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Stock and risk assessments on albacore (*Thunnus alalunga*) in the Indian Ocean based on AD Model Builder implemented Age-Structured Production Model (ASPM)

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Abstract

We applied an Age-Structured Production Model (ASPM) to assess the status of the albacore tuna stock (*Thunnus alalunga*) in the Indian Ocean using 61 years of data (1950-2010). The results suggested that the fishing effort (2010) is the above MSY level (F/Fmsy=1.21), while the spawning stock biomass (SSBT) is around at the MSY level (SSB/SSBmsy=1.15). This means that the current status of the albacore stock is the overfishing and its population is now reaching to its MSY level. The risk assessments suggested that current catch in 2010 (43,000 t) should be reduced to at least 20% (i.e., 34,000t, close to the MSY level: 33,000 t) to keep lower risks to violate Fmsy and SSBmsy levels.

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1. Introduction

We attempted the stock and risk assessments on albacore (*Thunnus alalunga*) (ALB) in the Indian Ocean based on AD Model Builder implemented Age-Structured Production Model (ASPM) using the data for 61 years from 1950-2010.

2. Input data to ASPM

To implement ASPM, we used ALB annual nominal catch by gear, standardized (STD) CPUE, CAA (catch-at-age) data by gear and also biological information. Below are descriptions of the data used in the ASPM runs.

2.1 Catch

We used the nominal catch data by gear (fleet) from the IOTC Secretariat. Fig. 1 shows the trends of catch by fleet type (in weight and number).

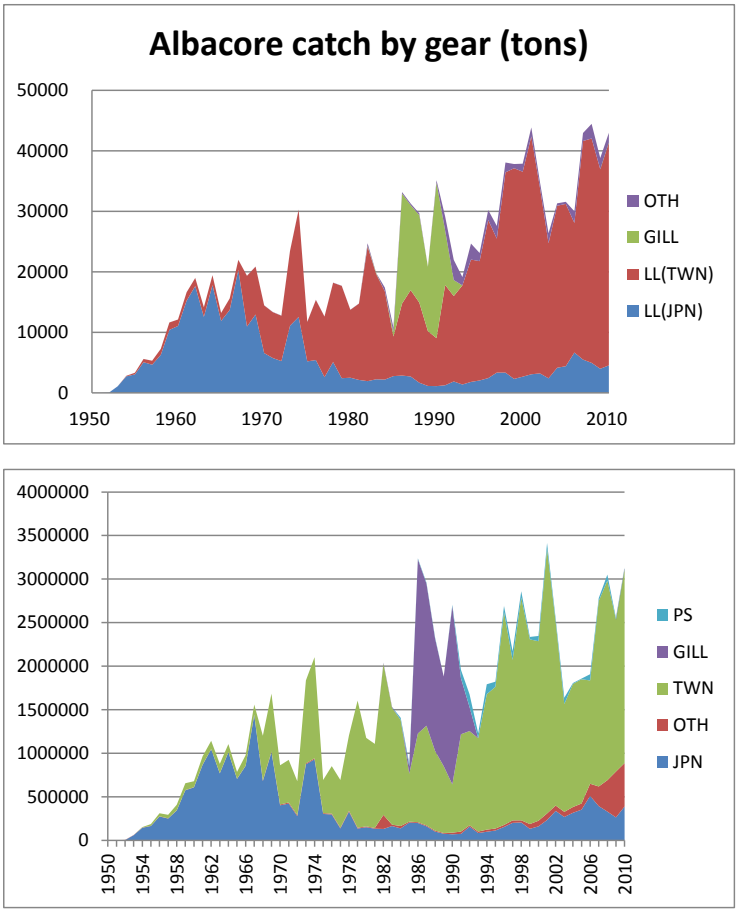


Fig. 1 Trend of albacore tuna catch in the Indian Ocean by gear type in weight (above) and in number (below). (Source: IOTC Secretariat, 2012)

2.2 Fleet

We used 2 types of fleet (gears), i.e., tuna longline (LL) and gillnet + (GL) including others surface gears.

2.3 Catch-at-age (CAA) and age structures

Using the catch-at-age (CAA) information (age 0-age13) (IOTC Secretariat), the age structure of albacore catch (1950-2010) was depicted in Fig. 2. From Fig. 2, we consider catch age 11-13 are negligible, thus we pool these catch as age 10+ and we define 11 age classes, i.e., age0-age10+.

