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Stock and risk assessments of albacore tuna (*Thunnus alalunga*) in the Indian Ocean by A Stock-Production Model Incorporating Covariates (ASPIC)

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Abstract

Japanese STD CPUE and catch are not well reflected, that is the reason why we could not get convergences in the ASPIC analyses with Japanese STD CPUE. This was also observed at the 1st WPTmT in Japan in 2004. ACPIC analyses could not get reasonable parameter estimations as all the analyses included Japanese CPUE. On the other hand, Taiwanese STD CPUE vs. Catch in 1980-2010 is reasonably reflected, that is the reason why we could get the convergence for this case. This was also observed at the 2nd WPTmT in Thai in 2008. In that time, only Taiwan STD CPUE was used and reasonable parameters were estimated.

The Kobe plot 1 shows the large confidential surfaces which imply that ASPIC analyses include large uncertainties. The current status of the Indian Ocean albacore stock is in the beyond MSY level for F ratio (Fratio=1.61) while TB ratio is close to its MSY level (0.86). The recent catch levels are about 40,000 which is 10,000 tons higher than the estimated MSY (about 30,000 tons). Hence the albacore stock is considered to be in the overfished status.

F ratio is considered to be very serious as KOBE plot 1 shows that large part of the 95% confidential surfaces cover more on F (MSY) levels (red area), while TB (Total biomass) ratio is less around the border of the MSY level. According to KOBE II (risk assessments), if catch at the MSY level were maintained, then TB will exceed TB(MSY) in 80% of the probability and F(MSY) in 70% in 2020 (10 years later). Under such circumstances, both catch and F should be kept below MSY levels until the risk probability will decrease.

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1. Introduction

We initially planned to attempt the stock assessment of albacore tuna in the Indian Ocean by Age Structure Production Model (ASPM). However, size data from Japan and Taiwan was biased thus Mr. Miguel Herrera (data manager, IOTC) suggested that size or age based stock assessments were not suitable to apply. Thus we changed to the age (size) aggregated assessment mode, i.e., A Stock-Production Model Incorporating Covariates (ASPIC) by Prager.

2. Data

Two major input data to ASPIC are catch by fleet and standardized CPUE by fleet. Following are explanation of this information.

2.1 Catch

We used the nominal catch data by gear (fleet) from the IOTC database (as of August, 2011). There are 4 gear types, i.e., (a) tuna longline (LL) fisheries (Japan type including Korea and others), (b) tuna longline fisheries (Taiwan type including Indonesian nod others), (c) Gillnet (GILL), (d) others including purse seine (PS) and pole and line or Bait Boat (BB). Japan and Taiwan type LL were defined by the IOTC Secretariat. Fig. 1 shows the trends of catch by fleet type.

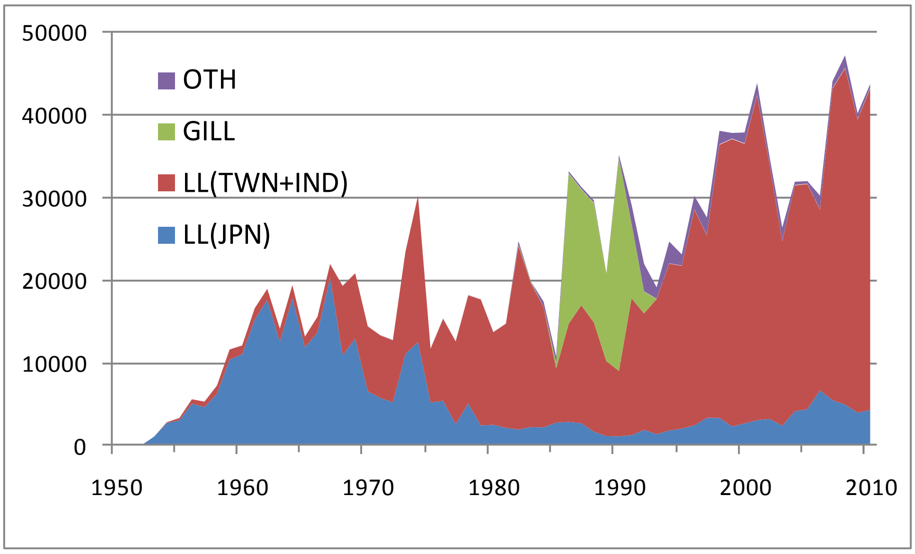


Fig. 1 Trend of albacore tuna catch in the Indian Ocean by gear (Fleet) type
(Source: IOTC database as of August, 2011)

2.2 CPUE

For the standardized (STD) LL CPUE, we used 3 types of STD CPUE series, i.e., (a) Japanese tuna LL (1970-2010), (b) Japanese tuna LL (1970-2010) and (c) Taiwanese tuna LL (1980-2010). (a) and (b) are from the paper by Matsumoto and Uosaki (IOTC-2011-WPTmT03-15, 2011) and (c) from Chen and Yeh (IOTC-2011-WPTmT03-16). Fig 2 shows comparison among these three indices which have been scaled by average values as 1.

