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Consideration of albacore parameters for stock assessments in the Indian Ocean

Tom Nishida[1/], Toshihide Kitakado[2/], Takayuki Matusmoto[1/],
Jiangfeng Zhu[3/] and Liang-kang Lee [4/]

1/ National Research Institute of Far Seas Fisheries, Fisheries Research Agency, Shizuoka, Japan

2/ Tokyo University of Marine Science and Technology, Tokyo, Japan

3/ Shanghai Ocean University, Shanghai, China

4/ National Kaohsiung Marine University, Kaohsiung, Taiwan

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Abstract

We reviewed seven albacore (ALB) parameters for stock assessments including (1) stock structure, (2) sex ratio, (3) growth equation, (4) natural mortality (M), (5) LW relations, (6) maturity-at-age and (7) life span and plus group age. In the review, we investigated those used in tuna RFMOs (ISC, ICCAT, WCPFC and IOTC). Then we suggested the most feasible parameters for ALB stock assessment in the Indian Ocean.

Contents

1. Introduction

IOTC 9th Working Party on Data Collection and Statistics (WPDCS09) (2013) and 16th Scientific Committee (SC16) (2013) recommended selecting the most appropriate Length-Weight relation (equation) from those collected by the IOTC Secretariat (IOTC-2013-WPDCS09-13). As recognized from this document, IOTC has collected a number of equations for tuna and tuna-like species.

This recommendation requests Working Parties to select the best one for each relevant species. Regarding albacore (ALB), as we will have its stock assessment this year in the 5th Working Party on Temperate Tuna (WPTmT05) and if we selected the LW relation during the WPTmT05, it would be too late for us to use the selected equation in the stock assessment. That is the major reason why we now evaluate and propose the best one in advance before WPTmT05.

In addition, for this opportunity, we will review biological and ecological parameters to be used for the stock assessments before the WPTmT05 and propose more appropriate ones for the 2014 assessment. This is because in the past, there were no extensive reviews of parameters used in the ALB stock assessments in the Indian Ocean.

In this occasion, we will review (1) stock structure, (2) sex ratio, (3) growth equation, (4) natural mortality (M), (5) LW relations, (6) maturity-at-age and (7) life span and plus group age. Then we determine the most feasible parameters for ALB stock assessment in the Indian Ocean. For the review, we will investigate those used in tuna RFMOs (ISC, ICCAT, WCPFC and IOTC).

2. Reviews

(1) Stock structure

In the Pacific and the Atlantic Ocean, two (north and south) stocks hypothesis has been used and stock assessments have been conducted for each stock. As for the Indian Ocean, it has a very small northern part, thus a single stock hypothesis has been applied, although there are some knowledge on intermingled areas with Pacific and Atlantic stock in its eastern and western end respectively. Nevertheless, we propose to use the single stock hypothesis for the 2014 stock assessment as in the past.

(2) Sex ratio

We assume that the sex ratio is 1:1 in the Indian Ocean, although sex ratios are heterogeneous in older ages. Hence we need to conduct stock assessment by considering such heterogeneity, but we don’t have enough information. Thus until such time that we have enough sex ratio information, we assume that the sex ratio is 1:1 in the Indian Ocean. In the most recent stock assessment in the N. Pacific (ISC) in April, 2014, ALB stock assessment was conducted using heterogeneous sex ratio. This is probably the first time to conduct ALB stock assessments incorporating sex ratios in tuna RFMOs.

(3) Growth equation

In the past, we used the growth equation, $L(t)=128.13\ [1-e^{-0.1620\ (t+0.8970)}]$ (Huang et al, 1990). However we realized that Loo around 120cm is realistic, while Loo more than 130cm or less than 110 cm are not realistic through this review work. This is also suggested by Sharma (IOTC) and Kiyofuhi (Japanese scientist, National Research Institute of Far Seas Fisheries, working on ALB in the N. Pacific).

Table 1 list a number of equations by Ocean and we plot those with the realistic Loo between 120cm and 130 cm in Fig. 1. From Fig. 1, growth equations of N Pacific by Well et al (2011 and 2013) well cover wider ranges based on otolith readings, while others narrow ranges. In addition, those by N. Pacific are the newest studies, which samples are covered by large geographical areas. Hence we select the most recent one by Well et al (2013) which is revised and improved one by Wells et al (2011).

