Scientific Report on
Stock Assessments of Yellowfin Tuna (*Thunnus albacares*), Bigeye Tuna (*Thunnus obesus*) and Skipjack Tuna (*Katsuwonus pelamis*) in Sulu and Sulawesi Seas by ASPIC*

*A Stock Production Model Incorporating Covariates

TD/RP/195

Joint Research Program on Tuna Resources in Sulu and Sulawesi Seas

Joint Research Program on Tuna Resources in Sulu and Sulawesi Seas

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Southeast Asian Fisheries Development Center

TD/RP/195 **November 2017**

Preparation and Distribution of this Document

This Scientific Report on Stock Assessments of Yellowfin Tuna (*Thunnus albacares*), Bigeye Tuna (*Thunnus obesus*) and Skipjack Tuna (*Katsuwonus pelamis*) in Sulu and Sulawesi Seas by ASPIC* (*A Stock Production Model Incorporating Covariates) was prepared by the Training Department of the Southeast Asian Fisheries Development Center (SEAFDEC/TD) in collaboration with the Scientific Working Group of the Joint Research Program on Tuna Resources in Sulu and Sulawesi Seas. This Report is distributed to the SEAFDEC Member Countries and Departments, partner agencies and other fisheries-related organizations, and to the public to make them aware of the activities of SEAFDEC and promote the visibility of the Center.

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* *A Stock Production Model Incorporating Covariates*

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This document has 50 pages including 42 Figs, 13 Tables and 4 Boxes in the main text.

Caveats

Results of stock assessments should be looked at with caution because of following reasons, i.e., (a) Stock assessments (YFT: yellowfin, BET: bigeye and SKJ: skipjack tuna) in the SSS water, may not be meaningful because they are small parts of Western and Central Pacific stocks (see Fig. 2), thus catch in SSS are about 19% (YFT), 12% (BET) and 14% (SKJ) of the catches in WCPFC water. But results may represent the stock status in the local (SSS) situation in some extent if emigration and immigration between the SSS water and WCPFC water are constant, (b) there are 23 years of catch in SSS, which are long enough for stock assessments. But aggregated catch of various species are often disaggregated to catch by species using average species compositions, which may produce biased in the estimated catch by species, (c) stock assessments were conducted by ASPIC without biological data and stock-recruit relationship, which may mask real population dynamics which may mislead the Kobe plot (stock status trajectories) and (d) results are highly relied on CPUE that is available only for 10 years, thus results are very sensitive by trends and/or jumps of CPUE series.

Summary

General conclusion

Box 1 shows results of ASPIC stock assessments in SSS comparing to those in WCPFC.

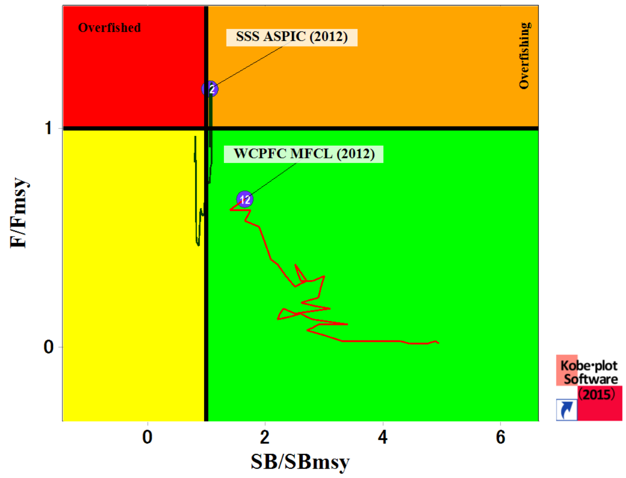
The YFT stock status is on the border between orange and red zone of the Kobe plots (unsafe zones). F (SSS) is much higher than F (WCPFCF) in recent years, which may imply existences of local high fishing pressures in the SSS water.

As for BET, the current stock clearly indicates the overfished status. But recent drops of F may be due to effort shift to YFT.

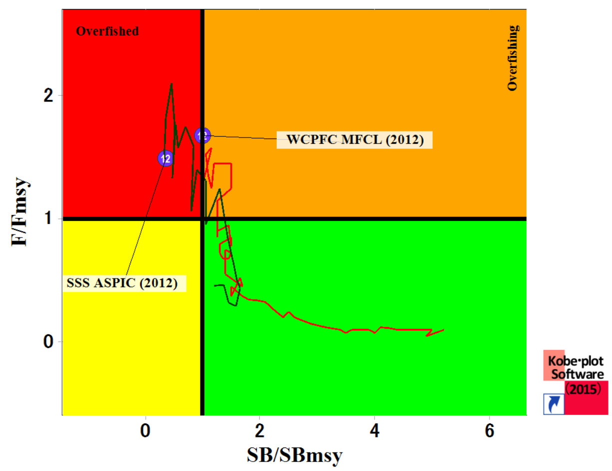
For SKJ, it is in the safe zone (green zone) in the Kobe plot. But, F is close to Fmsy and F has been increasing quickly in recent years, thus the SKJ stock may move to orange and red (unsafe) zones in the near future if current F continues.

Box 1 Summary of tuna stock assessments in SSS compared to those in WCPFC

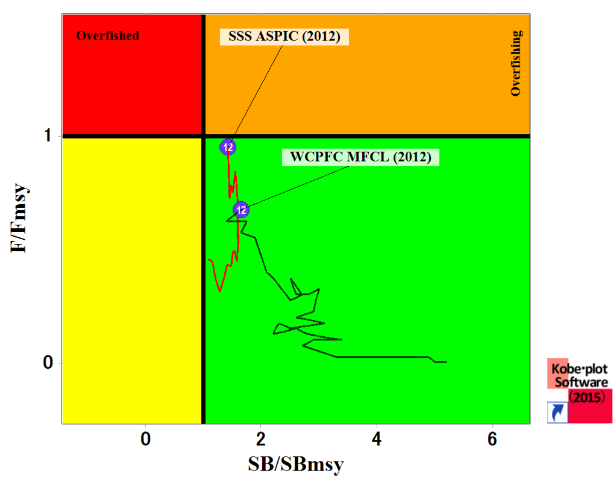
Yellowfin tuna



Bigeye tuna



Skipjack tuna



Comparisons to WCPFC

Stock statuses of YFT+BET+SKJ based on ASPIC stock assessments in SSS are similar to those in WCPFC, but they are more pessimistic than in WCPFC. This implies that higher F (SSS) has been used than in the WCPFC water. Consistent results may reflect the realistic situation in SSS.

Future considerations

Normally a long time is needed to produce satisfactory stock assessments because it will take considerable time to improve and solve errors, biases and problems that found in the 1st and consecutive stock assessments. It is the same situation for our case and following are points to improve:

- It may be interesting to attempt different stock assessment models using biological information such as age structured models (SCAA and ASPM) to compare results. However, such attempt should be conducted after problems in catch and CPUE are improved as explained in Caveats.

- We may wait a few more years so that we can get 13 years of CPUE data which may produce more robust stock assessments and with this we can conduct above mentioned other stock assessment models

1. Introduction

In the 45th SEAFDEC Council Meetings (2013), it was requested to develop the framework to facilitate collaborative tuna research activities. Consequently, SEAFDEC organized the "Sub-regional Technical Meeting for Development of Joint Research Program for Tuna Research in Sulu and Sulawesi Seas" in Malaysia in August 2013. This enabled SEAFDEC to come up with the Framework for Joint Research Program on Tuna Resources in Sulu and Sulawesi Seas (SSSs) (Fig. 1).

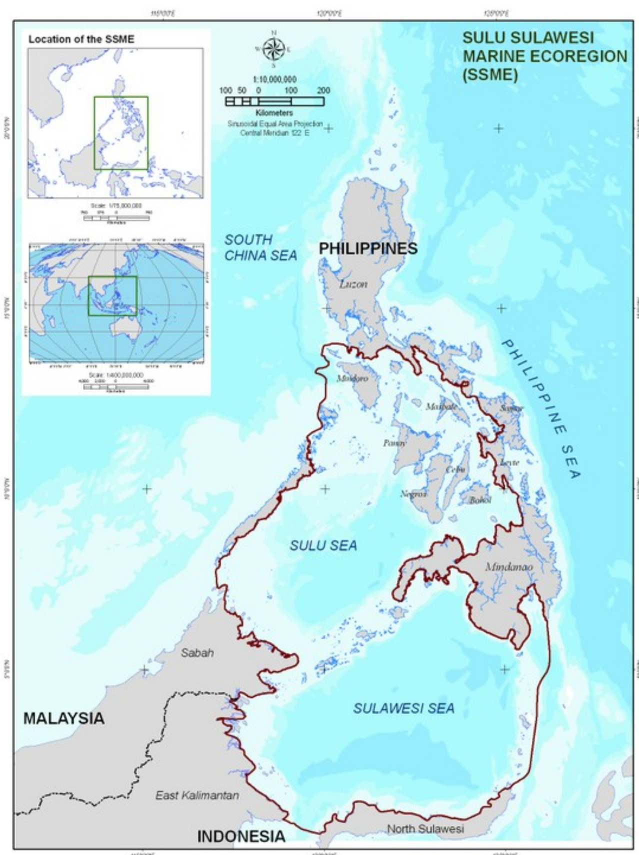


Fig. 1 Location and geological features of the Sulu and Sulawesi Seas

<u>The overall goal of this joint research program is to understand status and trend of tuna fisheries in SSSs</u> through collaborative research activities by the three SEAFDEC Member Countries surrounding the SSSs, namely, Indonesia, Malaysia, and the Philippines (Fig. 1). The Meeting in 2013 also agreed that the joint program should focus on three target species, i.e., Yellowfin tuna (*Thunnus albacares*) (YFT), Bigeye tuna (*Thunnus obesus*) (BET), and Skipjack tuna (*Katsuwonus pelamis*) (SKJ).

Under such background, it was agreed to conduct stock assessments for these three species by the ASPIC stock assessment model as one of activities during the Sub-regional Technical Meeting for Finalizing Work Plan of Activities for SEAFDEC Joint Program on Tuna Research in Sulu and Sulawesi Seas 19 to 21 August 2014, Tawau, Sabah, Malaysia.

This is the final report on the stock assessments of three species by the resource person and designated stock assessment scientists in three participating countries.

2. Stock structure

To conduct stock assessments, the knowledge of the stock structure is essential. This is because stock assessments need to be implemented by one stock unit for management. If we don't know the stock structure and conduct stock assessments, results are not meaningful as we don't know which particular stock can be managed by the results.

In our case, SSS is a small part of the Pacific Ocean. According to WCPFC and IATTC, two Pacific stocks are assumed for YFT, BET and SKJ, i.e., the Western-Central (WC) Pacific stock and the Eastern stock respectively. Thus, three species in SSS are a part of the WC Pacific stocks (Fig. 2).

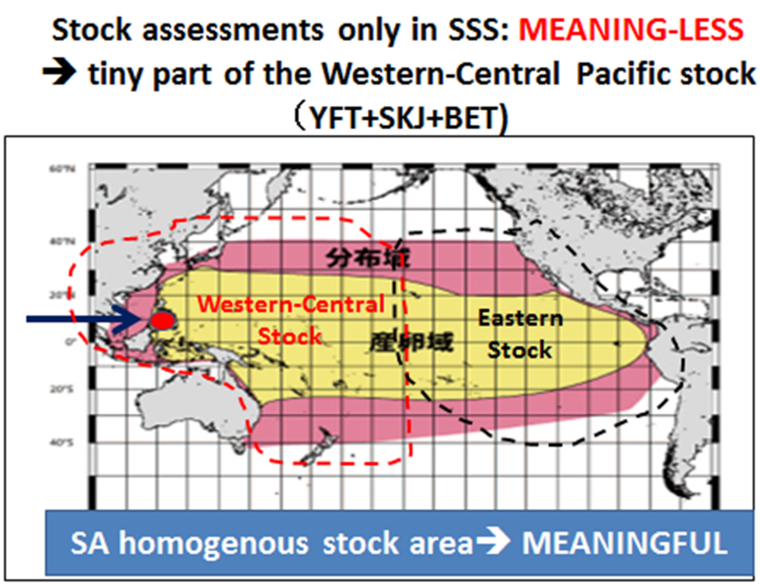


Fig. 2 Two stocks structures of YFT, BET and SKJ in the Pacific Ocean

<u>Then what is the reason to conduct stock assessments in SSS?</u> We have a good reason, i.e., to see the local situation (SSS) of the stock status just for reference. We can compare the stock status in SSS to the one in the WC Pacific. If both stock statuses are similar, it will imply that the situation of fishing pressure (F) and biomass (SSB) between SSS and the WC Pacific are proportional (relatively the same level). Or if the stock status in SSS is much worse than in whole WC Pacific, then it will imply that there is locally higher fishing pressure (high F) in SSS than in WC Pacific (Figs. 3-4).

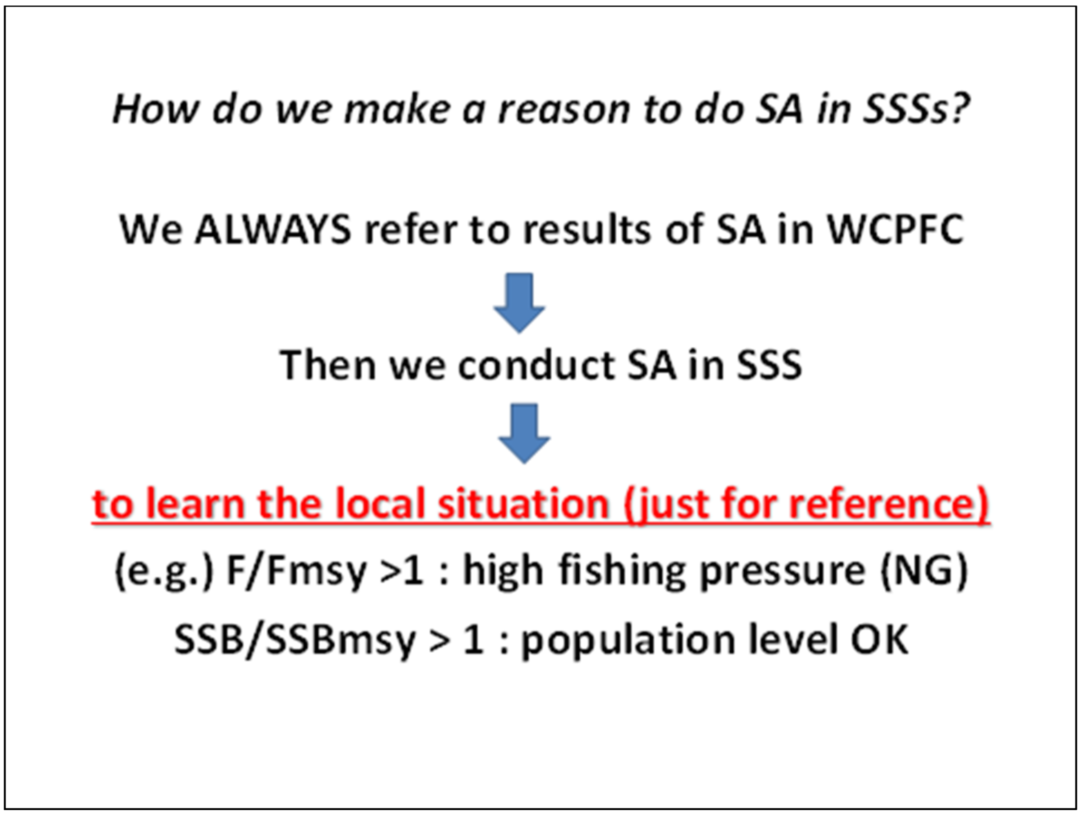


Fig. 3 Reason to conduct stock assessments in SSS waters,
a small part of the western-central stock

