ISC Pacific Bluefin tuna Stock Assessment 2016 (SA–WP07)

Completed in 2016–Feb. 29th to 2016–Mar. 12th at La Jolla, USA

ISC Pacific Bluefin tuna Working Group
Schedule for PBF Stock Assessment in 2016

❖ ISC PBFWG Workshop

- Scientists from:
  ◦ USA, Mexico, Korea, Chinese Taipei, Japan, and IATTC secretariat
- April 2015@Shizuoka
  ◦ Reviewed the last stock assessment in 2014 to clarify the issues.
  ◦ New idea for data preparation and assessment modeling.
- November 2015@Kaohsiung
  ◦ Finalized data preparation methods.
  ◦ Discussed about a simple model as a starting point of assessment modeling.
  ◦ The future projection setting and scenarios.
- Feb.-March 2016@La Jolla
  ◦ Established a benchmark assessment model.
  ◦ Conducted future projections.
  ◦ Concluded the Stock Status and Conservation Advice for PBF.
Outline

❖ Assessment model
  ○ Data
  ○ Assumptions for Biology and selectivity

❖ Results
  ○ Fits to the data, diagnostics
  ○ Biomass, Fishing mortality, Fishery impact
  ○ Future projection

❖ Conclusion
Overview of assessment model

❖ A fully integrated model (Stock Synthesis–Version 3)
  ○ Length–based, age–structured (0–20+) model

❖ Fishery data (From 1952 to 2014)
  ○ 2013–2014 were updated.

❖ Fishery definitions: 19 fisheries (Fleets)

❖ No–spatially defined model

❖ Given Growth, Maturity, Natural mortality, Stock–Recruitment relationship
Main differences from the last assessment

- Fishery definition
  - From 14 fleets to 19 fleets.

- CPUE standardization methods
  - Jpn LL (targeting effect) and Twn LL (area effect)

- Size comp. data
  - Method to raise to the catch number at size

- Growth curve

- Initial weighting of size composition data

- Methods to estimate the selectivity of fishery
  - Implement more time variant processes.
Assessment model

❖ Catch
  ○ 19 Fleets (1952-2014)

❖ Size composition
  ○ Raised to the total number of fish caught (Catch# at size)
  ○ 6 purse seines, 3 longlines, 3 set-nets, 2 trolls.
  ○ More information after 1990.

❖ CPUE based abundance indices
  ○ 2 Fleets for large adult (Jpn and Twn longlines).
  ○ 1 Fleet for age-0 fish (Japanese troll).
Size Compositions
CPUEs

<table>
<thead>
<tr>
<th>Survey#</th>
<th>Fisheries</th>
<th>Duration</th>
<th>Standardization</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Japanese Longline</td>
<td>1993-2014</td>
<td>ZINB</td>
</tr>
<tr>
<td>S2</td>
<td>Troll</td>
<td>1952-1973</td>
<td>GLM(LN)</td>
</tr>
<tr>
<td>S3</td>
<td>Troll</td>
<td>1974-1992</td>
<td>GLM(LN)</td>
</tr>
<tr>
<td>S5</td>
<td>Taiwanese Longline (S)</td>
<td>1980-2014</td>
<td>GLM(LN)</td>
</tr>
<tr>
<td>S9</td>
<td>Taiwanese Longline (S)</td>
<td>2000-2014</td>
<td>GLMM</td>
</tr>
</tbody>
</table>

a. Longline CPUEs
   ○ Large adult (age 7+)

b. Troll CPUE
   ○ Mainly age-0 fish
Assumption of Population dynamics

❖ Natural mortality
  ○ 1.6@age−0, 0.386@age−1, 0.25@age−2+

❖ Maturity
  ○ 20%@age−3, 50%@age−4, 100%@age−5+

❖ Growth, Length–Weight relationship
  ○ Von Bertalanffy growth function estimated externally.

