Received: 19 and 27 October 2013

Stock assessment of bigeye tuna (*Thunnus obesus*) in the Indian Oceanby Age-Structured Production Model (ASPM)

Tom Nishida
National Research Institute of Far Seas Fisheries,
Fisheries Research Agency, Shimizu, Shizuoka, Japan

Kiyoshi Itoh and Kazuharu Iwasaki
Environmental Simulation Laboratory (ESL),
Kawagoe, Saitama, Japan

October, 2013

Abstract

We applied an Age-Structured Production Model (ASPM) to assess the status of the bigeye tuna stock (*Thunnus obesus*) in the Indian Ocean using 61 years of data (1952-2012). The assessment results suggested that MSY=120,500 tons (catch in 2012=99,899 tons) and the SSB ratio (2012) is near the MSY level (1.10), while F ratio (2012) is much lower than the MSY level (0.42). The results suggested that the bigeye stock is in the healthy condition and the projection based on the current catch level (99,899 tons) suggest that the current level can increase the stock from 2013 and after.

Submitted to the IOTC WPTT15 (October 23-28, 2013), San Sebastian, Spain

1. Introduction

In this paper, we attempted to assess the bigeye tuna (*Thunnus obesus*) (BET) stock in the Indian Ocean using the ADMB implemented Age-Structured Production Model (ASPM) software. We assume that BET in the Indian Ocean is a single stock. The (previouly used) Fortran-implemeted ASPM software (Restrepo, 1997) has been recoded using AD Model Builder (Otter Research) and used here. The ADMB implemented ASPM software is detailed in the users' manual in another document submitted to this meeting (IOTC-2011-WPTT13-46).

An initial run was conducted before the meeting and the final run will be conducted during the meeting using the agreed parameters. In addition we plan to conduct a risk assessement based on the final ASPM results to investigate the probablities for SSB of falling below the estimated MSY level and F exceeding this level in next 10 years (2012-2022) during the meeting.

As the SS3 assessment is avaiable, we try to use same input inofrmation as much as possible, so that results between SS3 and ASPM can be comparable to some etxrtent.

2. Input data

To implement ASPM, we used BET annual nominal catch, standardized (STD) CPUE, CAA (catch-at-age) data by gear and also biological information for the period 1952 to 2012 (61 years). Below are descriptions of the data used in the ASPM runs.

2.1 Nominal catch and type of fleets

IOTC Secretariat provided nominal catch by gear type, longline (frozen and fresh), purse seines (log school and free school), BB (pole and line), line and others (Fig. 1). As LL (frozen and fresh) are similar gear, we use one LL. In addition, line is very small catch, it is included to others. Thus we use five fleets (LL, LOG, FREE, BB and OTH).

2.2 Standardized (STD) CPUE

As the base case, we used the Japanese STD_CPUE (Matsumoto et. al, 2013) (1960-2012). From the previous assessment (Nishida et al, 2011), it was learned that STD_CPUE in the tropical region had the better relation to the catch. This is due to major catch are from the tropical area. Thus we used STD_CPUE in tropical area.

