Received: 13, 17 & 28 October, 2012

IOTC-2012-WPTT14-40 Rev_2

Stock and risk assessments on yellowfin tuna (*Thunnus albacares*) in the Indian Ocean by AD Model Builder implemented Age-Structured Production Model (ASPM) and Kobe I + II software

Tom Nishida [1/], Rebecca Rademeyer [2/], Hirotaka Ijima [1/], Keisuke Sato [1/], Takayuki Matsumoto [1/], Toshihide Kitakado [2/] and Alan Fonteneau [4/]

1/ National Research Institute of Far Seas Fisheries, Fisheries Research Agency, Shimizu, Shizuoka, Japan

2/ University of Cape Town, Cape Town, South Africa

3/ Tokyo University of Marine Science and Technology, Tokyo, Tokyo, Japan

4/ IRD (Emeritus scientist), France

October, 2012

Abstract

We applied AD Model Builder implemented Age-Structured Production Model (ASPM) to assess the status of the yellow tuna stock in the Indian Ocean using 62 years of data (1950-2011). Results of the final ASPM indicate that the fishing effort (2011) is below the MSY level (F/Fmsy=0.61), while the spawning stock biomass (SSB) is above the MSY level (SSB/SSBmsy=1.35). The current catch (2011) is 303,000 tons which is below the MSY (320,000 tons). From these results, it is suggested that the catch level should not exceed the MSY level (320, 000 ton).

Contents

Submitted to the IOTC 14th WPTT (Working Party on Tropical Tuna) meeting, Oct., 24-29, 2012, Mauritius

1. Introduction

We attempted stock and risk assessments on yellowfin tuna (*Thunnus albacares*) (YFT) in the Indian Ocean using AD Model Builder implemented Age-Structured Production Model (ASPM) software and Kobe I+II software for available data for 62 years (1950-2011). Details on ADMB_ASPM model are described in IOTC-2012-WPM04-11, i.e., Users' Guide of ADMB_ASPM software (Version 2 with enhanced graphic functions).

2. Input data

To implement ASPM, we used YFT annual nominal catch, standardized (STD) CPUE, CAA (catch-at-age) and also biological information. Biological information has been well improved by numerous YFT recoveries from latest tagging program. These input data are described as follows:

2.1 Catch by fleet

We used 9 types of fleet (gears) exploiting YFT in the Indian Ocean as listed in Table 1. Fig. 1 shows the annual nominal catch by fleet (sources of the data: IOTC Secretariat, 2012).

Table 1 List of 11 fleet type used in the ASPM runs

No	Code	Gear name
(1)	BB	Pole and line
(2)	TROLL	Troll line
(3)	GILL	Gillnet
(4)	PS(log)	Purse seine log school
(5)	PS(free)	Purse seine free school
(6)	HAND	Hand line
(7)	LL(fresh)	Tuna longline (fresh)
(8)	LL(frozen)	Tuna longline (frozen)
(9)	OTH	Other gears

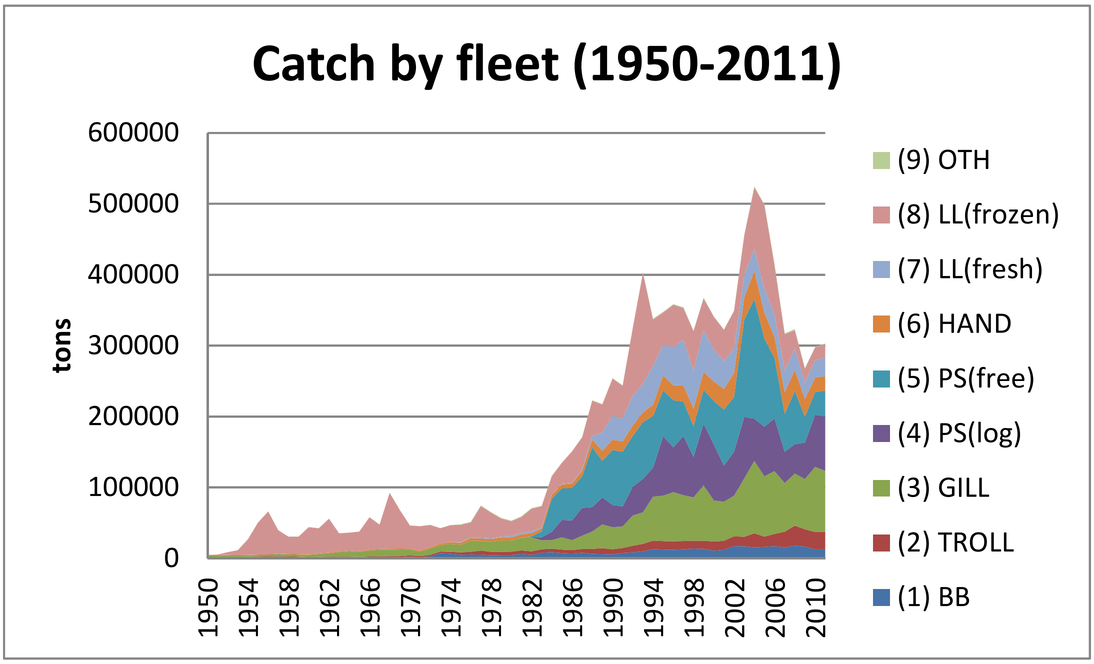


Fig. 1 Trends of YFT annual catch by fleet in weight (Source: IOTC Secretariat, 2012)

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

7 age composition are used (age0-age6+). Fig. 2 shows the catch-at-age (CAA) estimated by the IOTC Secretariat (2012). Fig 2(1)-Fig 2(9) show the CAA by fleet type.

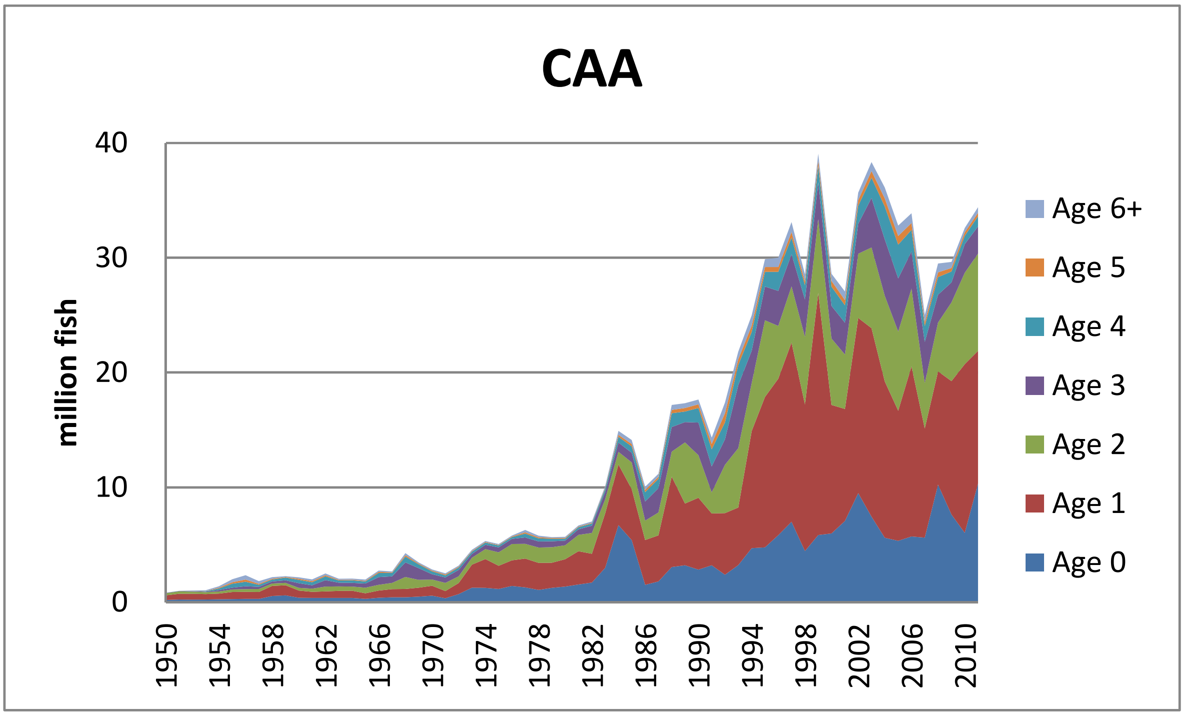


Fig. 2 Trend of annual catch-at-age

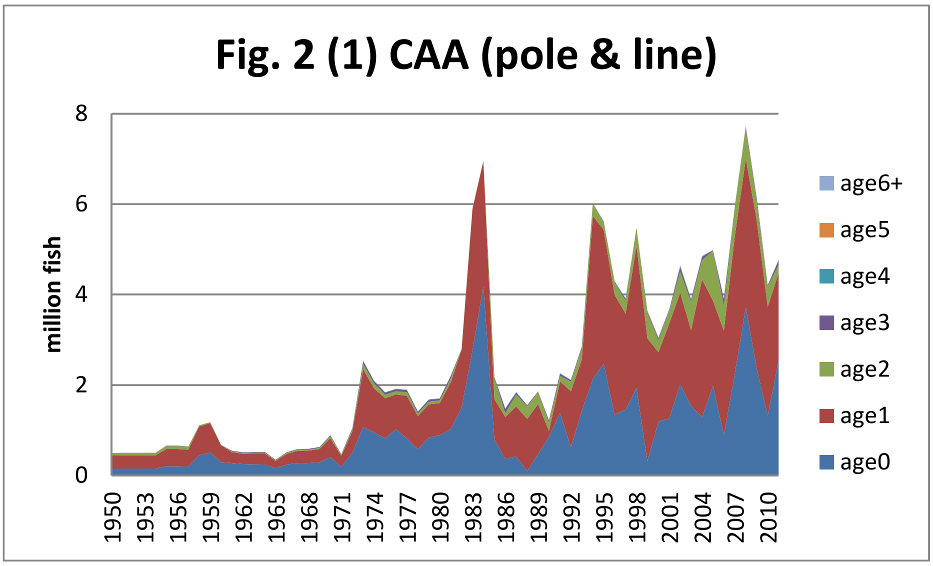


Fig. 2 (1) CAA (pole & line)
million fish
8
6
4
2
0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
age6+
age5
age4
age3
age2
age1
age0