❖ Stock Recruitment Relationship (S−RR)
  ○ Beverton–Holt Relationship (h=0.999, S.D. of log Rec. =0.6)

❖ Selectivity of Fisheries
  ○ Constant throughout the assessment period
  ○ Time varying selectivity
Von-Bertalanffy Growth Function

- VBGF parameters were re-estimated externally with otolith annuli and daily increments, which were obtained after ISC age determination WS at 2014.

\[ L_t = 249.9 \times (1 - e^{-0.188 \times (t+0.422)}) \]

- Variability of length-at-age (\( CV_L \)) were estimated internally at preliminary run.
Selectivity (1) Constant during assess. period

- Fleets associated with CPUEs
  - Troll, and Twn LL (South)
  - JLL (Time blocked)

- Other Fleets
  - Fleets with small number of fish caught (small sample size).
  - Fleets with no—substantial misfits.
Selectivity (2) Time varying selectivity

- Highly time varying selectivity
  - Fleets which prioritized as high priority.
    - Large catch amount, reliable size comp. data.
  - Japanese and EPO purse seine fleets.

Japanese Tuna Purse seine in Sea of Japan

EPO Purse Seine (Mex dominant period)
Results

- Goodness of fit to
  - CPUE based abundance indices
  - Size composition
- Likelihood profile over Log(R0)
- Biomass
- Recruitment
- Fishing mortality
Goodness of fit to CPUEs

S1: Jpn Longline (1993–2014)

S2: Jpn Longline (1952–1973)

R.M.S.E. = 0.209


R.M.S.E. = 0.149

S5: Jpn Troll (1980–2014)

R.M.S.E. = 0.194


R.M.S.E. = 0.273
Comparison of model fit to terminal CPUEs

2014 Stock Assessment

S1: Jpn Longline (1993–2014)

R.M.S.E.=0.522

2016 Stock Assessment


R.M.S.E.=0.265

R.M.S.E.=0.413

R.M.S.E.=0.273
Likelihood profiles over fixed Log($R_0$)

❖ Each component marked the lowest likelihood at a similar range of maximum likelihood estimate (MLE) of Log($R_0$).

○ CPUE(9.5), Size comp. (9.5), Recruitment Penalty (9.6)

○ Consistency regarding the population scale estimates.
Alternative scenario (Sensitivity analysis)

- Higher/Lower M
- Steepness (h=0.9)
- Weighting (Harmonic mean EffN / Input N weighting)
- Variability of length at age (SD=f(length))
- Time varying selectivity for Japanese LL
Retrospective Analysis

- No substantial tendency of estimation in the SSB for recent 9 terminal years
Spawning stock biomass

- Fluctuated ranging from 160,000 tons (1961) to 11,000 tons (1984).
- Declined from the second highest level of about 62,000 tons at 1996 to 12,000 tons at 2010.
- The decline appears to have ceased since 2010, and showed a tendency of slight increase.
- Terminal (2014) SSB was estimated to be 17,000 tons (2.6% SSB₀).
Recruitment

- Highly fluctuated with an average of 13.4 million fish.
- A low recruitment was estimated in the terminal year.
- The last 5 year’s average might be below the historical average.
Fishing mortality (F)

- Throughout the stock assessment period, average fishing mortality for age 0–2 juveniles was higher than that for age 3+.
- Age-specific F for intermediate ages (2–10 years) in recent years (2011–2013) are above the 2002–2004 F while those for age 0 as well as ages 11 and above are lower.
Reference points

- No limit/target reference points have been established for the PBF stock under the auspices of the WCPFC and IATTC.
- 2011–2013 $F$ exceeds the all calculated biological reference points except for $F_{\text{MED}}$ and $F_{\text{loss}}$.
- Fishing mortality has decreased slightly in recent years.

