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Weight-length relationship of North Western Pacific bluefin tuna

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Summary

A single best W-L relationship on Pacific bluefin tuna (PBF) for use in SS2 model was formulated using RJB data including wide fork length range and a large number of samples. The new formula was compared to the W-L relationship by Shingu *et al* (1974). The author used allometric model based on an equation in SS2 model. The additive and multiplicative error structures were assumed to estimate the W-L relationship of PBF, and the better relation was chose by comparing AIC values. Consequently, model with additive error was chosen, and the parameters estimated by using datasets including eviscerated weight were adopted as an appropriate one. Selected single best round weight-fork length relationship of PBF was $W = 1.7117 \times 10^{-5} \times L^{3.0382}$. Comparison of the W-L relationship derived here to that of Shingu *et al* (1974) demonstrated very little or no difference.

Introduction

The population dynamics of Pacific bluefin tuna (PBF) *Thunnus orientalis* will be assessed in May,2008, using an integrated analysis program of Stock Synthesis2 (SS-2)(Method 2007). A single weight-length (W-L) relationship is required to calculate total stock and spawning stock biomass in the SS2. However, for the preparation of length frequency data, various W-L relationships are needed to convert weight only data to length data, considering the conditions from which data were collected, such as season and area.

In the previous meeting (ISC-PBFWG, 2007,July), W-L relationships of PBF from samples collected in 1964 to 2007 were reviewed by Kai (2007) to understand the characteristics of the samples and to examine a mean of integrating the estimated different W-L relationships. A total of 74 W-L relationships for PBF and three W-L relationships for Atlantic and Mediterranean bluefin tuna were summarized and compared. Most of the relations and a W-L relationship by Shingu *et al*(1974) were similar and fall within a narrow range. Consequently, the weight-length relationship by Shingu *et al* (1974), which has been identified as preferred one by the PBF-WG, appears to be a representative relationship for PBF.

However, because differences in W-L relationships reported in the literatures (e.g.,Watanabe 2006; Ohshima 2007; Kai 2007; Ichinokawa 2007), are little among seasons, fishing areas, and sampling ports, it was recommended that for the purpose of conversion of individual weight data into length data, weight-length relationships that correspond to the conditions, such as fishing season be used. Such time-area variability is not purpose of this report.

The WG noted the need for a single best W-L equation for the use in the SS2 model. Because the Shingu *et al* (1974) equation was estimated with data for only large-sized fish from 171 to 219 cm, the WG recommended that further W-L analyses be carried out that include, all available data that representing the full length range of PBF. This new relationship should then be compared to the Shingu *et al* (1974) W-L relationship.

Therefore, the objectives of this study are to formulate a single best W-L relationship on PBF for use in SS2 model using the available data that represent the full length range of PBF, and to compare to the Shingu *et al* (1974) W-L relationship.

Material and Methods

Data source

Size data of PBF caught by the Japanese fisheries measured in the Research of Japanese Bluefin tuna (RJB) from 1994 to 2007 were used to formulate a W-L relationship on PBF. Database of RJB sampling program includes information on year, month, fished area, fished location (i.e. latitude, and longitude), landed port, size category for auction, processing conditions of fish measured (e.g., round, eviscerated), body weight in nearest 0.1 kg, or fork length in nearest 1cm. In this RJB database, three types of size data exist; weight only; length only; and weight and length. The weight only and length only data were eliminated from the estimation of W-L relationship. The datasets including both weight and length data were sorted by round and eviscerated weight in order to estimate W-L relationship precisely and accurately. The datasets used in this study were summarized in **Table1.**

Modeling of weight-length relationship

The simple allometric model based on an equation in SS2 model is as follows:

$$W = aL^b$$

where W is the body weight, L is the fork length, a and b are constants. The estimation of the parameters of the model depends on the error structure chosen for the data. Since it is difficult to judge error structure from scatter plots of size data, two standard models were used. One is a model with an additive error structure:

$$W = aL^b + \varepsilon \qquad \varepsilon \sim N(0, \sigma^2) \qquad \text{(A)}$$

where ε is the normal distribution with the mean zero and constant variance σ^2. Estimates of a and b are obtained from nonlinear least squares. The other is a model with a multiplicative error structure:

$$W = aL^b e^{\varepsilon} \qquad \varepsilon \sim N(0, \sigma^2) \qquad \text{(B)}$$

Estimates of a and b are obtained from least squares linear regression by taking logarithms of the equation. The model selection for (A) and (B) is done using Akaike's information criterion (AIC) (Akaike, 1973). The parameters of the model with minimum AIC is chose. It should be noted that the equations of log likelihood function in AIC are different between model (A) and (B). 95% confidence intervals of estimated curves are obtained by 1000 bootstrappings.