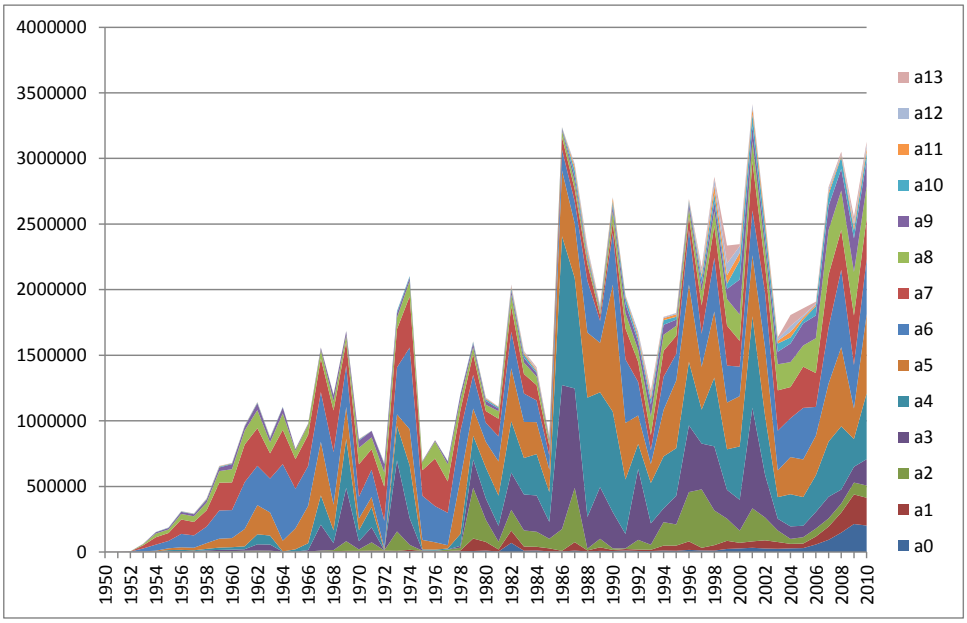


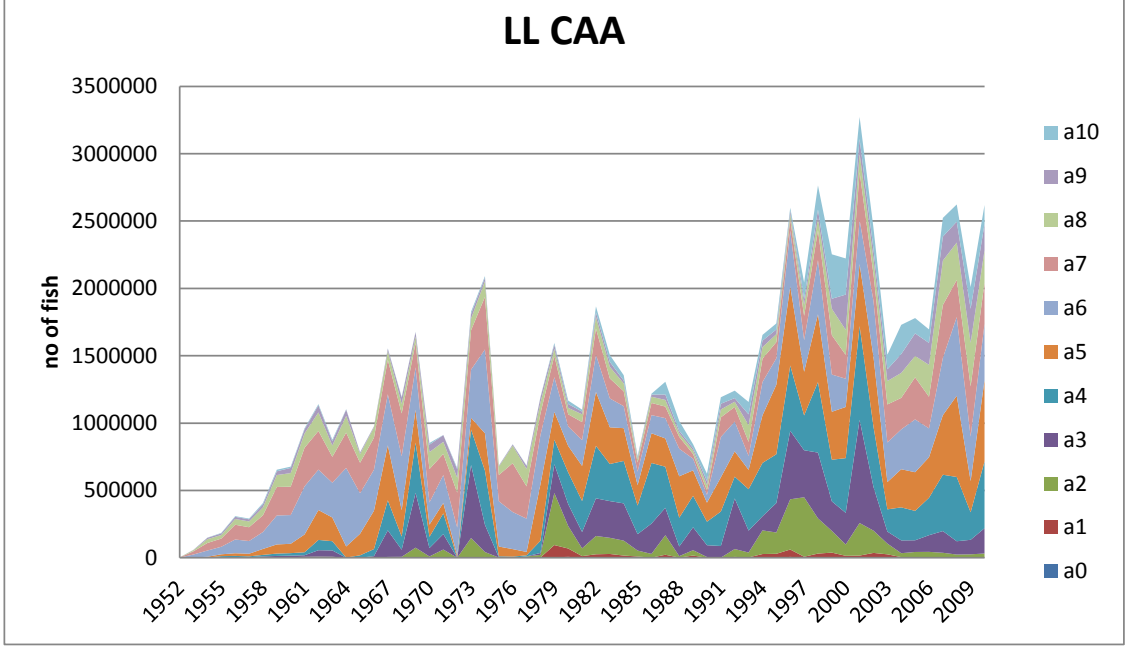
Fig. 2 Age compositions in the albacore catch

2.4 Minus and plus group by fleet

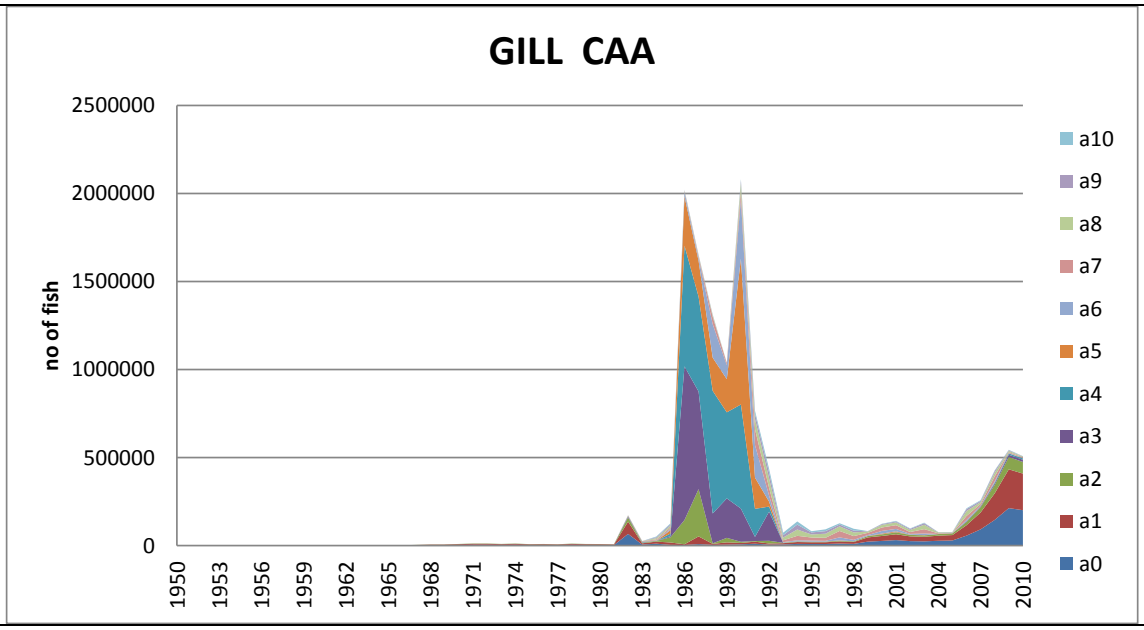
In ASPM, minus and plus group need to be defined by fleet to estimate effectively. To investigate this, we made annual trend of CAA by gear (Fig 3 and Table 1).

Table 1 Minus and plus group by fleet determined based on Fig 3.

	LL	GL
Minus group (age)	3	1
Plus group (age)	7	4



Minus group a3 or younger and Plus group a7 or older



Minus group a1 or younger and Plus group a4 or older

Fig. 3 CAA by gear to investigate minus and plus group

2.5 CPUE

For the standardized (STD) LL CPUE, 3 types of STD CPUE series are available, i.e., (a) Japanese tuna LL (1966-2010) (Matsumoto et al, 2012), (b) Korea tuna LL (1986-87 and 1990-2010) (Lee, et al, 2012) and (c) Taiwanese tuna LL (1980-2010) (Lee et al, 2012). From these graphs, the relation between Catch vs. STD CPUE (Taiwan) is realistic, thus we use STD CPUE (Taiwan).

