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Stock assessments of albacore (*Thunnus alalunga*) in the Indian Ocean by Age-Structured Production Model (ASPM)

Tom Nishida[1/], Takayuki Matsumoto[1/], Kazuharu Iwasak[2/] and Toshihide Kitakado[3/]

1/ National Research Institute of Far Seas Fisheries, Fisheries Research Agency, Shimizu, Shizuoka, Japan
2/ Environmental Simulation Laboratory (ESL), Kawagoe, Saitama, Japan
3/ Tokyo University of Marine Science and Technology, 5-7, Konan 4, Minato, Tokyo, 108-8477, Japan

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Abstract

Indian Ocean Albacore stock assessment was attempted by ASPM. Because of large uncertainties in extremely large number of drift gillnet CAA (catch-at-age) matrix (1982-1992) (max 10 million fish) caused by the fundamental problem (no size data), we could not obtain the plausible and realistic results. To overcome this type of situation, we plan to develop additional option to the current ASPM software that can handle original size or CAS (catch-at-size) data, so that ASPM can conduct stock assessment when no or not enough size data situation (NB: when no size data, that option can use substituted size data from other areas and conduct assessments).

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1. Introduction

We attempted the stock assessment on albacore (*Thunnus alalunga*) (ALB) in the Indian Ocean based on AD Model Builder implemented Age-Structured Production Model (ASPM) (ver. 5) (Nishida et al) (2014) using the data for 63 years from 1950-2012. It is important to have a few stock assessments from simple (e.g. ASPIC), medium (e.g. ASPM, ASAP) to integrated models (e.g. SS3), so that we can compare under different structure of the dynamic models and confirm results. This is also important from another aspect, i.e., we will have more “Line of Evidence” in the “Weight of Evidence” approach if we have similar results in a few stock assessments. This means that we have more certainty (confident) in the stock status **even** there are large uncertainties in the data and models.

2. Input information

To implement ASPM, we used ALB annual nominal catch by gear, standardized CPUE (STD_CPUE), CAA (catch-at-age) by gear and biological information. Below are descriptions of the data used in the ASPM runs.

2.1 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 assume a single stock hypothesis for the 2014 stock assessment as in the past.

2.2 Fleet

We used 5 types of fleet (gears), i.e., tuna longline (Japan): LL(J), tuna longline (Taiwan,China) LL(T) and drift gillnet in high seas (GILL) by Taiwan,China, purse seine (PS) and others(OTH), which is defined in the data sets produced by the IOTC Secretariat. OTH includes small scale surface fisheries such as troll, pole and lines, lines, gillnet (off shore) and other minor fisheries.

2.3 Nominal catch by gear

We used the nominal catch data by gear (fleet) from the IOTC Secretariat. Fig. 1 shows the trends of catch by fleet type (in weight and number).

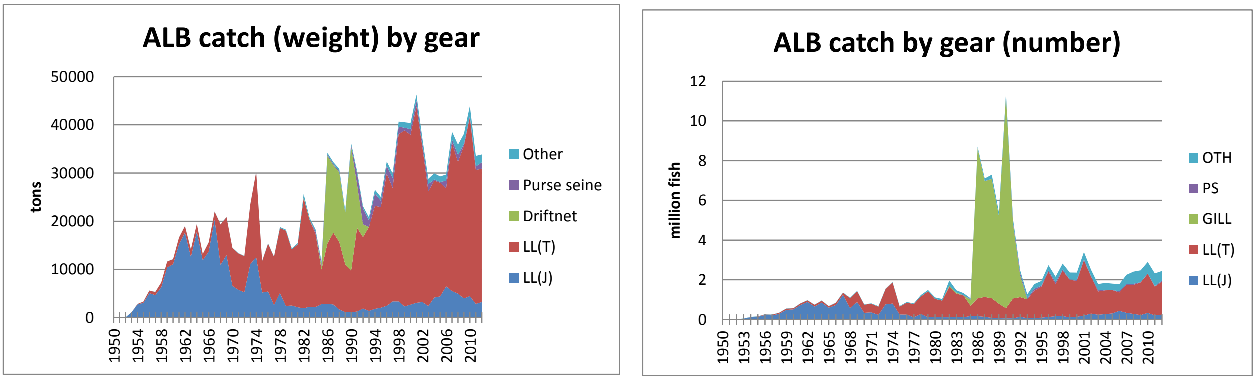


Fig. 1 Trend of albacore tuna catch in the Indian Ocean by gear type in weight (left) and in number (right). (Source: IOTC Secretariat, 2014)

However, catch in number in GILL (1982-1992) is very high comparing to the one used in 2012 stock assessment (Fig. 2). According to Miguel Herrera (IOTC data manager), this gap is caused by the following reason: There are no size samples available from GILL of Taiwan,China, thus substitutions need to apply to compute numbers. Then large discrepancy between 2012 and 2014 is due to change in the substitution schemes, i.e., Secretariat used average ALB weight PS data (about 24 kg), while 2014, the one in OTH (<u>surface fisheries which are more in agreement with the sizes that driftnet fisheries catch in southern waters</u>)(*) (3Kg). That is why number in 2014 is 8 times higher than in 2012 (see below).

