Stock and risk assessments of bigeye tuna in the Indian Ocean based on ASPIC

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Summary

An assessment for the Indian Ocean stock of bigeye tuna was conducted based on ASPIC. A time series of catch (1950-2015) and that of standardized CPUE (Japanese longline or longline 'joint') were used for the analysis with logistic and Fox models. Convergence and reasonable results were obtained for all the scenarios. The scenario with joint CPUE and Fox model was selected as a reference case based on representativeness of CPUE and value of objective function. According to the reference case, the stock status was estimated to be in the green zone of Kobe plot. Kobe II (risk assessments) indicated that the risk of B and F exceeding MSY level is lower than 50% if future catch is up to 40% and 20% higher than current level, respectively.

1. Introduction

Recently, assessment of bigeye tuna stock in the Indian Ocean was mainly conducted based on integrated model (Stock Synthesis), and ASPM (age structured production model) and ASAP (Age Structured Assessment Program) were also used. ASPIC (A Stock-Production Model Incorporating Covariates, Prager, 2004) is very simple model, which does not incorporate size data, fish movement, and so on. However, this model is still used for assessment of tuna stocks in the Indian and Atlantic oceans. Generally, it is necessary and important to compare the results of stock assessment based on more than one assessment models for cross check and to provide more robust results. Under these situations, we conducted stock assessment for Indian Ocean bigeye tuna based on ASPIC.

2. Data

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

2.1 Catch

We used the nominal catch data by gear (fleet) from the IOTC database (as of September, 2016). Fig. 1 shows the trends of catch by fleet type. Most of the catch is by longline fishery, but a certain proportion of catch was made by purse seine fishery after 1980s.

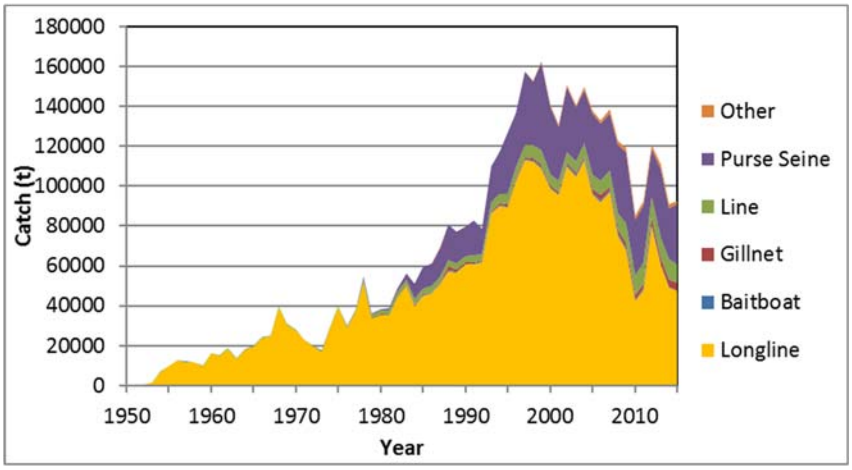

Fig. 1 Trend of bigeye tuna catch in the Indian Ocean by gear (Fleet) type.

(Source: IOTC nominal catch database as of September, 2016).

2.2 CPUE

Standardized (STD) CPUE for Japanese tuna LL (tropical area, model with subarea, 1960-2015) (Matsumoto et al, 2016) and joint CPUE by Japanese, Korean and Taiwanese longline fishery combined (area R1+R2, 1954-2015) (Hoyle et al., 2016) were used. As bigeye tuna is mainly caught in the tropical area, CPUE only in the tropical area (**Fig. 2**) was used. **Fig. 3** shows trend of these indices.