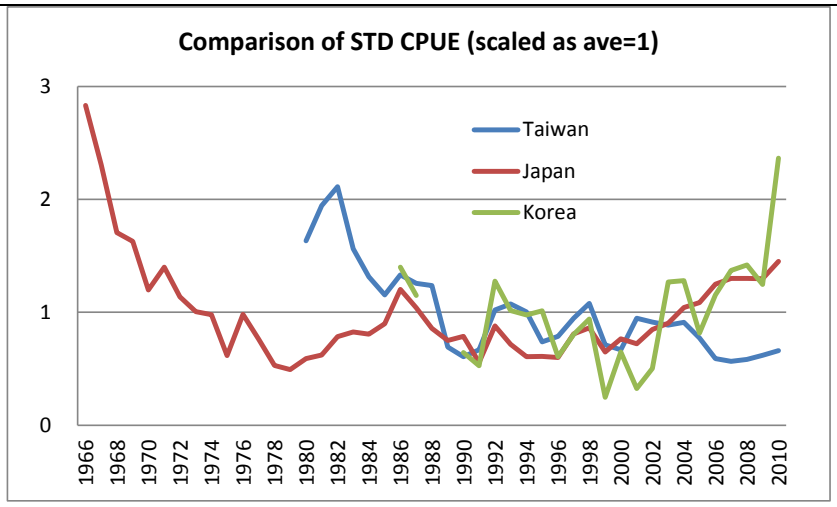
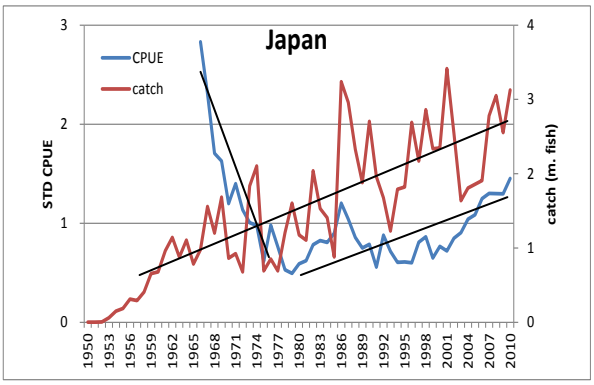


Fig 4. Comparison among 3 STD CPUEs



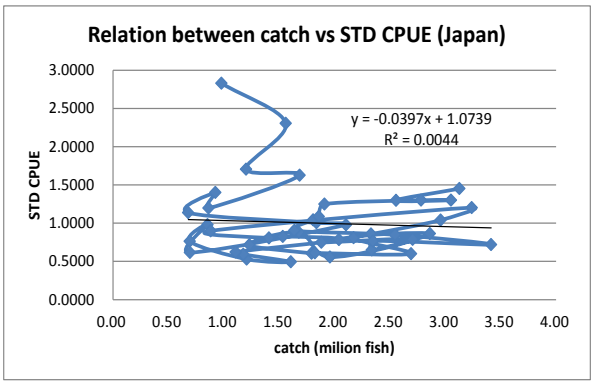
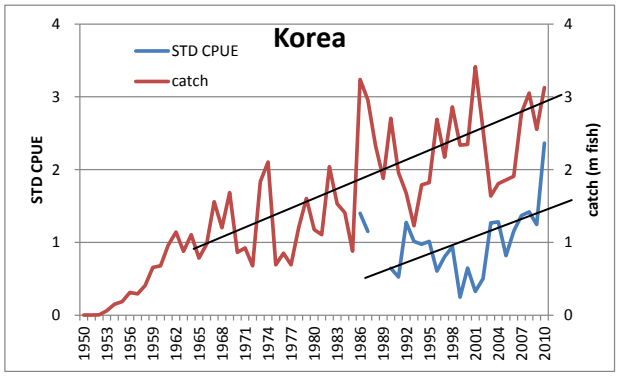


Fig. 5 Relation between catch vs. STD CPUE (Japan) by year (left) and scatterplot (right)



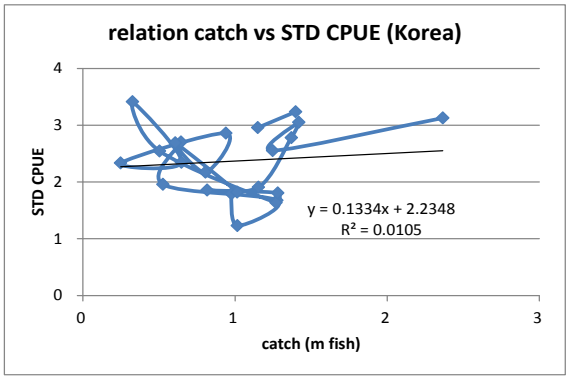
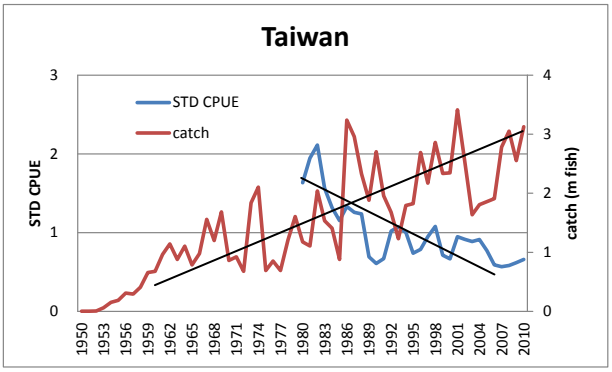


Fig. 6 Relation between catch vs. STD CPUE (Korea) by year (left) and scatterplot (right)



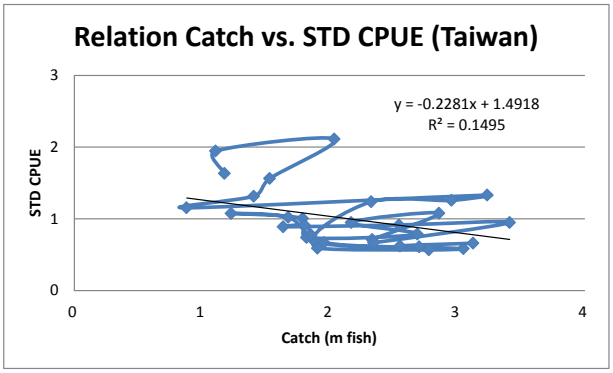


Fig. 7 Relation between catch vs. STD CPUE (Taiwan) by year (left) and scatterplot (right)

2.4 Biological information

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

(1) Natural mortality vector (M)

We applied *M* =0.2207 (Lee and Liu, 1992).

