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Received: 8 October 2015

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)

Contents (tbp)

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)

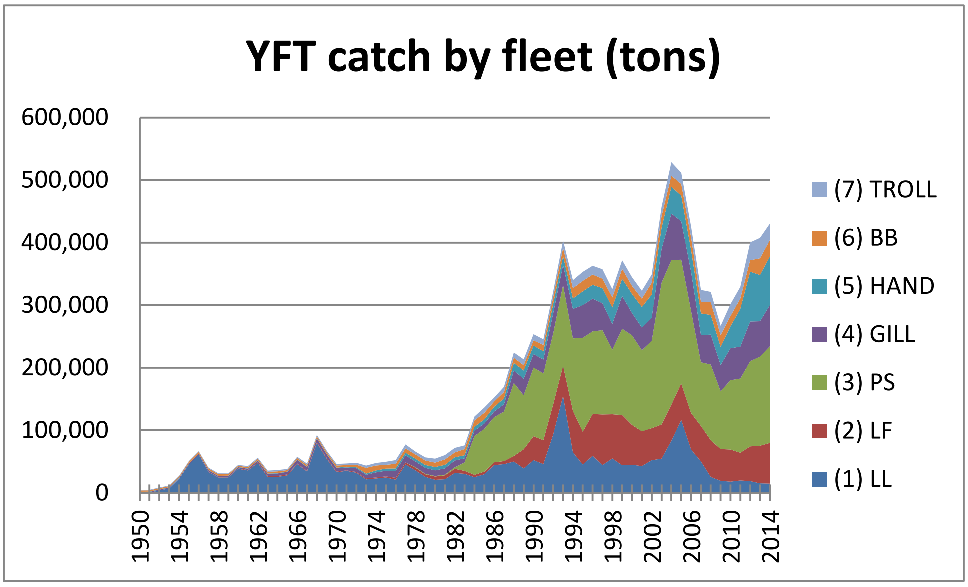


Fig. 1 YFT annual catch trends for 7 fleets (1950-2014)

(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.

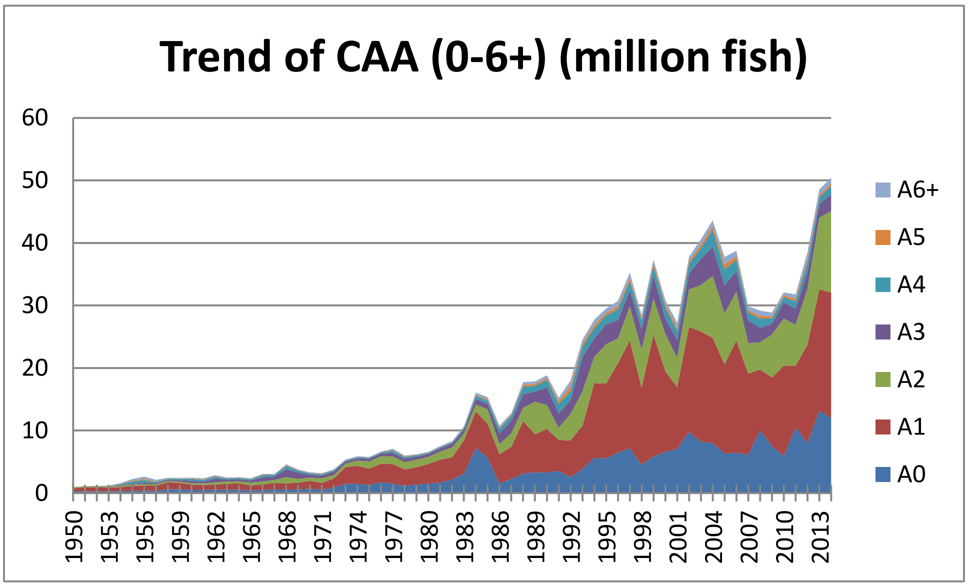
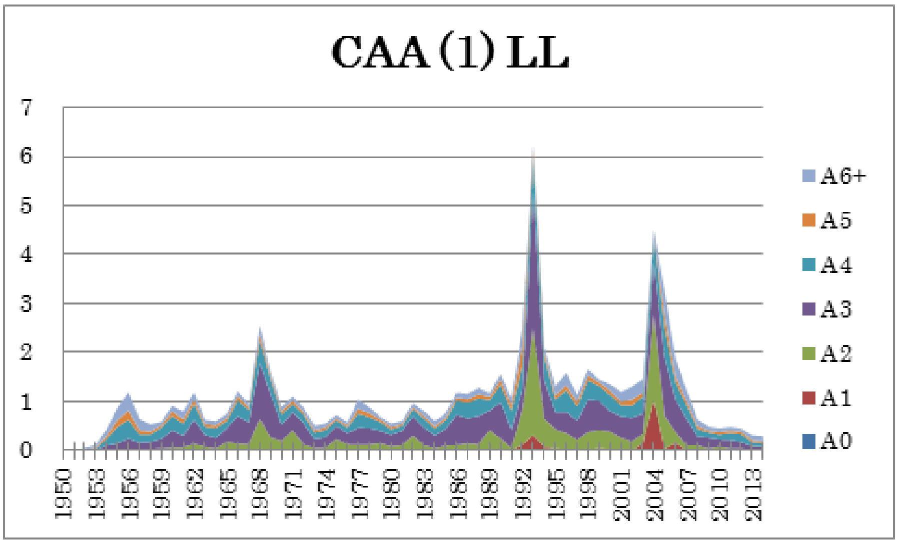
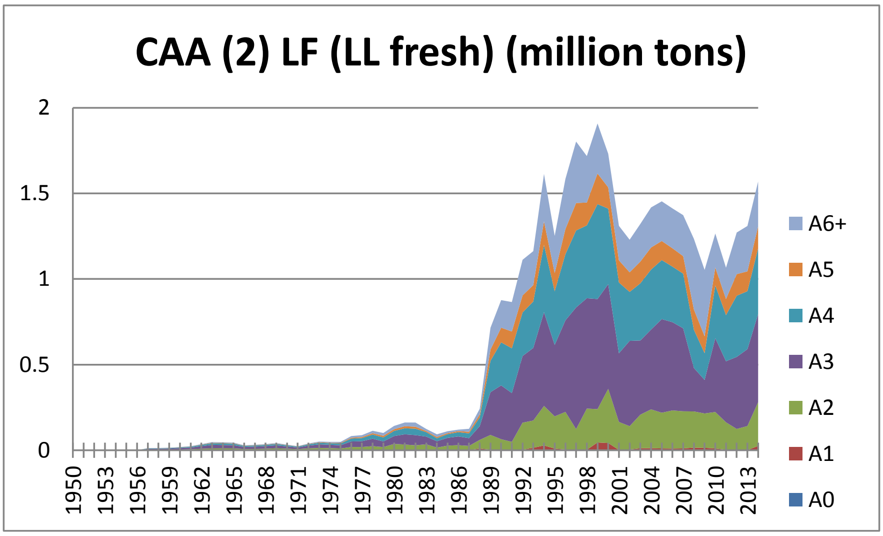