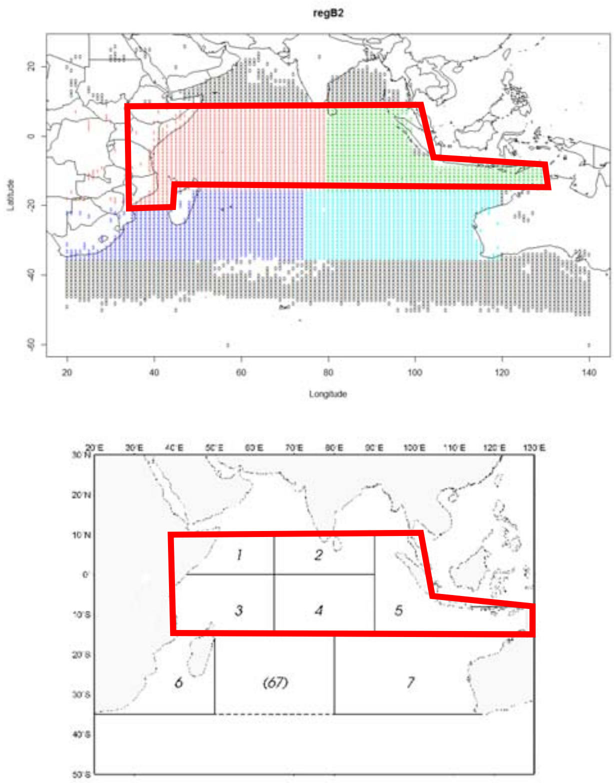

Fig. 2 Area definition (bounded area by red line) for joint CPUE by Japanese, Korean and Taiwanese longline fishery combined (top) and Japanese longline (bottom) CPUE used in this study.

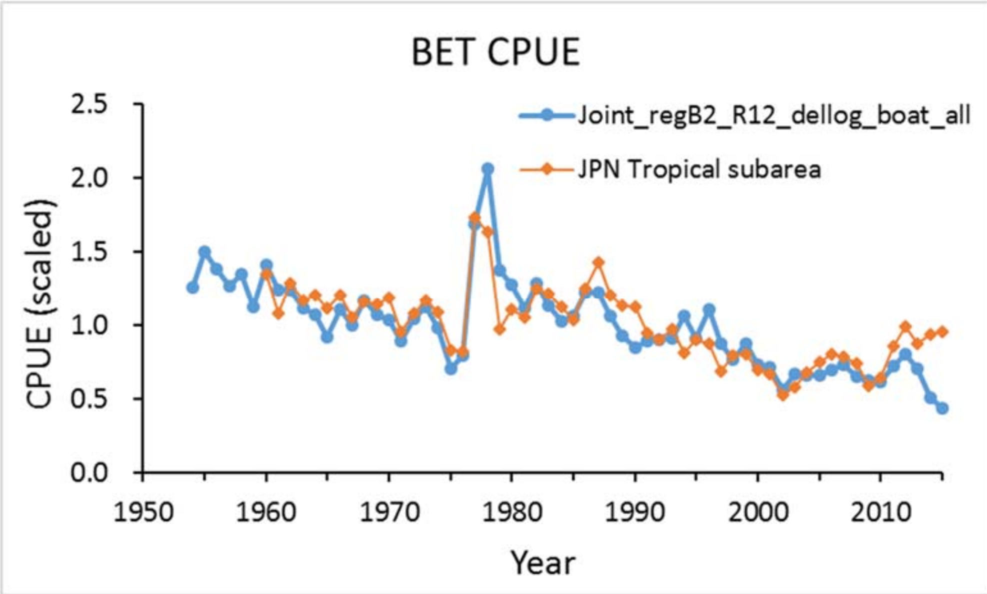

Fig. 3 CPUE used for ASPIC analysis.

3. ASPIC analyses

3.1 Initial ASPIC runs

We used logistic and Fox production model options available in the ASPIC software (ver. 5.34) developed by Prager (2004).

As for catch data, we thought that it is better to use the period as long as possible. Catch in IOTC database is available from 1950, so data for 1950-2015 were examined. Catch for fisheries other than longline was combined because CPUE for those fisheries are not available. Therefore, two fleets (longline and others) were defined and used. One CPUE (Japanese longline or joint CPUE) was incorporated for one scenario. B1/K (ratio of initial biomass to carrying capacity) was fixed at 0.9, considering that stock status in 1950 is close to virgin biomass. A total of four scenarios (logistic or Fox production model, Japanese longline or joint CPUE) were examined.