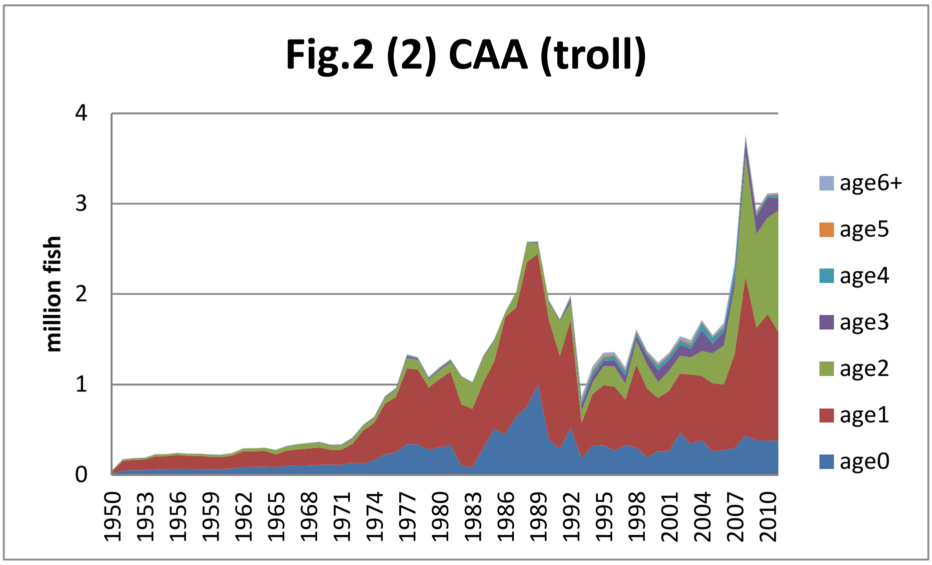


Fig.2 (2) CAA (troll)
million fish
4
3
2
1
0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
age6+
age5
age4
age3
age2
age1
age0

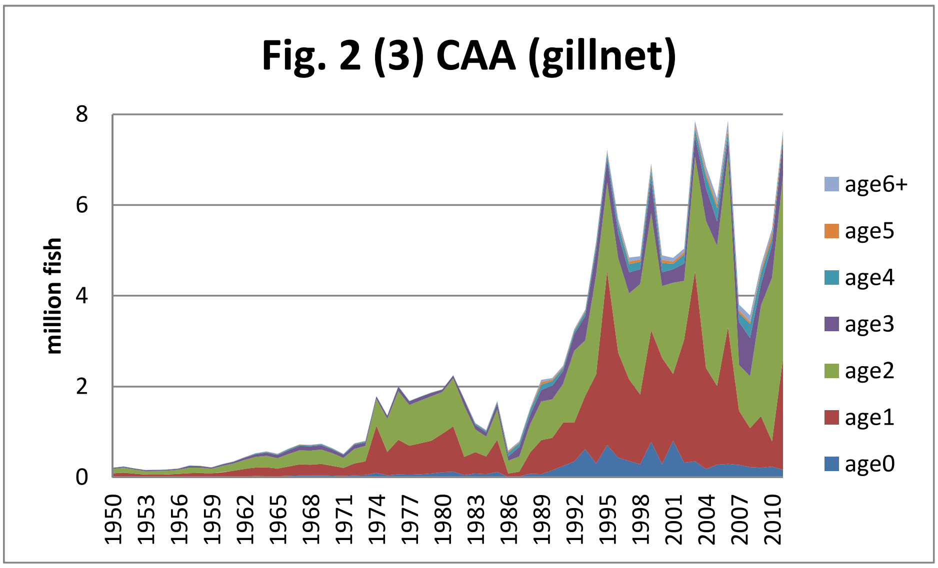


Fig. 2 (3) CAA (gillnet)
million fish
8
6
4
2
0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
age6+
age5
age4
age3
age2
age1
age0

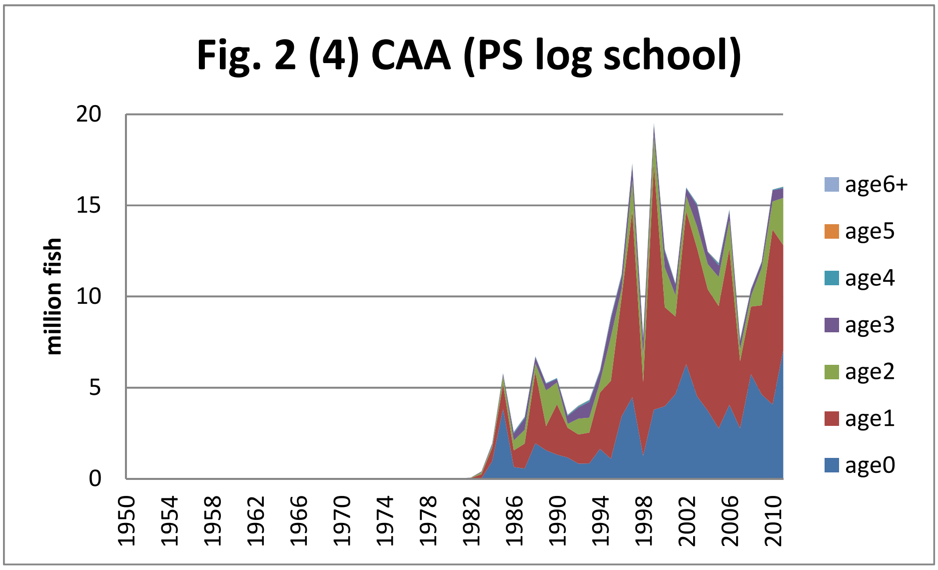


Fig. 2 (4) CAA (PS log school)
million fish
20
15
10
5
0
1950
1954
1958
1962
1966
1970
1974
1978
1982
1986
1990
1994
1998
2002
2006
2010
age6+
age5
age4
age3
age2
age1
age0

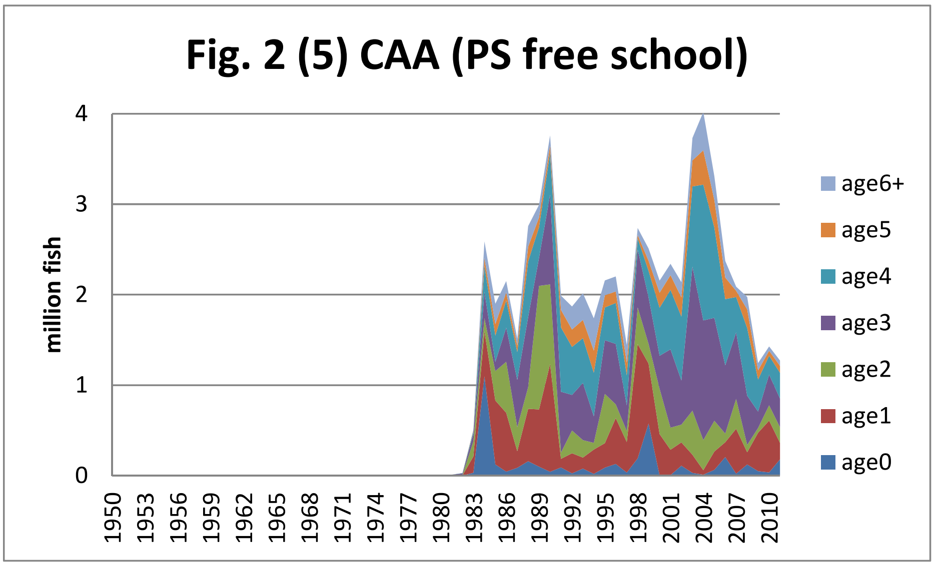


Fig. 2 (5) CAA (PS free school)
million fish
4
3
2
1
0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
age6+
age5
age4
age3
age2
age1
age0