Results

The relationships between weight and length can be derived from allometric model for different error structures: each using 71652 datasets of round weight and 155104 datasets of eviscerated weight, separately (Figure 1). Parameter estimates and AIC for models with an additive error structure and a multiplicative error structure for two datasets are given in table 2. Observed values of dataset of round weight that show the limited length range but with a low variability (Figure 1a), whereas dataset of eviscerated weight gave a wide length range with a high variability for about 150- 230 cm fork length (Figure 1b). Curves fitted for each error structure are different for dataset of round weight (Figure 1a), whereas those curves for dataset of eviscerated weight are too similar to distinguish (Figure 1b). 95% confidence intervals were substantially small for each dataset and each error structures. In comparison between models (A) and (B), model (A) was chosen by the value of AIC, for both dataset. Judging from the length range and number of data, the model (A) for dataset with eviscerated weight was selected as a single best W-L relationship of PBF and it was:

$$W = 1.4885 \times 10^{-5} \times L^{3.0382}$$

Conversion factor of eviscerated weight to whole body weight: 1.15 was applied as same as the value of Atlantic bluefin tuna. A converted W-L relationship of PBF:

$$W = 1.7117 \times 10^{-5} \times L^{3.0382}$$

Comparison of the W-L relationship derived here with those from various studies (Table 3) suggested very little or no differences from that reported by Shingu *et al* (1974) and ICCAT (1983) for Mediterranean bluefin tuna, but is different from those by Hsu *et al* (2000) and ICCAT (1983) for Atlantic bluefin tuna (Figure 2). Shingu *et al* (1974) and Hsu *et al* (2000) used eviscerated weight to estimate the W-L relationship for PBF.

Discussion

This study provided new single best W-L relationship derived from a wide fork length range (FL=24-268 cm; Table3) and a large number of samples (*n*=155104). Data used to estimate the

W-L relationship covered a whole year and many years: whole seasons: and almost entire PBF fishing areas around Japan (Table 1). This indicates that the influence of sampling bias should be relative low.

W-L relationship estimated by Hsu *et al* (2000) is clearly different from the W-L relationship estimated by present study. If the estimated curve by Hue *et al* (2000) represents the W-L relationship on large PBF, the W-L relationship estimated by this study have a possibility of overestimating the weight at large length range. To further investigate the possibility of such overestimation, W-L relationship of PBF should be estimated using both RJB and Taiwanese data.

In comparison of model (A) to model (B), Model (A) was chosen for both of datasets using AIC. This result indicated that the additive error was preferred to the multiplicative error for dataset of RJB, when a W-L relationship of PBF is estimated, using allometric model. The curves for dataset of round weight were apparently different between model (A) and (B) (Figure 1a). The difference of model structure seemed to have influenced on the fitting. Generally, an additive error structure is appropriate when the variability in weight at length is assumed to be constant. On the other hand, a multiplicative error structure is appropriate when variability in weight at length increases. The variability in weight at length in figure 1a is apparently constant compared to that in figure 1b. The difference of variability might cause a large difference of curves between model (A) and (B).

Dataset of round weight which usually contains small sized fish was mainly collected from set-net and troll fisheries (Table 1). Therefore, an additive error structure is appropriate for such fisheries when season or area specific W-L relationship of PBF would be estimated. However both error structures would be useful for the dataset of eviscerated weight, because a large number of datasets with wide variability in weight at length and wide length range are included.

This study suggested a W-L relationship of PBF which could be used to convert length to weight in order to use in SS2. Conversely, when we intend to convert weight only data to length (e.g., season specific W-L relationship is required for preparation of length frequency data), we must use different model: $L = aW^b$ and estimate the parameters according to the situations from which data are collected.

References

Akaike,H. 1973: Information theory and an extension of the maximum likelihood principle. In: Petrov BN, Csaki F (eds). Second international Symposium on Information Theory. Akademia Kiado,Budapest.267-281p.