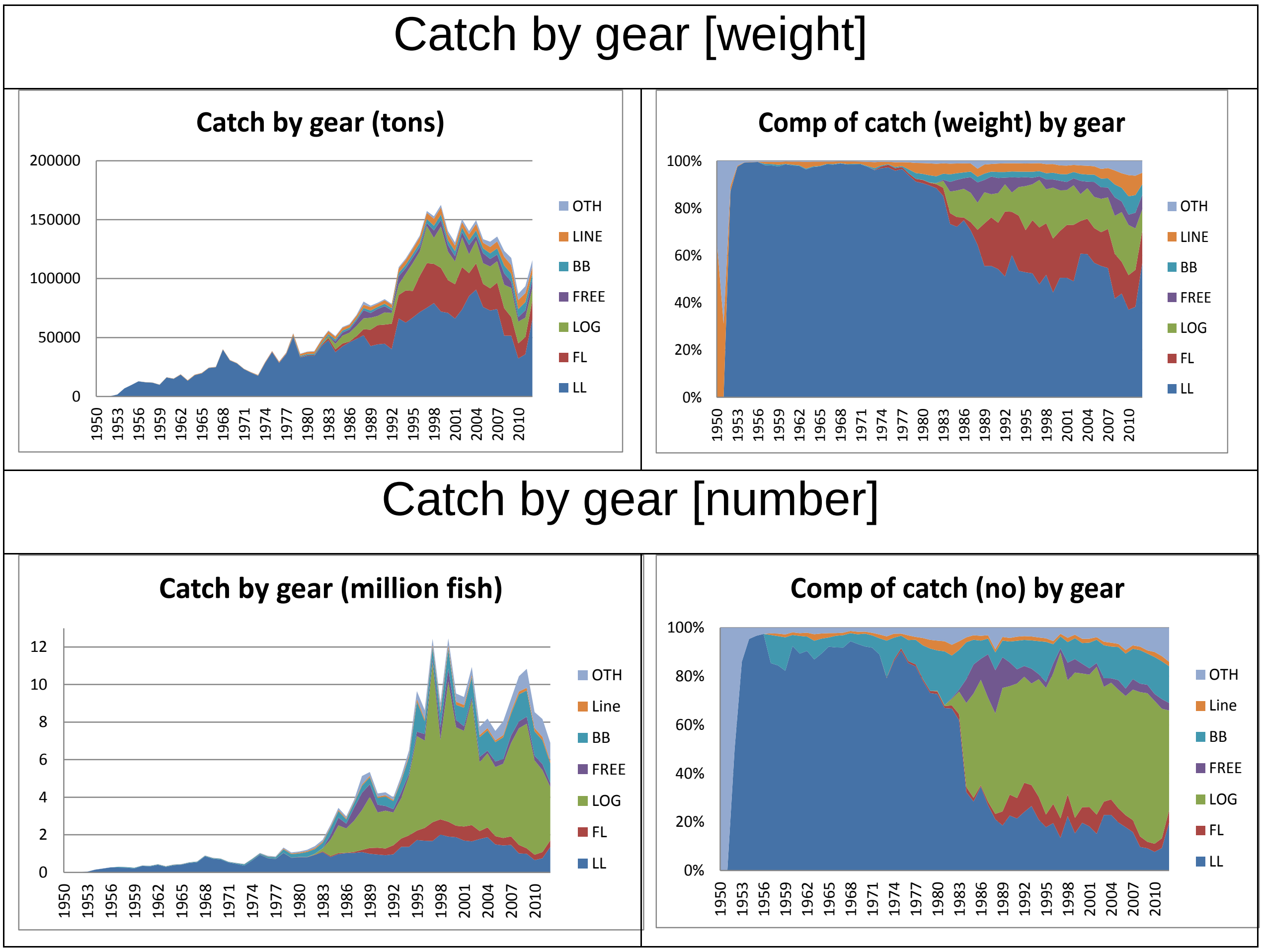


Fig. 1 trend of catch by gear (above: weight and below: number) (1950-2012)

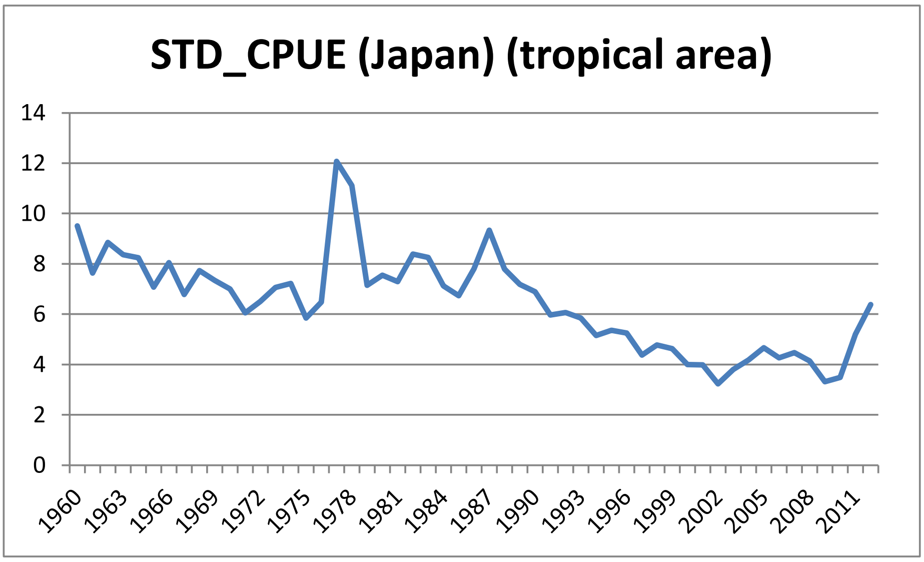


Fig. 2 Trend of STD_CPUE (Japan) (1960-2012)

2.3 Catch-At-Age (CAA)

The IOTC Secretariat provided the CAA matrix data by gear. Fig. 3 shows annual trends of CAA by gear.

