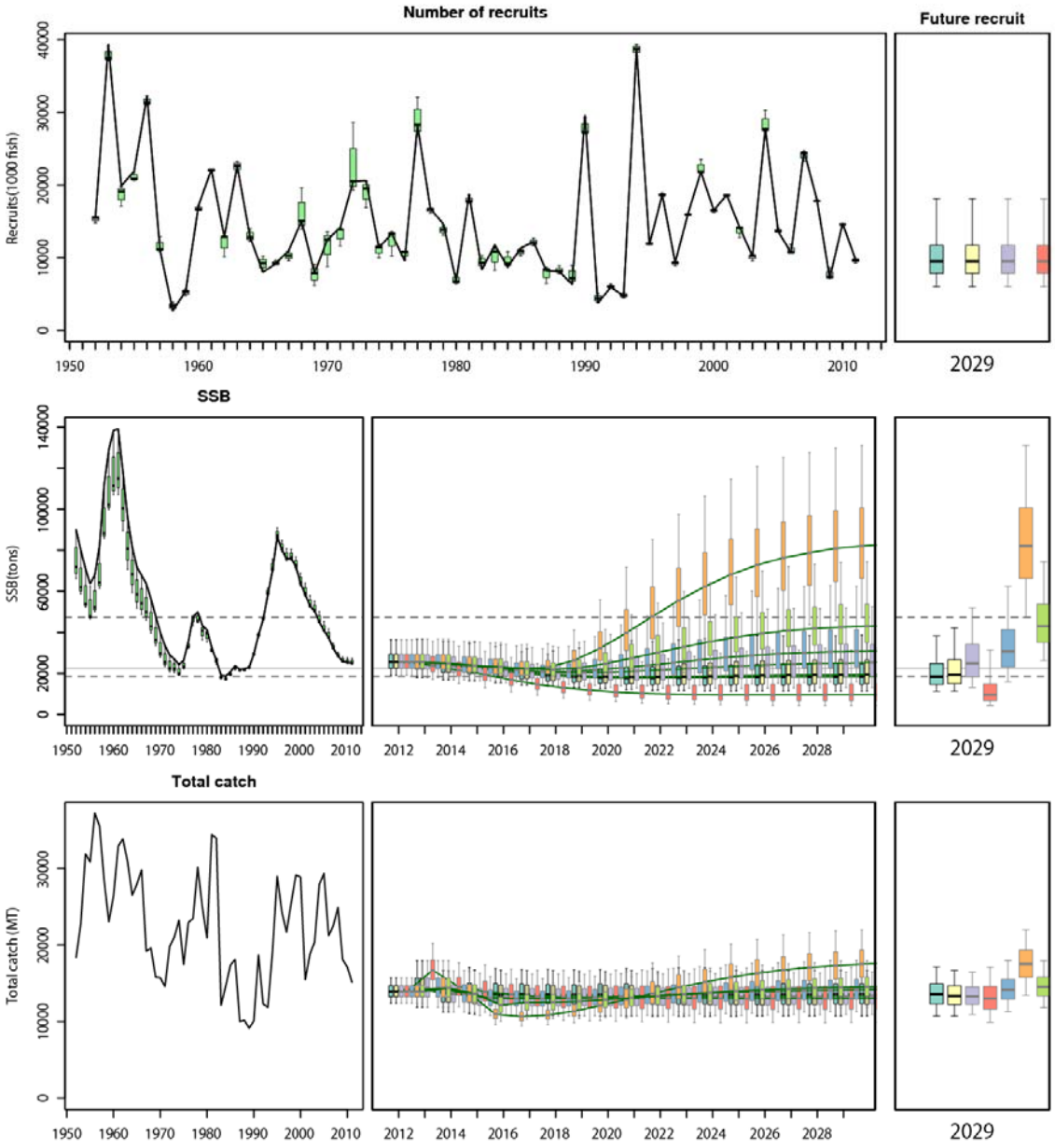
NC9`s scenarios	Future recruit level		Within 10 years from 2014					Within 15 years from 2014					Probability declining SSB bellow historically lowest observed	Mean yield in 2026 - 2028
	2014 - 2023 (10years)	From 2024	Probability achieving reference level at least one year					Probability achieving reference level at least one year						
			44KT (10%SSB0)	66KT (15%SSB0)	88KT (20%SSB0)	110KT (25%SSB0)	Historical Median(43KT)	44KT (10%SSB0)	66KT (15%SSB0)	88KT (20%SSB0)	110KT (25%SSB0)	Historical Median(43KT)		
No.1	Low	Low	3%	0%	0%	0%	4%	6%	1%	0%	0%	7%	79%	13664.7
	Low	Middle	3%	0%	0%	0%	4%	12%	2%	0%	0%	14%	78%	16320.9
	Middle	Middle	67%	44%	27%	15%	69%	89%	73%	54%	38%	90%	42%	22932.5
No.2	Low	Low	4%	1%	0%	0%	5%	8%	1%	0%	0%	9%	76%	13455.7
	Low	Middle	4%	1%	0%	0%	5%	15%	3%	1%	0%	17%	75%	15817.9
	Middle	Middle	71%	50%	33%	22%	72%	91%	78%	63%	49%	92%	39%	17572.0
No.3	Low	Low	8%	1%	0%	0%	9%	16%	3%	1%	0%	18%	62%	13380.1
	Low	Middle	8%	1%	0%	0%	9%	27%	6%	1%	0%	29%	61%	15447.2
	Middle	Middle	78%	57%	40%	26%	79%	96%	85%	71%	56%	96%	34%	17019.4
No.4	Low	Low	2%	0%	0%	0%	2%	4%	1%	0%	0%	5%	98%	13186.2
	Low	Middle	2%	0%	0%	0%	2%	8%	2%	0%	0%	9%	97%	15834.0
	Middle	Middle	62%	45%	30%	18%	64%	87%	75%	60%	45%	87%	80%	23565.0
No.5	Low	Low	15%	2%	1%	0%	16%	30%	6%	1%	0%	32%	51%	14195.6
	Low	Middle	15%	2%	1%	0%	16%	43%	12%	3%	1%	46%	51%	16225.3
	Middle	Middle	86%	66%	47%	30%	87%	98%	90%	78%	63%	98%	32%	24219.0
No.6	Low	Low	83%	45%	16%	4%	85%	97%	79%	46%	20%	98%	24%	17055.8
	Low	Middle	83%	45%	16%	4%	85%	99%	87%	59%	29%	99%	24%	18767.5
	Middle	Middle	99%	95%	86%	71%	99%	100%	100%	99%	96%	100%	22%	27453.9
No.7	Low	Low	29%	4%	1%	0%	31%	55%	14%	3%	1%	59%	31%	14453.7
	Low	Middle	29%	4%	1%	0%	31%	69%	24%	6%	1%	73%	31%	16502.3
	Middle	Middle	91%	73%	53%	36%	92%	99%	94%	84%	69%	99%	24%	23316.9



Appendix-figure 1a Comparison of future SSB trajectories by seven harvest scenarios with middle recruitment level (resampling from recruits in 1952-2011) based on the final base case SS run.



Appendix-figure 1b Comparison of future SSB trajectories by seven harvest scenarios with 10 years (2014-2023) low recruitment following 5 years average recruitment level (resampling from recruits in 1952-2011) from 2024 based on the finale base case SS run.



Appendix-figure 1c Comparison of future SSB trajectories by seven harvest scenarios with low recruitments (resampling from 1980-1989) based on the final base case SS run.