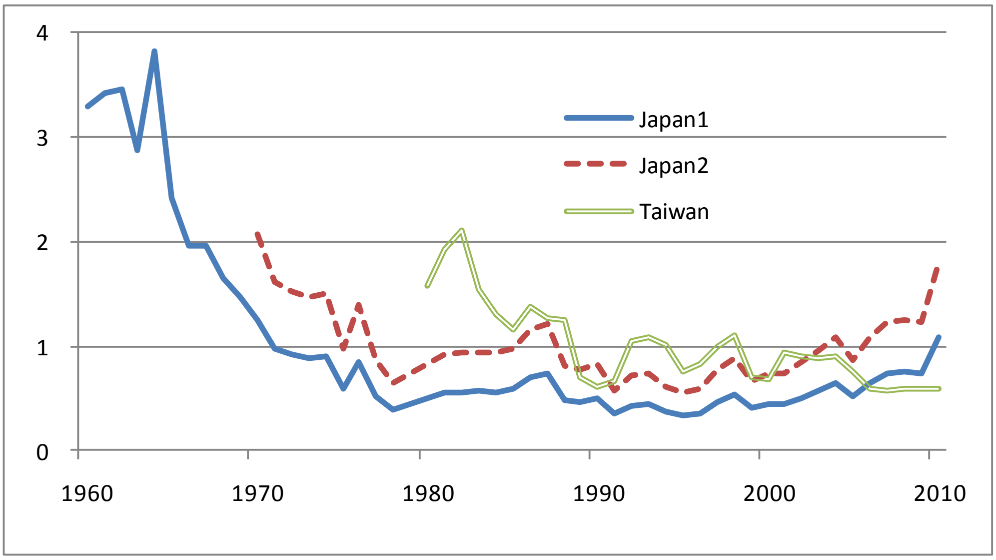


Fig 2. Comparison among 3 STD CPUEs

(Japan 1: 1960-2010, Japan 2: 1970-2010 and Taiwan: 1980-2010)

3. Evaluation on the relation between catch vs. STD CPUE

3.1 Evaluation 1 (catch vs. CPUE relations)

Before we attempted ASPIC analyses we evaluated if the relation between catch and STD CPUE are realistic. Fig 3 shows these relations by scatter plots. From Fig. 3 we understand that relations between catch vs. 2 Japanese STD CPUE series are neither well corresponded nor reflected. i.e., we expect the inverse relation in the normal (realistic) situation. On the other hand, the relation for the Taiwan STD CPUE and catch are reasonable and realistic.

