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Updated stock assessment of bigeye tuna (*Thunnus obesus*) resource in the Indian Ocean by the age structured production model(ASPM) analyses (1960-2004)

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Abstract

We updated the stock assessment of the bigeye tuna (BET) resource in the Indian Ocean using the age-structure production model (ASPM) with 45 years data from 1960-2004. It is resulted that MSY=97,415 tons and the stock is continuing at the over-fishing status because (a) the catch levels exceeded the MSY level in past ten years (1993-2004), (b) current to virgin levels of total & spawning stock biomass (SSB) were 0.36 and 0.53 (well below from 1, the critical level to keep MSY) respectively and (c) F & SSB (MSY) ratios (current levels to MSY) have been rapidly reaching to the critical level, i.e., 1 to sustain the MSY level. For this time, we could successfully estimate 90% confidence intervals for the various population parameters evaluated in the ASPM using the bootstrap experiments. Based on the comparative studies of four ASPM results in the past (2002, 2004, 2005 and 2006), it is likely that consistent and robust results have been evaluated in the past by the ASPM while there is a number of uncertainties described in the past IOTC WPTT reports.

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1. Introduction

In this paper, we updated the stock assessment of the bigeye tuna (BET) resource in the Indian Ocean using the age-structure production model (ASPM). The ASPM was used because this approach was recommended for the BET stock assessment in the IOTC ad hoc Working Party meeting on Methods (WPM) held in IRD, Sète, France 23-27, April, 2001 (Anonymous, 2001). The primary reason for the IOTC Ad hoc WPM meeting recommended is that there are not enough season-area specific size data to conduct age based approach such as VPA, while the ASPM can be conducted without such specific size data. Consequently, results by the ASPM have been accepted by the IOTC WPTTs and Scientific Committees in the past four years and used in Executive Summaries. For this time, we conducted the ASPM analyses for 45 years (1960-2004) by assuming again that BET in the Indian Ocean forms a single stock.

We did not use the earlier data in 1950s by the following reasons: The Japanese (bigeye) tuna fishing grounds were limited in the eastern Indian Ocean in 1950s and not fully expanded to the entire Indian Ocean. When many un-fished fishing grounds were included in the catch rates analyses, results such as the abundance trends will be seriously biased (Walters, 2003 or IOTC-2006-INF02). Thus we exclude the data in 1950s and used the data from 1960 after the Japanese longline fishing grounds were fully expanded to the entree the Indian Ocean.

2. ASPM

2.1 Input

We used the ASPM software developed by Victor Restrepo (1997) called as ASPMS (stochastic version of ASPM). Input data of the ASPM (Catch, Biological, Selectivity and Index) are explained as follows:

(1) Catch

The bigeye catch by gear type were obtained from the IOTC database (May, 2006). Fig.1 and Table 1 show the trend of the catch (1950-2004).

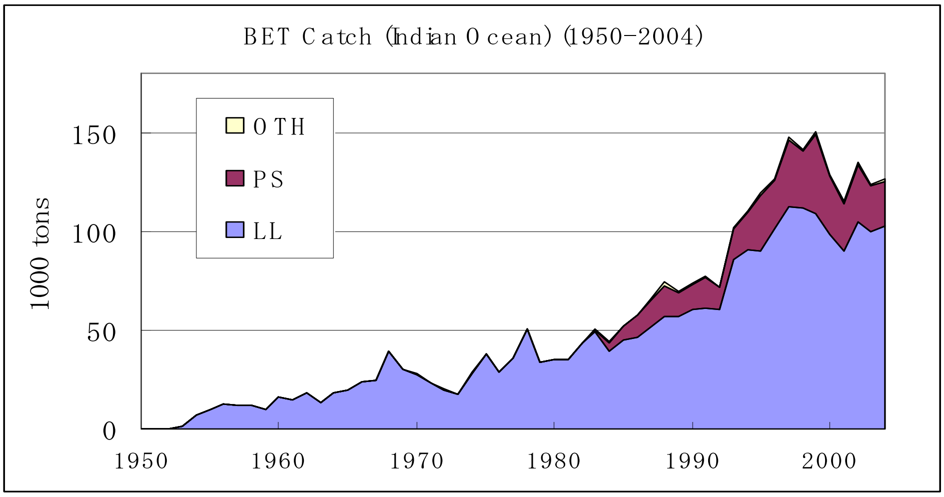


Fig. 1 Trend of the bigeye catches in the Indian Ocean (1950-2004) (IOTC database, as of May 2006)
Note: LL: tuna longline fisheries, PS: tuna purse seine fisheries, OTH: Other fisheries (Gillnet, troll, pole & line and handline)

Table 1 Catch statistics of bigeye tuna in the Indian Ocean (tons)(IOTC database, as of May 2006)

(tons)

Year	LL	PS	OTHERS	TOTAL
1950	0	0	1	1
1951	0	0	1	1
1952	280	0	1	281
1953	1,653	0	0	1,653
1954	6,850	0	0	6,850
1955	9,739	0	0	9,739
1956	12,846	0	0	12,846
1957	11,991	0	0	11,991
1958	11,655	0	0	11,655
1959	9,868	0	0	9,868
1960	16,115	0	1	16,116
1961	14,951	0	1	14,952
1962	18,482	0	1	18,483
1963	13,303	0	1	13,304
1964	18,025	0	1	18,026
1965	19,538	0	1	19,539
1966	24,129	0	1	24,130
1967	24,762	0	1	24,763
1968	39,501	0	1	39,502
1969	30,427	0	2	30,429
1970	27,753	0	84	27,837
1971	22,959	0	52	23,011
1972	19,994	0	62	20,056
1973	17,419	0	131	17,550
1974	28,351	0	128	28,479
1975	37,670	0	104	37,774
1976	28,543	0	144	28,687
1977	35,908	0	163	36,071
1978	50,541	5	122	50,668
1979	33,476	1	137	33,614
1980	34,862	21	109	34,992
1981	34,834	13	235	35,082
1982	43,380	116	112	43,608
1983	49,510	587	200	50,297
1984	39,684	4,020	375	44,079
1985	44,868	7,159	338	52,365
1986	46,704	10,626	498	57,828
1987	51,224	13,400	445	65,069
1988	57,053	15,057	2,257	74,367
1989	56,656	11,980	836	69,472
1990	60,474	12,667	546	73,687
1991	60,834	15,623	700	77,157
1992	60,165	11,259	456	71,880
1993	85,447	16,013	556	102,016
1994	90,643	18,880	664	110,187
1995	89,803	28,382	1,233	119,418
1996	101,461	24,529	906	126,896
1997	112,429	33,965	928	147,322
1998	112,104	28,334	936	141,374
1999	108,636	40,658	1,161	150,455
2000	98,372	29,859	641	128,872
2001	90,289	23,717	1,005	115,011
2002	104,647	29,042	1,235	134,924
2003	99,768	22,946	1,272	123,986
2004	102,629	22,586	1,300	126,515

Note: LL: tuna longline fisheries, PS: tuna purse seine fisheries, OTH: Other fisheries (Gillnet, troll, pole & line and handline)

(2) Biological parameters

ASPM requires 4 types of age-specific biological inputs, i.e., weights at the beginning and the mid year, natural mortality (M) and the fecundity. We used 9 age classes from age 0-8+. These inputs are obtained as follows:

Weight-at-age

Weight-at-age in the beginning and the mid year are estimated based on the following growth equations and the length-weight relationship. The same age-weight key based on this information and developed by IOTC (2003) was used (Table 2).

- L-W relationship

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 by Stequart and Conrad (2003)

$$L_{t(cm)} = 169\left(1 - e^{-0.32[t-(-0.336)]}\right)$$

Natural mortality (M)

In the past we have applied two different M vectors used by ICCAT and SPC but we have learned that the ICCAT M vector produced better fits to the model (IOTC, 2004). Hence we used the ICCAT M vector (Table 2).

Fecundity

We assume that fecundity is proportional the body weight at the middle of each age and also assume 0 fecundity for age 0-2 and 50% of fecundity for age 3 as in Table 2:

Table 2 Biological input parameters (*) used in the ASPM analyses

	Age	0	1	2	3	4	5	6	7	8
	ICCAT	0.8	0.8	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Weight (ton)	(beg)	0.00011	0.00386	0.01670	0.03160	0.04658	0.05994	0.07107	0.07993	0.08679
	(mid)	0.00123	0.00786	0.02398	0.03922	0.05352	0.06580	0.07577	0.08359	0.08958
Maturity(*)		0	0	0	0.5	1	1	1	1	1
Fecundity		0	0	0	0.0196	0.05352	0.06580	0.07577	0.08359	0.08958

(*) Maturity is listed as reference and it is not the input parameter.

(3) Selectivity

The selectivity-at-age for longline and purse seine fisheries (log and free school combined) were estimated using the growth curve by Stequart (2003) and separable VPA during the WPTT meeting in 2004. For this time we used the same selectivities. As suggested by Miyabe (2001), longline fisheries were divided by three periods (before 1976, 1977-91 and after 1992) due to their heterogeneity characteristics. Table 3 summarizes the selectivity.

Table 3 Selectivity used for the ASPM analyses

M	Fishery/Age➔	0	1	2	3	4	5	6	7	8
I	LL(1960-1976)	0	0.043	0.254	0.565	0.855	1	0.949	0.725	0.725
C	LL(1977-1991)	0	0.042	0.344	0.799	1	0.921	0.751	0.529	0.529
C	LL(1992-2002)	0	0.050	0.473	0.930	1	0.877	0.716	0.475	0.475
A T	PS(1960-2002)	0.673	1	0.484	0.387	0.346	0.246	0.122	0.048	0.025

(4) Standardized CPUE

We used Japanese and Taiwanese standardized (STD) CPUEs in the whole Indian Ocean estimated by Okamoto and Shono (2006) and Hsu (2006) which details are available in two other documents presented in this meeting (IOTC-WPTT-2006-__ and ___) respectively (Fig. 2). We used the Japanese STD CPUE as a base case, while Taiwanese STD CPUE for sensitivity attempts.