<table>
<thead>
<tr>
<th>Year</th>
<th>$F_{\text{max}}$</th>
<th>$F_{0.1}$</th>
<th>$F_{\text{med}}$</th>
<th>$F_{\text{loss}}$</th>
<th>$F_{10%}$</th>
<th>$F_{20%}$</th>
<th>Estimated SSB for terminal year of each reference period</th>
<th>Depletion ratio for terminal year of each reference period</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002-2004</td>
<td>1.86</td>
<td>2.59</td>
<td>1.09</td>
<td>0.80</td>
<td>1.31</td>
<td>1.89</td>
<td>41,069</td>
<td>0.064</td>
</tr>
<tr>
<td>2009-2011</td>
<td>1.99</td>
<td>2.78</td>
<td>1.17</td>
<td>0.85</td>
<td>1.41</td>
<td>2.03</td>
<td>11,860</td>
<td>0.018</td>
</tr>
<tr>
<td>2011-2013</td>
<td>1.63</td>
<td>2.28</td>
<td>0.96</td>
<td>0.70</td>
<td>1.15</td>
<td>1.66</td>
<td>15,703</td>
<td>0.024</td>
</tr>
</tbody>
</table>
○ The base-case assessment model is substantially improved from the 2014 assessment.

○ The SSB steadily declined from 1996 to 2010; and the decline appears to have ceased since 2010, although the stock remains near the historic low.

○ Estimates of recruitment showed large fluctuation, though the estimated recruitment level in 2014 was relatively low.

○ The average recruitment level for the last five years may have been below the historical average level.
Stock Status (Summary 2)

○ The current F (2011–2013) exceeds most of biological reference points commonly used by tRFMO except for $F_{\text{MED}}$ and $F_{\text{loss}}$, although F level has decreased in recent some years.

○ In summary, overfishing is occurring and the stock is overfished. If $F_{\text{MED}}$ is considered the threshold, the current F is just at the threshold level.
Stock Status (Summary 3)

- Historically, the WPO coastal fisheries group has had the greatest impact on the PBF stock.
- Since about the early 1990s the WPO purse seine fleets, in particular those targeting small fish, has increased its impact.
- The impact of the EPO fishery was large before the mid-1980s, thereafter decreasing significantly.
Future Projection

Completed in 2016–Feb. 29th to 2016–Mar. 12th at La Jolla, USA

-WCPFC SC12-

2016/8/6 Stones Hotel,
Bali, INDONESIA
Projection Scenario

❖ Harvesting Scenario (11 scenarios)

○ Same with the last assessment Scenario 6 (Scenario 1)

○ Approximation of the ‘WCPFC CMM 2015–04’ and ‘IATTC Resolution C–14–06’ (Scenario 2)

○ Stricter Catch limit (Scenario 5–10)
  ○ 10/20% reduction of catch limit for small fish/large fish/all sized fish.

○ Different definition of the threshold of the small and large fish.
  ○ 50 kg/80kg (Scenario 3–4)

○ Status Quo (Scenario 11)
  ○ Recent Fishing mortality (F2011–2013) and Current catch limit.
Projection Scenario