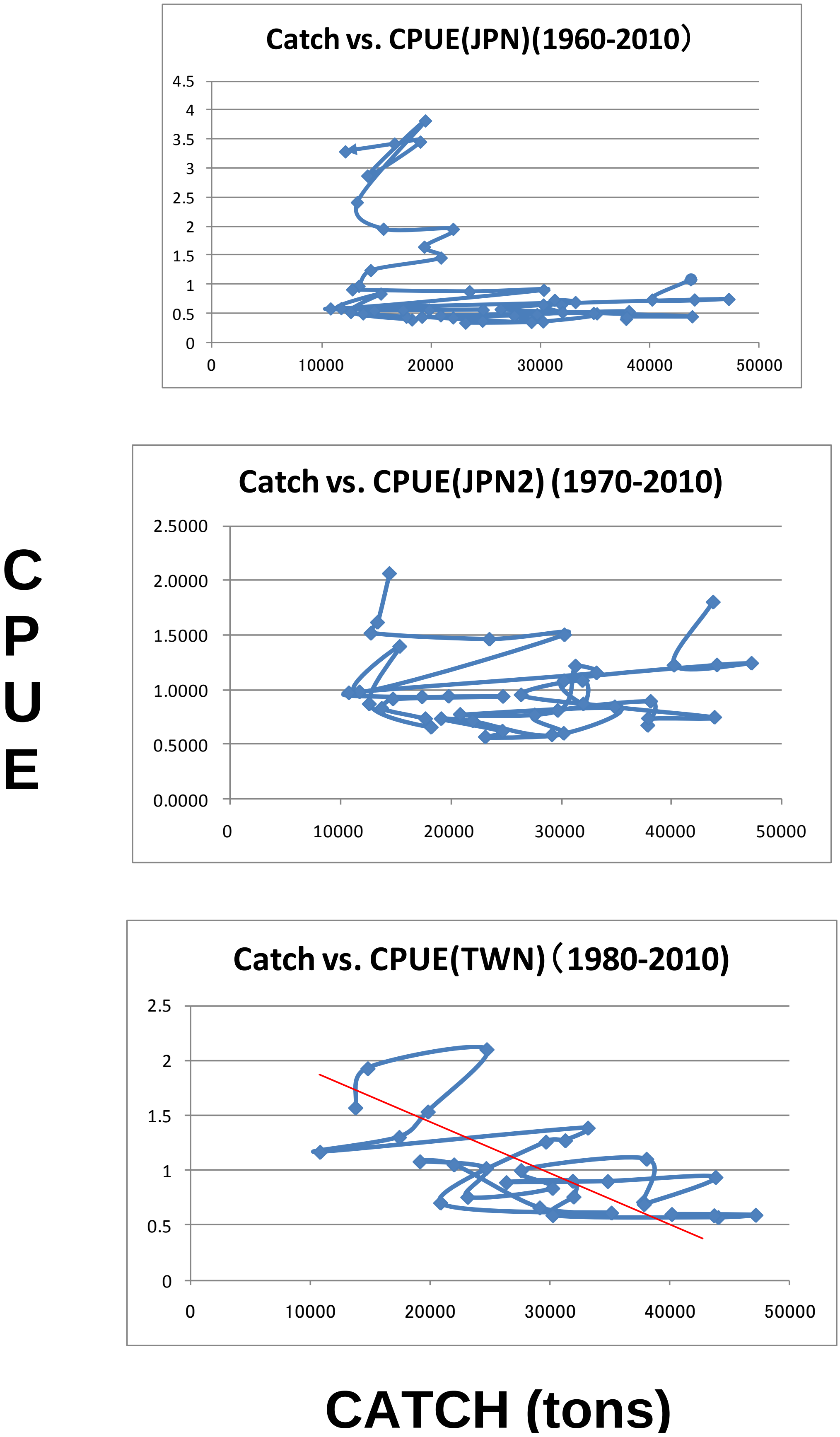


Fig 3 Relationship among catch vs. 3 different types of STD CPUE (Scaled)

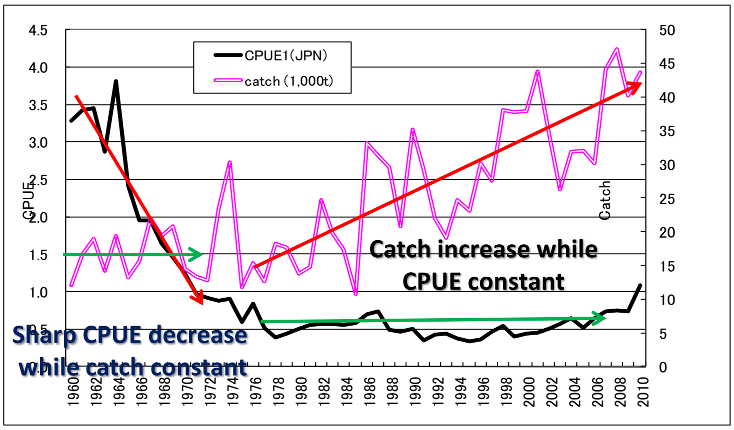
3.2 Evaluation 2 (catch and CPUE trends)

(1) Catch vs. STD CPUE (Japan: 1960-2010)

We further investigated the relations between catch and CPUE. Fig.4 shows trends of catch and STD CPUE (Japan 1960-2010). In the beginning (1960's) CPUE dropped sharply while catch are constant. From the mid 1970's to 2010, catch increased while CPUE are constant. There trends were neither realistic nor corresponded as we expect the inverse relation in the normal situation.

Fig 4
Problems
on C vs. CPUE
(Japan1,
1960-2010)

Problem C vs. CPUE(JPN:1960-2010)
not reflected [same situation as for YFT]

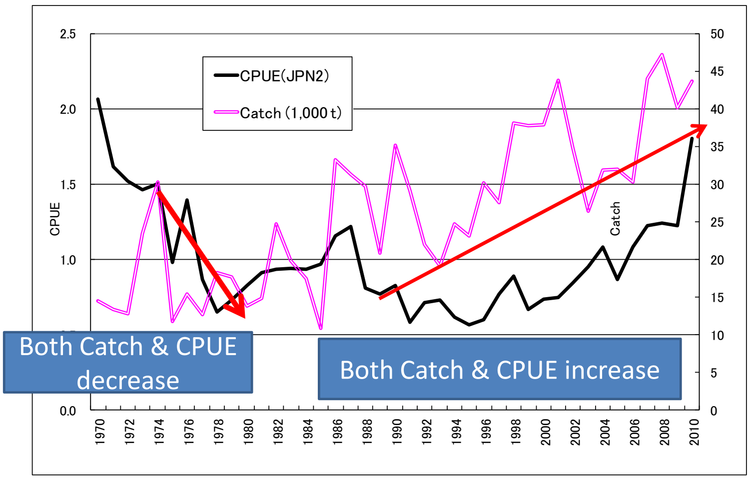


(2) Catch vs. STD CPUE (Japan: 1970-2010)

As the next step, we investigated the relations between catch and STD CPUE (Japan: 1970-2010) (Fig. 5). In the beginning (1974-1979) both CPUE and dropped sharply. From 1990's to 2010, both catch and STD CPUE increase. Therefore trends again were neither realistic nor corresponded.

Problem C vs. CPUE(JPN:1970-2010)

Fig 5
Problems
on C vs. CPUE
(Japan2,
1970-2010)



(3) Catch vs. STD CPUE (Taiwan: 1980-2010)

As the last check, we investigated the relations between catch and STD CPUE (Taiwan: 1980-2010) (Fig. 6). In this case the general trends between catch and CPUE are inversely correlated, which implied that the relation between catch and CPUE are realistic and corresponding.