Fig. 2 Trends of annual total CAA (age 0-6+)





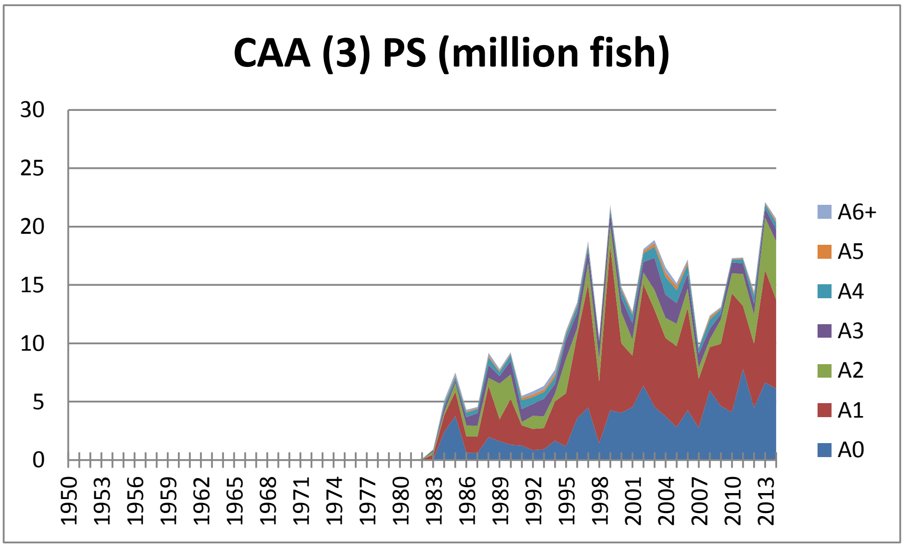


Fig.2 Annual CAA by fleet (1/3)

