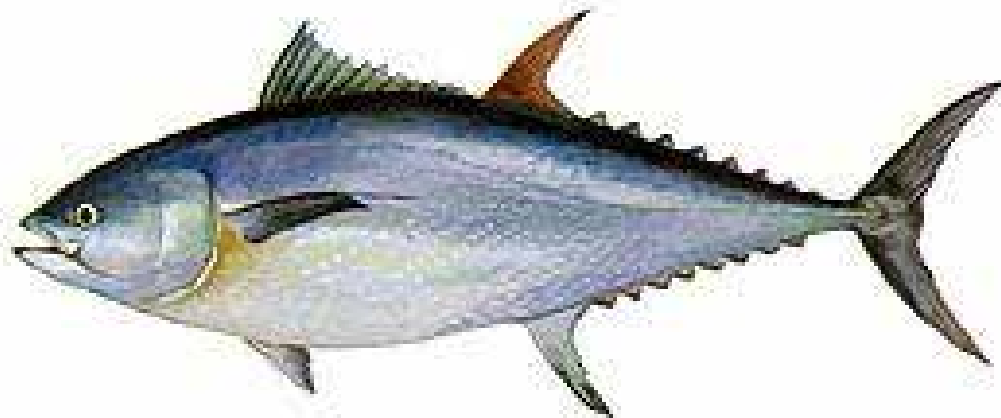# Stock Assessment of Pacific bluefin tuna (PBF)

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

Outline

- Back grounds

- Catch information

- Fishery data updates

- Specification of model

- Stock assessment results

- Stock status
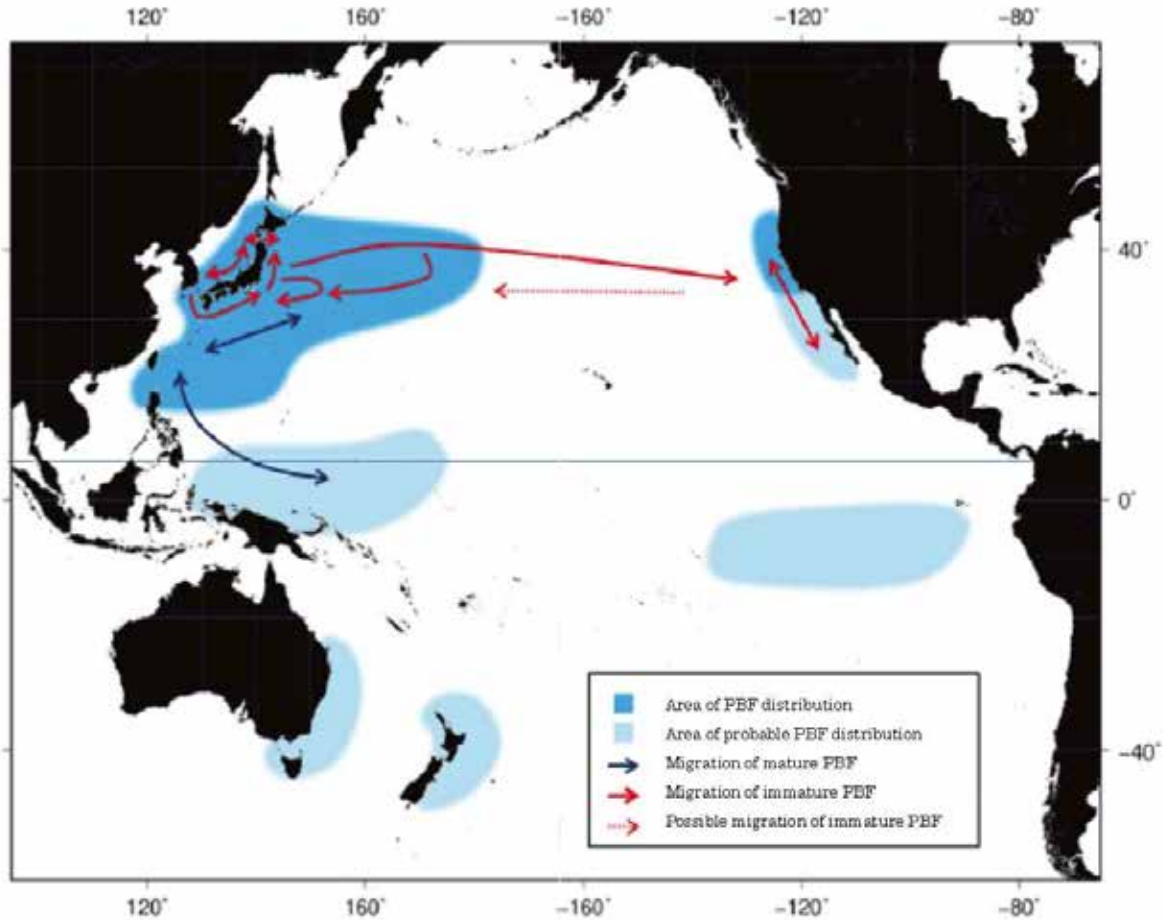
- Future projection

- Conservation advise

Back grounds

u ISC PBF working group is in charge of the stock assessment of Pacific bluefin tuna

u Current (July 2013~) WG chair

  u Ziro Suzuki (Japan)

u Scientists from IATTC, Mexico, Taiwan, USA, Korea and Japan are active members of the WG
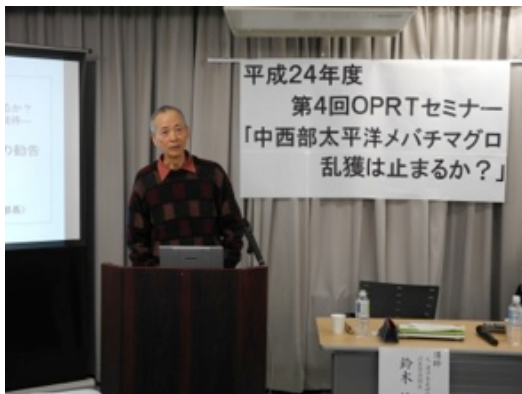
ISC's stock assessment working model

- ISC does not have its own scientific staff to conduct stock assessments

- ISC employs a working model to conduct stock assessment by the team of scientists from members including IATTC staff

- Usually model development and data preparation including data selection for stock assessment will be done through intercessional species group meeting between stock assessments.

- Active participations from members are essential for success of the stock assessment.

Distribution of PBF

Area of PBF distribution
Area of probable PBF distribution
Migration of mature PBF
Migration of immature PBF
Possible migration of immature PBF

u PBF starts spawning in Southern portion of Sea of Japan in June-Aug. 80% of age 3(about 30kg) is mature in SOJ(Tanaka 2006)

u Above 60 kg (over 150 cm FL, age 5+) PBF spawn in waters adjacent to the Ryukyu Islands in Japan to the east of Taiwan, exploited by JLL and TWLL

u A part of young bluefin make trans-pacific migration to EPO

The 2014 stock assessment update

u The latest full stock assessment was done in Nov 2012 with data through June 2011.

u The 2013 ISC Plenary decided to conduct a stock assessment update through updates of fishery data with additional two years (July 2011-June 2013)

  u The ISC Plenary proposed work plans for the assessment.

u The latest stock assessment were completed in February 2014 at the SWSFC in La Jolla, USA.

Work plans for stock assessment update in Feb. 2014 by ISC(ISC13 Plenary Report)

1. Conduct model run with an additional two years (2011 and 2012) of data using the same SS model (ver. 3.23b from the 2012 stock assessment) for the stock assessment platform and using the same model structure and parameters as the representative run (base-case run) from the 2012 stock assessment.

2. The stock assessment time period will be from July 1952 to June 2013.

3. The WG will not change the fishery data (quarterly catch, size composition) from 1952-2010 (July 1952-June 2011) that was used in 2012 stock assessment.

4. In the case of CPUE time series, due to the nature of the CPUE standardizations method, the whole time series will need to be re-standardized with the additional 2 years data.

Expected merits of updating stock assessment update (ISC13 Plenary Report)

1. With the additional 2 years (or optionally 3 years) of recruitment estimates, the WG can provide more accurate estimates of the immediate risk of declining SSB below the historically lowest observed SSB.

2. The 2012 stock assessment only evaluated the stock status before management measures were introduced (2011 by WCPFC, 2012 by IATTC) and this update will evaluate stock status since CMMs were introduced.

3. These additional 2 years of stock size and recruitment strength estimates enables the WG to address actual fishing mortalities under management (Fs in 2011 and 2012), recognizing that uncertainties still remain.
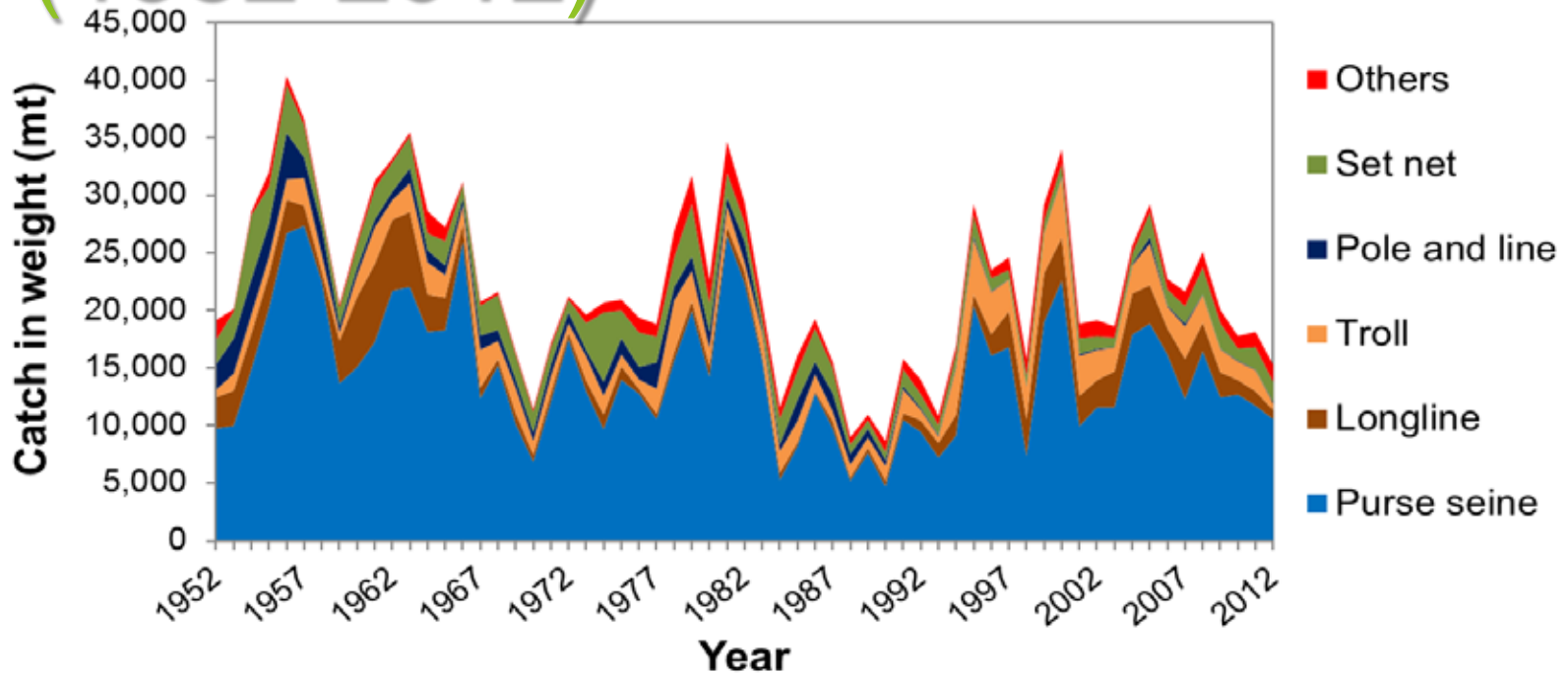
Catch information

