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Stock and risk assessments of swordfish (*Xiphias gladius*) in the Indian Ocean by ASPIC incorporating uncertainties

(Revised 1)

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Abstract

Stock and risk assessments were conducted by ASPIC software using 64 years data (1950-2013) for swordfish in the whole and the SW Indian Ocean. In the stock assessments, uncertainties caused by production models (Schaefer vs. Fox) and targeting effect (SWO cluster vs. NHBF) were taken into account.

As for the Whole Indian Ocean, the stock is now at the well safe zone (green zone in the Kobe plot), i.e., Total biomass (TB) ratio=1.64 and F ratio=0.52. Risk assessments suggests no risks violating MSY levels at all if the current catch in 2013 (31,000 tons) or less level continues next 10 years, while the low risk with 20% increases (37,000 tons) and high risks with 40% increase (44,000 tons) for both TB and F ratios.

As for the SW Indian Ocean, the stock is now at the recovering stage (yellow zone close to both MSY levels of TB and F in the Kobe plot), i.e., Total biomass (TB) ratio=0.95 and F ratio=0.93. Risk assessment suggests that there are high risks violating MSY levels of TB ratio levels next 10 years if the current catch in 2013 (7,300 tons) were increased by 10% or more, while low or no risks if the current catch or less level were continued. As for F ratio, even if the current catch level were reduced by 10% (6,600 tons), there are high risks violating MSY levels. If the current catch levels were reduced more than by 20% (5,900 ton), there are less or no risks next 10 years.

Contents

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1. Introduction

We attempted the stock assessment of swordfish (*Xiphias gladius*) (SWO) in the Indian Ocean by A Stock-Production Model Incorporating Covariates (ASPIC) using 64 years data (1950-2013). As in the past, we conducted stock assessments for 2 areas (whole Indian Ocean and the SW IO) because the local depletion in the SW Indian Ocean has been detected (Nishida and Wang, 2011) and we need to know the current situation.

2. Stock assessments in the whole Indian Ocean

2.1 Data

(1) Catch

We used the nominal catch data from the IOTC dataset (**as of Oct., 15, 2014)** (Fig. 1).

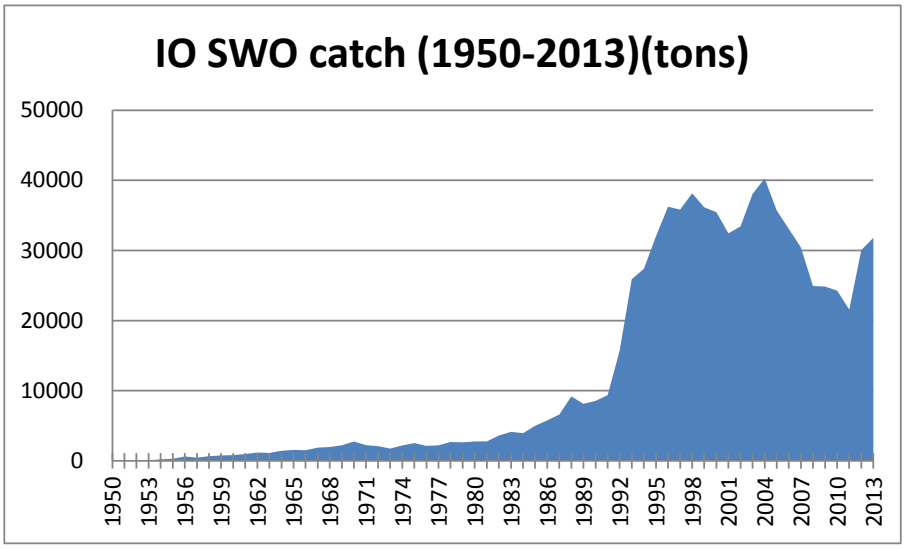


Fig. 1 Nominal catch of swordfish in the Indian Ocean (1950-2013) (**IOTC dataset, Oct., 15, 2014 version**)

(2) CPUE

We have 4 STD_CPUE (standardized CPUE) (Japan, Taiwan, Spain and Portugal) in the whole IO. Fig. 2a and 2b shows 4 STD_CPUE in 1971-2013 and in 1999-2013 respectively. JPN STD_CPUE shows the decreasing trend from 1971-2005 and afterward increasing trends and stabilized in

higher level, while they have big bumps. TWN STD_CPUE shows the increasing trend from 1980-1997, afterward constant trend, while they also have large bumps throughout. SPN and POR STD_CPUE trends show more or less flat trend

During 1991-1998, STD_CPUE trends between Japan and Taiwan show different trends, i.e., Japan shows the decreasing trend, while Taiwan, increasing trend. During 1999-2013, 4 STD_CPUE show more or less similar trend (flat trend).

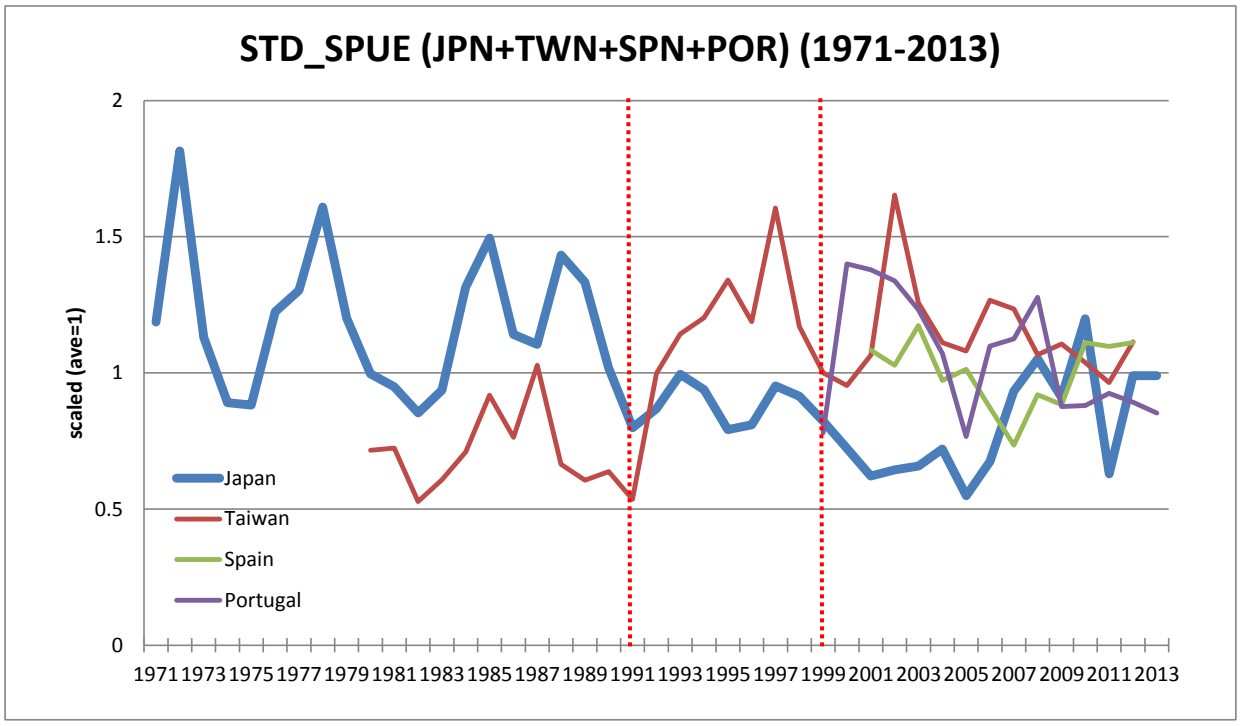


Fig 2a Comparisons of STD_CPUE among 4 fleets (Japan, Taiwan, Spain and Portugal) (1971-2013)