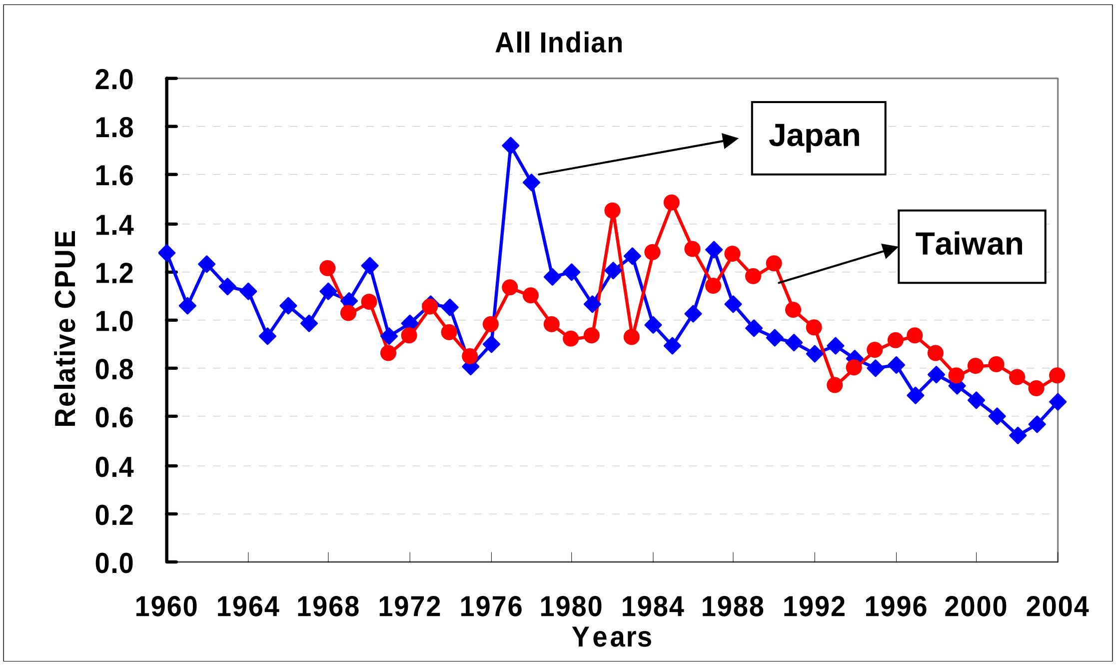


Fig. 2 Standardize CPUE of Japan (1960－2004) and Tawain (1968-2004) (scaled as the average values of eaach CPUE=1)

2.2 Sensitivity for steepness and Rho

We set the ASPM run for the Japanese STD CPUE (1960-2004) as a base case. As we have been facing the unrealistic steepness value (0.999) estimated in the past ASPM runs. To solve this problem, late Dr Geoff Kirkwood (past SC and WPTT Chairs) suggested to fix its values to test sensitivity. For this time, we followed his suggestion to test sensitivity by varying the selectivity from 0.7, 0.8 to 0.9.

In addition according to our last ASPM paper in 2005 submitted to the SC in 2005 (IOTC-SC-2005-INF10), we learned that results of ASPM were influenced by Rho values (values used to reduce biases caused by auto-correlation errors in the spawner-recruit relationship). Rho is one of the input parameters in the ASPM. In the last analyses we had Rho=0.07 as the best. Thus for this time, we also test its sensitivities by varying the ranges of Rho from 0.0 to 0.40 by 0.1 step size.

In the sensitivity analyses we use four criteria to evaluate the best parameters, -in (likelihood), R squared, CV (Virgin Biomass) and CV [SSB(virgin) to SSB(2004) ratio] obtained from the ASPM outputs. Table 4 shows result of the sensitivity analyses which indicated that Rho=0.1 is the best value and steepness=0.7 is the best value although there are not so much differences with others.

Table 4 Result of the sensitivity analyses for the steepness and Rho in the ASPM

Steepness	Rho	-ln (likelihood)	R squared	CV (Virgin Biomass)	CV SSB (virgin) to SSB (2004) ratio	Decision
0.7	0	NC				
	0.1	-129.8	0.900	0.292	4.002	Best & selected
	0.2	-129.8	0.899	0.304	9.552	
	0.3	NC				
	0.4	NC				
0.8	0	NC				
	0.1	-129.8	0.900	0.292	4.006	
	0.2	-129.8	0.899	0.312	9.623	
	0.3	NC				
	0.4	NC				
0.9	0	NC				
	0.1	-129.8	0.900	0.292	4.006	
	0.2	-129.8	0.899	0.312	9.623	
	0.3	NC				
	0.4	NC				

NC: no convergence ; yellow marked values means the best one in each criterion.

2.3 ASPM runs

Setting the ASPM run with Japanese STD CPUE (1960-2004) as a base we made five other ASPM runs for sensitivities by combining Japan and Taiwan STD CPUE and two different periods (1960-2004 and 1968-2004) as shown in Table 5. As results of six ASPM runs, all runs were properly converged and the base case (Run 1) was resulted to produce the most reasonable and robust estimates. Figs. 3-11 depict results of Run 1.

Table 5 SIX ASPM runs: INPUTS & RESULTS

	BASE CASE	SENSITIVITIES				
Run	**1**	2	3	4	5	6
INPUT DATA (whole Indian Ocean)						
Catch	LL and PS					
LW	Poreeyanond (1994) & Nakamura/Uchiyama (1966)					
Growth	Stequart (2003)					
Selectivity	LL (3 periods) and PS (log & free school combined)					
S-R	Beaverton-Holt model					
M vector	ICCAT type					
ASPM parameters	steepness=0.7 rho=0.1					
Period	**(a) 1960-2004**			**(b) 1968-2004**		
Standardized CPUE	Japan	Taiwan	Japan & Taiwan	Japan	Taiwan	Japan & Taiwan
RESULTS						
Results of ASPM	Converged					
ln(likelihood)	-130	-113	-172	-106	-106	-150
R-squared	0.91	0.85	0.68	0.91	0.85	0.67
MSY	9. 74	12.1	12.6	9.98	11.8	12.6
(10,000 tons)	12.6					
VirginSSB(million t) at (a) 1960 (b) 1978	1.06	1.34	1.46	1.05	1.31	1.39
SSB(MSY)	0.32	0.41	0.42	0.33	0.41	0.42
SSB(2004)	0.38	0.73	0.66	0.39	0.72	0.67
SSB(MSY) ratio =SSB2004/SSB(MSY)	1.19	1.78 (too high/ optimistic)	1.57 (too high/ optimistic)	1.12	1.76 (too high/ optimistic)	1.60 (too high/ optimistic)
SSB(VIRGIN) ratio =B2004/B(a) or (b)	0.36	0.54	0.45	0.37	0.55	0.48
F(MSY)	0.32	0.29	0.30	0.32	0.29	0.30
F(2004)	0.32	0.18	0.20	0.31	0.19	0.20
F(ratio) =F2004/F(MSY)	1.00	0.62 (too low/ optimistic)	0.67 (too low/ optimistic)	0.97	0.66 (too low/ optimistic)	0.67 (too low/ optimistic)
DECISION	Best run	Un realistic (too optimistic)	Un realistic (too optimistic)	Second best	Un realistic (too optimistic)	Un realistic (too optimistic)

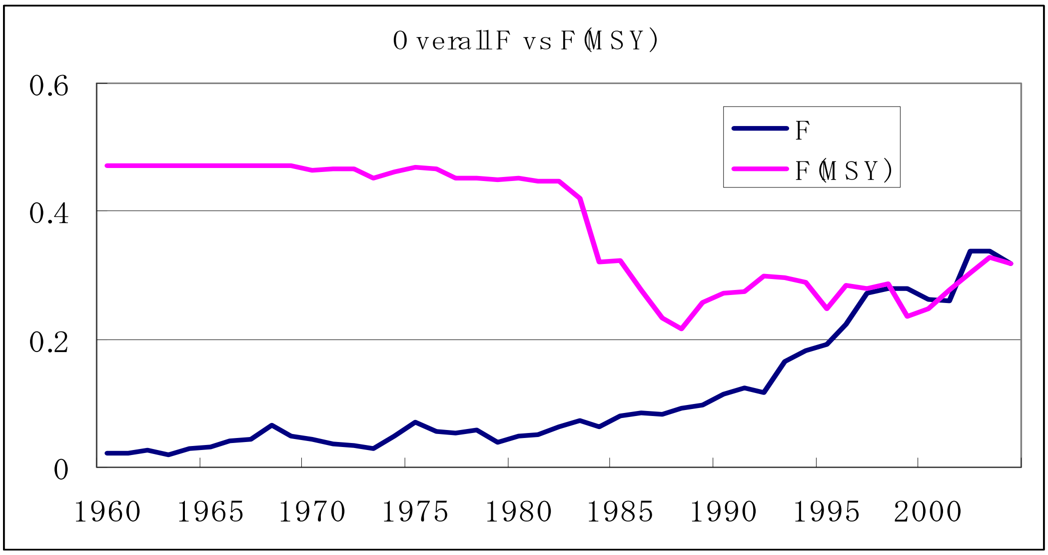


Fig. 3 Trends of overall F vs. F(MSY)

