Stock assessments of black marlin (*makaira indica*) in the Indian Ocean using A Stock-Production Model Incorporating Covariates (ASPIC) (1950-2015)

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ABSTRACT

ASPIC was used to conduct the stock assessment of black marlin in the Indian Ocean using total nominal catch (1950-2015) and standardized CPUE of Japanese longline fleets (1971-2015) and Taiwan longline fleets (1979-2015). We conducted ASPIC using 36 runs varying K values with two models (Schaefer and Fox model). Results suggest the Fox model (K=50,000) fits to the data as the best, based on R2, RMS (Root Mean Square) and B1/K values (we consider it is the virgin stock in 1950, thus we select the ASPIC run with estimated B1/K closer 1). ASPIC results suggests that the black marlin stock is the overfished status with F/Fmsy=2.02 and TB/TBmsy=0.59 (red zone in the Kobe plot). Risk assessments suggest that even catch were reduced by 40% of the current catch level (17,171 tons, average of catch 2013-1015), there are still high risks (more than 70%) to violate MSY level for both F/Fmsy and TB/TBmsy.

Contents

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1. INTRODUCTION

In this work, a non-equilibrium production model (A Stock-Production Model Incorporating Covariates, ASPIC) (Prager, 2005) is applied to conduct the stock assessment of black marlin in the Indian Ocean using historical catch and standardized CPUE.

2. HABITAT AND STOCK STRUCTURE

Black marlin (*Makaira indica*) is a large oceanic apex predator that inhabits tropical and subtropical Indo-Pacific oceans. Little is known on the biology of the black marlin in the Indian Ocean.

Black marlin is a highly migratory, large oceanic apex predator that inhabits tropical and subtropical waters of the Indian and Pacific oceans. Some rare individuals have been reported in the Atlantic Ocean but there is no information to indicate the presence of a breeding stock in this area.

Black marlin inhabits oceanic surface waters above the thermocline and typically near land masses, islands and coral reefs; however rare excursions to mesopelagic waters down to depths of 800 m are known. Black marlin associates with schools of small tuna, which is one of its primary food sources (also reported to feed on other fishes, squids and other cephalopods, and large decapod crustaceans).

No information on stock structure is currently available in the Indian Ocean; thus for the purposes of assessment, <u>one pan-ocean stock is assumed.</u> Long distance migrations at least in the eastern Indian Ocean (two black marlins tagged in Australia were caught off east Indian coast and Sri Lanka) support a single stock hypothesis. It is known that black marlin forms dense nearshore spawning aggregations, making this species vulnerable to exploitation even by small-scale fisheries. Spatial heterogeneity in stock indicators (catch–per–unit–effort trends) for other billfish species indicates that there is potential for localized depletion.

3. DATA

To run ASPIC, we need the global catch and standardized CPUE by fleet, which are explained as below.

3.1 Catch by fleet

Total nominal catch by fleet is obtained from the IOTC data sets prepared for WPB14 (IOTC, 2016) (Fig.1). According to Fig. 1, black marlin is caught mainly by longlines and gillnets. The remaining catches by others (lines, purse seine and others) are low (average: 12%, min: 1.2%, max: 31%).