# PBF catch by year and by country (1952-2012)
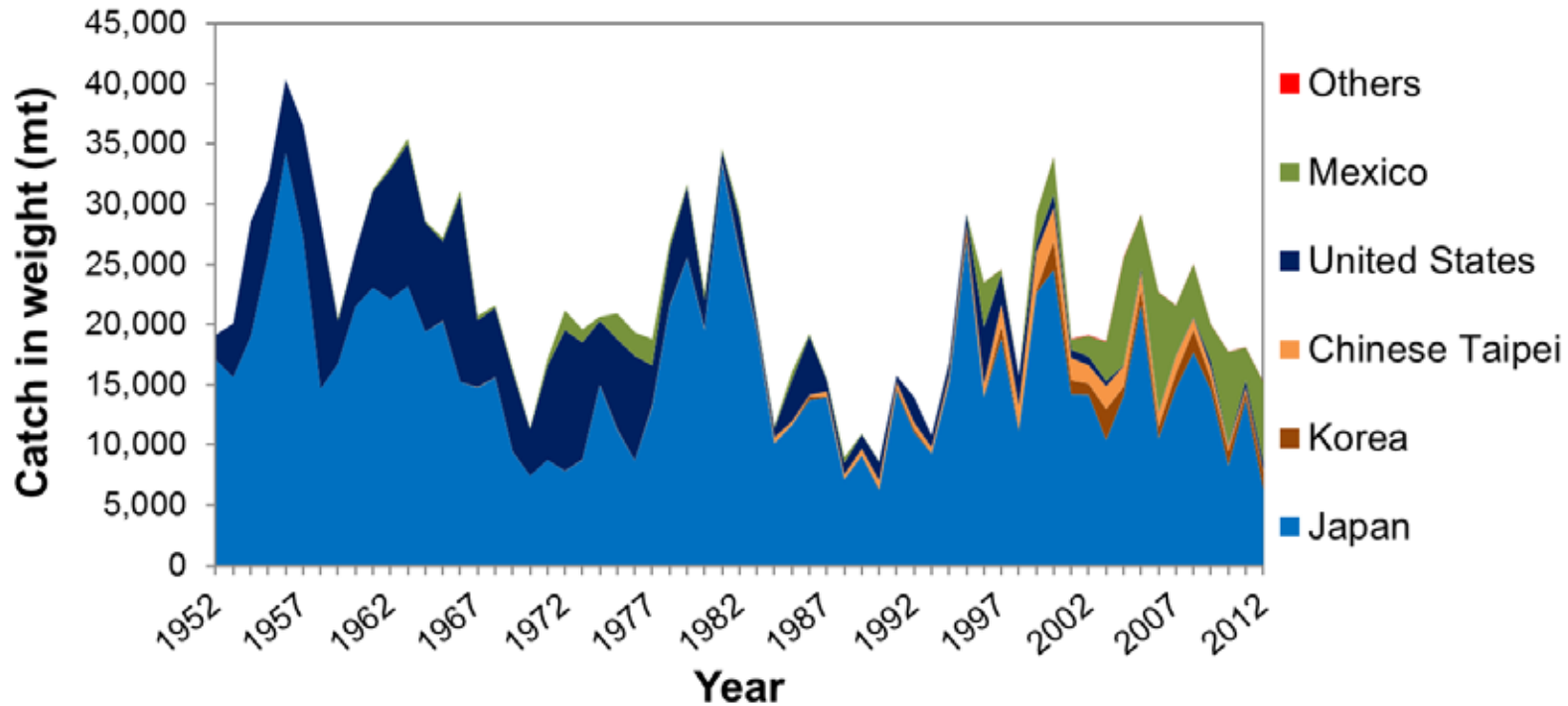
- u PBF were caught by fleets from Japan, Korea, Chinese Taipei, United States and Mexico.

- u Total catch in 2012 was 15,270 t (18,146 t in 2011).

- u **In EPO**, US caught a lot PBF until 1980s, Mexico increased catch after 2000s. US SPO catches certain amount(93~617t, in recent 5 years) of PBF

PBF catch by year and by gear (1952-2012)

u Purse seine fleets (including USA, Mexico, Korea and Japan) continued dominant fisheries in the total catch throughout the stock assessment period(1952-2013).

u Jpn PS in SOJ (age 3+), Jpn LL in waters off Nansei Islands (age 5+) and TW LL in waters south of JPN LL fishing ground (older than PBF caught by JLL) are the fisheries caught spawners

PBF catch at age (1952-2012)

Catch at age
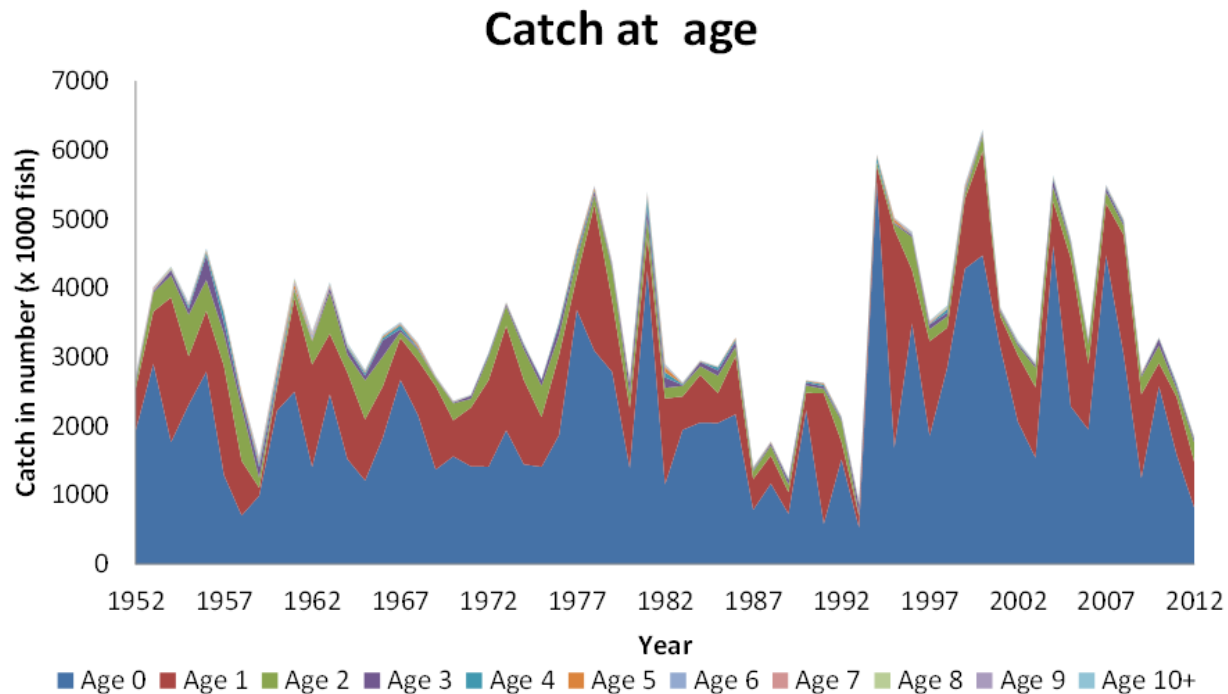
u Predominately composed of juvenile PBF

u Since the early 1990s, the catch of age 0 PBF has increased significantly

Fishery data updates

Summary table of fishery data updates

Fleet	Region	Fishery	Catch	Size	CPUE
F1	WCPO	Jpn LL	Updated	Updated	Updated
F2		SPeIPS	Updated	Updated	-
F3		TunaPSJS	Updated	Updated	-
F4		TunaPSPO	Updated	Updated	-
F5		JpnTroll	Updated	Updated	Updated
F6		JpnPL	Updated	Not used	-
F7		JpnSetNet	Updated	Updated	-
F8			Updated	Updated	-
F9			Updated	Updated	-
F10			Updated	Updated	-
F11		TWLL	Updated	Updated	Updated
F12	EPO	EPOPS	Updated	Updated	-
F13		EPOSports	Updated	Not used	-
F14	WCPO	Others	Updated	Updated	-