As a result, all the scenarios converged. Table 1 shows summary of specifications and results of ASPIC runs. There are some differences of the results among scenarios. Run 1 and Run 2 (with Japanese LL CPUE) got more optimistic results than Run 3 and Run 4 (with joint CPUE). The scenarios with Fox model got more optimistic results than those with logistic model. MSY was 96,700-156,400 tons, B (biomass in the beginning of 2016) was 478,000-1,628,000 tons, B (MSY) was 314,000-1,277,000 tons, B ratio (in the beginning of 2016) was 0.997-1.945 and F ratio (in 2015) was 0.31-0.93. These indicate that currently biomass is close to or over MSY level, and F is lower than MSY level.

Joint CPUE, which was created at this year's IOTC joint CPUE analysis, is based on operational data for three fleets (Japanese, Taiwanese and Korean longline) with vessel ID (fishing power) and targeting (cluster analysis). Therefore, it may be more representative of abundance of bigeye tuna stock. Compared the results of the scenarios with joint CPUE (Run 3 and 4), the value of objective function for Run 4 (Fox model) is smaller than that for Run 3 (logistic model). Taking these issues into account, Run 4 was selected as tentative base case in this document.

Table 2 is summary of the ASPIC analysis for Run 3. In this table, terminal year for the biomass estimated by ASPIC was regarded as 2015 because the timing of the biomass for terminal year was beginning of 2016, which is equivalent to the end of 2015. Fig. 4 shows historical trend for B ratio and F ratio based on the results of four scenarios. B ratio shows decreasing trend, but it increased after mid 2000s for Runs 1 and 2, and was comparatively constant in recent years for Runs 3 and 4. F ratio shows increasing trend, but it decreased with fluctuation after early or mid 2000s. Total catch was usually higher than current MSY level for the tentative base case (Run 4) after mid 1990s, but currently lower than MSY level. Fig. 5 shows CPUE fit for the four ASPIC runs. CPUE fit looks comparatively well for all the scenarios, indicating that the results of stock assessment are largely affected by the trend of CPUE used. Fig. **6** shows Kobe 1 plot based on the results of Run 4. The stock temporarily experienced orange zone (overfishing but not overfished). Currently the stock is in the green zone at point estimate.

Table 1 Summary and results of ASPIC runs.

Scenario No	Scenario name	years	Model	Fleets		CPUE		Statistical weight	B1/K
				LL	OT	JPN	Joint		
1	JPN Logi	1950-2015	Logistic	on	on	1960-2015 Tropical	-	Equal	Fix(0.9)
2	JPN Fox	1950-2015	Fox	on	on	1960-2015 Tropical	-	Equal	Fix(0.9)
3	Joint Logi	1950-2015	Logistic	on	on	-	1954-2015 R+R2	Equal	Fix(0.9)
4	Joint Fox	1950-2015	Fox	on	on	-	1954-2015 R+R2	Equal	Fix(0.9)

Scenario No	Scenario name	Objective function	MSY 1000t	B current million tons	B msy million tons	B ratio	F current	F msy	F ratio	K 1000t	r
1	JPN Logi	1.178	140.5	0.478	0.314	1.526	0.20	0.448	0.437	627	0.90
2	JPN Fox	1.190	156.4	0.513	0.264	1.945	0.18	0.593	0.308	717	0.59
3	Joint Logi	1.902	99.9	1.273	1.277	0.997	0.07	0.078	0.934	3417	0.12
4	Joint Fox	1.893	96.7	1.628	1.257	1.295	0.06	0.077	0.741	2554	0.10

B: total biomass, B ratio: $B_{current}/B_{MSY}$, F ratio: $F_{current}/F_{MSY}$.

Table 2 Indian Ocean bigeye tuna stock status summary based on the ASPIC analysis (Run4).

Management Quantity	**Indian Ocean**
Most recent catch estimate (t) (2015)	92,736
Mean catch over last 5 years (t) (2011-2015)	101,515
MSY (1000 t) (80%CI)	96.7 (55.2-125.7)
Current data period	1950-2015
F(Current)/F(MSY) (2015) (80% CI)	0.74 (0.49-1.49)
B(Current)/B(MSY) (2015) (80% CI)	1.30 (1.11-1.52)
SB(Current)/SB(MSY)	NA
B(Current)/B(0) (2015) (80% CI)	0.71 (NA)
SB(Current)/SB(0)	NA
SB(Current)/SB(Current, F=0)	NA