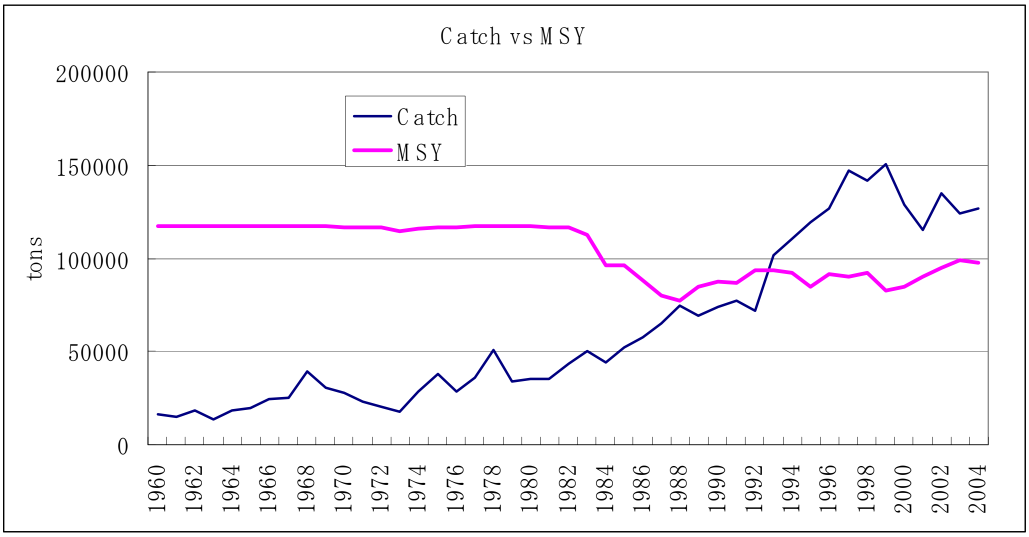


Fig. 4 Trends of catch vs. MSY

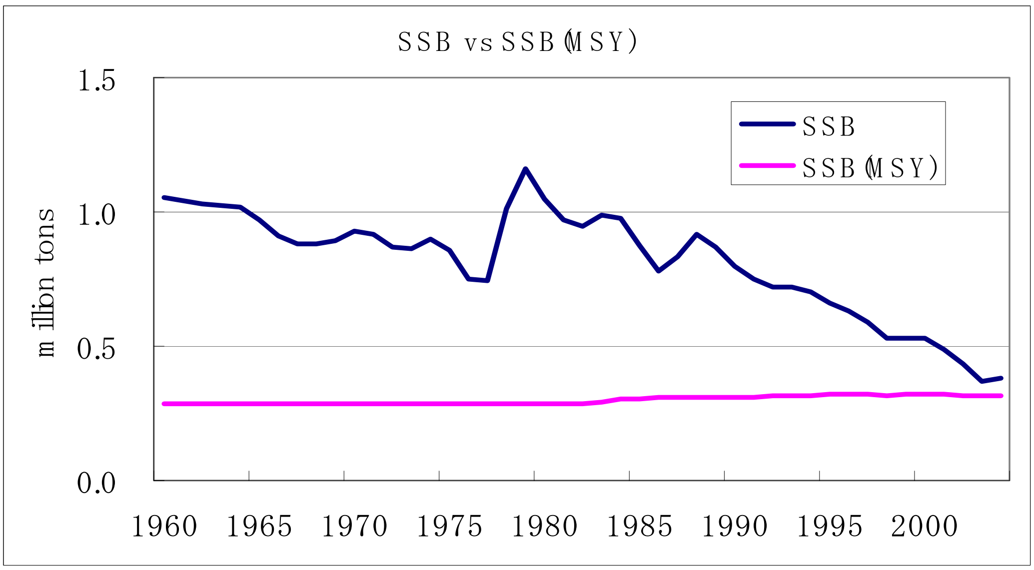


Fig. 5 Trends of mature biomass vs. mature biomass (MSY)

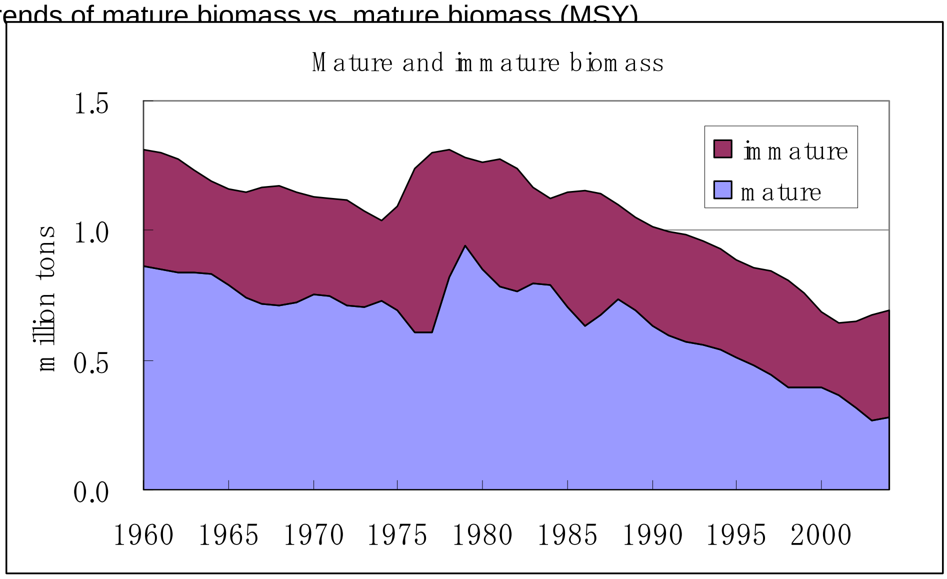


Fig. 6 Trends pf biomass (mature and immature)