Temporal coverage of catch, abundance indices and size composition data
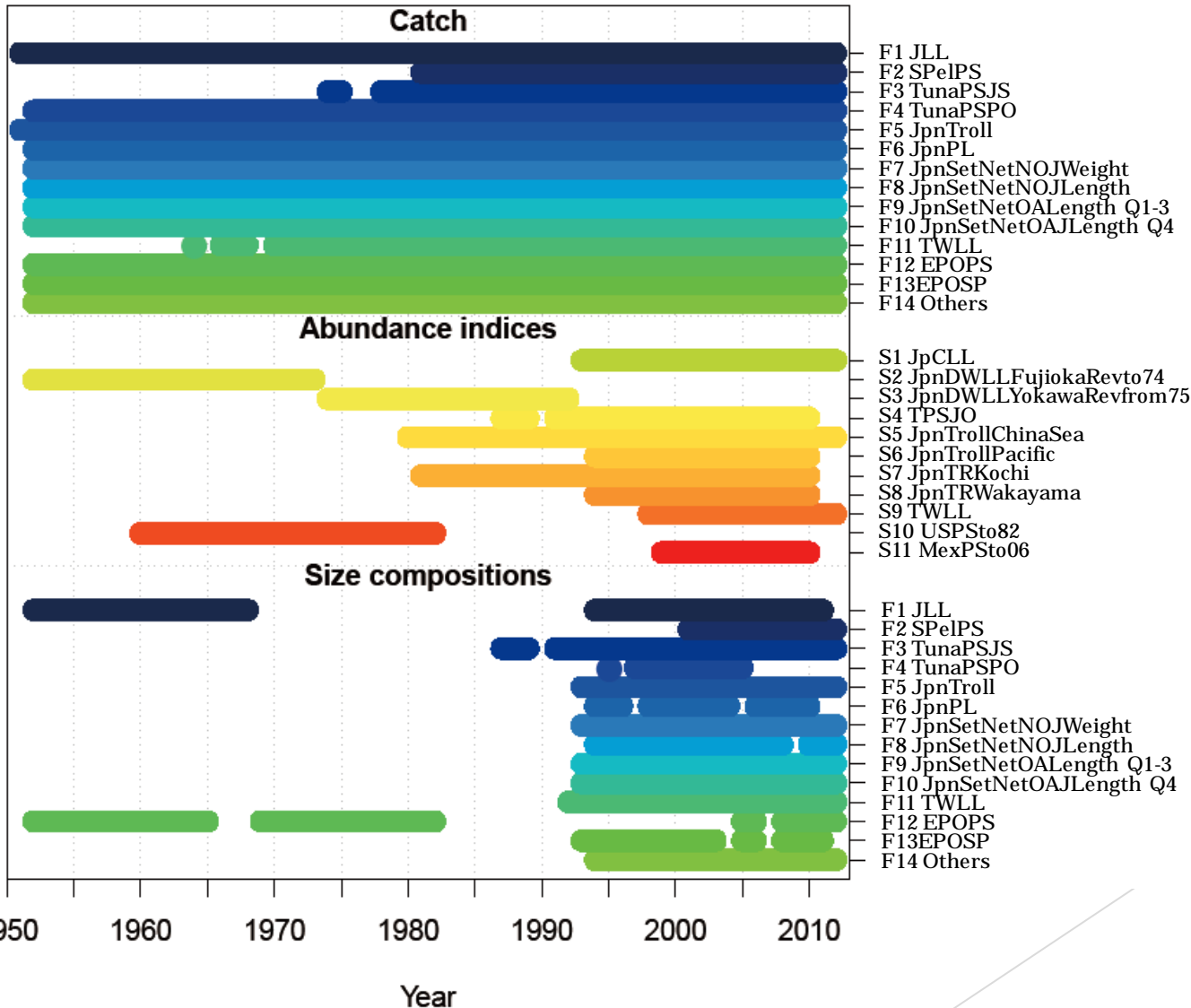
- u In EPO, USA(~1950s) and IATTC continued effort on size sampling

- u In WPO size sampling of JLL (F1) was rich ~1960s until when Jpn DWLL change their fishing ground to tropical, EPO, Atlantic oceans

- u In Japan, extensive size sampling started from 1990s

Specification of model

Data and model

u Input data

　　u Fishing year applied, starting from July and ending to June.

　　u Quarterly catch

　　u Quarterly size composition

　　u Standardized CPUE

　　　　u Japanese longline (JpnLL) for adult

　　　　u Taiwanese longline(TWLL) for adult

　　　　u Japanese troll (JpnTroll) for age-0

u Period: 1952-2012(July 1952-June 2013)

u No. of fleets: 14

u Stock assessment model

　　u Stock Synthesis v3.23b

Model settings

- Almost all model settings were same as the model used in the 2012 full assessment.

- Single stock and single spatial area including WCPO and EPO.

  - Essentially stock is expected to be mixed very well even between WPO and EPO

  - Implicit assumption that selex =gear selex and availability

- Maximum age is 20.

- Steepness is fixed to 0.999.

  - Smaller h is contradict to be the recent catch amount.

 - Monte Carlo simulation from life history parameters (Mangel's method, Iwata 2012) supported.

Growth curve

- Used externally determined VBGF parameters

- determined from otolith data with adjustment of observed length at age 0 from length comps

- L1=21.5cm at age=0 (July 1st)

- L2=109.194 at age=3

- k=0.157

- Linf=254.4

- CV_young (CV@L1): estimated

- CV_old=0.05:fixed(CV@L2)
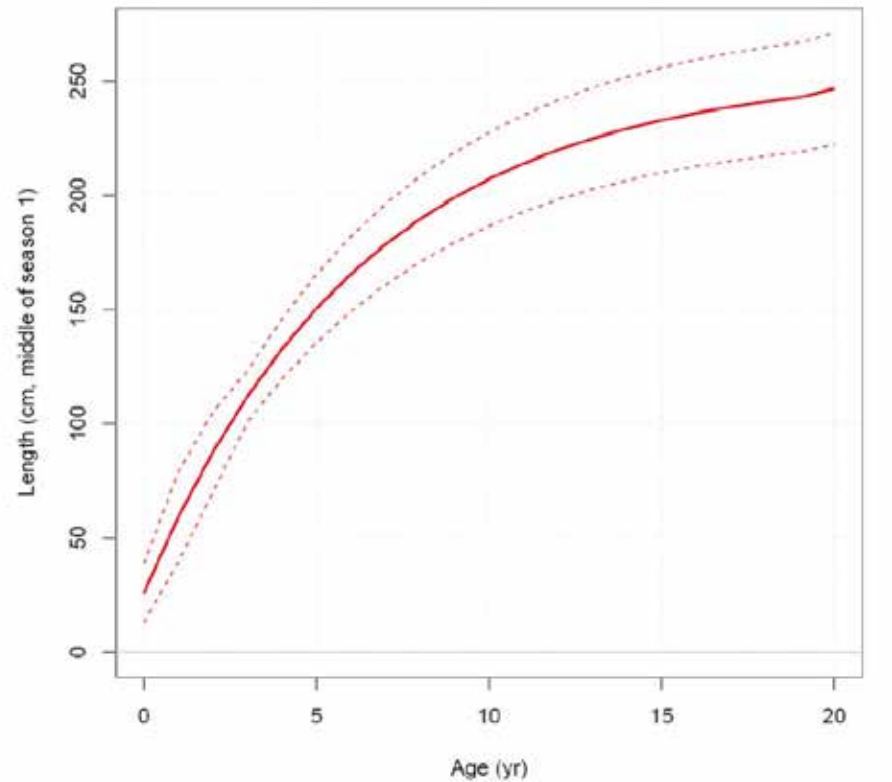
Natural mortality

- Externally input age specific natural mortality

- Age-0 M=1.6

  - Determined from tag recapture data

- Age-1 M=0.38 mimics SBT's M (determined from tagging) of same size

- Age-2 and older M =0.25 from life history consideration
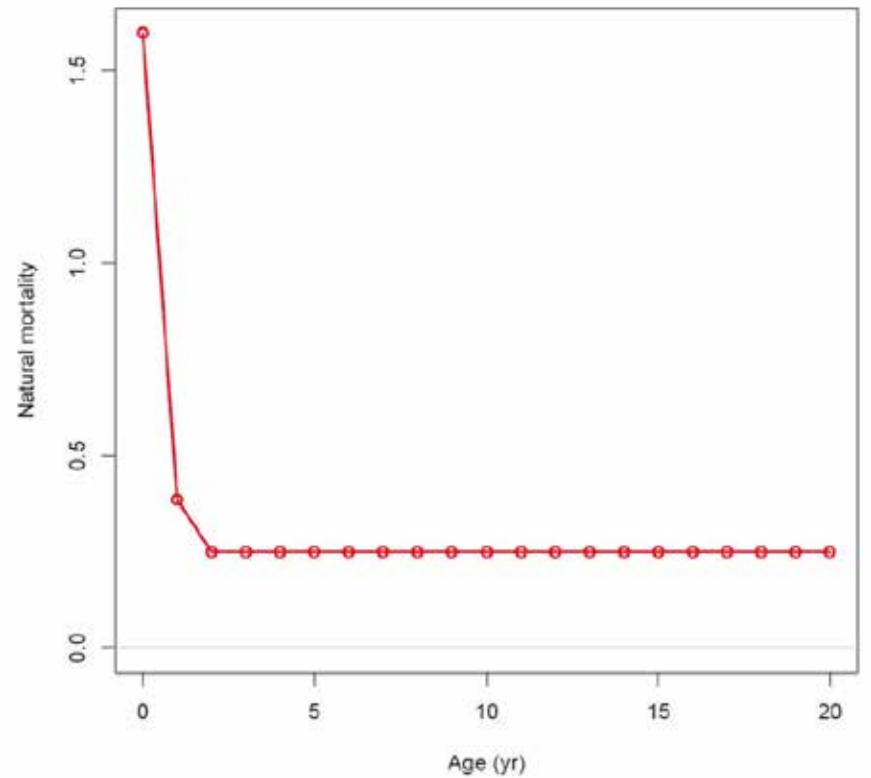
Maturity Schedule

u Age specific input maturity at age.
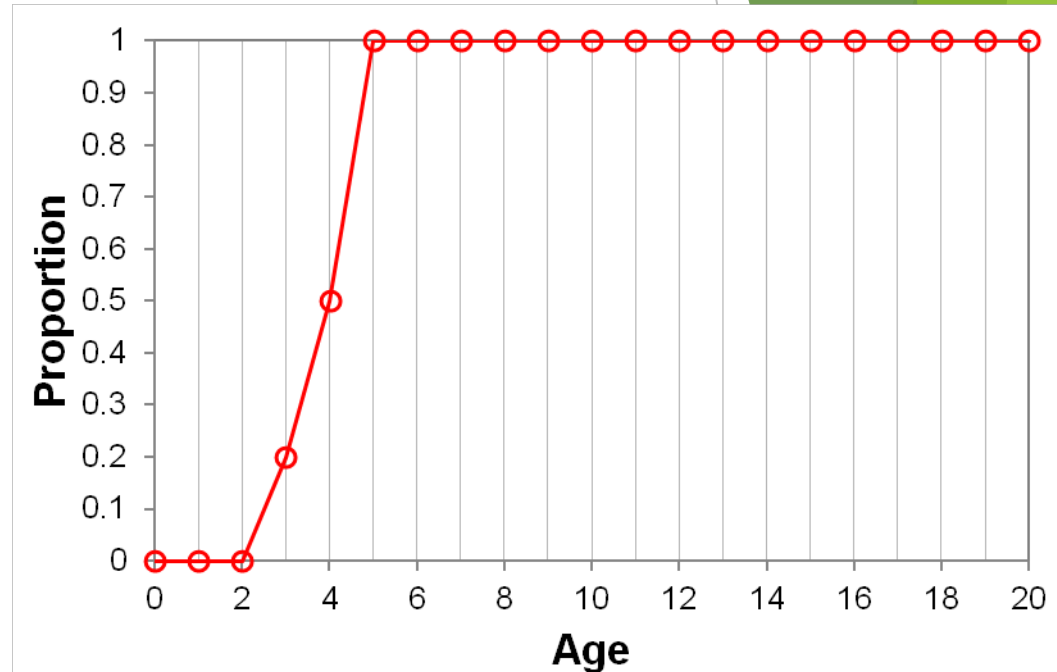
  - u Age 0-2: 0
  - u Age 3: 0.2
  - u Age 4: 0.5
  - u Age 5+: 1

u Rational :