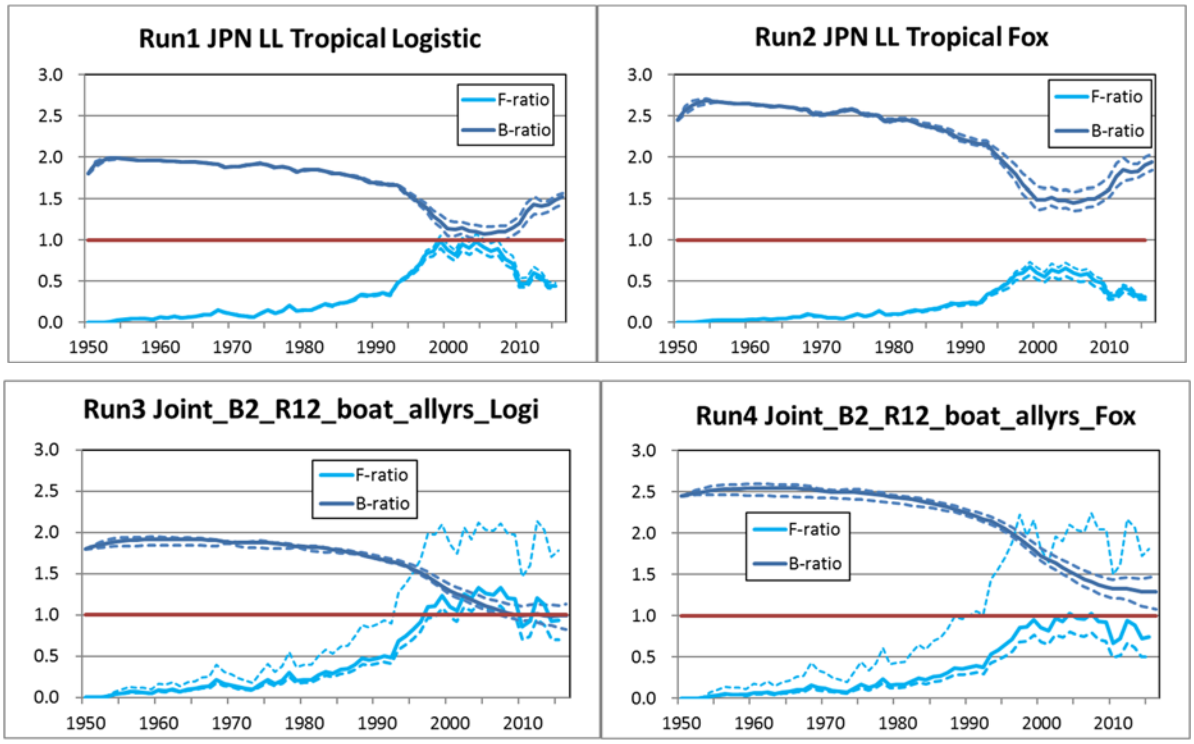

Fig. 4 Trajectories of B-ratio (B/BMSY) and F-ratio (F/FMSY) with 80% confidence limits (dashed lines) for ASPIC runs.

