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## **DRAFT: STOCK ASSESSMENT PAPERS**

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**DRAFT**

**Stock assessment of yellowfin tuna (*Thunnus albacares*)  
in the Indian Ocean by SCAA (Statistical-Catch-At-Age) (1950-2014)**

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October, 2015

**Abstract**

***tbp (to be provided)***

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*Submitted to the IOTC 17th WPTT (Working Party on Tropical Tuna) meeting, 19 to 28 October 2015, Montpellier, France.*

## 1. Introduction

We attempted stock assessments for the yellowfin tuna (*Thunnus albacares*) (YFT) resource in the Indian Ocean using SCAA (Statistical-Catch-At-Age) model and available data for 65 years (1950-2014). SCAA is conducted using the ADMB (AD Model Builder) implemented ASPM (Age-Structured Production Model) software developed by first two authors, which can perform both ASPM and SCAA. The ASPM (SCAA) software is available at <http://ocean-info.ddo.jp/kobeaspm/aspm/ASPM.zip> including software, Users' manual and case studies. In the last YFT stock assessments (2012), three models were used, i.e., MULTIFAN-CL (Langley et al, 2012), SS3 (Stock Synthesis III) (Ijima et al, 2012) and ASPM (Nishida et al, 2012). For this time, we update the assessments using SCAA in order to compare the results by SS3 (Langley, 2015).

## 2. Ecology and stock structure

A cosmopolitan species distributed mainly in the tropical and subtropical oceanic waters of the three major oceans, where it forms large schools. Feeding behaviour has been extensively studied and it is largely opportunistic, with a variety of prey species being consumed, including large concentrations of crustaceans that have occurred recently in the tropical areas and small mesopelagic fishes which are abundant in the Arabian Sea. It has also been observed that large individuals can feed on very small prey, thus increasing the availability of food for this species. Archival tagging of yellowfin tuna has shown that this species can dive very deep (over 1000 m) probably to feed on meso-pelagic prey. Longline catch data indicates that yellowfin tuna are distributed throughout the entire tropical Indian Ocean.

The tag recoveries of the RTTP-IO provide evidence of large movements of yellowfin tuna, thus supporting the assumption of a single stock for the Indian Ocean. The average distance travelled by yellowfin between being tagging and recovered is 710 nautical miles, and showing increasing distances as a function of time at sea.

## 2. Input data

To implement SCAA, we used YFT annual nominal catch, standardized (STD) CPUE, CAA (catch-at-age) and also biological information. Biological information has been improved by results of the EU funded tagging program. These input data are described as follows:

### 2.1 Catch by fleet

We used 8 types of fleet exploiting YFT in the Indian Ocean as listed in Table 1 according to available fleets in CAA prepared by IOTC Secretariat. Fig. 1 shows the catch trends by fleet (1950-2014).

Table 1 List of 7 fleets used in the stock assessment by SCAA

No	Code	Fleet
(1)	LL	Tuna longline (deep-freezing)
(2)	LF	Tuna longline (fresh) (Including negligible catch from coastal LL)
(3)	PS	Purse seine
(4)	GILL	Gillnet
(5)	HAND	Hand line
(6)	BB	Pole and Line Including negligible catch in the other category (Beach seine + Cast net + Danish Seine + Fish net + Lift net+ Trap)
(7)	TROLL	Troll line (Including negligible catch from sport fishing)

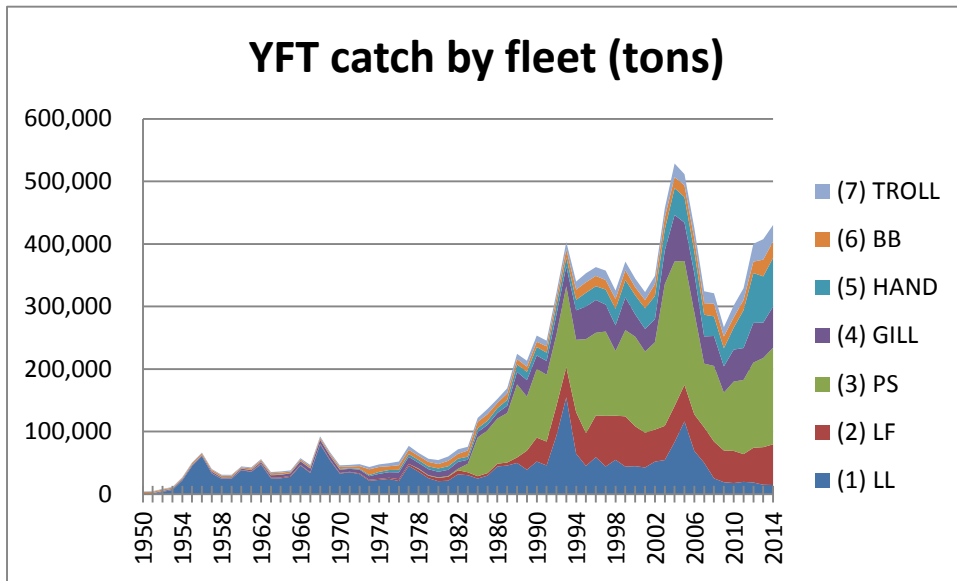


Fig. 1 YFT annual catch trends for 7 fleets (1950-2014)

(Source: IOTC Secretariat, 2015)

### 2.2 Age composition and Catch-at-age (CAA)

Seven age composition are used (age0-age6+) as in the last assessments in 2012. Fig. 2 shows the catch-at-age (CAA) estimated by the IOTC Secretariat (2015). Figs. 3-9 show the CAA trend by fleet.