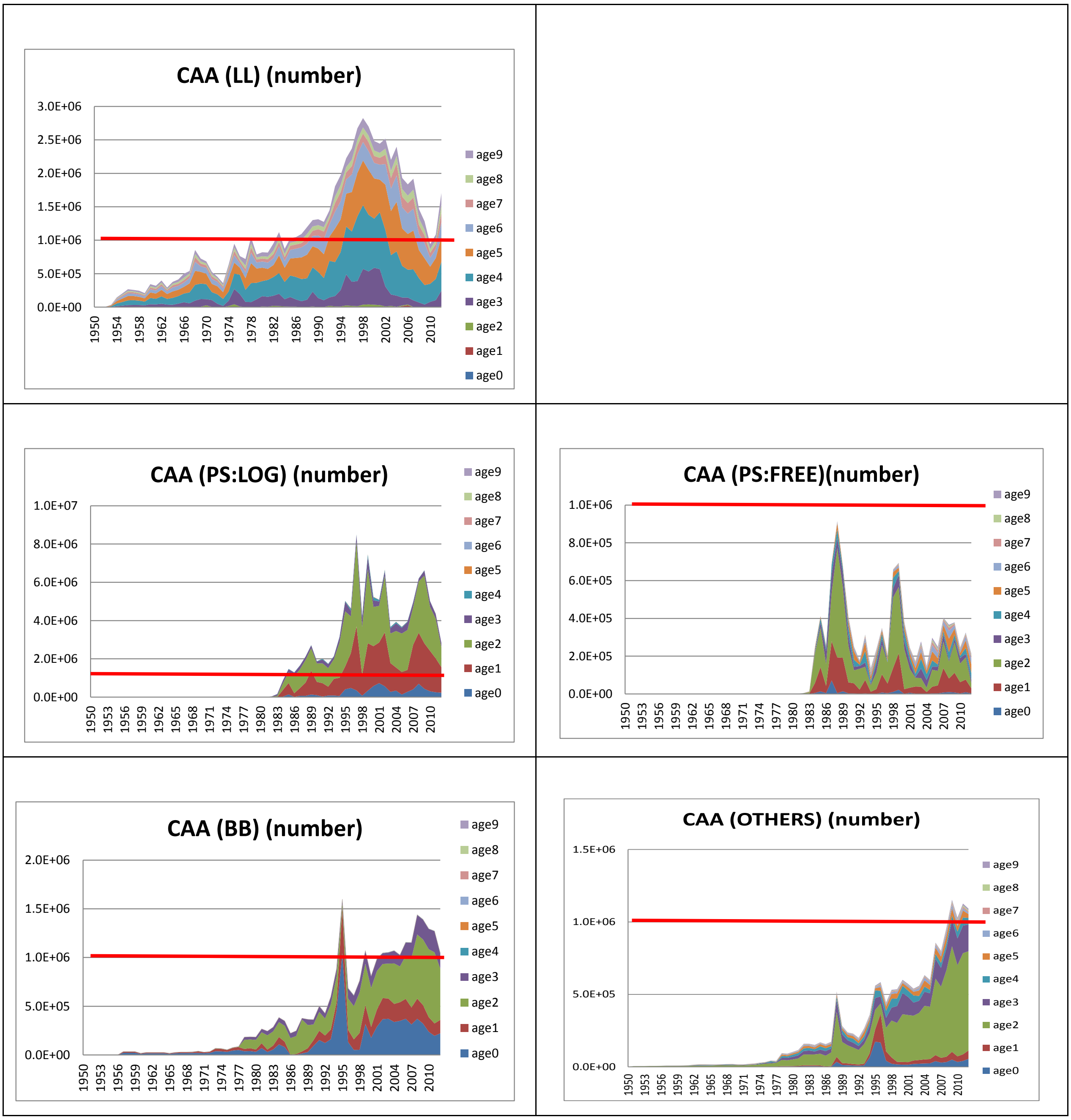


Fig. 3 CAA by gear (LL, PS: LOG, PS:FREE, BB and OTHER)

The horizontal red line represents the 1 million fish level.

LL and PS (LOG) are the similar catch level, while PS (FREE), BB and OTHER, the similar level.

As for the age compositions, LL catch older fish (age 3 or older), while other 4 gears (LOG, FREE, BB and OTHEDR) catch younger fish (age 2 or younger)

2.4 Biological information

In the ASPM analyses, 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.

(1) Natural mortality vector (*M*)

We applied annual *M* vectors used in Fig. 12 of the SS3 paper (Langley et al, 2013) (Box 1).

Box 1 *M* vectors

Natural mortality by age

#age	0	1	2	3	4	5	6	7	8	9
	0.8	0.8	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4

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

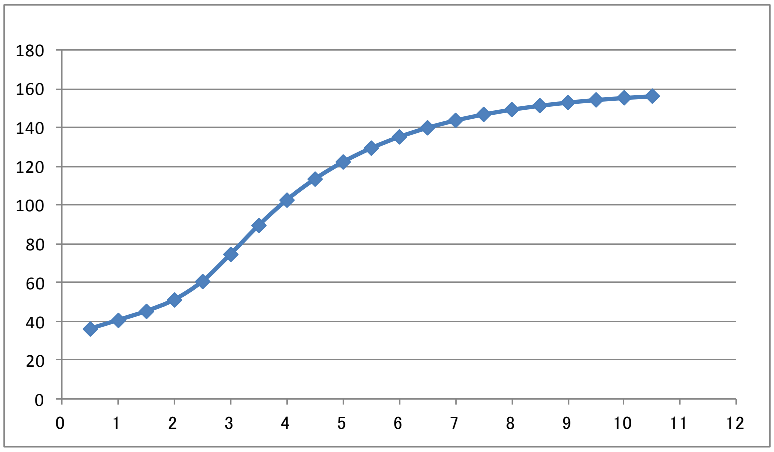
Using the growth curve derived by Eveson and Polacheck (2009, IOTC-2008-WPTT-09) (Box 2) and the LW relationships (Box 3), we computed weight-at-age by 0.5 year (Box 4). These are also used in SS3 (Langley et al 2013).

Box 2 Indian Ocean BET growth equation (Laslett et al, 2008)

$$L(t) = L_\infty \left(1 - e^{-k_2(t-t_0)} \left\{ \frac{1+e^{-\beta(t-t_0-\alpha)}}{1+e^{\beta\alpha}} \right\}^{-(k_2-k_1)/\beta} \right)$$

Species	L_∞	k_1	k_2	α	β	t_0
BET	160	0.071	0.4207	5.6033	2.999	-3.09

Length (cm)



Age

Box 3 LW relation

For fork length < 80 cm: $W = (2.74 \times 10^{-5}) l^{2.908}$ Poreeyanond (1994) (Indian Ocean)

For 80cm <=fork length: $W = (3.661 \times 10^{-5}) l^{2.90182}$ Nakamura and Uchiyama (1966) (Pacific Ocean)

Box 4 BET Weights-at-age (tons) in the Indina Ocaen

Beginning of the year weights by age (tons)

# age	0	1	2	3	4	5	6	7	8	9
	0.00065	0.00149	0.00296	0.00891	0.02353	0.04013	0.05452	0.06565	0.07373	0.07938

#

Middle of the year weights by age (tons)

# age	0	1	2	3	4	5	6	7	8	9
	0.00106	0.00206	0.00473	0.01552	0.03195	0.04771	0.06050	0.07004	0.07682	0.08150

(3) Maturity-at-age

We assume that the proportion-at-maturity is 0% for age 0-2, 50% for age 3 and 100% for age 4-9+ (Box 5).