Table 1 Summary of growth equations by Ocean (tuna RFMO), range and method

Ocean	Equations L: fork length(cm) t: year	Range(cm) Sample size (n)	Authors (year)	Estimation method	Assessment year (RFMO) models
Indian	$L(t)=128.13\ [1-e^{-0.1620\ (t+0.8970)}]$	65-106 (n=227)	Huang *et al.* (1990)	Scale patterns	
	$L(t)=163.70\ [1-e^{-0.1019\ (t+2.0668)}]$		Lee and Liu (1992)	Vertebrate rings	
	$L(t)=136.00\ [1-e^{-0.1590\ (t+1.6849)}]$		Hsu (1991)	Size frequency	
	$L(t)=147.50\ [1-e^{-0.1260\ (t+1.8900)}]$	51-131 (n=469)	Lee and Yeh (2007)	Spine and Vertebra	2012 (IOTC) SS3+ASPM
N Pacific	$L(t)=146.50\ [1-e^{-0.149\ (t+0.8600)}]$	48-95	Yabuta and Yukinawa (1963)	Scale patterns	
	$L(t)=120.00\ [1-e^{-0.1840\ (t+1.9450)}]$		Well et al (2011)	Otolith	2011 (ISC) SS3
	$L(t)=124.10\ [1-e^{-0.164\ (t+2.2390)}]$	52-128	Well et al (2013) (revised of 2011)	Otolith	2014 (ISC) SS3
S Pacific	$L(t)=121.00\ [1-e^{-0.1340\ (t+1.9220)}]$	44-110	Labelle *et al.* (1993)	Vertebrate rings	2011 (WCPFC) MFCL
	$L(t)=102.90\ [1-e^{-0.3210\ (t+1.107)}]$	48-108	Farley+Clear(2008)	Otolith	
N Atlantic	$L(t)=124.74\ [1-e^{-0.2300\ (t+0.9892)}]$	46-113	Bard (1981)	Spine (n=352)	2013 (ICCAT) SS3 MFCL,VPA+2BOX
	$L(t)=127.10\ [1-e^{-0.2300\ (t+0.9892)}]$	40-119	Santiago and Arrizabalaga (2005)	Spine	
S Atlantic	$L(t)=147.50\ [1-e^{-0.1260\ (t+1.8900)}]$	51-131 (n=469)	Lee and Yeh (2007)	Spine and Vertebra	

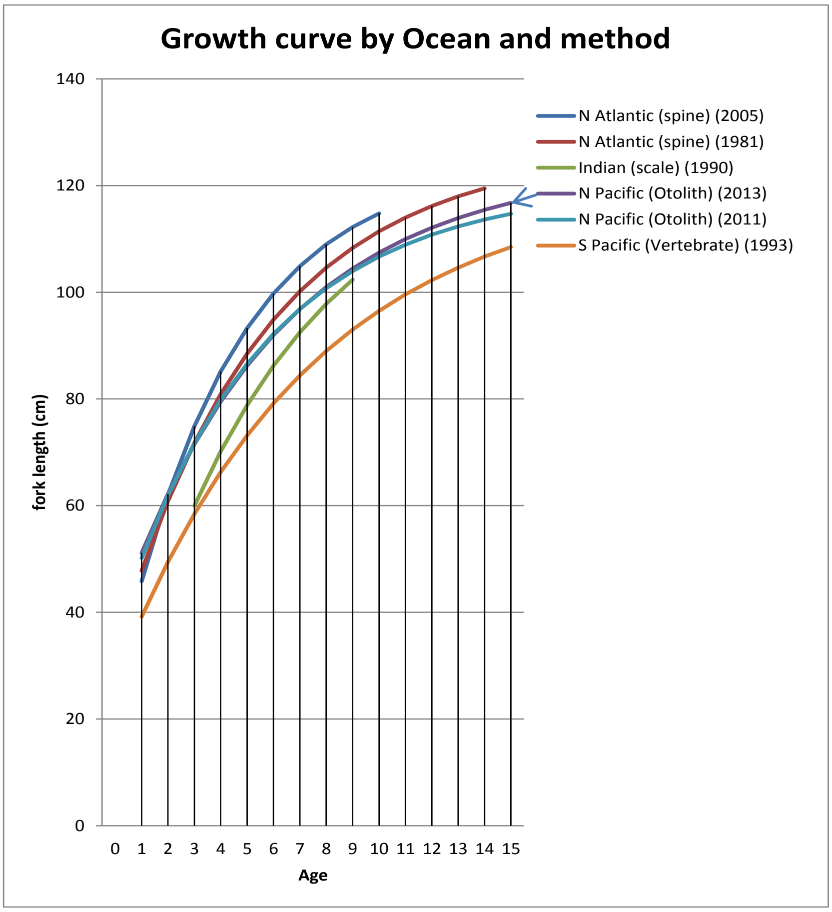


Fig. 1 Growth curves by Ocean (tuna RFMO) and method

(4) M (Natural mortality)

Table 2 and Fig. 2 show M by Ocean (tuna RFMO) and its estimation method. M=0.3 is commonly used in the North Pacific and the North Atlantic, while M=0.4, in the South Pacific. These two values might be biologically realistic, but their theoretical background is unknown. M vector in the North Atlantic is scientifically derived, but the values are likely high.

Two M (0.2207 and 0.2060) in the Indian Ocean are lower than others. But these two Indian Ocean specific M values are similar and consistent and they are scientifically derived, thus we consider that these two M are suitable for Indian Ocean. One of two M derived by Lee and Liu (1992) was used in the last assessment (IOTC, 2012). But it was based on tuna longline data, thus we consider that this M (0.2207) is applicable for adult albacore (age 5 or older). We consider that M for immature albacore are much high than those for adult. Thus we assume that M=0.4 is for age 0 and M for age 1-4 is proportional between 0.4 (age 0) and 0.2207 (adult: age 5 or older), i.e., M=0.4 (age 0), M=0.3641 (age 1), M=0.3283 (age 2), M=0.2924 (age 3) and M=0.2566 (age 4) and M=0.2207 (age 5 or older). Please note that we will not propose M=0.2060 by Lee et al (1990) as this M are for all ages and M by age considering for this time is more realistic.