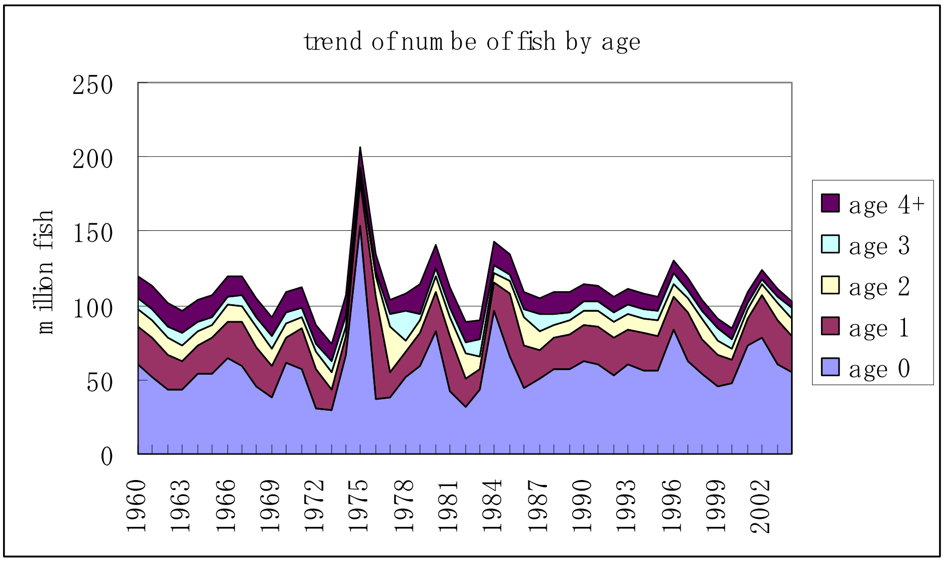


Fig. 7 Trends of number of fish by age

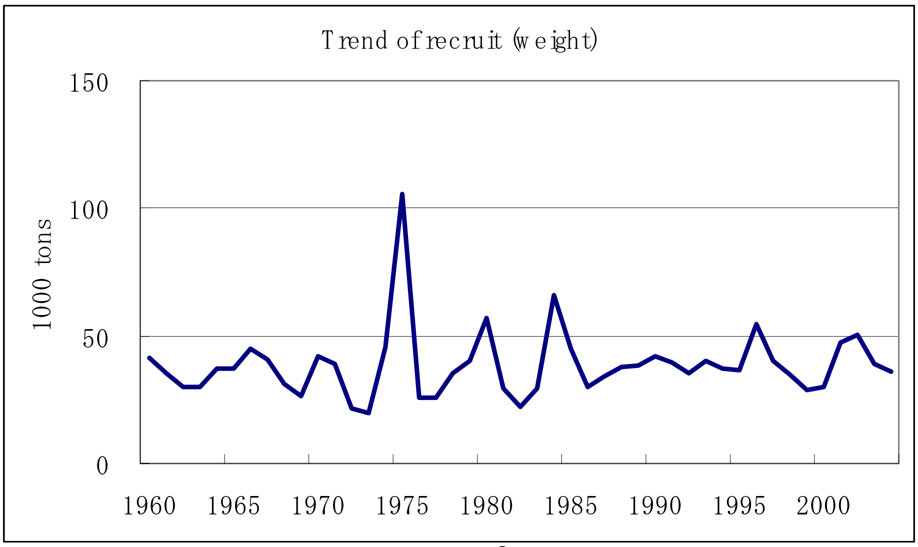


Fig. 8 Tren

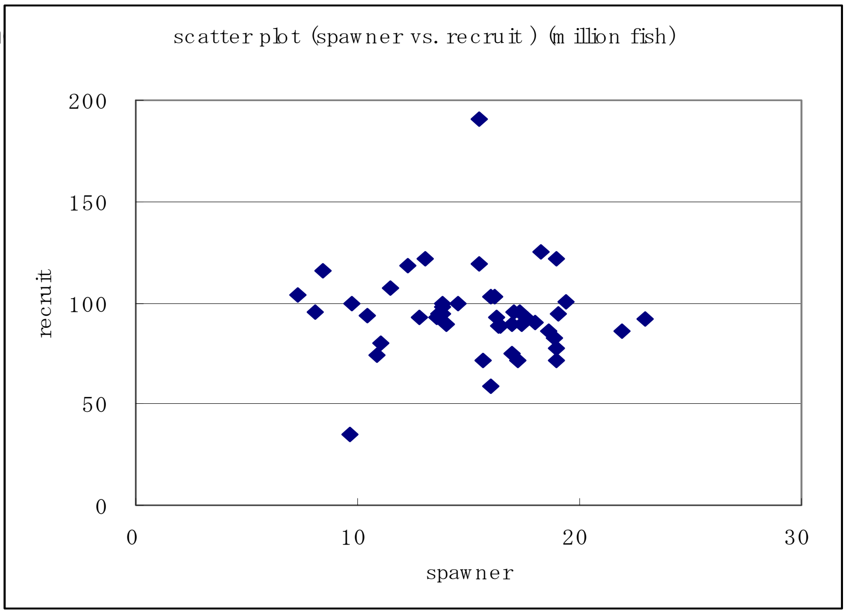


Fig. 9 Scatter plot (spawner vs. recruit)

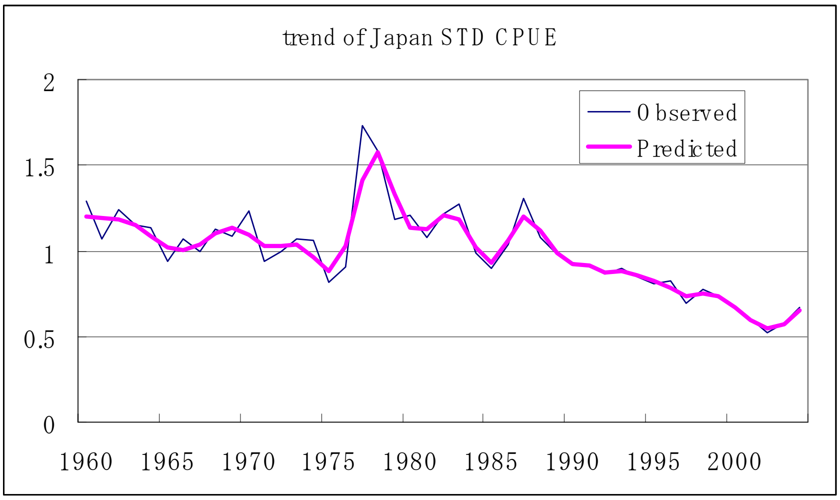


Fig. 10 Trends of observed and predicted standardized CPUE (Japan)

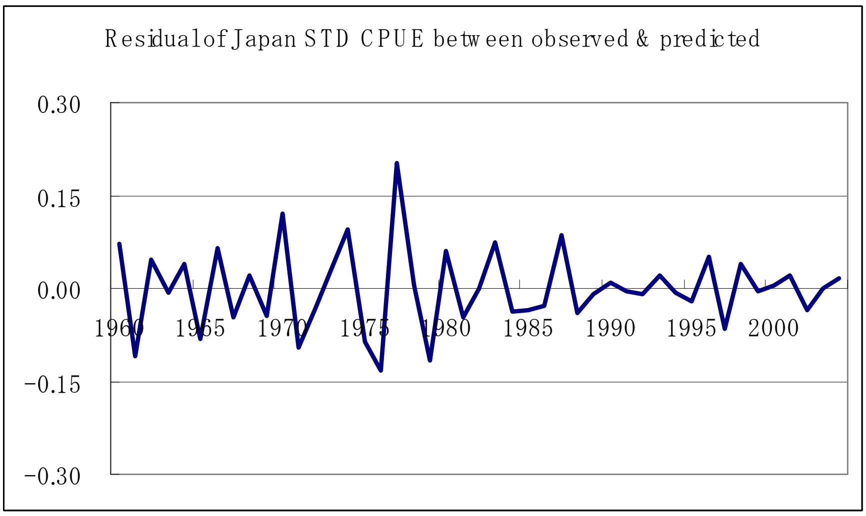


Fig. 11　Trends of residuals of Japan STD CPUE

2.4 Confidence intervals (CI) by bootstraps

IMPORTANT NOTE

In the past BET assessments by the ASPM, we could not get the reasonable confidence intervals. We thought that the cause of this problem was due to the program structure problem in the ASPM. But for this time, we re-examined our macro programs and procedures to compute the CI. Then we found a few errors (bugs) in our macro programs to link among ASPM, excel and batch procedures. After we corrected these bugs, we realized that the revised programs and procedures could provide the reasonable CI.

Based on the updated ASPM result (Run 1) using the revised macro programs and procedures, we estimated the confidence interval of the MSY using 330 times of the bootstrap experiments by adding the random noises into CPUEs and the Spawner-Recruit relations. The methods are described as below:

<u>Methods</u>

ASPM parameters

(a) Add the normal random numbers into the Japanese standardized CPUEs (1960-2004);
(b) Do 330 times of the ASPM Runs using the 330 sets of the CPUE created in (a);
(c) Get 330 S-R relations (B-H model) from the 330 times of the ASPM runs;

MSY for the additional steps

(d) Using each S-R relation with the age specific selectivity (from the ASPM results), estimate MSY by optimizing age specific F.
(e) Repeat (d) 330 times and get 330 MSY values;
(f) Estimate SE then compute confidence intervals based on 330 MSY values.

Although we attempted 330 times bootstraps, we could get the convergences only for 124 times. Using 124 results, we computed SE and 90% CI.

Table 6 shows the summary of points and the confident intervals for MSY and various ASPM parameters based on the bootstraps.

Table 6 Summary of estimated CI for MSY and various ASPM parameters based on the bootstraps.

	Unit	90% lower CI	Point estimates	90% upper CI
[MSY]				
MSY	tons	79,840	97, 415 (SE=9,250)	114,990
[TB: Total Biomass]				
TB(1960)	million tons		1.31	
TB(2004)			0.69	
TB(MSY) ratio (2004 to MSY)	rate between 0 & 1	0.42	0.53 (SE=0.06)	0.64
[SSB]				
SSB(MSY)	million tons		0.32	
SSB(1960)			1.06	
SSB(2004)			0.38	
SSB(MSY) ratio (2004 to MSY)	rate between 0 & 1	0.85	1.19 (SE=0.18)	1.53
SSB(virgin) ratio (2004 to 1960)		0.27	0.36 (SE=0.05)	0.45
[F]				
F(MSY)	instantaneous annual mortality rate		0.32	
F(1960)			0.02	
F(2004)			0.32	
F(MSY) ratio (2004 to MSY)	rate between 0 & 1	0.20	1.00 (SE=0.20)	1.38

3. Comparisons among ASMP results (2002, 2004, 2005 and 2006)

Table 7 and Figs. 12-14 show summaries of the comparisons among ASPM results in the past, i.e., WPTT4 (2002), WPTT6 (2004), SC8 (2005) and WPTT8 (2006).

Table 7 Summary of comparisons among ASPM results (2002, 2004, 2005 and 2006)

Year assessed		2002 (WPTT4)	2004 (WPTT6)	2005 (SC8)	2006 (WPTT8)
Method (software)		ASPMS (software created by Restrepo,1997)			
Period analyzed		1960-1999 (40 years)	1960-2002 (42 years)	1960-2003 (44 years)	1960-2004 (45 years)
Area		Whole Indian Ocean			
Catch		LL and PS			
Selectivity (estimated by separable VPA)		LL (3 periods) and PS (2 periods)			
		Miyabe et al (2002)	WPTT6 (2004)		
CPUE (Okamoto et al)		Japan (1960-1999)	Japan (1960-2002)	Japan (1960-2002)	Japan (1960-2004)
M vector		ICCAT type:0.8 (age 0-1) and 0.4 (age 2-8)			
S-R		Beaverton-Holt model			
steepness		0.99 (estimated)	0.99 (estimated)	0.99 (estimated)	0.70 (fixed)
LW		Poreeyanond (1994) (less than 80cm) & Nakamura/Uchiyama (1966) (80cm or larher)			
Growth		Tankevich (1982)	Stequart and Conrad (2003)		
MSY (tons)	MSY(Point) [90% CI]	101,522	96,858	99,212	97, 415 [79,840-114,990]
	current catch (tons)	150,455 (1999)	123,942 (2002)	123,986 (2003)	126,515 (2004)
	90 % CI	NA			
TB Total biomass	TB (virgin) ratio =TB(current)/TB(virgin) [90% CI]	0.61	0.50	0.49	0.53 [0.42-0.64]
SSB Spawning stock biomass	SSB(virgin) ratio =SSB(current)/SSB(virgin) [90% CI]	0.51	0.36	0.28	0.36 [0.27-0.45]
	SSB(MSY) ratio =SSB(current)/SSB(MSY) [90% CI]	2.34	1.56	1.20	1.19 [0.85-1.53]
	F ratio =F(current)/F(MSY) [90% CI]	0.66	0.98	0.89	1.00 [0.62-1.36]