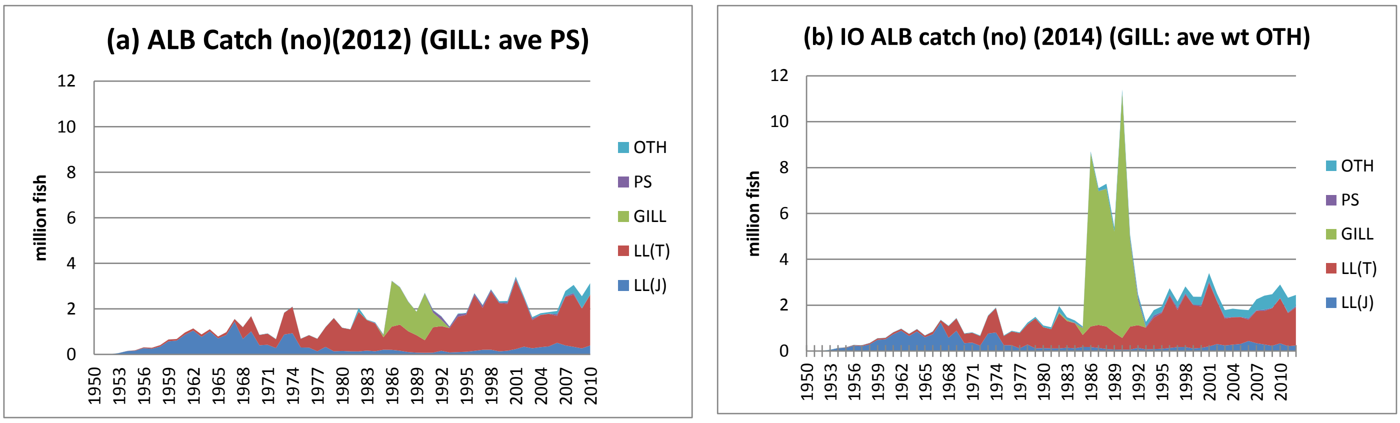


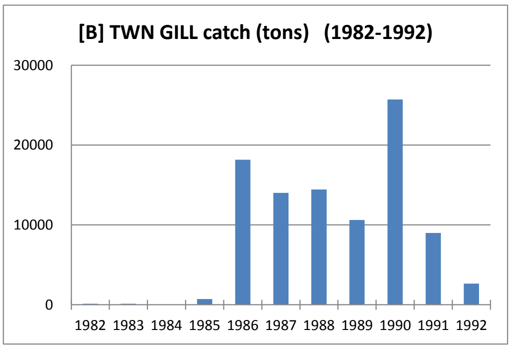
Fig. 2 Indian Ocean Albacore catch by gear in number
Number of GILL is estimated by IOTC Secretariat using
(left) Average weight (24kg) of ALB caught by PS fisheries (2012)
(right) Average weight of ALB (3Kg) caught by OTH fisheries (2014)

2.4 CAA (GILL)

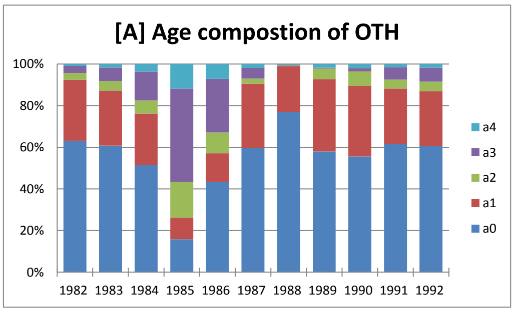
CAA by gear is provided by Secretariat. However age compositions of GILL CAA (1982-1992) are constant in this period. As they vary by year, we assume that age composition (selectivity) of GILL are similar to OTH [see (*) above] then we estimated GILL CAA (Box 1).

Box 1 Estimation of GLL CAA using annual age composition (selectivity patterns) of OTH

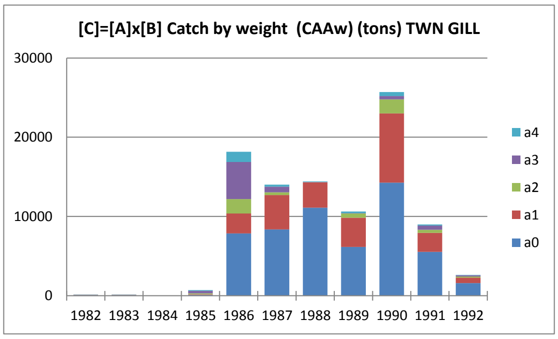
(1) TWN GILL catch in tons



(2) Age comp of OTH gear



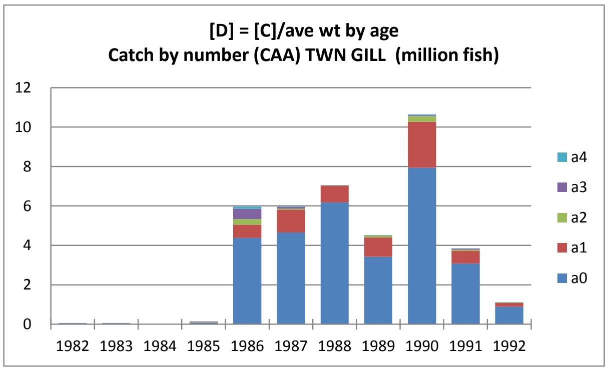
(3) GILL CAAw is computed by (1) x (2) assuming selectivity of OTH similar to GILL



Then using average weights of ALB by age shown Table (below), which are estimated growth equation by Wells et al (2013) and length-weight relationship by Penney (1994) (see page 10).

Age (middle of year)	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5
weight (kg)	1.8	3.7	6.2	9.1	12.1	15.1	18.0	20.8	23.4	25.7	27.8	29.7	31.4	32.8	34.1	35.2	36.2	37.0	37.7	38.3

(4) Estimate CAA of GILL by (3)/ average weight by age



2.3 Plus group age

The IOTC Secretariat provide CAA (age 0-20+) by fleet. According to IOTC-2014-WPTmT-16, plus group age are different among RFMOs (Oceans) (Fig. 5). We need to decide scientifically valid plus group.

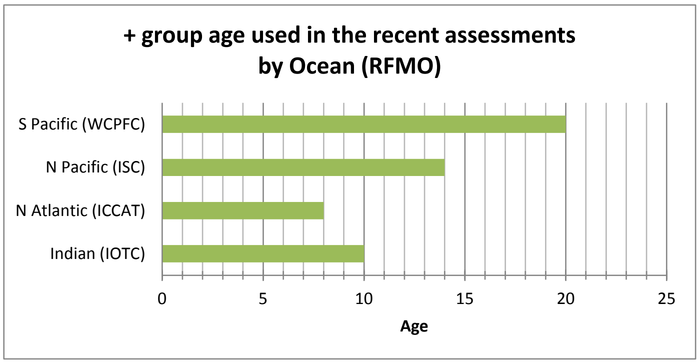


Fig. 5 Plus group used in recent stock assessments in different tuna RFMOs

The IOTC Secretariat provide CAA (age 0-20+) by fleet and we explore optimum plus group using this CAA. Based on personal communications with three professors, Butterworth (Cape Town University), Hiramatsu (Tokyo University) and Shono (Kagoshima University), they suggest three rough clues to decide the optimum plus age group:

(i) 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.

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

(iii) 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.

Then we investigated these three criteria to select plus group age. Regarding criterion (i), Fig 6 shows compositions of the plus group in the total catch, which suggested Age 15 or younger ages, satisfied (ii) 2% criteria. Regarding (ii), we investigated 0 (zero) catch in CAA then we found years 1950-1951, there are 0 catch in Age 15+ or younger plus age groups. This we will use the data from 61 years (1952-2012).

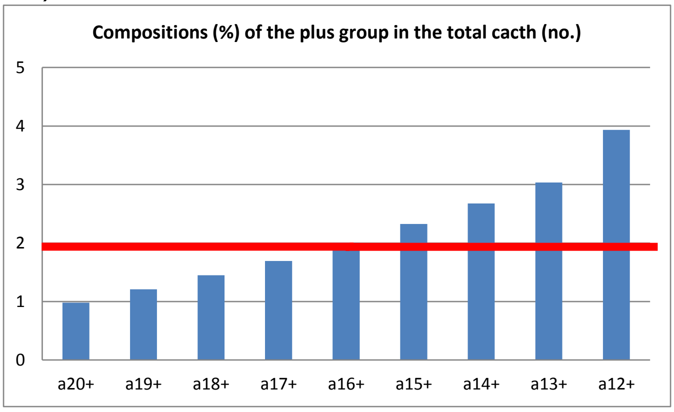


Fig. 6 Compositions of the plus group in the total catch

Table 1 number of catch in plus group ages (12+ to 20+).

