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A re-consideration of growth pattern of skipjack on the western central Pacific

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A re-consideration of growth pattern of skipjack on the western central Pacific

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SUMMARY

Several types of research were carried out to estimate growth parameter of skipjack tuna (*Katsuwonus pelamis*). However, those estimated parameters were not included for stock assessment in the WCPO because of their lower fitting for otolith data. To obtain the good-fitted growth parameter, we addressed model selection using several candidates of alternative growth models (Richard, Gompertz, and Schnute) and to fit age-length data from the otolith research. These alternative growth models were compared with the von Bertalanffy (VB) model that was usually used for previous studies. After the model selection, Schnute model, which does not assume maximum asymptotic size, was selected as the best model. That result implies the VB model could not explain the growth of skipjack well, while it is likely that lack of large size samples near the asymptotic size causes fail to estimate true L_{inf}. Improving the estimation of the growth parameters of skipjack, data collection from large fishes (especially > 60 cm) are necessarily and the VB model should be compared with the model not assuming L_{inf} with using this updated data again. We also attempted to fit the VB model using combine the otolith data with size data from the tagging-recapture survey (JPTP). Fitted parameter did not change largely from the parameters estimated by only otolith research. However, the growth of juvenile period that estimated by Multifan-CL was faster than our study result. If the actual growth were slower than current assumption, skipjack maturity age would be elderly. Hence, growth curve needs to be clear in the future study included with all available data.

INTRODUCTION

Clarifying length at age relationships on skipjack is important for stock assessment to estimate maturity at size from catch data and then parameters of reproduction. Using the von Bertalanffy (VB) model, there were several attempts to estimate growth pattern of skipjack in the WCPO (Table 1). However, the estimated parameters were currently not included in the integrated model of stock assessment because their fitting condition were not good. To reflect this situation, the length at age were calculated from inside of the stock assessment model (Multifan-CL) in the WCPO stock assessment of skipjack tuna (Hoyle et al. 2010). However, otolith data still is considered to include growth information of skipjack tuna and we need to find the appropriate growth parameter for skipjack tuna in WCPO. In this research, 1) we attempted model fitting using the previous otolith research data with alternative growth models and 2) reanalyzed the VB model using the otolith data and size data of tagging-recapture (JPTP).

METHOD

To examine growth model, otolith ring daily increments and fork length data from Kayama (2006) were used. This data set includes the dataset from Tanabe et al. (2003). Sampling area, sampled gear, research period, sample size and other information were described in Table 2 and Figure 1. Four models including the VB model were considered as candidates of growth patterns of skipjack. We fitted those models to the otolith-size data and carried out model selection. Expected size $\hat{L}_t$ at the quarterly age t is express as below;

1. von Bertalanffy

$$\hat{L}_t = L_\infty \left(1 - \exp\left(-k(t - t_0)\right)\right)$$

2. Richard

$$\hat{L}_t = L_\infty \left(1 + \frac{1}{p}\exp\left(-k(t - t_0)\right)\right)^{-p}$$

3. Gompertz

$$\hat{L}_t = L_\infty\left(-\beta\exp(-k^t)\right)$$

4. Schnute

$$\hat{L}_t = \left(r_0 + \beta\exp(-kt)\right)^p$$

Actual measured fork length L_t was described with using $\hat{L}_t$ as below;

$$L_t \sim Normal(\hat{L}_t, \sigma)$$

To select best available growth curve, WAIC (Watanabe 2009, Vehtari et al. 2015) was calculated from fitted models and model selection had been carried out with the smallest WAIC model as the best.

Tagging-recapture size data was derived from JPTP programs after 1997 (N= 1009, Fig. 1, McKechnie et al. 2016). The dataset includes folk length at release (L_{tag}), folk length at recapture (L_{rec}) and time at liberty (δ). Parameter estimation with combination of otolith and tagging data was implemented according to the method of Minte-Vera et al. (2015) for only the VB model. Model equations are described as below;

$$\begin{cases} \hat{L}_{oto} = L_\infty\left(1 - \exp\left(-k(t - t_0)\right)\right) \\ D_\delta = \hat{L}_{rec} - \hat{L}_{tag} \\ \quad = -L_\infty\left(\exp\left(-k(t' + \delta - t_0)\right) - \exp\left(-k(t' - t_0)\right)\right) \\ L_{oto} \sim Normal(\hat{L}_{oto}, \sigma_1) \\ D_\delta \sim Normal(\hat{D}_\delta, \sigma_2) \\ t' \sim Uniform(0, A_{max}) \\ A_{max} = 20 \end{cases}$$