Table 2 Summary of M by Ocean (tuna RFMO) and its estimation method

Ocean	Parameters	Authors (year)	Estimation method	Assessment year (RFMO)
Indian (IOTC)	0.2207	Lee and Liu (1992)	Estimated by Z=q*F+M using LL data	2012(IOTC) ASPM and SS3 (0.4 for sensitivity)
	0.2060	Lee *et al*.（1990）	Pauly（1980） method (using temperature)	(Not used in the assessment)
N. Atlantic (ICCAT)	0.3			2013 (ICCAT) SS3, MFCL and VPA+2BOX
	(age 0-14) 0.63; 0.46; 0.38; 0.34; 0.31; 0.29; 0.31; 0.34; 0.38; 0.44; 0.55; 0.55; 0.55; 0.55; 0.55	Santiago (2004)	M is from SPC (2003) and M by age is estimated by Chen and Watanabe (1988) using the Bard's method	Uses as sensitivity for 0.3
N. Pacific (ISC)	0.3	Watanabe et al (2006)		2011 (ISC) SS3 + VPA-2BOX 2014 (ISC) SS3
S. Pacific (WCPFCF)	0.4 (0.3 and 0.5)	Hoyle et al (2012) (sensitivity)		2012 (WCPFC) MFCL

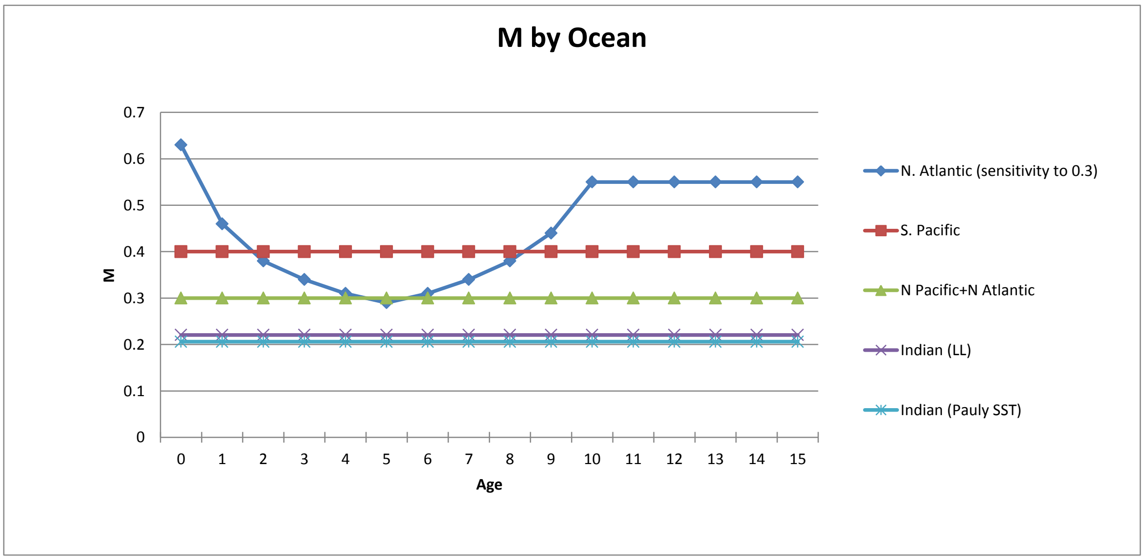


Fig. 2 M by Ocean (tuna RFMO) and its estimation method

Fig. 2 depicts the M vector that we propose for ALB stock assessments in the Indian Ocean, i.e., M=0.4 (age 0), M=0.3641 (age 1), M=0.3283 (age 2), M=0.2924 (age 3) and M=0.2566 (age 4) and M=0.2207 (age 5 or older). In conclusion, we propose these M vector as the base case and M=0.3 as the sensitivity (Fig. 3) as M=0.3 is commonly used in the North Pacific and the North Atlantic and it is also about the average value in the base case.

We selected the slower growth curve (Well et al, 2013), which corresponds to proposed lower M by age and it makes sense from a biological perspective.

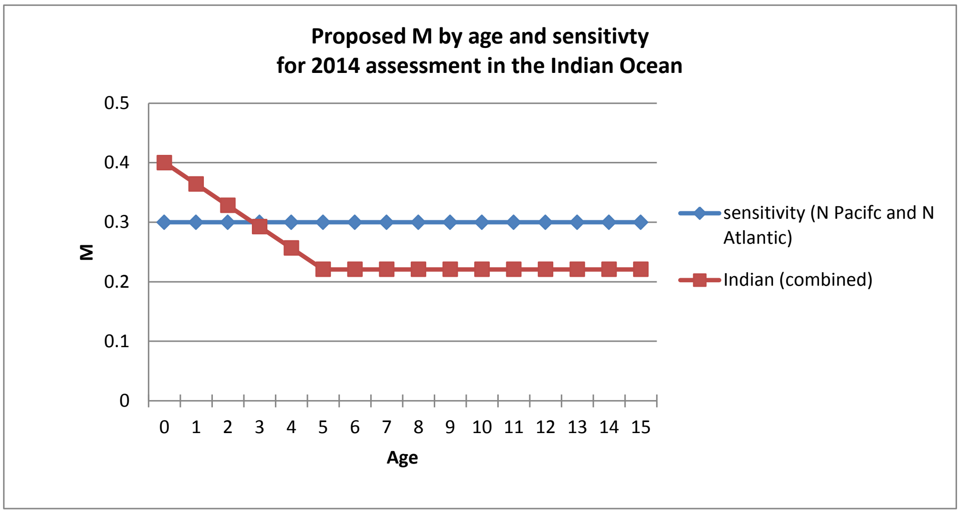


Fig. 3 Proposed M by age (base case) and sensitivity for the 2014 IOTC ALB assessment

(5) LW relation

Table 3 and Fig. 4 show the LW relations by Ocean (tuna RFMO) and fisheries. Those from the IOTC Secretariat (OTC-2013-WPDCS09-13) are also included.