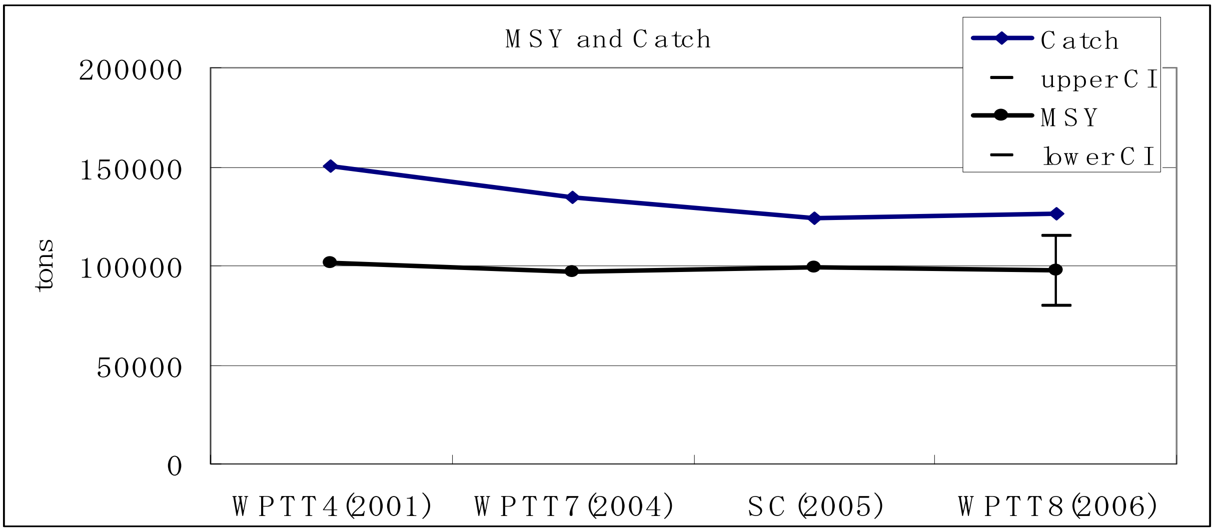


Fig. 12 Trend of estimated MSY and catch evaluated in the past four BET stock assessments by ASPM.

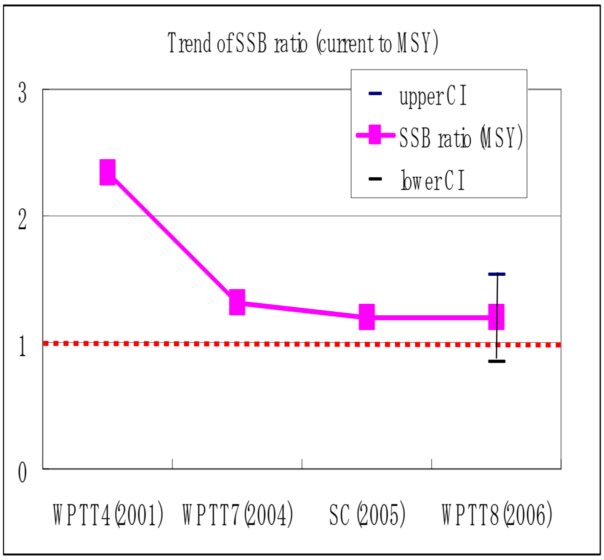


Fig. 13 SSB (MSY) ratio (current to MSY)

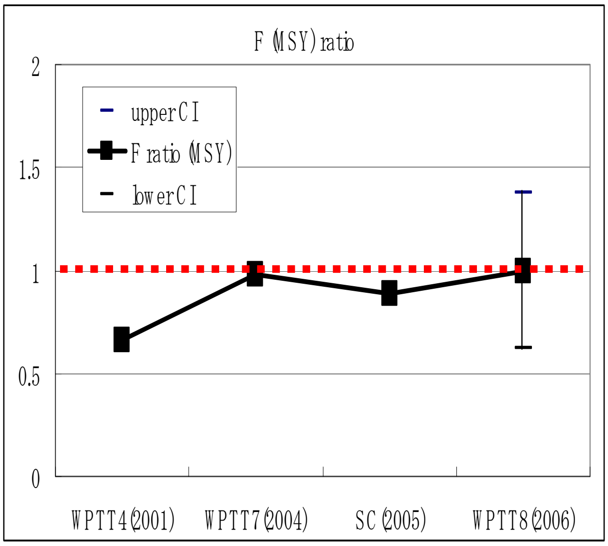
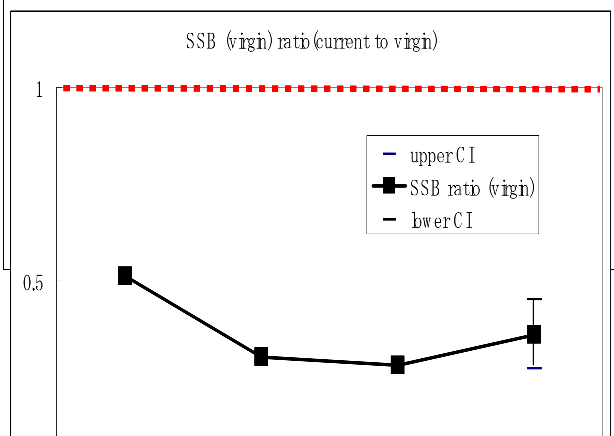


Fig. 14 F (MSY) ratio (current to MSY)



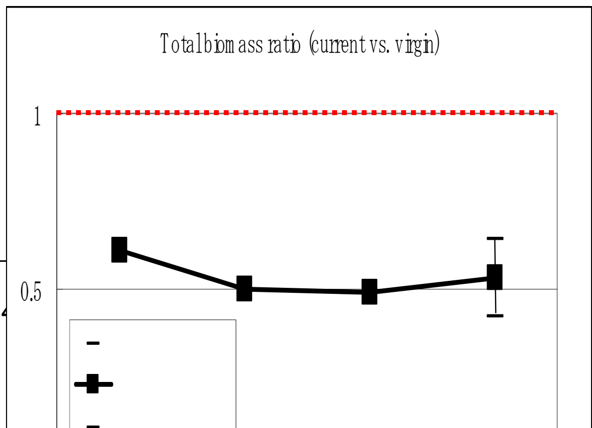


Fig. 15 SSB (virgin) ratio (current to virgin)	**Fig. 16 TB (virgin) ratio (current to virgin)**

4. Discussion

(1) Taiwan STD CPUE

It is the first time that the trends of the standardized Taiwan CPUE became very similar to the Japanese one, especially in recent years unlike in the past. This caused that the all the ASPM even with Taiwan STD CPUE could get conversions and provided reasonable results, unlike in the past, i.e., the ASPM with Taiwan could not get conversion and even if conversion were made, the estimated parameters were un-realistic. This implies that Taiwan STD CPUE for this time is improved than those in the past.

However even with the improved Taiwan STD CPUE, it was resulted that the ASPM results with Japan STD CPUE showed slightly better fits to the model and provided more realistic results.

(2) Sensitivity analyses for steepness and Rho

We have been facing the unrealistic steepness value (0.999) estimated in the past ASPM runs. To solve this problem, we fixed its values to test sensitivity. In addition according to our last ASPM paper in 2005 submitted to the SC in 2005(IOTC-SC-2005-INF10), we learned that results of ASPM were influenced by Rho values (values used to reduce biases caused by auto-correlation in the spawner-recruit relationship). Thus we also tested its sensitivities. As a result we get Rho=0.1 and steepness=0.7 as the best value although there are not so much differences with other testing values in terms of criteria.

(3) Confidence intervals (CI)

In the past BET assessment by the ASPM, we could not get the reasonable confidence intervals. We thought that the cause of this problem was due to the program structure problem in the ASPM (see IOTC-SC-2005-INF10). But for this time, we re-examined our macro programs and procedures to compute the CI. Then we found a few errors in our macro programs to link among ASPM, excel and batch procedures. After we corrected these bugs, we realized that the revised programs and procedures could provide the reasonable CI.

(3) Comparison of the past ASPM results

Based on the comparative studies of four ASPM results in the past (2002, 2004, 2005 and 2006), it is likely that consistent and robust results have been evaluated in the past by the ASAM (see Table 7 & Figs. 12-14), while there is a number of uncertainties described in the past IOTC WPTT reports

(4) Suggestion to resources managements

For this time, we could obtain similar ASPM results in the past which indicated again that stock has been continuing the over-fishing status and furthermore BET stock status has become more pessimistic because (a) the catch levels exceeded the MSY level (97,415 tons) in past ten years (1993-2004), (b) current to virgin levels of total & spawning stock biomass (SSB) were 0.36 and 0.53 (well below from 1, critical level to keep MSY) respectively and (c) F & SSB (MSY) ratios (current levels to MSY) have been rapidly reaching to the critical level. Based on these clear and consistent facts obtained in the past 4 ASPM assessments we strongly recommend that all catch and fishing effort for any gears should be reduced to the MSY level immediately.

Acknowledgements and Condolences

We thank late Geoff Kirkwood to suggest us to improve the ASPM runs. Taking this opportunity we would like to express our sincere condolences on his sudden passing away in last March. Further we here acknowledge Geoff's great leaderships and excellent supervisions to our past WPTT and SC as Chairs. Special thanks are towards Victor Restrepo (ICCAT) to assist to solve the ASPM structure problems.