(2) Beginning- and mid-year weights-at-age

Beginning- and mid-year weights-at-age were estimated as follow: (a) using the growth equation (Lee and Yeh, 2006) (Fig. 8), size-at-age was calculated, then (b) using the length-weight relationship, $W=aL^b$ (a= 0.0000569070 and b= 2.75140) (data from the Indian Ocean, Taiwanese gillnet fishery by Chien-Chung Hsu), weight-at-age was calculated (Box 1).

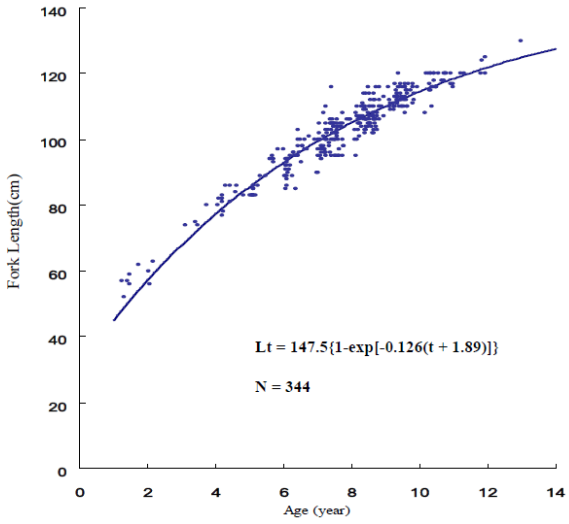


Fig. 8 ALB growth equation (Lee and Yeh, 2006)

Box 1 ALB Weights-at-age (tons) in the Indian Ocaen

Beginning of the year weights by age (tons)

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13
wt (tons)	0.00074	0.00202	0.00389	0.00623	0.00891	0.01180	0.01480	0.01780	0.02076	0.02360	0.02631	0.02885	0.03121	0.03340

Middle of the year weights by age (tons)

Age	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5
wt (tons)	0.00130	0.00288	0.00501	0.00754	0.01034	0.01329	0.01630	0.01929	0.02219	0.02497	0.02760	0.03005	0.03233	0.03442

(3) Maturity-at-age

We assume that the fecundity is proportional to maturity. Based on the executive summary on ALB (IOTC, 2011), maturity-at-age is considered to 0% for age 0-3, 25% for age 4, 50% age 5, 75% age 5 and 100% for age 7 or older (Box 2).

Box 2 ALB Maturity-at-age

Proportion maturity by age

# age	0	1	2	3	4	5	6	7	8	9	10+
	0	0	0	0	0.25	0.50	0.75	1	1	1	1

3. Initial ASPM run (Base case)

Using the input data, we attempted the initial five ASPM runs, i.e., h (steepness) estimated and h fixed (0.6, 0.7, 0,8 and 0.9). As a result, we got conversion with h=0.7 (Table 1). Results (estimated parameters) are depicted in Fig. 9-15. Results suggested that the fishing effort (2010) is the above MSY level (F/Fmsy=1.33), while the spawning stock biomass (SSBT) is around at the MSY level (SSB/SSBmsy=1.05). Risk assessments are planned to be conducted during the working group meeting.

Table 2 Specification and results of Initial five ASPM runs

h	estimated	Fixed			
	Not converged	0.6	0.7	0.8	0.9
Likelihood_components_and_weights (goodness-of-finess)					
Total	Not converged	Not converged	-11.945	Not converged	Not converged
Indices			-32.296		
CAA			18.103		
SR_fits			2.248		
R2			0.625		
Estimated parameters					
SSB0 (1,000t)			366.8		
MSY (1,000t)			33.3		
F2010/Fmsy			1.33		
SSB2010/ SSBmsy			1.05		

4. Additional ASPM runs (sensitivities)

We attempted 5 sensitivity runs. Table 3 and Fig. 16 shows the results. Considering the good-of-find ness we suggested the ASPM run S2 produced the best result.

Table 3 Summary of ASPM runs (base case + 5 senilities)

	Base case	S1	S2	S3	S4	S5
CPUE	Taiwan		Taiwan + Japan			Taiwan +Japan+ Korea
	No weighting		Weighted ave by catch			
	1980-2020					1990-2020
h	0.7	0.7	0.7	0.8	0.6	0.7
M	0.2207 (Lee and Liu, 1992).	0.40 (WCPFC) T+J	0.2207 (Lee and Liu, 1992).			
Likelihood_components_and_weights (goodness-of-fitness) Ranks (points) are assigned to each run from the best fit to the worst in 4 criteria, i.e., (4), (3), (2) and (1).						
Total	-11.945(2)	-11.903 (1)	-15.948(4)	-15.861(3)	Not converged	Not converged
Indices	-32.296(1)	-32.955 (2)	-35.704(3)	-35.847(4)		
CAA	18.103(3)	18.587 (1)	17.997(4)	18.219(2)		
SR_fits	2.248(2)	2.465 (1)	1.759(4)	1.768(3)		
R2	0.625(3)	0.647 (4)	0.603(1)	0.607(2)		
Rank (total points)	11 (3rd best)	9 (4th best)	16 (best)	13 (2nd best)		
Estimated parameters						
SSB0 (1,000t)	366.8	256.5	367.1	341.89394	Not Converged	Not Converged
MSY (1,000t)	33.3	36.7	33.3	35.696		
F2010/Fmsy	1.33	0.88	1.21 (0.45-1.98)	0.96		
SSB2010/ SSBmsy	1.05	1.25	1.15 (0.64-1.66)	1.32		