  - u 80% of age 3 caught by JPN PS in SOJ was mature (Tanaka 2006)
  - u In EPO, age 3 is also exploited by PS but no spawning in EPO was recorded

u Young spawners (age 3,4) are not exploited by longline

Stock assessment results

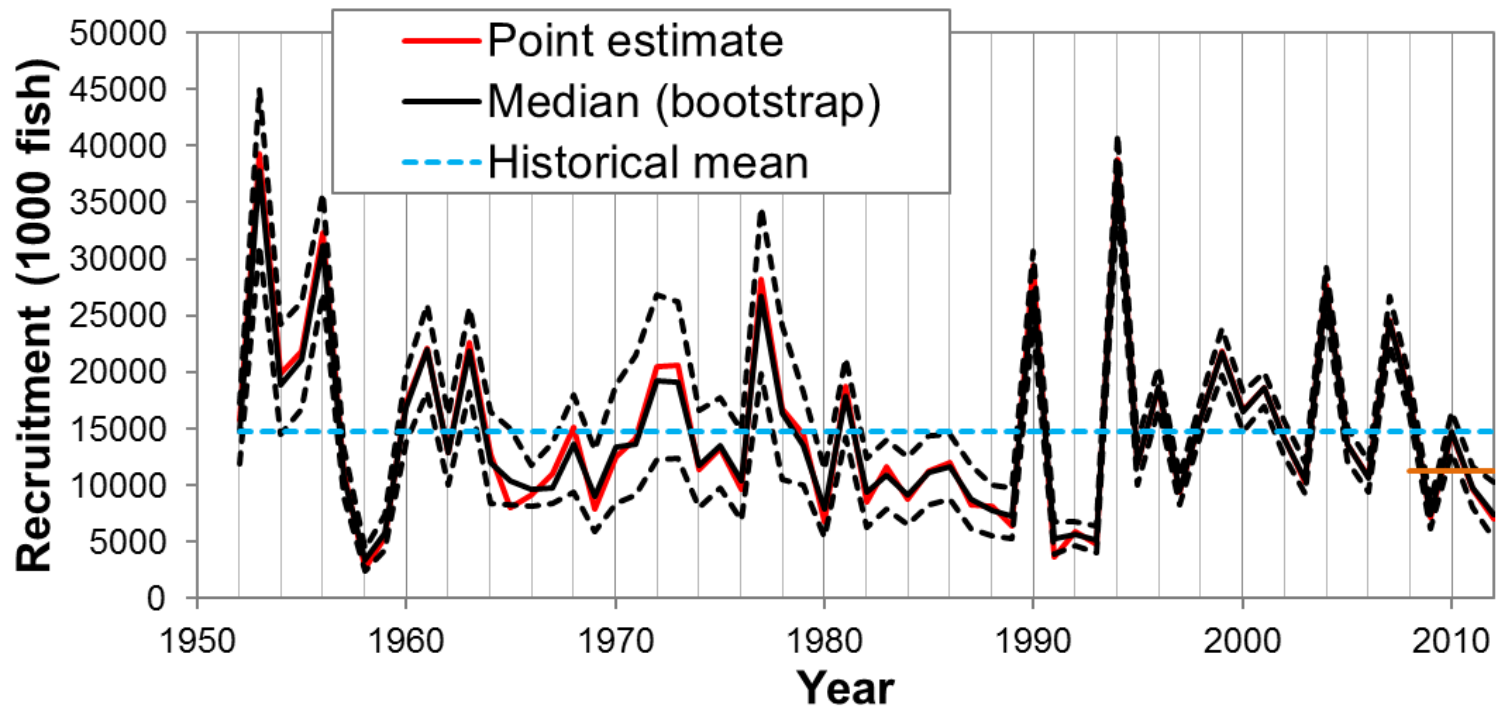# Spawning stock biomass
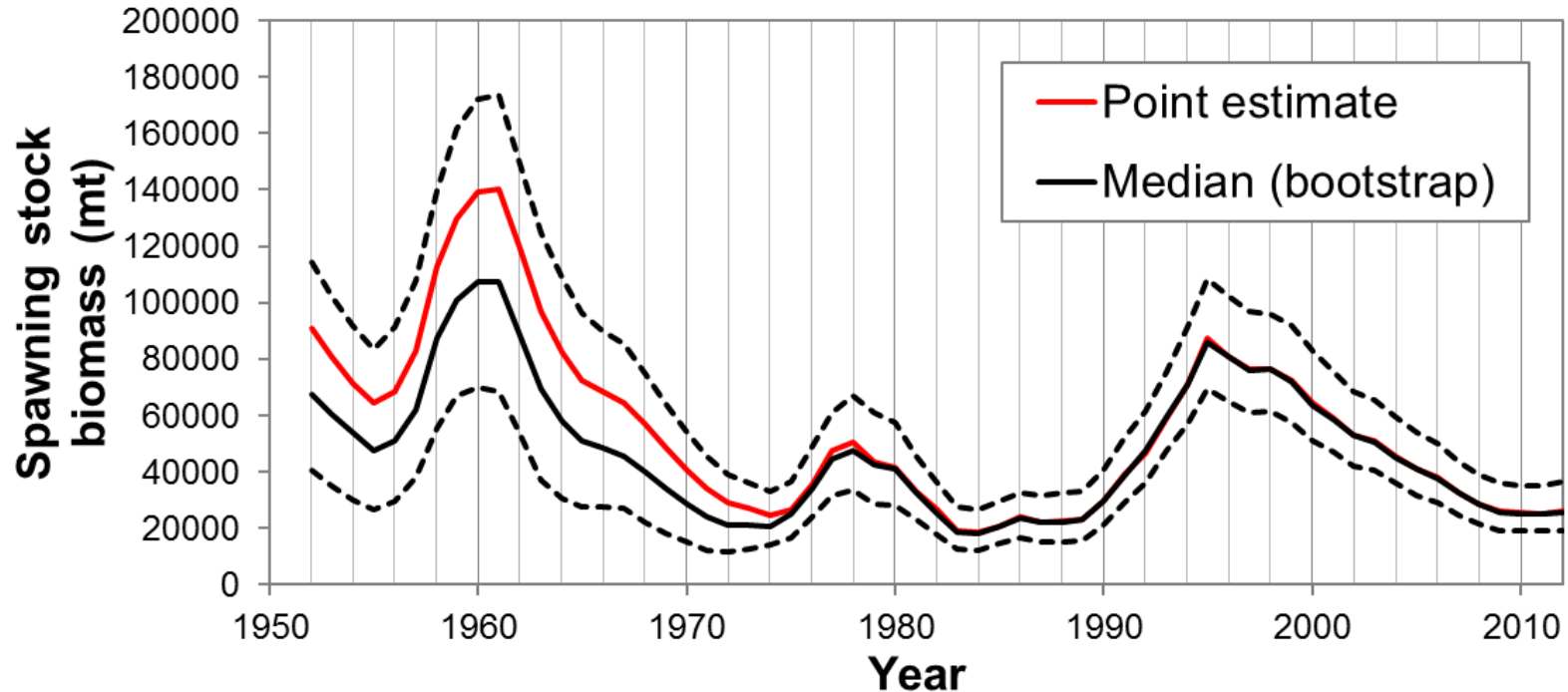
- The current (2012) spawning stock biomass was 26,324 mt, near historically low levels.

- Depletion ratio (SSB$_{2012}$/Unfished SSB) was 0.042.

Recruitment

u Recruitment level in 2012 was relatively low (the 8th lowest in 61 years)

u Mean recruitment for the last five years was likely to be below the historical average level.