All parameters were calculated by Bayesian inference with Markov Chain Monte Carlo sampling and means of posterior were regarded as representative values. We used Stan 2.9.0 (http://mc-stan.org/) for MC sampling and R 3.3.1 (R Core Team 2016) for data handling.

RESULT

・Otolith-size data

Parameter estimations for models of (1) – (4) were shown in Table 3 and differences of each growth curve was displayed in Figure 2. After the model selection with WAIC, Schnute model was selected as the best model (Figure 2 and Table 3). When otolith data was fitted to the VB model, almost large sized data (> 60cm) were out of 95% Bayesian credible intervals (Figure 2) and that growth rate (*k*) are relatively low (Table 3). The length at age that was estimated Multifan-CL was quite different otolith data and that growth of juvenile period are faster than the VB and the Schnute model (Figure 2).

・Combination of otolith data with tagging data

The parameter of the VB model estimated by otolith with tagging data was shown in Table 4 and that predicted growth curve was shown in Figure 3. The difference estimation results between otolith with tagging data and only otolith data were a little and each estimation error was decreased but predicted size of older fishes was not good as well as prediction with only otolith data.

DISCUSSION AND CONCLUSION

The result indicates that precision of size prediction was better by using the model not assuming L_{inf} than the VB model. One of the reason was thought the lack of samples of large fishes near the asymptotic size. Larger estimation weight on size ranges where length increases exponentially causes decreasing accountability for the prediction of older fishes. To improve this issue, data collection from large fishes (especially > 60 cm) are necessarily and then the VB models should be compared with the model not assuming L_{inf} with using updated data.

Our result also indicated that tagging data did not affect parameters on VB models but only shrinking estimation error. However, Multifan-CL estimated faster growth curve than our study result that was estimated by otolith and tag-recapture data. If actual growth were slower than current assumption, maturity of skip jack would be delay. Relatively small samples of large fishes on tagging data may lead similar result of otolith analysis, indicating that integrated data from other areas would improve the parameter estimation. This should be addressed for the future stock assessment improvement.

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Table 1 Estimated parameters on von Bertalanffy models in the past researches

Reference & Year	L_{inf}	k	t_0	Unit
Hampton 2000	65.1	1.3	0	cm; Year base
Leroy 2000	62.17	2.373	-0.04	cm; Year base
Tanabe et al. 2003	93.6	0.43	0.49	cm; Quarter base
Hoyle et al. 2010	Direct estimation of FL@age by MFCL			cm; Quarter base

Table 2 Sampling information for otolith-size data from Kayama (2006).

Area Def.	Latitude	Longitude	Year	Gear type	N
A	0-20N	146-179E	2000-2002	PS, PL	98
B	20-30N	128-149E	2001-2003	PL	74
C	30-41N	130-153E	1997-2002	PL, PS, TL, GN	426

PS: Purse seine, PL: Pole and Line, TL: Troll Line, GN: Gill Net

Table 3 Estimated parameters and WAICs from 4 candidates of growth model based on otolith-size dataset.

Parameters	von Bertalanffy		Richard		Gompertz		Schnute	
	mean	SD	mean	SD	mean	SD	mean	SD
L_{inf}	67.84	2.10	59.32	1.37	61.12	1.53	-	-
k	0.24	0.02	0.44	0.02	0.41	0.02	-0.20	0.02
t_0	-0.65	0.07	0.97	0.05	-	-	-	-
p	-	-	-1.01E+14	9.18E+13	-	-	0.30	0.01
β	-	-	-	-	1.53	0.03	3.01E+05	8.60E+04
r_0	-	-	-	-	-	-	-3.24E+05	9.50E+04
σ	3.72	0.10	4.06	0.11	4.04	0.11	3.17	0.09
WAIC	3668.9	62.4	3778.2	69.4	3778.7	64.2	3450.9	50.8