Table 3 Summary of LW relation by Ocean (tuna RFMO) and fisheries

Ocean	Equations W: Round weight (kg) L: Fork length (cm)	Authors (year)	Type of gear, ranges and n (sample size)	Assessment year (RFMO)
Indian	$W = (3.3830 \times 10^{-5})*L^{2.8676}$ (Male) $W = (4.1830 \times 10^{-5})*L^{2.8222}$ (Female) $W = (3.3783 \times 10^{-5})*L^{2.8449}$ (Ave)	Lee and Kuo (1988)	Gillnet	Not used in the assessment
	$W = (5.6907 \times 10^{-5})*L^{2.75140}$	Hsu	Gillnet (n=2,499) (46-112 cm)	2012 (IOTC) SS3+ASPM
Medi -terranean	$W = (4.1830 \times 10^{-5})*L^{2.8000}$	www.fishbase.org	Surface (n=598) (60-88cm)	Not used in the assessment
N. Atlantic	$W = (1.3390 \times 10^{-5})*L^{3.1066}$	Santiago (1993)	All (n=714) (42-117cm)	2013 (ICCAT) SS3, MFCL and VPA+2BOX
S. Atlantic	$W = (1.3718 \times 10^{-5})*L^{3.0973}$	Penney (1994)	All (n=1,008) (46-118cm)	Not used in the assessment
N. Pacific	$W = (8.7000 \times 10^{-5})*L^{2.6700}$	Watanabe *et al.* (2006)	All (Japan + USA + Taiwan) (1989-2004)	2011 (ISC) SS3 + VPA-2BOX
S. Pacific	$W = (0.69587 \times 10^{-5})*L^{3.2351}$	Hampton (2002)	All	2012 (WCPFC) MFCL

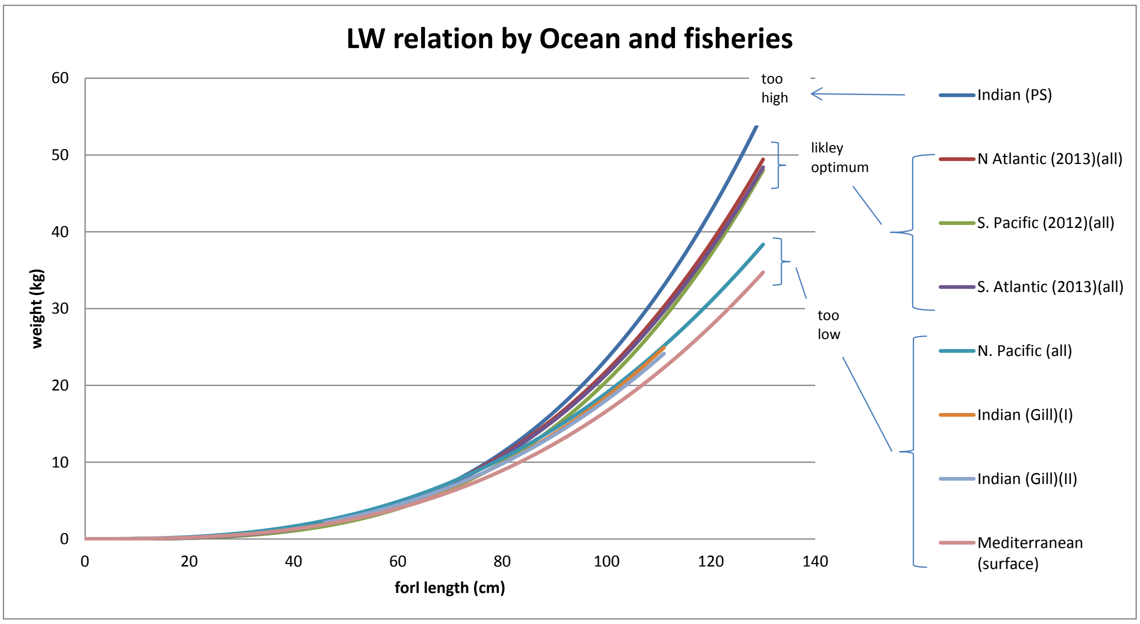


Fig. 4 LW relation by Ocean (RFMO) and Fisheries

LW relations in Indian Ocean are based on the data from gillnet fisheries (GILL) and purse seine fisheries (PS), thus ranges of fork lengths are limited. Hence LW relations are likely biased to some extents, which, hence, produce higher (PS) and lower (GILL) LW curves as shown in Fig. 4. The same situation is also observed in the LW relation of the Mediterranean Sea based on the surface fisheries producing the lower LW relation.

Thus we consider that the LW relations using all fisheries (using wider ranges of fork lengths) are more realistic. There are 4 LW curves using all fisheries data. Among 4, 3 curves are located in the middle ranges (N+S Atlantic and S. Pacific) in Fig. 4, while the one in the N. Pacific, lower than 3 curves.

Under such situation, we will select the best LW relation from these three LW relations (Fig. 5). They are almost identical. As both Indian Ocean and South Atlantic have some geographical common features, we propose to use the LW relation in the South Atlantic (2013), i.e., $W = (1.3718 \times 10^{-5}) * L^{3.0973}$ developed by Penny (1994).