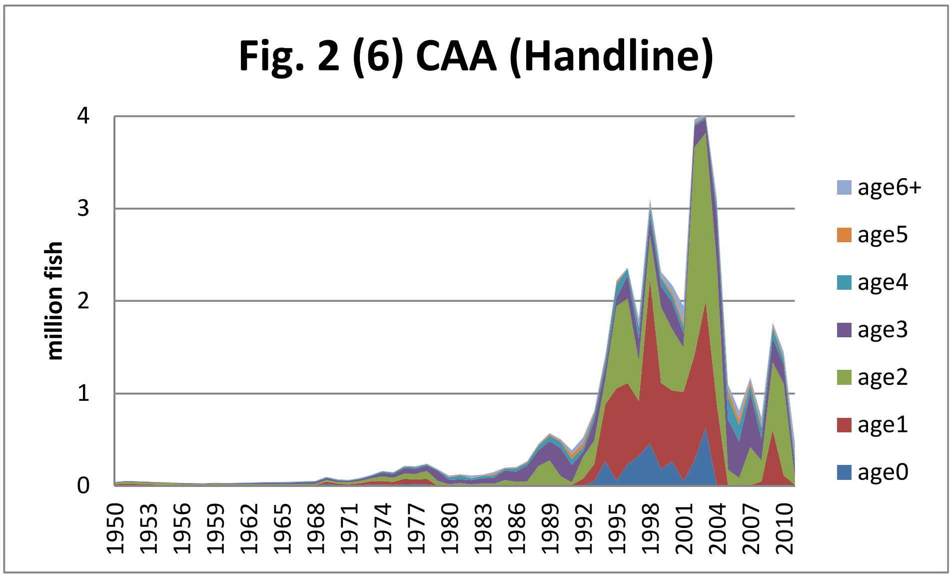


Fig. 2 (6) CAA (Handline)
million fish
4
3
2
1
0
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
age6+
age5
age4
age3
age2
age1
age0

Fig. 2 (7) LL (fresh)

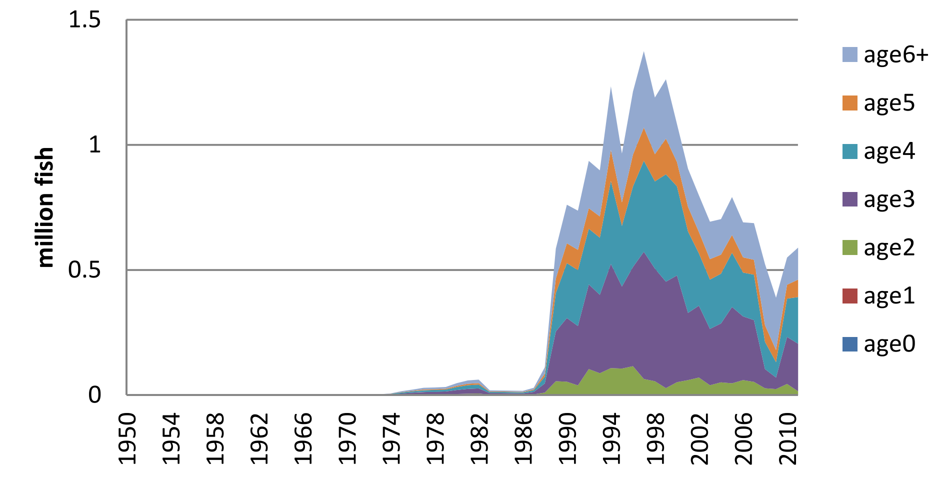


Fig. 2 (8) LL(Frozen)

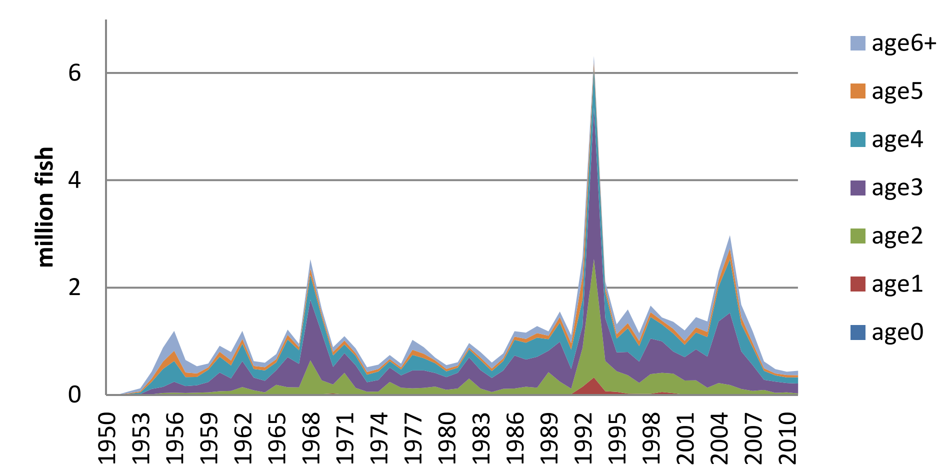
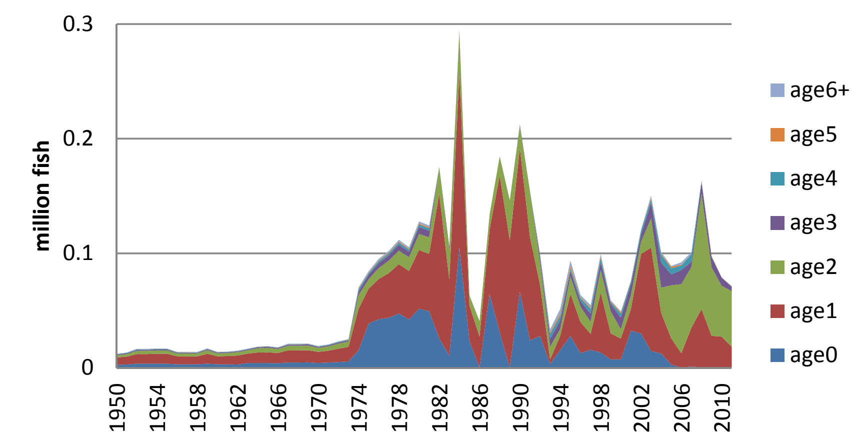


Fig. 2 (9) CAA (others)



2.3 Plus and minus group

In the ADMB_ASPM, plus and minus groups need to be set up, in order to implement robust optimizations. 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 1).

Table 1 Minus and plus group determined based on compositions of CAA by age.

No	Code	Minus group	Plus group	Period of available CAA data
(1)	BB		Age 2+	Whole (1950-2011)
(2)	TROLL		Age 2+	
(3)	GILL		Age 4+	
(4)	PS(log)		Age 3+	1977-2011
(5)	PS(free)		Age 6+	
(6)	HAND		Age 5+	Whole (1950-2011)
(7)	LL(fresh)	Age 2-	Age 6+	1973-2011
(8)	LL(frozen)	Age 2-	Age 6+	1952-2011
(9)	OTH		Age 4+	Whole (1950-2011)

2.4 Spatial and stock structure

As ASPM does not have the spatial components, ASPM is the space aggregated model. We assume that YFT is a single stock. We consider that YFT stock is fully mixed at the scale of the entire Indian Ocean and make fast and wide movements based on the result partially confirmed by the tagging recovery data.

2.5 Standardized (STD) CPUE

As for the base case run, we used the Japanese STD CPUE by Matsumoto et al (2012), which has 8 cases of STD CPUE (2 periods x 4 different areas). 4 different areas mean all fishing areas (2-5) and main areas (2, 3 and 5) with and without area 2 (Fig 3 and Table 2). Please note that, in 2011, there were no Japanese tuna longline fisheries (no CPUE data) in area 2 (off Somalia) due to the pirate activities. That is why Matsumoto et al (2012) made STD CPUE with area 2 (no 2011 data) and without area 2 for 4 cases (2 periods and 2 fishing grounds) (Table 2).

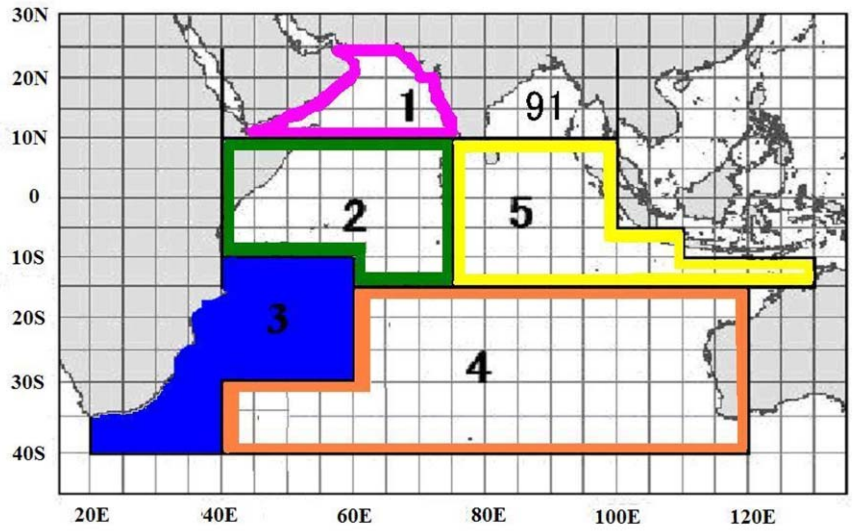


Fig.3 Sub-areas used in the GLM for YFT STD CPUE (Matsumoto et al, 2012)
All fishing areas: 2-5 and Main fishing areas: 2, 3 and 5. Areas 1 (Taiwan) and 91 were not used.