Table 4 Estimated parameters from von Bertalanffy model integrated with tagging-recapture data

Parameters	**von Bertalanffy with JPTP data**	
	mean	**SD**
L_{inf}	68.44	1.058
k	0.23	0.007
t_0	-0.68	0.035
p	-	-
β	-	-
r_0	-	-
σ	3.74	0.10

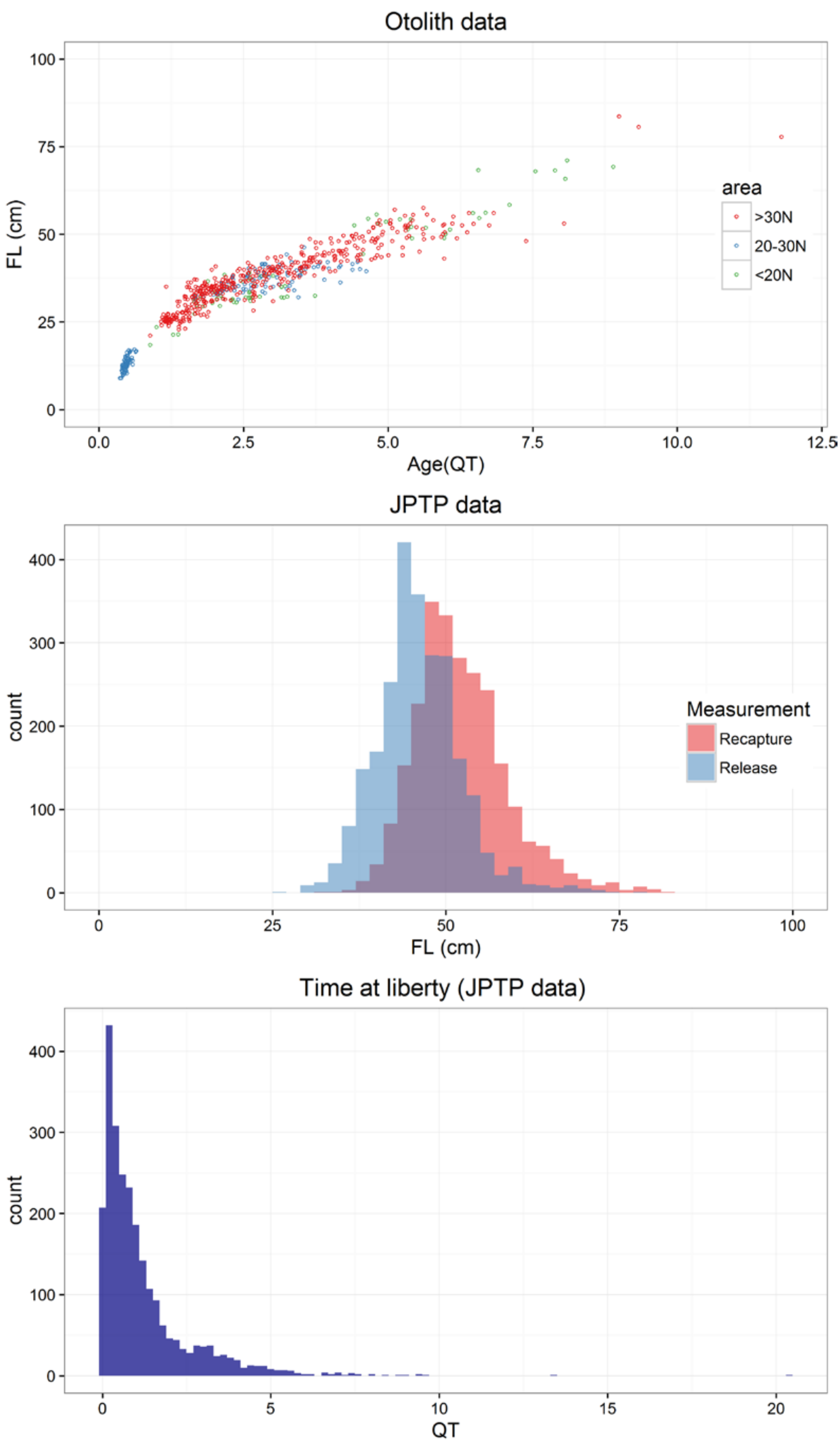

Figure 1 Size and time-at-liberty data distribution of Otolith-size data and tagging-recapture data.