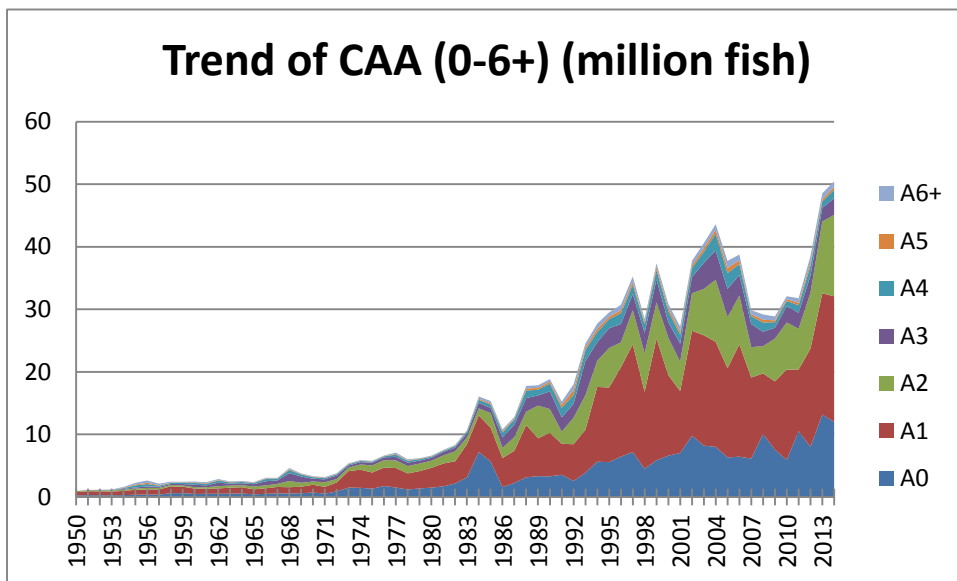


Fig. 2 Trends of annual total CAA (age 0-6+)

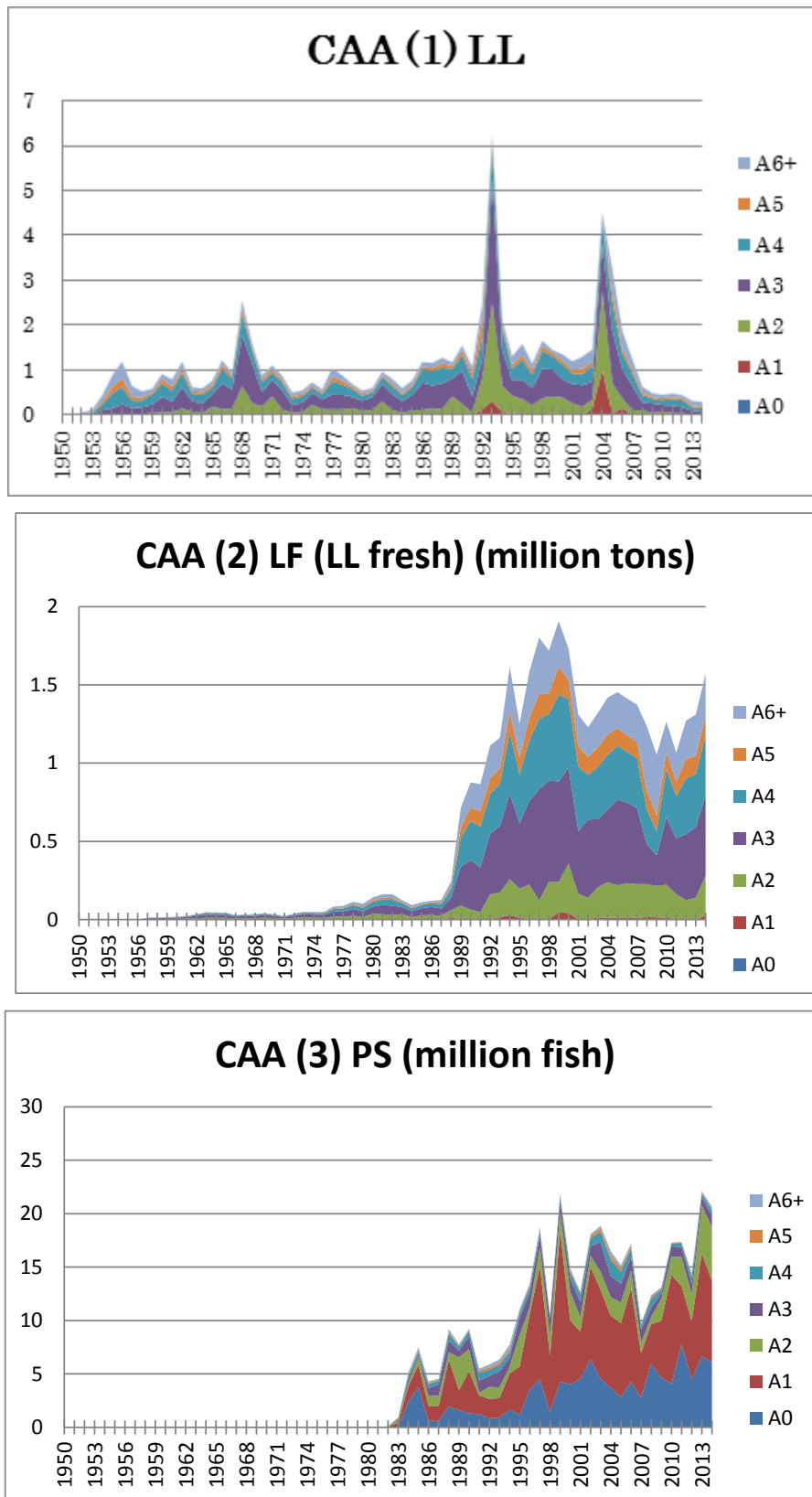


Fig.2 Annual CAA by fleet (1/3)