Box 5 Maturity and fecundity of YFT in the Indian Ocean

Proportion maturity by age

# age	0	1	2	3	4	5	6	7	8	9
	0	0	0	0.5	1	1	1	1	1	1

3. ASPM

3.1 Base case (initial) run

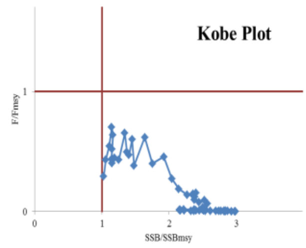
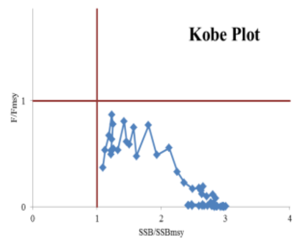
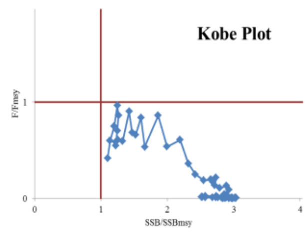
We attempted to conduct the initial (base case) ASPM runs using same input parameters in SS3 as much as possible, so that both results are comparable. Table 1 compare specs of the base case runs between SS3 (Langley et al, 2013) and ASPM (this paper).

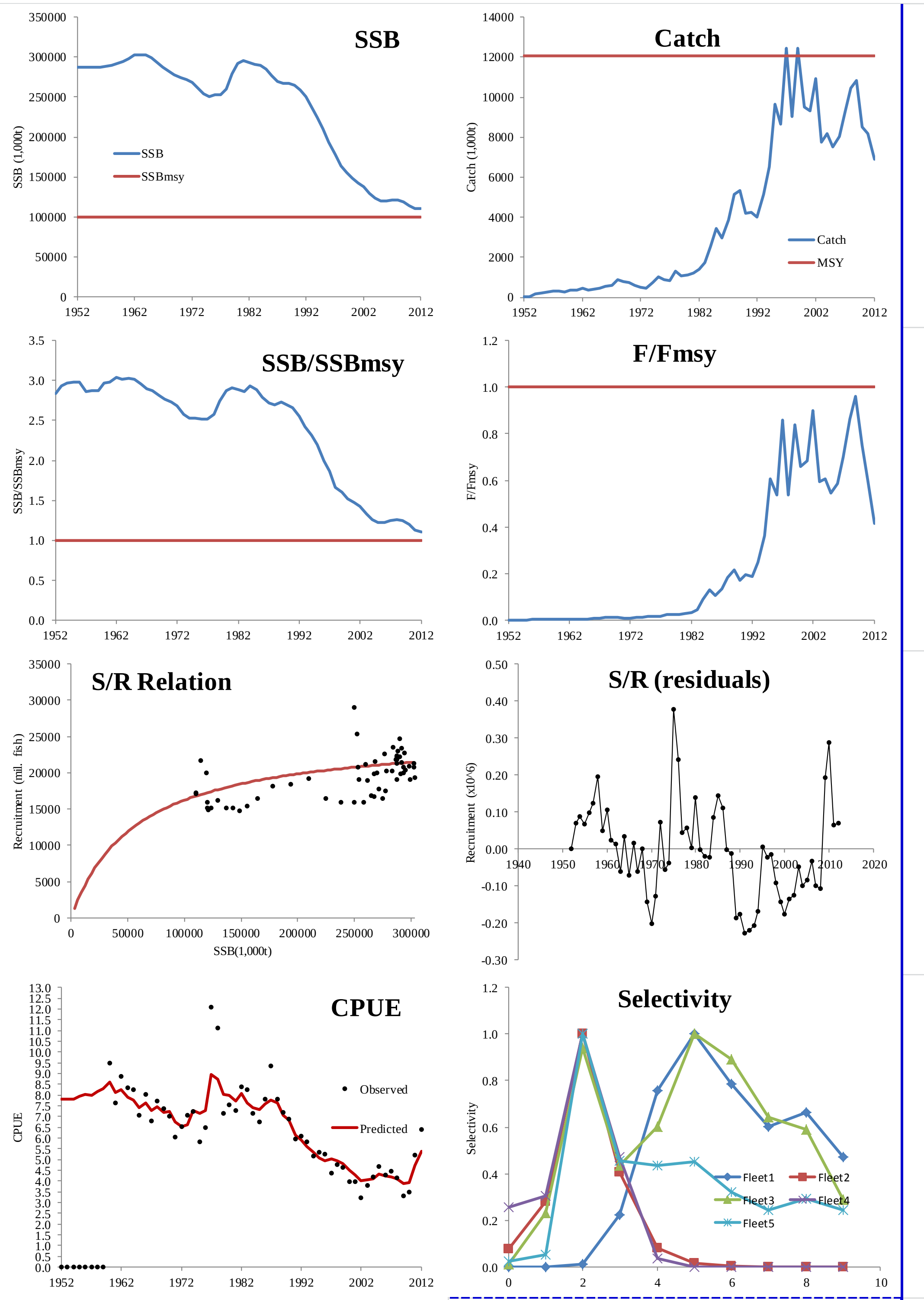
Using base case steepness (h=0.7, 0.8 and 0.9), we could not get the parameters (Table 2). Then we explored h=0.65 and h=0.6. With h=0.6 we could get conversion and we further explore Sigma-R for 0.2, 0.3 and 0.4 in addition to the base case Sigma-R=0.6. As a results, Sigma-R=0.3 produced the best good-of-fitness of the data to ASPM. Then we selected this scenario (h=0.6, Sigma-R=0.3) as the result of the initial ASPM run. Table 2 and Figs. 4-6 show results.