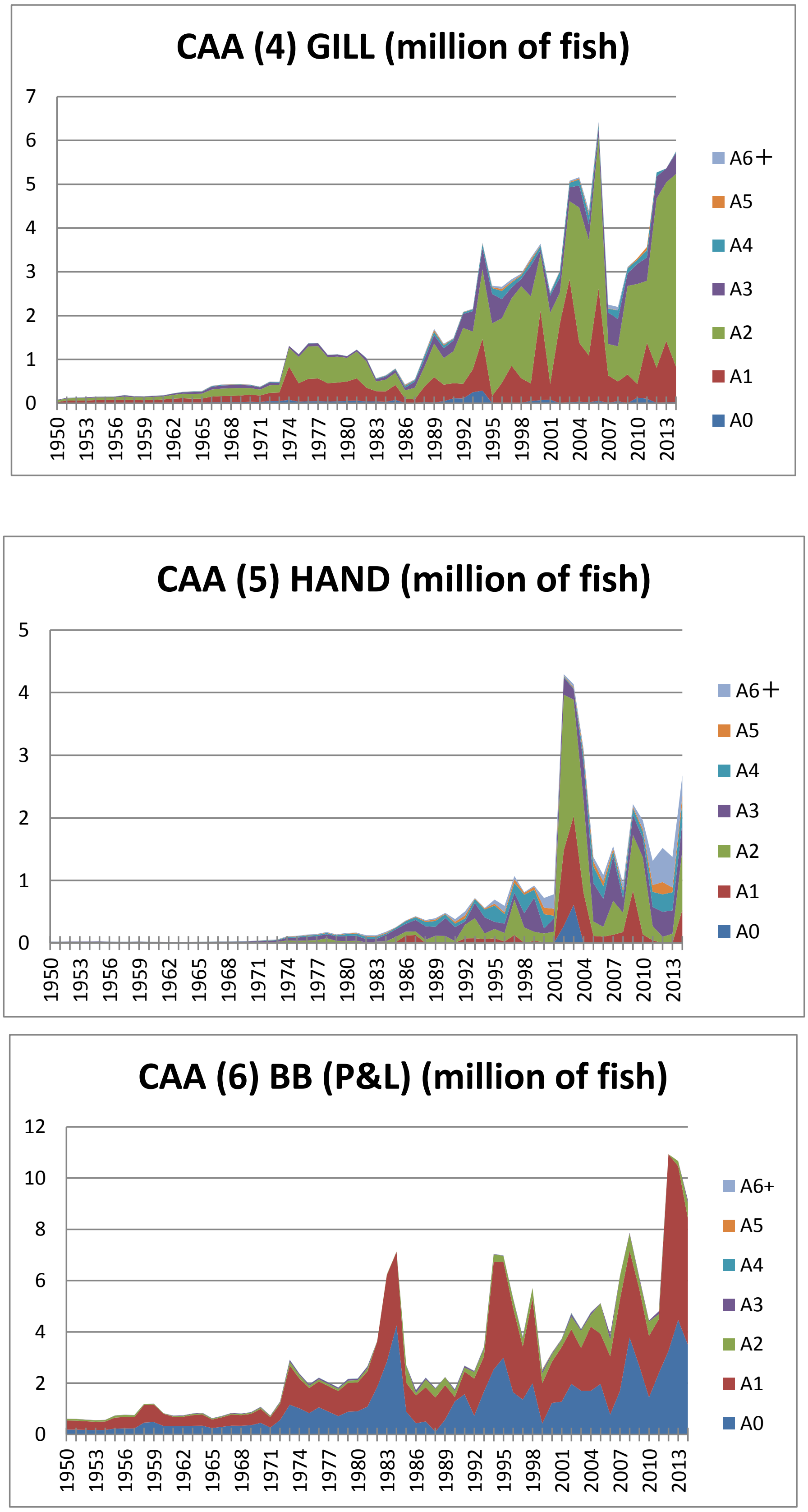


Fig.2 Annual CAA by fleet (2/3)

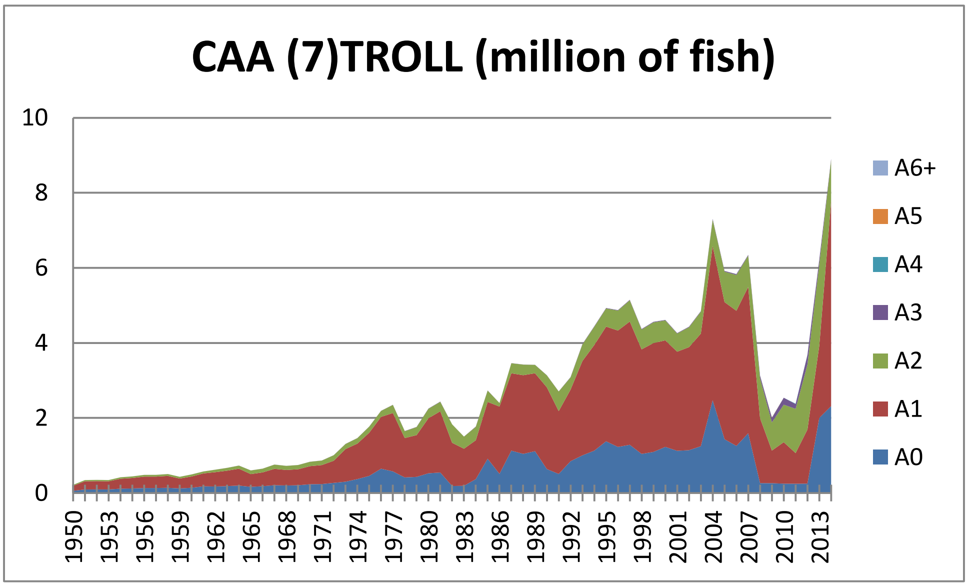


Fig.2 Annual CAA by fleet (3/3)