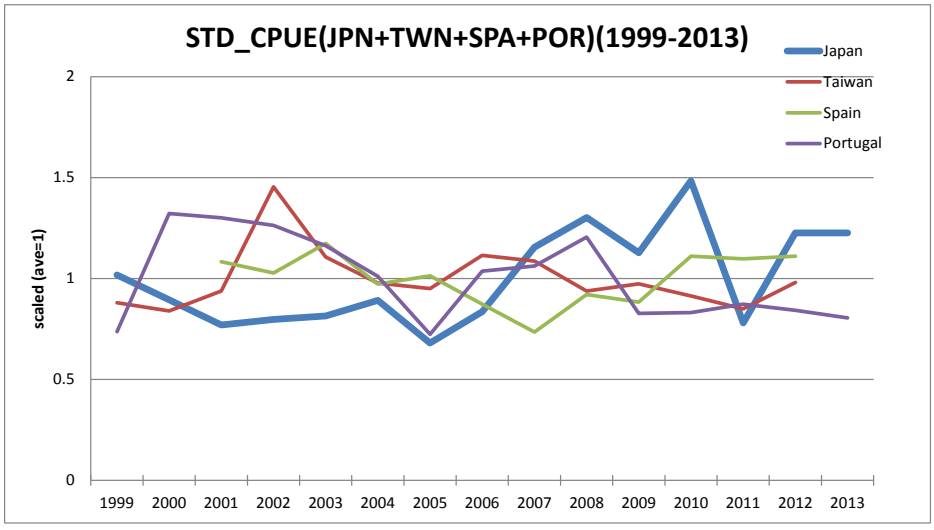


Fig 2b Comparisons of STD_CPUE among 4 fleets (Japan, Taiwan, Spain and Portugal) (1999-2013).

(3) Relation between nominal catch vs. STD_CPUE (Fig. 3)

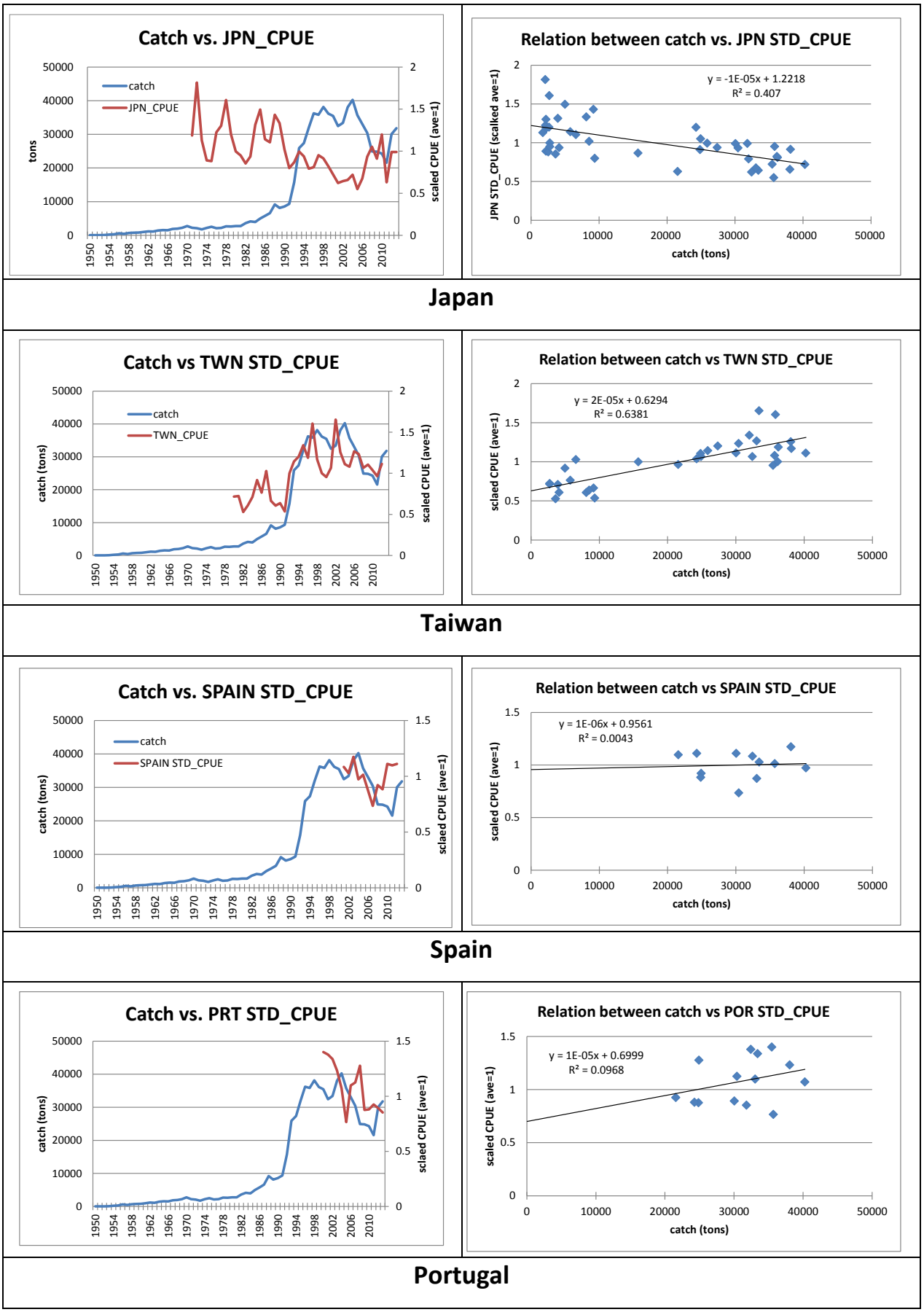


Fig. 3 Comparisons between nominal catch vs. STD_CPUE by fleet (Whole Indian Ocean)

Based on Fig. 3, only Japan has the negative correlation between nominal catch and STD_CPUE, hence we use JPN_CPUE for ASPIC runs.

2.2. ASPIC runs

We used the ASPIC software (ver. 5.05) developed by Prager (2004). For details of this software, refer to "User's Manual for ASPIC: A Stock-Production Model Incorporating Covariates (ver. 5) and auxiliary programs, Population Dynamics Team, Center for Coastal Fisheries and Habitat Research, National Oceanic and Atmospheric Administration, Beaufort, North Carolina, USA: National Marine Fisheries Service Beaufort Laboratory Document BL-2004-01" by Prager (2004).

In ASPIC, we set up 4 scenarios (Table 1) to incorporate uncertainties between models (FOX vs. Schaefer) and also between targeting effects (SWO cluster vs. NHBF) (Fig.4). We assume B1950 =K. Table 1 and Figs. 5-6 show results. To represent these uncertainties, we used weighted average of RMSE (Root Mean Square Errors) and Fig. 7 and Table 1 show the results.