Fishing mortality by age
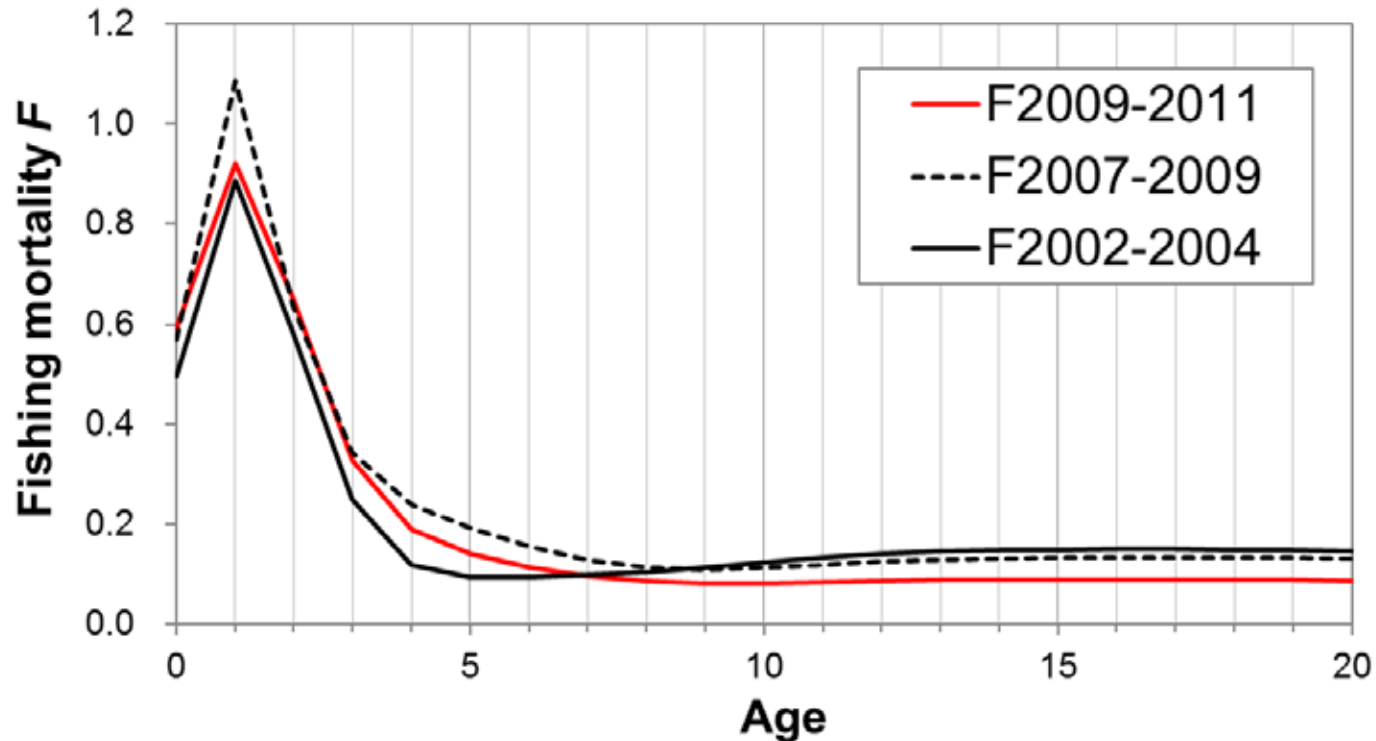
u Fs in 2009-2011 relative to 2002-2004 (the base period for the current WCPFC Conservation and Management Measure 2010-04) show 19%, 4%, 12%, 31%, 60%, 51% and 21% increases for ages 0-6, respectively, and 35% decrease for age 7+.

u There were apparent decreases of Fs in 2009-2001 relative to 2007-2009 at ages of 1 ,2 and 3

F at age by gear

Biological Reference Points

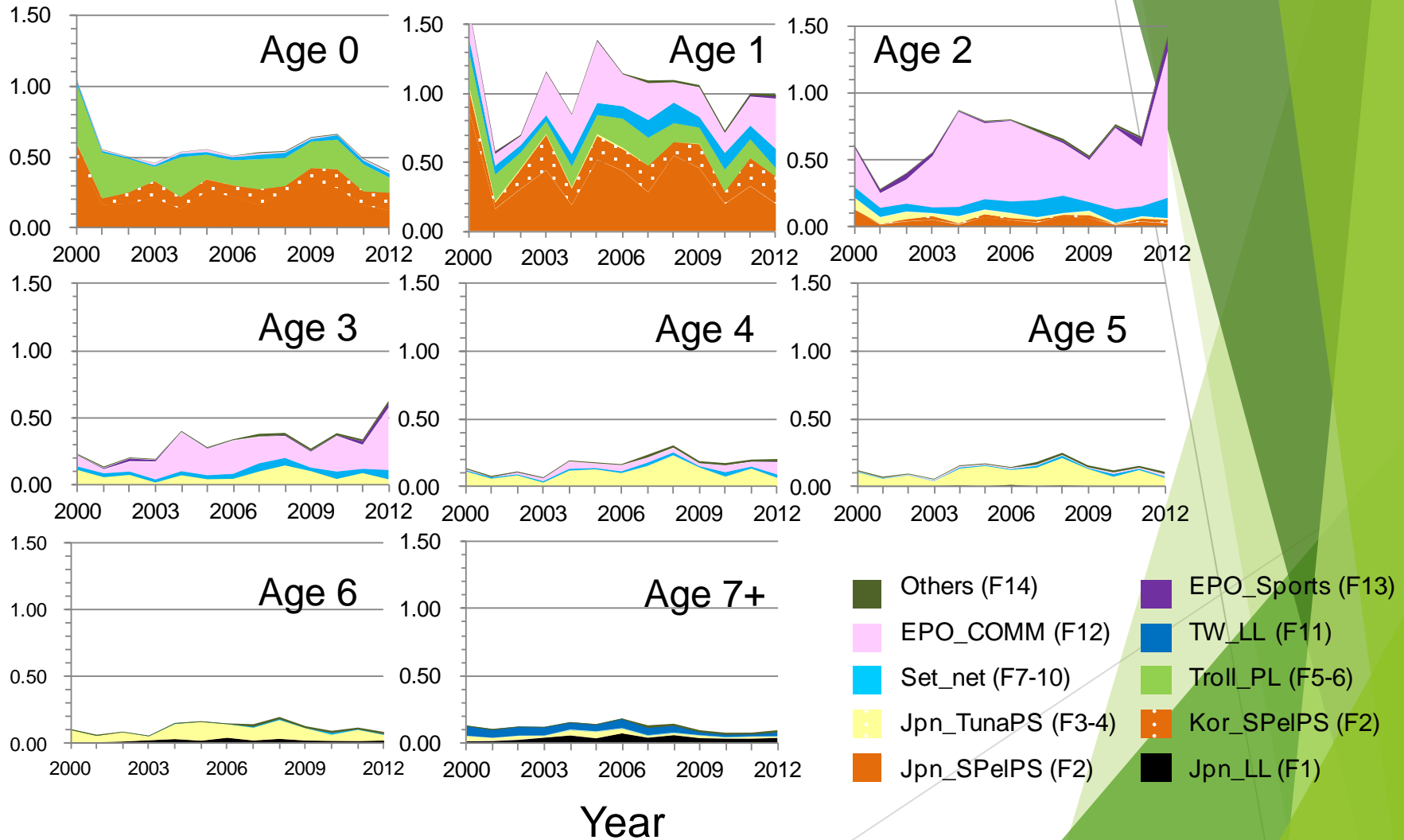- No target or limit reference points have been established for the PBF stock under the auspices of the WCPFC and IATTC.

- Current F ($F_{2009-2011}$) was above all BRPs except for F_{loss}.

- **Therefore, overfishing is occurring and the stock is overfished.**

	F_{Max}	$F_{0.1}$	F_{Med}	F_{loss}	$F_{10\%}$	$F_{20\%}$	$F_{30\%}$	$F_{40\%}$
$F_{2002-2004}$	1.70	2.44	1.09	0.84	1.16	1.68	2.26	2.98
$F_{2007-2009}$	2.09	2.96	1.40	1.08	1.48	2.14	2.87	3.79
$F_{2009-2011}$	1.79	2.54	1.25	0.97	1.32	1.90	2.55	3.36

Note: Values above 1.0 mean overfishing.

Stock status

Impact on SSB by fisheries
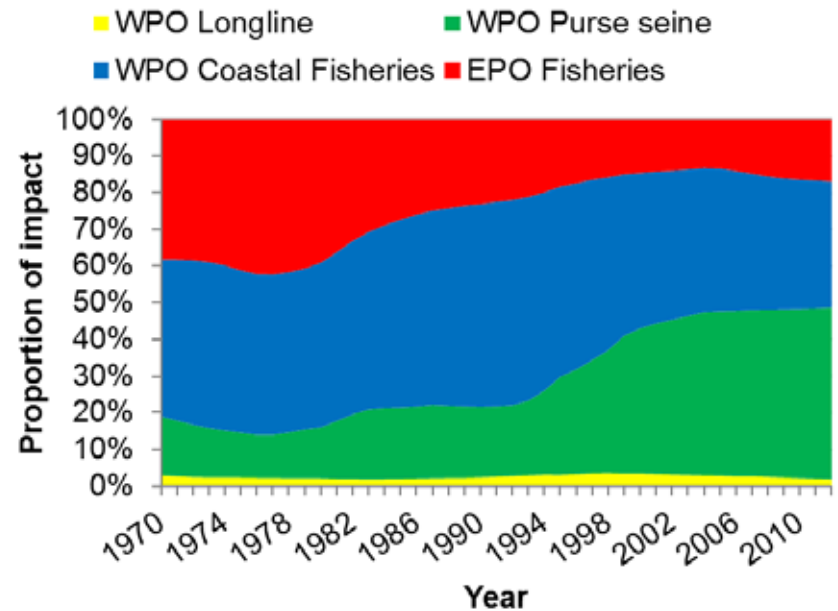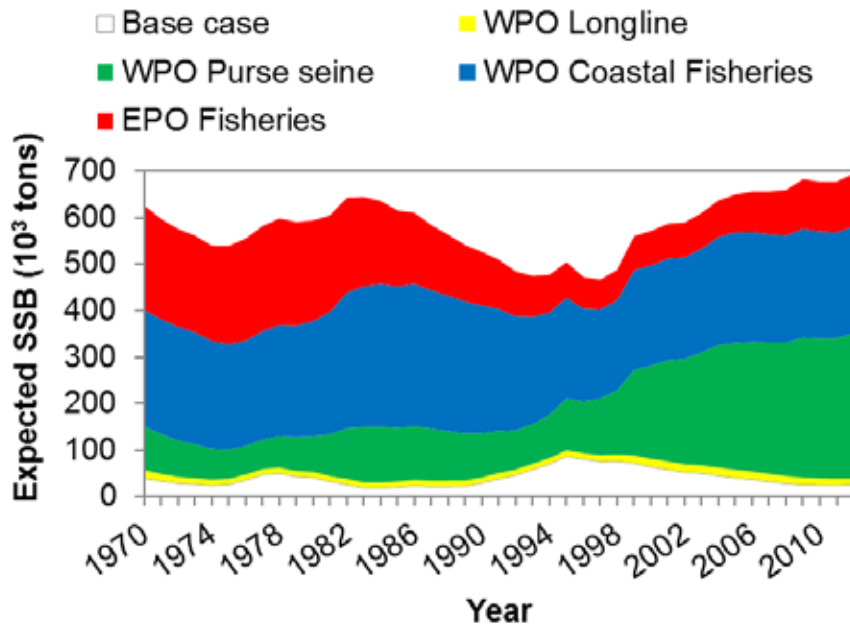
u Catching a high number of smaller fish can have an greater impact on future spawning stock biomass than catching the same weight of larger mature fish.