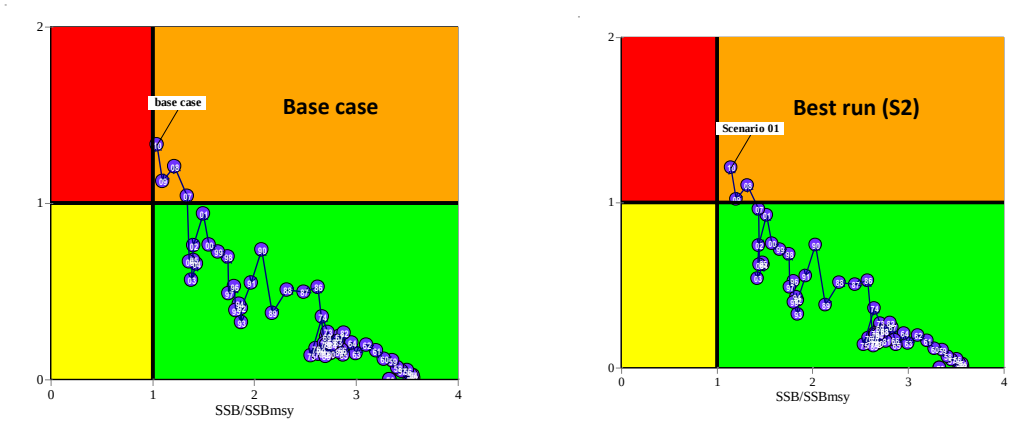


Fig 9 Kobe plot 1: (left) base case and (right) the best results (S2)