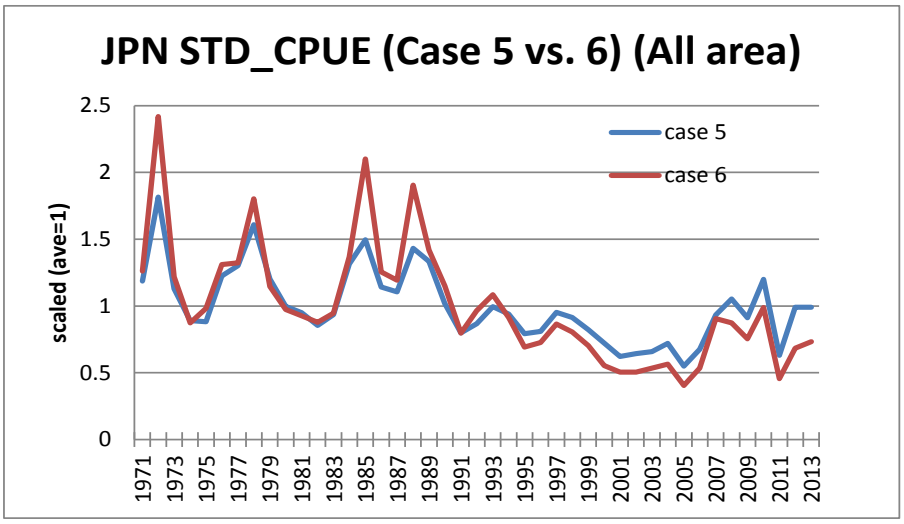


Fig 4 JPN STD_CPUE used for the ASPIC runs (case 5: SWO cluster and case 6: NHBF)

(Refer to Table 1)

Table 1 ASPIC runs incorporating uncertainties (4 scenarios) and results (1950-2013)

Scenario	Elements of uncertainty		R2 (CPUE)	RMSE (over all)	MSY (tons)	TB(2013) /TB(MSY)	F(2013) /F(MSY)
	Model	Targeting effect					
(1)	FOX	SWO cluster	0.416	0.2017	44,480	1.93	0.37
(2)		NHBF	0.420	0.2003	37,300	1.46	0.57
(3)	SCHAEFER	SWO cluster	0.455	0.2706	35,970	1.69	0.51
(4)		NHBF	0.419	0.2808	34,260	1.38	0.66
Overall ASPIC results incorporating uncertainties (weighted average by 1/RMSE)					38,450	1.63	0.52

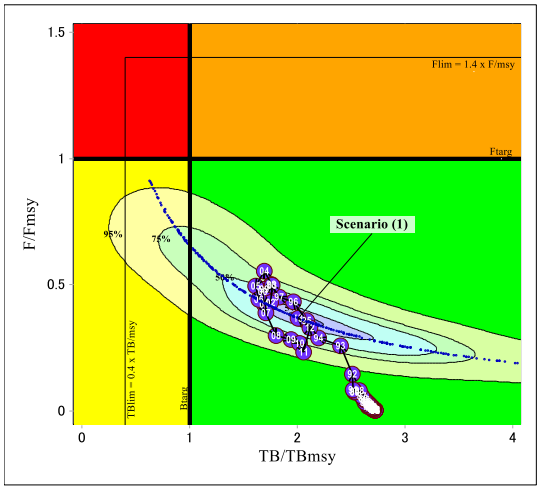
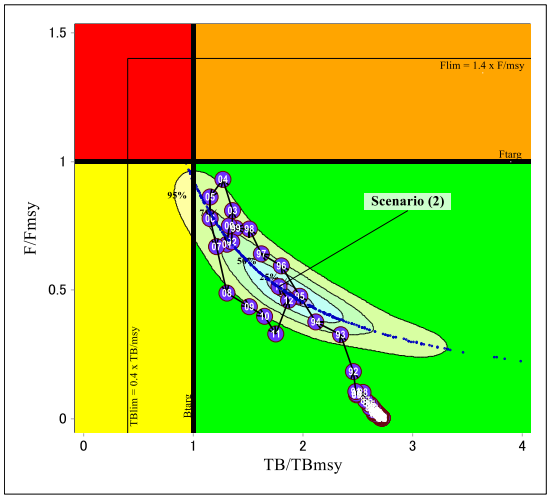
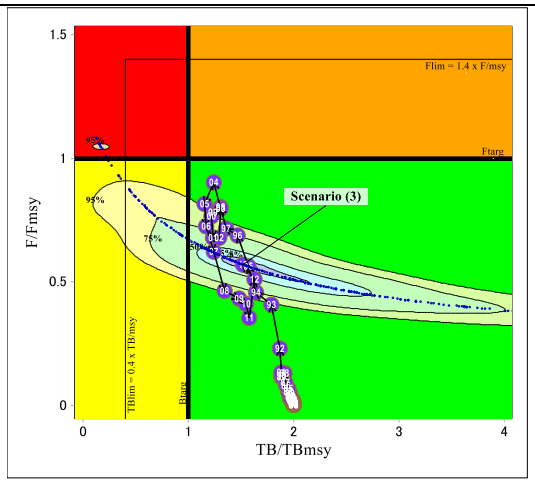
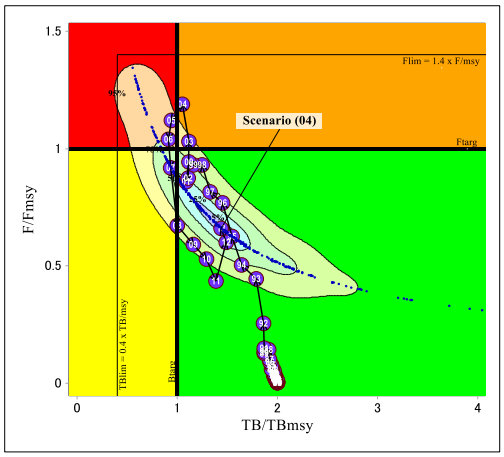
	SWO cluster	NHBF
FOX		
	Scenario (1)	Scenario (2)
SCHAEFER		
	Scenario (3)	Scenario (4)

Fig. 5 Kobe plots of ASPIC results (4 scenarios) showing uncertainties among and within and scenarios.