Two examples of Kobe plot
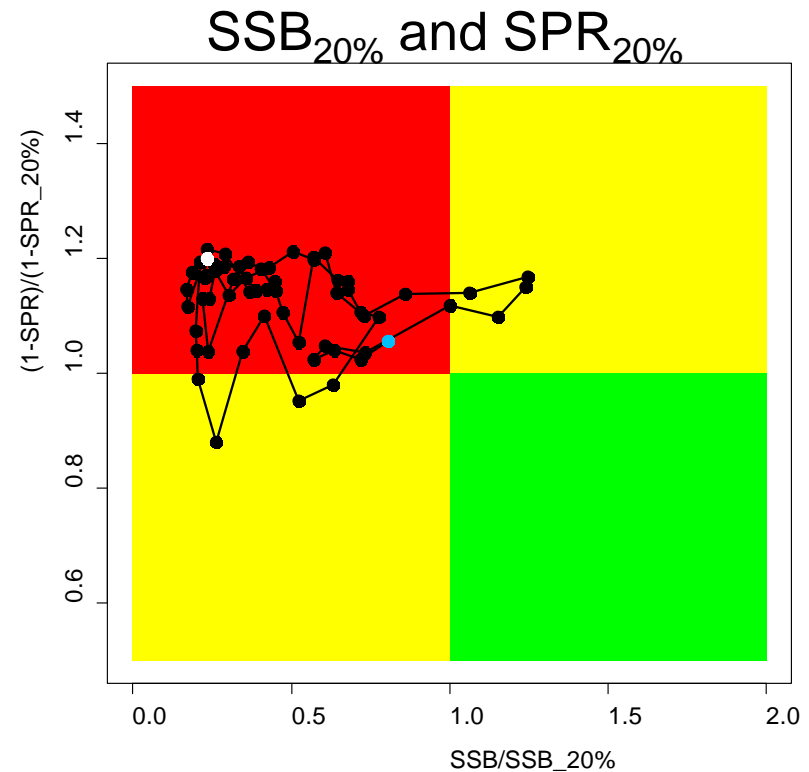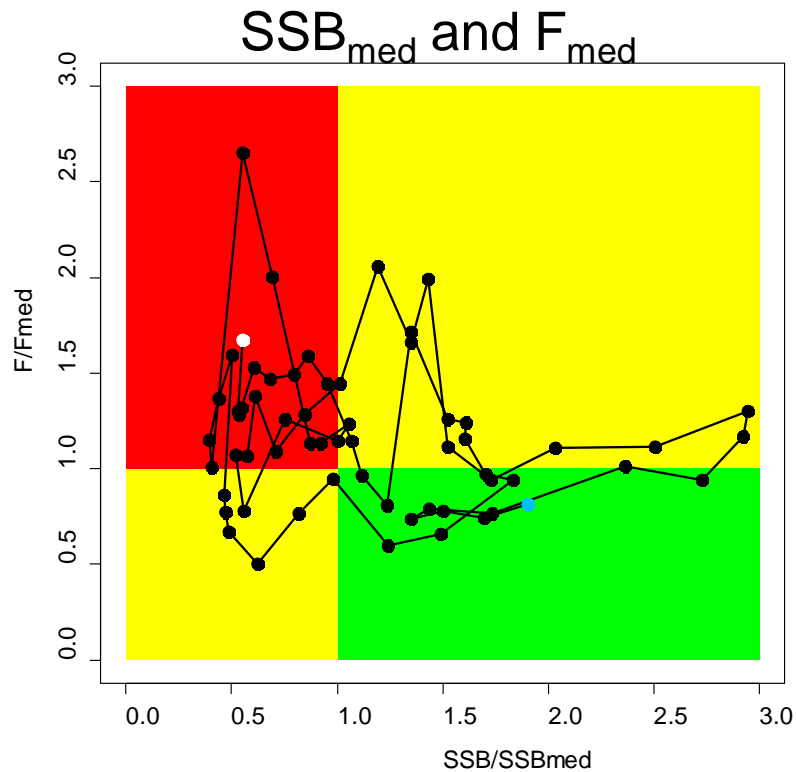
- For illustrative purposes, two examples of Kobe plots were presented.
- Because no reference points for PBF have yet been agreed to, these versions of the Kobe plot represent alternative interpretations of stock status in an effort to prompt further discussion.

Summary of stock status

- The current (2012) spawning stock biomass was 26,324 mt, near historically low levels.

- Mean recruitment for the last five years may have been below the historical average level.

- Overfishing is occurring and the stock is overfished.

Model fitting problem

- Poor fit to CPUEs and length compositions from longline fisheries of Japan and Chinese Taipei targeting adult PBF

- Inconsistent year trends of CPUE between JpnLL and TWLL

  - inevitable because of different target age class or model is too simple

  - Or

  - One of two is wrong?

- Availability difference hypothesis is not enough?
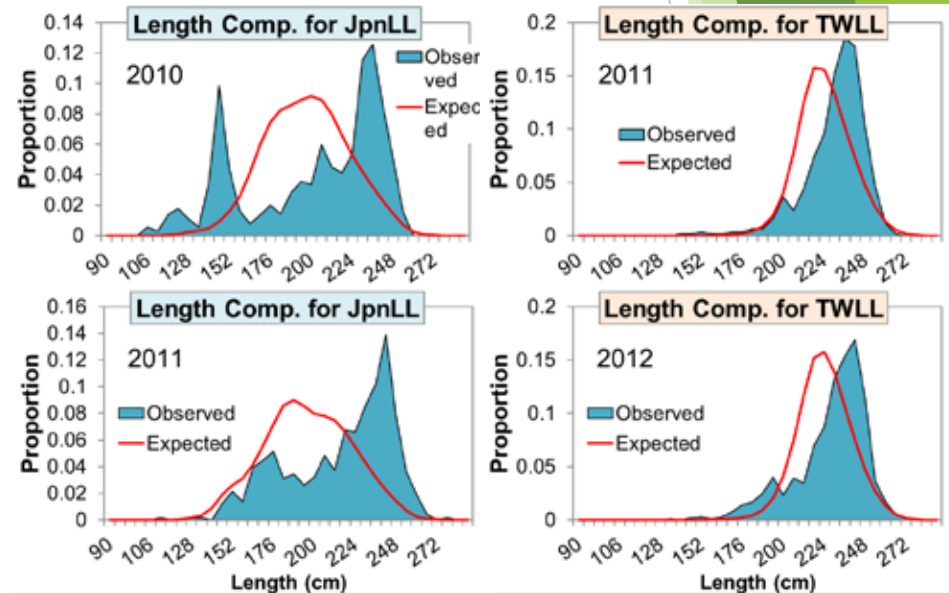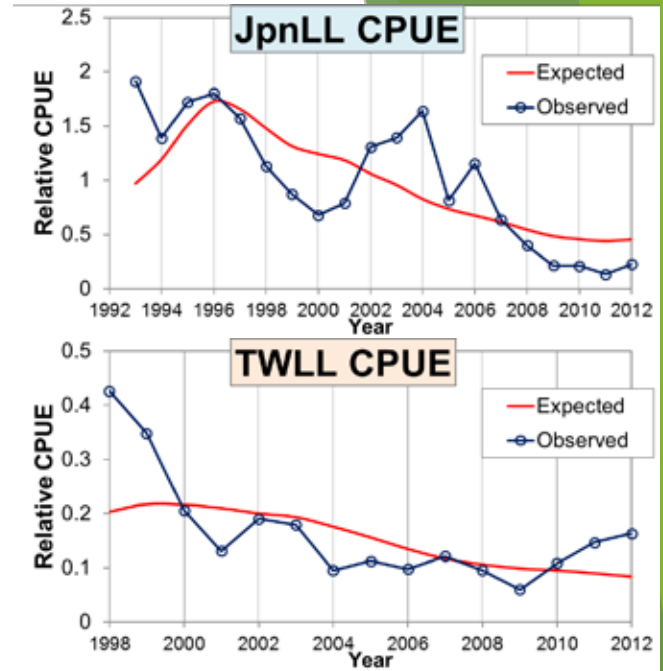
- Sensitivity runs were conducted to examine effects of updates of CPUE and length comp. data for JpnLL and TWLL

Specification of 4 sensitivity runs

Run #	JpnLL		TWLL	
	Latest 2 yrs CPUE	Latest 2 yrs length comp.	Latest 2 yrs CPUE	Latest 2 yrs length comp.
1 (Base case)	Updated	Updated	Updated	Updated
2	Updated	Updated	Not used	Not used
3	Not used	Not used	Updated	Updated
4	Not used	Not used	Not used	Not used

Results of sensitivity runs - 1

u Four runs has similar declining SSB trends.

    u After 2005, there were slight divergences among Runs 1-4.

u Recruitment estimates were robust across the runs.

Spawning stock biomass

—Run 1 —Run 2 —Run 3 —Run 4

Recruitment

—Run 1 —Run 2 —Run 3 —Run 4
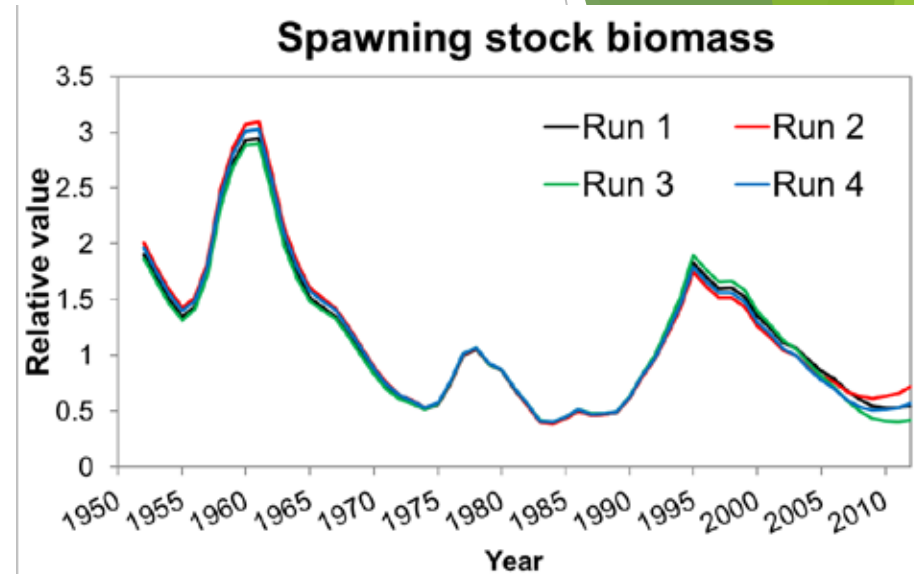
Results of sensitivity runs - 2