❖ Recruitment Scenario (3 scenarios)
  ○ Historical average level
  ○ Low recruitment level observed in past (1980–1989)
  ○ Expected recruitment under Stock-recruit. relationship with steepness=0.9
### Results (Performance table)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Harvesting Scenario #</th>
<th>Fishing mortality</th>
<th>Catch limit</th>
<th>Threshold of Small/Large</th>
<th>Recruitment scenario</th>
<th>Probability that SSB exceeds 38,000 tons (SSB median of Bootstrap analysis runs)</th>
<th>Probability that SSB exceeds 41,000 tons (SSB median of Basecase model)</th>
<th>Probability that SSB is more than 43,000 tons (SSBmed@last assessment)</th>
<th>Probability that SSB is more than 10%SSB0</th>
<th>Probability that SSB is more than 20%SSB0</th>
<th>Average Catch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario1</td>
<td>50% of 2002-2004 average catch for WPO commercial fisheries</td>
<td>scenario 6 in 2014 assessment</td>
<td>30 kg</td>
<td>Low recruitment</td>
<td>77.0%</td>
<td>88.8%</td>
<td>89.9%</td>
<td>69.7%</td>
<td>83.3%</td>
<td>85.2%</td>
<td>64.3%</td>
</tr>
<tr>
<td>Scenario2</td>
<td>50% of 2002-2004 average catch for WPO fisheries</td>
<td>2002-2004 average catch for WPO fisheries</td>
<td>50 kg</td>
<td>Low recruitment</td>
<td>80.5%</td>
<td>91.5%</td>
<td>94.0%</td>
<td>73.8%</td>
<td>87.9%</td>
<td>90.7%</td>
<td>69.1%</td>
</tr>
<tr>
<td>Scenario3</td>
<td>90% of scenario 2</td>
<td>same as Scenario 2</td>
<td>80 kg</td>
<td>Low recruitment</td>
<td>86.4%</td>
<td>94.6%</td>
<td>96.5%</td>
<td>80.6%</td>
<td>91.9%</td>
<td>94.7%</td>
<td>76.6%</td>
</tr>
<tr>
<td>Scenario4</td>
<td>F2002-2004</td>
<td>same as Scenario 2</td>
<td>90% of scenario 2</td>
<td>Low recruitment</td>
<td>90.0%</td>
<td>96.5%</td>
<td>98.1%</td>
<td>85.3%</td>
<td>94.8%</td>
<td>97.0%</td>
<td>81.5%</td>
</tr>
<tr>
<td>Scenario5</td>
<td>80% of scenario 2</td>
<td>same as Scenario 2</td>
<td>30 kg</td>
<td>Low recruitment</td>
<td>97.5%</td>
<td>99.6%</td>
<td>99.9%</td>
<td>96.1%</td>
<td>99.3%</td>
<td>99.7%</td>
<td>94.8%</td>
</tr>
<tr>
<td>Scenario6</td>
<td>same as Scenario 2</td>
<td>same as Scenario 2</td>
<td>80% of scenario 2</td>
<td>Low recruitment</td>
<td>82.6%</td>
<td>93.0%</td>
<td>95.0%</td>
<td>75.9%</td>
<td>89.9%</td>
<td>92.1%</td>
<td>71.3%</td>
</tr>
<tr>
<td>Scenario7</td>
<td>same as Scenario 2</td>
<td>same as Scenario 2</td>
<td>80% of scenario 2</td>
<td>Low recruitment</td>
<td>98.3%</td>
<td>99.8%</td>
<td>99.9%</td>
<td>97.4%</td>
<td>99.6%</td>
<td>99.9%</td>
<td>96.3%</td>
</tr>
<tr>
<td>Scenario8</td>
<td>same as Scenario 2</td>
<td>same as Scenario 2</td>
<td>80% of scenario 2</td>
<td>Low recruitment</td>
<td>99.9%</td>
<td>100%</td>
<td>100%</td>
<td>99.9%</td>
<td>100%</td>
<td>100%</td>
<td>99.9%</td>
</tr>
<tr>
<td>Scenario9</td>
<td>same as Scenario 2</td>
<td>same as Scenario 2</td>
<td>80% of scenario 2</td>
<td>Low recruitment</td>
<td>98.4%</td>
<td>99.9%</td>
<td>100%</td>
<td>97.5%</td>
<td>99.9%</td>
<td>100%</td>
<td>97.5%</td>
</tr>
<tr>
<td>Scenario10</td>
<td>same as Scenario 2</td>
<td>same as Scenario 2</td>
<td>80% of scenario 2</td>
<td>Low recruitment</td>
<td>99.4%</td>
<td>100%</td>
<td>100%</td>
<td>99.9%</td>
<td>100%</td>
<td>100%</td>
<td>99.9%</td>
</tr>
<tr>
<td>Scenario11</td>
<td>same as Scenario 2</td>
<td>same as Scenario 2</td>
<td>80% of scenario 2</td>
<td>Low recruitment</td>
<td>99.9%</td>
<td>100%</td>
<td>100%</td>
<td>99.9%</td>
<td>100%</td>
<td>100%</td>
<td>97.5%</td>
</tr>
</tbody>
</table>