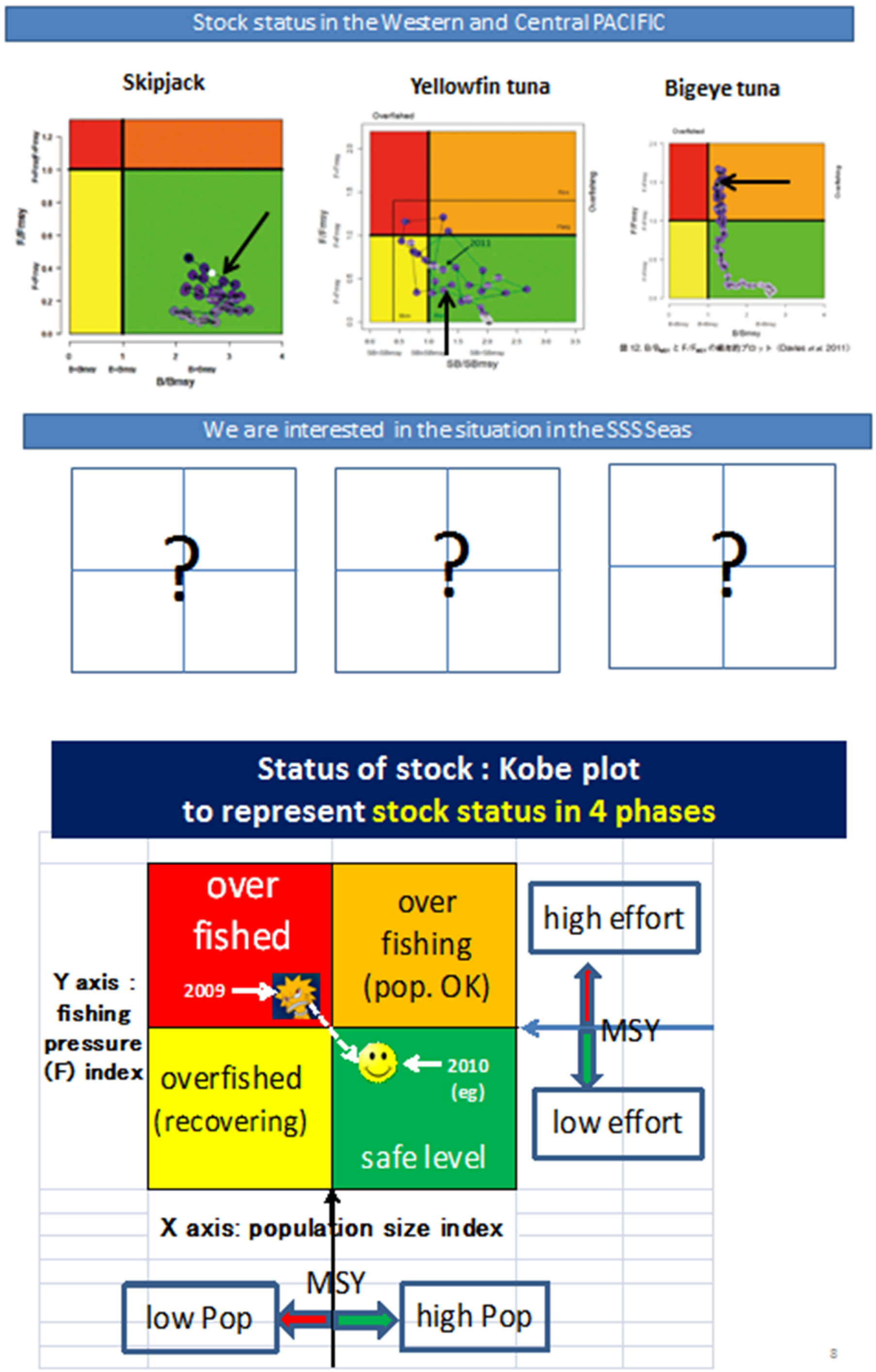


Fig. 4
(Top) Stock status of SKJ, YFT and BET in the Western and Central Pacific
(Kobe plot: stock trajectory),
(Middle) The one in SSS (?) (to be investigated)
(bottom) definition of the Kobe plot.

3. Selection of stock assessment models for SSS

There are three (3) major types of stock assessment models (Table 1). As for stock assessments in SSS, we need various reference points such as MSY, Fmsy and SSBmsy to be used for management criteria. Since only type No 3 method can provide various reference points, we use this approach, i.e., there are four types of normal stock assessment models based on long term historical fisheries data. Fig. 5 and Box 2 summarize specifications of four different stock assessment models in Type 3 category.

Table 1 Three categories of stock assessments

Type No.	Type	Major Information	Data period	Reference point (MSY, Fmsy, SSBmsy etc.)	Models
1	Demography	Parameters			Leslie matrix PSA
2	Normal (quantitative) stock assessments	Real data	Short term (Snap shot)	Partially available, but only for the short term (subjective)	● ELEFAN ● Fi STAT
3			Long term historical fisheries data (10 years or longer)	Available (more objective due to a longer term data)	**(1) SRA (Catch only method)** **(2) Production model (ASPIC etc.)** **(3) Age (size) structured models (VPA, SCAA, ASPM etc.)** **(4) Integrated models (SS3, MULTIFAN-CL etc.)**

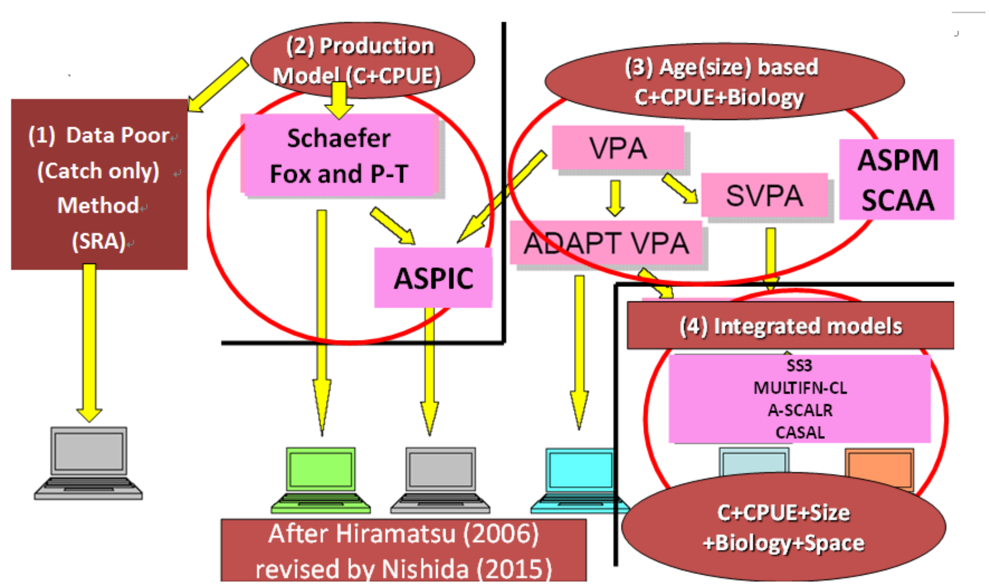


Fig. 5 Schematic diagram of four different types of stock assessment models in Type 3.

Box 2 Specification (data requirements) of 4 types of stock assessment models in type 3

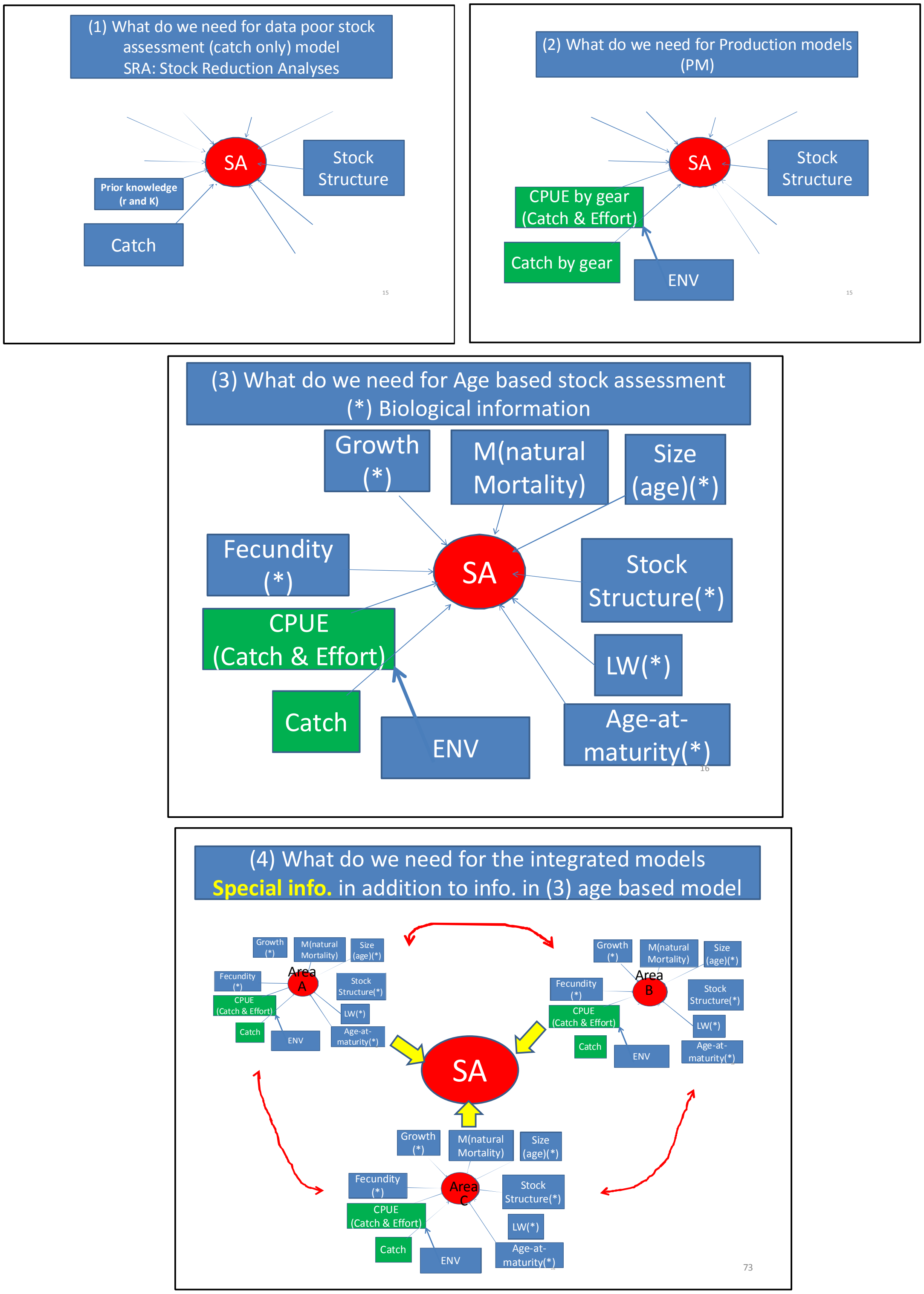


Fig. 6 simplifies the data requirements for four types of stock assessment models in the type 3 category. For our project, we have catch and CPUE as well as biological data, but we will attempt (2) PM (production model) as a first step. In the future, we may attempt (3) age/size based stock assessment models. (4) Integrated approach is beyond our scope as they are too complicated and not suitable for our case.

As for PM, we will use *A Stock Production Model Incorporating Covariates* (ASPIC), which is the most standard approach and has been used by many scientists worldwide.

What types of data we need..

	C	CPUE	size	biology	space/tag
(1) Catch	X				
(2) PM	X	X			
(3) Age/size	X	X	X	X	
(4) Integrated	X	X	X	X	X

Fig. 6 Data requirements for four stock assessment models

4. Historical catch and CPUE data

The manual to collect and compile necessary catch and CPUE data for the ASPIC stock assessment was made by the resource person in December, 2014. Then the manual was distributed to relevant scientists in Indonesia, Malaysia and Philippines in January 2015, one month before *"Working Groups Meeting and Technical Meeting on Joint Program on Tuna Research in Sulu and Sulawesi Seas 10th to 11th February 2015, Bangkok, Thailand".*

Following the manual, Dr Ali Suman and Dr Suwarso Mas (Indonesia), Mr Hj Samsudin bin Basir (Malaysia) and Mr Noel Barut and Ms Grace Lopez (Philippines) provided the necessary data, which are summarized as below:

4.1 Catch

As a result of the investigation, it was found that the maximum common years for available catch data for Indonesia, Malaysia and Philippines are 23 years (1990-2012). Some species aggregated catch data were disaggregated by species compositions from research data or average species compositions of historical catch data by species.

Tables 2-4 and Figs. 7, 10 and 13 show total catch by country for YFT, BET and SKJ (1990-2012) respectively. YFT and SKJ catch show the increasing trends, while BET catch shows the increase by 1998 afterwards the decrease trend.

Figs. 8, 11 and 14 show catch trends of SSS and WCPFC (without SSS) and Fig 9, 12 and 15 for catch compositions between SSS and WCPFC (without SSS).

Table 2 Estimated yellowfin tuna (YFT) catch in SSS by country (1990-2012)

	Indonesia	Malaysia	Philippines	Total
1990	3,907	1,474	70,600	75,982
1991	4,003	1,474	83,215	88,692
1992	4,714	1,474	39,195	45,383
1993	5,424	1,474	38,496	45,395
1994	8,252	1,474	54,997	64,724
1995	8,839	1,474	53,063	63,376
1996	10,380	1,058	53,344	64,782
1997	10,255	470	71,142	81,866
1998	15,155	413	71,142	86,710
1999	14,702	394	71,142	86,238
2000	14,910	394	71,142	86,446
2001	16,355	465	71,142	87,962
2002	20,687	533	68,189	89,408
2003	18,463	494	79,620	98,577
2004	18,290	514	81,939	100,744
2005	18,751	518	96,749	116,018
2006	14,196	510	94,384	109,090
2007	30,078	510	113,584	144,172
2008	31,007	510	103,889	135,406
2009	29,561	502	87,425	117,489
2010	24,050	509	82,000	106,559
2011	59,096	627	51,607	111,330
2012	75,028	803	61,580	137,411

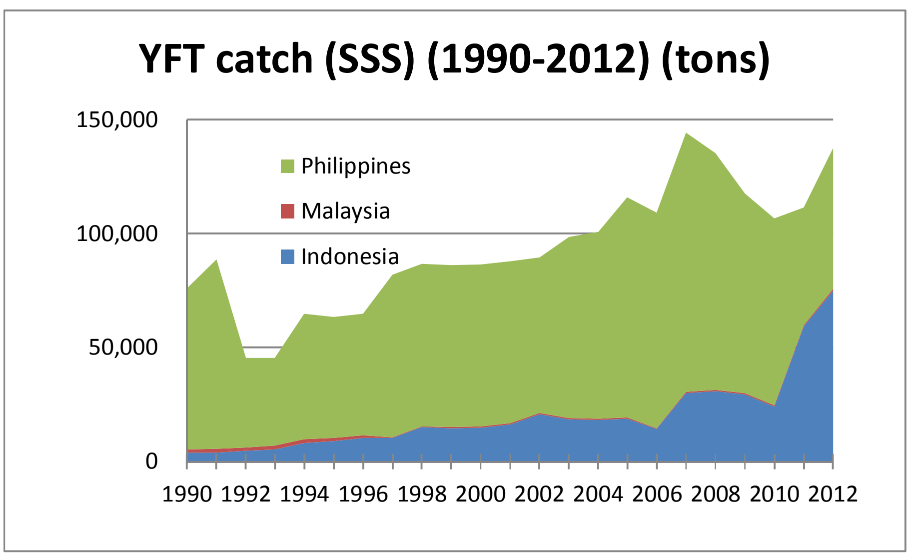


Fig. 7 Estimated yellowfin tuna (YFT) catch in SSS by country (1990-2012)