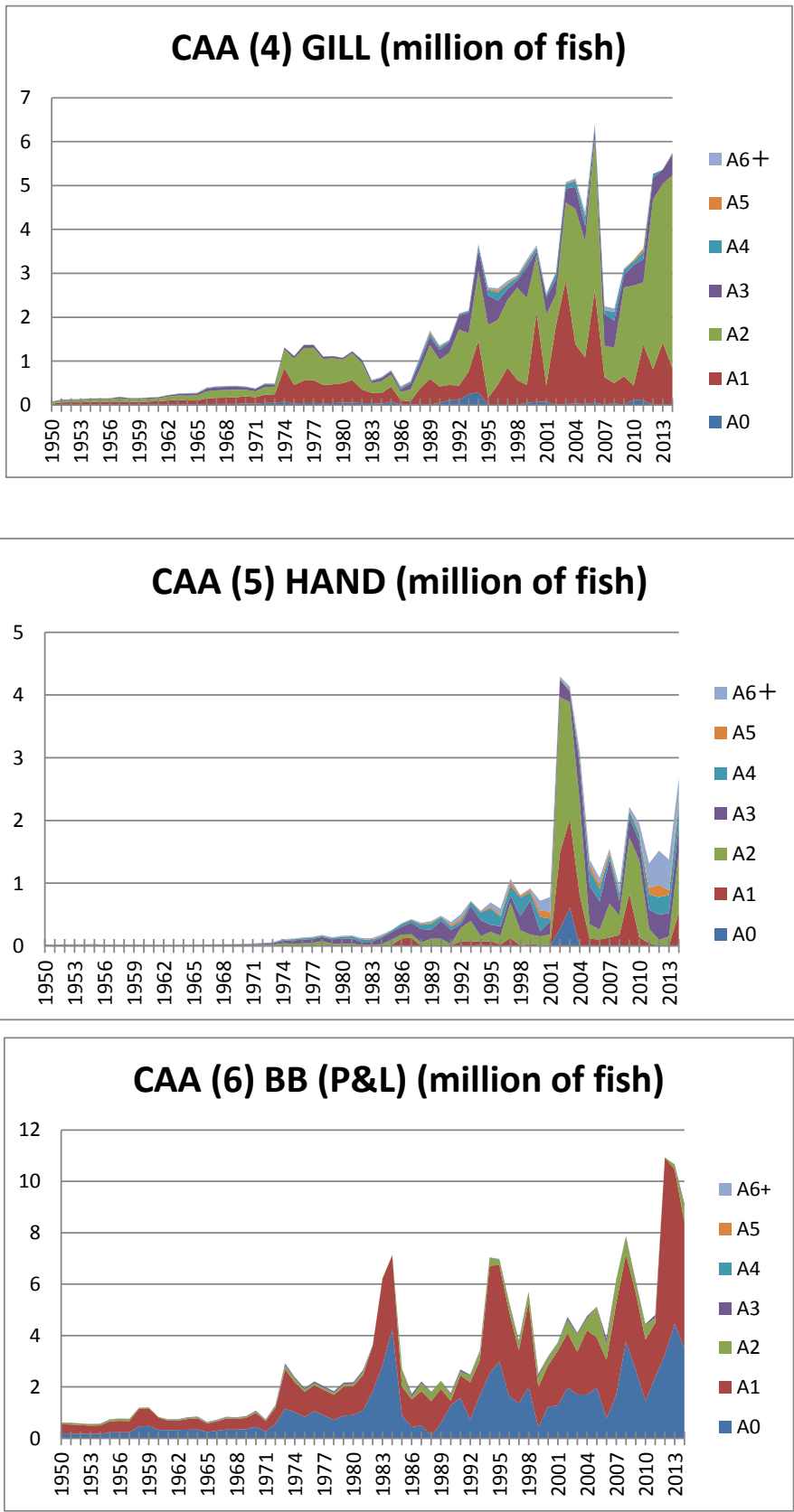


Fig.2 Annual CAA by fleet (2/3)

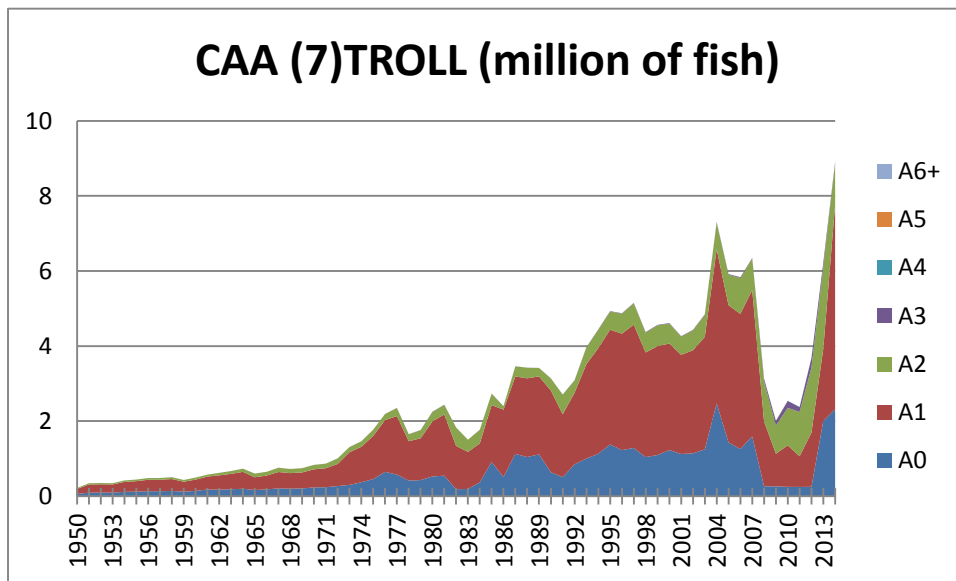


Fig.2 Annual CAA by fleet (3/3)

### 2.3 Plus and minus group

In running SCAA, plus and minus groups need to be set up, in order to implement robust optimization. Based on the CAA information by fleet, we determined plus and minus groups which CAA by age composes less than 2% of the total CAA (Table 2).