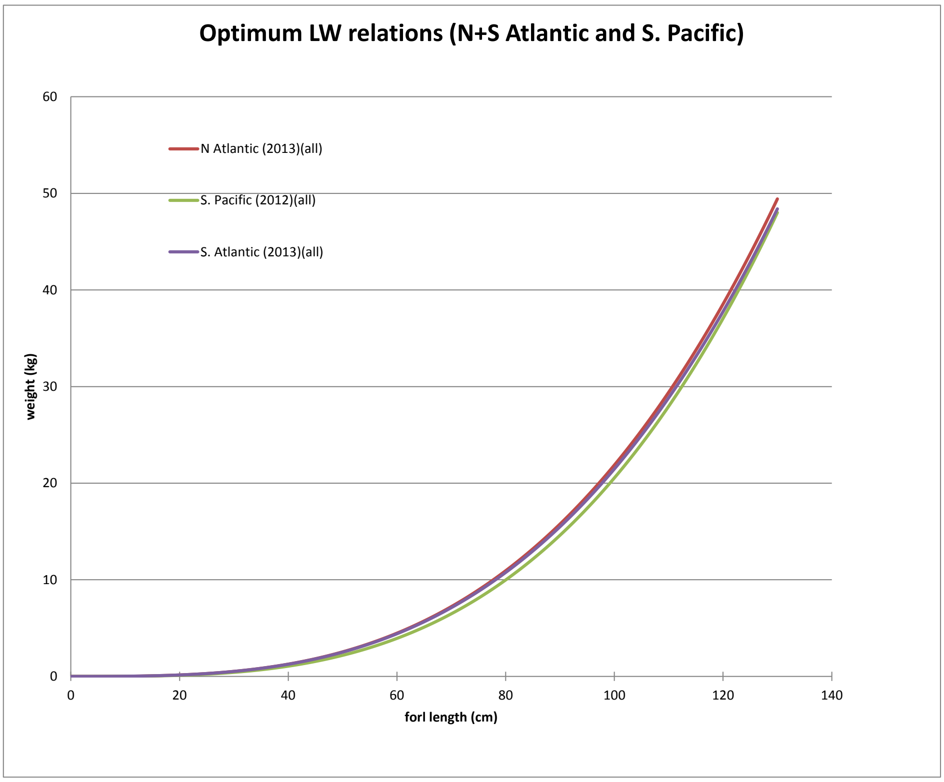


Fig. 5 Three LW relations developed using many types of fisheries data

Fig. 6 shows the proposed LW curve by Penney (1994) (S Atlantic), i.e., $W = (1.3718 \times 10^{-5}) * L^{3.0973}$

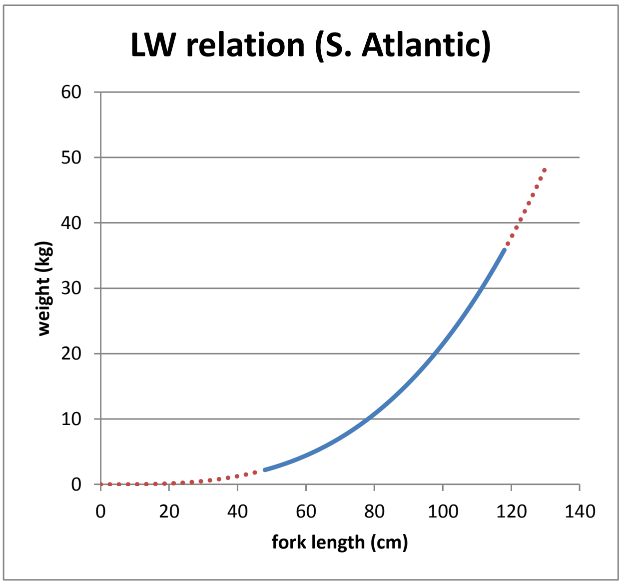


Fig. 6 Proposed LW curve by Penney (1994) (S Atlantic), i.e., $W = (1.3718 \times 10^{-5}) * L^{3.0973}$

(6) Maturity-At-Age

Table 4 and Fig. 7 show the summary of Maturity-At-Age information by Ocean (tuna RFMO).

4 types of Maturity-At-Age show similar trends (Fig. 7). 2 types in the South Pacific are upper and lower boundaries. Maturity-At-Age in the Indian Ocean and in the North Atlantic (also North Pacific) is same (0.5 for age 5). Those for Age 4 and 6 in the Indian Ocean are estimated by proportional allocation between 0 (age 4) and 1 (age 6) used in N Atlantic and N Pacific.

Farley et al (2012) (S. Pacific) covered large sample and also the most recent study while the previous one by Bard (1981) (Atlantic) is a bit outdated, we propose the one by Farley et al. (2012) (Figs. 7-8).