**Note:**
- **Scenario 1:** 50% of 2002-2004 average catch for WPO fisheries, scenario 6 in 2014 assessment.
- **Scenario 2:** 50% of 2002-2004 average catch for WPO fisheries.
- **Scenario 3:** 50% of 2002-2004 average catch.
- **Scenario 4:** 90% of scenario 2.
- **Scenario 5:** same as Scenario 2.
- **Scenario 6:** same as Scenario 2.
- **Scenario 7:** 90% of scenario 2.
- **Scenario 8:** 80% of scenario 2.
- **Scenario 9:** same as Scenario 2.
- **Scenario 10:** same as Scenario 2.
- **Scenario 11:** F2011-2013.
○ Current CMMs and Status Quo under low recruitment scenario.
Results

- Current CMMs under Average and Low recruitment scenario.
Results

○ Comparisons of 10% reduction scenarios under low recruitment scenario.

- Scenario 2: Current CMM
- Scenario 5: Reduction for small fish
- Scenario 6: Reduction for large fish
- Scenario 7: Reduction for all fish

Spawning stock biomass (t)

2014 2019 2024 2029 2034

Fishing year
Comparisons of different of threshold for small/large fish under low recruitment scenario and current CMMs.
Under all examined scenarios, including a stronger stock-recruitment (h=0.9) scenario, the initial WCPFC rebuilding target would be achieved.

The probability of achieving the initial WCPFC rebuilding target would increase if more conservative management measures were implemented, such as increasing the size in the threshold of small fish or further reducing the catch limit.

A 10% reduction in catch limit for small fish would have a larger effect on recovery than a 10% reduction for large fish.

Recommended to fix the period to calculate initial rebuilding target of SSB_{MED}.
Conclusion

○ Stock assessment model was updated for the benchmark assessment 2016, and the base-case model is a substantially improved from the last assessment.

○ Results are similar with the last assessment; the stock is still at near historic low and current fishing mortality is above the all reference points except $F_{loss}$ and $F_{med}$.

○ The initial rebuilding target of WCPFC would be achieved by higher probability than the level prescribed in the WCPFC CMM, if current WCPFC CMM and IATTC Resolution are strictly complied.
Thank you
### Future research plan prioritized by ISC

<table>
<thead>
<tr>
<th>Item</th>
<th>Specific plan</th>
<th>Priority</th>
<th>Time frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stock-recruitment relationship</td>
<td></td>
<td>high</td>
<td>short term</td>
</tr>
<tr>
<td>Population structure</td>
<td>Genetic population structure inferred from Close-Kin data</td>
<td>high</td>
<td>short term</td>
</tr>
<tr>
<td>Better understanding of fishery data</td>
<td>New CPUE indices for intermediate age between recruit and large adult</td>
<td>high</td>
<td>short term</td>
</tr>
<tr>
<td></td>
<td>cause of change in the trend of Japanese longline CPUE with focus on geostatistical modeling</td>
<td>highest</td>
<td>short term</td>
</tr>
<tr>
<td></td>
<td>Improve Taiwanese index with focus on spatio-temporal change</td>
<td>high</td>
<td>short term</td>
</tr>
<tr>
<td></td>
<td>Improvements of recruitment index</td>
<td>high</td>
<td>short term</td>
</tr>
<tr>
<td>Independent estimate of spawning biomass</td>
<td>Close-kin genetics</td>
<td>high</td>
<td>longer term</td>
</tr>
<tr>
<td>Evaluation of growth to improve length frequency fitting</td>
<td>Seasonal timing, annual variation, regional and sex-specific change of growth</td>
<td>second highest</td>
<td>short term</td>
</tr>
</tbody>
</table>
Comparison of Growth curve

- VBGF at Stock Assessment 2014
  - Based on Shimose (2009) with Ad-hoc adjustment for the length of age 0.125 fish.