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IOTC-2006-WPTT8-22
(Addendum 3)

Updated stock assessment of bigeye tuna (*Thunnus obesus*) resource
in the Indian Ocean by the age structured production model(ASPM) analyses
(1960-2004)

Tom Nishida and Hiroshi Shono

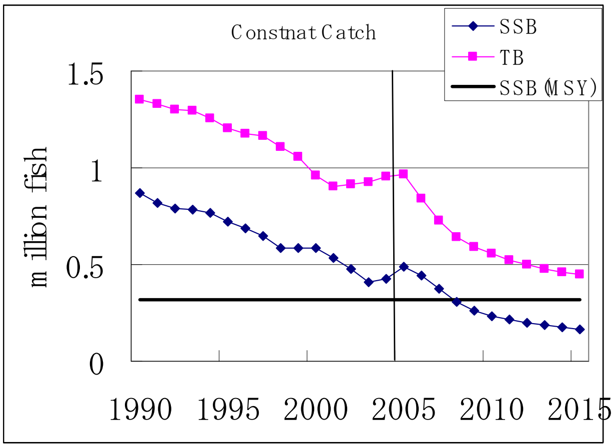
Addendum D Results of the ASPM run for the final and agreed base case----

Addendum E Results of the future projection for the base case -----------------

Table 10 **Results of the ASPM run for the final and agreed base case**

	Base case	**M1 [90% CI]**	M2
INPUT			
STD CPUE	Japan (1960-2004)		
Steepness	0.80 (fixed)		
Rho	0.10 (fixed)		
OUTPUT			
Criteria for goodness of fit			
ln(likelihood)	-129.75	-131.08	-131.21
R-squared	0.900	0.907	0.907
CV (virgin biomass)	0.292	0.287	0.311
CV (B1 ratio)	4.002	3.286	3.683
MSY vs. Catch			
MSY(tons)	97,415	**99,244 [82,718-115,770]**	104,063
Catch (2004)	126,518		
TB: Total biomass			
TB (1960: virgin) (million tons)	1.31	1.38	1.26
TB (2004: current) (million tons)	0.69	0.72	0.70
TB (virgin) ratio (current to virgin)	0.53	**0.52 [0.41-0.63]**	0.56
SSB: Spawning stock biomass			
SSB(1960: virgin) (million tons)	1.06	1.15	1.02
SSB (2004: current) (million tons)	0.38	0.43	0.40
SSB(MSY) (million tons)	0.32	0.35	0.32
SSB (MSY) ratio (current to MSY)	1.19	**1.23 [0.91-1.55]**	1.14
SSB(virgin) ratio (current to virgin)	0.36	**0.37 [0.28-0.47]**	0.39
F: Instantaneous fishing mortality			
F(2004: current)	0.32	0.29	0.30
F(MSY)	0.32	0.30	0.33
F ratio (current to MSY)	1.00	**0.97 [0.57-1.37]**	0.91
Comments		**The best fit (Based on criteria)**	

Addendum E Results of the future projection for the base case (point estimates)

<table>
<tr><th>Catch control</th><th>F control</th></tr>
<tr><td>

Constant catch at the 2004 level (LL= PS=)</td><td>Constant F at the 2004 level (LL= PS=)</td></tr>
<tr><td>Constant catch at the 2004 level (LL= PS=)</td><td></td></tr>
<tr><td></td><td></td></tr>
</table>

IOTC-2006-WPTT8-22
(Addendum 3)

Updated stock assessment of bigeye tuna (*Thunnus obesus*) resource
in the Indian Ocean by the age structured production model(ASPM) analyses
(1960-2004)

Tom Nishida and Hiroshi Shono

Addendum D Results of the ASPM run for the final and agreed base case---- 21
Addendum E Results of the future projection for the base case ------------------ 22
Addendum F Comparisons among results by 5 SA methods (for discussion)----- 23-24

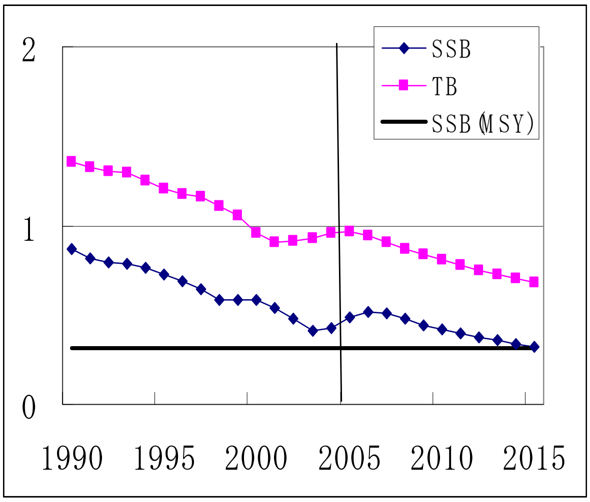
Table 10 **Results of the ASPM run for the final and agreed base case**

	Final base case M1 **[80% CI]** **to be provided in July 28(Fri)**
INPUT	
STD CPUE	Japan (1960-2004)
Steepness	**0.80 (fixed)**
Rho	0.10 (fixed)
OUTPUT	
MSY vs. Catch	
MSY(tons)	**111,195** **[xx.xxx – xxx.xxx]**
Catch (2004)	126,518
TB: Total biomass	
TB (1960: virgin) (million tons)	1.38
TB (2004: current) (million tons)	0.72
TB (virgin) ratio (current to virgin)	**0.52** [0.xx-0.xx]
SSB: Spawning stock biomass	
SSB(1960: virgin) (million tons)	1.15
SSB (2004: current) (million tons)	0.43
SSB(MSY) (million tons)	0.32
SSB (MSY) ratio (current to MSY)	**1.34** [0.xx-1.xx]
SSB(virgin) ratio (current to virgin)	**0.39** [0.xx-0.xx]
F: Instantaneous fishing mortality	
F(2004: current)	0.29
F(MSY)	0.36
F ratio (current to MSY)	**0.81** [0.xx-1.xx]

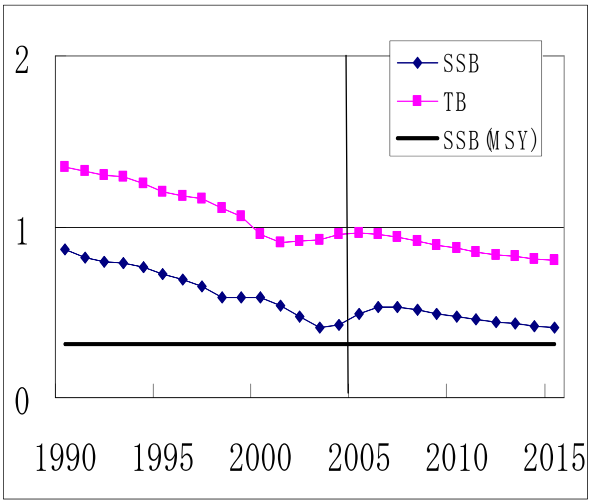
Addendum E Results of the future projection for the base case (point estimates)(2005-2015)

Catch control	F control
(Y-scale : million tons)	

Catch control

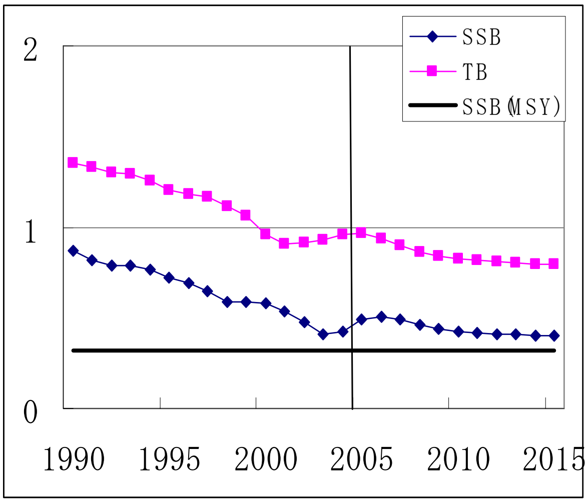


Current catch in 2004
(LL=102,866 tons and PS=23,628 tons)

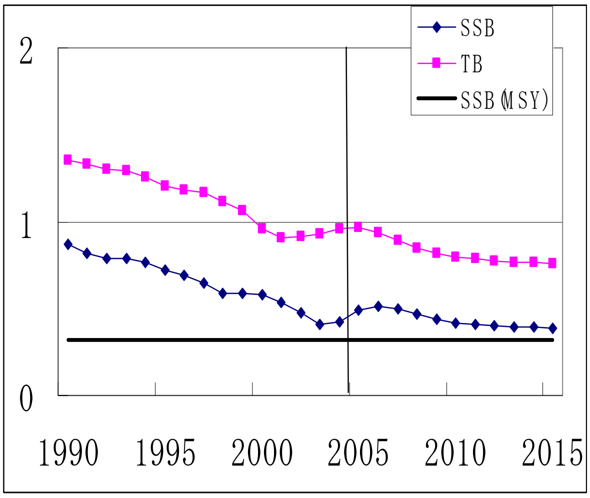


10% reduction of the current 2004 catch
(LL=92,597 tons and PS=21,266 tons)