	F_{Max}	$F_{0.1}$	F_{Med}	F_{loss}	$F_{10\%}$	$F_{20\%}$	$F_{30\%}$	$F_{40\%}$	Depletion ratio
$F_{2002-2004}$									
Run1	1.70	2.44	1.09	0.84	1.16	1.68	2.26	2.98	0.042
Run2	1.73	2.47	1.09	0.85	1.16	1.68	2.26	2.99	0.054
Run3	1.78	2.55	1.16	1.03	1.24	1.79	2.40	3.17	0.031
Run4	1.77	2.52	1.13	0.89	1.21	1.75	2.36	3.11	0.043
$F_{2007-2009}$									
Run1	2.09	2.96	1.40	1.08	1.48	2.14	2.87	3.79	0.042
Run2	1.93	2.74	1.25	0.99	1.34	1.94	2.60	3.43	0.054
Run3	2.34	3.31	1.54	1.38	1.65	2.38	3.20	4.23	0.031
Run4	2.11	2.98	1.36	1.07	1.46	2.11	2.84	3.74	0.043
$F_{2009-2011}$									
Run1	1.79	2.54	1.25	0.97	1.32	1.90	2.55	3.36	0.042
Run2	1.61	2.30	1.11	0.88	1.19	1.71	2.29	3.02	0.054
Run3	2.02	2.86	1.37	1.23	1.46	2.11	2.83	3.73	0.031
Run4	1.77	2.52	1.20	0.95	1.29	1.85	2.49	3.27	0.043

Summary of sensitivity runs

u All runs indicated that SSB in recent years were close to historical lowest level, although there were slight divergences among 4 runs.

u All runs indicated that stock is overfished and overfishing is occurring.

u Results of sensitivity analysis are consistent to the conclusion of stock status from base case run.

Future projection

Current(2014) management measures in EPO and WCPO

- 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,
  - 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.

Requests from WCPFC NC9

1. Provide range of historical variation in recruitment or other appropriate measures, specifically, information for the low recruitment period during the 1980s, and for the last 10 years.

2. Conduct future projection based on 7 harvesting scenarios proposed by NC9.

7 harvesting scenarios proposed by WCPFC NC9

#	WCPO			EPO COMM
	Fishing effort	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

*Juvenile corresponds to fish of ages 0 through 3 (less than 30 kg)

Specifications of future projection

- Each simulation starts from 2012.

- F at age and N at age in 2012 is taken from 300 parametric bootstrap SS runs.

- For each bootstrap replicate, 20 simulations conducted with resampled recruitment in 1952-2011.

  - Future recruitment were set based on the historical variation.

- 6000 stochastic simulations by 2028 with 7 harvesting scenarios proposed by WCPFC NC9.

- EPO : annual quota for commercial fleet, 2002-2004 average F

Harvest scenario condition

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 (<30kg)** 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.

Definition of juvenile
(Population dynamics vs management simulation)

u The ISC-PFBWG has noted differences in the definition of "juveniles" by NC9 and stock assessment (if it is recognized as non mature individuals) those specified in the stock assessment model.

  u NC9

    u Juvenile : fish of ages 0 through 3 ((and) less than 30 kg)

  u Population dynamics in stock assessment (including future projections)

    u Juvenile : non-mature individuals (age 0 – age 2 :100%, age 3 : 80%, age 4 50%)

u Therefore, the PBFWG recognized that juvenile catch reduction, including all non-mature individuals, should be considered in management decisions.

u However, how we can actually reduce juvenile catch of age 3 by 50% without changing catch of matured individuals of age 3, which are indistinguishable virtually from juveniles? Need more direction if it is the what we want to do.

Historical variation in recruitment
(Ishida et al. 2014, ISC/14/PBFWG-1/06)

Recruitment from 1980 to 2012

- There were two break points between 1993 and 1994, and between 2008 and 2009.

- Recruitments in 1980-1993 and 2009-2012 were significantly lower than the historically average recruitments.

- Duration of different productivity phase may be on the order of 14 or 15 years.

Future recruitment

- For recruitments in 2012 and 2013 which has already occurred, re-sampling was conducted from the recruitment in 1986-1988.

    - Years of 1986-1988 were the lowest 3 years of recruitment in 1980-1989.

- Two definitions of future recruitment

    - Average recruitment scenario

        - Re-sampled from the whole stock assessment period (1952-2011).

    - Low recruitment scenario

        - Re-sampled from the period of 1980-1989.

Recruitment scenario #	2014-2023	From 2024
1	Low	Low
2	Low	Average
3	Average	Average

SSBrecent,F=0

- A "dynamic $SSB_{F=0}$" was calculated by projecting setting F=0 with randomly drawing from recent 10 years (2002-2011) recruitments

  - Average recruitment (2002-2011) is about same as average of whole stock assessment period

  - =630KT
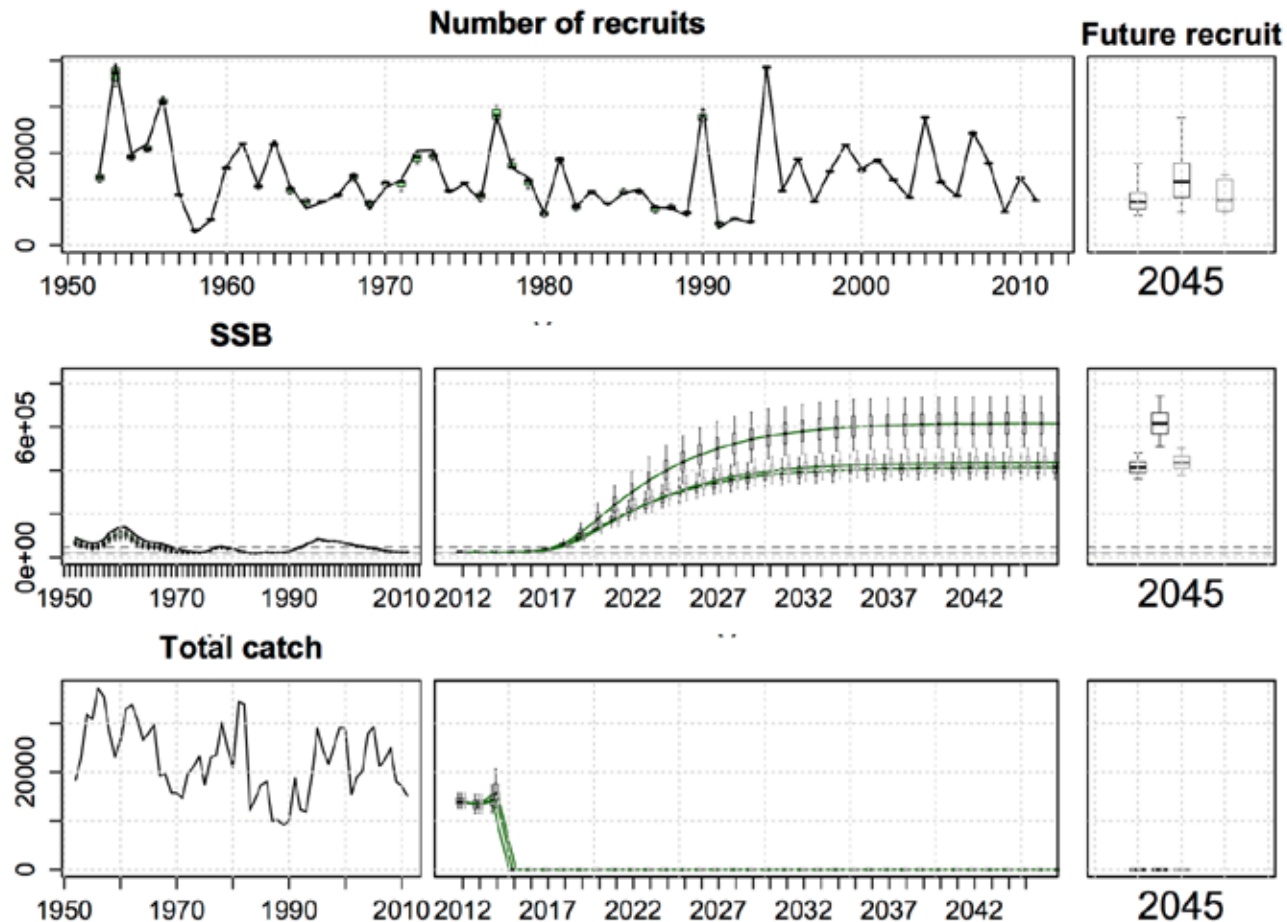
Recruitment, SSB and total catch under recruitment scenario 1 (Low for initial 10 yrs and low for subsequent 5 yrs

- If the low recruitment in recent years continues, the risk of SSB below its historical lowest would increase.