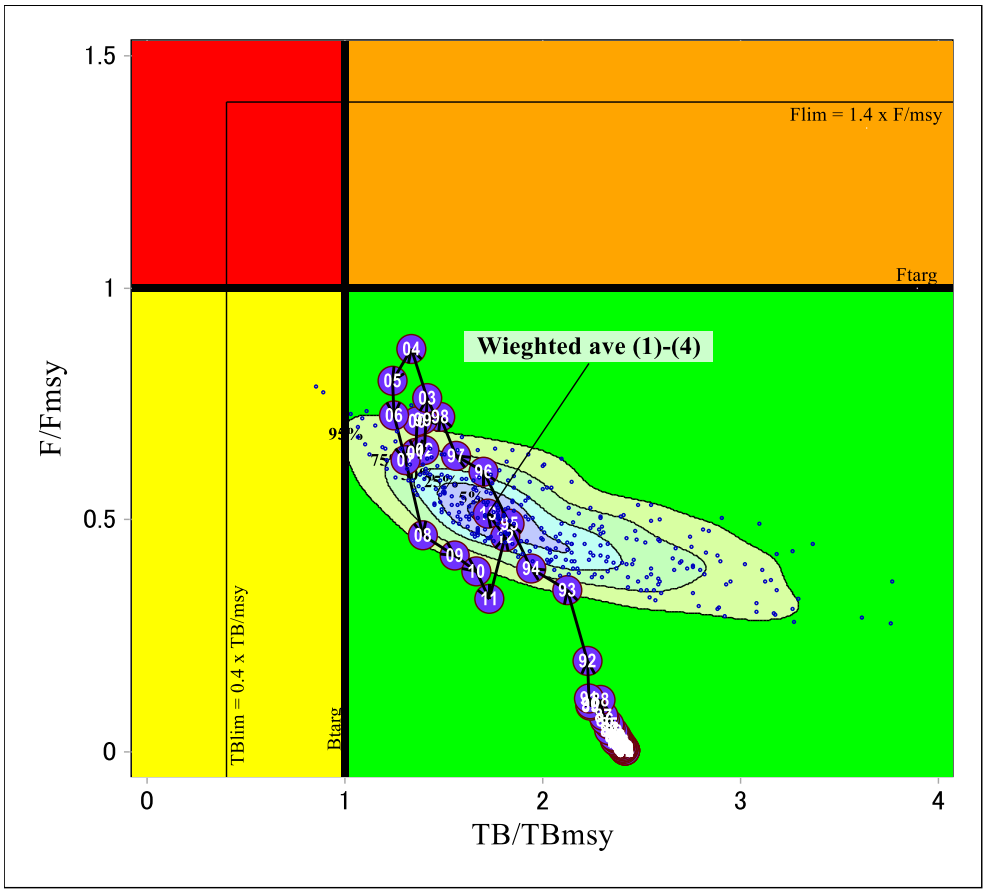


Fig. 6 Kobe plot incorporating uncertainties in 4 scenarios (weighted average of 1/RMSE)

Table 2 Summary of ASPIC result

Management Quantity	Whole Indian Ocean
Most recent catch estimate (t) (2013)	31,804
Mean catch over last 5 years (t) (2009-2013)	26,510
MSY (1000 t) (80%CI)	38.5 (26.3-56.2)
Data Period used in assessment	1950-2013 (64 years)
F(2013)/F(MSY) (80% CI)	0.52 (0.48-0.55)
TB(2013)/TB(MSY) (80% CI)	1.63 (1.60-1.69)
SB(2013)/SB(MSY)	NA
TB(2013)/TB(1950)	0.76
SB(2013)/SB(1950)	NA
TB(2013)/TB(2013, F=0)	NA
SB(2013)/SB(2013, F=0)	NA

2.3 Discussion (ASPIC)

(1) Why we got much more optimistic stock status this time than in last time (2011)?

In the last stock assessment by ASPIC (2011) using 30 years data (1980-2009), the Kobe plot shows more conservative phase (Fig. 7) than those in this time (Figs. 5-6). This gap is likely caused likely by the following reason, i.e., the previous assessment in 2011 used CPUE for 30 years [B]-[C] (1980-2009), while for this time for 43 years [A]-[D] (1971-2013). This means that the stock assessment for this time include the recent recovery phase [D], which likely made much optimistic stock status (Fig. 8).

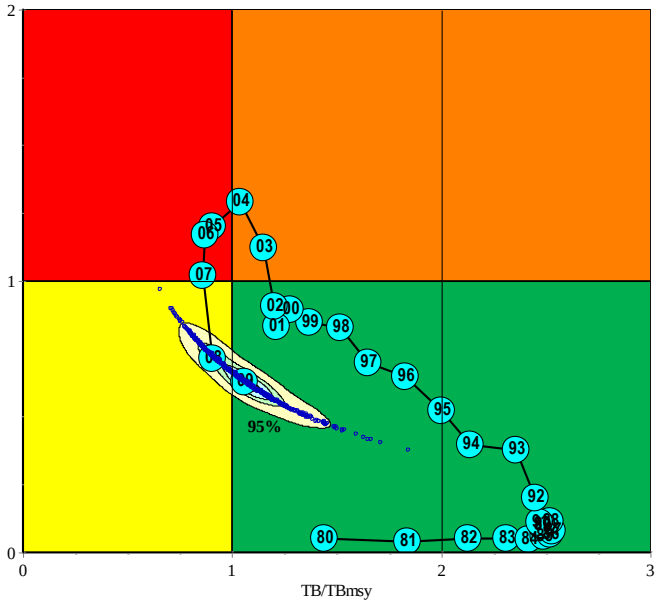


Fig. 7 Kobe plot of the 2011 stock assessment by ASPIC using 1980-2009 data (Nishida and Wang, 2011)

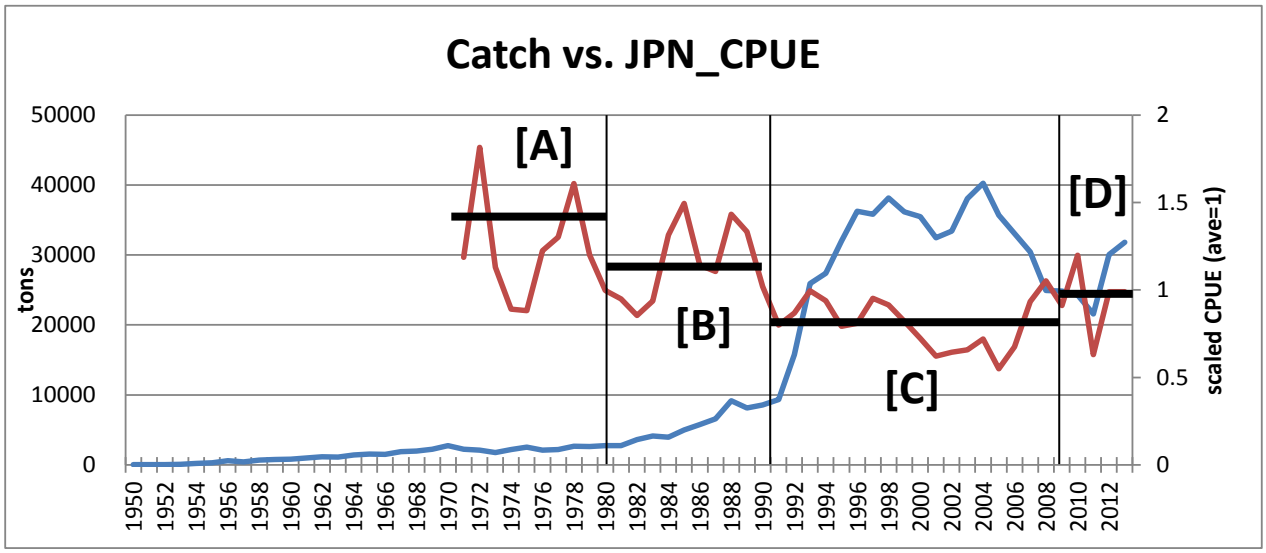
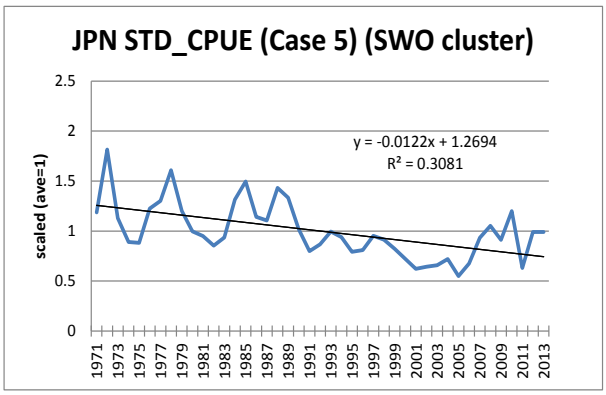
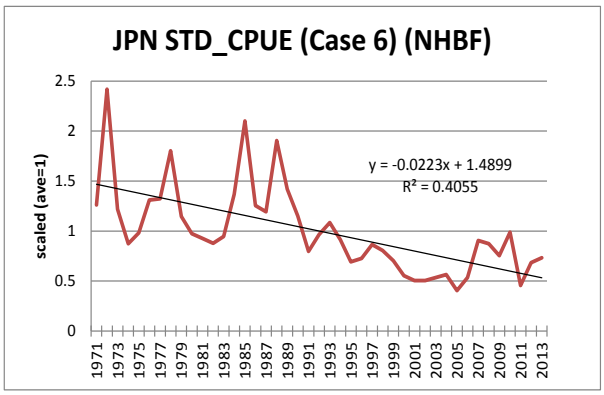