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

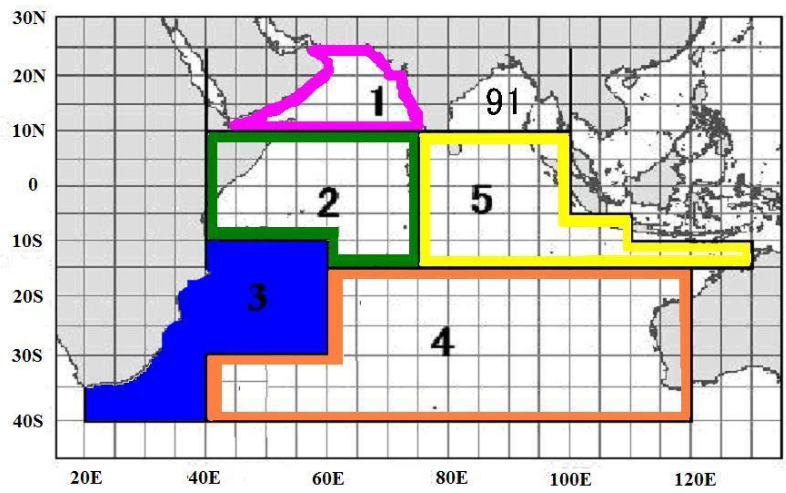


Fig.3 Sub-areas used in the GLM for YFT STD CPUE (Ochi et al, 2015)
Aggregated annual STD_CPUE based on 2 areas model (23 combined and 5) are used.

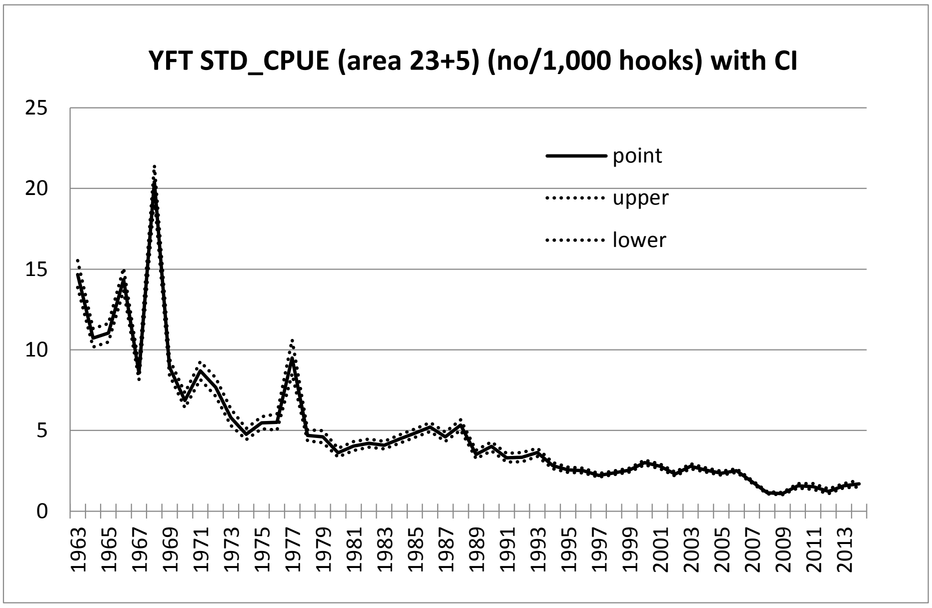


Fig. 4 Estimated YFT STD_CPUE (Ochi et al, 2015)

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).

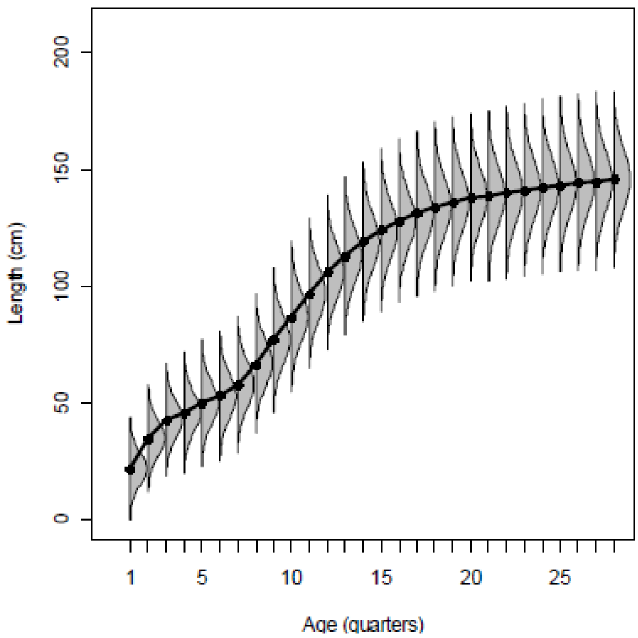


Fig. 5 YFT growth curve (Fonteneau, 2008)

(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.