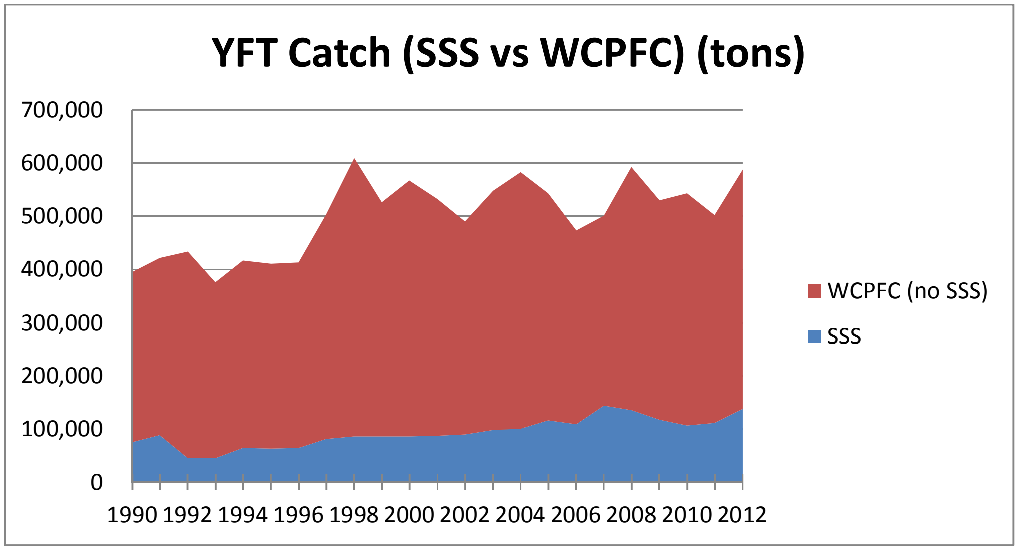


Fig. 8 YFT Catch (SSS and WCPFC without SSS)

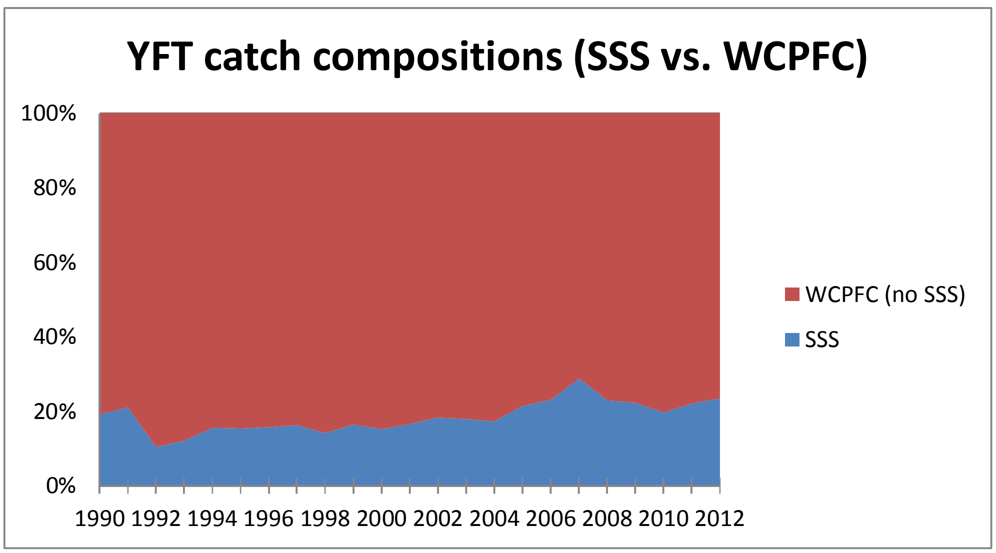


Fig. 9 YFT Catch compositions (SSS and WCPFC without SSS)

Table 3 Estimated bigeye tuna (BET) catch by country (1990-2012) in the SSS water

	Indonesia	Malaysia	Philippines	Total
1990	3,145	147	8,505	11,798
1991	3,223	147	9,675	13,045
1992	3,795	147	5,750	9,692
1993	4,366	147	4,862	9,376
1994	6,643	147	7,303	14,093
1995	7,115	147	8,420	15,683
1996	8,356	106	10,335	18,797
1997	8,255	47	14,470	22,772
1998	12,199	41	16,428	28,669
1999	11,835	39	7,959	19,833
2000	12,002	39	13,137	25,179
2001	13,165	46	10,195	23,407
2002	8,820	53	8,391	17,265
2003	14,862	49	9,332	24,244
2004	11,790	51	10,125	21,967
2005	5,545	52	11,749	17,346
2006	6,380	51	10,981	17,412
2007	5,254	51	7,689	12,994
2008	7,991	51	8,649	16,691
2009	8,108	50	8,463	16,621
2010	5,007	51	7,110	12,168
2011	5,747	63	4,215	10,025
2012	10,020	80	6,920	17,020

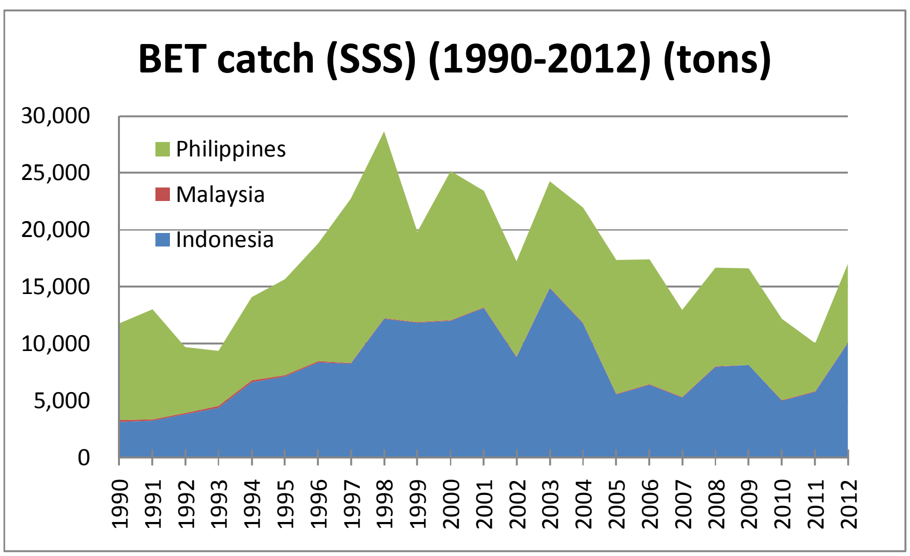


Fig.10 Estimated bigeye tuna (BET) catch by country (1990-2012) in the SSS waters

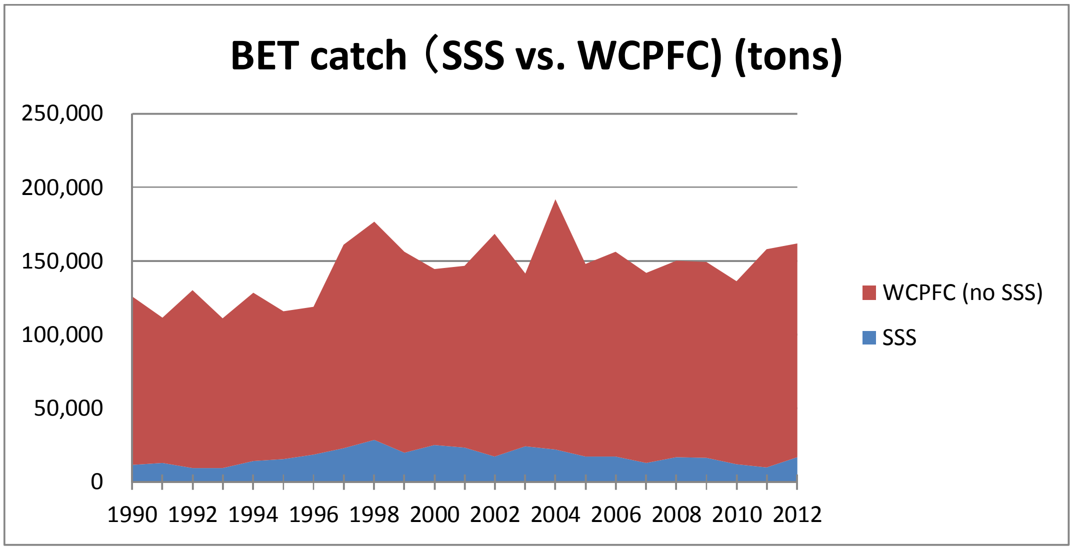


Fig. 11 BET Catch (SSS and WCPFC without SSS)

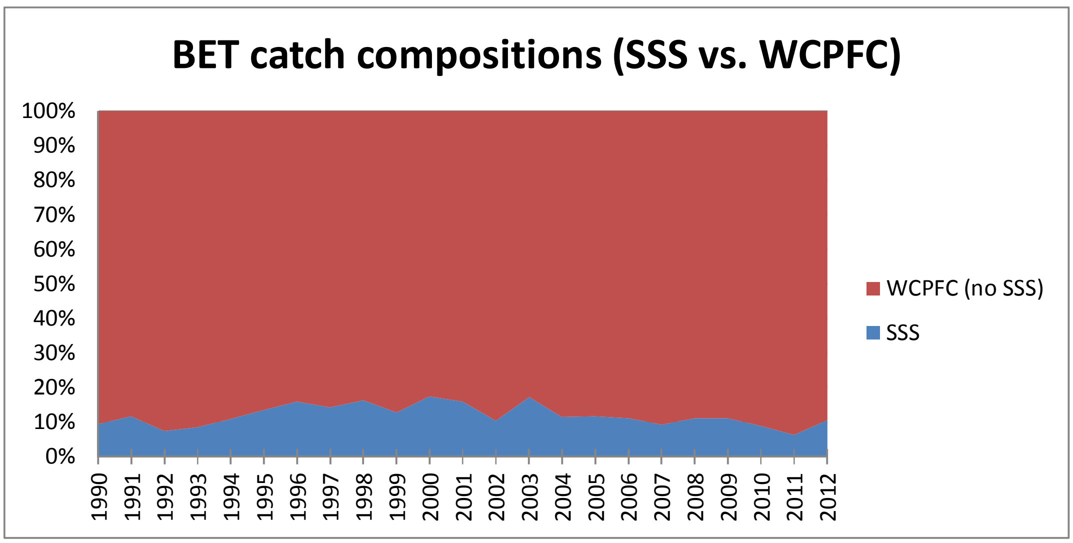


Fig. 12 BET Catch compositions (SSS and WCPFC without SSS)

Table 4 Estimated Skipjack tuna (SKJ) catch by country (1990-2012) in the SSS water

	Indonesia	Malaysia	Phippines	Total
1990	14,097	421	99,705	114,223
1991	14,332	421	102,394	117,147
1992	18,473	421	83,179	102,073
1993	22,614	421	68,081	91,116
1994	27,929	421	84,560	112,910
1995	27,099	421	110,111	137,631
1996	30,798	302	110,004	141,104
1997	39,689	134	101,150	140,973
1998	64,585	118	101,150	165,853
1999	67,495	112	101,150	168,757
2000	68,825	113	101,150	170,088
2001	65,699	133	101,150	166,982
2002	65,517	152	92,296	157,965
2003	60,219	141	119,790	180,150
2004	72,261	147	105,117	177,525
2005	76,530	148	125,269	201,947
2006	47,463	146	145,880	193,489
2007	80,429	146	167,762	248,337
2008	85,012	146	203,674	288,832
2009	65,517	144	184,046	249,706
2010	92,110	145	163,383	255,638
2011	94,786	179	136,835	231,800
2012	148,222	229	148,820	297,271

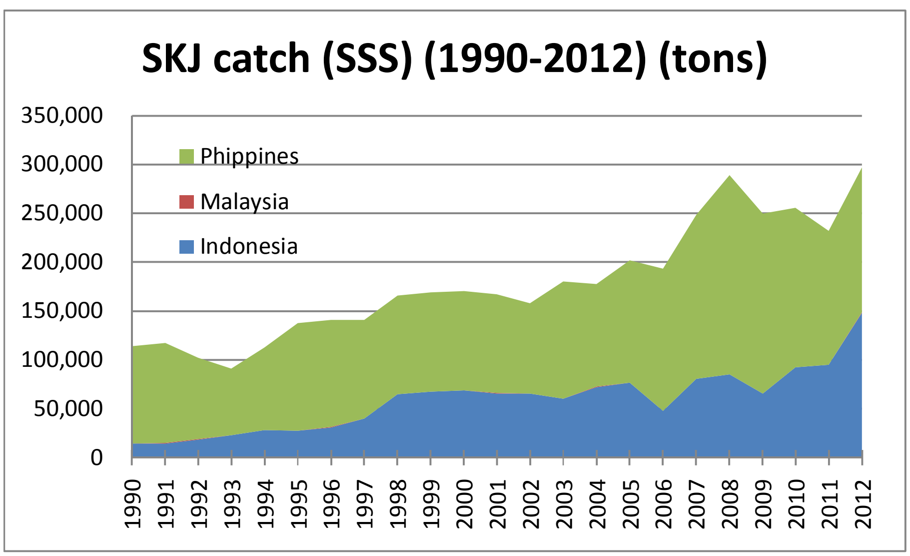


Fig. 13 Estimated skipjack tuna (SKJ) catch by country (1990-2012)

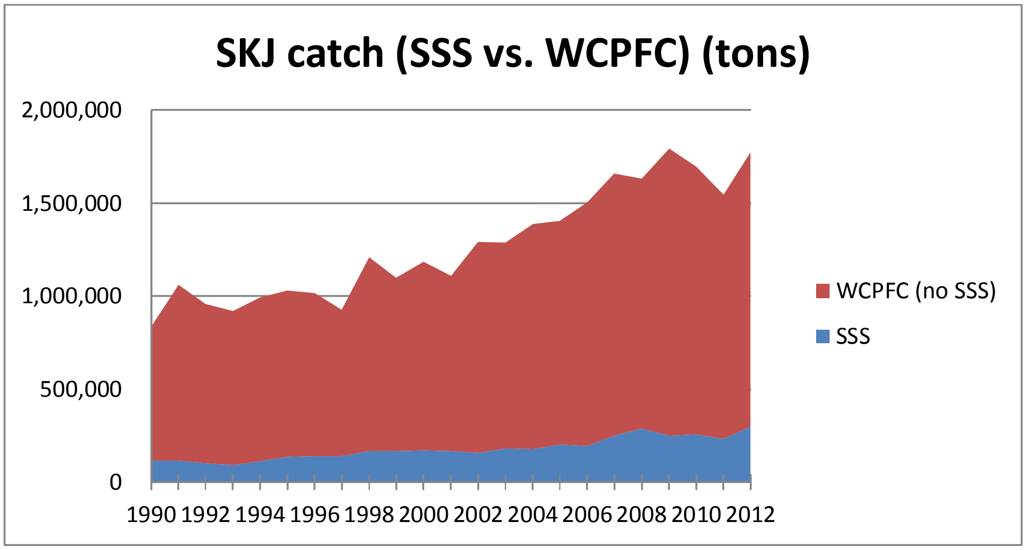


Fig. 14 SKJ Catch (SSS and WCPFC without SSS)

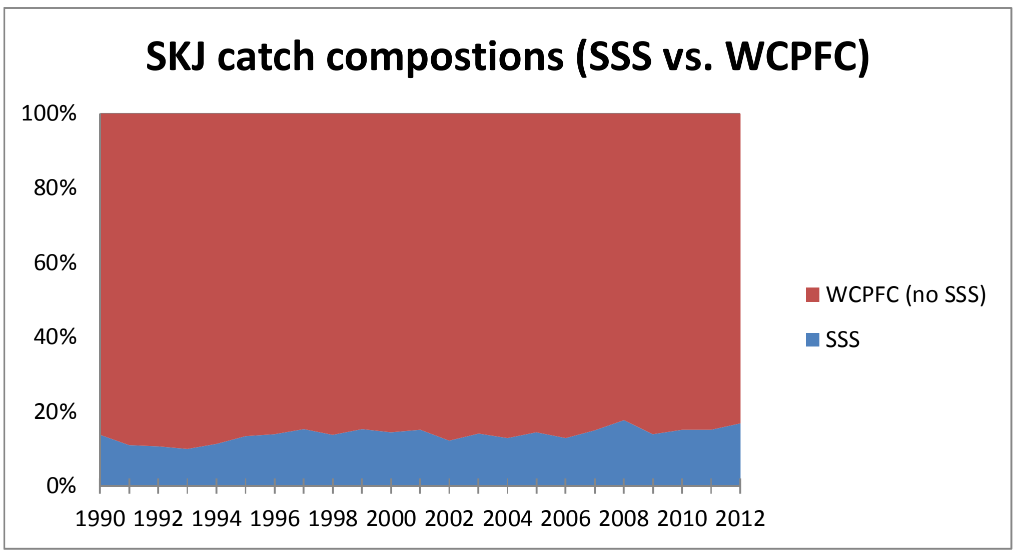


Fig. 15 SKJ Catch compositions (SSS and WCPFC without SSS)

Table 5 shows annual average compositions of YFT+BET+SKJ catch in SSS to the total catch in WCPFC, which range 12-19%. These rates are realistic.