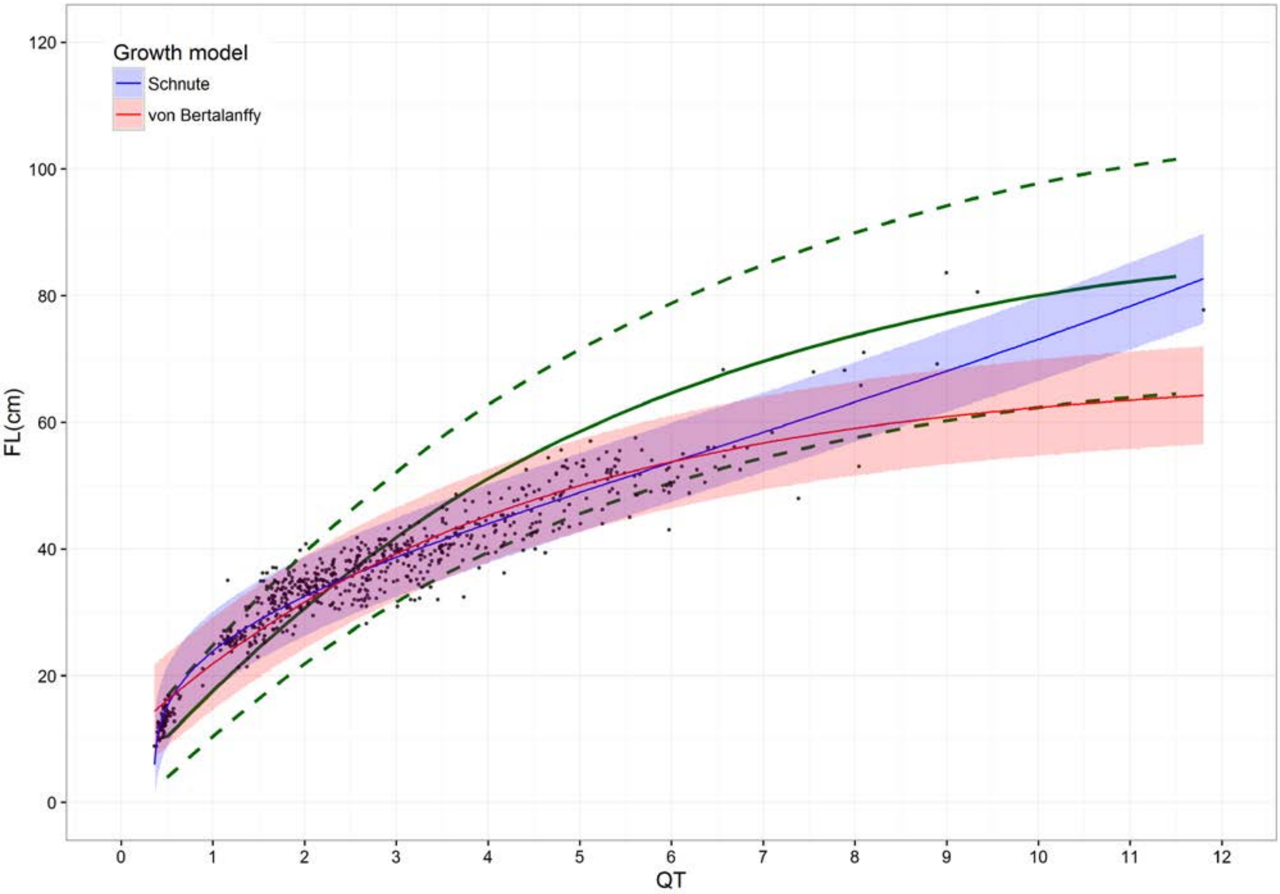

Figure 2 Scatter plots of age-length relationships on the otolith research and estimated growth curves. Solid lines indicate average of model predicted value (red: von Bertalanffy, blue: Schnute, green: Multifan-CL) and shades on von Bertalanffy and Schnute model indicate 95% Bayesian credible intervals. Broken lines on MFCL estimation indicate upper and lower limits of 95% confidence interval.