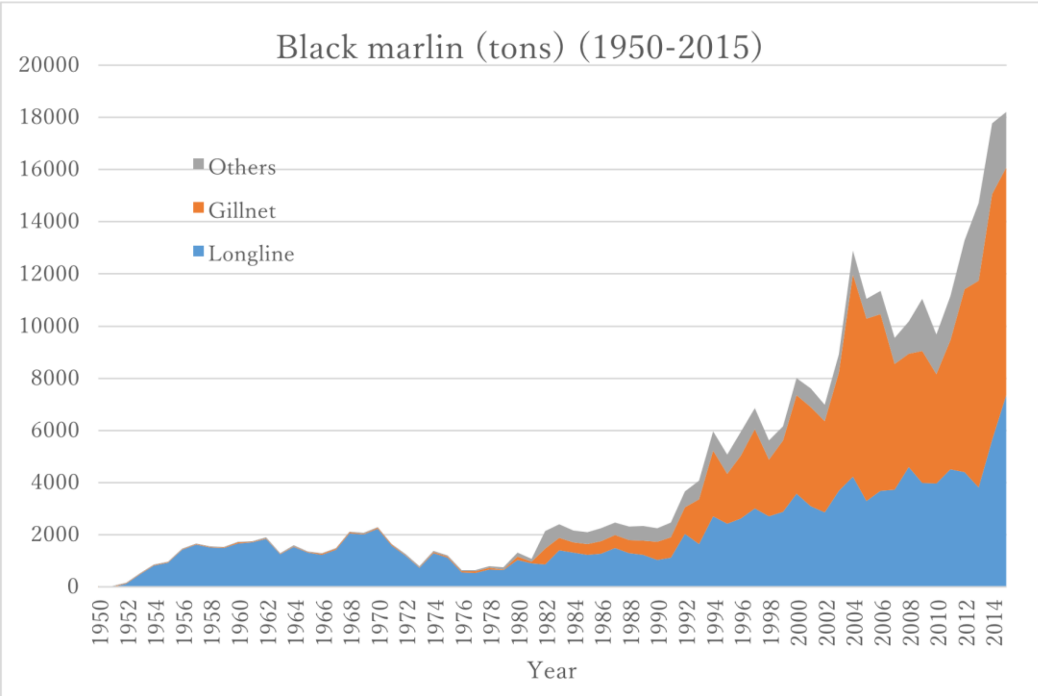


Fig. 1 Trend of nominal catch of black marlin by fleet (IOTC, 2016)

Black marlin is generally considered to be a bycatch except the sport fishing and tuna longlines in some early period. Catch trends for black marlin before were more or less constant with (max) 2,000 tons, but after 1980, catch have been increasing with some ups and downs and the recent catch level is about 18,000 tons.

3.2 Standardized CPUE

Five standardized CPUE (2 Japan, 1 Taiwan and 2 Indonesia) are available as shown in Table 1 and Fig. 1.

Table 1 Five standardized CPUE for black marlin

Code	Authors	Period	Method	Year (documents number)
JPN1	Uozumi	1967-1997	Log normal GLM	1998 (IPTP)
JPN2	Yokoi et al	1971-2015	Log normal GLM (1971-1991) Delta log normal GLM (1991-2015)	2016 (IOTC-2016-WPB14-19)
TWN	Wang	1979-2015	Delta log normal GLM (1979-2015)	2016 (IOTC-2016-WPB14-20)
IND1	Setyadji +	2005-2014	Negative binominal (NB)	2016 (IOTC-2016-WPB14-21)
IND2	Andrade		Zero inflated negative binominal (ZINB)	

