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# Exploratory application of SS incorporating conditional age at length data from otolith aging

**Yukio Takeuchi**

National Research Institute of Far Sea Fisheries,
Fisheries Agency 5-7-1 Orido, Shimizu, Shizuoka 424-8633, Japan

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## Summary

## Introduction

The stock assessment of Pacific bluefin tuna (PBF) has been conducted using SS with length based age structured setting. SS requires specifying growth curve parameters. In the case of PBF VBGF growth curve parameters externally derived from otolith ageing data (Shimose et al 2008) has been used. On the other hand, SS is capable to use ageing data directly through several ways. In order to capture real uncertainties from ageing PBF WG recommended utilizing otolith ageing data directly within SS model. This working paper reports results of an application of conditional length at age data of PBF to SS.

## Materials and methods

### Conditional age at length likelihood function

When ageing data is applied to SS, the recommended way is use as conditional age at length data (see p.XX of SS3 3.23 user manual). This is essentially to use multinomial likelihood stratified by each length bin, allowing ageing error and intended to avoid the effect of size selectivity. Taylor et al 2004 proposed similar log likelihood function to estimate growth curve parameters from ageing data. They concluded, "Using simulated data sets, estimated growth parameters using the multinomial likelihood were unbiased when fishing mortality was not too high and the shape of the vulnerability function was correct."

### SS model configuration to apply ageing data

SS model used in the last stock assessment was upgrade to use conditional length at age. Main changes of model configuration is as follows,

A) Introduction of population length bin as defined 1cm bin from 10cm to 296cm
B) Age at L2 was changed from 3 to 20 to enable estimation of growth curve parameters
C) Introduction of sex structure assuming half of recruitment is female
D) SS model is upgraded from 3.10b to 3.23b for future convenience

Remaining part of the model configurations remains same as 2010update.

### Ageing data

Shimose and Takeuchi (2012) described the most recent status of ageing of Pacific Bluefin tuna from otolith annual ring, which also includes growth curve estimates by sex as well as sex combined one. Otolith data was compiled by age composition by year, month, fleet, gender (if sex structured model is used), length interval by 1cm bin. Age of the ageing data whose estimated age was older than 20 was set to 20 to keep compatibility with maximum age in 2010 update. There are a few samples collected from very minor gear such as headlining in Okinawa islands. Gear code of these minor gear data was assigned to fleet definition used in 2010update based on similarities of fishing grounds. In the sex-structured data, unknown gender data were still used as unknown gender. Consequently 729 otolith samples out of original 1690 samples remained. This is due to the fact more than half of otolith samples were collected after fishing year 2007. Another difference from the data set used in Shimose and Takeuchi 2012 is ageing data from Taiwan also used as ageing data with unknown gender information when estimating sex specific growth curve.

### SS run scenario

We tested 5 SS run scenarios (see table 2). Among them 3 scenarios are no sex structured model while 2 scenarios has sex structure. We also noted run 00 in table 2 was included as assessment of effect of change of SS version and introduction of population bin compared with 2010update.

## Results and discussions

### Effects of SS version and population bin (run 0)

Although the results of comparison was not shown here for save of space, It is hardly seen any difference between the results of 2010 update and run 0, while run 0 consumed a lot more memory and took longer execution time.

### Estimation of growth curve without conditional age at length (run 01)

Estimated length at age 0 was higher (24.4355cm) than that of 2010 update (21.5432cm), Brody's K was also estimated lower(0.18) compared with 0.195 in 2010update. Length at age 20 was estimated lower (210.884cm) compared with 230.511cm in 2010Update.

### Estimation of growth curve with conditional age at length (run02)

Use of conditional age at length data made estimated length at age 0 even higher (25.1135cm) than that of run01, although Brody's K was also estimated lower (0.168266) compared with 0.18 in run01. Length at age 20 was estimated higher (217.366cm) than run01 but still lower compared with 230.511cm in 2010Update.

### Estimation of sex specific growth curve parameters without conditional age at length data (run11)

Unless conditional age at length data used, estimated lengths at age 0 and age 20 of female become lower (18.cm, 206cm respectively) than that of run01, although Brody's K was estimated higher (0.21) compared with 0.18 in run01. Length at age 0 of male was estimated to be lower (21cm) with slightly higher length at age 20 (215.504cm). Brody's K was estimated slightly higher (0.191) than run01.