(1950-1951 include 0 catches)

	a20+	a19+	a18+	a17+	a16+	a15+	a14+	a13+	a12+
1950	0	0	0	0	0	0	0	0	0
1951	0	0	0	0	0	0	0	0	0
1952	12	16	20	26	34	50	50	68	103
1953	52	74	87	109	141	210	239	339	702
1954	182	242	293	367	442	697	848	1546	3780
1955	856	989	1116	1247	1437	2699	2519	4225	6598
1956	885	1118	1588	2086	2526	4059	4146	6117	9837
1957	1009	1252	1757	2252	2628	4042	3747	5733	8314
1958	1713	2193	3033	3772	4552	7096	6682	9813	13840
1959	1972	2547	3513	4430	5354	8188	7547	11149	14495
1960	1734	2217	3018	3944	4737	7270	6796	9940	13855
1961	1495	1886	2531	3918	4588	6827	6319	8856	10861
1962	1607	2175	2789	3580	4260	6665	6241	9597	13648
1963	2413	3314	4317	5544	6492	9975	8964	13185	15729
1964	1634	2045	2755	3465	4159	6743	6844	10261	23906
1965	1636	2799	3553	4307	5040	7529	6863	9440	11649
1966	2039	2583	3397	4231	5066	7971	6858	9877	10683
1967	984	1591	2172	2609	3167	4807	5277	7076	10381
1968	4359	6293	8509	10740	12911	19542	18604	24966	27580
1969	4371	5410	6617	8325	9673	15520	13261	19202	29097
1970	13130	16354	21608	26510	31487	50111	43716	62872	64060
1971	6612	8259	12348	16439	18839	27853	23673	32752	38584

Regarding the criterion (i), we selected the growth curve by Well et al (2013) that cover age up to 15 (Fig. 7) (for details, see page 10), which suggested that age 1-15 are valid and CAA in other age need to be pooled. Then we checked (ii) and (iii) and age 15+ satisfied these two conditions. As a conclusion, we decide to use Age 15+ (plus group).

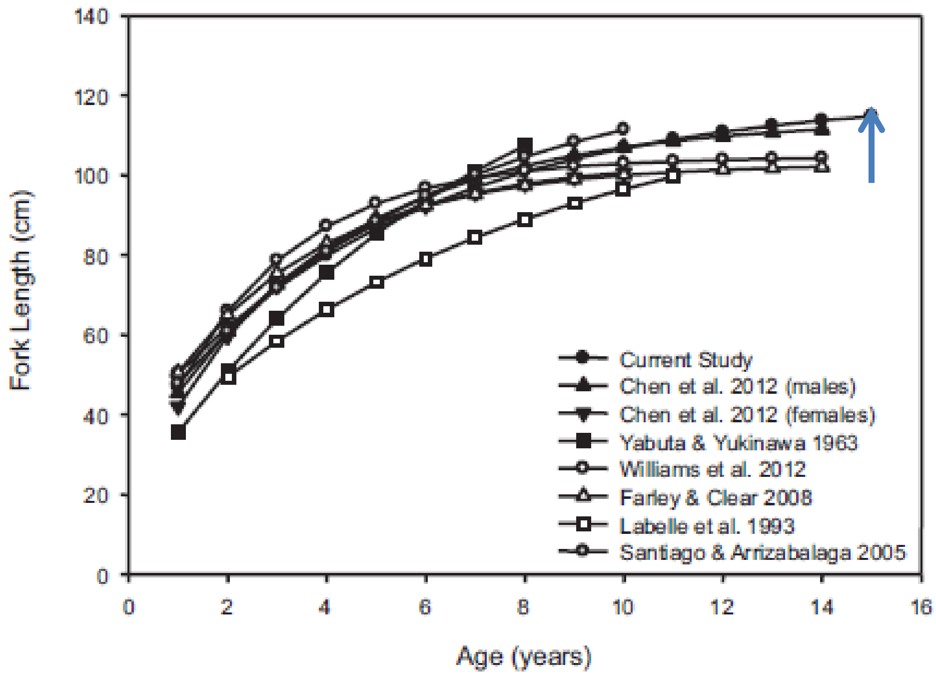


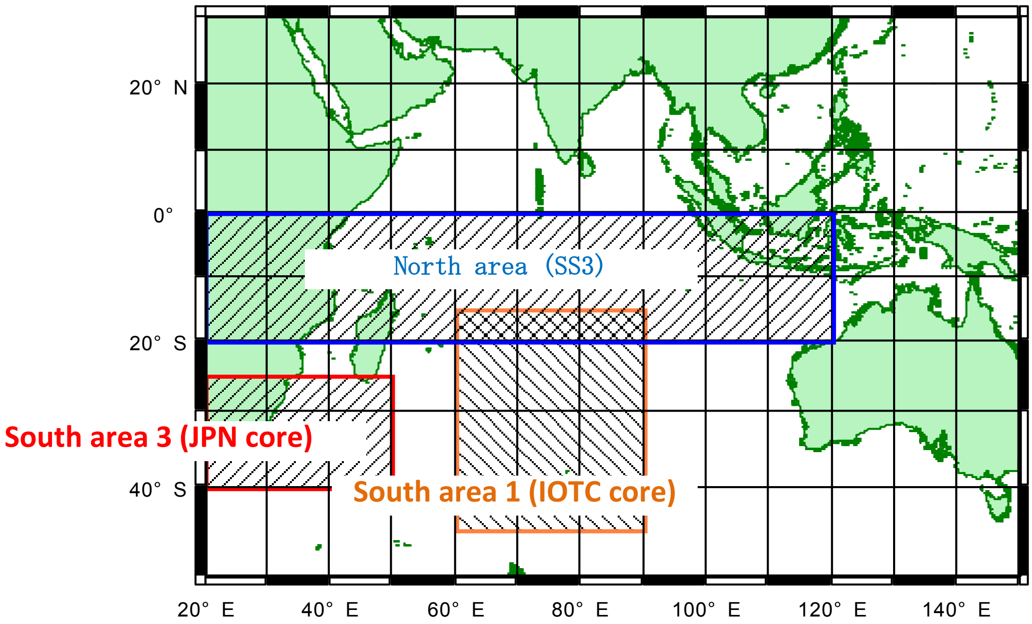
Fig. 7

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).