Table 2 Minus and plus group determined based on compositions of CAA by age.

No	Code	Fleet	Minus group	Plus group	Period of available CAA data
(1)	LL	Tuna longline (deep-freezing)	Age 1-	Age 6+	1952-2014
(2)	LF	Tuna longline (fresh)	Age 2-	Age 6+	1957-2014
(3)	PS	Purse seine		Age 5+	1977-2014
(4)	GILL	Gillnet	Age 1-	Age 4+	1950-2014
(5)	HAND	Hand line	Age 1-	Age 6+	1950-2014
(6)	BB	Pole and Line		Age 3+	1950-2014
(7)	TROLL	Troll line		Age 2+	1950-2014



### 2.5 Standardized (STD) CPUE

We used the Japanese STD CPUE by Ochi et al (2015). There are two types of STD\_CPUE series, (a) 3 areas model (2+3+5) and (b) 2 areas model (23+5) (see Fig. 3). We used 2 areas model as there are no or a few operations in recent years in area 2 by the piracy activities which makes unreliable STD\_CPUE data. We used the aggregated annual STD\_CPUE in area 23+5. Fig 3. W

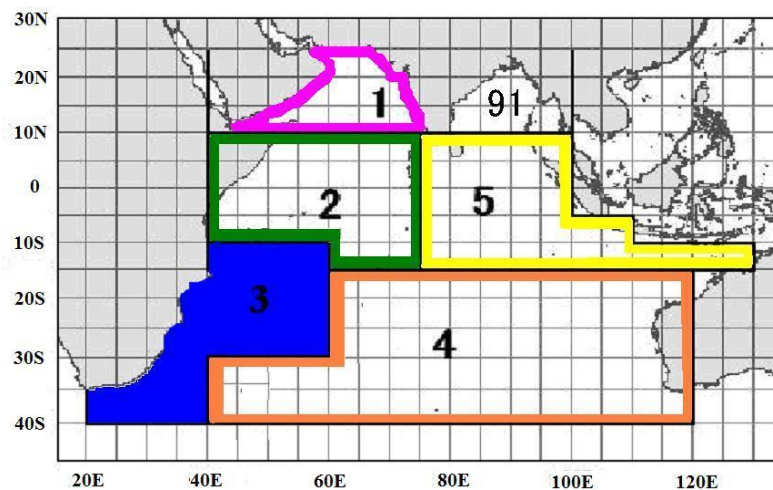


Fig.3 Sub-areas used in the GLM for YFT STD CPUE (Ochi et al, 2015)  
 Aggregated annual STD\_CPUE based on 2 areas model (23 combined and 5) are used.

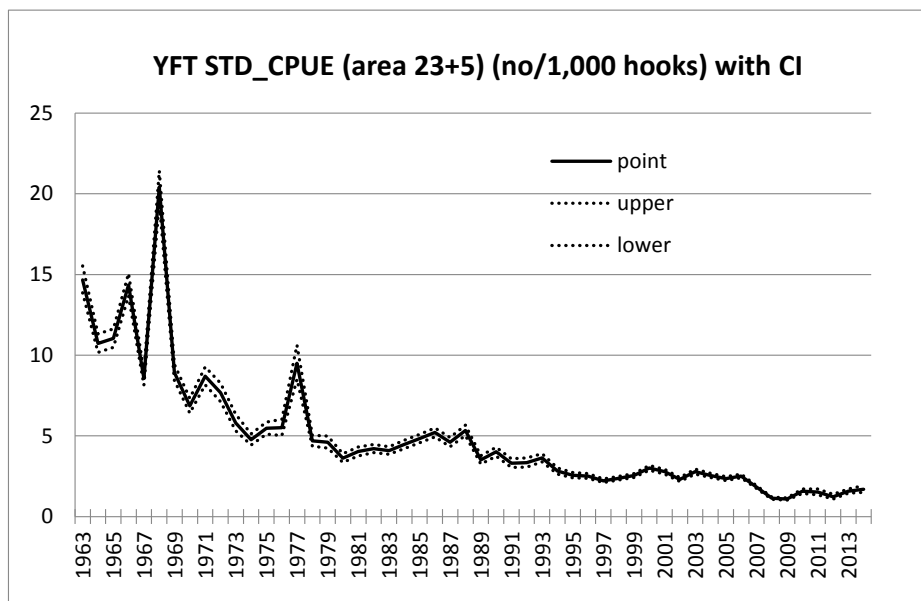


Fig. 4 Estimated YFT STD\_CPUE (Ochi et al, 2015)

## 2.6 Biological information

In the SCAA, three types of age-specific biological inputs are needed, i.e., natural mortality-at-age ( $M$ ), weight-at-age (beginning and mid-year) and maturity-at-age.

### (1) Age specific natural mortality ( $M$ )

We applied quarterly  $M$  (base case) developed by Langley (2015) by converting to age specific  $M$  as shown in Table 3.