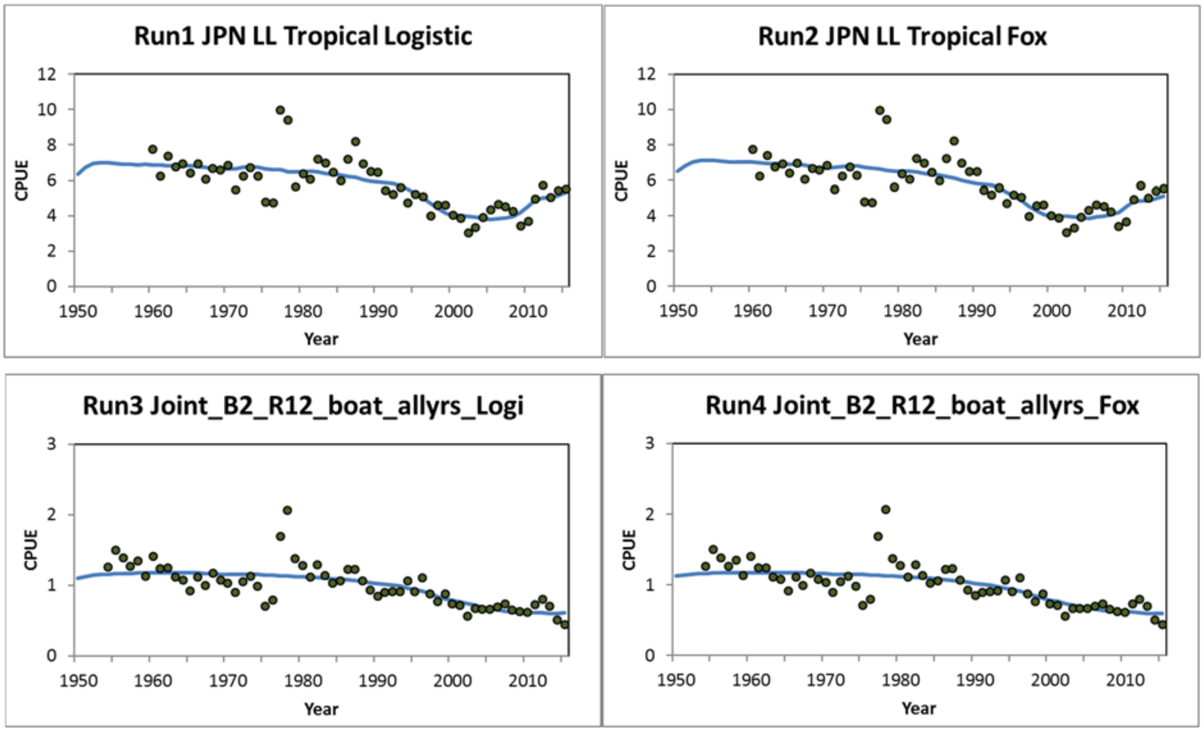

Fig. 5 CPUE fit for the four ASPIC runs. Line: estimated, circles: observed (input data).

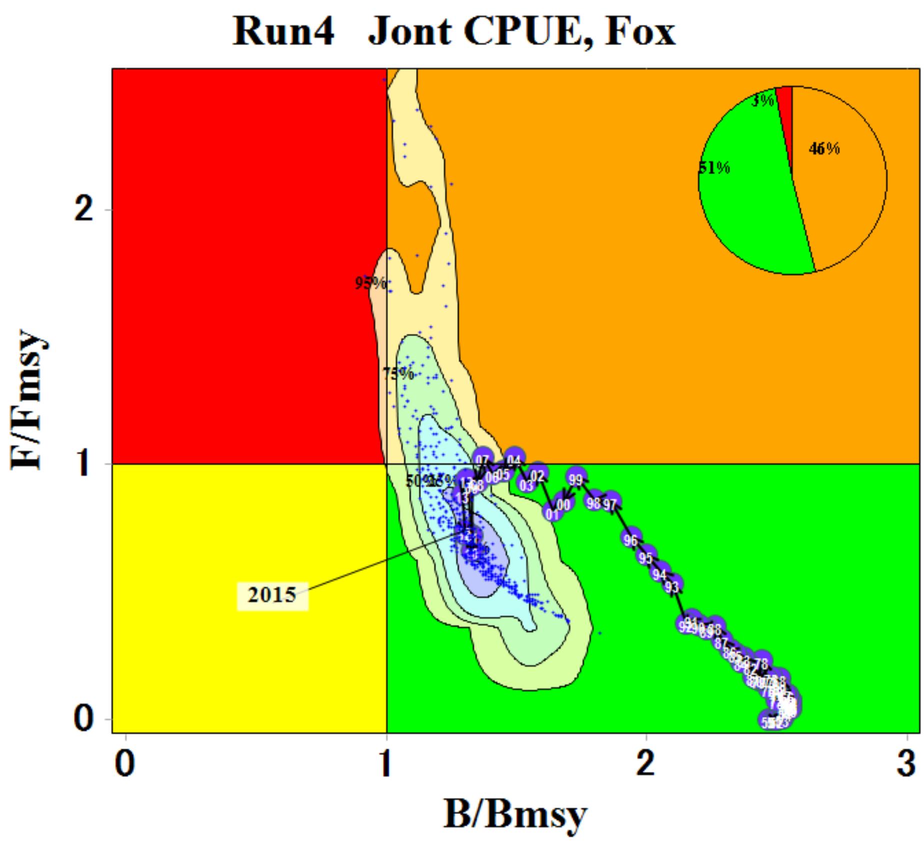

Fig. 6 Kobe plot with 95% confidence surface for Run 4.