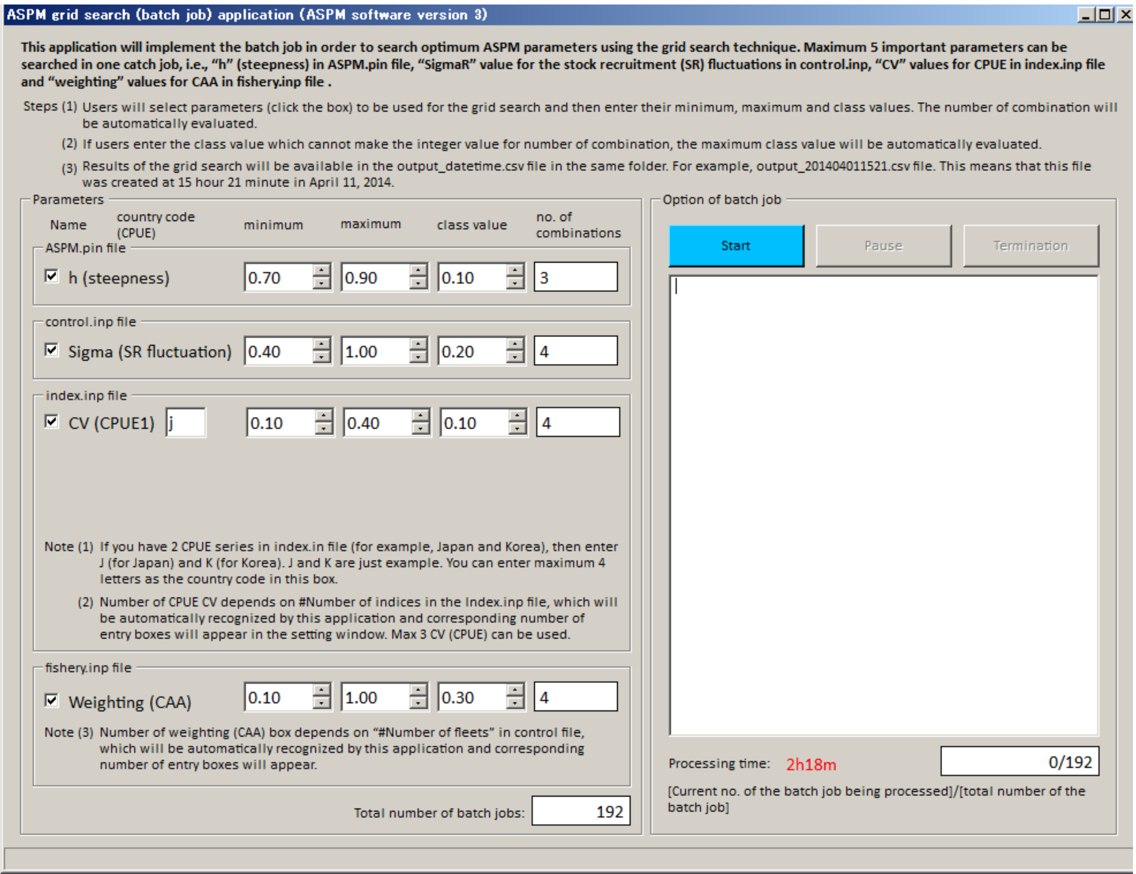
Table 4 Seeding values of selectivity by fleet in the initial SCAA run for base case

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, Sigma(SR)=0.4, CV(CPUE)=0.2 and Weight (CAA)=0.1. Results are shown in Figs 6-8.