Table 1 Comparison of specs of the base case between SS3 (Langley et al, 2013) and ASPM (this paper)

	SS3	ASPM
Stock structure	Single stock hypothesis	
Spatial structure	3 areas	1 area (aggregated)
Temporal structure	quarterly	annual
Age structure	Age 0-9+ (quarterly basis)	Age 0-9+ (annual basis)
Fleet	7 fleets: LL, LL(fresh), BB, PS(free), PS(log),Line and OTH by area	5 fleets : LL, BB, PS(free), PS(log) and OTH
Catch	1952-2011	1952-2012
CAS	1952-2011	
CAA		1952-2012
STD_CPUE	Japan 1960-2011 by Q per. comm. with Satoh et al (2012)	Japan 1960-2012 by year Matsumoto et al (2013)
CV STD_CPUE	0.1	
Tagging data	applied	
Steepness	0.7, 0.8 and 0.9	
R-sigma	0.6	
Selectivity	Estimated by models	Estimated by ad hoc (model-free)
Natural mortality	0.8/yr (age 0-2)+0.4/yr(age 3-9+) Quarterly basis	0.8/yr (age 0-2)+0.4/yr(age 3-9+) Annual basis
LW relation	For fork length < 80 cm: $W = (2.74 \times 10^{-5})l^{2.908}$ Poreeyanond (1994) (Indian Ocean) For 80cm <=fork length: $W = (3.661 \times 10^{-5})l^{2.90182}$ Nakamura and Uchiyama (1966) (Pacific Ocean)	
Growth Equation	Eveson and Polacheck (2009, IOTC-2008-WPTT-09)	

Table 2 Results of the base case runs

Steep-ness	seeding values SSB (1952) Million tons (in natural log)	Sigma R	Results: Likelihood_components _and_weights	Results: Kobe plot
Base case runs				
0.90	10 (13.82)	0.6	Hessian does not appear to be positive definite	
	15 (16.52)		Not converged	
0.80	10 (13.82)		Not converged	
	15 (16.52)		Hessian does not appear to be positive definite	
0.70	10 (13.82)		Hessian does not appear to be positive definite	
	15 (16.52)		Hessian does not appear to be positive definite	
Extra runs as no parameters were obtained in the base case runs				
0.65	10 (13.82)	0.6	Hessian does not appear to be positive definite	
	15 (16.52)		Hessian does not appear to be positive definite	
0.60	10 (13.82)	0.6	Total −107.861 Indices −96.238 CAA −14.019 SR_fits 2.217 Negpen 0.006 R−square 0.855	
		0.4	Total −105.098 Indices −96.173 CAA −12.805 SR_fits 3.732 Negpen 0.006 R−square 0.852	
		0.3 Best Goodness of fitness	Total -102.338 Indices -96.08 CAA -11.744 SR_fits 5.376 Negpen 0.006 R-square 0.848	
		0.2	Hessian does not appear to be positive definite	
	15 (16.52)	0.6	Hessian does not appear to be positive definite	



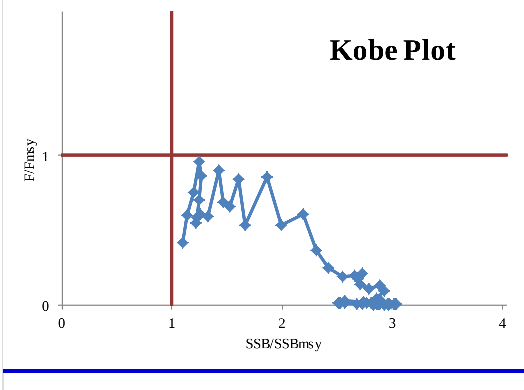


Fig. 4
Results of the base case ASPM run (I)