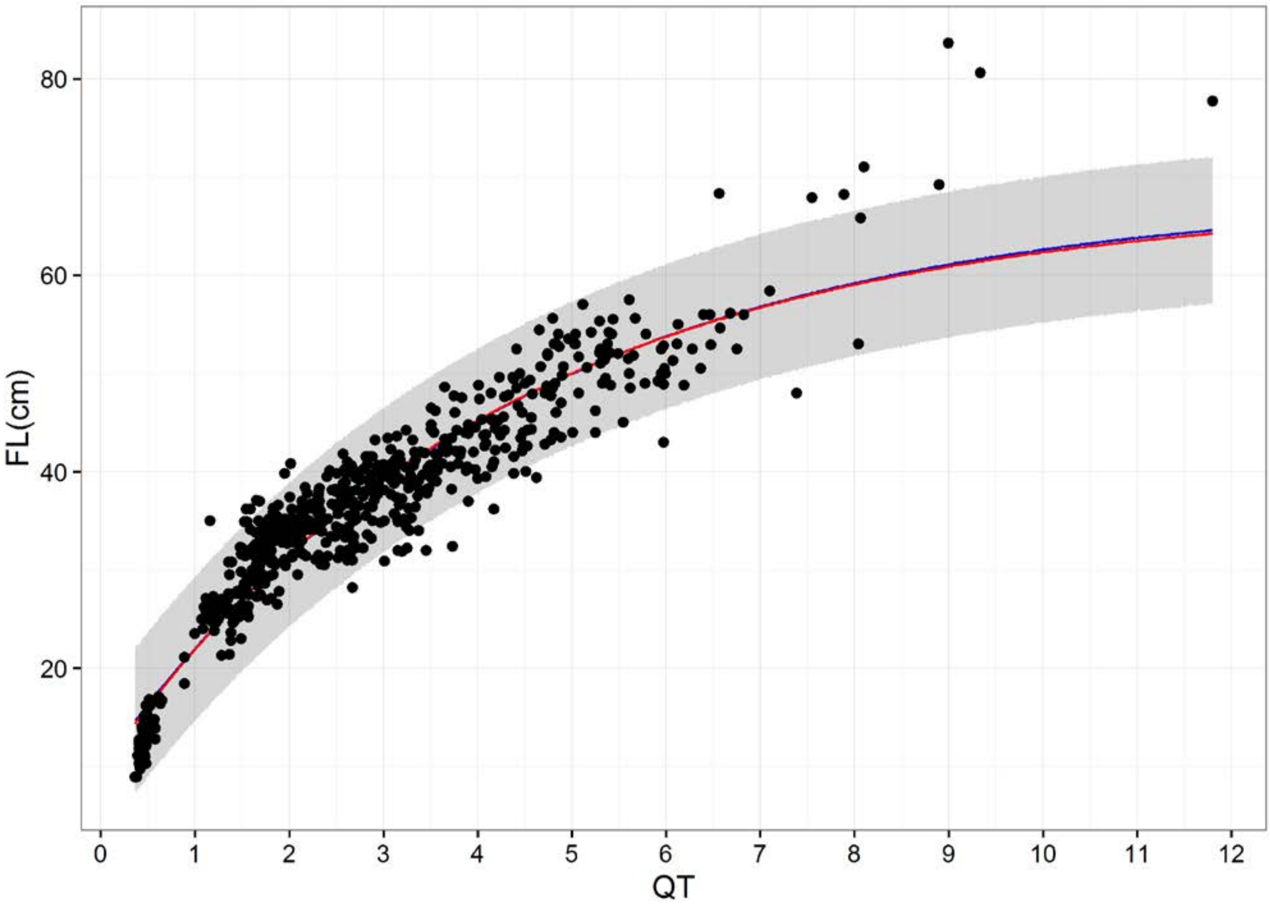

Figure 3 Scatter plot of age-length relationships on the otolith research and estimated growth curve calculated from von Bertalanffy (VB) model integrated with tagging-recapture data. Blue line shows prediction form integrated VB model and red line shows otolith VB model. Shade indicates 95% Bayesian credible interval from the integrated VB model.