Table 5 Annual average compositions of YFT+BET+SKJ catch in SSS to the total catch in WCPFC

	Average annual composition of SSS catch in the WCPFC catch
YFT	19%
BET	12%
SKJ	14%

4.2 Nominal and standardized CPUE

CPUE is the key parameter for stock assessment models (2) - (4) in type 3. If we don't have CPUE we need to use (1) data poor method with only catch data. In our case, we have a number of CPUE from three countries. Thus, we can use CPUE and need to evaluate its quality. This is because some CPUE may not include realistic figures due to various types of errors such as miss-identification of species, biases in sampling, data entries/processing, etc.

Thus, we need QC (Quality Control) to select realistic CPUE. There are six ways to conduct QC. Box 3 shows the list of the criteria we applied.

Box 3 Method to evaluate nominal CPUE

(1) Make sure if we have 10 years or more CPUE data for reliable stock assessments
(2) We remove big jumps in CPUE series (especially 3 times or higher ones)
(3) Make sure CPUE are not species aggregated;
(4) At least 2 CPUE series from different gears are similar;
(5) When 2 CPUE series or more are compared, CPUE need to be scaled (normally average=1); and
(6) Catch and CPUE are negatively correlated;

We received CPUE data from Indonesia, Malaysia and Philippines. We evaluate nominal CPUE using the criteria listed in Box 3. We applied General Linear Model (GLM) to standardize nominal CPUE

(1) Indonesia

A few historical CPUE data were reported, but after the careful examinations, it was realized that they could not be used for stock assessments because CPUE are based on catch with aggregated species.

(2) Malaysia

CPUE (Catch and effort) data (1995-2005 and 2011-2013) are provided by Malaysia. The estimation of efforts was calculated based on actual sampling in Semporna Sabah (Fig. 16) in 2014.

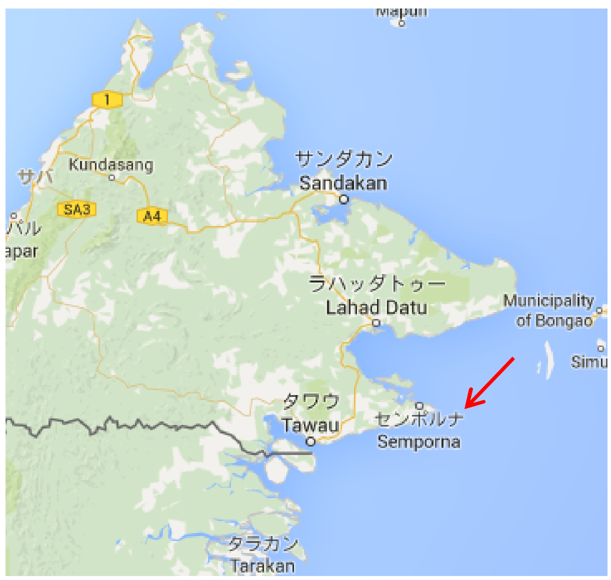


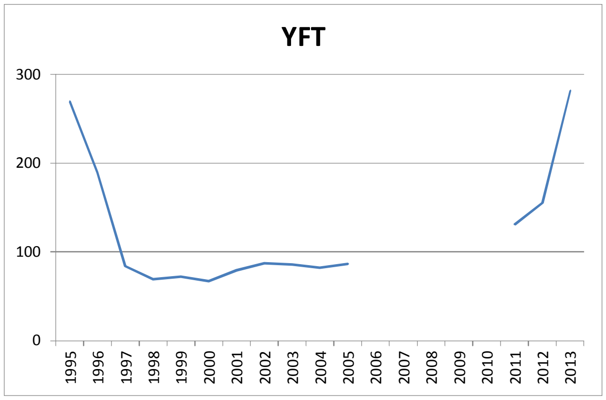
Fig. 16 Location of Semporna Sabah

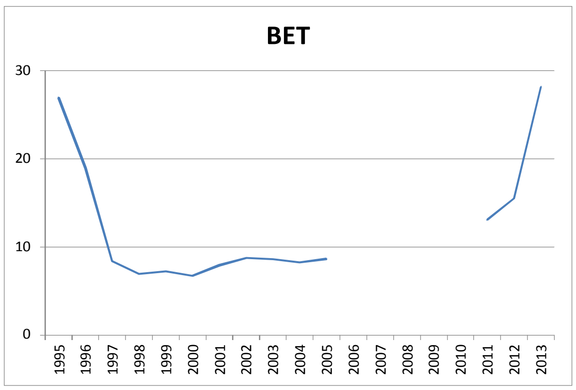
Fisheries are HANDLINE by TRADITIONAL BOATS with following additional information:

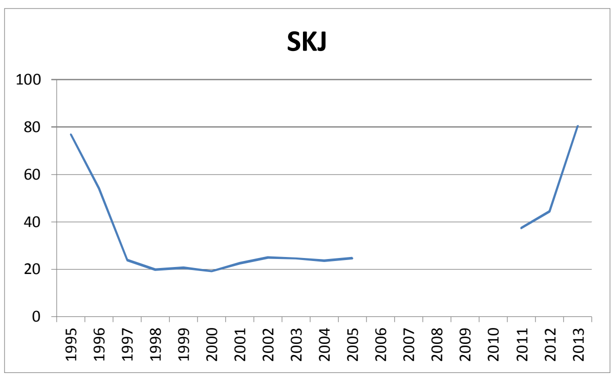
- Handline operators consisted of 4-5 fishermen on each boat;
- Each fisher represents one hook;
- Each trip takes 4-5 days; and
- For each boat, they make 2 fishing trips per month

Annual nominal CPUE are computed as catch/trip. Box 4 shows the nominal CPUE. CPUE trends of 3 species are more or less similar. This may be caused by the fact that the same ratios have applied to species aggregated catch to the same efforts. Thus, we decided not to use these CPUE.

Box 4 Nominal CPUE (kg/trip) (YFT+BET+SKJ)
based on the data collected in Semporna, Sabah, Malaysia







(3) Philippines

Many CPUE data sets are provided (2002-2013) by BFAR, which are compiled into one excel file. Hence it was easy to process the data. Table 6 shows its specification. There are 10 gear types and 24 sampling sites (Fig. 17) including ALL areas (Table 6).

Table 6 Specification of the CPUE data set by year, location and gear type
(Number indicate sample size)

year	location	DGN	GILL	H+L	HAND	LL	MHL	OTOSHI	PS	RING	TROLL
2002	ALL1						12				
2003	ALL1						12			12	
2005	ALL1						12			12	
2006	ALL1						12		12	12	
2007	ALL1			12	12	12	12		12	12	
2008	ALL1	12		12			12		12	12	12
	Davao Gulf				12		12				
	Moro Gulf				12						
	Visaysan Sea			12							
2009	ALL1	12				12	12		12	12	
	Cuyo East Pass			12							
	Moro Gulf				12						
	Sibuyan Sea			12							
	Sulu Sea			24							
2010	ALL1	12	12				12		12	12	12
	Cuyo East Pass	12									
	Davao Gulf				12		12				
	Moro Gulf				12						
	Sibuyan Sea			12							
	Sulu Sea			24							
	Visaysan Sea			12							
2011	ALL1	12							12	12	12
	Davao Gulf				12		12				
	Illana Bay						12				
	Moro Gulf				12						
	Norte				12						
	Palawan				12						
	Visaysan Sea			12	12						
	Zamboanga				12						
2012	ALL1		12					12	12	12	12
	ALL2	12									
	Balut				12						
	Burias Island			12							
	Celebes				12						
	Cuyo East Pass						12				
	Cuyo East Pass?	12									
	Davao Gulf			12	12		12				
	Illana Bay						12				
	Indonesia				12						
	Irian				12						
	Kalamansig				12						
	Mati				12						
	Mindoro Strait			12			12				
	Moro Gulf				12						
	Norte				12						
	Romblon			12							
	Seven Island				12						
	Tawi Tawi				12						
	Visaysan Sea			12							
	Zamboanga				12						
2013	ALL1	12									

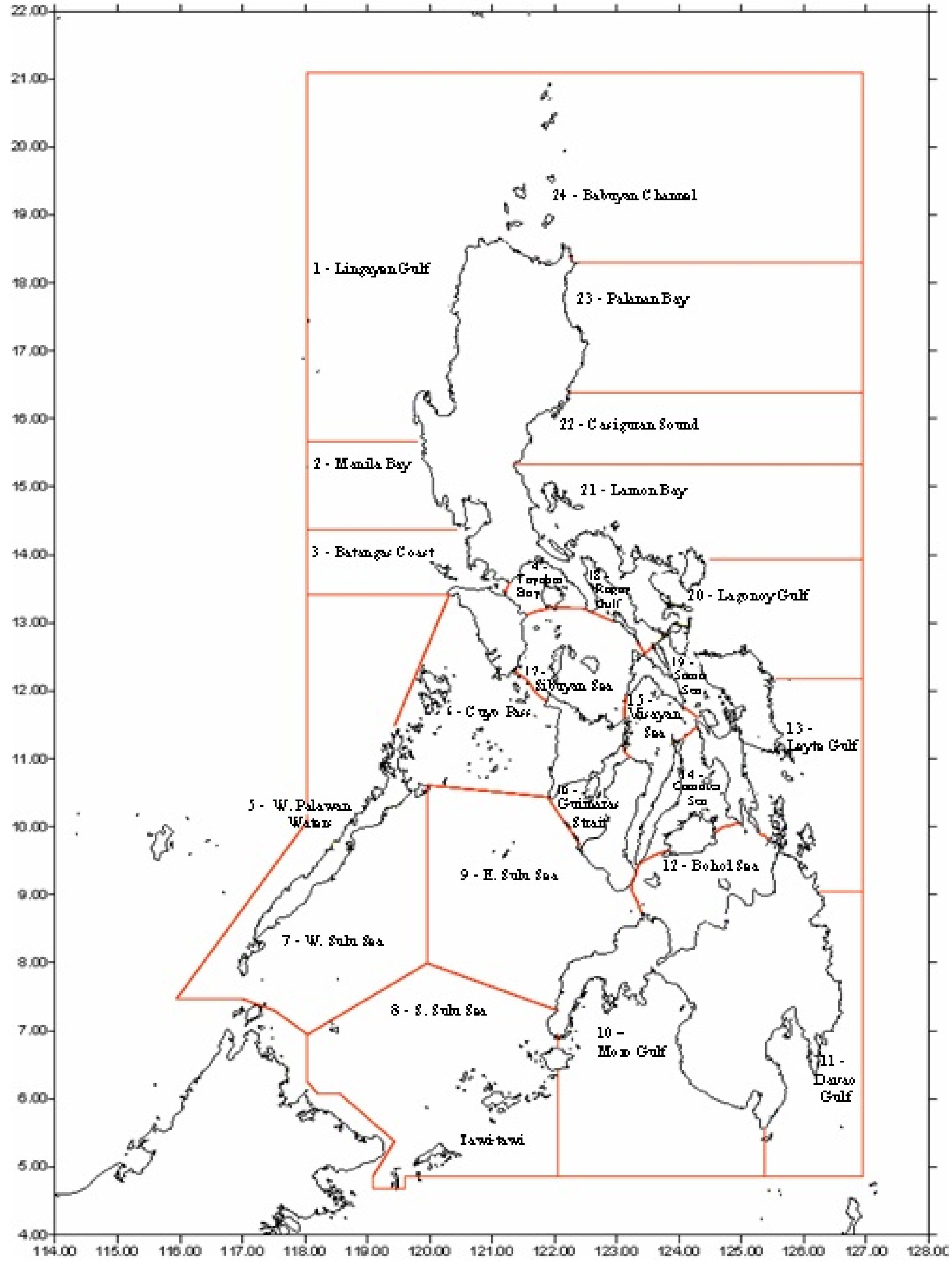


Fig. 17 . Map of the Philippines showing the 24 statistical fishing grounds

In addition, we refer to standardized CPUE of 3 species available in the paper, "Fishery trends and abundance of tuna stocks in the Moro Gulf (Philippine Region 12), estimates of depletion due to fishing and Maximum Sustainable Yield" by Keith Bigelow (NOAA Fisheries, USA and Department of State Embassy Science Fellow, Philippines), Elaine Garvilles and Noel Barut (BFAR\NFRDI, Philippines) and Patrick Lehodey and Inna Senina (CLS, France). Table 7 lists the standardized CPUE used in this document.

Table 7 Available standardized CPUE (Region: Moro Gulf) data in the document by Bigelow et al (2015)

Species	Gear	Year
Yellowfin tuna	Handline	2004-2012
	Purse seine	2005-2014
Bigeye tuna	Handline	2004-2012
	Purse seine	2005-2014
Skipjack	Purse seine	2005-2014

Yellowfin tuna (YFT)

To examine available long time series of CPUE data, we made CPUE summary table for sample size by gear type, location and year (Table 8). Based on Table 8, there are five long time series CPUE data sets (5 years or more), i.e., DGN (Drift gillnet, all area), Handline (Moro Gulf), MHK (multiple hook and line, all area), PS (purse seine, all area) and RING (ring net, all area), which are indicated by yellow markers in Table 8.