Hsu,C,C., LIU,H,C., WU,C,L.,HUANG,S,T., and LIAO,H,K.2000. New information on age composition and length-weight relationship of bluefin tuna, Thunnus thynnus, in the southwestern North Pacific. Fisheries Sci.66:485-493.

ICCAT.1984.Report of the Preparatory bluefin tuna meeting, Italy May 1983. ICCAT Collective Volume of Scientific Papers 19: 12-15

Ichinokawa,M.2007. Length frequency of Pacific bluefin tuna caught by Japanese longliners. ISC PBF-WG-11.

Kai,M., and Ichinokawa,M.2007. Length frequency of sampled data in the Pacific bluefin tuna caught by Japanese Set-net. ISC PBF-WG-7.

Methot, RD.2007. User Manual for the Integrated Analysis Program Stock Synthesis 2 (SS2). Model Version 2.00c, Feb 27,2007-Updated Mar 26, 2007.

Oshima,K., Yamada,H., and Takeuchi,U.2007. Calculation of length frequency data of Pacific bluefin tuna from Japanese pole-and-line fisheries for use of stock synthesis 2. ISC PBF-WG-5.

Shingu,C., Warashina,Y., and Matsuzaki,N.1974.Distribution of bluefin tuna exploited by longline fishery in the western Pacific Ocean.Bull.Far Seas.Fish.Res.Lab.10.109-121p.

Watanabe,K., Yamada,H., and Takahashi,M.2006. An investigation of length-weight relationship for Pacific bluefin tuna. ISC PBF-WG-6.

Table.1 Summary of size data of RJB including both weight and length data.

Category		Available peiod	Number of size data		
			Round weight	Eviscerated weight	Total
Year	1994	1994-2007	4612	11994	16606
	1995	-	4495	3353	7848
	1996	-	7566	10453	18019
	1997	-	5631	11228	16859
	1998	-	5184	10179	15363
	1999	-	5736	13870	19606
	2000	-	5574	11108	16682
	2001	-	5492	4128	9620
	2002	-	4346	6992	11338
	2003	-	4091	7789	11880
	2004	-	2961	15996	18957
	2005	-	7115	21286	28401
	2006	-	6767	15708	22475
	2007	-	2082	11020	13102
Quarter	1	1994-2007	13251	2874	16125
	2	-	12147	70071	82218
	3	-	18304	75466	93770
	4	-	27950	6693	34643
Area	J1	2001-2007	239	4376	4615
	J2	-	11069	3911	14980
	J3	-	2789	2812	5601
	J4	-	7562	6129	13691
	J5	-	2	3922	3924
	J6	-	721	0	721
	J7	-	3670	29266	32936
	J8	-	4440	22949	27389
	J9	-	1012	4500	5512
	J10	-	1	1235	1236
	Unknown	1994-2007	40147	76004	116151
Fishery	JLL	1994-2007	140	39542	39682
	JPL	-	3533	0	3533
	LPS	-	1861	100710	102571
	SPS	-	3026	192	3218
	SET	-	30882	5144	36026
	TRO	-	28091	2048	30139
	NON	-	2949	181	3130
	OTH	-	1170	7287	8457
Sex	Male	1999-2007	10	4147	4157
	Female	-	8	5442	5450
	Unknown	1994-2007	71634	145515	217149
ALL			71652	155104	226756

Table.2 Parameter estimates and AIC for W-L relationships of PBF.

Model	error structure	Round weight				Eviserated weight			
		n	$a\times10^{-5}$	b	AIC	n	$a\times10^{-5}$	b	AIC
A	additive	71652	4.8747	2.7983	187128	155104	1.4885	3.0382	1147515
B	multiplicative		1.6267	3.0563	491284		1.8544	2.9948	1311647

Table.3 Some representatives of the round weight-fork length relationship of Pacific bluefin tuna