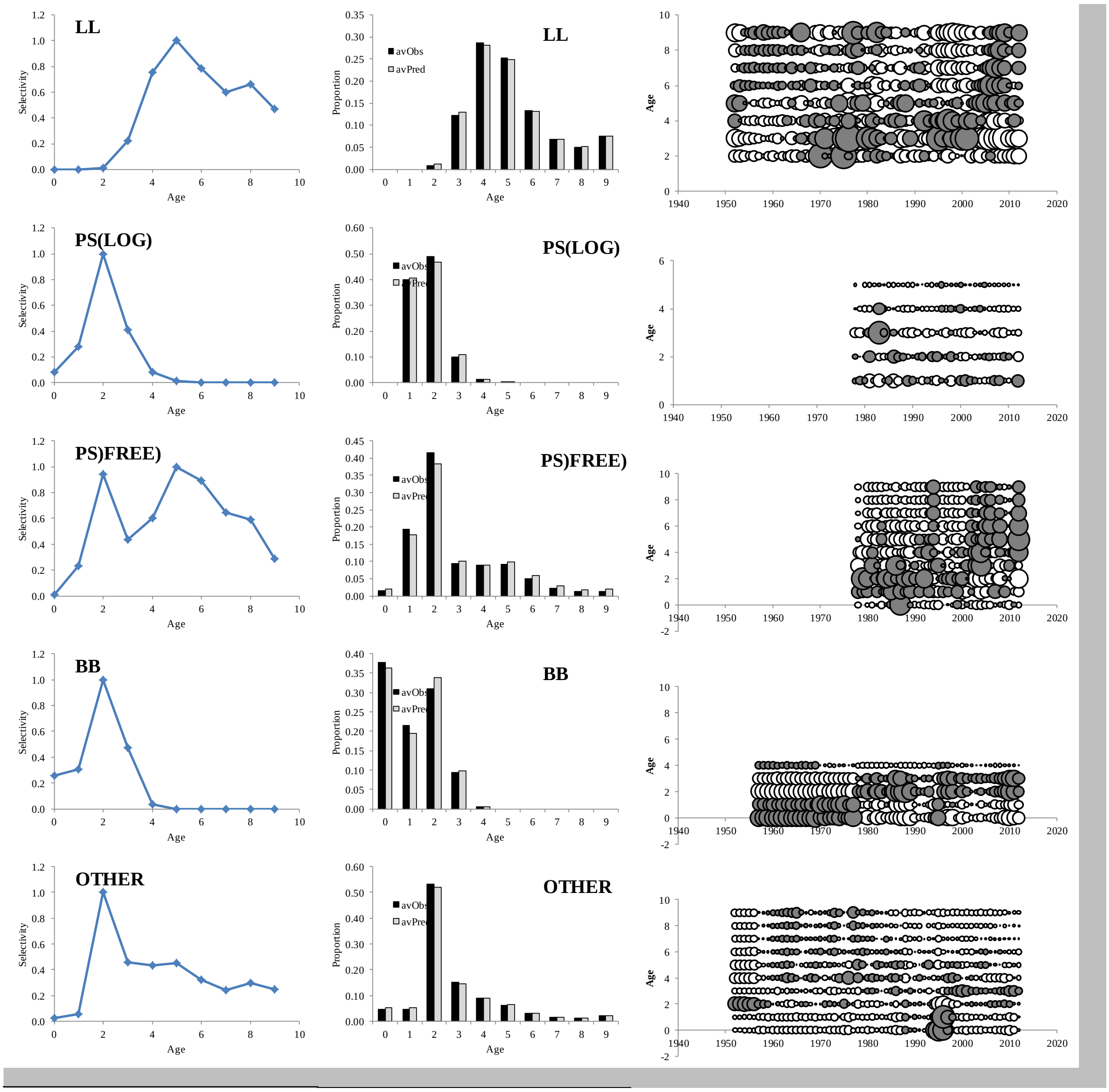


Fig. 5 Results of the base case ASPM run (II)