### (2) Beginning- and mid-year weight-at-age growth curve

Beginning- and mid-year weights-at-age were estimated as follows: (a) using the growth equation by Fonteneau (2008) (Fig. 5), size-at-age was calculated, then (b) using the length-weight relationship,  $GGT=a(FL)^b$  ( $a=0.0000094007$  and  $b=3.126843987$ ) (IOTC, 2015) and the conversion factor for (Whole weight)  $=(GGT)*1.13$  (IOTC, 2015), beginning- and mid-year weights-at-age were computed (Table 3).

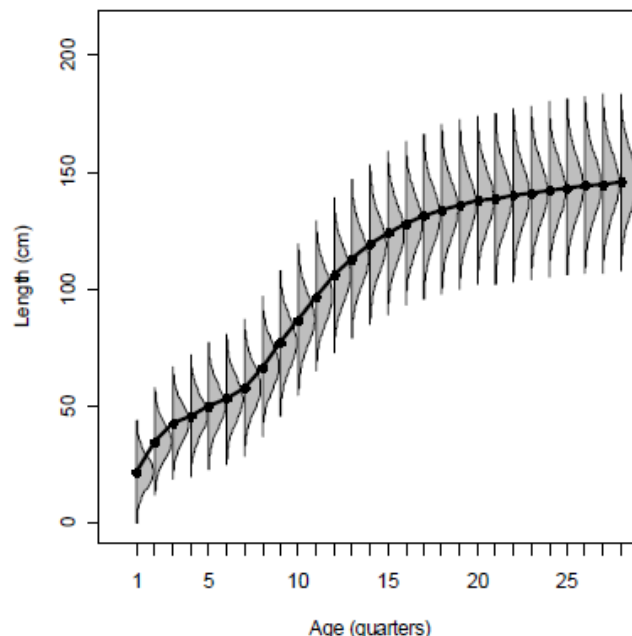


Fig. 5 YFT growth curve (Fonteneau, 2008)

### (3) Maturity-at-age

We applied length based maturity ogives used by Nishida et al (2012). We converted it to the age based maturity probabilities, which is shown in Table 3.

Table 3 Summary of age specific M, weight and maturity

Age	M (derived from Fonteneau, 2008)	Weight-at-age (ton)		Maturity-at-age(%) (Nishida et al, 2012)
		beginning	middle	
0	1.240	0.00017	0.00136	0
1	0.552	0.00218	0.00347	0
2	0.552	0.00841	0.01732	50
3	0.756	0.02792	0.03733	100
4	0.756	0.04432	0.04983	100
5	0.596	0.05286	0.05604	100
6+	0.552	0.05864	0.06077	100

### 3. Initial SCAA run (Base case)

We attempted the initial SCAA (base case) run using input data introduced in the previous Section. As a first step, we put some seeding values for selectivities as shown Table 4.

Table 4 Seeding values of selectivity by fleet in the initial SCAA run for base case

Age	minus group	plus group	0	1	2	3	4	5	6+
(1) LL(frozen)	Age 1-	Age 6+		0.0	0.1	0.9	(1)	1	1
(2) LF (fresh)	Age 2-	Age 6+			0.0	0.5	(1)	1	1
(3) PS		Age 5+	0.2	0.6	0.6	0.8	(1)	0.7	
(4) GILL	Age 1-	Age 4+		0.0	(1)	0.3	0.2		
(5) HAND	Age 1-	Age 6+		(1)	1	1	1	1	1
(6) BB		Age 3+	(1)	0.9	0.2	0.1			
(7) TROLL		Age 2+	0.1	(1)	0.7				

### Grid search

Using the initial input values and the seeding values (Table 4) (base case), we search the optimum parameters by varying 3 parameters shown in Box 1. This grid search was conducted by the grid search option available in ASPM/SCAA software (Box 1). The optimum parameters are obtained in  $h=0.6$ ,  $\text{Sigma}(\text{SR})=0.4$ ,  $\text{CV}(\text{CPUE})=0.2$  and  $\text{Weighting}(\text{CAA})=0.1$ . Results are shown in Figs 6-8.

#### Box 1 Grid search

**ASPM grid search (batch job) application (ASPM software version 3)**

This application will implement the batch job in order to search optimum ASPM parameters using the grid search technique. Maximum 5 important parameters can be searched in one catch job, i.e., "h" (steepness) in ASPM.pin file, "SigmaR" value for the stock recruitment (SR) fluctuations in control.inp, "CV" values for CPUE in index.inp file and "weighting" values for CAA in fishery.inp file.

Steps (1) Users will select parameters (click the box) to be used for the grid search and then enter their minimum, maximum and class values. The number of combination will be automatically evaluated.  
 (2) If users enter the class value which cannot make the integer value for number of combination, the maximum class value will be automatically evaluated.  
 (3) Results of the grid search will be available in the output\_datetime.csv file in the same folder. For example, output\_201404011521.csv file. This means that this file was created at 15 hour 21 minute in April 11, 2014.

Name	country code (CPUE)	minimum	maximum	class value	no. of combinations
<b>ASPM.pin file</b>					
<input checked="" type="checkbox"/>	h (steepness)	0.70	0.90	0.10	3
<b>control.inp file</b>					
<input checked="" type="checkbox"/>	Sigma (SR fluctuation)	0.40	1.00	0.20	4
<b>index.inp file</b>					
<input checked="" type="checkbox"/>	CV (CPUE1) j	0.10	0.40	0.10	4
<b>fishery.inp file</b>					
<input checked="" type="checkbox"/>	Weighting (CAA)	0.10	1.00	0.30	4

Note (1) If you have 2 CPUE series in index.in file (for example, Japan and Korea), then enter J (for Japan) and K (for Korea). J and K are just example. You can enter maximum 4 letters as the country code in this box.  
 (2) Number of CPUE CV depends on #Number of indices in the Index.inp file, which will be automatically recognized by this application and corresponding number of entry boxes will appear in the setting window. Max 3 CV (CPUE) can be used.  
 Note (3) Number of weighting (CAA) box depends on "#Number of fleets" in control file, which will be automatically recognized by this application and corresponding number of entry boxes will appear.