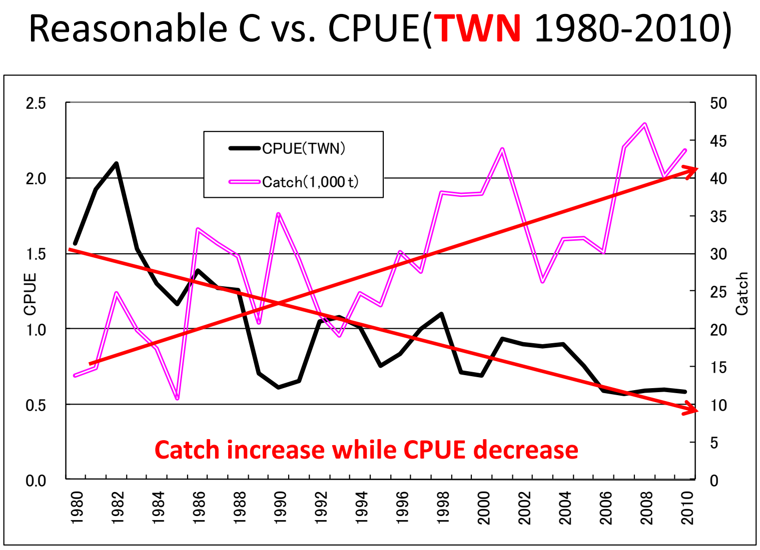


Fig 6 Reasonable relation between C. vs. Taiwan CPUE

4. ASPIC analyses

4.1 Initial ASPIC runs

We used the FOX production model option available in 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, 101 Pivers Island Road, Beaufort, North Carolina 28516 USA: National Marine Fisheries Service Beaufort Laboratory Document BL-2004-01” by Prager (2004).

Initially we set up 14 scenarios to search realistic and reasonable parameters by combining 4 starting period (1850-, 1960-, 1970-, and 1980-) and 3 types of STD CPUE (Japan 1: 196-2010, Japan 2: 1970-2010 and Taiwan: 1980-2010) (Table 1). For some scenarios we combined LL (Japan) and LL (Taiwan) and used one CPUE.

After the reviews of the initial works of this paper at the National Research Institute of Far Seas Fisheries (NRIFSF), it was suggested to attempt ASPIC runs using the average CPUE between Japan and Taiwan. We attempted using ‘simple average’ and ‘weighed average by catch” of JAPAN STD CPUE 2 (1970-2010 but we use only 1980-2010 common period to the one in Taiwan) and TAIWIN CPUE (1980-2010). We attempted 4 starting years (1950-, 1960-, 1970- and 1980-) for each case (Scenarios 15-18 and 19-22 respectively). Table 1 shows the results.

Table 1 Summary and results of 22 scenarios of ASPIC runs

years	S. No	Fleets			CPUE			R2	MSE	MSY 1000t tons	TB 2010 million tons	TB msy	TB ratio	F 2010	F msy	F ratio
		LL (J)	LL (T)	GL	JPN1 1960-2010	JPN2 1970-2010	TWN 1980-2010									
1950-2010	1	on	on	on	on		on	NC (not converged)								
	2	on	on	on		on	on	NC (not converged)								
	3	on		on	on			NC (not converged)								
	4	on		on		on		NC (not converged)								
	5	on		on			on	NC (not converged)								
1960-2010	6	on	on	on	on		on	NC (not converged)								
	7	on	on	on		on	on	NC (not converged)								
	8	on		on	on		on	NC (not converged)								
	9	on		on		on	on	NC (not converged)								
	10	on		on			on	NC (not converged)								
1970-2010	11	on	on	on		on	on	NC (not converged)								
	12	on		on		on		NC (not converged)								
	13	on		on			on	NC (not converged)								
1980-2010	14	on		on			on	0.73	0.0047	36.1	0.21	0.16	1.33	0.20	0.23	0.89

TB: total biomass

[Scenario 15-18] Simple average of CPUE between Japan2 and Taiwan (1980-2010)

years	S. No	Fleets			Simple AVE CPUE (JPN2+TWN) 1980-2010	R2	MSE	MSY 1000t tons	TB 2010 million tons	TB msy	TB ratio	F 2010	F msy	F ratio
		LL (J)	LL (T)	GL										
1950-2010	15	on		on	on	NC (not converged)								
1960-2010	16	on		on	on	NC (not converged)								
1970-2010	17	on		on	on	NC (not converged)								
1980-2010	18	on		on	on	NC (not converged)								

[Scenario 19-22] Weighted average CPUE (by catch) between Japan2 and Taiwan (1980-2010)

years	S. No	Fleets			Weighted AVE CPUE (JPN2+TWN) (weighted by catch) 1980-2010	R2	MSE	MSY 1000t tons	TB 2010 million tons	TB MSY million tons	TB ratio	F 2010	F msy	F ratio
		LL (J)	LL (T)	GL										
1950-2010	19	on		on	on	14.9 too low	0.0108 too low	46.0	0.162	0.099 too low	1.59	0.27	0.47	0.59
1960-2010	20	on		on	on	NC (not converged)								
1970-2010	21	on		on	on	NC (not converged)								
1980-2010	22	on		on	on	NC (not converged)								

As a result, we only could obtain the conversion and get parameters in Scenarios 14 and 19, while all others were not converged. The goodness of fitness of scenario 19 between the ASPIC model and the data was very poor (R2=15% and MSE=0.0108) and the TB (MSY) =99,000 tons was too low comparing to the MSY=36,100 tons.

One the other hand, the goodness of the fitness for scenario 14 was very well (R2=73% and MSE=0.0047) and all the estimated parameters are reasonable and realistic, i.e., MSY=36,100 tons, TB (Total biomass in 2010)=0.21 million tons, TB(MSY)=160,000 tons, TB(ratio)=1.33, F(2010) =0.21, F(MSY)=0.23 and F(ratio in 2010)=0.89. Thus we decided that scenario 14 is the best one among 22 scenarios under the current information.