- VBGF at current base case (2016)
  - Based on otolith annuli and daily increments obtained after “Age determination workshop”

Black : Stock Assessment 2016
Red: Stock Assessment 2014
<table>
<thead>
<tr>
<th>Fleet #</th>
<th>Fleet name</th>
<th>Unit of Comp data (Size bin definition)</th>
<th>Size data included</th>
<th>Available period (Fishing year)</th>
<th>Source of sample size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fleet1</td>
<td>JPLL</td>
<td>Length</td>
<td>JPLL</td>
<td>1952-1968, 1993-2014</td>
<td>Scaled Number of fish measured</td>
</tr>
<tr>
<td>Fleet2</td>
<td>JPSPPS (Seas1, 3, 4)</td>
<td>Length</td>
<td>JPSPPS (Season 1, 3, 4)</td>
<td>2002-2014</td>
<td>Number of landing well measured</td>
</tr>
<tr>
<td>Fleet3</td>
<td>KROLPS</td>
<td>Length</td>
<td>KROLPS</td>
<td>2010-2014</td>
<td></td>
</tr>
<tr>
<td>Fleet5</td>
<td>JPTPSPO</td>
<td>Length</td>
<td>JP TPSPO</td>
<td>1995-2006</td>
<td>Number of landing well measured</td>
</tr>
<tr>
<td>Fleet6</td>
<td>JPTroll (Season 2-4)</td>
<td>Length</td>
<td>JP Troll (Season 2-4)</td>
<td>1994-2014</td>
<td>Total month of well sampled port</td>
</tr>
<tr>
<td>Fleet8</td>
<td>JP Setnet (Season 1-3)</td>
<td>Length</td>
<td>JP Setnet (Season 1-3)</td>
<td>1993-2014</td>
<td>Total month of well sampled port</td>
</tr>
<tr>
<td>Fleet9</td>
<td>JP Setnet (Season 4)</td>
<td>Length</td>
<td>JP Setnet (Season 4)</td>
<td>1993-2014</td>
<td>Total month of well sampled port</td>
</tr>
<tr>
<td>Fleet10</td>
<td>JP Setnet in Hokkaido and Aomori</td>
<td>Weight</td>
<td>JP Setnet in Hokkaido and Aomori</td>
<td>1994-2014</td>
<td>Total month of well sampled port</td>
</tr>
<tr>
<td>Fleet11</td>
<td>JP Handline &amp; Tsugaru Longline</td>
<td>Weight</td>
<td>JP Handline &amp; Tsugaru Longline</td>
<td>1994-2014</td>
<td>Total month of well sampled port</td>
</tr>
<tr>
<td>Fleet12</td>
<td>TWLL (South)</td>
<td>Length</td>
<td>TWLL (South area)</td>
<td>1992-2014</td>
<td>Scaled Number of fish measured</td>
</tr>
<tr>
<td>Fleet14</td>
<td>MX Commercial Fisheries (PS)</td>
<td>Length</td>
<td>MX Commercial Fisheries (PS)</td>
<td>2005-2006, 2008-2013</td>
<td>Number of haul well measured</td>
</tr>
<tr>
<td>Fleet16</td>
<td>Troll4Pen</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fleet17</td>
<td>TWLL (North)</td>
<td>Length</td>
<td>TWLL (North area)</td>
<td>2009-2014</td>
<td>Scaled Number of fish measured</td>
</tr>
<tr>
<td>Fleet18</td>
<td>JPSPPS (Season 2)</td>
<td>Length</td>
<td>JPSPPS (Season 2)</td>
<td>2003-2012, 2014</td>
<td>Number of landing well measured</td>
</tr>
<tr>
<td>Fleet19</td>
<td>JPSPPS (Seas1)</td>
<td>Length</td>
<td>JPSPPS (Season 1)</td>
<td>1994-2004, 2006-2011</td>
<td>Total month of well sampled port</td>
</tr>
</tbody>
</table>

*1 Size composition data of Fleet 2 and 3 were combined. A selectivity pattern was estimated and shared by those two fleets.
*2 Size composition data of Fleet 7 was not used in the assessment model. The selectivity pattern estimated for Fleet 6 was mirrored.
*3 Size composition data of Fleet 10 and 11 were combined. A selectivity pattern was estimated and shared by those two fleets.
*4 Size composition data of Fleet 15 was not used in the assessment model. The selectivity pattern estimated for Fleet 13 was mirrored.
*5 Fleet 16 was assumed the age based selectivity to catch only age-0 fish. Thus size composition data was not used in the assessment model.