2.4 CPUE

Table 1 Eight standardized CPUE (STD_CPUE) in 6 (sub) areas (Figs 4 and 5)

STD_CPUE	ALL (Fig. 5)	North (SS3)	South			
			Area 1 (IOTC core area)	Area 2a (TWN core)	Area 2b (TWN core)	Area 3 (JPN core)
Japan		(1)				(2)
Taiwan	(3)	(4)	(5)	(6)	(7)	(8)
Korea	(not available as of July 21)					



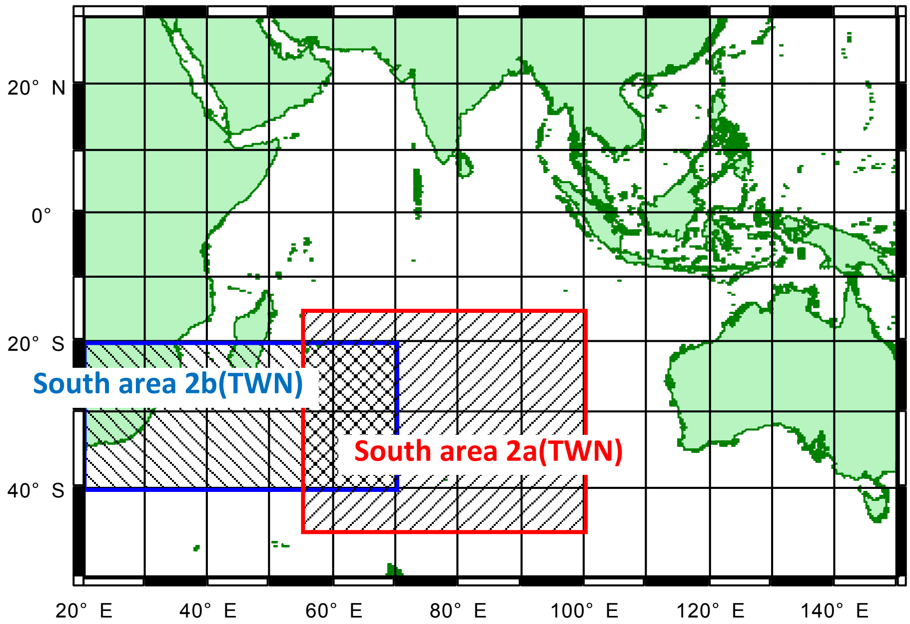


Fig 4 Seven core (sub) areas defined by Japan, Taiwan and IOTC

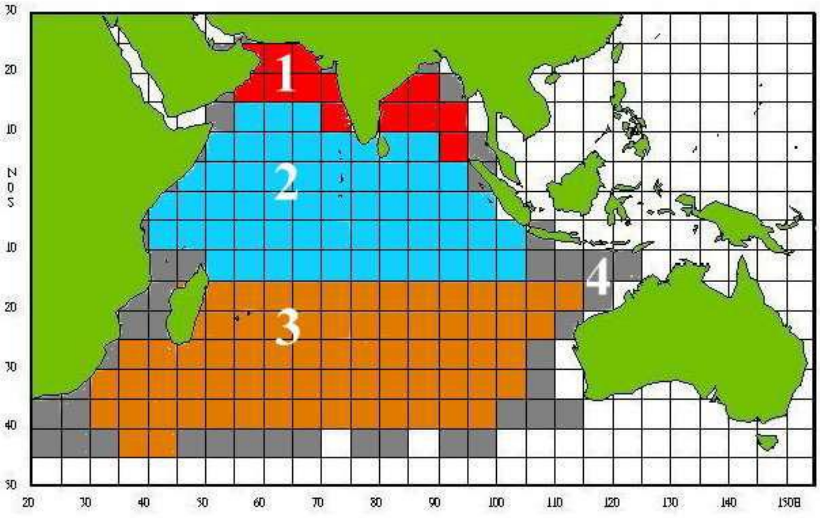


Fig 5 Whole area for STD_CPUE (Taiwan LL)

Fig. 6 shows eight STD_CPUE available in WPTmT05. Then, we compared relations between total catch vs. 8 STD_CPUE (Fig. 7). 2 STD_CPUE (Japan) had the positive correlation while 6 STD_CPUE (Taiwan) negative. Among 6 TWN STD_CPUE, STD_CPUE in the whole area has the highest negative correlation. Hence we used it for ASPM. As ASPM use whole area, this STD_CPUE in the whole area is consistent to this approach.

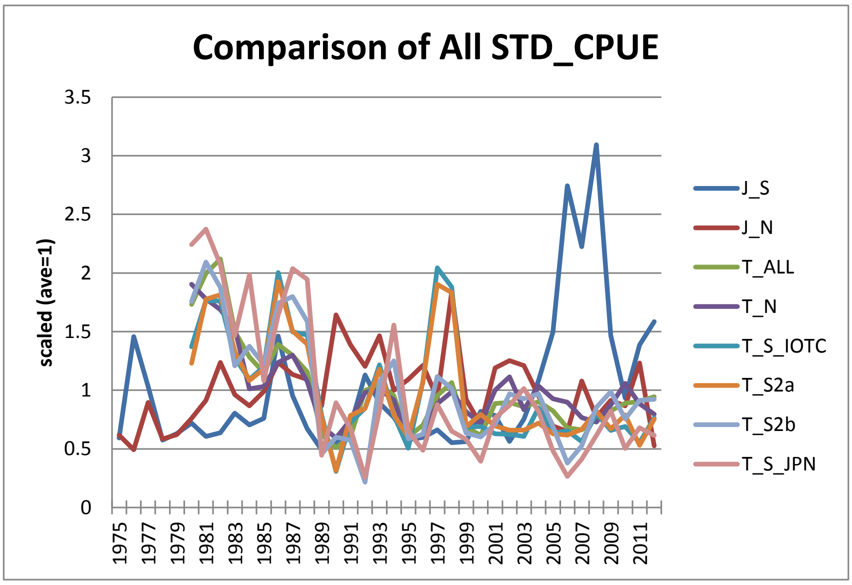
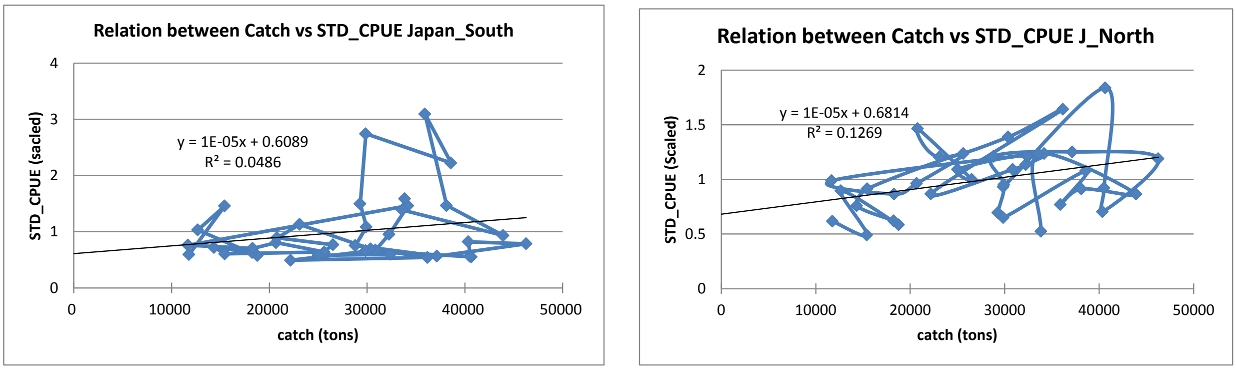