Option of batch job

Start [Pause] [Termination]

Processing time: 2h18m 0/192

[Current no. of the batch job being processed]/[total number of the batch job]

Total number of batch jobs: 192

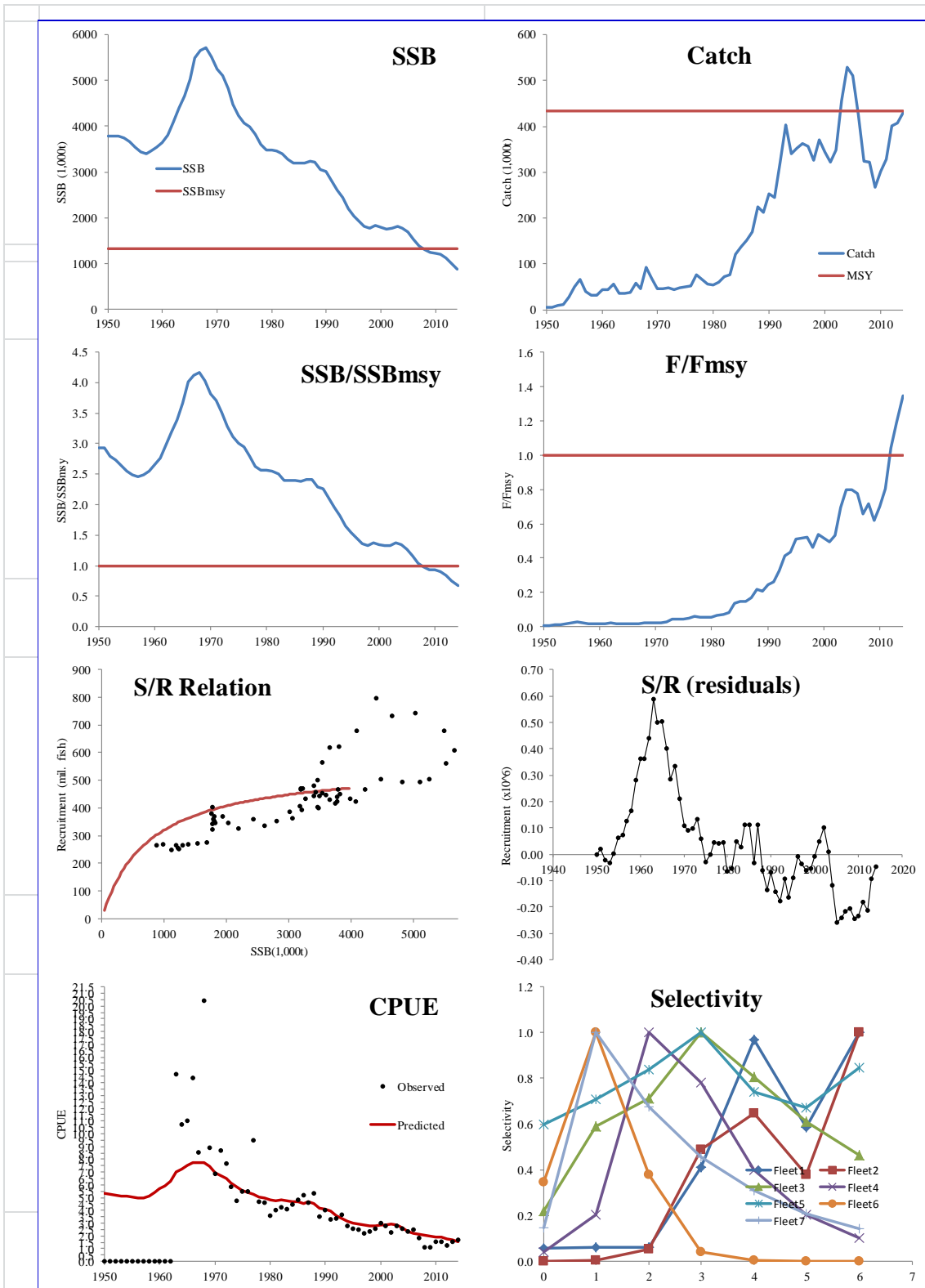


Fig. 6 Results of SCAA base case

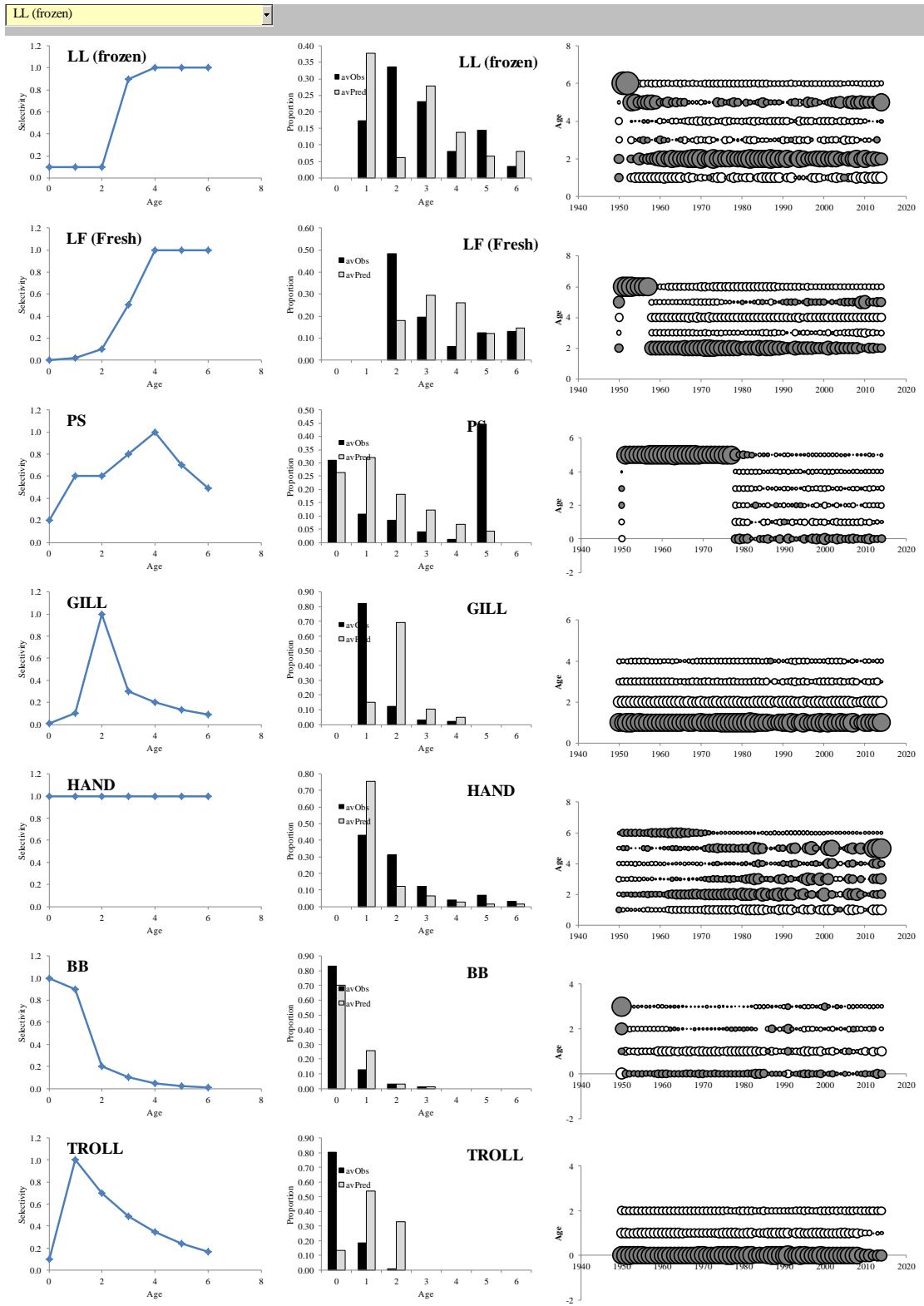


Fig. 7 Results of SCAA run (selectivities)

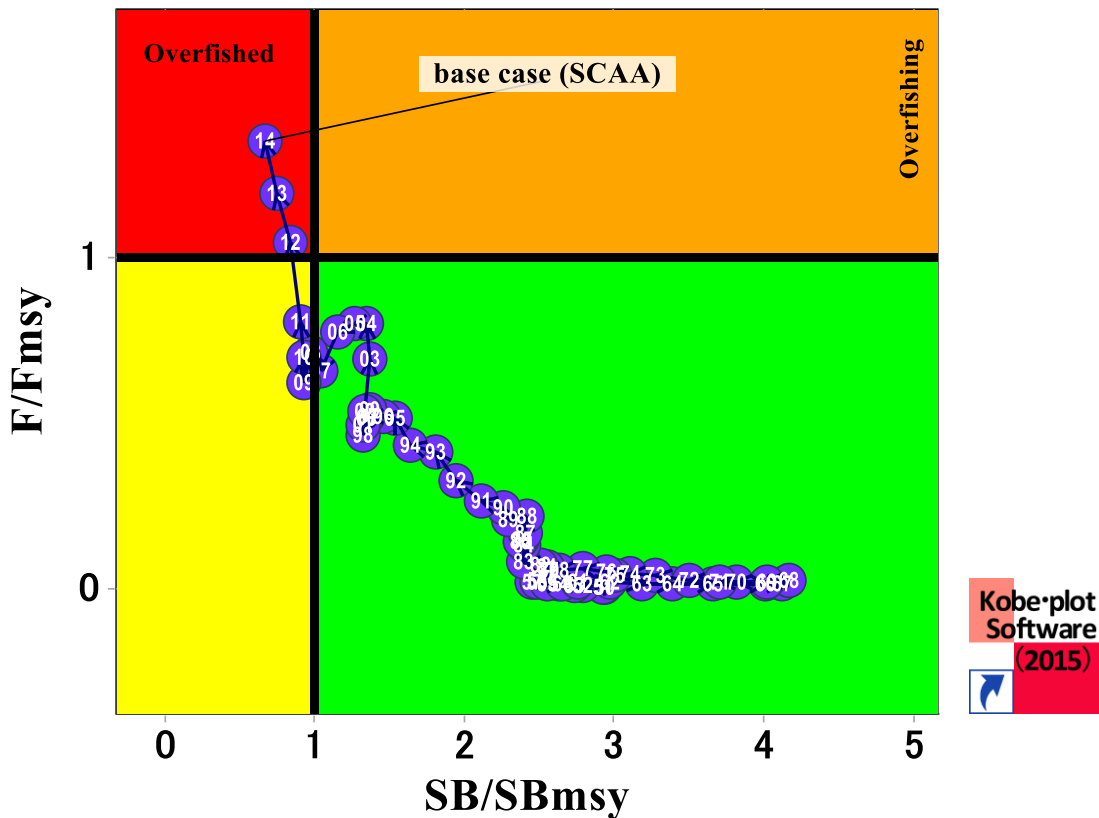


Fig 8 Kobe plot (base case)