Box 1 Grid search



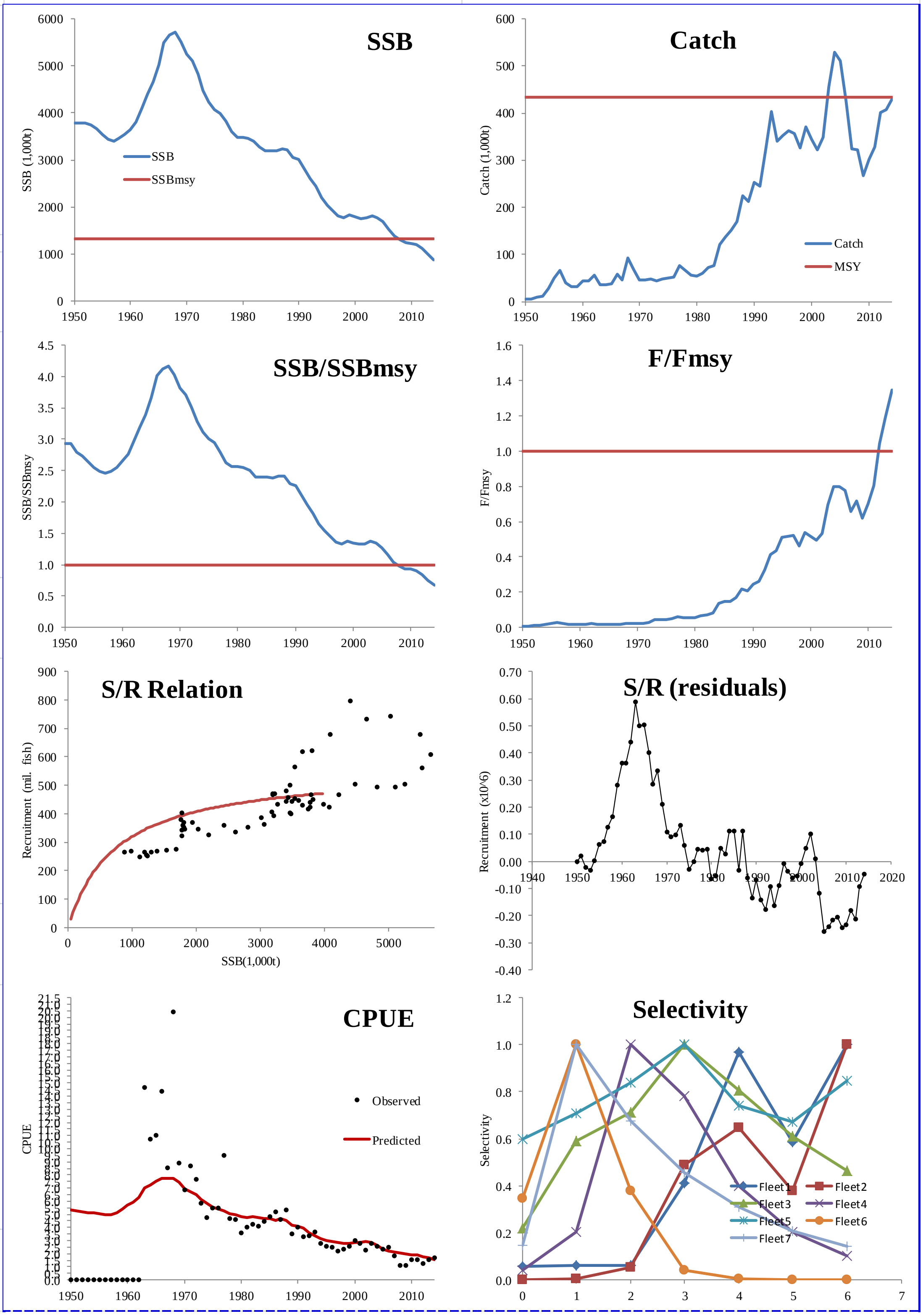


Fig. 6 Results of SCAA base case

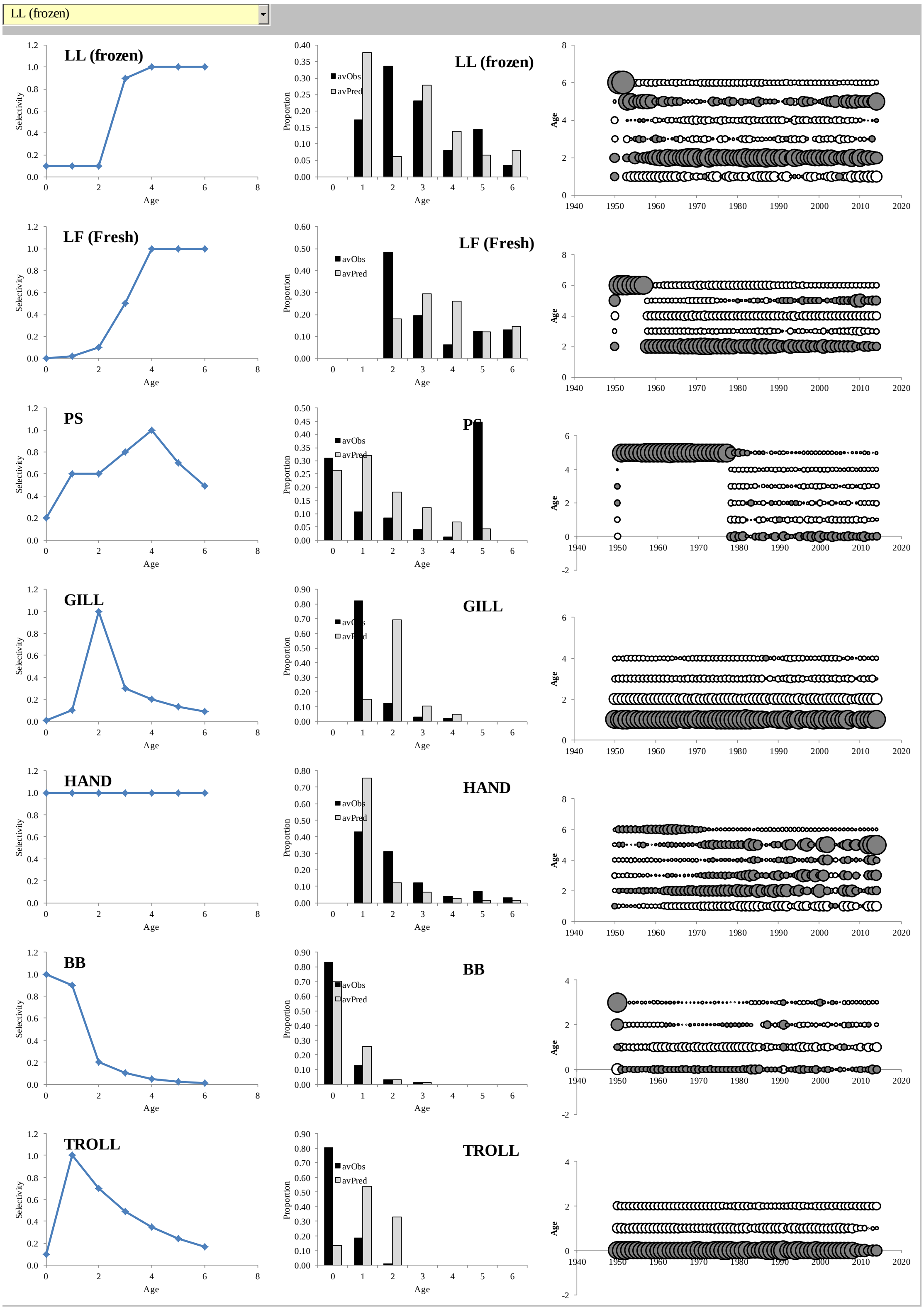