Fig. 6 Comparisons of 8 STD_CPUE series

Japan (2 series)



Taiwan (6 series)

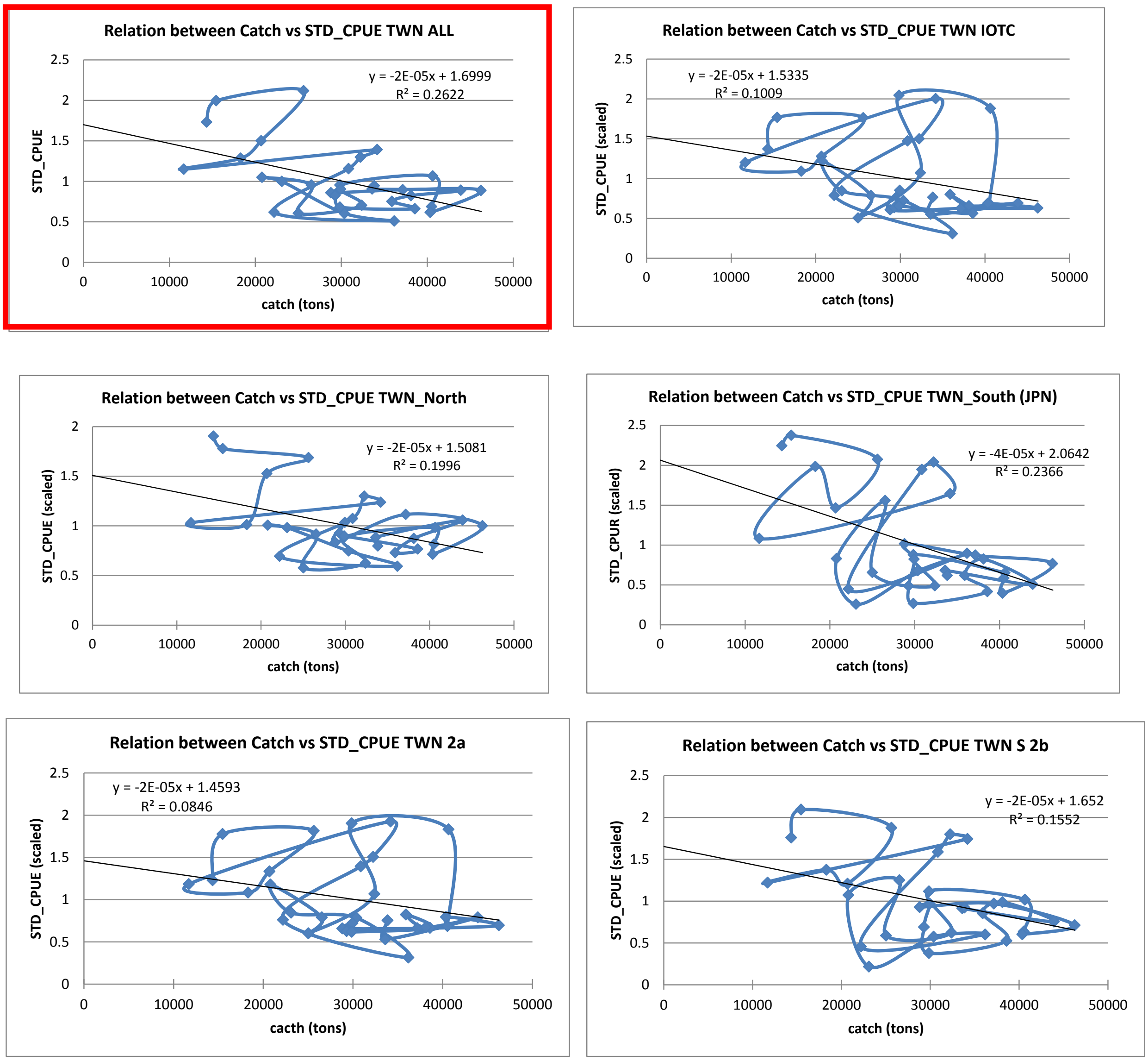


Fig. 7 Relations between total ALB catch vs. 8 STD_CPUE series

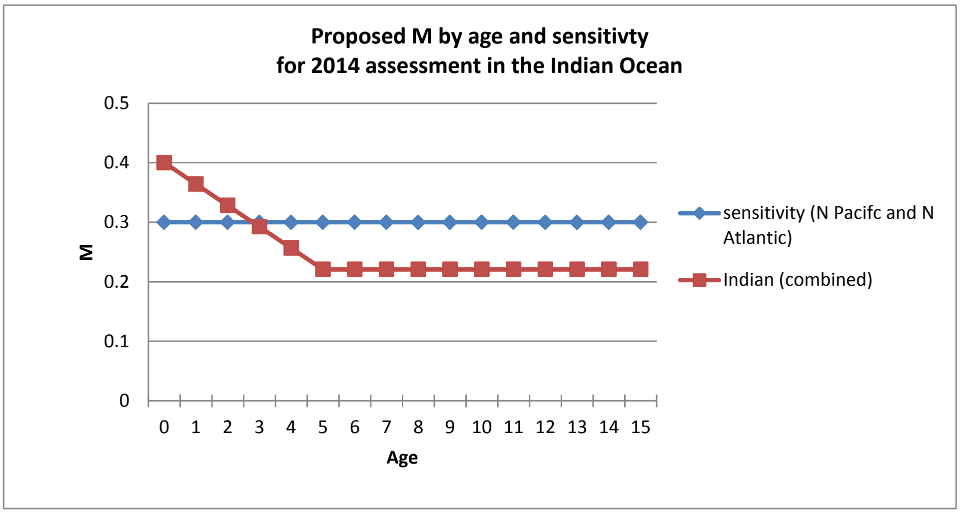
2.5 Biological information

In the ASPM, three types of age-specific biological inputs are needed, i.e., natural mortality-at-age (*M*), weights-at-age (beginning and mid-year) and proportion maturity-at-age. Based on the review of these parameters by Nishida et al (2014) (IOTC-2014-WPTmT05-16), we follow suggestions made by that paper.