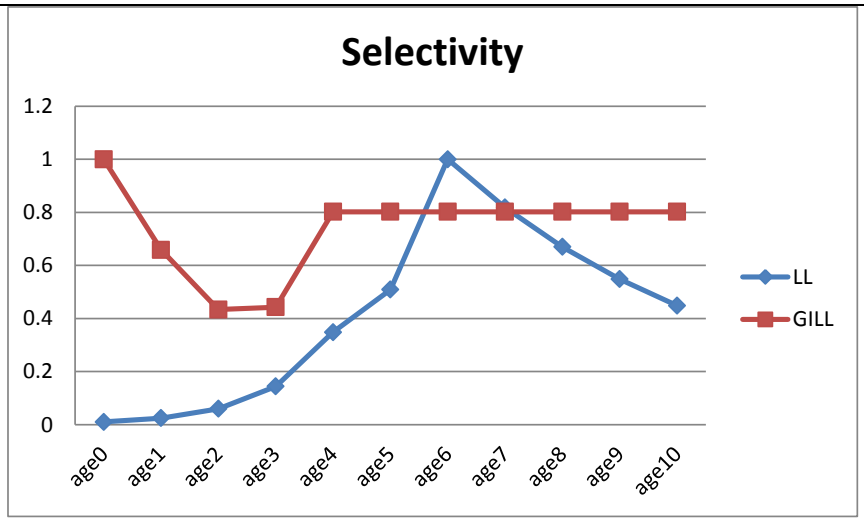


Fig. 10 Estimated selectivity for LL and GILL

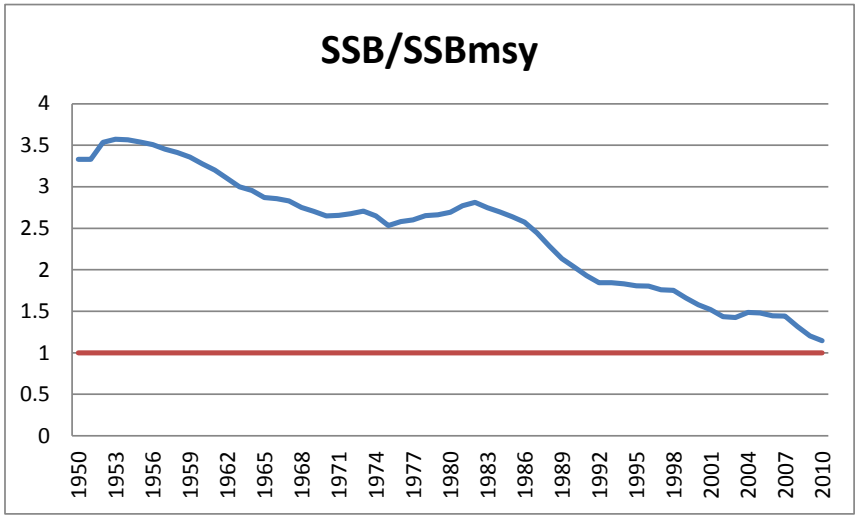


Fig. 11 Annual trends of SSB/SSBmsy

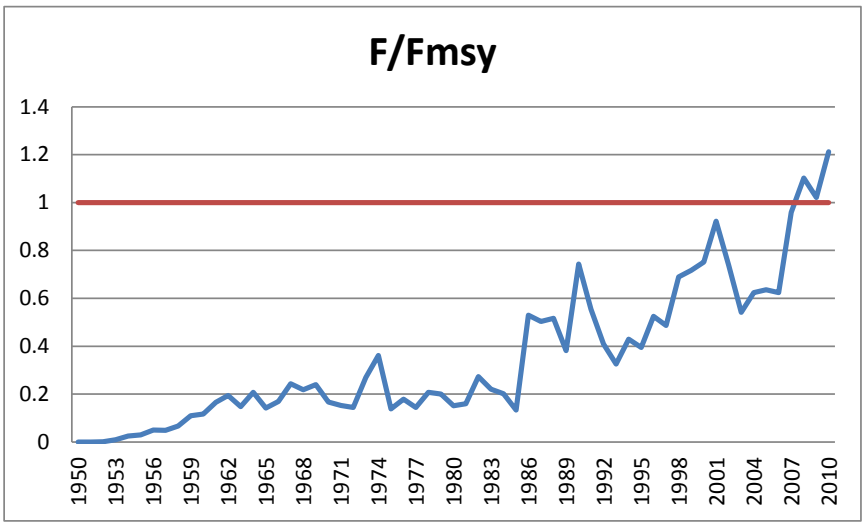


Fig.12 Annual trend of F/Fmsy

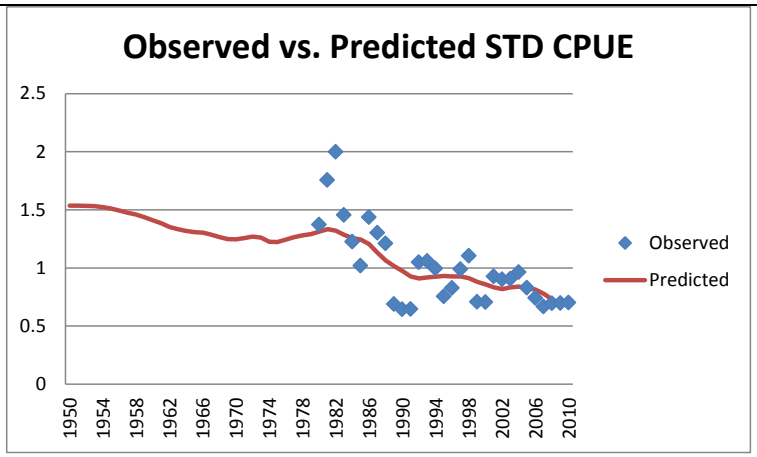


Fig. 13 Observed and predicted STD CPUE

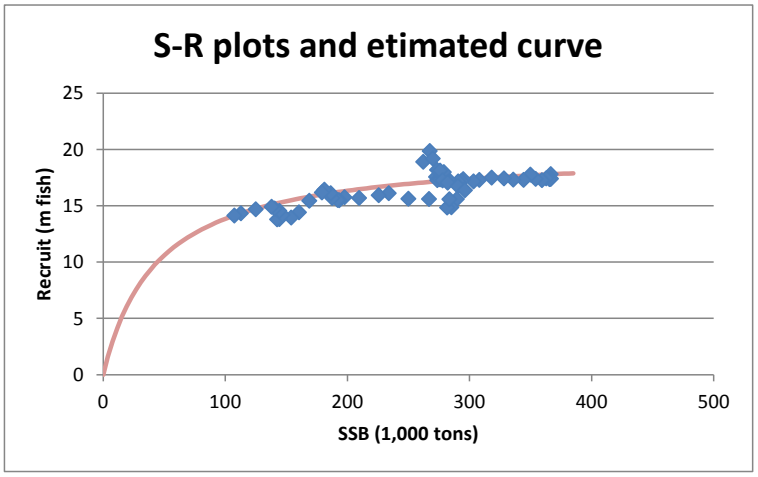


Fig. 14 Observed SR points and predicted SR curve(h=0.7)

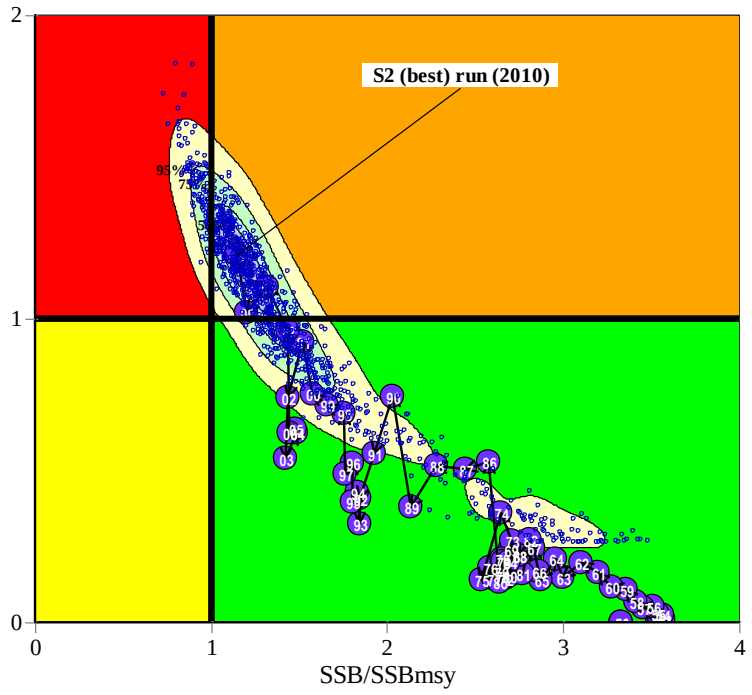


Fig. 15 Kobe plot 1 with confidence surface (S2: Best ASPM run)

Table 4 Indian Ocean albacore stock status summary (ASPM run S2)

Management Quantity	ASPM (Nishida et al, 2012) (rev 3 final) (this paper)
Most recent catch estimate (t) (2010)	42,968
Mean catch over last 5 years (t) (2006-2010)	39,833
h (steepness)	0.7 (fixed)
MSY (1,000 t) (80% CI)	33.3 (31.1-35.6)
Current Data Period (catch)	1950-2010
CPUE	Japan+Taiwan (annual) (weighted ave by catch) (1980-2010)
F(Current)/F(MSY) (80% CI)	1.21 (0.45-1.98)
SSB(2010)/SSB(MSY) (80% CI)	1.15 (0.64-1.66)
TB(2010)/TB(MSY)	NA
SSB(2010)/SSB(0) (80% CI)	0.32 (NA)
TB(2010)/TB(0)	NA
SSB(2010) /SSB(Current, F=0)	NA

5. Projections and risk assessments

Future projections for SSB and F for 10 years (2011-2020) are conducted using MCMC function available in the ASPM software, i.e., 1,000 sampled data by 0.5 million simulations with sampling every 500th intervals.5 scenarios by different levels of catch are applied, i.e., current catch level, ±10%, ±20%, 30% and ±40% of the current level. Fig. 16-17 shows results for SSB and F respectively.

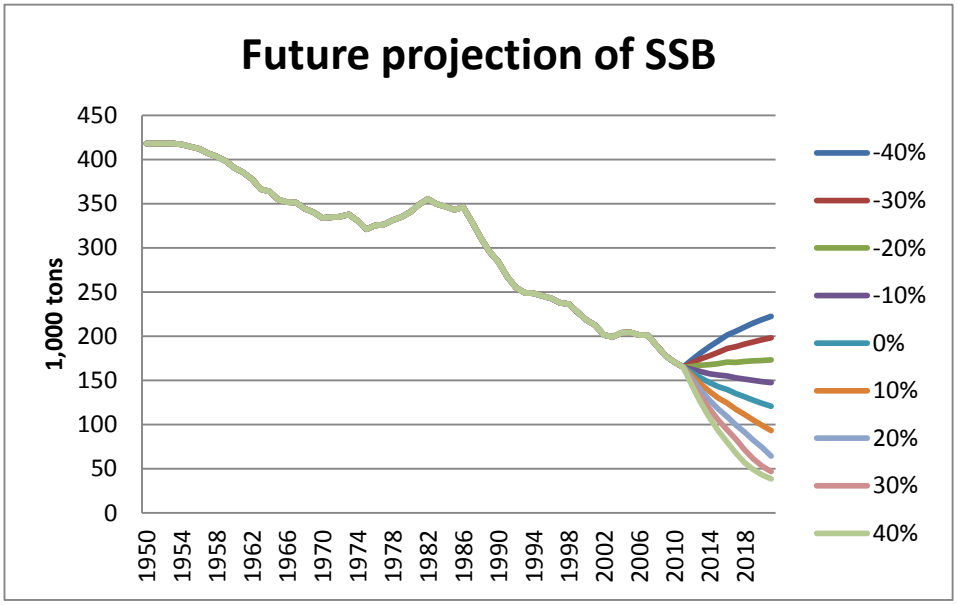


Fig. 16 Future projection of SSB under 5 scenarios.