Fig. 7 Results of SCAA run (selectivities)

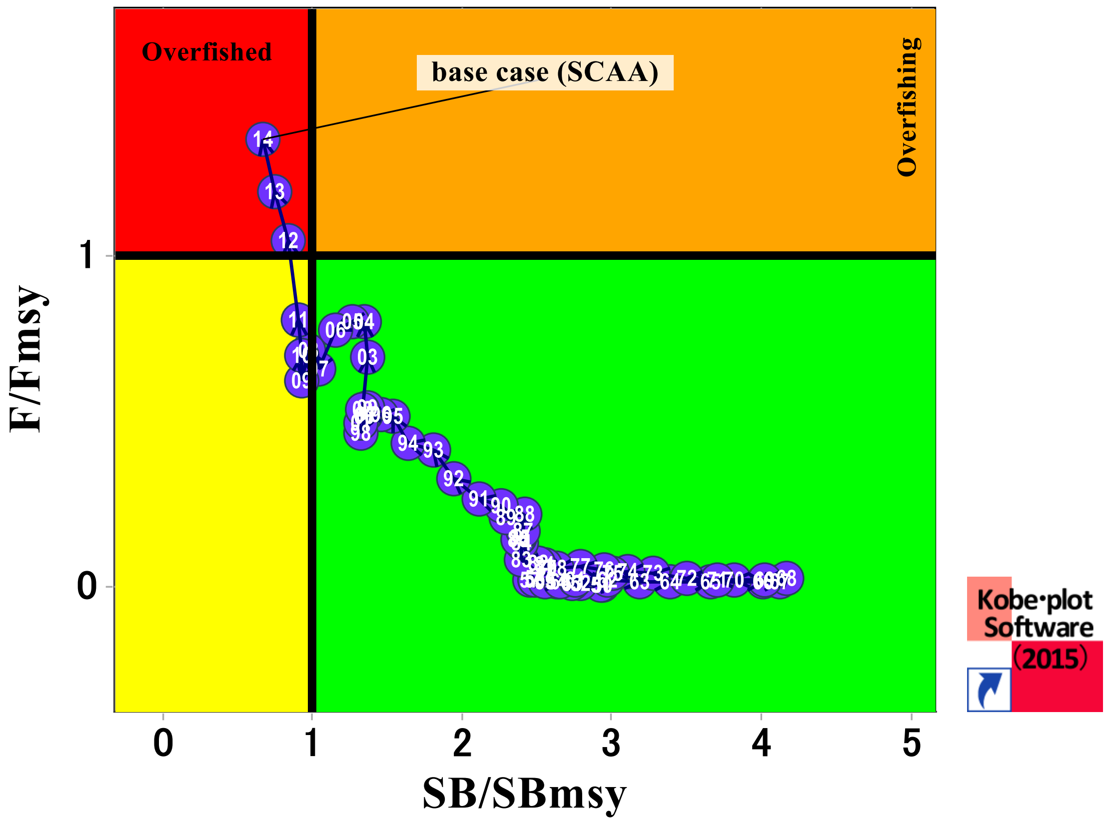


Fig 8 Kobe plot (base case)