Table 8 Sample size of YFT CPUE data set by gear type, location and year (yellow marker parts are the CPUE data set with a long term (5 years or more) (BFAR database).

gear	location	2002	2003	2005	2006	2007	2008	2009	2010	2011	2012	2013
DGN	ALL1						12	12	12	12		12
	ALL2										12	
	Cuyo East Pass								12			
	Cuyo East Pass?										12	
GILL	ALL1								12		12	
H+L	ALL1					12	12					
	Burias Island										12	
	Cuyo East Pass							12				
	Davao Gulf										12	
	Mindoro Strait										12	
	Romblon										12	
	Sibuyan Sea								12			
	Sibuyan Sea							12				
	Sulu Sea							24	24			
	Visaysan Sea						12		12	12	12	
HAND	ALL1					12						
	Balut										12	
	Celebes										12	
	Davao Gulf						12		12	12	12	
	Indonesia										12	
	Irian										12	
	Kalamansig										12	
	Mati										12	
	Moro Gulf						12	12	12	12	12	
	Norte									12	12	
	Palawan									12		
	Seven Island										12	
	Tawi Tawi										12	
	Visaysan Sea									12		
	Zamboanga									12	12	
LL	ALL1					12		12				
MHL	ALL1	12	12	12	12	12	12	12	12			
	Cuyo East Pass										12	
	Davao Gulf						12		12	12	12	
	Illana Bay									12	12	
	Mindoro Strait										12	
OTOSHI	ALL1										12	
PS	ALL1				12	12	12	12	12	12	12	
RING	ALL1		12	12	12	12	12	12	12	12	12	
TROLL	ALL1						12		12	12	12	

We also examined the standardized CPUE by Bigelow et al (2015) (Table 7). After examinations, three STD_CPUE series are clarified as the selected (realistic) input for ASPIC, i.e., standardized CPUE of PS (Bigelow *et al*, 2015), Handline (Bigelow *et al*, 2015) and Multi Hook and Line (BFAR database). Please note that nominal PS and Handline CPUE were standardized by GLM. Fig. 18 shows three standardized CPUE which are scaled as average STD_CPUE =1. These three CPUE show the similar trends except a few bumps.

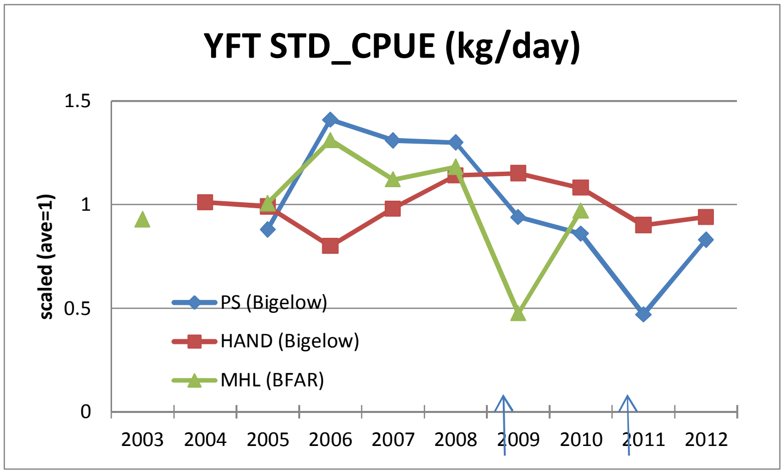


Fig. 18 Three yellowfin tuna standardized CPUEs in SSS.

However, we consider that 2 points (2009 in MHL and 2011 in PS) in Fig.18 showing big drops are not realistic comparing to other points in the same year. Thus, we remove these two points which produce more smooth and realistic CPUE trends (Fig 19).

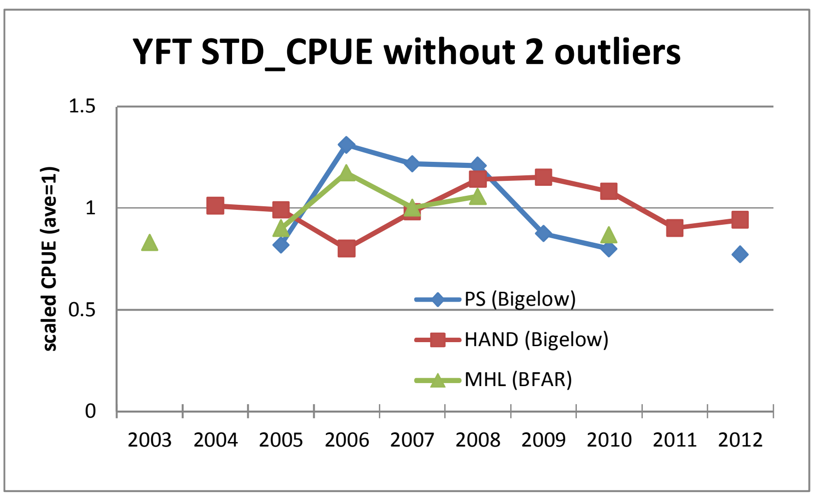


Fig. 19 Three YFT standardized CPUEs without 2 outliers in SSS for ASPIC

As we use the global nominal catch, we use the average standardized CPUE of these three gears. Fig. 20 shows the average standardized CPUE, which are scaled as average STD_CPUE =1.

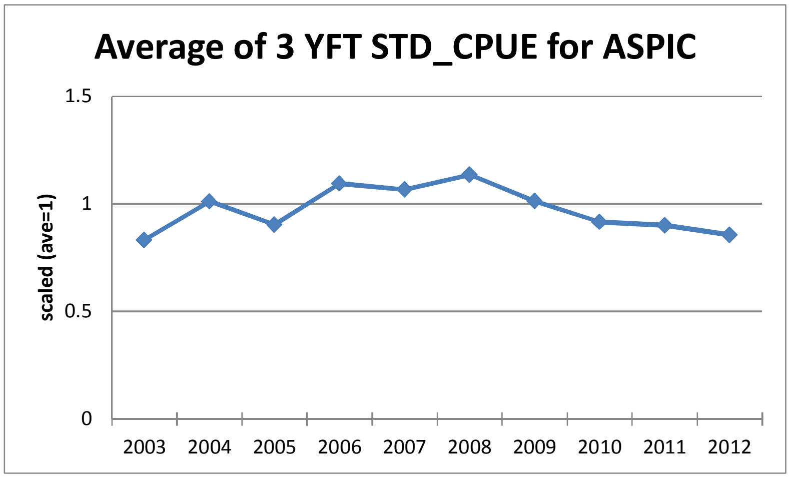


Fig. 20 Average standardized CPUE of three STD_CPUE in Fig 19.

The average standardized CPUE in SSS is like standardized CPUE of purse seine fisheries (Japan, Korea, Taiwan and USA) in the tropical Western and Central Pacific Convention Area (Fig. 21). This confirms that estimated standardized CPUE in SSS is likely reliable.

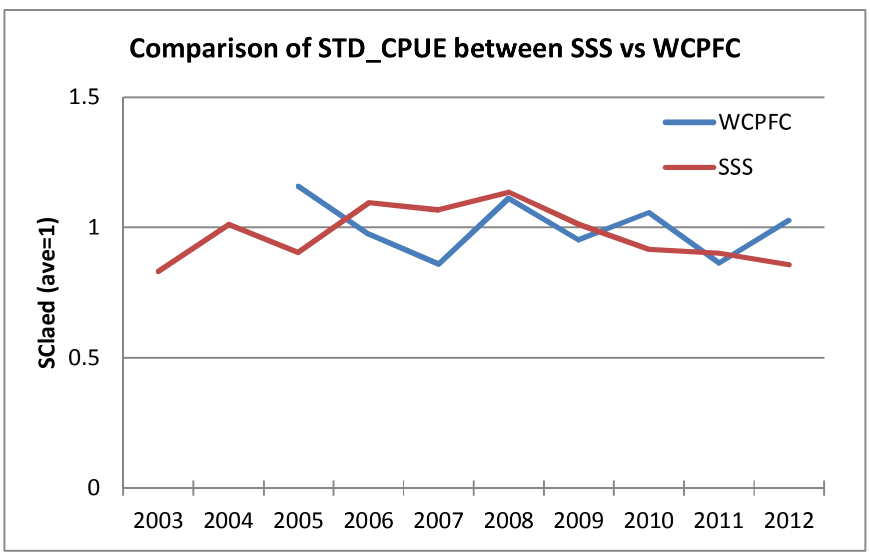


Fig. 21 Comparisons of standardized CPUE between SSS and WSPFC (Average CPUE of Japan, Korea, Taiwan and USA) (Scaled as ave.=1)

Bigeye tuna

To examine available long time series of CPUE data, we made CPUE summary table for sample size by gear type, location and year (Table 9). Based on Table 9, there are five long time series CPUE data sets (5 years or more), i.e., DGN (Drift gillnet, all area), Handline (Moro Gulf), MHK (multiple hook and line, all area), PS (purse seine, all area) and RING (ring net, all area), which are indicated by yellow markers in Table 9.

Table 9 Sample size of BET CPUE data set by gear type, location and year (yellow marker parts are the CPUE data set with a long term (more than 5 years) (BFAR database)

gear	location	2002	2003	2005	2006	2007	2008	2009	2010	2011	2012	2013
⊟DGN	ALL1						12	12	12	12		12
	ALL2										12	
	Cuyo East Pass								12			
	Cuyo East Pass?										12	
⊟GILL	ALL1								12		12	
⊟H+L	ALL1					12	12					
	Burias Island										12	
	Cuyo East Pass							12				
	Davao Gulf										12	
	Mindoro Strait										12	
	Romblon										12	
	Sibuyan Sea								12			
	Sibuyan Sea							12				
	Sulu Sea							24	24			
	Visaysan Sea						12		12	12	12	
⊟HAND	ALL1					12						
	Balut										12	
	Celebes										12	
	Davao Gulf						12		12	12	12	
	Indonesia										12	
	Irian										12	
	Kalamansig										12	
	Mati										12	
	Moro Gulf						12	12	12	12	12	
	Norte									12	12	
	Palawan									12		
	Seven Island										12	
	Tawi Tawi										12	
	Visaysan Sea									12		
	Zamboanga									12	12	
⊟LL	ALL1					12			12			
⊟MHL	ALL1	12	12	12	12	12	12	12	12			
	Cuyo East Pass										12	
	Davao Gulf						12		12	12	12	
	Illana Bay									12	12	
	Mindoro Strait										12	
⊟OTOSHI	ALL1										12	
⊟PS	ALL1				12	12	12	12	12	12	12	
⊟RING	ALL1		12	12	12	12	12	12	12	12	12	
⊟TROLL	ALL1						12		12	12	12	

We also examined the standardized CPUE by Bigelow (2015) (Table 7). After examining candidate STD_CPUEs, two STD_CPUE series are clarified as the realistic input for ASPIC, i.e., standardized CPUE of PS (BFAR) and Handline (Bigelow et al, 2015). Please note that nominal PS CPUE was standardized by GLM. Fig. 22 shows two standardized CPUE which are scaled as average STD_CPUE =1. These two CPUEs show the similar trends.

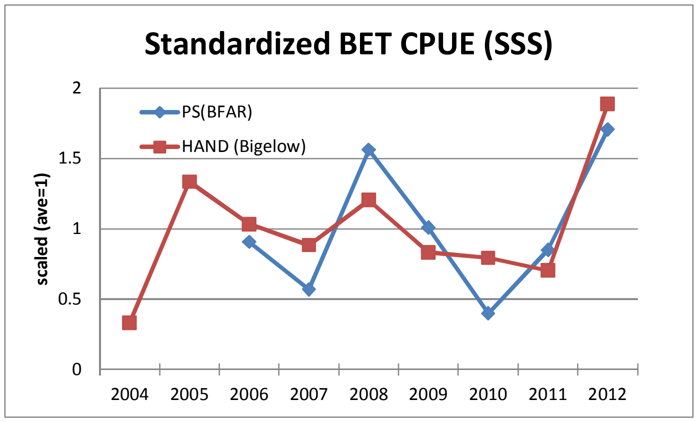
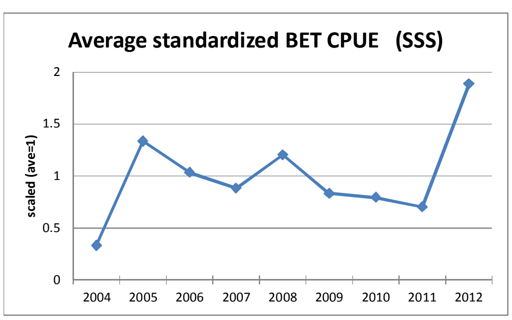


Fig. 22 Two BET standardized CPUEs in SSS to be used for ASPIC

As we use the global nominal catch, we use the average standardized CPUE of these two gears. Fig. 23 shows the average standardized CPUE, which are scaled as average STD_CPUE =1. However, STD_CPUE 2004=>2005 and 2011=>2012 show unrealistic jumps (more than 3 times), thus we exclude 2 points (2004 and 2012) for ASPIC runs (Fig. 24). This standardized CPUE series shows more realistic and natural declining trend.



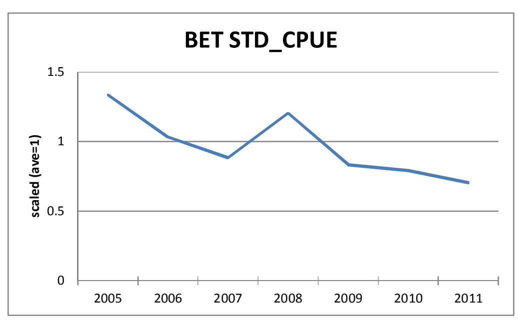


Fig. 23 Average standardized CPUE of two BET STD_CPUEs in Fig 15 (2004-2012).

Fig. 24 BET STD_CPUE without 2 outliers. (2005-2011)

Skipjack tuna (SKJ)

To examine available long time series of CPUE data, we made CPUE summary table for sample size by gear type, location and year (Table 10). Based on Table 10, there are five long time series CPUE data sets (more than 5 years), i.e., DGN (Drift gillnet, all area), Handline (Moro Gulf), MHK (multiple hook and line, all area), PS (purse seine, all area) and RING (ring net, all area), which are indicated by yellow markers in Table 10.

Table 10 Sample size of SKJ CPUE data set by gear type, location and year (yellow marker parts are the CPUE data set with a long term (5 years or more).

gear	location	2002	2003	2005	2006	2007	2008	2009	2010	2011	2012	2013
⊟DGN	ALL1						12	12	12	12		12
	ALL2										12	
	Cuyo East Pass								12			
	Cuyo East Pass?										12	
⊟GILL	ALL1								12		12	
⊟H+L	ALL1					12	12					
	Burias Island										12	
	Cuyo East Pass							12				
	Davao Gulf										12	
	Mindoro Strait										12	
	Romblon										12	
	Sibuyan Sea								12			
	Sibuyan Sea							12				
	Sulu Sea							24	24			
	Visaysan Sea						12		12	12	12	
⊟HAND	ALL1					12						
	Balut										12	
	Celebes										12	
	Davao Gulf						12		12	12	12	
	Indonesia										12	
	Irian										12	
	Kalamansig										12	
	Mati										12	
	Moro Gulf						12	12	12	12	12	
	Norte									12	12	
	Palawan									12		
	Seven Island										12	
	Tawi Tawi										12	
	Visaysan Sea									12		
	Zamboanga									12	12	
⊟LL	ALL1					12	12					
⊟MHL	ALL1	12	12	12	12	12	12	12	12			
	Cuyo East Pass										12	
	Davao Gulf						12		12	12	12	
	Illana Bay									12	12	
	Mindoro Strait										12	
⊟OTOSHI	ALL1										12	
⊟PS	ALL1				12	12	12	12	12	12	12	
⊟RING	ALL1		12	12	12	12	12	12	12	12	12	
⊟TROLL	ALL1						12		12	12	12	

We also examined the standardized CPUE by Bigelow (2015) (Table 7). After all examinations of candidate CPUE, two STD_CPUE series are clarified as the realistic input for ASPIC, i.e., standardized CPUE of PS (Bigelow et al, 2015) and Handline (BFAR, 2014). Please note that nominal Handline CPUE was standardized by GLM. Fig. 25 shows three standardized CPUE which are scaled as average STD_CPUE =1. These two CPUEs show the similar trends.