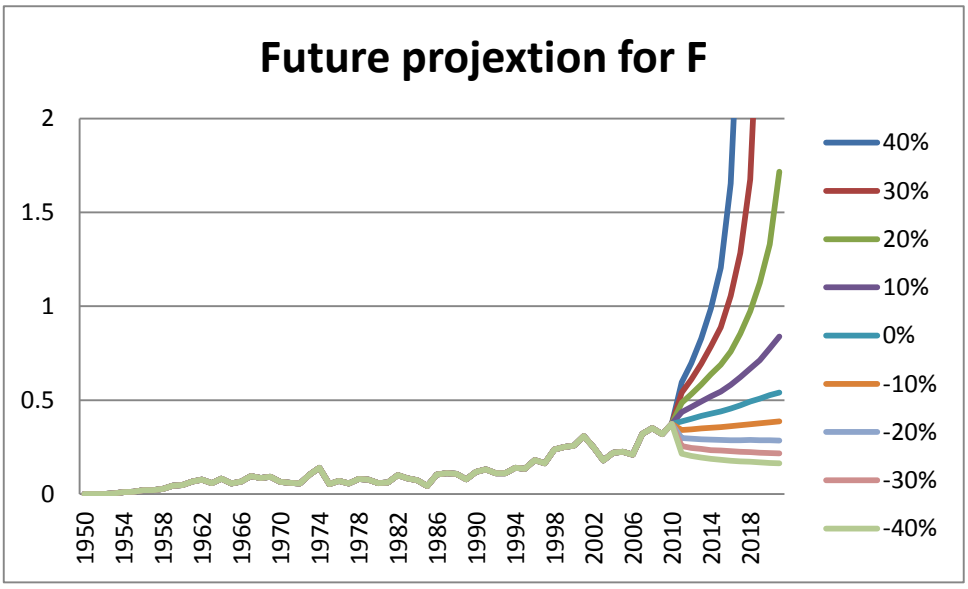


Fig. 16 Future projection of F under 5 scenarios.

Risk assessments (Kobe II) are conducted to investigate probabilities of SSB and F violating MSY levels during 2011-2020. We made 7 scenarios for the risk assessments, i.e., status quo (catch in 2010), ±10%, ±20% and ±40% to see how these catch levels affect the risk probabilities. Table 5 and Fig 17 show the results of the risk assessments for SSB numerically and graphically and Table 6 and Fig. 18 for F.

Table 5 Results of the risk assessments (Kobe 2) for SSB (numerical presentation)

Legend: Green (low risk: 0.25 < Pr.), Yellow (low-moderate risk : 0.25<=Pr < 0.5)
Orange (medium – high risk : 0.50<=Pr <0.75) and Red (High risk : 0.75 <=Pr)
Pr: risk probability to exceed SSBmsy

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
−40%	0.101	0.008	0.002	0.001	0	0	0	0	0	0
−30%	0.101	0.05	0.042	0.044	0.05	0.048	0.054	0.056	0.058	0.063
−20%	0.101	0.091	0.081	0.087	0.099	0.096	0.107	0.111	0.115	0.127
−10%	0.101	0.194	0.239	0.291	0.342	0.37	0.409	0.437	0.459	0.489
0	0.101	0.296	0.396	0.495	0.584	0.644	0.71	0.762	0.803	0.821
10%	0.101	0.434	0.572	0.677	0.757	0.811	0.853	0.881	0.902	0.923
20%	0.101	0.572	0.748	0.858	0.929	0.978	0.996	1	1	1
30%	0.101	0.683	0.847	0.925	0.965	0.989	0.998	1	1	1
40%	0.101	0.794	0.945	0.992	1	1	1	1	1	1

Common Legend (Table 5 and Fig. 17)

Green (low risk: 0.25 < Pr.), Yellow (low-moderate risk : 0.25<=Pr < 0.5)
Orange (medium – high risk : 0.50<=Pr <0.75) and Red (High risk : 0.75 <=Pr)
Pr: risk probability to violate SSBmsy