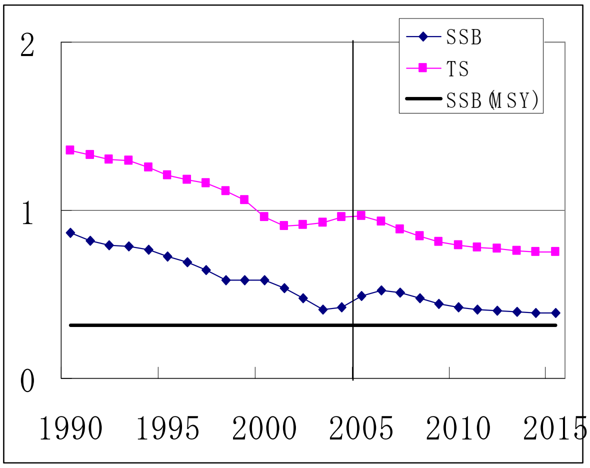
F control



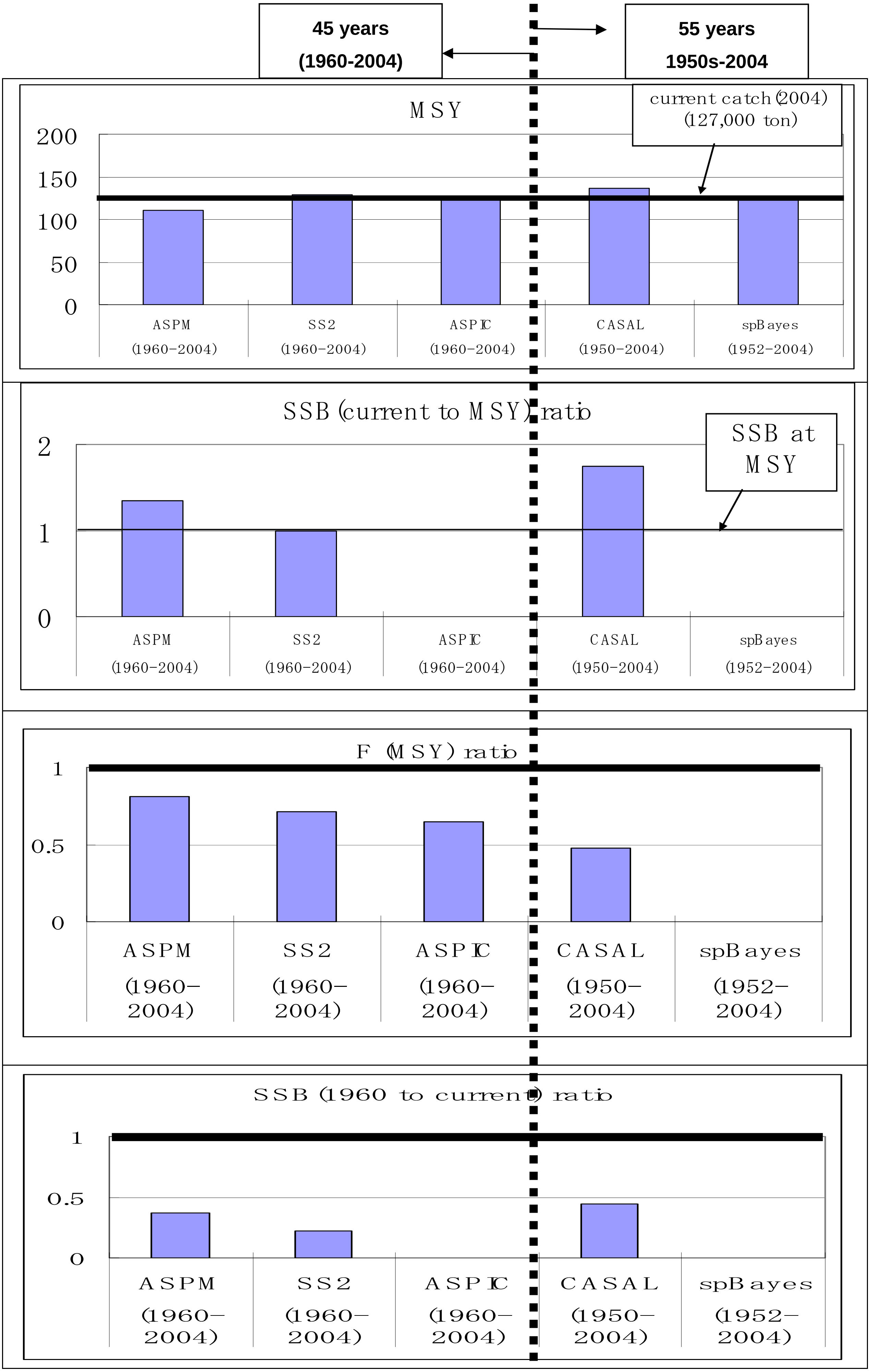
Current F in 2004(F=0.293)

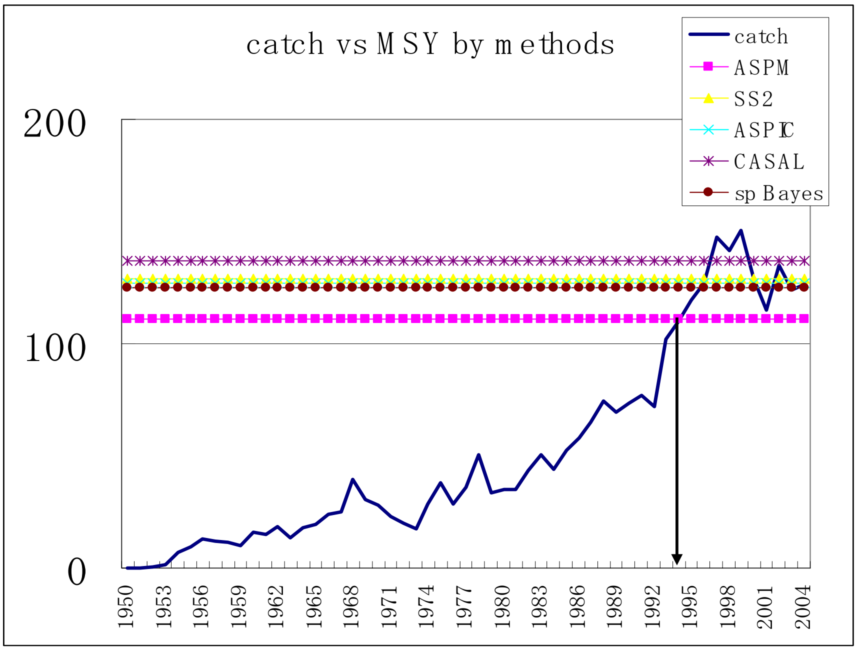


Average F (2000-2002) (F=0.265)



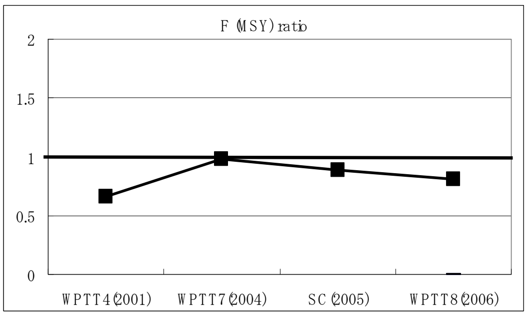
Average F (1998-2001)(F=0.251)

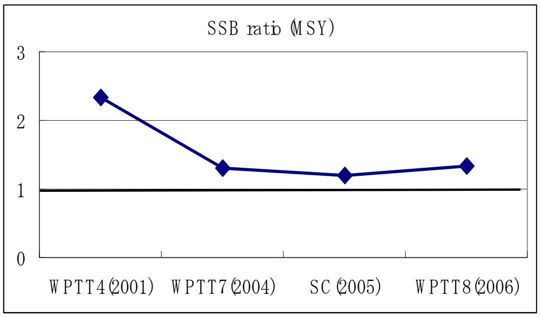

45 years
(1960-2004)
55 years
1950s-2004
MSY
current catch (2004)
(127,000 ton)
200
150
100
50
0
ASPM (1960-2004)
SS2 (1960-2004)
ASPIC (1960-2004)
CASAL (1950-2004)
spBayes (1952-2004)
SSB (current to MSY) ratio
SSB at MSY
2
1
0
F (MSY) ratio
1
0.5
0
SSB (1960 to current) ratio
1
0.5
0



COMMENTS

- If we accept the results of all 5 methods, we face uncertainty to interpret the results.
- The results are different by the period of the analyzed years, i.e., analyses by the shorter period data (1960-2004) [ASPM, SS2 and ASPIC] produced more conservative results than those by the longer period of the data (1950s-2004) [CASAL and spays].
- The current catch [127,000 tons] is around MSY [111,000-137,000] for all cases. In most conservative case [ASPM] the catch is above MSY for 10 years since 1993. While the least conservative case [CASAL] catch were above only for 3 years.
- In all the cases, the current SSB is the less than a half of the 1960 level (virgin level for the ASPM, SS2 and ASPIC). This suggests the concerning situation of the BET stock.
- However, F ratio (current to MSY level) is less than 1 (critical point) and SSB ratio (current to MSY level) is above 1 (critical level).
- Even for the conservative ASPM, F ratio & SSB ratio show the improving trend from the past analyses (see below).





Conclusions

The stock is likely recovering in last 1-2 years as the results of all 5 SA show the similar trends. But there are large uncertainties (discrepancies) in results among these 5 approaches. Considering pre-cautionary approach, we need to look at more conservative results to make adequate advices to the managers.