Fig. 8 Trend of JPN STD_CPUE (4 phases) [A]-[D] and the catch trend

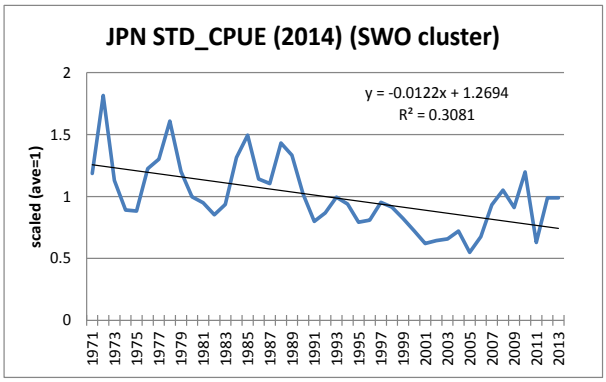
(2) Why STD_CPUE (SWO cluster) made ASPIC results much optimistic than the one (NHBF)?

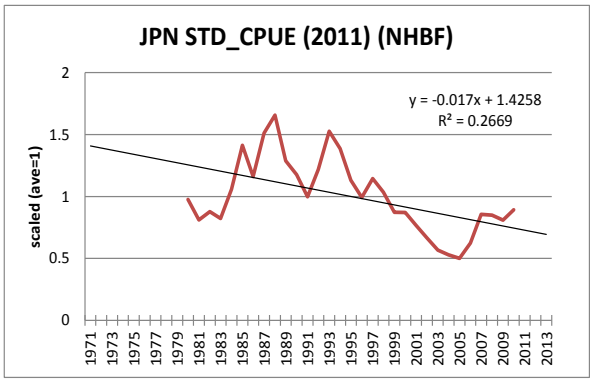
The reason is considered as follows: Targeting effect by NHBF cluster makes CPUE trends much steeper than the one by SWO cluster. This is easily understood from the comparison of STD_CPUE between 2 targeting effect (Fig. 9). Average slope of STD_CPUE with NHBF is much lower than the one by SWO cluster. This means that STD_CPUE with SWO cluster will produce much less stock reduction over the period than the one by NHBF, i.e., it makes the stock more optimistic.





Comparison of STD_CPUE within 2014 (slope: -0.0122 vs. -0.0223)





Comparison of STD_CPUE between 2014 vs. 2011 (slope : -0.0122 vs. -0.017)

Fig. 9 Comparison JPN STD_CPUE between 2 different target effects: SWO cluster vs. NHBF

(3) Why JPN STD_CPUE produced more realistic trends?

Japanese tuna LL has been exploiting SWO as bycatch in the whole Indian Ocean. This means that Japanese tuna LL likely performs "simple random sampling" for SWO, which make CPUE more realistic (abundance) trends even they have a lot of noises (bumps).

As for TWN tuna LL, they targets SWO for sometimes and for other times, exploits as bycatch when they target other species such as albacore, bigeye tuna, yellowfin tuna and southern Bluefin tuna. Thus, their samplings strategies are not consistent, which make CPUE biased with large fluctuations. It is likely that even SWO cluster as targeting correction factor are used, large biases causes by such inconsistent samplings may be not able to be reduced. In fact, STD_CPUE with SWO cluster (targeting correction factor) (case 4 in Fig. 8) (Wang and Nishida, 2014) are much smoother than the one with species compositions (case 2). But, the rough trends between two are more or less same because of inconsistent samplings.

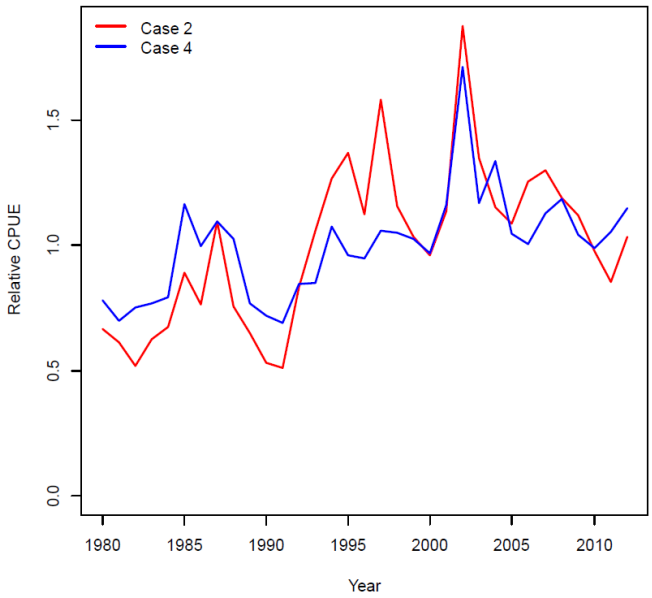


Fig. 10 Comparison of TWN STD_CPUE by different targeting correction factor
(Wang and Nishida, 2014)
(Case 2: species composition; and case 4: SWO cluster)

As Spain and Portugal LL, the time series of their CPUE are short and it is difficult to explain reasons why their STD_CPUE and catch are not well corresponding as shown Fig. 2

2.4 Risk assessments (Kobe II)

Based on 500 time bootstraps by ASPIC software, we conducted risk assessments for TB ratios and F ratios. Box 1 shows results. Box 1 suggests no risks violating MSY levels at all if the current catch (31,000 tons) or less level continues next 10 years, while the low risk with 20% increases (37,000 tins) and high risks 40% (44,000 tons) for both TB and F ratios.

Box 1 Kobe II risk assessment for TB ratio and F ratios (Whole Indian Ocean)

Color legends (4 probabilities ranges of risks violating MSY levels)

0-0.25	0.25-0.50	0.50-0.75	0.75-1

(1) TB (Total biomass) ratio

	years later	1	2	**3**	4	5	6	7	8	9	**10**
catch level	catch (tons)	2014	2015	**2016**	2017	2018	2019	2020	2021	2022	**2023**
-40%	18,650	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
-20%	24,867	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
current (2013)	31,084	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
20%	37,301	0.05	0.12	**0.15**	0.18	0.22	0.24	0.27	0.28	0.30	**0.34**
40%	43,518	0.13	0.28	**0.40**	0.52	0.60	0.70	0.75	0.80	0.87	**0.89**

(2) F ratios

	years later	1	2	**3**	4	5	6	7	8	9	**10**
catch level	catch (tons)	2014	2015	**2016**	2017	2018	2019	2020	2021	2022	**2023**
-40%	18,650	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
-20%	24,867	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
current (2013)	31,084	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
20%	37,301	0.02	0.11	**0.13**	0.18	0.22	0.24	0.26	0.28	0.30	**0.33**
40%	43,518	0.20	0.36	**0.47**	0.53	0.63	0.71	0.77	0.81	0.87	**0.89**

3. Stock assessment in the SW Indian Ocean

3.1 Data

(1) Catch

We used the nominal catch data in the SW region available in the IOTC dataset for SWO stock assessments published in October 15, 2014 (Fig. 11).