Table 4 Summary Maturity-at-age by Ocean (tuna RFMO)

Ocean	Parameters	Authors (year)	Assessment year (RFMO)
Indian	0 (age <=3), 0.25 (age=4), 0,5 (age=5), 0.75 (age 6) and 1 (age =>7)	Anon (2012)	2012 (IOTC) SS3+ASPM
N. Atlantic	0 (age <=4), 0.5 (age=5) and 1.0 (age =>6)	Bard (1981)	2013 (ICCAT) MFCL, VPA+2BOX and SS3
N. Pacific			2011 (ISC) SS3 +VPA-2BOX
S. Pacific	Age (0-20) 0, 0, 0, 0.09, 0.47, 0.75, 0.88, 0.94, 0.97, 0.99, 0.99, 1, 1, 1, 1, 1, 1, 1, 1, 1	Biological data by Farley et al (2012) and the method by Hoyle (2008)	2012 (WCPFC) MFCL
	0 (age<=4), 0.23 (age 5), 0.57 (age=6), 0.88 (age=7) and 1 (age=> 8)	Anon (2011)	2011 (ISC) SS3 +VPA-2BOX

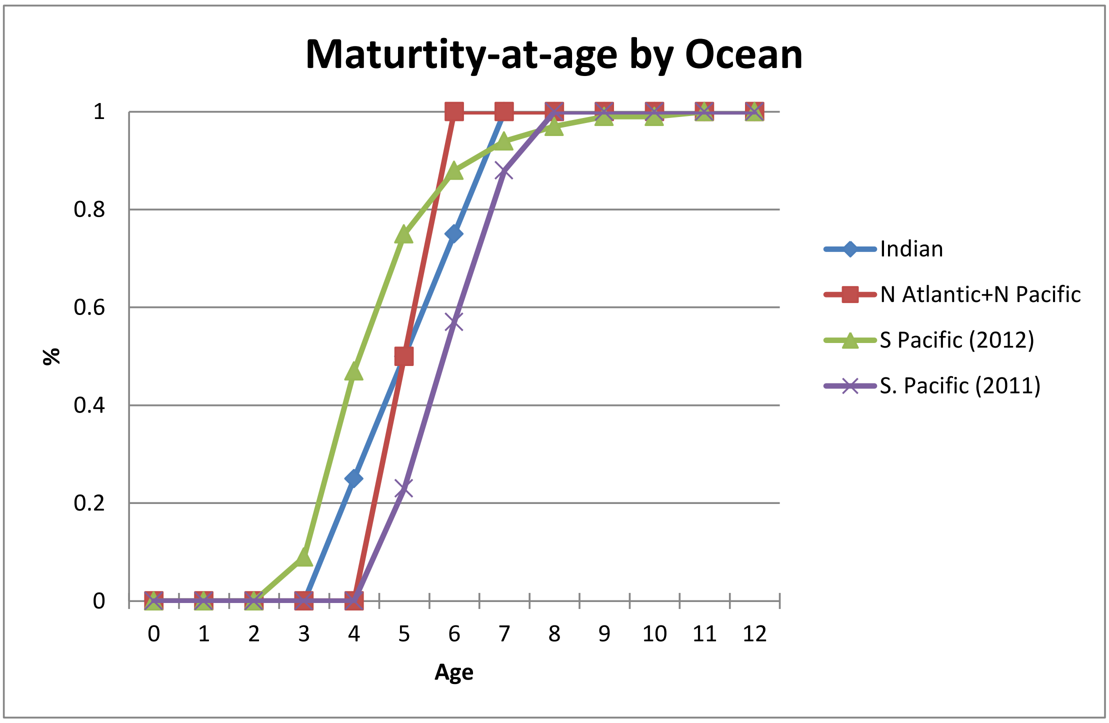


Fig.7 Maturity-at-age by Ocean (tuna RFMO)

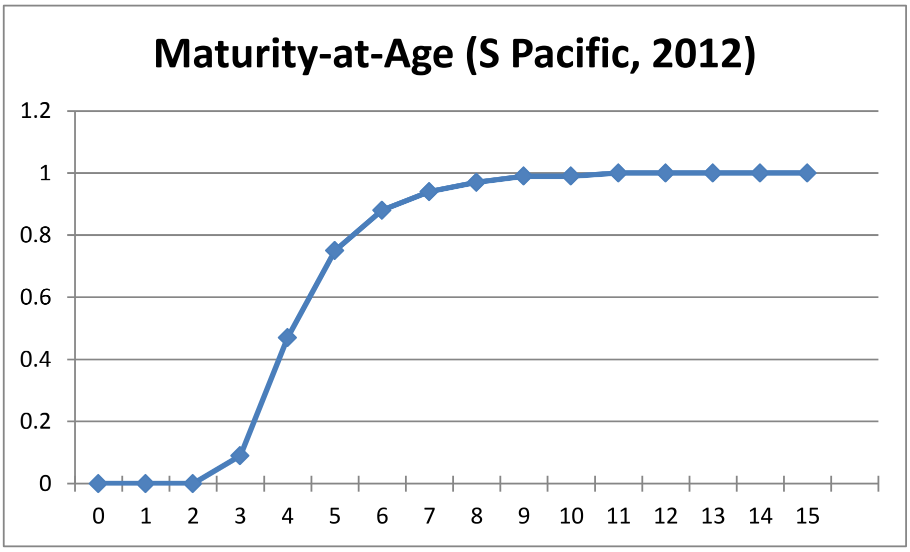


Fig. 8 Proposed Maturity-at-age (S Pacific) by Farley et al (2012)

(7) Life span and + group age

Table 5 shows the life span and + group age and Fig. 9 depicts +group age by Ocean (tuna RFMO).