Table 2 Eight (8) cases of Japanese STD CPUE (Matsumoto et al, 2012)

Period	1963-2011				1980-2011			
Fishing area (Fig. 3)	All		Main		All		Main	
case no.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Area 2 (2011 data are excluded)								
Area 3								
Area 4								
Area 5								
r2	0.46	0.57	0.48	0.59	0.42	0.50	0.43	0.51
Best result				Best and used for base case				

We examined the relations to see there are negative correlations between STD CPUE vs. total catch, in order to evaluate good STD CPUE series. Then, it was resulted that STD CPUE in the longer period (1963-2011) showed better negative correlations than in the shorter period (1980-2011). In addition, it was also found that main fishing areas performed better than in all areas. It was further resulted that STD CPUE without area 2 performed better than those with area 2 excluding the 2011 data. As a conclusion, we selected the best case no. (4), i.e., STD CPUE in the main fishing ground with areas 3 and 5 (no area 2) in 1963-2011 for the base case ASPM run.

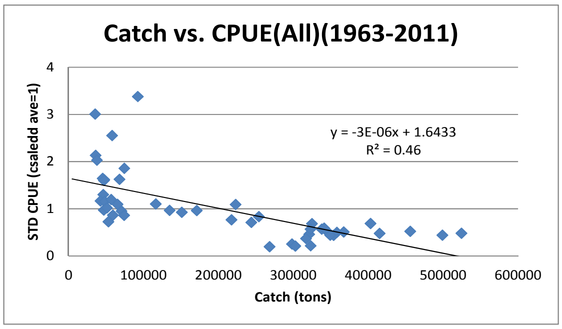
2.6 Biological information

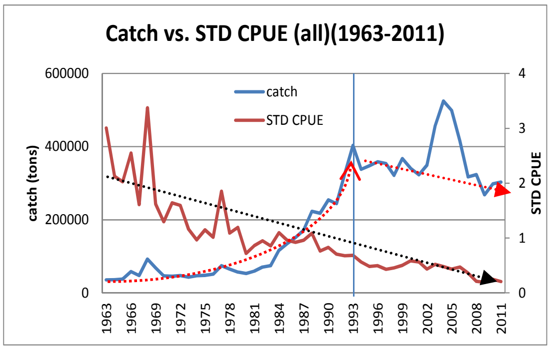
In the ASPM, three types of age-specific biological inputs are needed, i.e., natural mortality-at-age (*M*), weights-at-age (beginning and mid-year) and maturity-at-age.

(1) Age specific natural mortality (M)

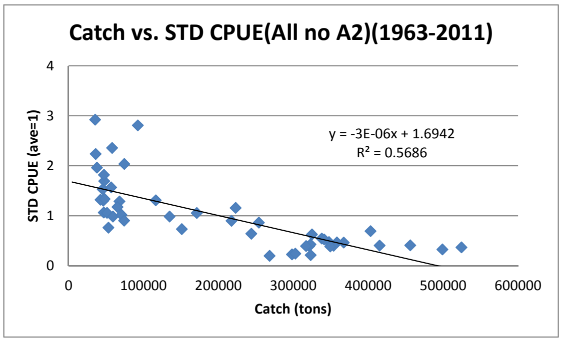
We applied M used by the ICCAT, i.e., 0.8 for age 0-1 and 0.6 for age 2 or older.

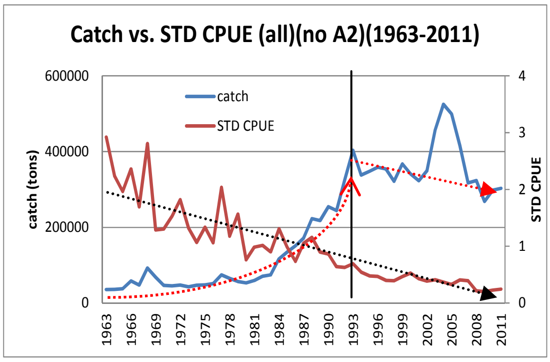
<table>
<tr><th>No</th><th>Catch vs. STD CPUE
(scatterplots)</th><th>Catch vs. STD CPUE
(annual trends)</th></tr>
<tr><td>(1)

All
2
3
4
5</td><td>

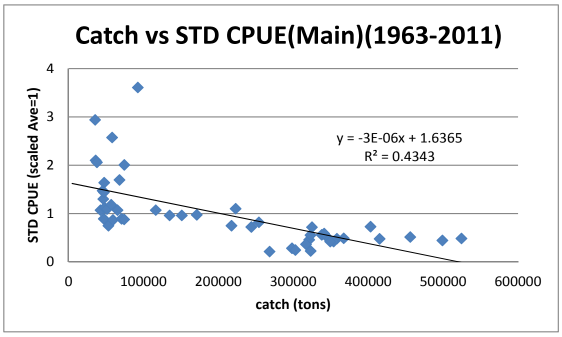
r2=0.46</td><td>
</td></tr>
<tr><td>(2)

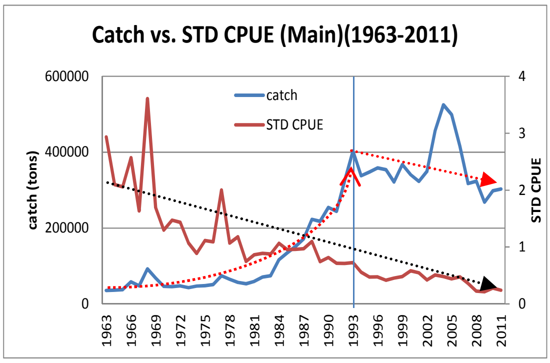
All

3
4
5</td><td>

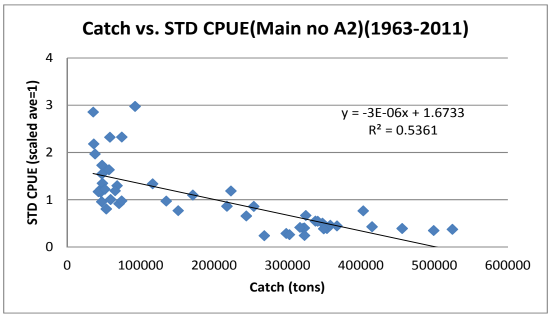
r2=0.57</td><td>
</td></tr>
<tr><td>(3)

Main

2
3
5</td><td>

r2=0.48</td><td>
</td></tr>
<tr><td>(4)

Main

3
5</td><td>

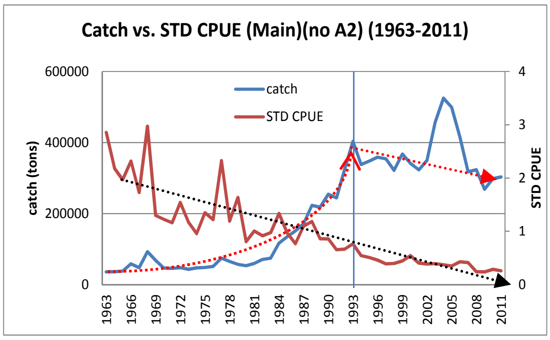
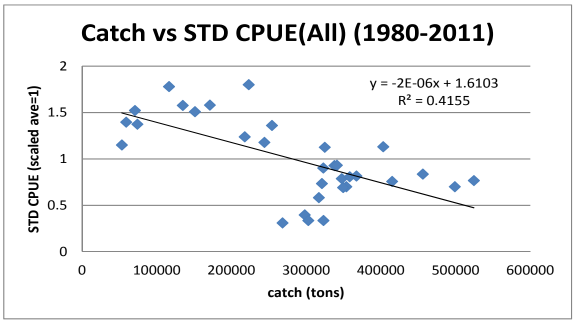
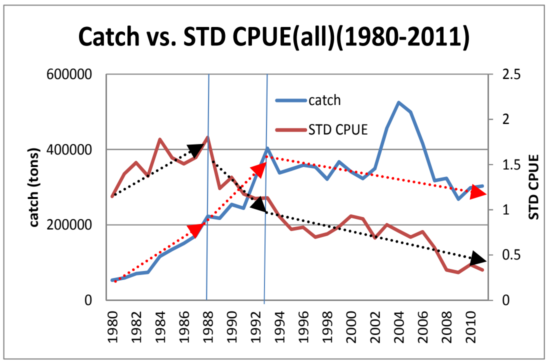
r2=0.59 (Best)</td><td>
</td></tr>
<tr><td>feature</td><td>Generally there are negative (realistic) correlations between catch vs. STD CPUE
(ave r2=0.52)</td><td>There are 2 periods in relations between catch vs. STD CPUE, i.e., the first one (1980-1993) for negative (realistic) correlations and the 2nd one (1993-2011) for positive (unrealistic).</td></tr>
</table>

Fig. 3 Comparisons between catch vs. Japanese STD CPUE (1963-2011)

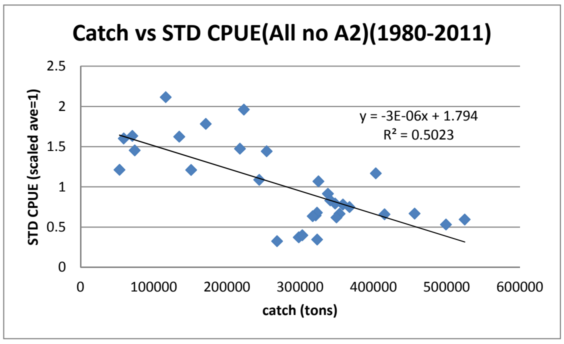
(Left) scatterplots and (Right) annual trends