(1) Natural mortality vector (M) (Box 2)

Box 2 Natural mortality (M) used in ASPM

Age	Base case M (Age 0)=0.4 M (age 5+)=0.2207 (Lee and Liu, 1992) M(age 1-4): propotions of abobe two Ms
0	0.4
1	0.3641
2	0.3283
3	0.2924
4	0.2566
5 or older	0.2207

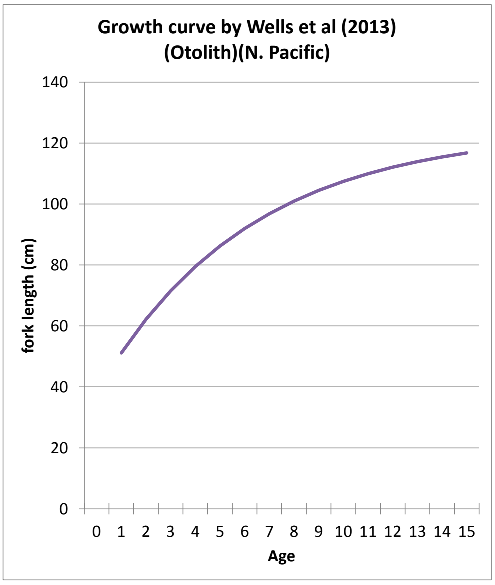


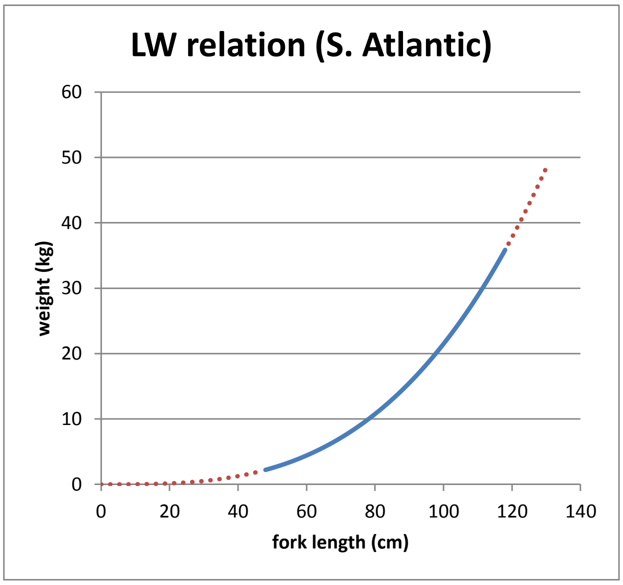
(2) Beginning- and mid-year weights-at-age

Beginning- and mid-year weights-at-age are computed as explained in Box 3

Box 3 Computation process of beginning- and mid-year weights-at-age as follow:

(a) using the growth equation by Wells et al (2013), size-at-age was calculated, (b) using the length-weight relationship, $W = (1.3718 \times 10^{-5}) * L^{3.0973}$ by Penney (1994) (S Atlantic), weight-at-age was calculated as shown in Table below.





Age (beginning of year)	weight (kg)	Age (middle of year)	weight (kg)
0	1.1	0.5	1.8
1	2.7	1.5	3.7
2	4.9	2.5	6.2
3	7.6	3.5	9.1
4	10.5	4.5	12.1
5	13.6	5.5	15.1
6	16.6	6.5	18.0
7	19.4	7.5	20.8
8	22.1	8.5	23.4
9	24.6	9.5	25.7
10	26.8	10.5	27.8
11	28.8	11.5	29.7
12	30.6	12.5	31.4
13	32.1	13.5	32.8
14	33.5	14.5	34.1
15	34.7	15.5	35.2
16	35.7	16.5	36.2
17	36.6	17.5	37.0
18	37.4	18.5	37.7
19	38.1	19.5	38.3
20	38.6	20.5	38.9

(3) Maturity-at-age

We assume that the fecundity is proportional to maturity. We use maturity–at-age based on biological data in the South Pacific Ocean by Farley et al (2012) (Table 2) and the estimation method by Hoyle (2008).

Table 2 Maturity-at-age based on Farley (2012) and Hoyle (2008)

Age	0	1	2	3	4	5	6	7	8	9	10	11	12+
Maturity –at-age	0	0	0	0	0.09	0.47	0.75	0.88	0.94	0.97	0.99	0.99	1

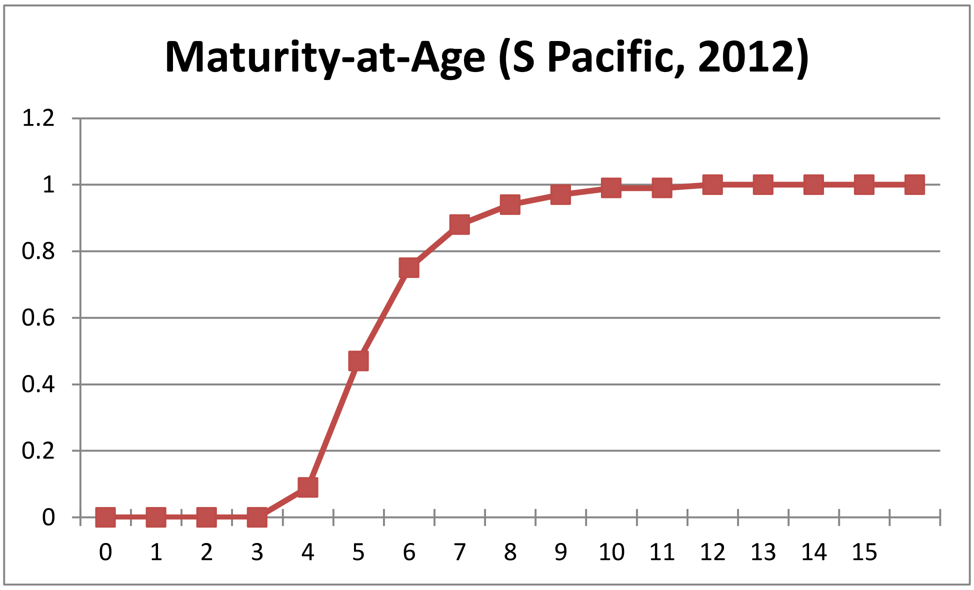


Fig. 8 Maturity-at-age (S Pacific) based on Hoyle (2008) and Farley (2012)

3. ASPM runs (base case and sensitivity runs)

We use the base case as below.

- Catch and CAA : 1952-2012
- Taiwan STD_CPUE (global) (1980-2012)
- Hybrid age specific M
- Wells (Growth) and Penny (LW) CAA and Wt-at-age
- Farley's Maturity-at-age
- Steepness=0.7
- CV (CPUE)=0.1
- Sigma (SR)=0.7
- B0=B1952

But we could not get the conversions, then we explore further to search optimum parameters around this base case scenario. Then we found the most plausible option (Table 3). Then we run sensitivities and result are shown in Box 4. As a result, Base case produce the most plausible results which are depicted in Figs. 9-11 and the conclusion of the result is described in Box 5.