Table 5 Summary of life spans and + group age by Ocean (tuna RFMO)

Ocean	Parameters (Years old)	Authors (year)	Method	Assessment year (RFMO)
Indian	8	Huang *et al.* (1990)	Scale	Not used in assessment
	10+	IOTC (2012)		2012 (IOTC) SS3+ASPM
	13			Not used in assessment
N. Atlantic	8+	ICCAT (2013)		2013 (ICCAT) MFCL, VPA+2BOX and SS3
S. Atlantic				Not used in assessment
N. Pacific	16 or more	Anon (2013)	Tagging (based on the long term recovery)	Not used in assessment
	14+			2011 (ISC) SS3 + VPA-2BOX
S. Pacific	11		Tagging (based recovery data)	Not used in assessment
	20			2012 (WCPFC) MFCL

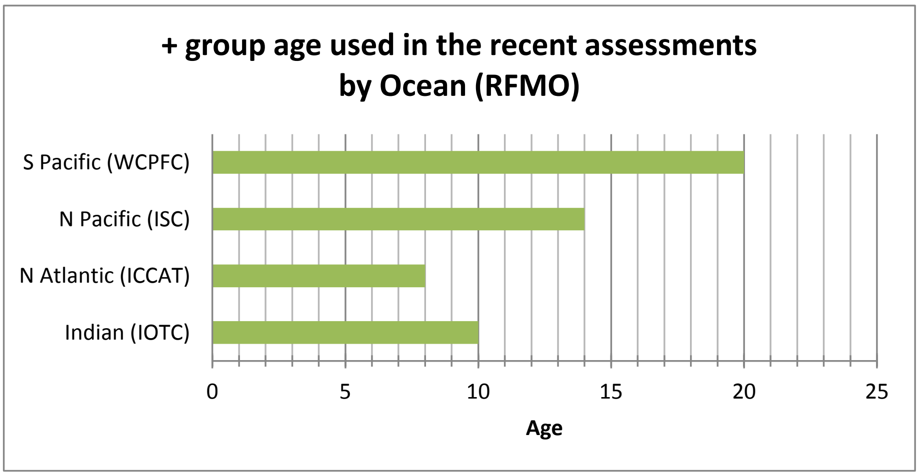


Fig.9 + group age used by the most recent assessments by Ocean (tuna RFMO)

There are large discrepancies in life span among Oceans (tuna RFMOs). According to the tag recovery information, Age 16 is recorded as the maximum one (Table 5). Based on Table 5, we understand that the life span with age 12 or older is more or less realistic.

As populations in older ages are very small, tuna RFMOs use + group age for stock assessments as shown in Fig.9, i.e., 8+ in the North Atlantic Ocean, 10+ in the Indian Ocean, 14+ in the North Pacific Ocean and 20+ in the South Pacific Ocean. These + group ages are also highly fluctuated. Age 20+ is likely too high. If we exclude Age 20+, Age 10+ in the Indian Ocean is about the middle one between 8+ and 14+ and it was used in the last stock assessment in 2012.

Based on personal communications with three professors, Butterworth (Cape Town University), Hiramatsu (Tokyo University) and Shono (Kagoshima University), following points are rough clues to decide the plus age group (or last age):

(i) If the age determination is difficult starting from some age (by otolith reading for example), that age and older ages should be pooled as the plus group.

(ii) There will be biases in the stock assessment results if the population in plus group is more than 20% or less than 2% of the total population.

(iii) If 0 catch is included in the plus group in any year, it will be difficult to conduct assessments.

For the point (i), the growth curve by Well et al (2013) that we selected, cover age up to 15 (Fig. 10), which was used as the last age in SS3 in the most recent assessment (last April) for north Pacific ALB (ISC). In addition, 13+ was suggested if we use the growth equation by Lee and Yeh (2007). But as we will use the one by Well et al (2013), 15+ is considered to be more appropriate. For points (ii) and (iii), we need to evaluate them by investigating real CAA provided by IOTC Secretariat.

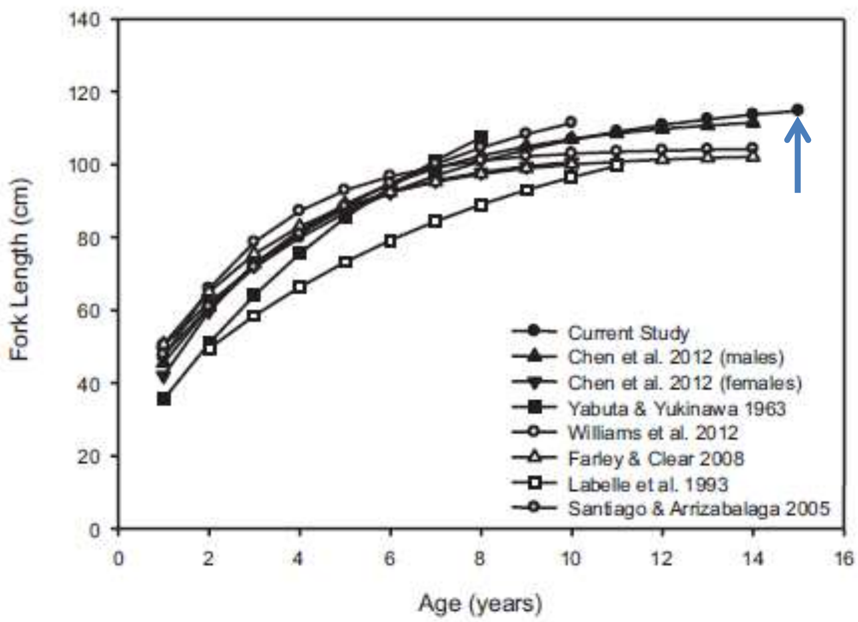


Fig. 10 Length-at-age estimates of the specialized VB growth model generated from this study and VB models from other albacore studies in the North Pacific (black), South Pacific (white), and North Atlantic (gray).