4.2 Second Run for scenario 14

Although we selected the scenario 14 as the best, during the meeting, Dr Kolody (IOTC) pointed out the problem on B (1980) > K (Fig. 7). Then we contacted Dr Prager (ASPIC software developer) then he suggested not to estimate B1/K and fix that parameter in the input file using 0.9, 0.8, 0.7 etc. to see the sensitivities. Then we tested sensitivities (Table 2). As a result B/K=0.9 provide the reasonable estimates then we decided to re-run scenario 14 by fixing B/K=0.9.

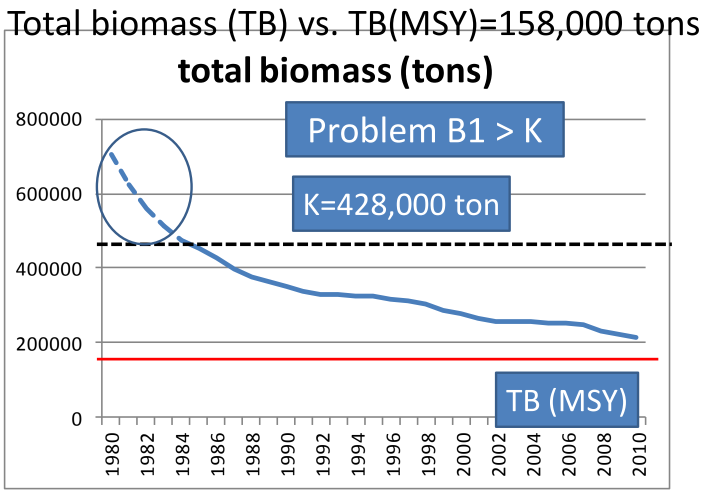


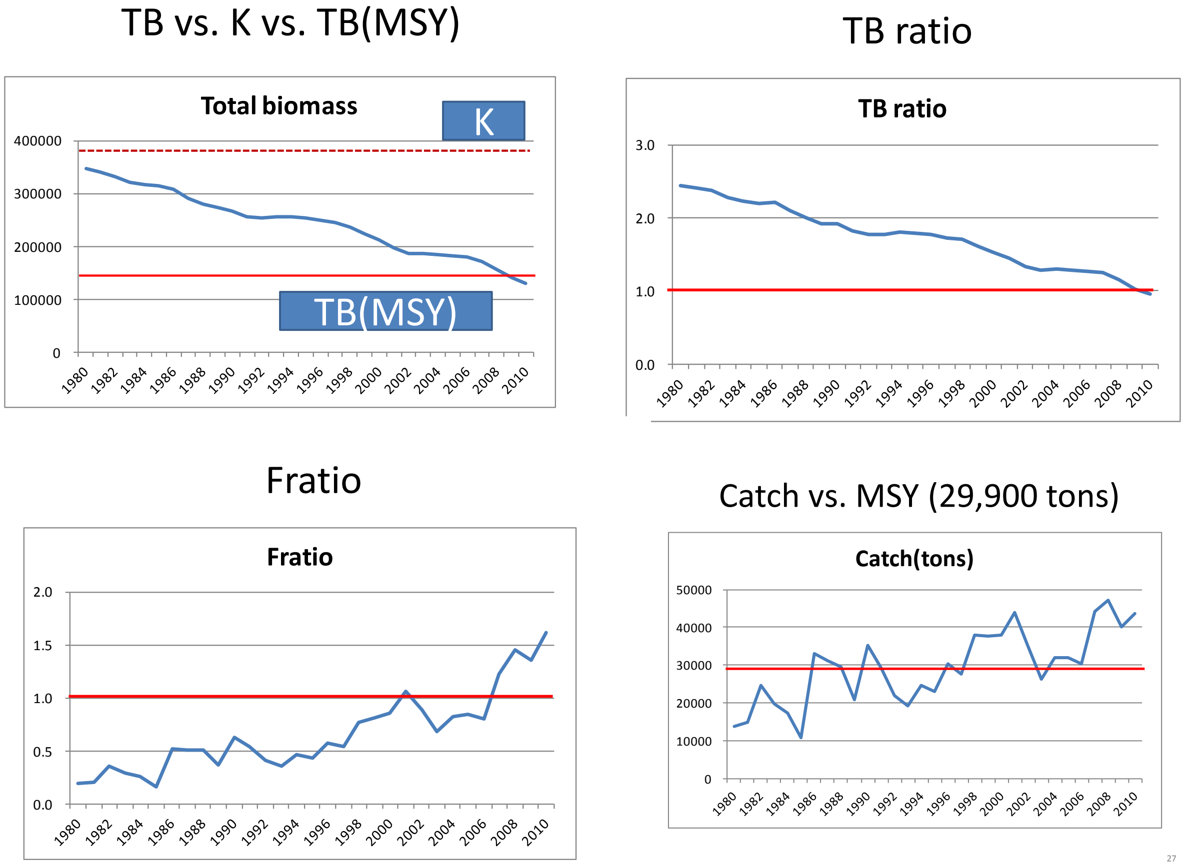
Fig. 7 Problem on B1 >K

20

Table 2 Sensitivity analyses on B/K using 0.9, 0.8 and 0.7

K1/B	R2	MSE	MSY	TBratio	F ratio
0.90	**0.59**	**0.0059**	**29,940**	**0.86**	**1.61**
0.80	NC				
0.70	NC				

Fig. 8 shows the results of the second run on scenario 14 with fixed B/K=0.9 and Fig. 9 shows the Kobe plots. Confidence surfaces of the Kobe plots are based on 500 generated data using the ASPIC results. Table 3 is the summary of the ASPIC analyses requested by the IOTC Secretariat.