Table 3 Most plausible ASPM run around the base case scenario

M	h (steepness)	Sigma (SR)	CPUE CV	Weighting (CAA)	SSB0 (1000 tons)	Total likelihood	R2	SSBmsy	MSY (1000 tons)	SSB/SSBmsy	F/Fmsy
hybrid (0.22-0.4)	0.67	0.2	0.1	0.1	582	-53.727	0.417	271	41	1.66	0.53

Box 4

Results of 7 sensitivity runs

➔ Revised base case : the best scenario

scenario	plus group	M	h (steepness)	Sigma (SR)	CPUE CV	Weighting (CAA)	SSB0 (1000 tons)	Total likelihood	R2	SSBmsy	MSY (1000 tons)	SSB/SSBmsy	F/Fmsy
base case	15+	hybrid (0.22-0.4)	0.67	0.2	0.1	0.1	582	-53.727	0.417	271	41	1.66	0.53
sensitivity (1)	15+	0.2	not converged										
sensitivity (2)	15+	0.3	not converged										
sensitivity (3)	15+	0.4	not converged										
sensitivity (4)	12+	hybrid (0.22-0.4)	0.67	0.2	0.1	0.1	574	-53.688	0.416	273	42	1.68	0.51
sensitivity (5)	12+	0.2	not converged										
sensitivity (6)	12+	0.3	not converged										
sensitivity (7)	12+	0.4	not plausible results										

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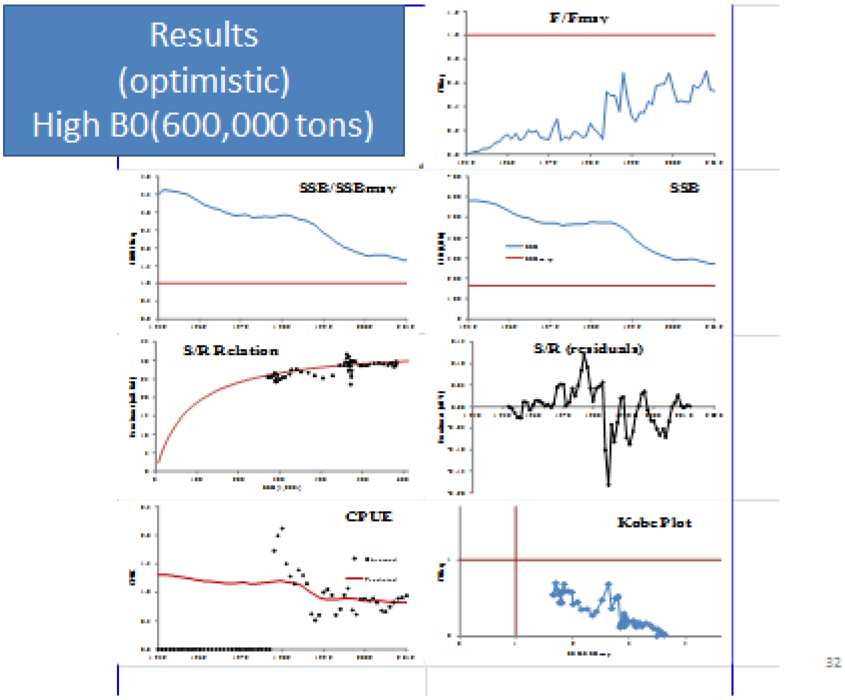

Fig 9 Results of base case ASPM run (1)

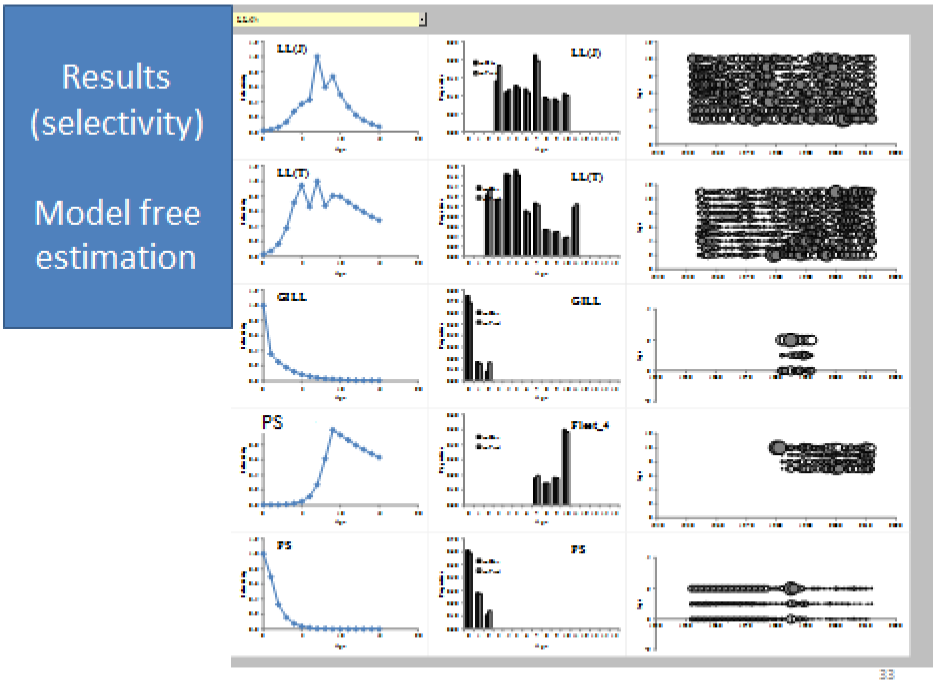

Fig 10 Results of base case ASPM run (2)

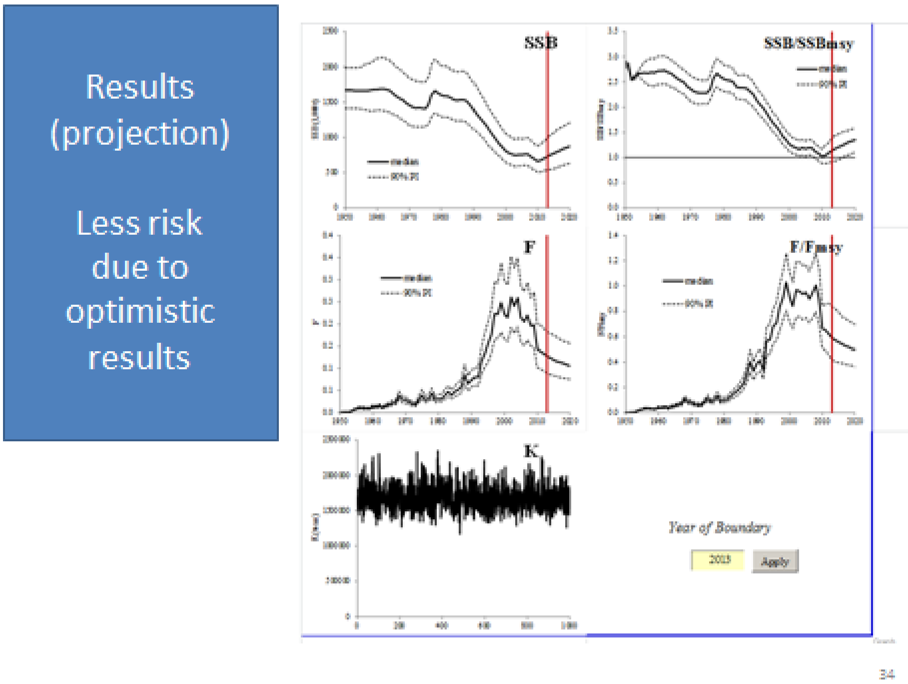

Fig 11 Results of base case ASPM run (3) (projection)

BOX 5

Conclusion

Results too optimistic (not plausible)

Considering the current situation and results (other SA)

ASPM results do not reflect the stock status

ASPM results should not be considered as the management advice

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4. Discussion (Box 6-8)

Box 6

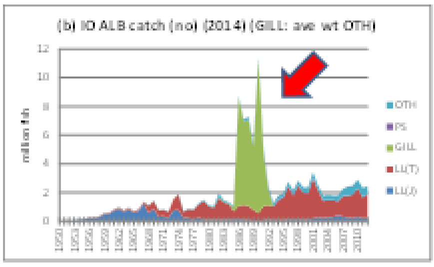
Discussion (1) Why so optimistic ?