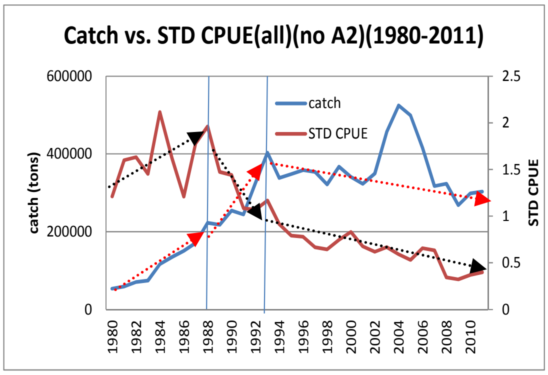
<table>
<tr><th>No</th><th>Catch vs. STD CPUE
(scatterplots)</th><th>Catch vs. STD CPUE
(annual trends)</th></tr>
<tr><td>(1)

All
2
3
4
5</td><td>

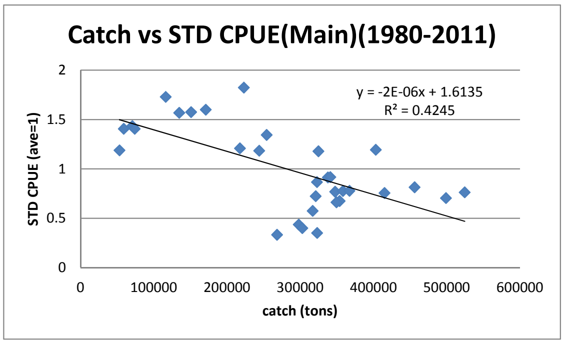
r2=0.42</td><td>
</td></tr>
<tr><td>(2)

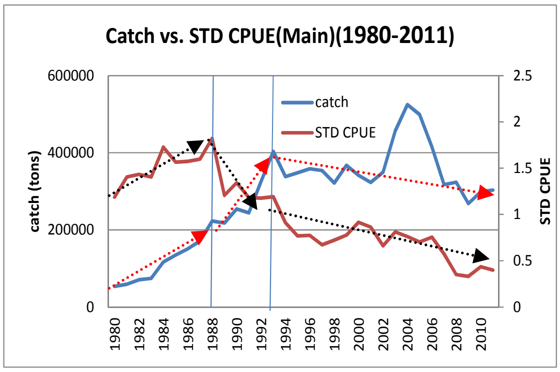
All

3
4
5</td><td>

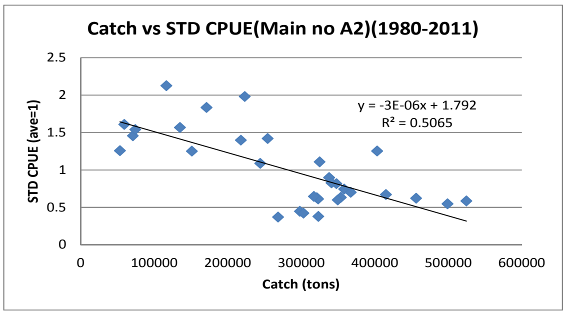
r2=0.50</td><td>
</td></tr>
<tr><td>(3)

Main

2
3
5</td><td>

r2=0.43</td><td>
</td></tr>
<tr><td>(4)

Main

3
5</td><td>

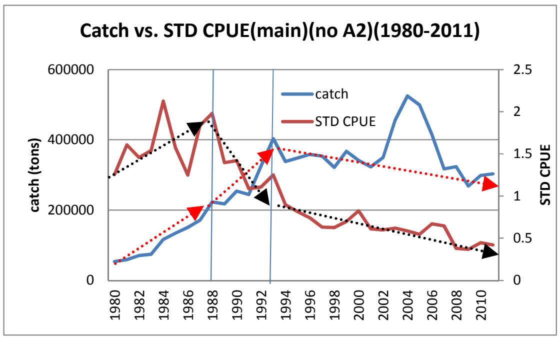
r2=0.51</td><td>
</td></tr>
<tr><td></td><td>Generally there are negative (realistic) correlations between catch vs. STD CPUE
(ave r2=0.46)</td><td>There are 3 different periods in relations between catch vs. STD CPUE, i.e., 2 periods (1980-88 and 1993-2011) show positive (unrealistic) correlations and the other one (1989-92) for negative (realistic)</td></tr>
</table>

Fig. 4 Comparisons between catch vs. Japanese STD CPUE (1980-2011)

(Left) scatterplots and (Right) annual trends

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

Beginning- and mid-year weights-at-age were estimated as follow: (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, 2012) and the conversion factor for (Whole weight) =(GGT)*1.13 (IOTC, 2012), beginning- and mid-year weights-at-age were computed (Table 3).

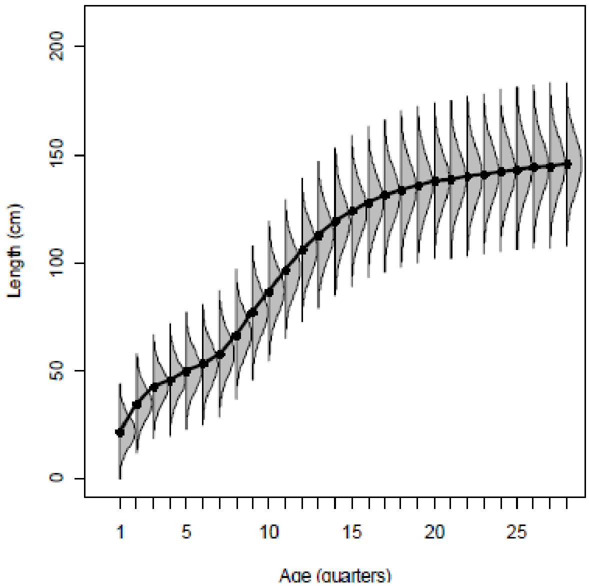


Fig. 5 YFT growth curve (Fonteneau, 2008)

(3) Maturity-at-age

By referring to the YFT executive summary (IOTC, 2011), Ijima et al (2012) and Langley et al (2012), we assume that maturity rate is 0% at ages 0-1, 50% at age 2 and 100% ages 3 or older (Table 3).

Table 3 Summary of age specific M, weight and maturity

Age	M(ICCAT)	weight-at-age (ton)		maturity-at-age(%)
		beginning	middle	
0	0.8	0.00017	0.00136	0
1	0.8	0.00218	0.00347	0
2	0.6	0.00841	0.01732	50
3	0.6	0.02792	0.03733	100
4	0.6	0.04432	0.04983	100
5	0.6	0.05286	0.05604	100
6+	0.6	0.05864	0.06077	100

3. Initial ASPM run (Base case)

We attempted the initial ASPM (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 ASPM run for base case

Age	0	1	2	3	4	5	6
(1) BB	0.31	1.00	0.17				
(2) TROLL	0.35	1.00	0.27				
(3) GILL	0.04	0.28	1.00	0.40	0.24		
(4) PS(log)	0.27	1.00	0.74	0.37			
(5) PS(free)	0.01	0.09	0.27	1.00	0.89	0.64	0.47
(6) HAND	0.05	0.13	0.37	0.85	0.99	1.00	
(7) LL(fresh)			0.02	0.81	1.00	0.97	0.88
(8) LL(frozen)			0.35	0.87	1.00	1.00	1.00
(9) OTHERS	0.16	0.30	1.00	0.47	0.59		

Then we used 5 types of steepness (h), i.e., estimated h and h=0.7, 0.8 and 0.9. But we could not get reasonable results (no conversion) with ICCAT Mi. As MFCL (Langley et al, 2012) used M (age 2 or older) (0.48-0.60) (ave 0.53), we changed to M=0.5 for age 2 or older as the alternative, then we got the reasonable results when h=0.9 which is defined as the base case. Table 5 shows these results and Figs 8-9 and Table 6 show the major results and Fig. 10 shows the Kobe plot I (stock trajectory).

Table 5 Results of the initial search of optimum steepness and M.

M	steepness	Steepness Fixed		
	Estimated	0.7	0.8	0.9
[ICCAT] 0.8 (age 0-1) 0.6 (age 2 or older)	[Not converged]	[Not converged]	[Not converged]	MSY=311,452 t SSB2011=288,143 t (SSB2011 : too low)
[ICCAT] 0.8 (age 0-1) [MFCL(Langley et al, 2012)] 0.5 (age 2 or older)	[Not converged]	[Not converged]	[Not converged]	MSY=308,279 t SSB2011=1,08,971 t [BASE CASE]