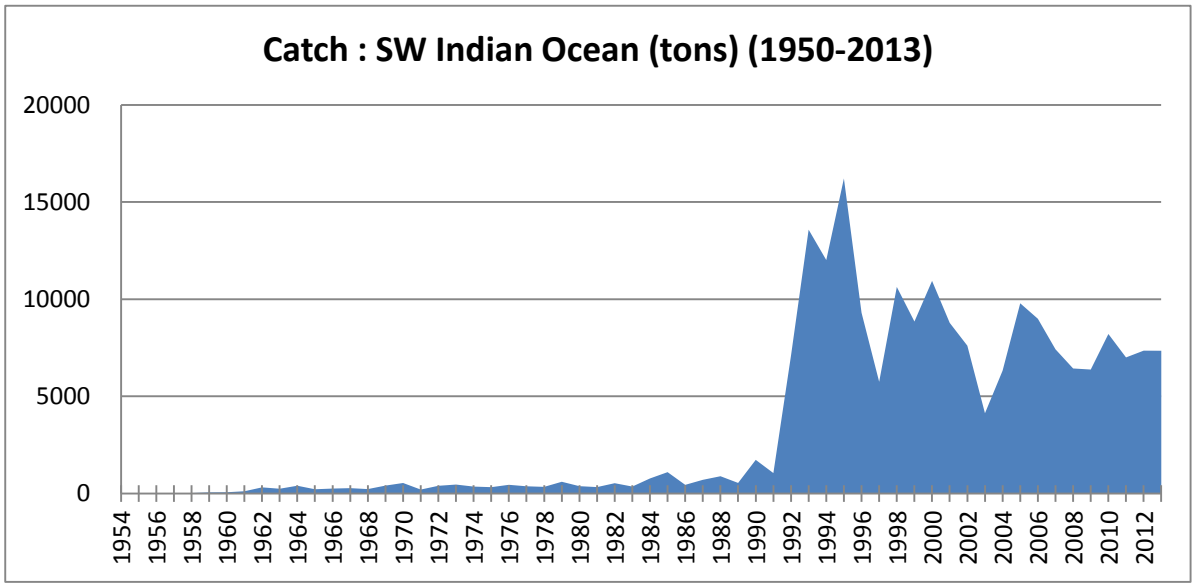


Fig 11 Nominal catch (ton) used for the ASPIC analyses for the SW Indian Ocean (IOTC dataset for stock assessments, October 15, 2014)

(2) STD_CPUE

We have 4 STD_CPUE (standardized CPUE) (Japan, Taiwan, Spain and Portugal) in the whole IO. Fig. 12a and 12b shows 4 STD_CPUE in 1971-2013 and in 1999-2013 respectively. JPN STD_CPUE shows the decreasing trend in general with large bumps (ups and downs). TWN STD_CPUE shows the increasing trend from 1980-1993, afterward the decreasing trend, while they also have large bumps throughout. SPN and POR STD_CPUE trends show more or less flat trend

During 1980-1993, STD_CPUE trends between Japan and Taiwan show different trends, i.e., Japan shows the decreasing trend, while Taiwan, increasing trend, while both shows the

decreasing trend during 1993-2013. 4 STD_CPUEs show more or less similar trend (flat trend) except a big jump in JPN STD_CPUE in 2008.

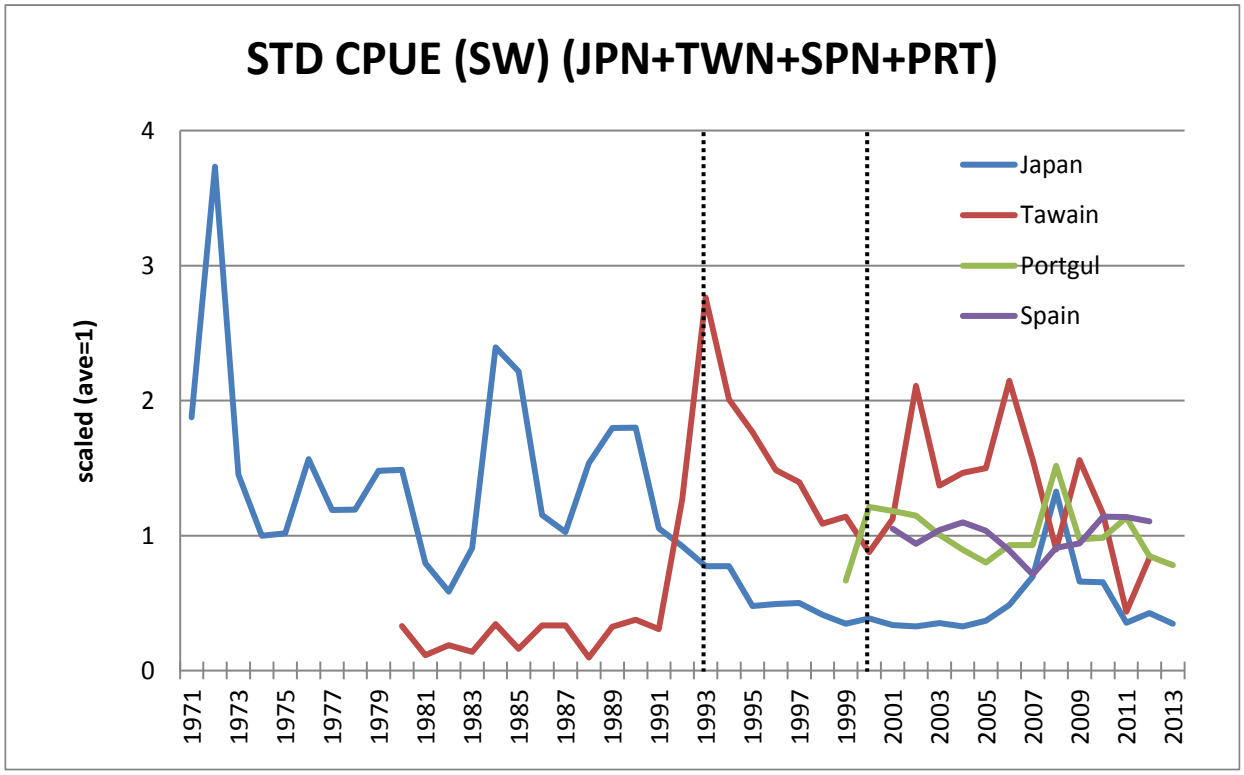


Fig 12a STD_CPUE in the SW Indian Ocean (Japan, Taiwan, Spain and Portugal) (1971-2013)