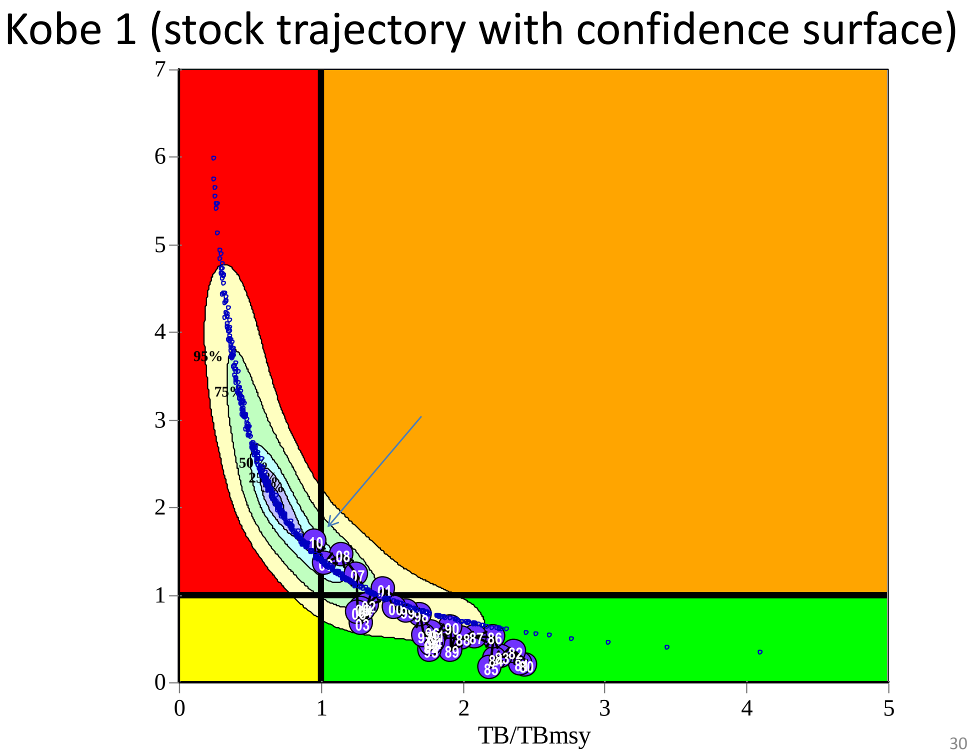


Fig. 9 Kobe plot with 95% confidence surface for scenario 14 with fixed B/K=0.9

Table 3 Indian Ocean albacore stock status summary based on the ASPIC analyses

Management Quantity	Indian Ocean
Most recent catch estimate (t) (2010)	43,714
Mean catch over last 5 years (t) (2006-2010)	41,076
MSY (1000 t) (80%CI)	29.9 (21.5-33.1)
Current Data Period	1980-2010
F(Current)/F(MSY) (80% CI)	1.61 (1.19-2.22)
B(Current)/B(MSY) (80% CI)	0.89 (0.65-1.12)
SB(Current)/SB(MSY)	NA
B(Current)/B(0) (80% CI)	0.39 (NA)
SB(Current)/SB(0)	NA
SB(Current)/SB(Current, F=0)	NA

5. Risk assessments

5 tuna RFMOs meetings in Kobe in 2007 recommended to produce the Kobe plot (stock trajectory) and also in Barcelona, Spain in 2010 they recommended to conduct the risk analyses for SSB (spawning stock biomass) ratio or TB (total biomass) ratio (our case). Degrees of risks are represented by probabilities to exceed TB ratio=1 (at MSY level) and F ratio =1 (at MSY level). Risks will be evaluated by 5 scenarios, i.e., in case catch level of the current year were continued and in case ±20% and ±40% of that catch were continued. Using these 5 scenarios they suggested evaluating risk probabilities in 3 and 10 years. To conduct the risk assessments, we generated 500 bootstraps to obtain possible values of TB ratios and F ratios by utilizing ASPIC-P (projection module available in ASPIC).

5.1 Risk assessments on TB ratio

Using results of the ASPIC analyses on scenario 14 with fixed B/K, 500 values of TB ratio and F ratio were generated by the bootstrap function available in the ASPIC-P for 2011-2020. As a first step, we made future projections of TB rations (Fig. 10). Then we made the Kobe 2 risk matrix

(Table 3) and diagram (Fig.11). These results indicated the high risk of TB(ratio) exceeding TB(MSY) level in the future if catch were not reduced significantly (e.g. less than the MSY level).