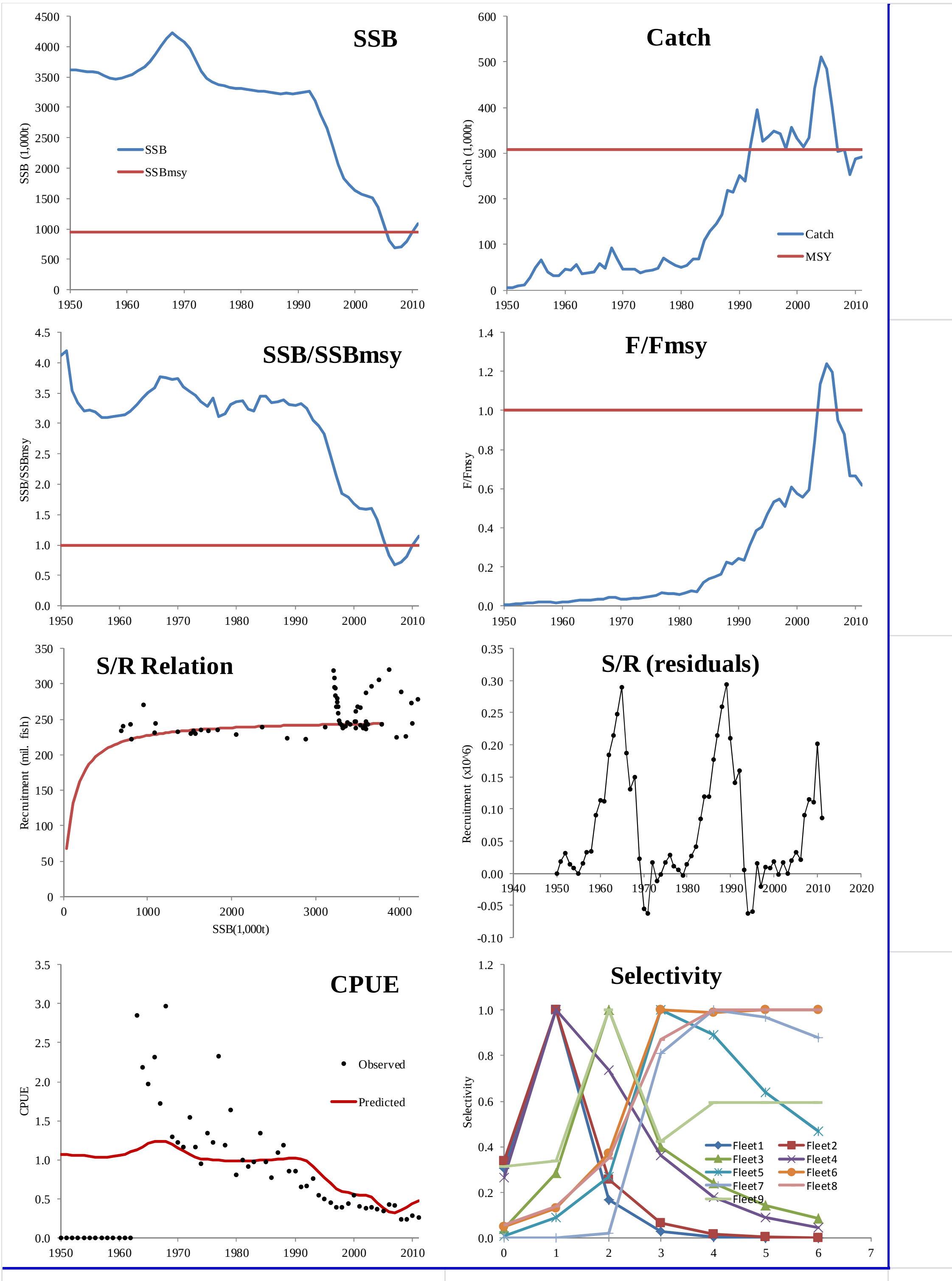
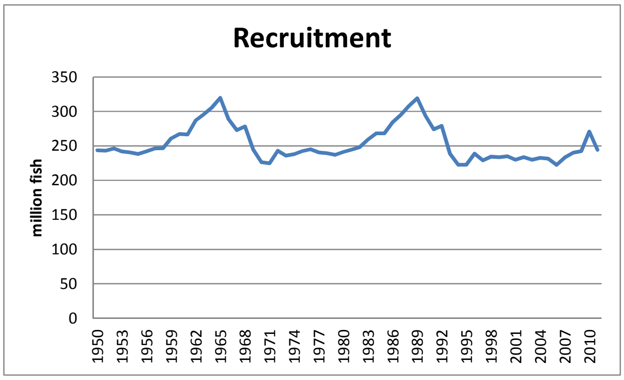


Fig. 8

Results of the initial ASPM run (base case)



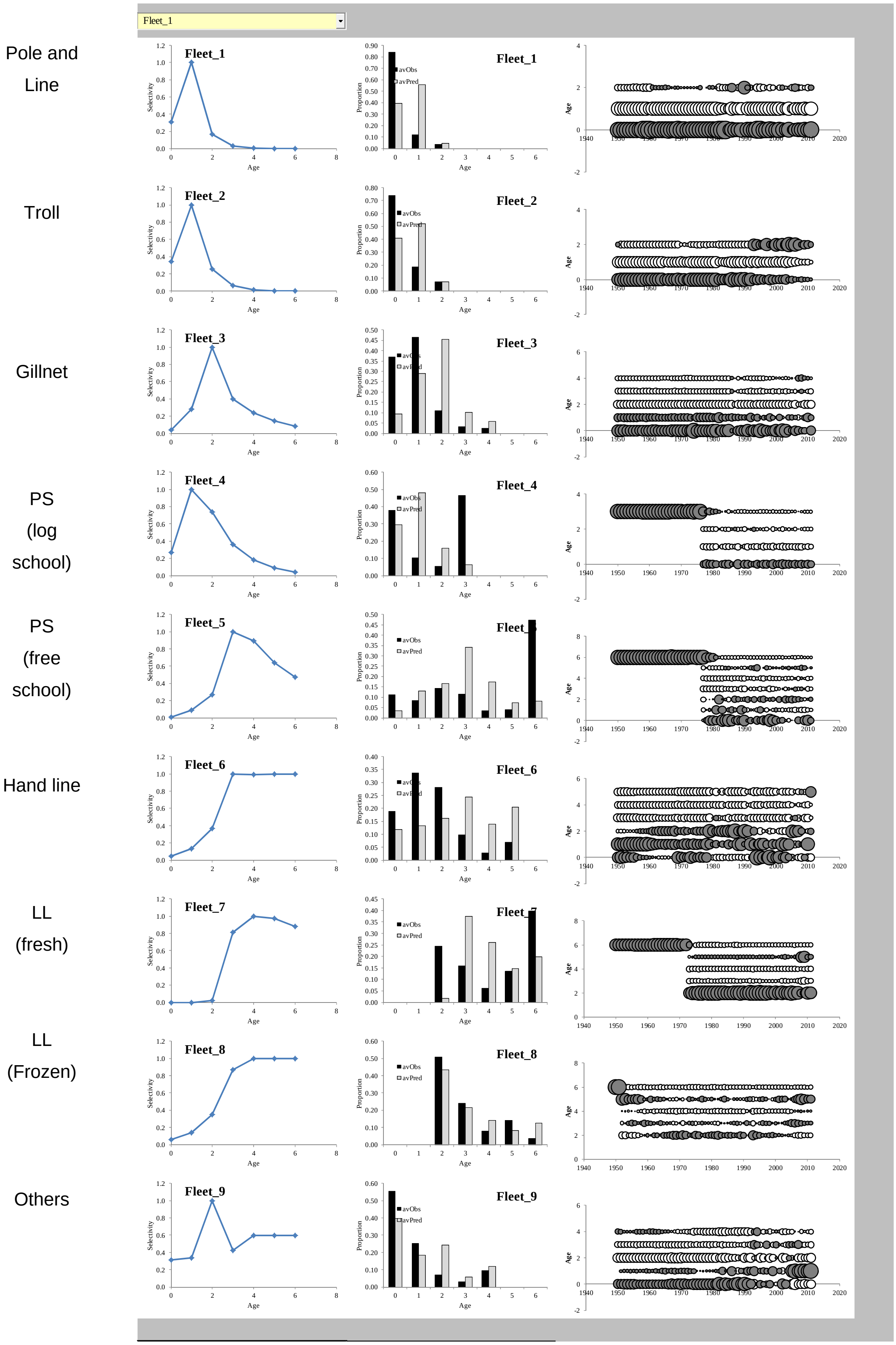


Fig. 9 Estimated selectivity by fleet and their residuals.

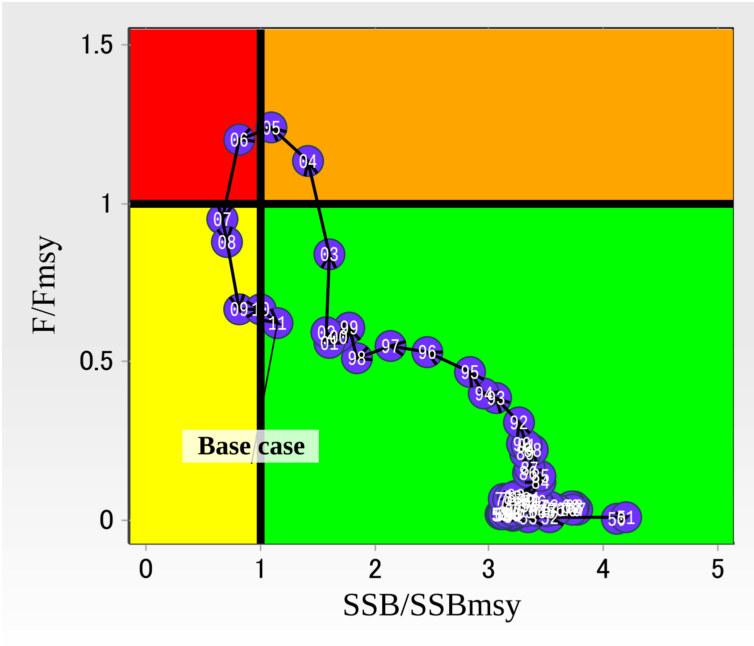


Fig 10 Kobe plot I (stock trajectory) (base case)