IOTC-2006-WPTT8-22
(Addendum 4)

Updated stock assessment of bigeye tuna (*Thunnus obesus*) resource
in the Indian Ocean by the age structured production model(ASPM) analyses
(1960-2004)

Tom Nishida and Hiroshi Shono

Addendum G ASPM run for the final and agreed base case with 90% CI-------- 25

Table 11 **Results of the ASPM run for the final and agreed base case with 90%CI**
(Note: 90% confidence intervals are based on the 332 bootstrap experiments)

	Final base case M1 [90% CI]
INPUT	
STD CPUE	Japan (1960-2004)
Steepness	**0.80 (fixed)**
Rho	0.10 (fixed)
OUTPUT	
MSY vs. Catch	
MSY(tons)	**111,195** **[94,738 –127,652]**
Catch (2004)	126,518
TB: Total biomass	
TB (1960: virgin) (million tons)	1.38
TB (2004: current) (million tons)	0.72
TB (virgin) ratio (current to virgin)	**0.52** [0.43-0.61]
SSB: Spawning stock biomass	
SSB(1960: virgin) (million tons)	1.15
SSB (2004: current) (million tons)	0.43
SSB(MSY) (million tons)	0.32
SSB (MSY) ratio (current to MSY)	**1.34** **[1.04-1.64]**
SSB(virgin) ratio (current to virgin)	**0.39** **[0.31-0.47]**
F: Instantaneous fishing mortality	
F(2004: current)	0.29
F(MSY)	0.36
F ratio (current to MSY)	**0.81** **[0.54-1.08]**

IOTC-2006-WPTT-22
(Addendum 1)

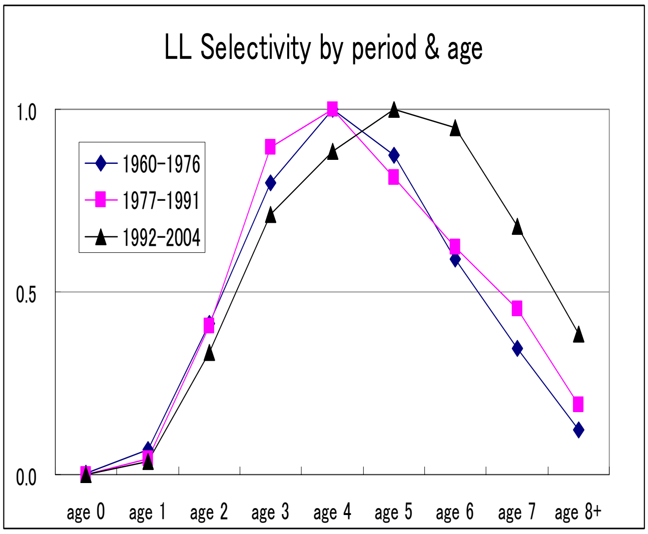
Updated stock assessment of bigeye tuna (*Thunnus obesus*) resource in the Indian Ocean by the age structured production model(ASPM) analyses (1960-2004)

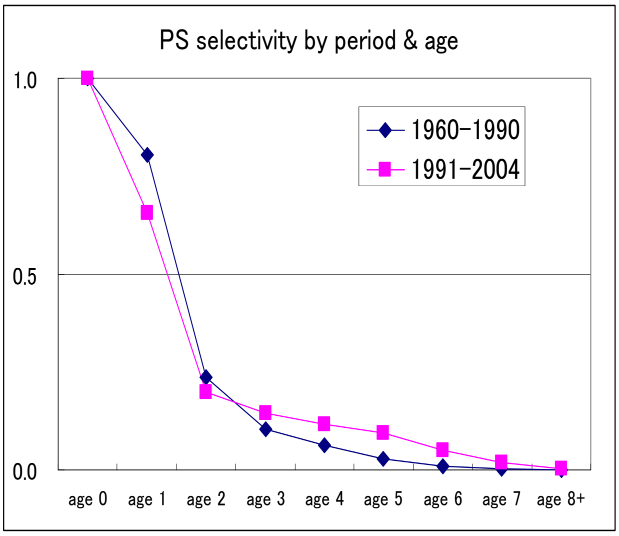
Tom Nishida and Hiroshi Shono

Addendum A Revised Table 3--- 17
Addendum B Sensitivity ASPM runs for 2 additional M vectors-------- 18-19

Addendum A : Revised Table 3 Selectivity by gear, period and age

gear	period	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8+
LL	1960-1976	0.002	0.069	0.414	0.797	1.000	0.875	0.590	0.346	0.121
	1977-1991	0.001	0.044	0.408	0.895	1.000	0.813	0.624	0.452	0.191
	1992-2004	0.000	0.034	0.333	0.713	0.884	1.000	0.949	0.678	0.386
PS	1960-1990	1.000	0.803	0.236	0.105	0.063	0.028	0.008	0.002	0.000
	1991-2004	1.000	0.655	0.198	0.144	0.117	0.093	0.049	0.019	0.004





Addendum B Sensitivity ASPM runs for 2 additional M vectors (M1 & M2)

Table 7 M vectors by age (base case and two additional ones for sensitivity analyses)

	age 0	age 1	age 2	age 3	age 4	age 5	age 6	age 7	age 8+
Base case	0.8	0.8	0.4	0.4	0.4	0.4	0.4	0.4	0.4
M1	1.0	0.6	0.3	0.4	0.4	0.4	0.4	0.4	0.4
M2	1.0	0.6	0.3	0.4	0.4	0.4	0.6	0.6	0.6

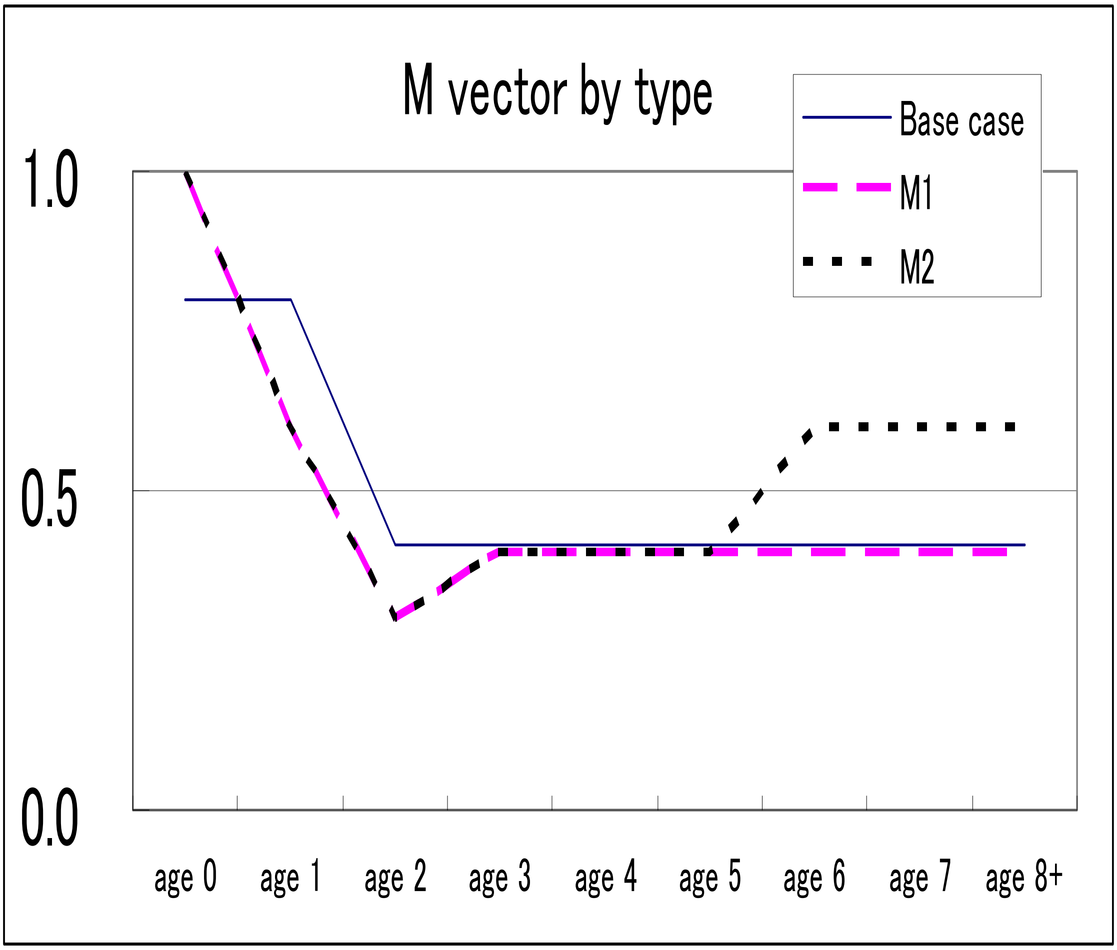


Fig. 17 M vectors by age (base case and two additional ones for sensitivity analyses)

Table 8 ASPM Results for base case & sensitivity trials

	Base case	M1	M2
INPUT			
STD CPUE	Japan (1960-2004)		
Steepness	0.70 (fixed)		
Rho	0.10 (fixed)		
OUTPUT			
Criteria for goodness of fit			
ln(likelihood)	-129.75	-131.08	-131.21
R-squared	0.900	0.907	0.907
CV (virgin biomass)	0.292	0.287	0.311
CV (B1 ratio)	4.002	3.286	3.683
MSY vs. Catch			
MSY(tons)	97,415	99,244	104,063
Catch (2004)	126,518		
TB: Total biomass			
TB (1960: virgin) (million tons)	1.31	1.38	1.26
TB (2004: current) (million tons)	0.69	0.72	0.70
TB (virgin) ratio (current to virgin)	0.53	0.52	0.56
SSB: Spawning stock biomass			
SSB(1960: virgin) (million tons)	1.06	1.15	1.02
SSB (2004: current) (million tons)	0.38	0.43	0.40
SSB(MSY) (million tons)	0.32	0.35	0.32
SSB (MSY) ratio (current to MSY)	1.19	1.23	1.14
SSB(virgin) ratio (current to virgin)	0.36	0.37	0.39
F: Instantaneous fishing mortality			
F(2004: current)	0.32	0.29	0.30
F(MSY)	0.32	0.30	0.33
F ratio (current to MSY)	1.00	0.97	0.91
Comments		**The best fit (Based on criteria)** *CI will be available In 24 hours*	