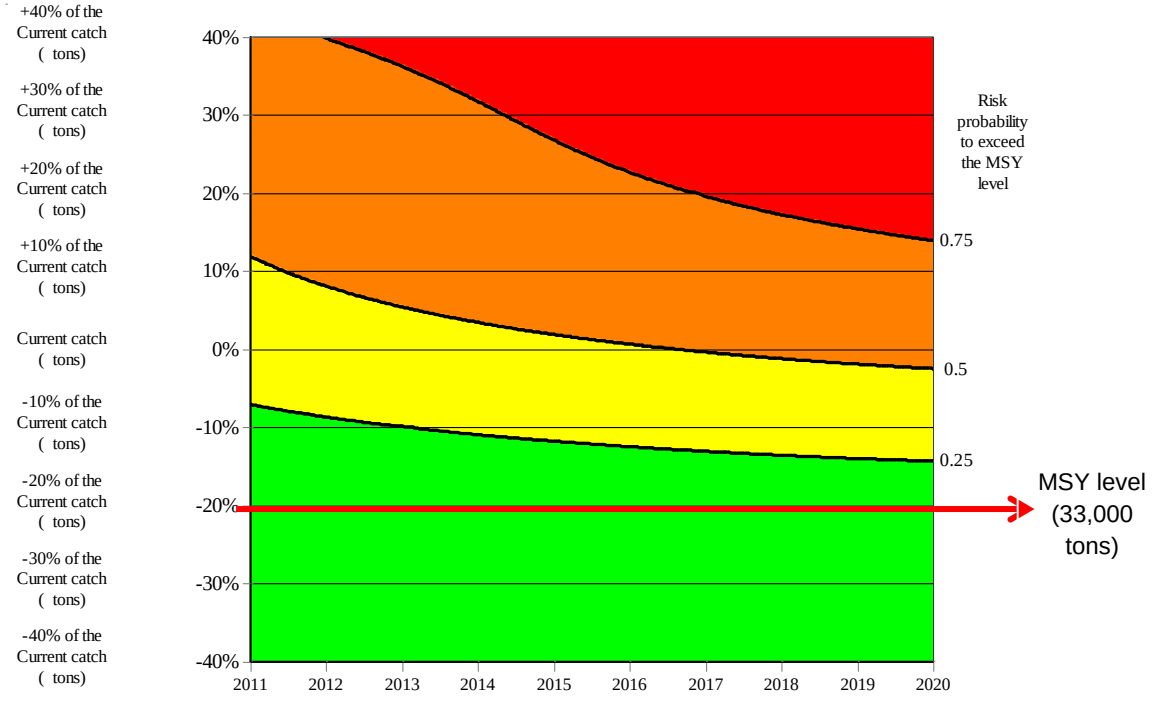


Fig. 17 Results of the risk assessments (Kobe 2) for SSB (graphical presentation)

Table 6 Results of the risk assessments for F (numerical presentation) (Kobe Matrix 2)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
−40%	0	0	0	0	0	0	0	0	0	0
−30%	0.02	0.01	0.01	0.01	0	0	0	0	0	0
−20%	0.09	0.08	0.07	0.06	0.07	0.07	0.08	0.08	0.08	0.09
−10%	0.21	0.22	0.23	0.25	0.28	0.3	0.31	0.33	0.35	0.37
0%	0.32	0.37	0.41	0.45	0.47	0.5	0.53	0.55	0.57	0.58
10%	0.45	0.51	0.56	0.59	0.62	0.66	0.68	0.69	0.69	0.7
20%	0.57	0.64	0.67	0.7	0.71	0.73	0.74	0.75	0.76	0.78
30%	0.66	0.7	0.73	0.74	0.76	0.78	0.79	0.8	0.81	0.81
40%	0.71	0.74	0.76	0.79	0.8	0.82	0.83	0.83	0.84	0.84

Common Legend (Table 6 and Fig. 18)

Green (low risk: 0.25 < Pr.), Yellow (low-moderate risk : 0.25<=Pr < 0.5)
Orange (medium – high risk : 0.50<=Pr <0.75) and Red (High risk : 0.75 <=Pr)
Pr: risk probability to violate Fmsy

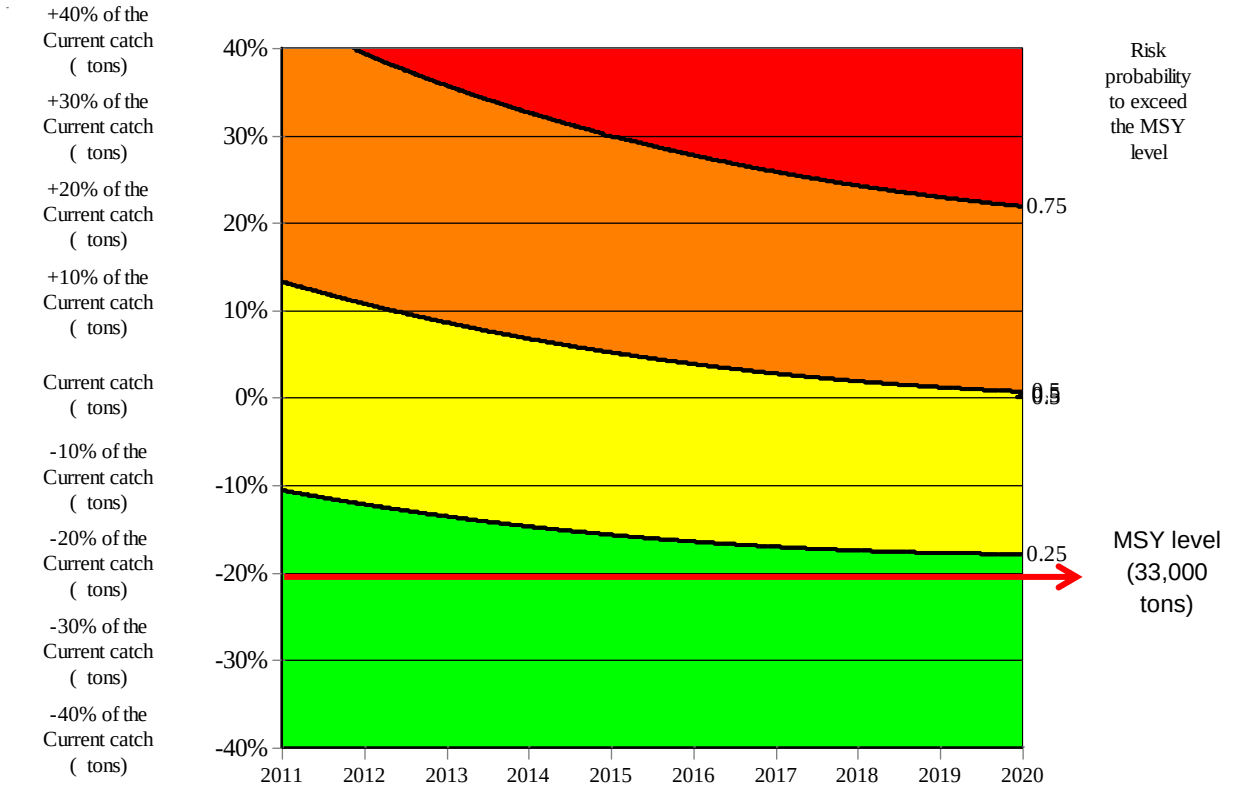


Fig. 18 Results of the risk assessments (Kobe 2) for F (graphical presentation)

The risk assessments suggested that current catch in 2010 (43,000 t) should be reduced to at least 20% (i.e., 34,000t, close to the MSY level: 33,000 t) to keep lower risks to exceed Fmsy and SSBmsy levels.

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