Table 5 Indian Ocean yellowfin stock status summary (SCAA base case)

Management Quantity	ASPM/SCAA software (Nishida et al) <a href="http://ocean-info.ddo.jp/kobeaspm/aspm/ASPM.zip">http://ocean-info.ddo.jp/kobeaspm/aspm/ASPM.zip</a>
Most recent catch estimate (t) (2015)	430,327
Mean catch over last 5 years (t) (2011-2015)	373,824
h (steepness)	0.6 (fixed)
MSY (1,000 t) (80% CI)	433 (tbp)
Current Data Period (catch) CPUE	1950-2015 Japan (annual) (Main fishing area: 23 and 5)(1963-2014)
F(2014)/F(MSY) (80% CI)	1.34 (tbp)
SSB(2014)/SSB(MSY) (80% CI)	0.66 (tbp)
SSB(2014)/SSB(1950) (80% CI)	0.23 (tbp)
SSB(2011) /SSB(Current, F=0)	NA

6. Risk assessments (Kobe II) (tbp)

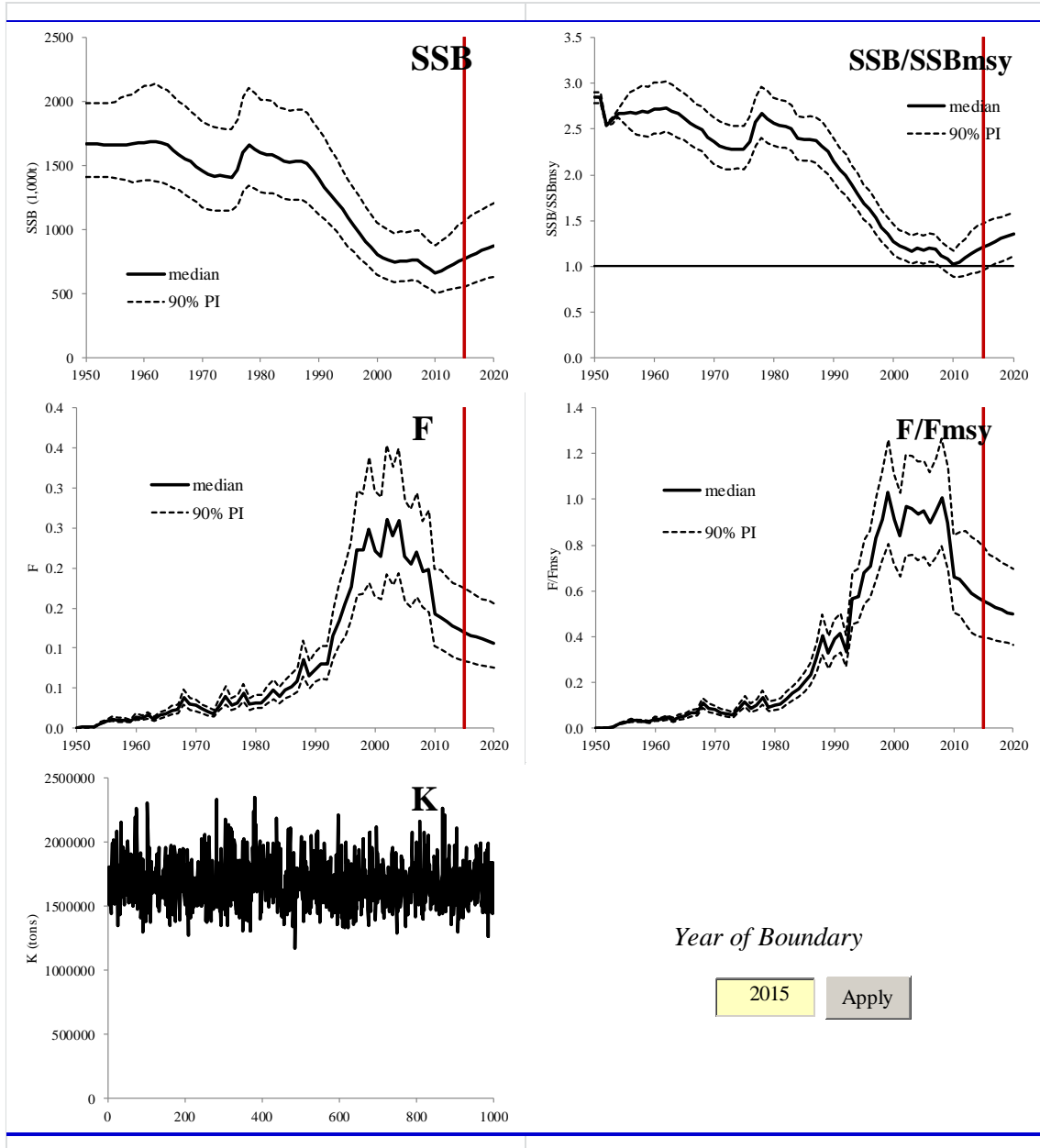


Fig. 8 Future projection by MCMC based on recent catch level (average catch in 3 years: 2012-2014).



## Acknowledgements

We sincerely thanks to James Greehan and Lucia Pierre (Data section, IOTC) and Miguel Herrera (ex IOTC data manager) for providing the nominal catch and Catch-At-Age (CAA) data of yellowfin tuna in the Indian Ocean used in the SCAA stock assessments.

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