- Only the harvest scenario 6 achieved increase of SSB above "at least" historical median more than 80% within 10 yrs from 2014.
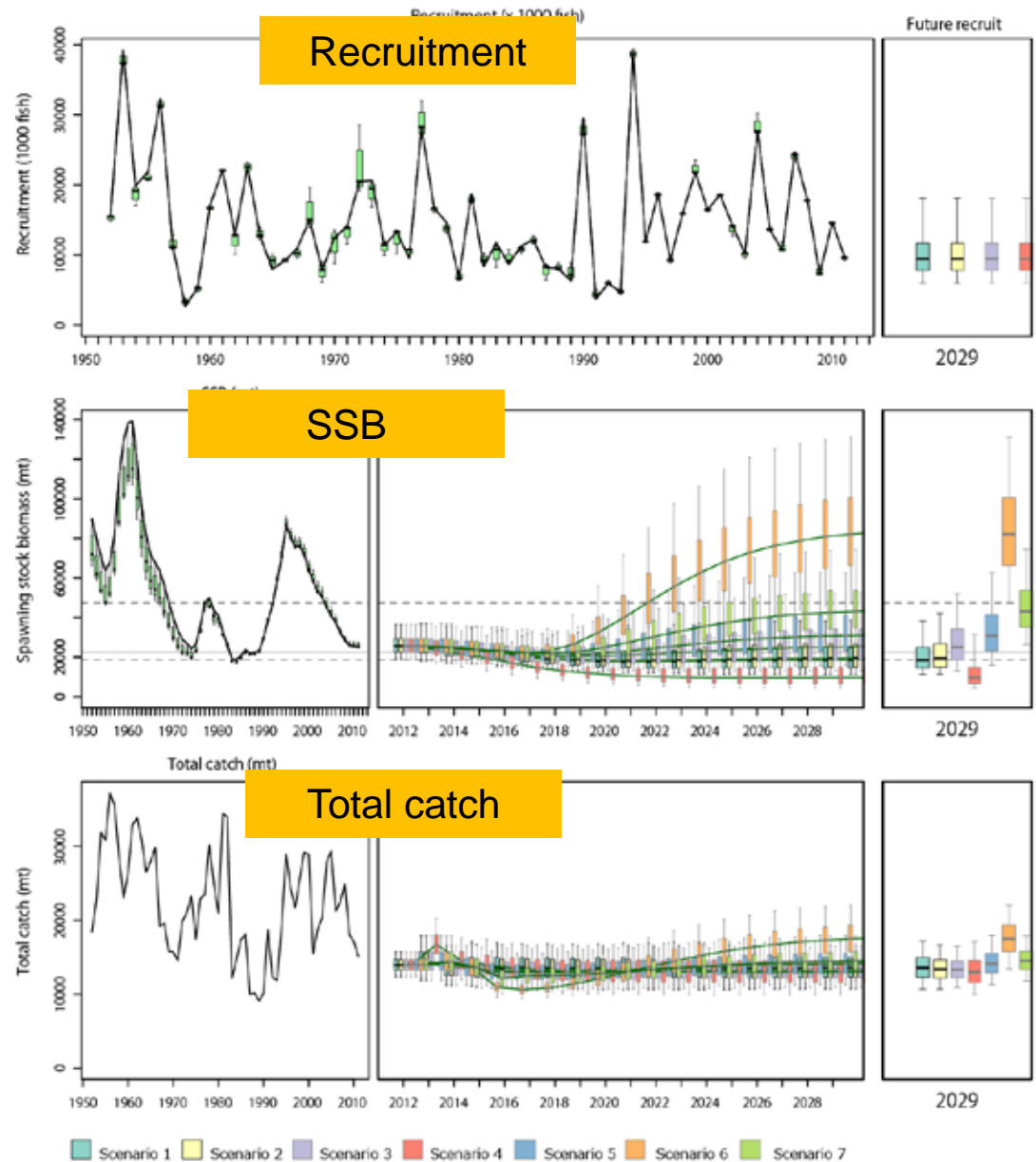
Recruitment, SSB and total catch under recruitment scenario 2 (Low for initial 10 yrs and average for subsequent 5 yrs

u Only the harvest scenario 6 achieved increase of SSB above historical median more than 50% within 10 yrs from 2014.

Performance table of 7 harvesting scenarios proposed by NC9

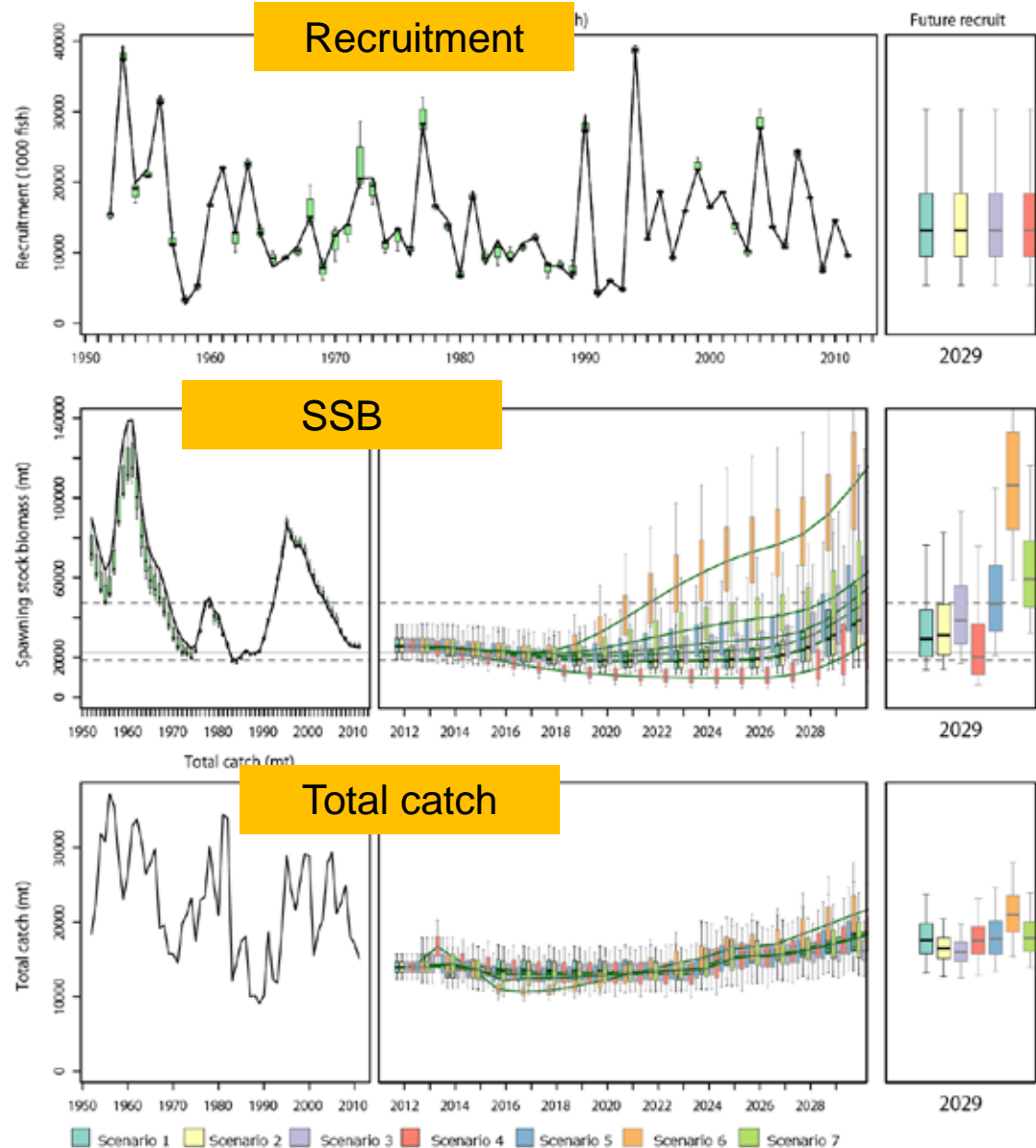| Scenario #	Future recruit level		Within 10 years from 2014 Probability achieving reference level at least one year					Within 15 years from 2014 Probability achieving reference level at least one year					Mean yield in 2026 - 2028
	2014 - 2023 (10years)	From 2024	62KT (10%SSB_0)	93KT (15%SSB_0)	124KT (20%SSB_0)	155KT (25%SSB_0)	Historical Median(43KT)	62KT (10%SSB_0)	93KT (15%SSB_0)	124KT (20%SSB_0)	155KT (25%SSB_0)	Historical Median(43KT)	
No.1	Low	Low	0%	0%	0%	0%	4%	1%	0%	0%	0%	7%	13,665
	Low	Average	0%	0%	0%	0%	4%	3%	0%	0%	0%	14%	16,321
	Average	Average	48%	24%	10%	4%	69%	76%	50%	29%	15%	90%	22,932
No.2	Low	Low	1%	0%	0%	0%	5%	2%	0%	0%	0%	9%	13,456
	Low	Average	1%	0%	0%	0%	5%	4%	0%	0%	0%	17%	15,818
	Middle	Average	53%	30%	16%	8%	72%	80%	59%	40%	26%	92%	17,572
No.3	Low	Low	1%	0%	0%	0%	9%	4%	0%	0%	0%	18%	13,380
	Low	Average	1%	0%	0%	0%	9%	8%	1%	0%	0%	29%	15,447
	Average	Average	60%	36%	20%	10%	79%	87%	67%	48%	31%	96%	17,019
No.4	Low	Low	1%	0%	0%	0%	2%	1%	0%	0%	0%	5%	13,186
	Low	Average	1%	0%	0%	0%	2%	2%	0%	0%	0%	9%	15,834
	Average	Average	48%	27%	13%	5%	64%	77%	57%	37%	20%	87%	23,565
No.5	Low	Low	3%	0%	0%	0%	16%	8%	1%	0%	0%	32%	14,196
	Low	Average	3%	0%	0%	0%	16%	16%	2%	0%	0%	46%	16,225
	Average	Average	70%	43%	22%	10%	87%	92%	75%	52%	32%	98%	24,219
No.6	Low	Low	51%	12%	2%	0%	85%	84%	39%	9%	2%	98%	17,056
	Low	Average	51%	12%	2%	0%	85%	90%	51%	17%	4%	99%	18,768
	Average	Average	96%	83%	61%	38%	99%	100%	98%	91%	77%	100%	27,454
No.7	Low	Low	6%	1%	0%	0%	31%	18%	2%	0%	0%	59%	14,454
	Low	Average	6%	1%	0%	0%	31%	30%	4%	0%	0%	73%	16,502
	Average	Average	77%	49%	26%	13%	92%	96%	81%	59%	38%	99%	23,317

Note: SSB_0 was calculated using the most recent 10 years recruitment.

υ Scenario 6 performs best across the three recruitment scenarios.

Summary of future projections

- **Status quo** (continuation of measures in 2014 in the following years, Scenario 1) is **not expected to increase SSB**, if recent low recruitment continues.

- No scenario except for Scenario 6, the strictest one, demonstrates increase of SSB assuming the current low recruitment continues.

- Probability in the table above is calculated as number of simulation which reach "a target SSB" at least once during specific years (10 years or 15 years)

Conservation Advise from ISC

The current (2012) PBF biomass level is near historically low levels and experiencing high exploitation rates above all biological reference points except for F_{loss}. Based on projection results, the recently adopted WCPFC CMM (2013-09) and IATTC resolution for 2014 (C-13-02) if continued in to the future, are not expected to increase SSB if recent low recruitment continues.

Conservation Advise from ISC

In relation to the projections requested by NC9, only Scenario 6 , the strictest one, results in an increase in SSB even if the current low recruitment continues (Figure 11). 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.

Conservation Advise from ISC

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 , even under full implementation (Scenario 1)

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 used in 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.

Next stock assessment

u The next full stock assessment of PBF by ISC is planed to conduct early in 2016.