Table 6 Indian Ocean yellowfin stock status summary (ASPM base case)

Management Quantity	ASPM (Nishida et al, 2012) (this paper)
Most recent catch estimate (t) (2011)	302,939
Mean catch over last 5 years (t) (2007-2011)	302,064
h (steepness)	0.9 (fixed)
MSY (1,000 t) (80% CI)	308,279 (270,141-346,859)
Current Data Period (catch)	1950-2011
CPUE	Japan (annual) (tropical areas 3+5) (1963-2010)
F(Current)/F(MSY) (80% CI)	0.62 (0.32-0.92)
SSB(2011)/SSB(MSY) (80% CI)	1.15 (0.76-1.54)
TB(2011)/TB(MSY)	NA
SSB(2011)/SSB(0) (80% CI)	0.24 (NA)
TB(2011)/TB(0)	NA
SSB(2011) /SSB(Current, F=0)	NA

4. Final ASPM runs

Based on the discussion made after results of the first run was presented, we made the extra run which settings and results are shown below:

New settings

- M=1 .0 (age 0), M=0.5 (age 1), M=0.3 (age 2+) (approximate values of **Dortel** and **Eveson**)
- SR CV=0.6 (**SS3** and **MFCL**)
- JPN STD CPUE:
  MAIN fishing grounds (including sub-area 2)
- New growth curve : **Eveson**
- Starting year : 1950

Results (initial attempt)

h		
0.7	0.8	0.9
NC	NC	NC

NC: not converged

M may be too low?

We could not get convergences in the initial runs and we considered that M may too low. Thus we change lower M as shown below. Results are shown below and next 2 pages.

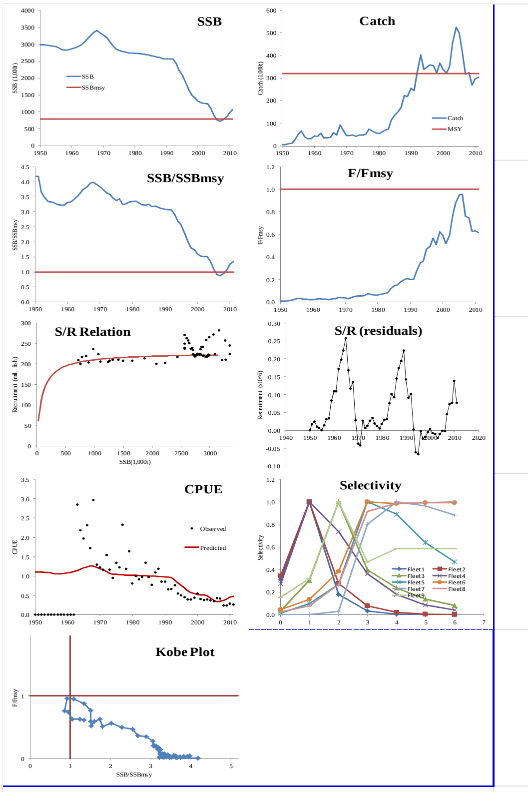
2nd attempt (lower M age 2+)

1.0 (age 0), 0.5 (age 1) and 0.4 (age 2+)

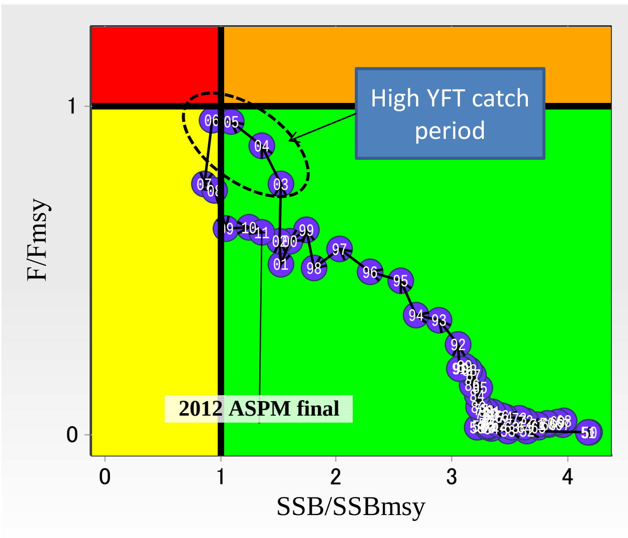
h		
0.7	0.8	0.9
NC	NC	MSY=320,403 B/Bmsy=1.35 F/Fmsy=0.61

NC: not converged

Major Results



Summary (final results)



MSY =320,000 t

Catch(2011) =303,000 t

Fratio=0.61

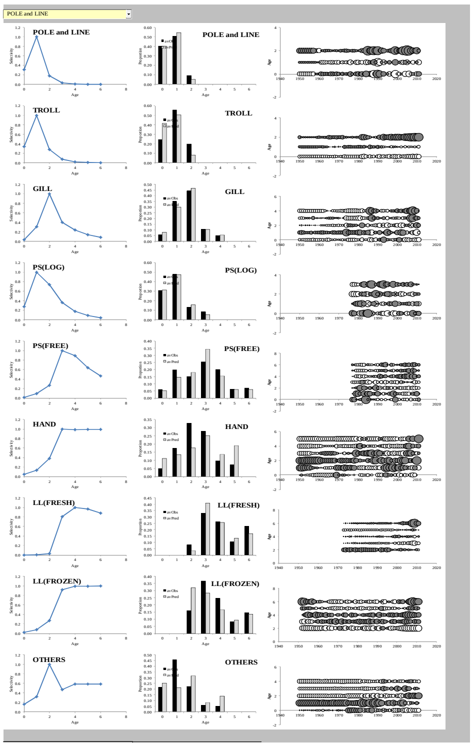
SSBratio=1.35

Green zone

Results
Selectivity

Reasonably estimated

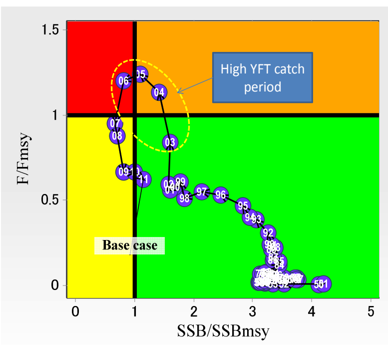
But
Some residuals show
odd patterns



Summary

Higher M
(ICCAT+ MFCL: base case)
0.8 0.8 and 0.5(age 2+)
Pessimistic

Summary
(Preliminary results)



MSY =308,000 t

Catch(2011) =303,000 t

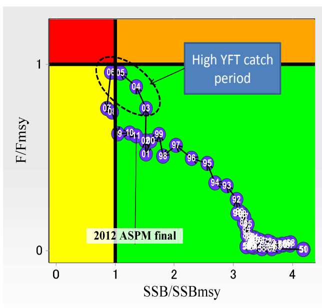
Fratio=0.62

SSBratio=1.15

Entering Green zone

Lower (middle level) M
(between base case and New M)
1.0, 0.5 and 0.4 (age 2+)
Optimistic

Summary
(final results)



MSY =320,000 t

Catch(2011) =303,000 t

Fratio=0.61

SSBratio=1.35

Green zone

Table 6 Indian Ocean yellowfin stock status summary (ASPM final run)

Management Quantity	ASPM (Nishida et al, 2012) (this paper)
Most recent catch estimate (t) (2011)	302,939
Mean catch over last 5 years (t) (2007-2011)	302,064
h (steepness)	0.9 (fixed)
MSY (80% CI)	320,403 (283,403-358,262)
Current Data Period (catch)	1950-2011
CPUE	Japan (annual) (Main fishing ground: area 2+3+4) (1963-2010)
F(Current)/F(MSY) (80% CI)	0.61 (0.31-0.91)
SSB(2011)/SSB(MSY) (80% CI)	1.35 (0.96-1.74)
TB(2011)/TB(MSY)	NA
SSB(2011)/SSB(0) (80% CI)	0.36 (NA)
TB(2011)/TB(0)	NA
SSB(2011) /SSB(Current, F=0)	NA

5. Discussion

5.1 Initial run

Age composition

Although we used 7 age composition (age0-age6+), in the future we may need to increase to 8-10 years if we will get longer term durations of many number YFT tag recoveries

Natural mortality

Based on Tagging recovery data we newly estimated average Z=0.50 (Fig. 11). As we used M=0.5 (age 2 or older), if Z=0.50 is more realistic, our M is very high and we need to explore more using lower M in the future.