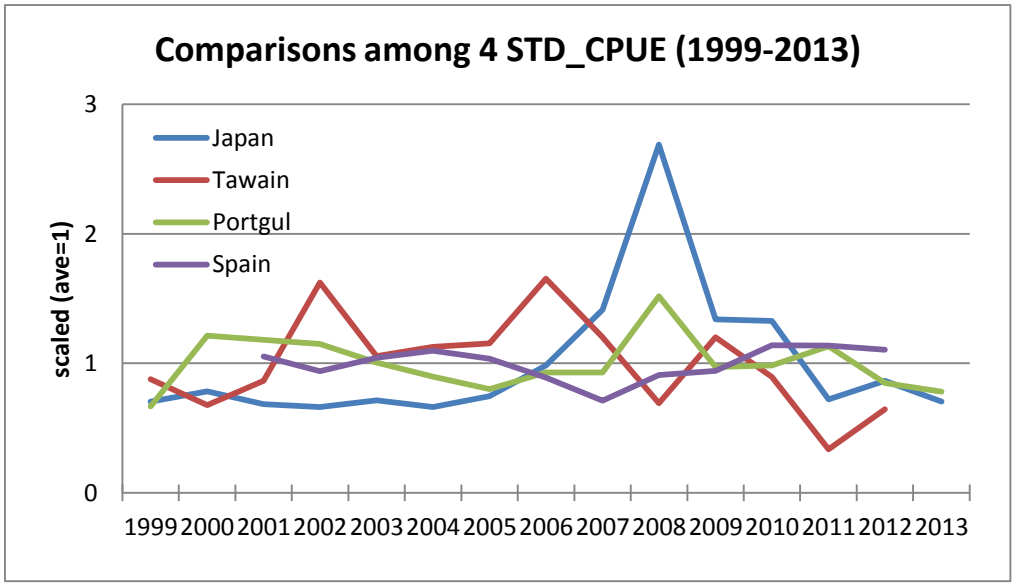


Fig 12b STD_CPUE in the SW Indian Ocean (Japan, Taiwan, Spain and Portugal) (1999-2013)

(3) Relation between nominal catch vs. 4 STD_CPUE (Fig. 13)

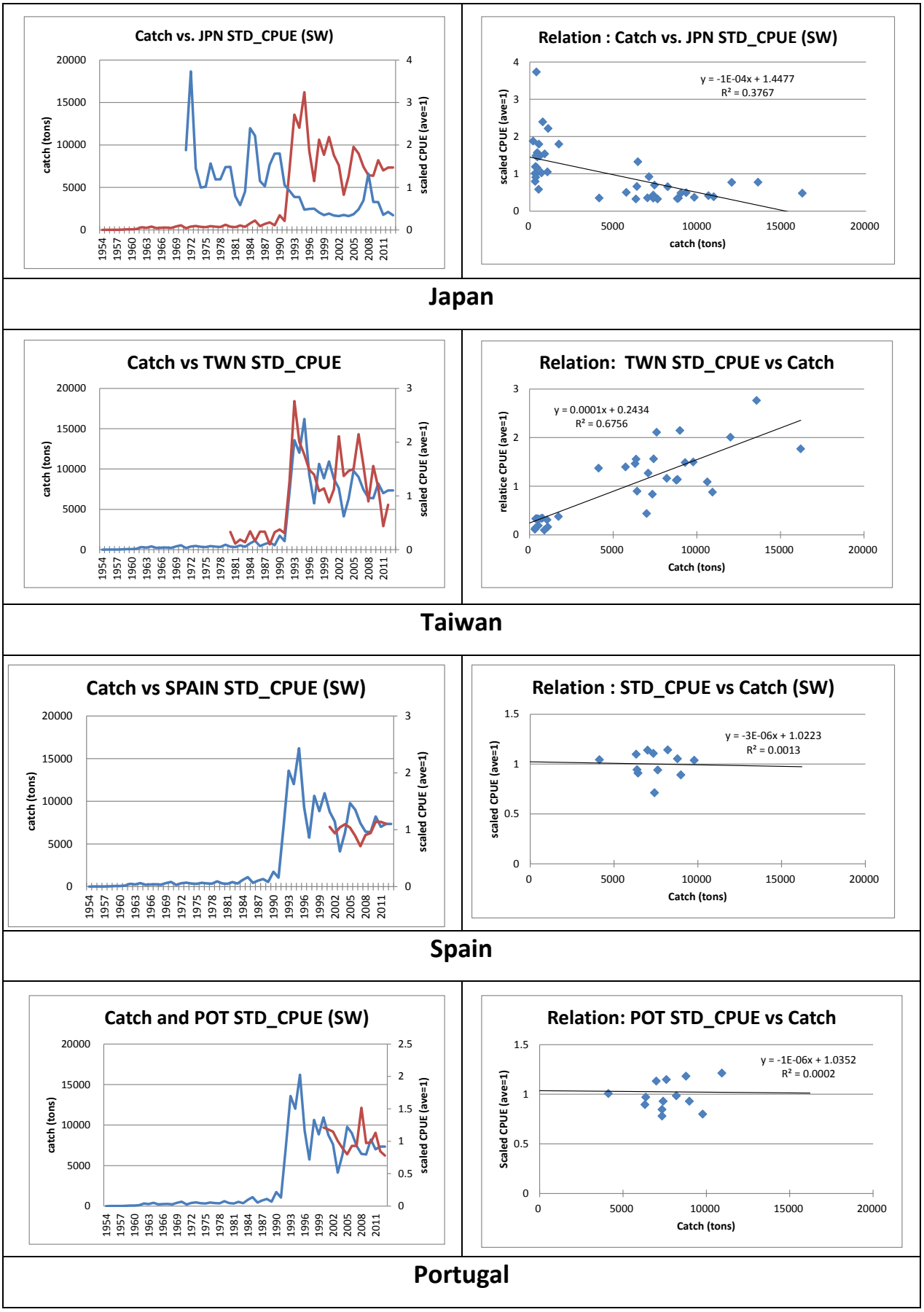


Fig. 13 Comparisons between nominal catch vs. STD_CPUE by fleet (SW Indian Ocean)

Based on Fig. 13, only Japan has the negative correlation between nominal catch and STD_CPUE, hence we use JPN_CPUE for the ASPIC.

3.2. ASPIC runs

We run ASPIC in the same way as in the Whole Indian Ocean using 4 scenarios (Table 3). Table 3 and Fig. 14 show the results. Scenarios (1) and (2) could not get convergences and (3) had poor fits to the model hence reasonable confidence surface could not be obtained. Hence, for the SW IO ASPIC, scenario (4) is considered to be the best results (Fig. 15). Table 3 shows the summary.

Table 3 ASPIC runs incorporating uncertainties (4 scenarios) and results (SW IO) (1950-2013)

Scenario	Elements of uncertainty		R2 (CPUE)	RMSE (over all)	MSY (tons)	TB(2013) /TB(MSY)	F(2013) /F(MSY)
	Model	Targeting effect					
(1)	FOX	SWO cluster	Not converged				
(2)		NHBF	Not converged				
(3)	SCHAEFER	SWO cluster	0.112	0.7714	9,965	0.43	1.13
(4)		NHBF	0.418	0.4041	8,507	0.95	0.93
Scenario selected	As (1)+(2) were not converged and (3) has lower R2 and higher RMSE (much less fit) than in (4) and could not provide confidence surface, Scenario (4) is selected as the best representative result of the ASPIC assessment.						