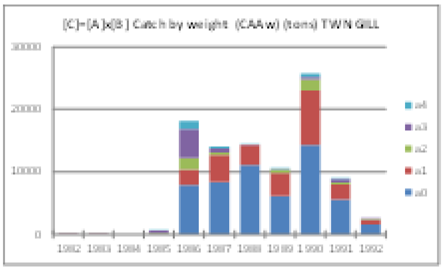
GILL affects

No size data for huge catch (mid 1980-1990)

10 million fish ➔ no age compositions

huge uncertainty (bias) CAA ➔ positively affect?





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Box 7

Discussion (2) : Why Plus group are not sensitive? Almost identical results between Age 15+ and 12+

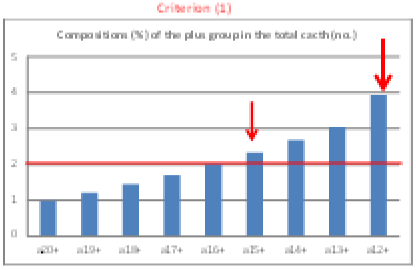
Butterworth suggestions 2%-20% criteria.

We just look at 2% level : Age 15+ (2%) and Age 12+ (4%)

2% difference ➔ less sensitive (similar results)?

Evaluation ALB Plus group based on CAA (IOTC Secretariat)

Criterion (1)



We need to check also the 20% level.

Probably 10% is the optimum !? ➔ Future works

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Box 8

Discussion (3) : Errors (uncertainties) in CAA conversion : size to age

IOTC Secretariat incorporates
Statistical treatment (Prob. classification errors)
if enough data (YFT, BET.....) (under improvement)
(not simple slicing method)

But if not enough data
Slicing method (ALB is the case)

Thus we have more uncertainties in ASPM results

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5 Future works (Box 9-10)

Box 9

Future works

To overcome the problem of No or not enough size data
(e.g., GILL for this time) (ASPM)

Need additional option (ASPM) incorporating size data
(mini version of SS3)

Then Why not use SS3?

Need special skill + talents
(Simon, Rishi, Adam, Kitakado....) can do..

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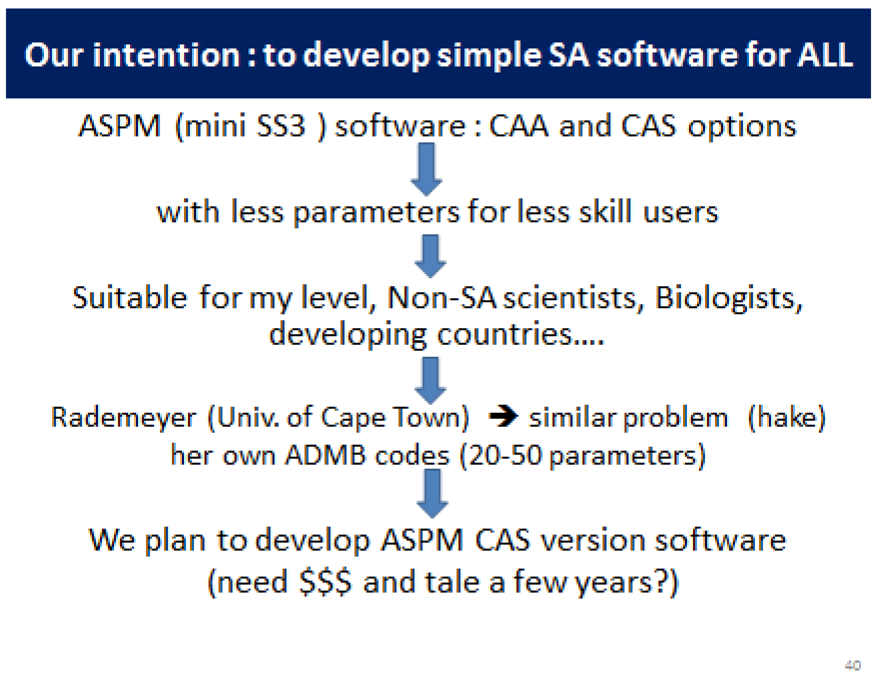
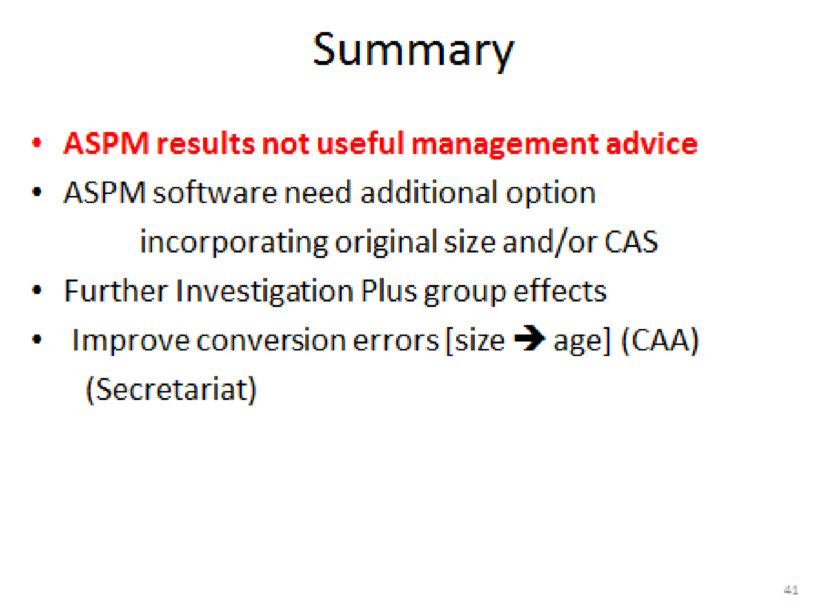
Box 10



6. Summary (Box 11)

Box 11



Acknowledgements

We sincerely thank to Miguel Herrera, Data manager (IOTC) for providing the nominal catch and Catch-At-Age (CAA) data of albacore tuna in the Indian Ocean. We also appreciate Rebecca Rademeyer (University of Cape Town, South Africa) helped ASPM runs.

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