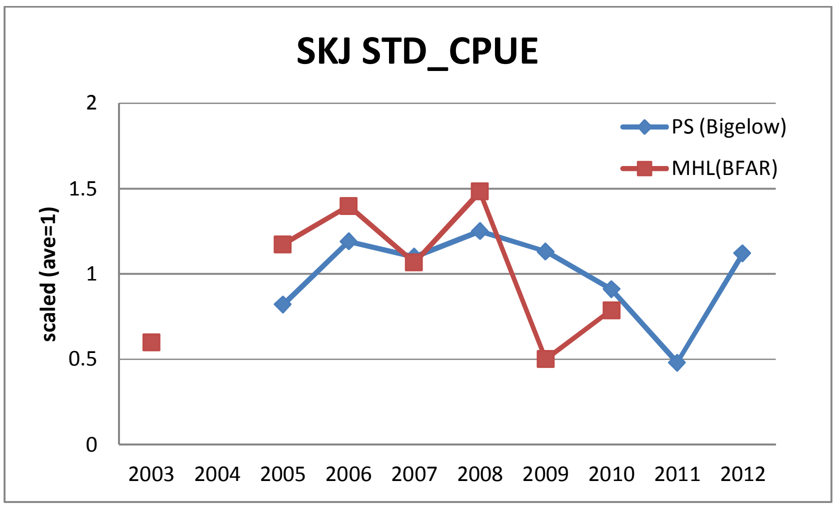


Fig. 25 Two SKJ standardized CPUEs in SSS to be used for ASPIC

As we use the global nominal catch, we use the average standardized CPUE of these two gears. Fig. 26 shows the average standardized CPUE, which are scaled as average STD_CPUE =1.

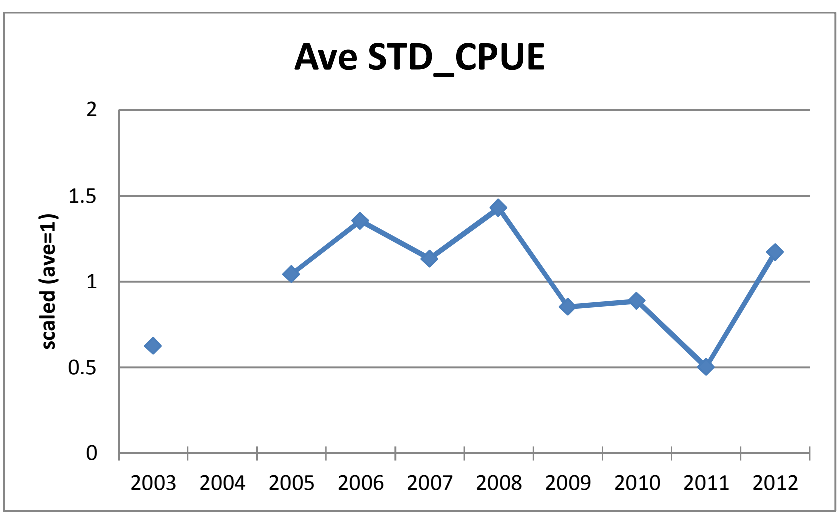
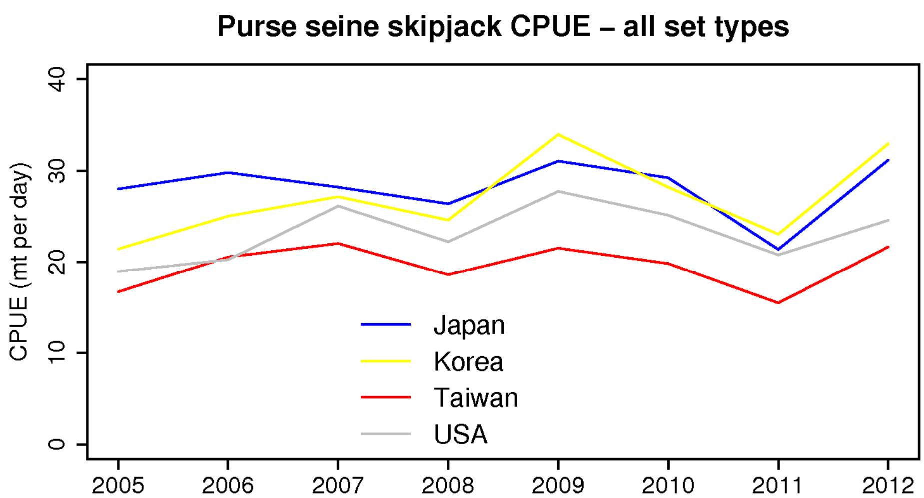


Fig. 26 Average standardized CPUE of two SKJ STD_CPUE in Fig 17.

The average standardized CPUE in SSS is like standardized CPUE of purse seine fisheries (Japan, Korea, Taiwan and USA) in the tropical Western and Central Pacific Convention Area (Fig. 27). This confirms that estimated standardized CPUE in SSS is likely reliable.



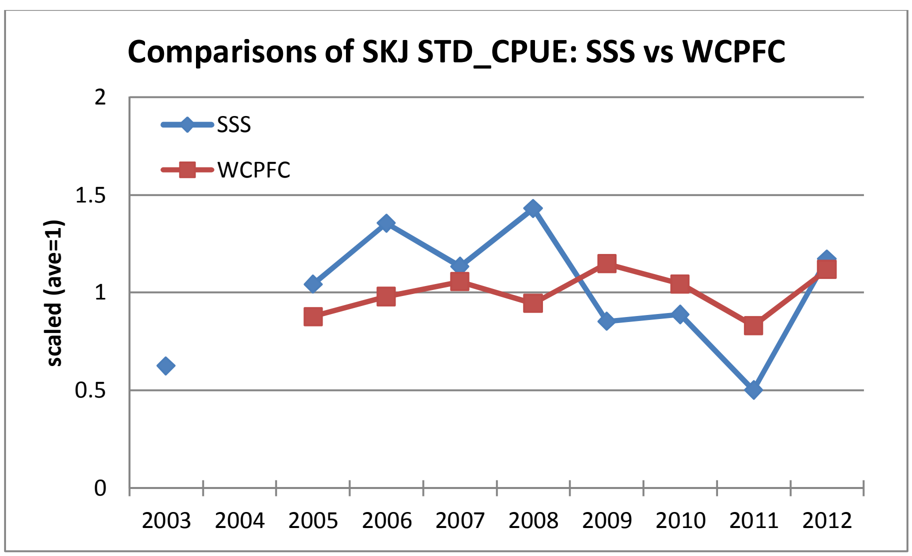


Fig. 27 (*Above*) Standardized YFT CPUE for all set types combined in PS fleets fishing in the tropical WCPFC Area (Williams and Terawasi, 2013).

(Below) Comparisons of standardized CPUE between SSS and WSPFC (Average CPUE of Japan, Korea, Taiwan and USA) (Scaled as Ave=1)

5. ASPIC

We are now ready to run ASPIC for three species (YFT, BET and SKJ) as we have essential data, i.e., catch and standardized CPUE.

5.1 Yellowfin tuna

Using catch and standardized CPUE in SSS (Fig. 28), we attempted ASPIC (Schaefer and Fox model). Figs 28 and 29 suggest that the relation between catch vs. standardized CPUE are not good as we don't see the clear negative Correlations.

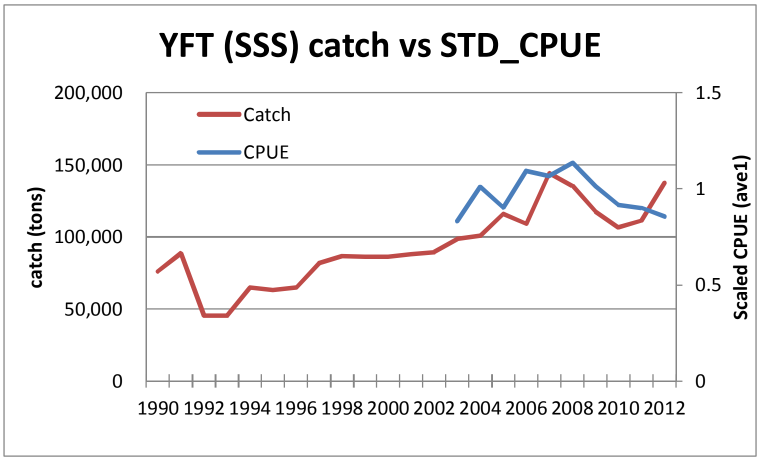


Fig. 28 Input (Catch and standardized CPUE) for ASPIC

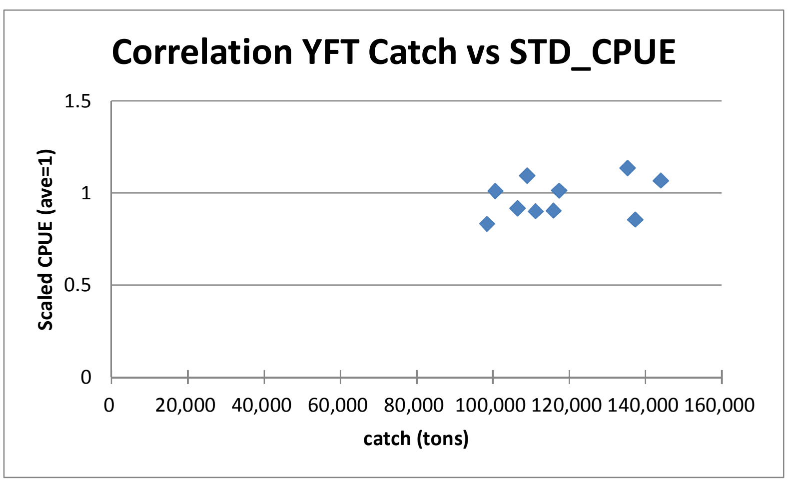


Fig. 29 Correlation between catch and STD_CPUE

ASPIC runs

Eight scenarios are attempted as shown in Table 11. Only one scenario (4) got the conversion. This may be due to poor correlation between catch and STD_CPUE. Figs. 30-32 show the Kobe plot which is compared with the one in WCPFC (MULTIFAN-CL).

The stock status in SSS is much worse than in WCPFC in terms of both F and Biomass. This implies that there is local YFT stock depression due to relatively higher fishing effort than in the whole WCPFC area.

Table 11 Eight scenarios for ASPIC runs and results

Scenario number	Production Model	B0/K		Results					
				estimated B0/K	RMSE (*)	R2 CPUE	MSY 1,000 tons	Fratio	TBratio
1	Schaeffer	Estimated		nc					
2		Fixed	0.8		nc				
3			0.6		nc				
4			0.4		0.120	0.042	112	1.18	1.03
5	Fox	Estimated		nc					
6		Fixed	0.8		nc				
7			0.6		nc				
8			0.4		nc				

(*) Root Mean Square Errors. nc: not converged

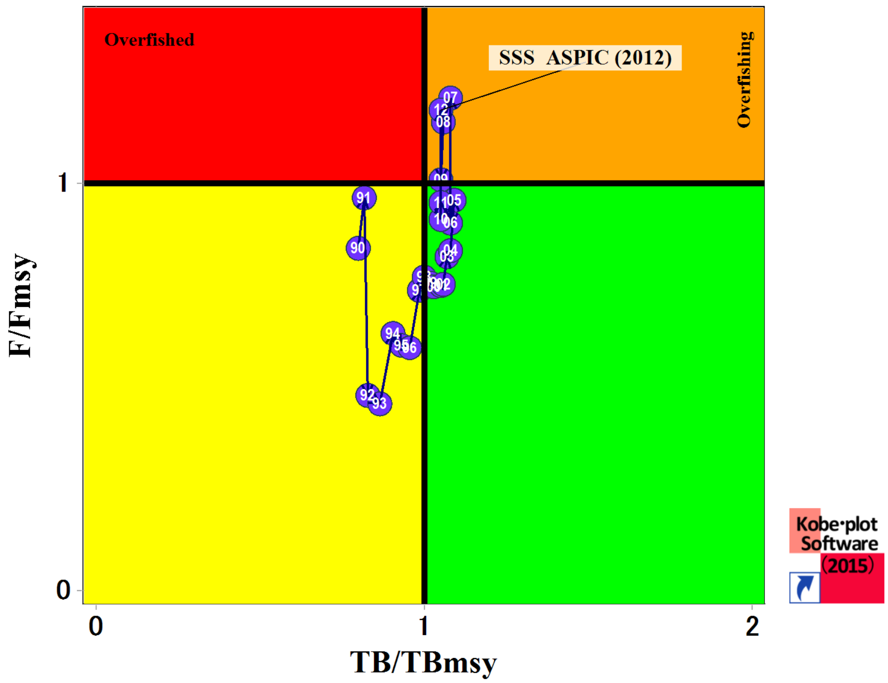


Fig. 30 Kobe plot of ASPIC results (SSS)

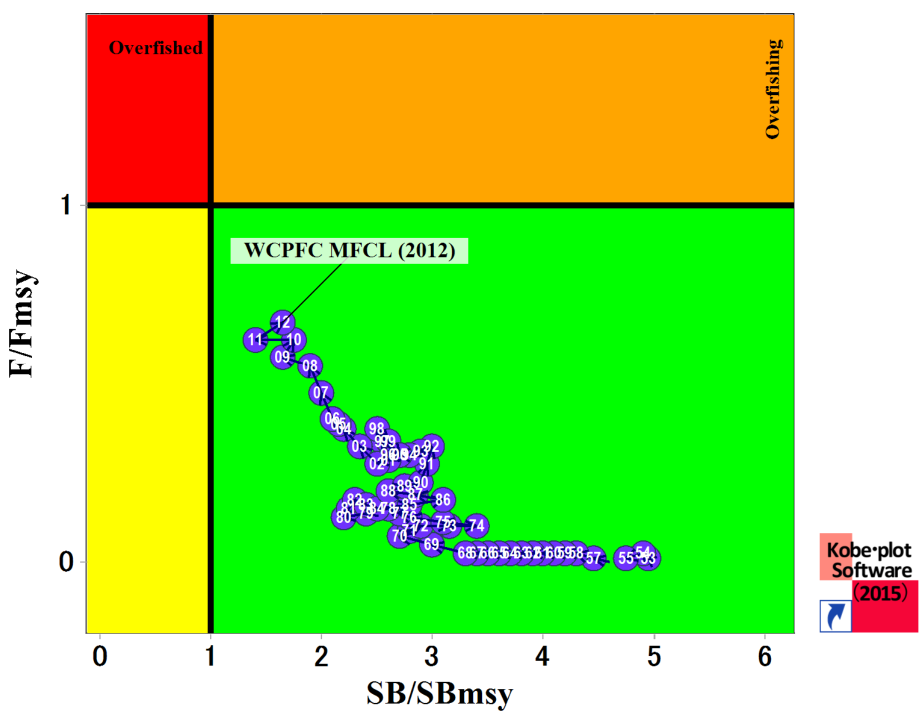


Fig. 31 Kobe plot of MULTIFAN-CL results (WCPFC)