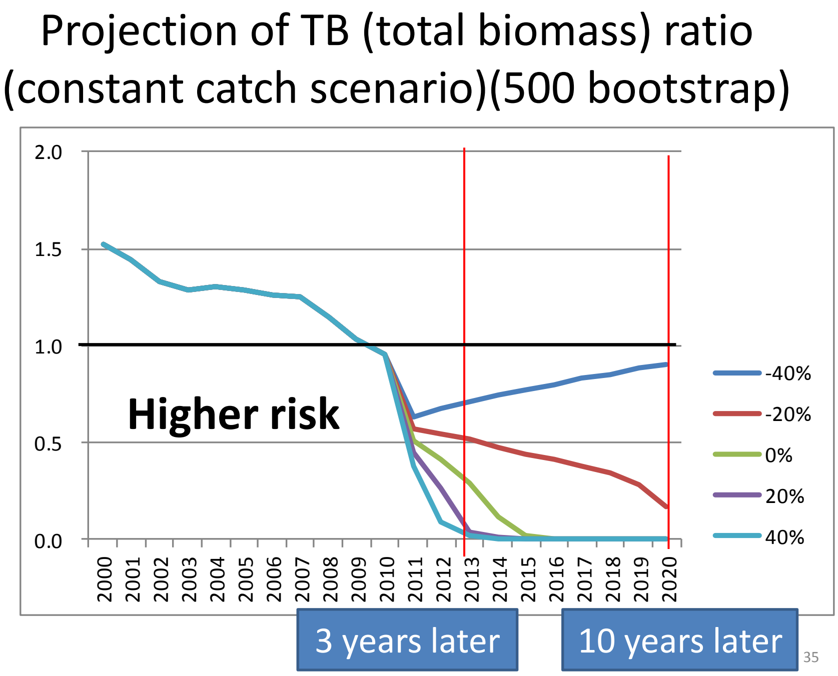


Fig.10 Future projection of TB ratio

Table 3 Kobe II risk matrix

Kobe II : risk matrix (TB)
probability exceeding TB(MSY)

Legend		0.9-1.0		0.8-0.9		0.7-0.8		< 0.7		
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
-40%	0.698	0.768	0.762	0.742	0.716	0.704	0.688	0.676	0.664	0.64
-20%	0.722	0.77	0.782	0.794	0.818	0.842	0.856	0.882	0.894	0.912
0%	0.828	0.82	0.84	0.86	0.892	0.918	0.932	0.96	0.974	0.982
20%	0.948	0.944	0.946	0.952	0.954	0.962	0.98	0.988	0.99	0.992
40%	0.988	0.986	0.988	0.988	0.988	0.99	0.99	0.992	0.996	0.996

3 years later

10 years later

36

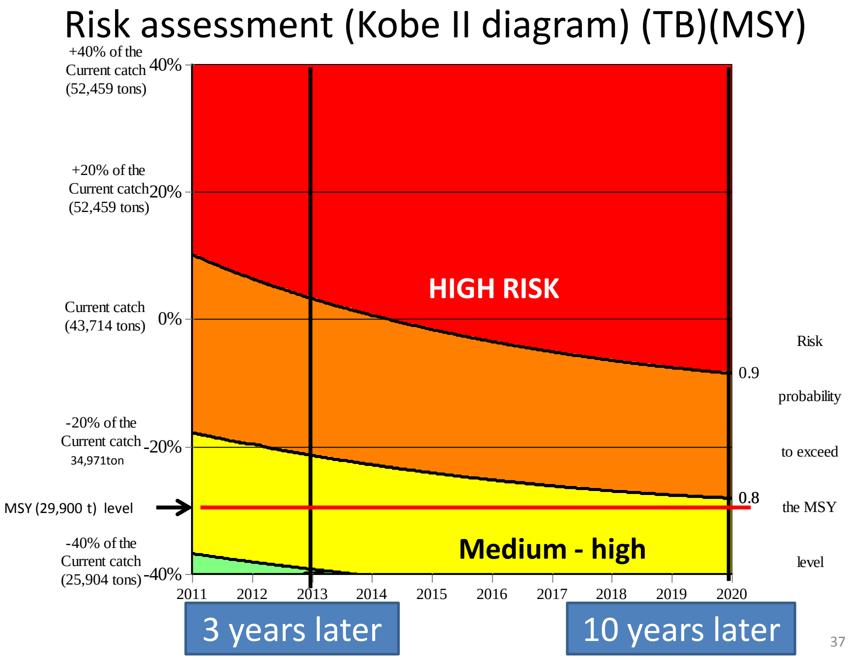


Fig. 11 Diagram of Kobe plot II (risk assessment) for TB ratio

5.2 Risk assessments on F ratio

In the same way as for TB ratio, the future projection (Fig.12), Kobe 2 matrix (Table 4) and its diagram (Fig. 13) were made. These results also indicated the high risk of F ratio exceeding F(MSY) level in the future if catch were not reduced significantly (e.g. less than the MSY level).