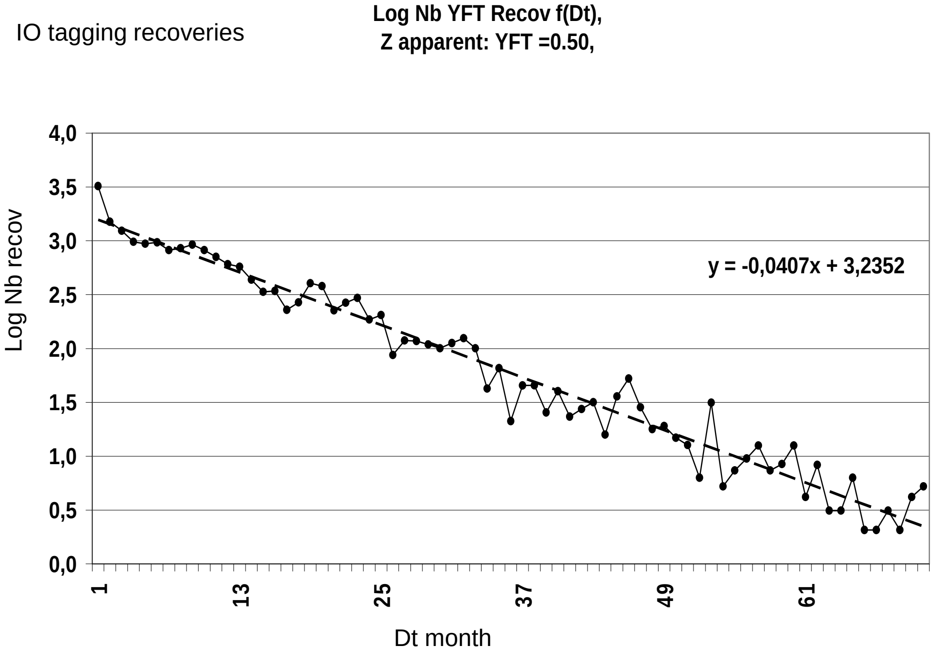


Fig. 11 Estimated Z by tagging recovery data (Fonteneau, 2012)

Growth curves

We compared the growth curve by Fonteneau (2008) with the newly estimated one by Dortel et al, (2012) (Fig. 11) which show similar pattern. This implied that we can keep the growth curve in the base case.

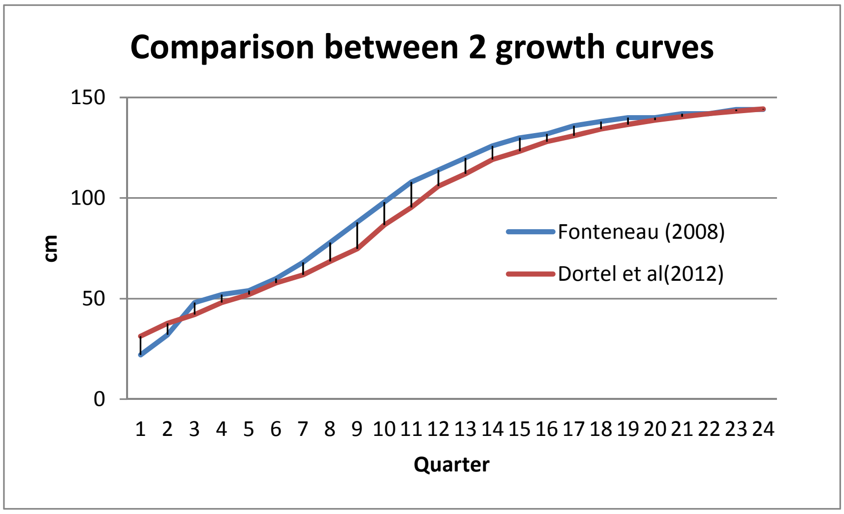
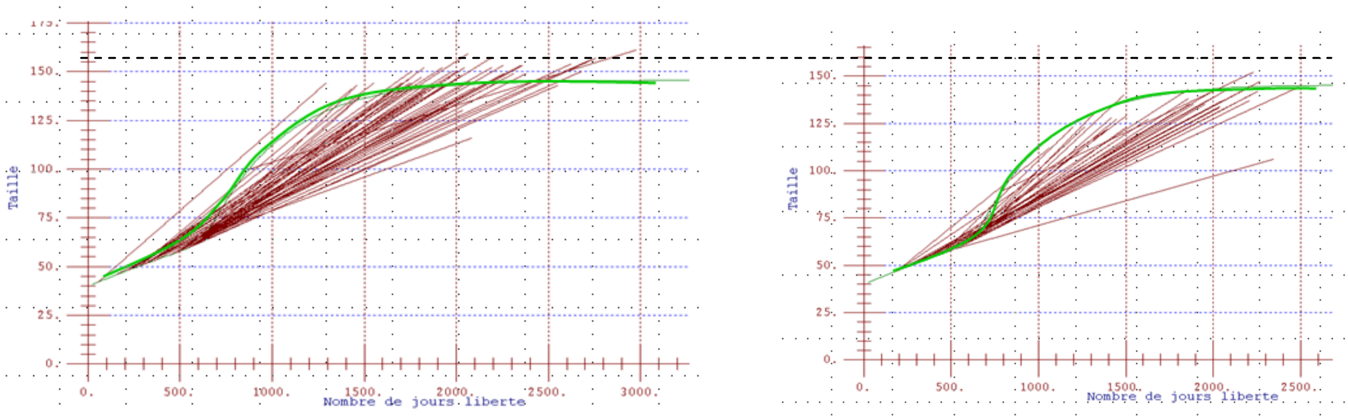


Fig.11 Comparison between two growth curves by Fonteneau (2008) and Dortel et al (2012)

In reality, female YFT has a lower L infinity thus our uni-sex growth curve classfy older and smaller female (Fig. 12) as intermediate ages, which produce potential biases in the CAA table.



Male Female

Fig 12 Comarison of grwoth curves between male (left) and female (right) (Everson, 2008 and Fonteneu, personal communicatio)

STD CPUE

As Polacheck (2006) discussed, early CPUEs (1950's) were widely in excess of the real decline of the YFT stock. That is why we did not use these CPUE and we used CPUE from 1963-2011 which is consider to be less biased period.

Area 2 has been the major YFT fishing ground. But due to the pirate activities, there are no operations in area 2 in 2011. STD CPUE case (4) without area 2 was selected as the best STD CPUE. We concern STD CPUE without area 2. But that annual trends of STD CPUE between the case (3) with area 2 (to 2010) and the case (4) without area 2 are very similar. This implied that YFT are a single stock and well mixed, thus it will be no problem that we can use case (4) STD CPUE without area 2.

In general the relation between catch and STD CPUE are fair (negative correlations) (see left columns of Figs. 3 and 4). But if you look details (see right columns of Figs. 3 and 4), there is 1 un-realistic period later years (1980-2011) in the longer term series (1963-2011), while 2 periods (1980-88 and 1993-2011) showing unrealistic positive relations in the shorter series (1980-2011). That is why we sued the STD CPUE in the longer term.

Estimated Recruitment

Estimated trends of recruitment are constant and very stable (Fig. 8) which is also similar to the one estimated by SS3 (base case) (Ijima et al, 2012). We need to discuss its validity.

5.2 Final run

Discussion

Results are generally reasonable ... BUT...

- SR fits still not satisfactory
- Problems : residuals of selectivity
- Uncertainty of CAA unknown vs. [± group]

All many be inter-related?

Risk assessments (Kobe II) suspended

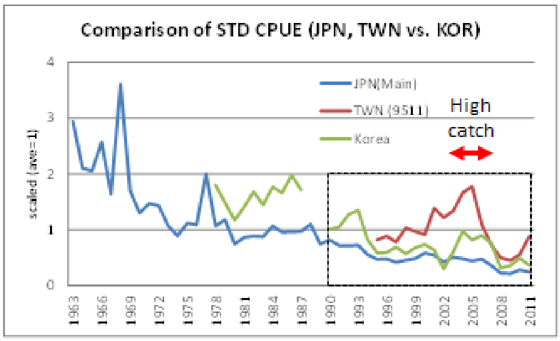
(high risk to provide potentially biased information)

Future works

- Explore the **optimum starting year** (e.g. SS3 :1963, MFCL: 1972)
- Investigate **uncertainty** in CAA (**Cooper**)
- Investigate problems in the **SR residuals**
- Investigate problems of **residuals in selectivity**
- Evaluate STD CPUE

Comparison of STD CPUE(JPN, TWN vs. KOR)

Common target correction factor : No of hooks between Float



KOR : in-between (similar to both JPN and TWN) (1990-2011)
JPN : high YFT catch(2003-2006) not reflected (STD too successful?)

6. Risk assessments (Kobe II)

Due to various problems discussed in the previous section, we decided not to conduct the risk assessment.

7. Conclusion

Results of the final ASPM indicate that the fishing effort (2011) is below the MSY level (F/Fmsy=0.61), while the spawning stock biomass (SSB) is above the MSY level (SSB/SSBmsy=1.35). The current catch (2011) is 303,000 tons which is below the MSY (320,000 tons). From these results, it is suggested that the catch level should not exceed the MSY level (320, 000 ton).

Acknowledgements

We sincerely thank to Miguel Herrera, Data manager (IOTC) for providing the nominal catch and Catch-At-Age (CAA) data of yellowfin tuna in the Indian Ocean. We also very much appreciate Adam Langley providing useful information for ASPM runs.

References

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.

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

Ijima, . I. Sato, T. Matsumoto, H. Okamoto, T. Nishida and T. Kitakado (2012)Stock assessment of yellowfin tuna in the Indian Ocean using SS3 IOTC–2012–WPTT14–39

Langley, A., Hampton, J., Kleiber, P., Hoyle, S. 2007. Stock assessment of yellowfin tuna in the western and central Pacific Ocean, including an analysis of management options. WCPFC SC3 SA WP-1, Honolulu, Hawaii, 13-24 August 2007

Langley, A., M. Herrera and J. Million (2012) Stock assessment of yellowfin tuna in the Indian Ocean using MULTIFAN-CL IOTC–2012–WPTT14–38

Murua, H., Bruyn, de P., Aranda, M. 2011. A comparison of stock assessment practices in tuna-RFMOs IOTC-2011-WPTT-13-47.

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