4. Risk assessments

Five tuna RFMOs meetings in Kobe in 2007 recommended to produce Kobe plot (stock trajectory) and also in Barcelona in 2010 they recommended to conduct the risk analyses for SSB (spawning stock biomass) or B (total biomass) ratio (our case). Degrees of risks are represented by probabilities to exceed B 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 (2015) was continued and in case ±10%, ±20% and ±40% of current catch were continued (constant catch). Catch in 2016 was assumed to be the average of 2013-2015 catch (98,149t) because the catch in 2016 almost can't be controlled. Using these scenarios, they suggested evaluating risk probabilities within 10 years. To conduct the risk assessments, we generated 500 bootstraps to obtain possible values of B ratios and F ratios by utilizing ASPIC-P ver. 3.16 (projection module available in ASPIC).

4.1 Risk assessments on B ratio

Using results of the ASPIC analysis for Run 4 (tentative base case), 500 values of B ratio and F ratio were generated by the bootstrap function available in the ASPIC-P for 2016-2025 (2016-2026 for biomass level). As a first step, we made future projections of B ratios (Fig. 7). Then we made the Kobe 2 risk matrix (

Table 3). These results indicated low (<50%) risk of B ratio not exceeding B (MSY) level in the future if future catch is even 40% higher than current level.

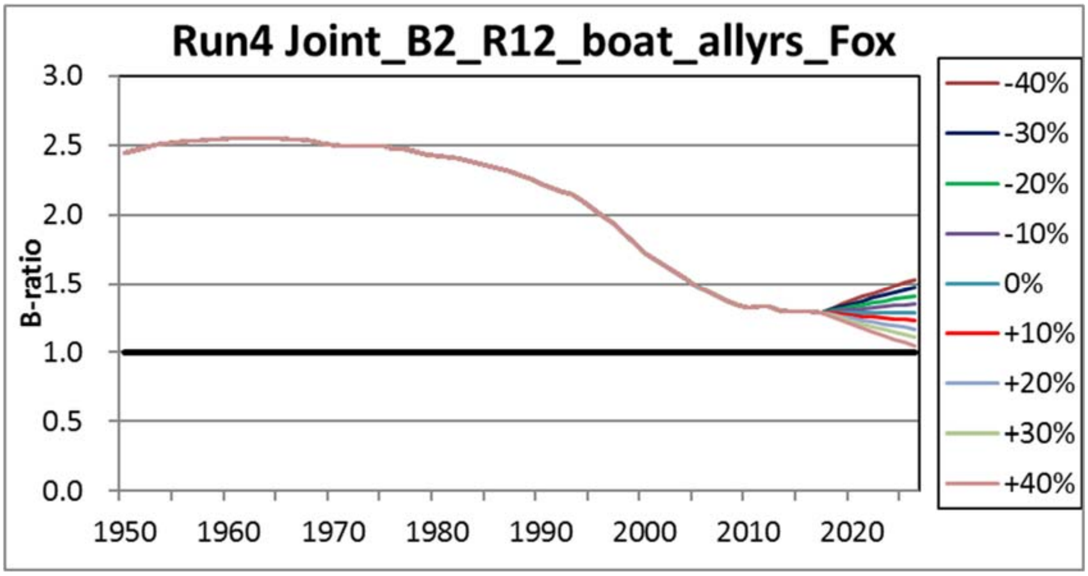

Fig. 7 Future projection of B ratio with constant catch for Run 4.

Table 3 Kobe II risk matrix for B ratio (probability of not exceeding MSY level) under constant catch for Run 4. “Catch level” means increase or decrease from current (2015) level.