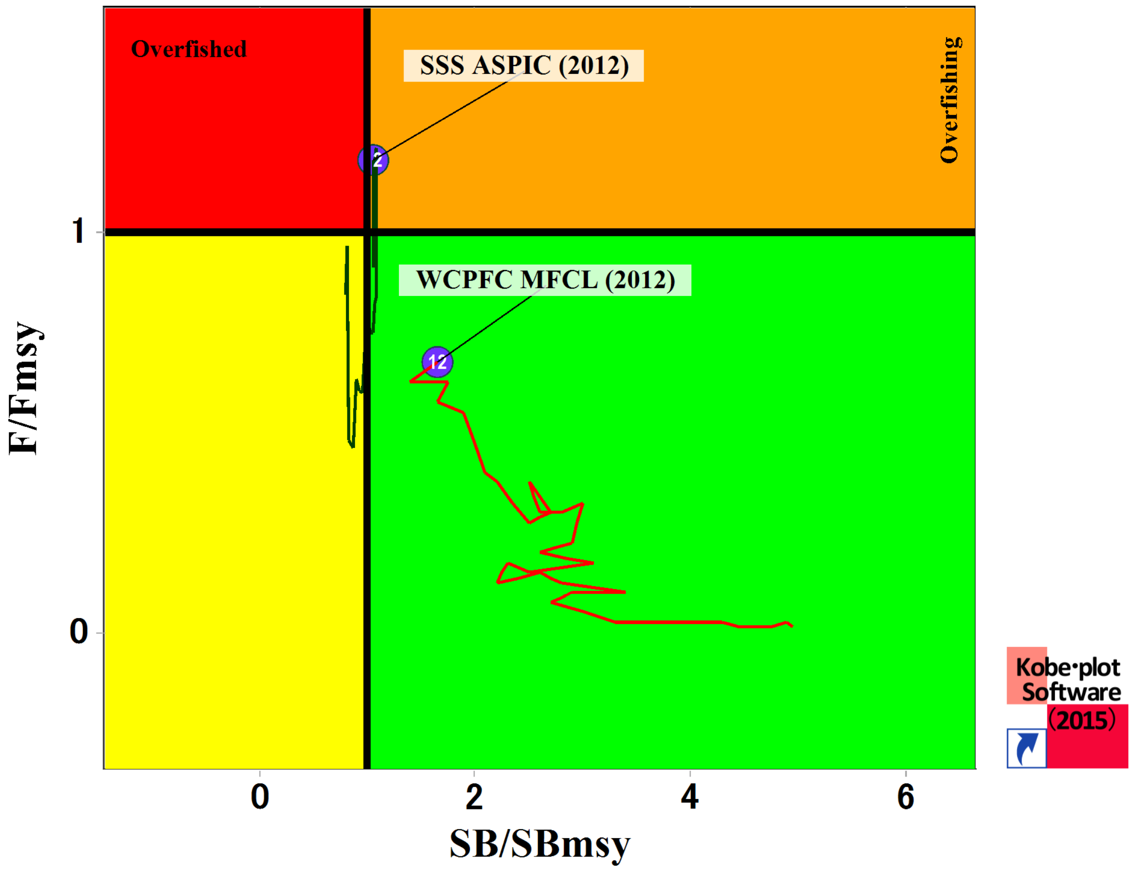


Fig. 32 Kobe plots of YFT ASPIC (SSS) and MULTIFAN-CL (WCPFC) results

5.2 Bigeye tuna

Using catch and standardized CPUE in SSS (Fig. 33), we attempted ASPIC (Schaeffer and Fox model). Figs 33 and 34 suggest that the relations between catch vs. standardized CPUE are not good as we don't see the clear negative Correlations.

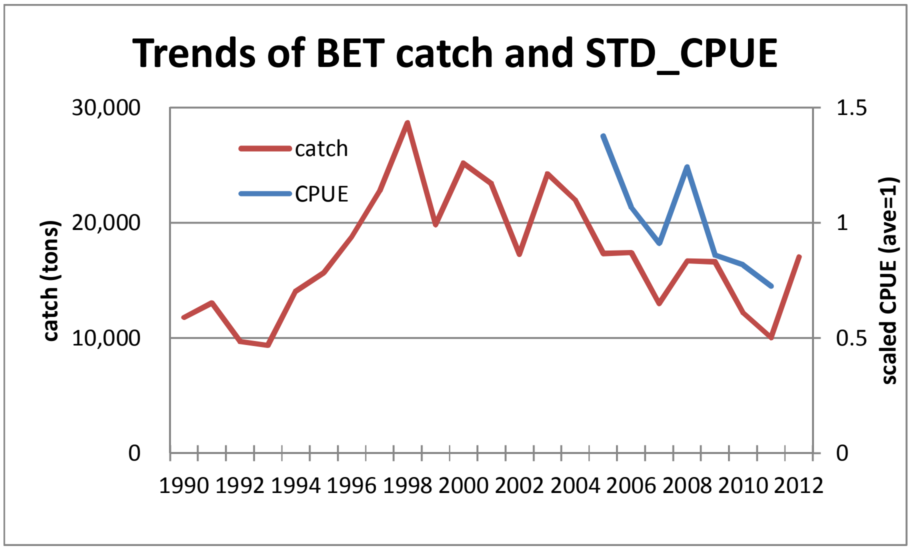


Fig. 33 Input (Catch and standardized CPUE) for ASPIC

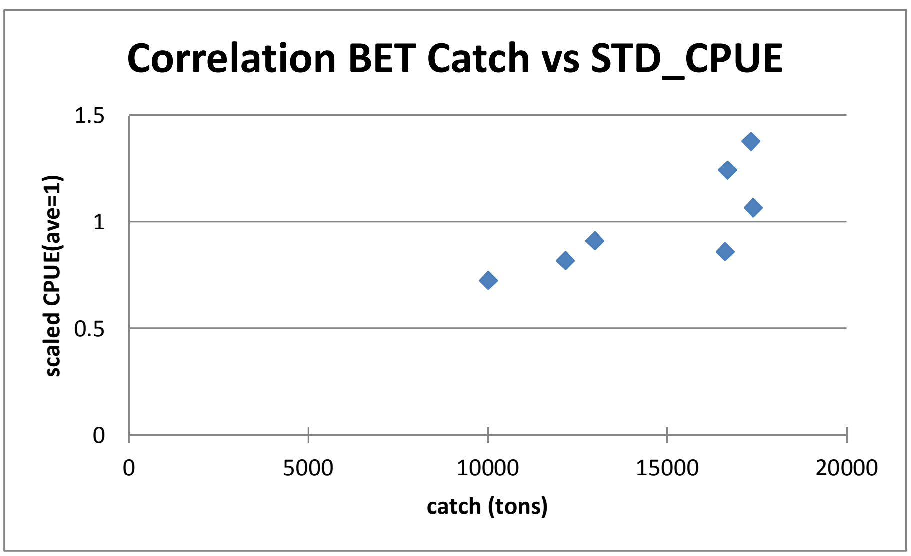


Fig. 34 Correlation between catch and STD_CPUE

ASPIC runs

Eight scenarios are attempted as shown in Table 12. Schaefer model fits better than Fox model. The best scenarios are 3 and 4. Scenario 3 fits slightly better than Scenario 4. Thus, we select the result of Scenario 3. Figs. 35-37 show the Kobe plot which is compared with the one in WCPFC (MULTIFAN-CL).

The stock status in SSS is much worse than in WCPFC in terms of Biomass. However, F in SSS is better than in WCPFC. F in SSS was higher than in WCPFC in 2003-2010 which reduced biomass and created the local depression in SSS. However, F was much reduced in 2011-2012 and the biomass is expected to recover in the future.

Table 12 Eight scenarios for ASPIC runs and results

Scenario number	Production Model	B0/K		Results					
				estimated B0/K	RMSE (*)	R2 CPUE	MSY 1,000 tons	Fratio	TBratio
1	Schaeffer	Estimated		nc					
2		Fixed	0.8		nc				
3			0.6		0.140	0.738	20	1.53	0.33
4			0.4		0.141	0.737	20	1.54	0.33
5	Fox	Estimated		nc					
6		Fixed	0.8		nc				
7			0.6		0.150	0.707	17	3.71 Too high	0.24
8			0.4		nc				

(*) Root Mean Square Errors

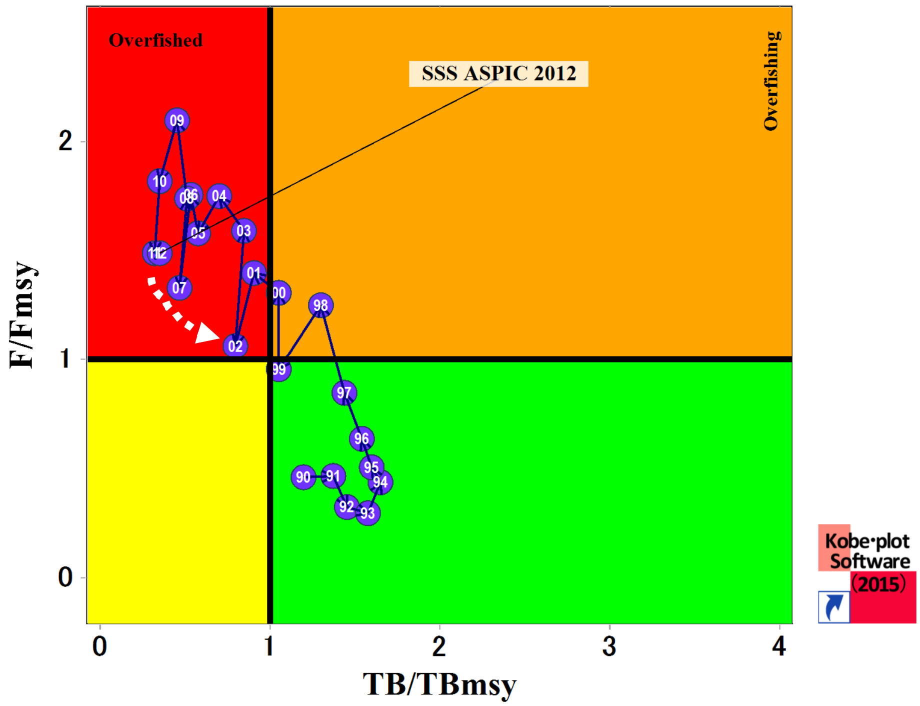


Fig. 35 Kobe plot of ASPIC results (SSS)

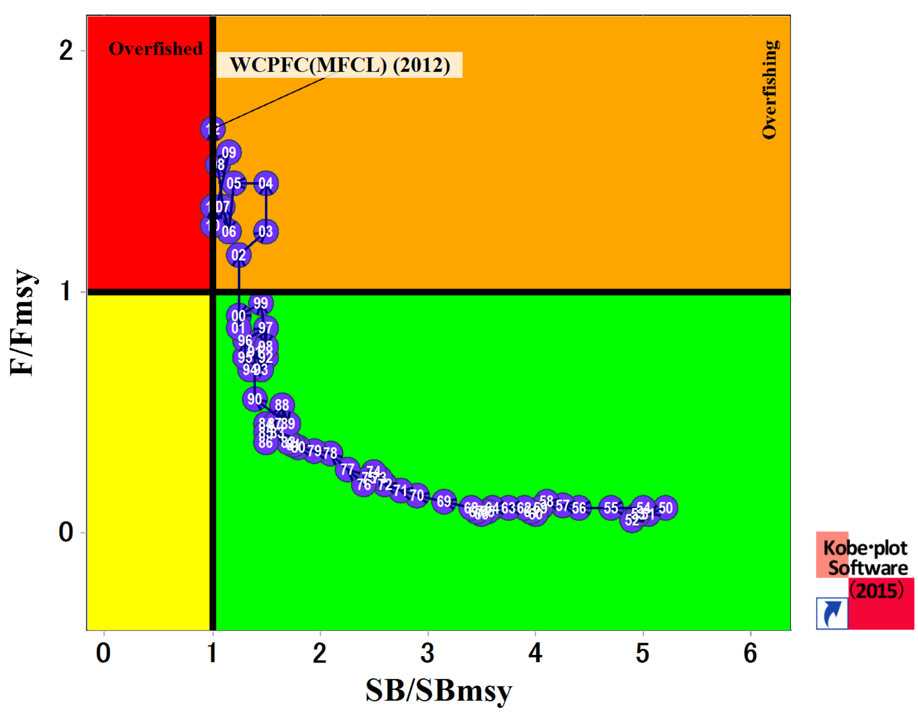


Fig. 36 Kobe plot of MULTIFAN-CL results (WCPFC)

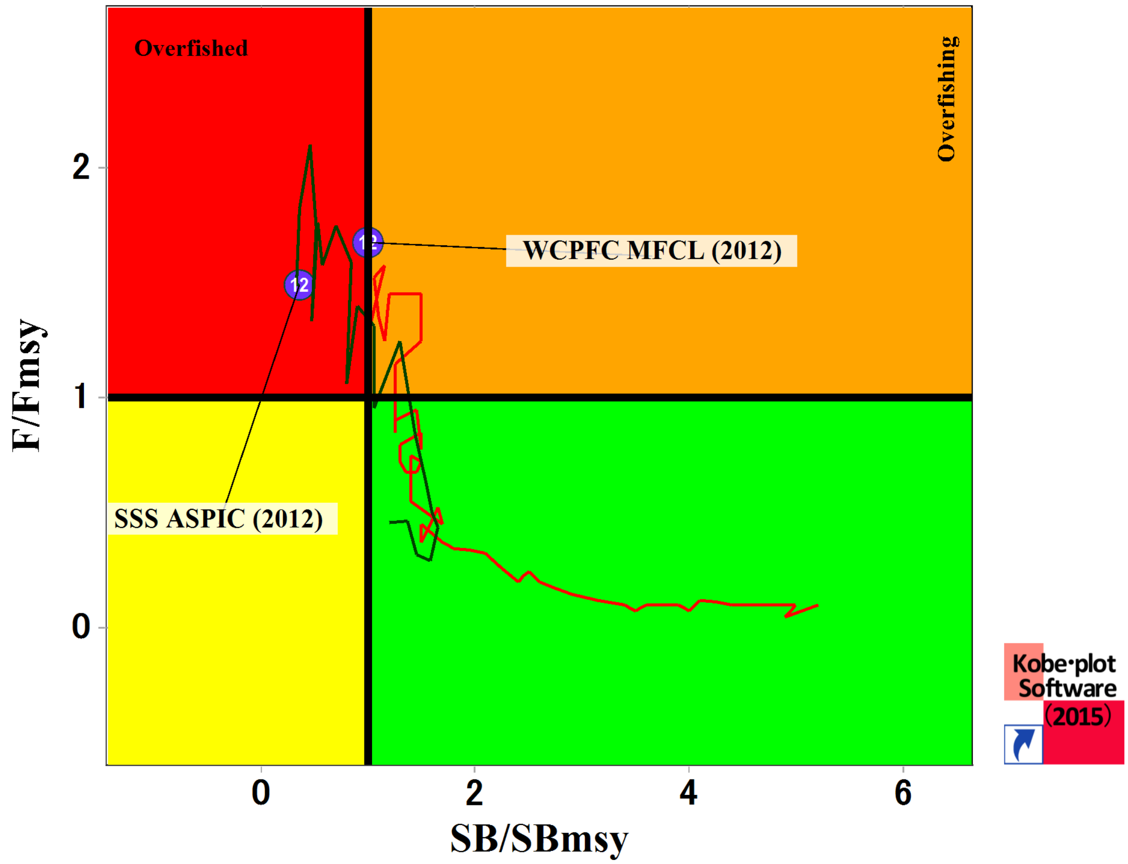


Fig. 37 Kobe plots of ASPIC (SSS) and MULTIFAN-CL (WCPFC) results

5.3 Skipjack

Using catch and standardized CPUE in SSS (Fig. 38), we attempted ASPIC (Schaeffer and Fox model). Figs 38 and 39 suggest that the relations between catch vs. standardized CPUE are not good as we don't see the clear negative Correlations.