### Estimation of sex specific growth curve parameters with conditional age at length data (run12)

Use of conditional age at length data by known-sex and unknown-sex made estimated length at age 0 of female close (21.1093cm) to that of 2010update which is substantially higher than that of Shimose and Takeuchi (2012). Brody's K was also estimated higher (0.17991) than Shimose and Takeuchi (2012). On the contrary Length at age 20 was estimated lower (213.867cm) Length at age 0 of male, on the other hand estimated quite higher (24.0103cm) with quite lower Brody' s K (0.124243) and slightly lower length at age 20 (238.986cm)

### Estimated growth curve parameters

Results of preliminary runs with conditional length at age data suggested that use of them has an effects stabilizing growth curve parameters into feasible range, in particular for length at age 0. This can be interpreted that length frequency data of Pacific Bluefin tuna is informative to length at age 0. On the other hand it is uncertain that length frequency as well as other input data used in Pacific stock assessment can improve the estimation of length at maximum age as well as Brody's K. Current trial runs did not use recent years otolith data since 2010 update only covers the period until June 2008 so that revised trial runs with input data for next stock assessment might improve estimates.

### Possible optimization of conditional length at age data

In this working paper ageing data was compiled by gear and by FL with 1cm bin. 1cm bin was used to fully utilize the precision of length measurement. However this results in very sparse age composition data by each bin. Consequently, 237 conditional age at length data only has one sample. 339 data only has less than 4 samples. Although from the user manual of SS it is unclear how bootstrapping replication is done for age composition data, if multinomial random number with sample size of conditional age at length buy length bin is used, bootstrap distribution should have problems. One possible solution may be use of wider length bin in conditional age at length. But wider length bin lose information of precision of length. Loss of precise length information may make growth curve parameter estimation in SS imprecise. When conditional length at age data be used in real stock assessment it is necessary to carefully optimize length bin definition to allow good statistical property as well as precise estimate of growth curve parameters.

### Potential optimization of model configuration of SS

2010 Update defined maximum age of population dynamics as age 20. Otolith ageing data indicated some number of Pacific Bluefin survives more than 20 years. Extension of maximum age of the stock assessment to the age older than age 20 might improve the fit to the conditional age at length, although it will scarify the computational efficiency.

### Feasibility of sex structured model in stock assessment

As demonstrated, use of conditional age at length data can improve the estimate of length at age 0 compared with growth curve parameter estimates solely by ageing data. On the other hand improvement for Brody's K and maximum length is unclear. This should be due to the fact that substantial amount of otolith data of older animals have missing gender information. In addition, current input data used for these trials does not include any input data with gender information other than ageing data. If, for example, length composition of longline fishery with gender information is used, estimated length at maximum age by sex may be improved. Probably the decision whether sex structured model be used depends on the availability of data informative to sex specific population dynamics in addition to the ageing data.

## References

Shiose, T., and Takeuchi, Y. (2012), Updated sex specific growth parameters for Pacific bluefin tuna *Thunnus orientalis*, ISC/12-1/PBFWG/12

Taylor, N.,G., Walters, C.,J., and Martell, S.J.D. (2005), A new likelihood for simultaneously estimating von Bertalanffy growth parameters, gear selectivity, and natural and fishing mortality, CJFAS,62, 215-223

Tables and figures

Table 1 Available otolith ageing data by gender and fishing year provided from Tamaki Shimose. This data set should be identical to one used in Shimose and Takeuchi (2012). However total number of otolith is 1690 while table 1 of Shimose and Takeuchi indicated 1692 sample is used.

| | Female | Male | unknown sex | Total |
|---|---|---|---|---|
| 1992 | 0 | 0 | 3 | 3 |
| 1997 | 0 | 0 | 1 | 1 |
| 1998 | 2 | 0 | 9 | 11 |
| 1999 | 6 | 6 | 7 | 19 |
| 2000 | 2 | 12 | 30 | 44 |
| 2001 | 1 | 5 | 2 | 8 |
| 2002 | 2 | 2 | 14 | 18 |
| 2003 | 1 | 21 | 18 | 40 |
| 2004 | 5 | 2 | 10 | 17 |
| 2005 | 1 | 1 | 120 | 122 |
| 2006 | 25 | 17 | 182 | 224 |
| 2007 | 99 | 89 | 159 | 347 |
| 2008 | 87 | 73 | 300 | 460 |
| 2009 | 120 | 169 | 83 | 372 |
| 2010 | 2 | 2 | 0 | 4 |
| Total | 353 | 399 | 938 | 1690 |

Table 2 Summary of scenarios used in this document. “2010Update” and “Shimose and Takeuchi 2012” in VBGF column refer to the growth curve parameters used in 2010Update and those listed in table 1 of Shimose and Takeuchi (2012) respectively. Runs 03 and 04 used sex combined growth curve parameters. Run 1 used sex specific version of growth curve parameters.

| | Gender | estimate growth | VBGF parameters | Otolith data |
|---|---|---|---|---|
| run 0 | N | N | 2010Update | N |
| run 01 | N | Y | | N |
| run 02 | N | Y | | Y |
| run 11 | Y | Y | | N |
| run 12 | Y | Y | | Y |