Catch level	Catch (t)	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
-40%	55,642	79%	80%	82%	85%	90%	92%	94%	95%	96%	97%	98%
-30%	64,915	79%	80%	82%	84%	87%	90%	92%	94%	95%	95%	95%
-20%	74,189	79%	80%	81%	83%	84%	87%	90%	91%	93%	94%	94%
-10%	83,462	79%	80%	80%	82%	83%	84%	86%	87%	89%	90%	91%
0%	92,736	79%	80%	80%	81%	82%	82%	83%	83%	83%	84%	84%
+10%	102,010	79%	80%	80%	80%	80%	80%	79%	80%	80%	79%	79%
+20%	111,283	79%	80%	79%	79%	78%	77%	76%	75%	74%	73%	70%
+30%	120,557	79%	80%	79%	77%	76%	73%	72%	70%	68%	64%	60%
+40%	129,830	79%	80%	78%	76%	72%	70%	68%	63%	58%	53%	51%

4.2 Risk assessments on F ratio

In the same way as for B ratio, the future projection (Fig. 8) and Kobe 2 matrix (

Table **4**) were made. These results indicated high risk of F ratio exceeding F (MSY) level in the future if future catch is >20% higher than current level.

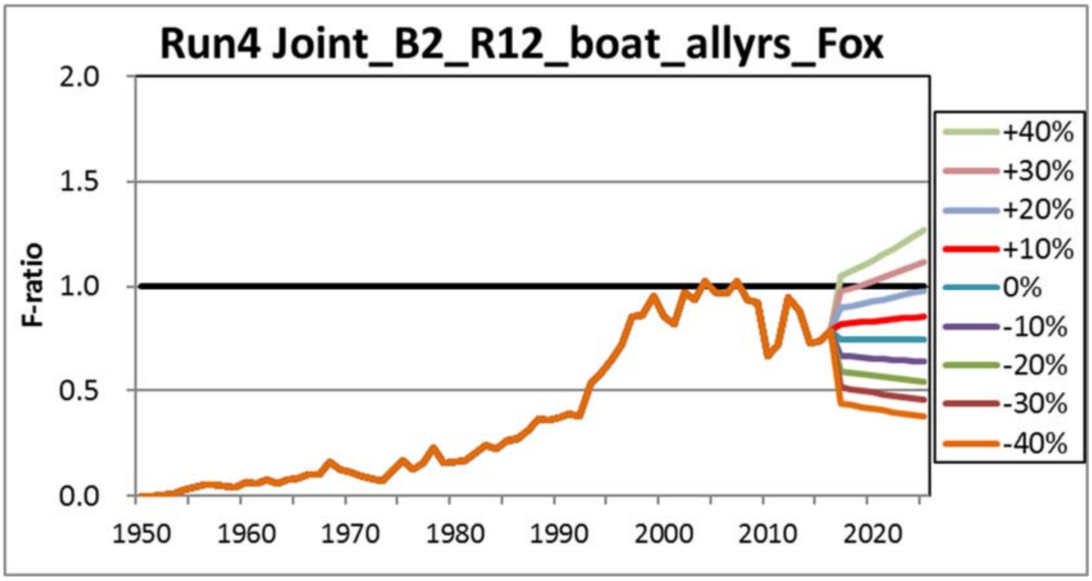

Fig. 8 Future projection of F ratio with constant catch for Run 4.

Table 4 Kobe II risk matrix for F ratio (probability of exceeding MSY level) under constant catch for Run 4. “Catch level” means increase or decrease from current (2015) level.

Catch level	Catch (t)	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
-40%	55,642	78%	100%	100%	100%	100%	100%	100%	100%	100%	100%
-30%	64,915	78%	99%	100%	100%	100%	100%	100%	100%	100%	100%
-20%	74,189	78%	97%	98%	98%	99%	99%	100%	100%	100%	100%
-10%	83,462	78%	92%	93%	95%	95%	96%	97%	97%	98%	98%
0%	92,736	78%	83%	83%	84%	85%	86%	87%	88%	89%	89%
+10%	102,010	78%	75%	75%	75%	74%	73%	74%	74%	73%	72%
+20%	111,283	78%	62%	61%	59%	58%	57%	54%	51%	49%	47%
+30%	120,557	78%	50%	49%	45%	42%	39%	36%	33%	30%	27%
+40%	129,830	78%	39%	34%	31%	27%	24%	23%	20%	17%	14%

5. Retrospective analysis

Retrospective analyses were conducted for one scenario (Run 4, joint CPUE Fox model) of ASPIC model. Both catch and CPUE data in recent years were removed from one to eight years.