3. Discussion

In some tuna RFMOs (e.g., ISC, ICCAT), they normally have extra data preparatory meetings (including discussion on parameters) basically one year before assessment meetings. But for IOTC, we don't have time to have such meetings due to the fact that we already have many other meetings. We suggest that we need to discuss this issue in each Working Party in 2014 to move forwards.

To understand uncertainties, we well understand that we need to attempt various sensitivities as suggested by Sharma. However, if there is too many sensitivity, we will have many scenarios and may be not able to handle during the meeting. In last assessment, we have 4 scenarios (ASPM) and 6 (SS3), which was considered to be the optimum number in the short meeting period. For this time, we expect 6-12 scenarios, for example, 3 types of steepness including the base case, 2 for Sigma_R and 2 for M as an example. We think that 12 scenarios is the maximum number.

4. Summary

Table 6 shows our proposal on biological and ecological parameters to be applied to the 2014 albacore stock assessment in the Indian Ocean in the WPTmT05 (July, 28-31, 2014, Busan, Korea).

Acknowledgements

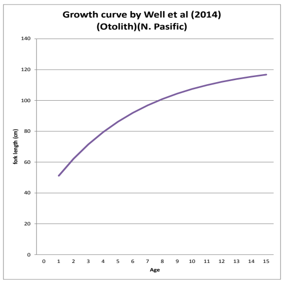
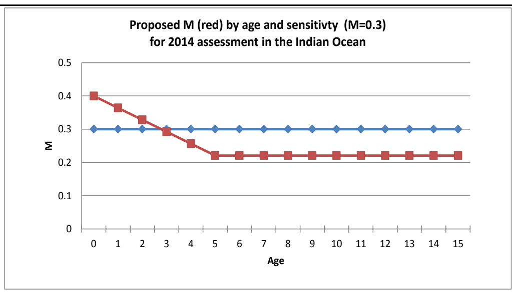
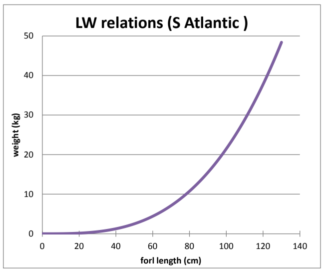
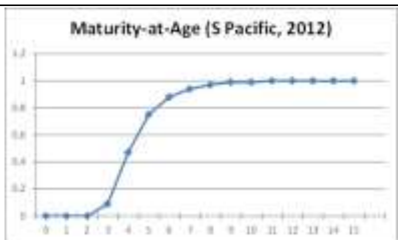
We deeply appreciate following experts to provide useful suggestions and information (alphabetical order of the last name):

Dr Haritz Arrizabalaga (AZTI, Spain),
Dr Doug Butterworth (University of Cape Town, South Africa)
Dr Kazuhiko Hiramatsu (University of Tokyo)
Dr Simon Hoyle (former SPC)
Dr Hidetada Kiyofuhi (National Research Institute of Far Seas Fisheries, Japan)
Dr Rishi Sharma (IOTC)
Dr Hiroshi Shono (Kagoshima University)

Table 6 Summary on the proposed parameters (revised) for the 2014 ALB stock assessments in the Indian Ocean

(Note 1) Parameters with (*) are same as before (2012 assessment) and others are different.

(Note 2) For SS3, some parameters will be arranged for quarterly based ones.

<table>
<tr><th>Parameters</th><th>Base case</th><th>Sensitivity</th></tr>
<tr><td>(1) Stock structure (*)</td><td>Single</td><td rowspan="3">(not considered)</td></tr>
<tr><td>(2) Sex ratio (*)</td><td>1:1</td></tr>
<tr><td>(3) Growth equation
$L(t)=124.10\,[1-e^{-0.164\,(t+2.2390)}]$
Well et al (2013)
(N. Pacific)</td><td>
</td></tr>
<tr><td>(4) M by age
<table><tr><th>age</th><th>M</th></tr><tr><td>0</td><td>0.4000</td></tr><tr><td>1</td><td>0.3641</td></tr><tr><td>2</td><td>0.3283</td></tr><tr><td>3</td><td>0.2924</td></tr><tr><td>4</td><td>0.2566</td></tr><tr><td>5 or older</td><td>0.2207</td></tr></table>Combination of Lee and Liu (1992) (Indian) and M=0.4 (S Pacific)</td><td>
</td><td>M=0.3
(N. Pacific)
****
M=0.4
(S. Pacific)
(if time available)</td></tr>
<tr><td>(5) LW relation
$W = (1.3718 \times 10^{-5}) * L^{3.0973}$
Penny (1994)
(S. Atlantic)</td><td>
</td><td rowspan="3">(not considered)</td></tr>
<tr><td>(6) Maturity-at-age
Age (0-15): 0, 0, 0, 0.09, 0.47, 0.75, 0.88, 0.94, 0.97, 0.99, 0.99, 1, 1, 1,
Farley et al (2012) (S. Pacific)</td><td>
</td></tr>
<tr><td>(7) Plus group age (last age)
N. Pacific and suggestions made by Butterworth, Hiramatsu and Shono</td><td>15+ (provisional)
Two points (below) will be examined to decide the final plus group (last age).
There will be biases in the stock assessment results if the population in plus group is more than 20% or less than 2% of the total population.
If 0 catch is included in the plus group in any year, it will be difficult to conduct assessments.</td></tr>
</table>

References by Ocean (tuna RFMO)

(Note) If you have questions about references, please contact the first author (Nishida)

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