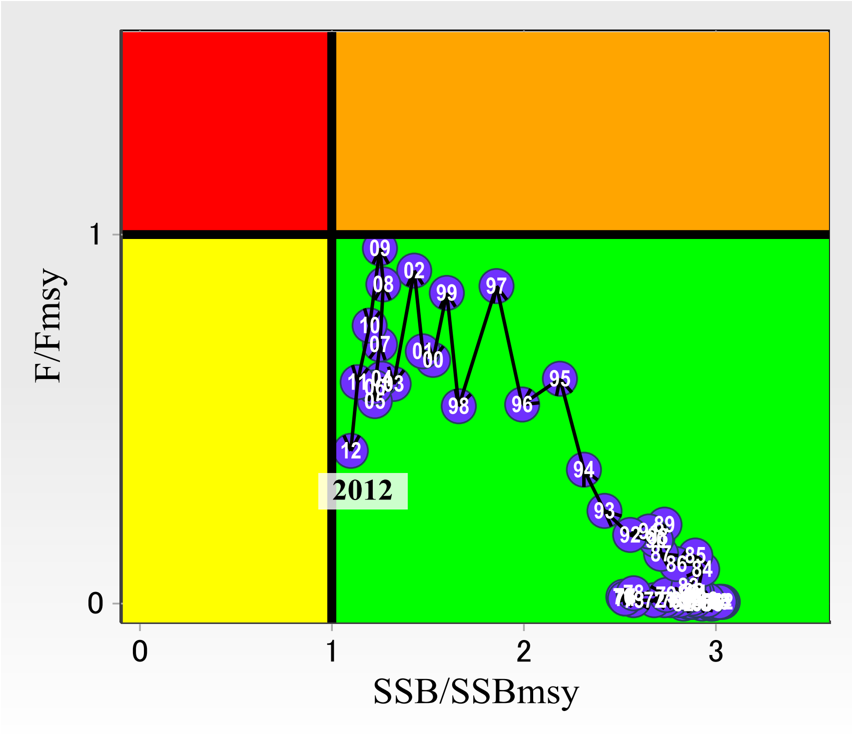
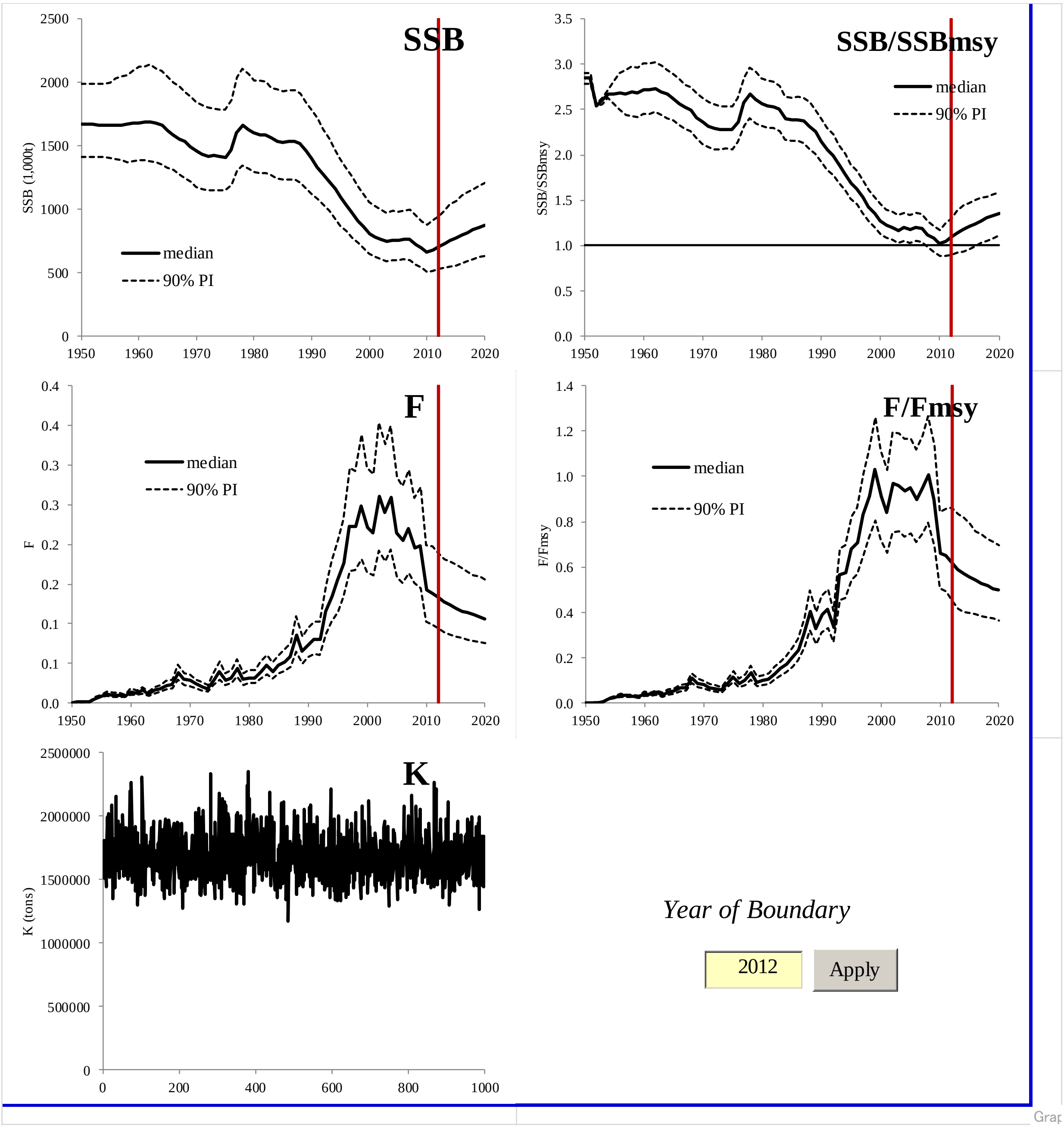


Fig. 6 Kobe plot (stock trajectory) for the initial ASPM run

Table 3 Indian Ocean bigeye stock status summary based on the ASPM analyses

Management quantity	**ASPM**
Most recent catch estimate (t) (2012)	115,793
Mean catch over last 5 years (t) (2008–2012)	107,603
MSY (80% CI)	120,530 (90,722–150,288)
Data period (catch)	1952-2012
CPUE series	Japan (tropical area)
CPUE period	1960-2012
$F_{current}/F_{MSY}$ (80% CI)	0.42 (0.27–0.74)
$B_{current}/B_{MSY}$ (80% CI)	n.a.
SB_{2012}/SB_{MSY} (80% CI)	1.10 (0.88–1.32)
B_{2012}/B_{1952} (80% CI)	n.a.
SB_{2012}/SB_{1952} (80% CI)	0.38 (n.a.)
$SB_{2012}/SB_{current,\ F=0}$	n.a.

Deterministic projection based on the 2012 catch for 5 fleets.



Acknowledgements

We sincerely thank to **Miguel Herrera**, Data manager (IOTC) for providing the nominal catch and Catch-At-Age (CAA) data of bigeye tuna in the Indian Ocean.

References

Anonymous (2001) Report of the IOTC ad hoc working party on methods, Sète, France 23-27, April, 2001: 20pp.

Beverton, R. J. H., and S. Holt. 1957. On the dynamics of exploited fish populations. Reprinted in 1993 by Chapman and Hall, London. 553 pp.