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

Management Quantity	ASPM/SCAA software (Nishida et all) http://ocean-info.ddo.jp/kobeaspm/aspm/ASPM.zip
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)	1950-2015
CPUE	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)

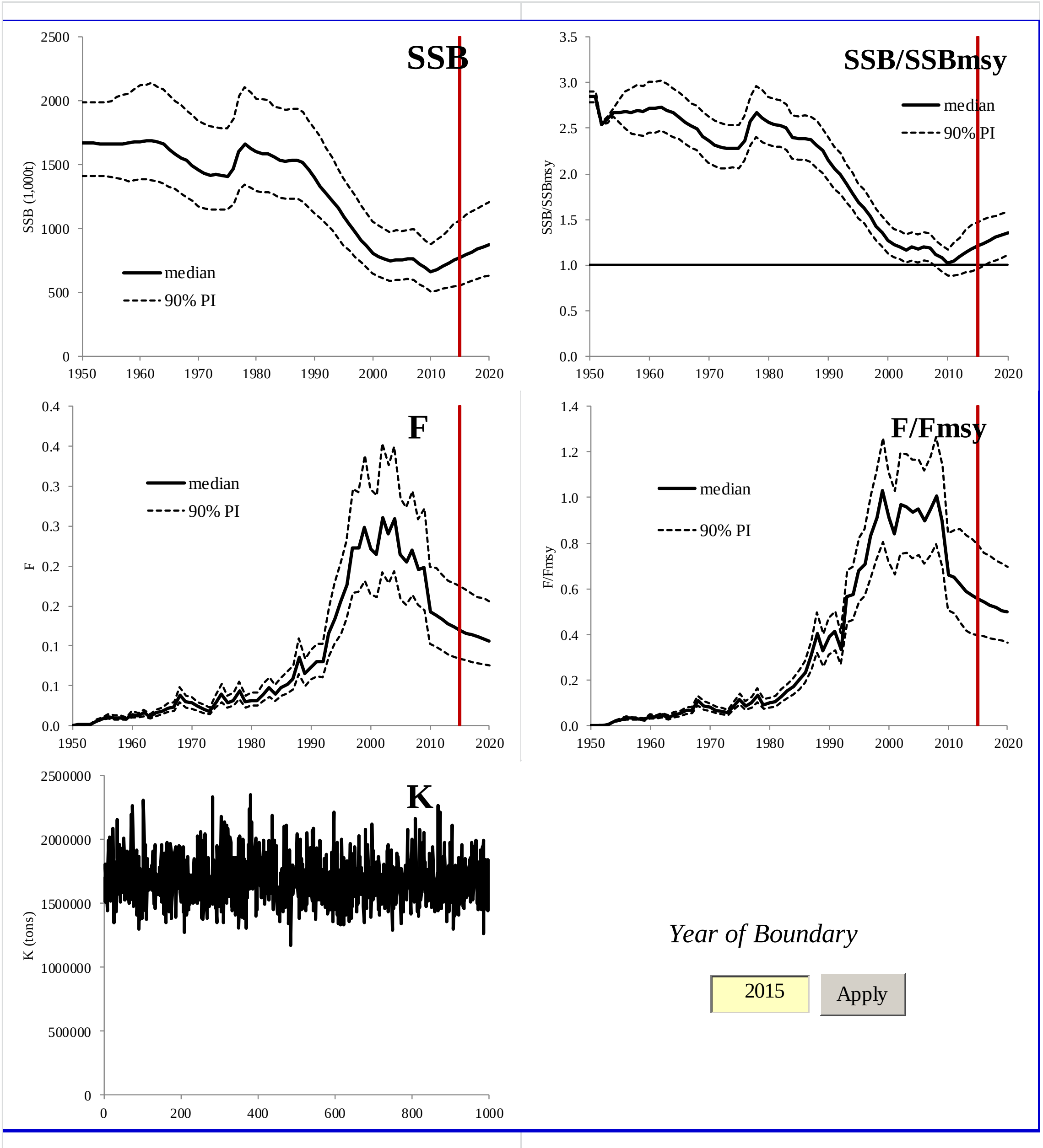


Fig. 8 Future projection by MCMC based on recent catch level (average catch in 3 years: 2012-2014).

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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