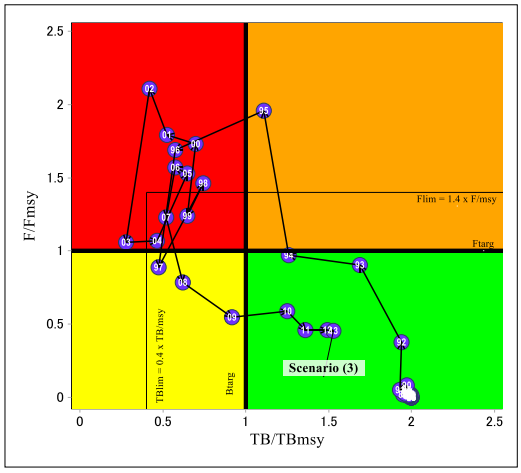
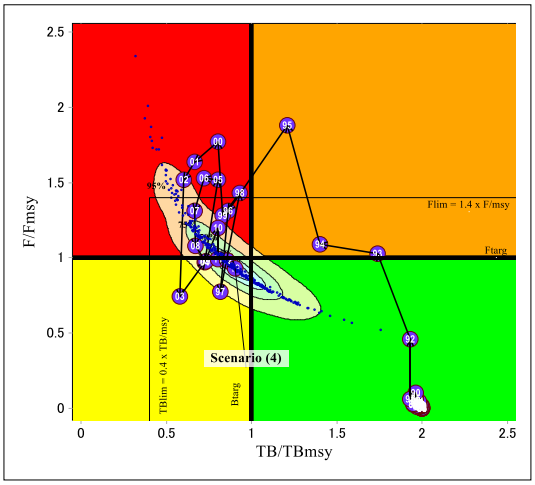
	SWO cluster	NHBF
FOX	Not converged	Not converged
	Scenario (1)	Scenario (2)
SCHAEFER		
	Scenario (3) Confidence surface could not be evaluated due to constrains in F pre-set in the ASPIC software	Scenario (4)

Fig. 14 Kobe plots of ASPIC results (4 scenarios) showing uncertainties among and within and scenarios.

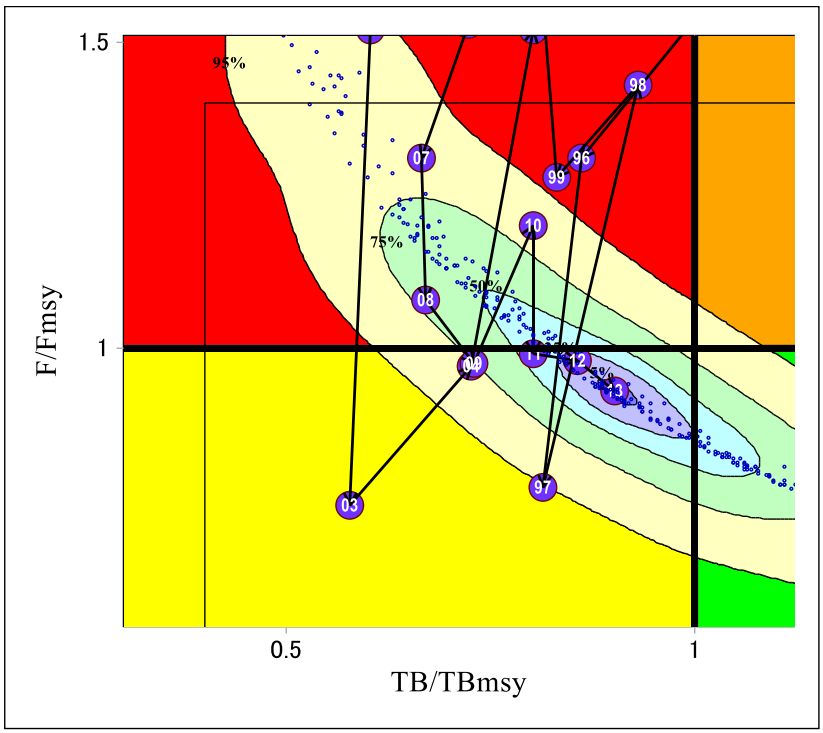


Fig. 15 Magnified Kobe plot of scenario (4) as the best representative of ASPIC runs

Table 3 Summary of ASPIC result (SW IO)

Management Quantity	SW Indian Ocean
Most recent catch estimate (t) (2013)	7,349
Mean catch over last 5 years (t) (2009-2013)	7,260
MSY (1000 t) (80%CI)	8.51(7.76-9.22)
Data Period used in assessment	1950-2013 (64 years)
F(2013)/F(MSY) (80% CI)	0.93 (0.65-1.28)
TB(2013)/TB(MSY) (80% CI)	0.95 (0.69-1.24)
SB(2013)/SB(MSY)	NA
TB(2013)/TB(1950)	0.45
SB(2013)/SB(1950)	NA
TB(2013)/TB(2013, F=0)	NA
SB(2013)/SB(2013, F=0)	NA

3.3 Risk assessments (Kobe II) (SW IO)

Based on 500 time bootstraps using ASPIC software, we conducted risk assessment for TB ration and F ratios for next 10 years. Box 2 shows results. Box 2 suggests that there are high risks violating MSY levels of TB ratio levels next 10 years if the current catch were increased by 10% or more, while low or no risks if the current catch or less level were continued.

As for F ratio, even if the current catch level were reduced by 10%, there are high risks violating the MSY levels. If the current catch levels were reduced more than by 20%, there are less or no risks next 10 years.

Box 2 Kobe II risk assessment for TB ratios and F ratios (SW Indian Ocean)

Color legends (4 probabilities ranges of risks violating MSY levels)

0-0.25	0.25-0.50	0.50-0.75	0.75-1

(1) TB ratio

	years later	1	2	**3**	4	5	6	7	8	9	10
catch level	catch (tons)	2014	2015	**2016**	2017	2018	2019	2020	2021	2022	2023
-40%	4,409	0.24	0.09	**0.02**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-30%	5,144	0.31	0.13	**0.03**	0.02	0.01	0.01	0.01	0.01	0.00	0.00
-20%	5,879	0.37	0.19	**0.10**	0.04	0.02	0.02	0.01	0.01	0.01	0.01
-10%	6,614	0.43	0.28	**0.18**	0.12	0.07	0.05	0.04	0.04	0.03	0.03
current (2013)	**7,349**	0.49	0.40	**0.31**	0.26	0.21	0.18	0.16	0.14	0.14	0.12
10%	8,084	0.52	0.53	**0.52**	0.50	0.47	0.45	0.43	0.43	0.41	0.40
20%	8,819	0.62	0.65	**0.71**	0.76	0.80	0.83	0.84	0.85	0.87	0.90
30%	9,554	0.69	0.82	**0.92**	0.96	0.98	0.99	0.99	1.00	1.00	1.00
40%	10,289	0.71	0.86	**0.94**	0.98	0.99	0.99	1.00	1.00	1.00	1.00

(2) F ratio

	years later	1	2	**3**	4	5	6	7	8	9	**10**
catch level	catch (tons)	2014	2015	**2016**	2017	2018	2019	2020	2021	2022	**2023**
-40%	4,409	0.10	0.03	**0.01**	0.01	0.00	0.00	0.00	0.00	0.00	**0.00**
-30%	5,144	0.10	0.06	**0.02**	0.01	0.01	0.01	0.00	0.00	0.00	**0.00**
-20%	5,879	0.33	0.30	**0.24**	0.19	0.17	0.13	0.11	0.09	0.05	**0.05**
-10%	6,614	0.54	0.56	**0.58**	0.62	0.64	0.67	0.69	0.69	0.67	**0.68**
current (2013)	**7,349**	0.72	0.81	**0.84**	0.87	0.90	0.91	0.91	0.92	0.92	**0.93**
10%	8,084	0.85	0.91	**0.94**	0.97	0.97	0.98	0.98	0.98	0.98	**0.98**
20%	8,819	0.92	0.98	**0.98**	0.99	0.99	0.99	0.99	0.99	0.99	**0.99**
30%	9,554	0.97	0.99	**1.00**	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
40%	10,289	0.99	1.00	**1.00**	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**

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