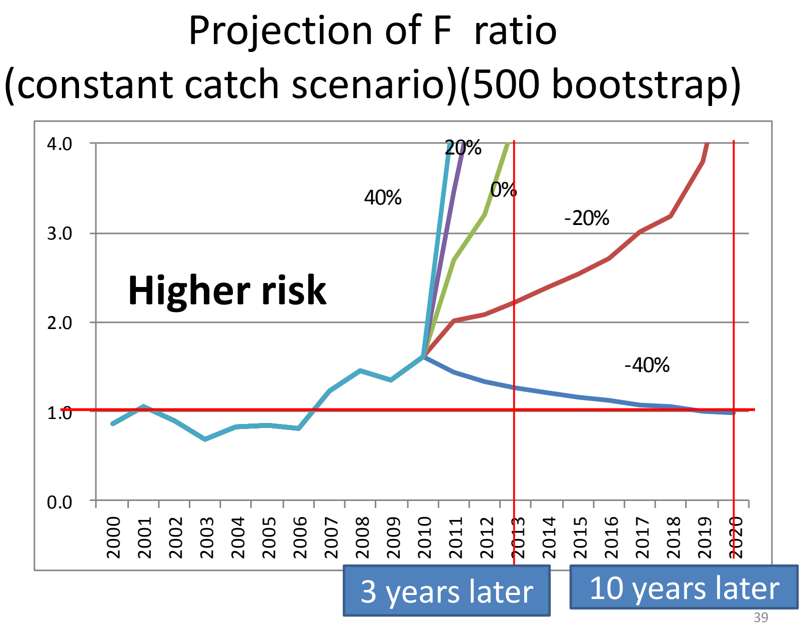


Fig.12 Future projection of TB ratio

Table 4 Kobe2 risk matrix

Kobe II : risk matrix (F)
probability exceeding F(MSY)

Legend		0.9-1.0		0.8-0.9		0.7-0.8		< 0.7		
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
-40%	0.678	0.662	0.652	0.644	0.614	0.586	0.558	0.534	0.514	0.48
-20%	0.836	0.856	0.872	0.892	0.908	0.916	0.924	0.94	0.954	0.954
0%	0.912	0.932	0.954	0.98	0.982	0.988	0.99	0.992	0.992	0.996
20%	0.968	0.984	0.99	0.992	0.994	0.996	0.996	0.998	0.998	0.998
40%	0.988	0.992	0.994	0.996	0.998	0.998	0.998	1	1	1

3 years later

10 years later

40

Risk assessment for F(MSY) (Kobe II diagram)

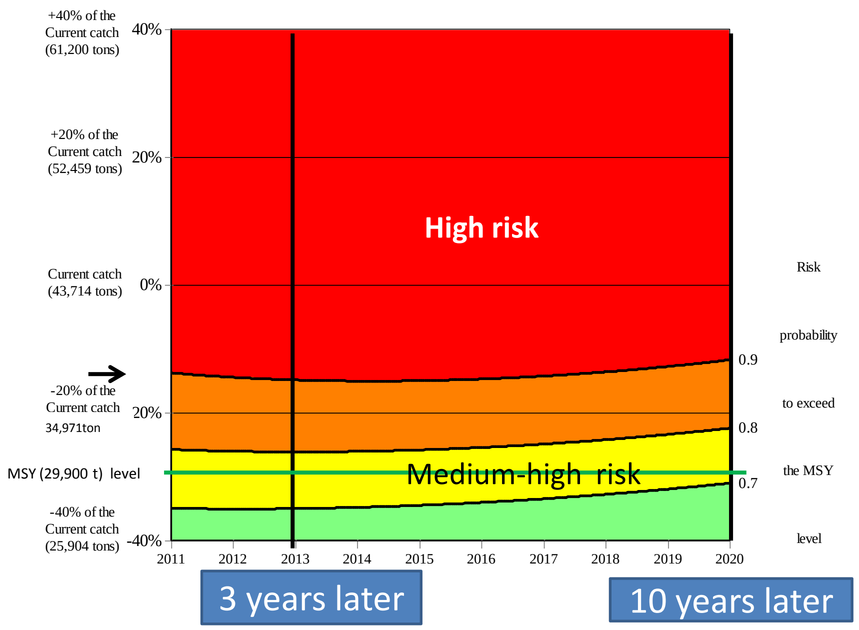


Fig. 13 Diagram of Kobe plot II (risk assessment) for TB ratio

4. Summary

(1) Japanese STD CPUE and catch are not well reflected, that is the reason why we could not get convergences in the ASPIC analyses with Japanese STD CPUE. This was also observed at the 1st WPTmT in Japan in 2004. ACPIC analyses could not get reasonable parameter estimations as all the analyses included Japanese CPUE.

(2) On the other hand, Taiwanese STD CPUE vs. Catch in 1980-2010 is reasonably reflected, that is the reason why we could get the convergence for this case. This was also observed at the 2nd WPTmT in Thai in 2008. In that time, only Taiwan STD CPUE were used and reasonable parameters were estimated.

(3) The Kobe plot 1 shows the large confidential surfaces which imply that ASPIC analyses include large uncertainties.

(4) The current status of the Indian Ocean albacore stock is in the beyond MSY level for F ratio (Fratio=1.61) while TB ratio is close to its MSY level (0.86). The recent catch levels are about 40,000 which is 10,000 ton higher than the estimated MSY (about 30,000 ton). Hence the albacore stock is considered to be in the overfished status.

(5) F ratio is considered to be very serious as KOBE plot 1 shows that large part of the 95% confidential surfaces cover more on F (MSY) levels (red area), while TB (Total biomass) ratio is less around the border of the MSY level.

(6) According to KOBE II (risk assessments), if catch at the MSY level were maintained, then TB will exceed TB(MSY) in 80% of the probability and F(MSY) in 70% in 2020 (10 years later).

(7) Under such circumstances, both catch and F should be kept below MSY levels until the risk probability will decrease.

Acknowledgments

We thank Dr Mike Prager (developer of the ASPIC) (retired from the NMFS, NOAA, NS, USA and now in Portland, Oregon, USA) who assisted our ALB analyses. Also many gracias for Mr. Miguel Herrera (IOTC) to provide the newest nominal catch data set for our analyses. Final thanks for Drs Kolody and Hoyle for their various suggestions during the meeting.

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