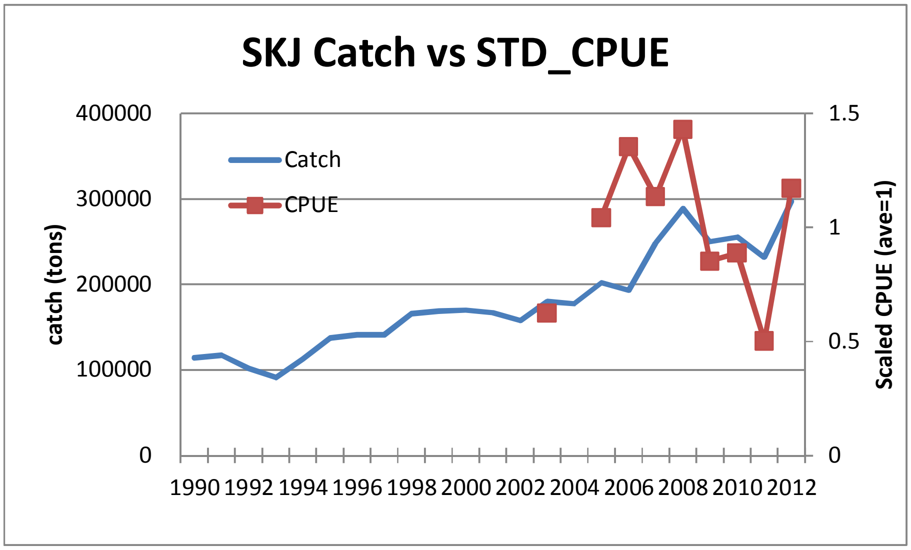


Fig. 38 Input (Catch and standardized CPUE) for ASPIC

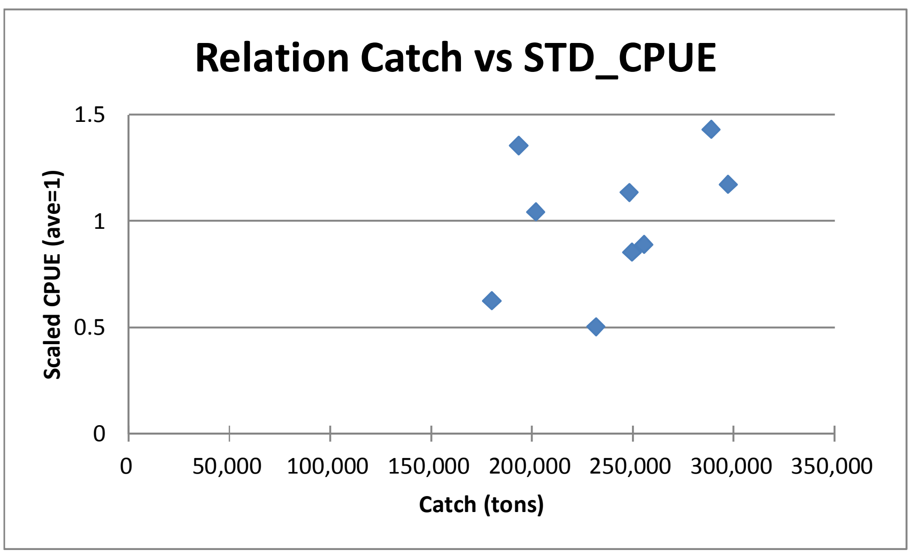


Fig. 39 Correlation between catch and STD_CPUE

ASPIC runs

Eight scenarios are attempted as shown in Table 13. The best scenarios are likely 4 and 8. Considering the current WCPFC situation, Fratio = 1.38 (Scenario 4) is high. Thus, we select Scenario 8 for SSS. Figs. 40-42 shows the Kobe plot which is compared with the one in WCPFC (MULTIFAN-CL).

The stock status in SSS is much worse than in WCPFC in terms of F, while biomass levels are in the same situation. This implies that F in SSS is relatively higher than in WCPFC, while the biomass levels are the same.

Table 13 Eight scenarios for ASPIC runs and their results

Scenario number	Production Model	B0/K		Results					
				estimated B0/K	RMSE (*)	R2 CPUE	MSY 1,000 tons	Fratio	TBratio
1	Schaeffer	Estimated		Not converged					
2		Fixed	0.8		Not converged				
3			0.6		0.396	0.008	211	1.12	1.23
4			0.4		0.391	0.036	203	1.38	1.03
5	Fox	Estimated		Not converged					
6		Fixed	0.8		Not converged				
7			0.6		0.396	0.005	253	0.69	1.67
8			0.4		0.393	0.026	223	0.95	1.38

(*) Root Mean Square Errors

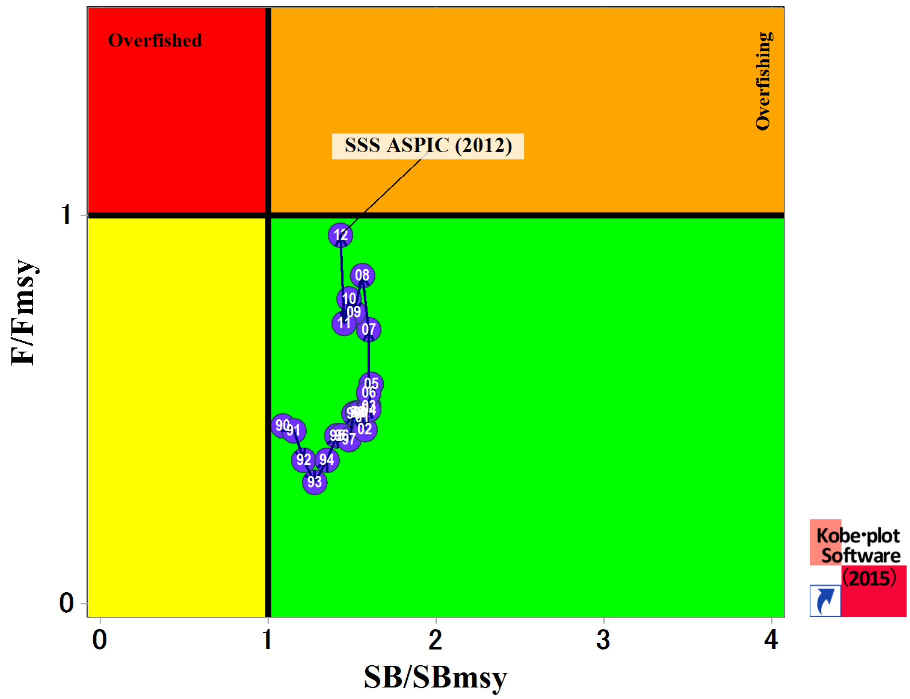


Fig. 40 Kobe plot of ASPIC results (SSS)

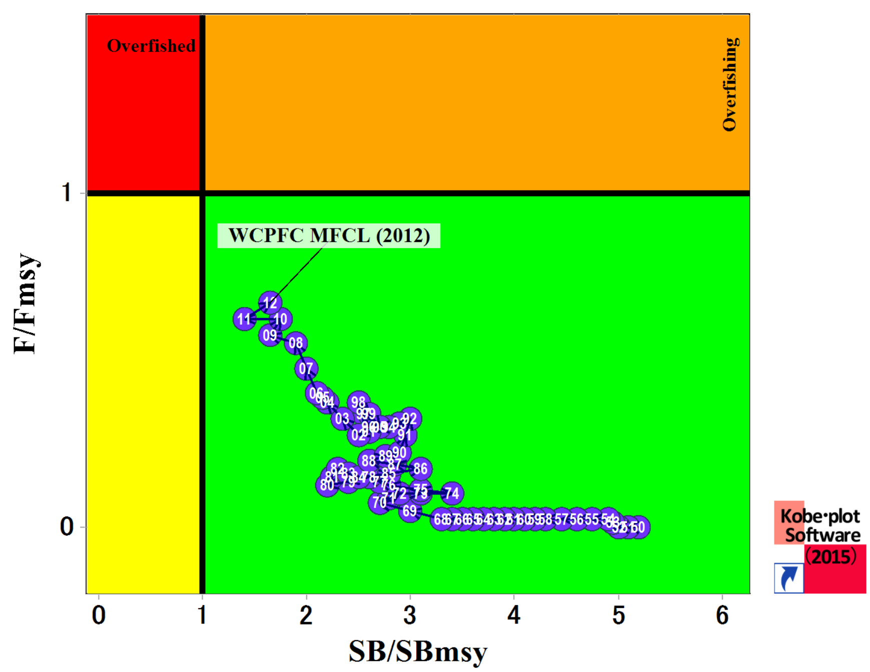


Fig. 41 Kobe plot of MULTIFAN-CL results (WCPFC)

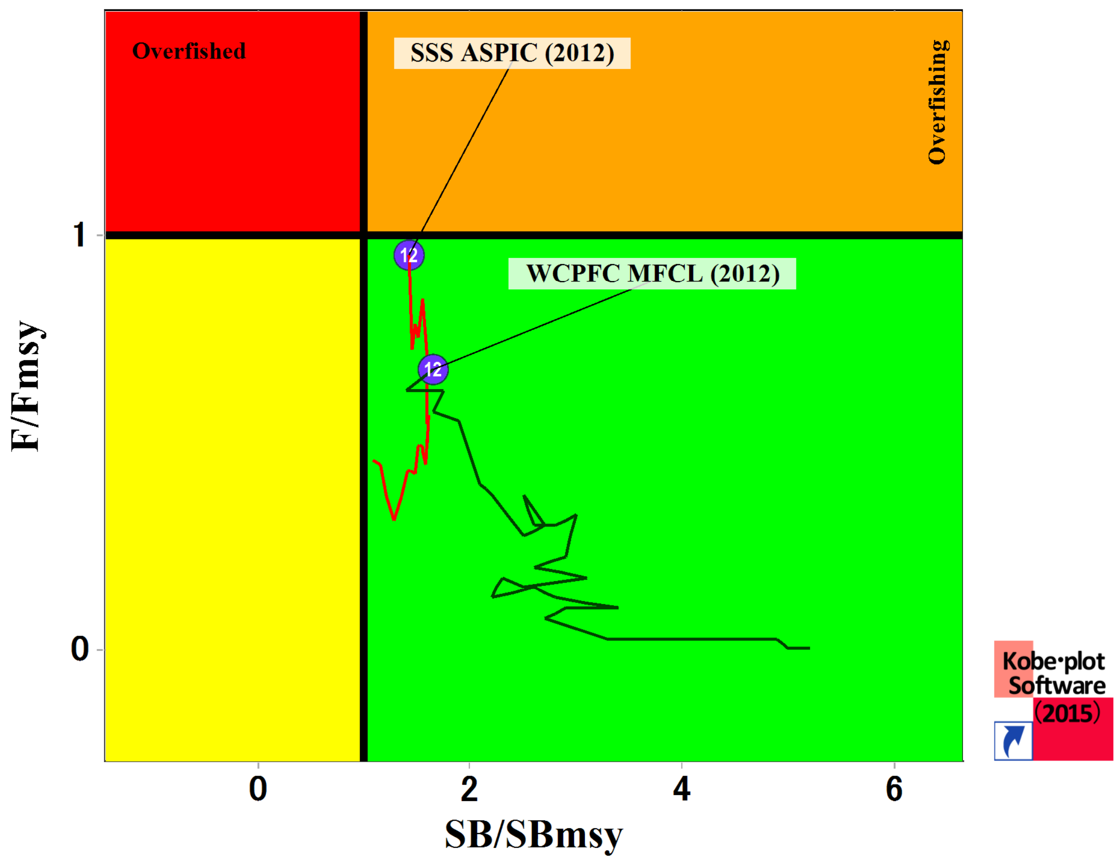


Fig. 42 Kobe plots of ASPIC (SSS) and MULTIFAN-CL (WCPFC) results

6 Discussion

(1) Catch

Estimated catch (YFT+BERT+SKJ) are likely plausible as they are 19% (YFT), 12% (BET) and 14% (SKJ) of the WCPFC catch, which is reflected to the size of fisheries in SSS. However, we need to improve disaggregation method for species aggregated catch data, i.e., we need to apply season and area specific species compositions.

(2) Time series of catch and CPUE

Time series (number of years) of catch is 1990-2012 (23 years), which is sufficient for stock assessments, while CPUE for 10 years (2003-2012) are the minimum period. Due to the short time series of CPUE, results are very sensitive by trends of CPUE. For sometimes, one CPUE point influences results of stock assessments. Hence results of stock assessments should be looked with caution.

(3) Relation between catch and standardized CPUE

There were not clear negative correlations between catch and CPUE, which implies that standardized CPUE may not reflect to the abundance.

(4) Stock status of YFT in SSS (Box 1, page 3) and comparison with the WCPFC

The results of stock assessments suggest that the current (2012) fishing pressure (F) in SSS is 18% higher than in the Fmsy level, while total biomass is about the MSY level. As for the one in WCPFC, both F and total biomass are within safe levels (green zone in the Kobe plot). This suggests that F level in the SSS is locally higher than in the western-central Pacific waters, while total biomass (population) level is locally lower than in WC Pacific waters.

(5) Stock status of BET in SSS (Box 1, page 3) and comparison with the WCPFC

The results of ASPIC stock assessments suggest that the current (2012) fishing pressure (F) in SSS is 53 % higher than in the Fmsy level and total biomass is less than 67% than in the TBmsy level. This clearly shows that BET stock in SSS is in the overfished status.

As for the one in WCPFC, F is also more than 50% higher than in the MSY level, while spawning stock biomass is about the MSY level. Hence the stock status for both SSS and WCPFC are not in the healthy conditions.

(6) Stock status of SKJ in SSS (Box 1, page 3) and comparison with the WCPFC

The results of ASPIC stock assessments suggest that the current (2012) fishing pressure (F) in SSS is about in the MSY level, while the total biomass is 38% higher than in the TBmsy level. This indicates that SKJ stock status in SSS is in the healthy status (green zone), although F is close to MSY level. As for the one in WCPFC is in the safe condition, i.e., both F and TB are in the green zone.

(7) Comparison of the Kobe plot (trajectories) between SSS and WCPFC

The Kobe plot patterns between SSS and WCPFC are highly different for all three species. This is because both stock statuses are based on different stock assessment models, i.e., SSS by ASPIC based on catch and CPUE, and WCPFC by MULTIFAN-CL based on catch, CPUE, biological information and movements. ASPIC results are heavily influenced by CPUE trends in SSS, while MUTIFAN-CL by CPUE and biological factors.

(8) Future works

We may wait a few more years, so that we can get 13 years of CPUE data which may produce more robust ASPIC stock assessments. Furthermore, we can also conduct other stock assessment models such as age structured models using biological data such as SCAA (Statistical-Catch-At-Age).

(9) Results of stock assessments

It is hoped that results of stock assessments for this time will be used as a reference to consider the managements as YFT and BET are not in healthy conditions in the SSS waters.

Recommendations

(1) For species aggregated catch, investigate season-area specific species compositions, and then apply them to dis-aggregate and re-estimate catch by species.

(2) Investigate the reasons why there are less negative correlation between catch and CPUE.

(3) After a few more years when CPUE are accumulated and (1) +(2) are completed, attempt ASPIC again and compare the results.

(4) When (3) is implemented, try also future projections and risk assessments (Kobe II) using the results of ASPIC, to see probabilities of risks violating MSY levels on F and TB (Total biomass) in the future.

(5) Attempt also age structured stock assessment models with biological data (for example, SCAA: Statistical-Catch-At-Age) to compare with results by ASPIC and MULTIFAN-CL.

(6) Additional Capacity Buildings are essential for participating countries to be able to conduct ASPIC.

(7) It will be ideal if results of stock assessments for this time may be discussed in participating countries as references of tuna managements.

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