Deriso, R. B., T. J. Quinn, and P. R. Neal.1985. Catch-age analysis with auxiliary information. Can. J. Fish. Aquat.Sci.42:815-824.

Goodyear, C. P. 1993. Spawning stock biomass per recruit in fisheries management: foundation and current use.p.67-81 in S. J. Smith, J. J. Hunt, and D. Rivard (eds.) Risk evaluation and biological reference points for fisheries management. Can. Spec. Publ. Fish. Aquat. Sci. 120

Hilborn, R.1990. Estimating the parameters of full age structured models from catch and abundance data. Bull. Int. N. Pacific Fish Comm.50: 207-213.

ICCAT. 1997. Report for biennial period 1996-97. Part I (1996), Vol.2. Int. Int. Comm. Cons. Atl. Tunas. 204pp.

IOTC. 2002-2008. Working documents in WPTT (Working party on Tropical Tuna) available in the IOTC web site at http://www.iotc.org/

Matsumoto, T., H. Okamoto and T. Kitakado, 2013. Japanese longline CPUE for yellowfin tuna in the Indian Ocean up to 2012 standardized by generalized linear model. IOTC-2013-WPTT15-37, 1-43.

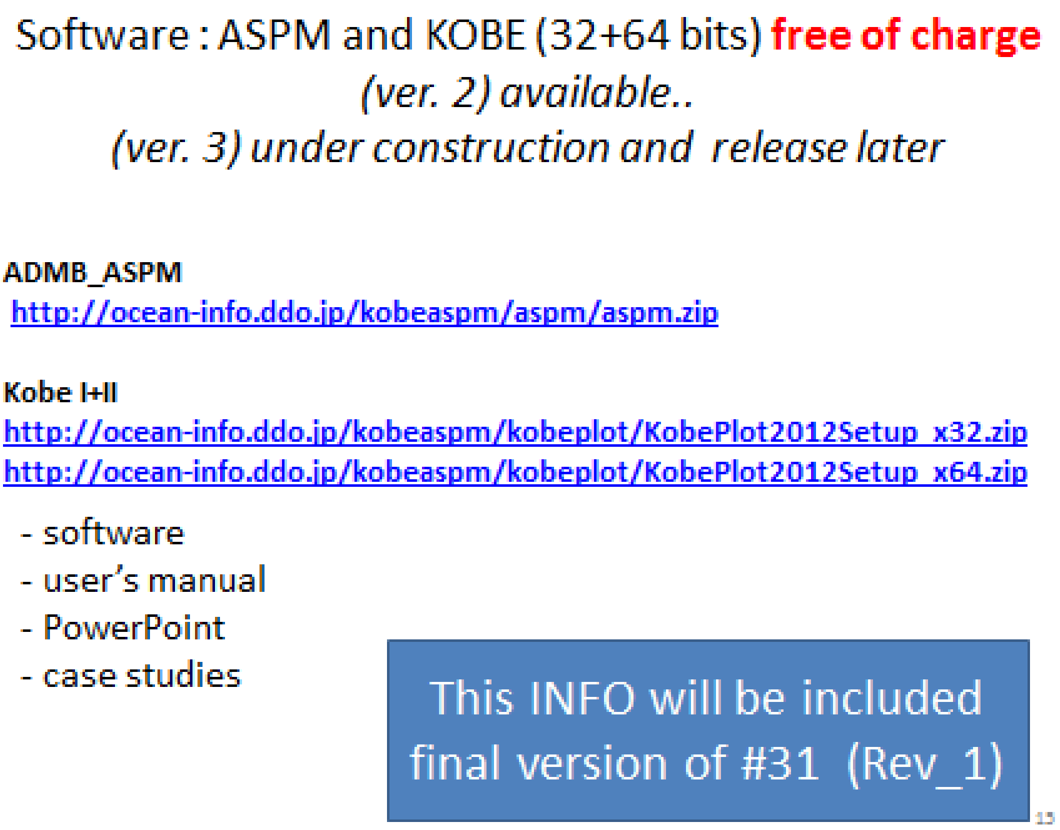
Prager, M. H. 1994. A suite of extensions to a no equilibrium surplus-production model. Fish. Bull. 92:374-389.

Punt, A. E. 1994. Assessments of the stocks of Cape hakes, Merluccius spp. Off South Africa. S. Afr. J. Mar. Sci. 14 : 159-186.

Restrepo, V. 1997. A stochastic implementation of an Age-structured Production model (ICCAT/ SCRS/97/59), 23pp. with Appendix

Schaefer, M. B 1957. A study of dynamics of the fishery for yellowfin tuna in the eastern tropical Pacific Ocean. IATTC Bull. Vol. 2: 247-285.

APPENDIX


Software : ASPM and KOBE (32+64 bits) free of charge
(ver. 2) available..
(ver. 3) under construction and release later
ADMB_ASPM
http://ocean-info.ddo.jp/kobeaspm/aspm/aspm.zip
Kobe I+II
http://ocean-info.ddo.jp/kobeaspm/kobeplot/KobePlot2012Setup_x32.zip
http://ocean-info.ddo.jp/kobeaspm/kobeplot/KobePlot2012Setup_x64.zip
- software
- user's manual
- PowerPoint
- case studies
This INFO will be included final version of #31 (Rev_1)
13