L-W relationship	Length ranges (cm)	Number of samples	Stock	Authors
$W=1.7117\times10^{-5}FL^{3.0382}$	24-268	155104	North Western Pcific	The present study
$W=3.4235\times10^{-5}FL^{2.9100}$	171-219	100	South west in Japan waters	Shingu *et al* (1974)
$W=2.6516\times10^{-5}FL^{2.9340}$	50-290	1774	Taiwan waters	Hsu *et al* (2000)
$W=2.9500\times10^{-5}FL^{2.8989}$	—	—	Eastern Atlantic	ICCAT (1983)
$W=2.8610\times10^{-5}FL^{2.9290}$	—	—	Western Atlantic	ICCAT (1983)
$W=1.9607\times10^{-5}FL^{3.0092}$	—	—	Mediterranean	ICCAT (1983)

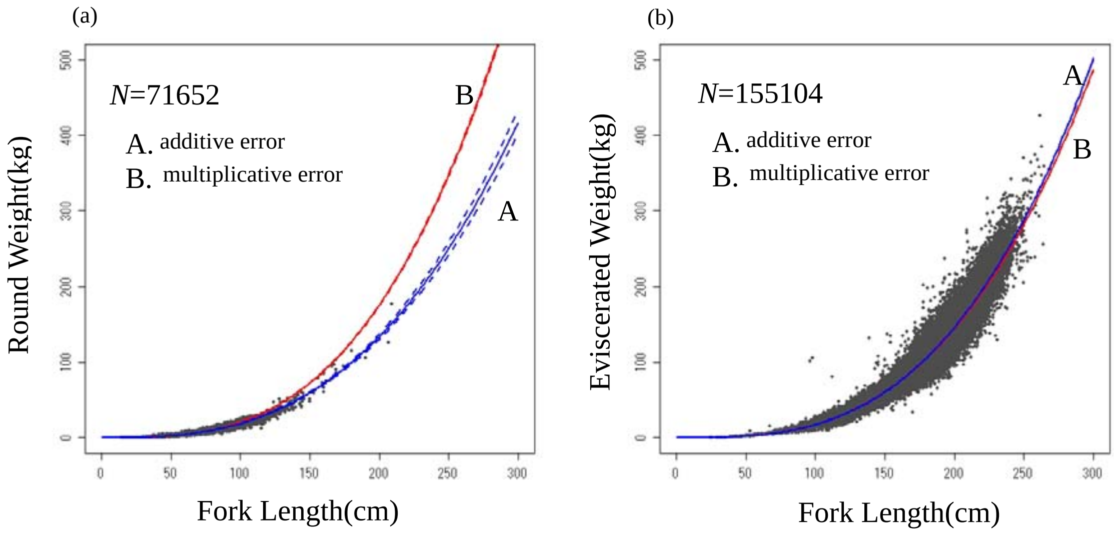

Figure 1 Observed (dots) and estimated (solid line) values of PBF for (a) round and (b) eviscerated weight at length for different error structures: A, additive; B, multiplicative. Broken lines represent 95 % confidence intervals of estimated curves by 1000 bootstrapings.

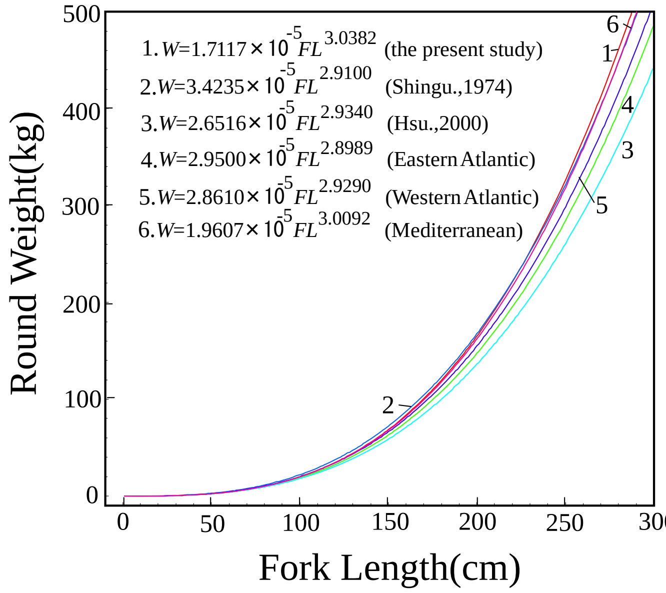

Figure 2 Comparison of the W-L relationships derived from the present study with some previously reported curves. The curves corresponding to the equations and curves numbered 1, 2 and 3 are in eviscerated weight and hence adjusted by 1.15 to convert into round weight.