Fig. 9 shows the results of retrospective analyses for Run 4. The scenarios which excluded the data by five to seven years didn’t converge. The scenario which excluded the data by eight years shows strange trajectory for F ratio. As for the other scenarios, although comparatively large difference (up to more or less 40%) was observed near the terminal year, the results were close to that for the base model.

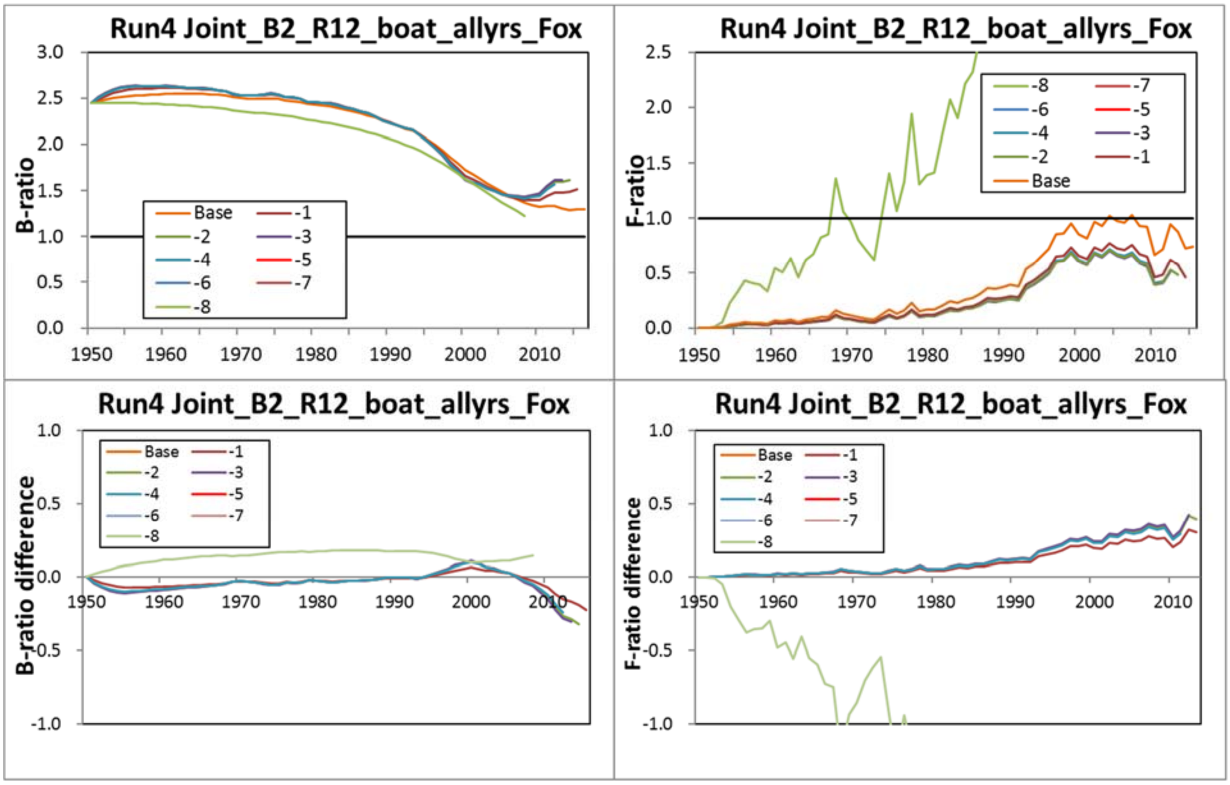

Fig. 9. Results of retrospective analyses for ASPIC model (Run 4). Top: values of F-ratio and B-ratio, bottom: difference from base model.

References

Hoyle, S. D., Kim, D. N. Lee, S. I., Matsumoto, T., Satoh, K. and Yeh, Y. M. (2016) Collaborative study of tropical tuna CPUE from multiple Indian Ocean longline fleets in 2016. IOTC–2016–WPTT18–XX.

Matsumoto, T., Nishida, T., Satoh, K. and Kitakado, T. (2016) Japanese longline CPUE for bigeye tuna in the Indian Ocean standardized by GLM. IOTC–2016–WPTT18–13.

Prager, M. (2004) 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