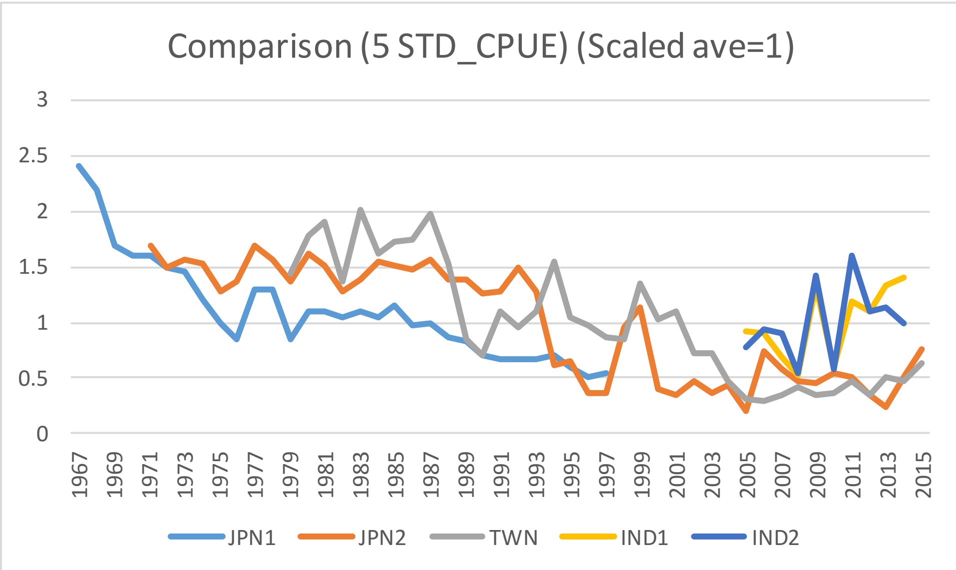


Fig. 1 Trends of five standardized CPUE (Black marlin) (tuna longline)

3.3 Selection of standardized CPUE for ASPIC

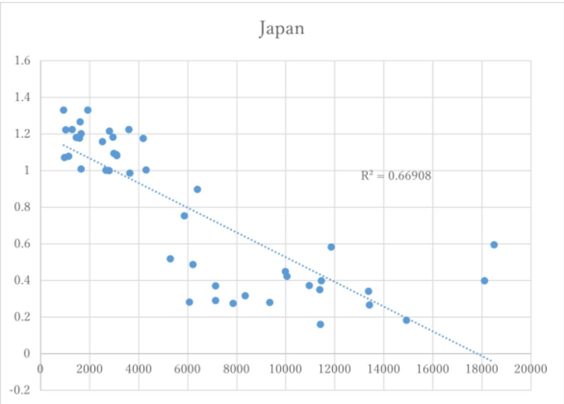
(1) JPN1 and JPN2

By following three reasons, we use JPN2 for ASPIC:

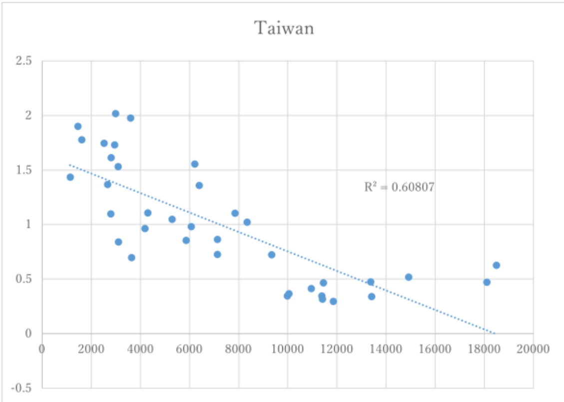
- JPN1 used old catch and effort data (1967-1999). Occasional revisions and updated are not reflected;
- JPN2 is the most updated data and has a longer time series than JPN1; and
- JPN1 use large sub areas in GLM (different from the core area approach)

(2) JPN2, TWN, IND1 and IND2 (Relations between catch vs standardized CPUE)

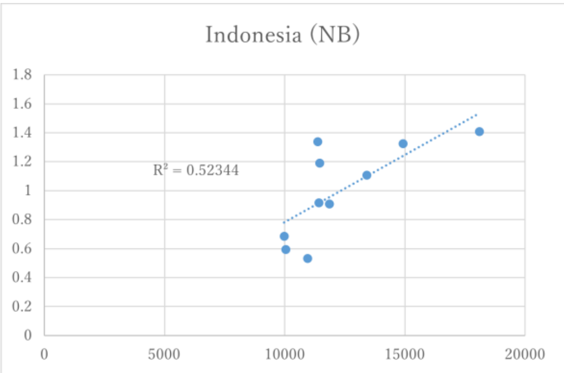
Fig.2 shows relation between catch and standardized CPUE (JPN2, TWN, IND1 and IND2). JPN2 and TWN STD_CPUE show strong negative (plausible) correlations, while IND1 and IND2, positive (un-plausible). Thus we use JPN2 and TWN standardized CPUE for ASPIC.



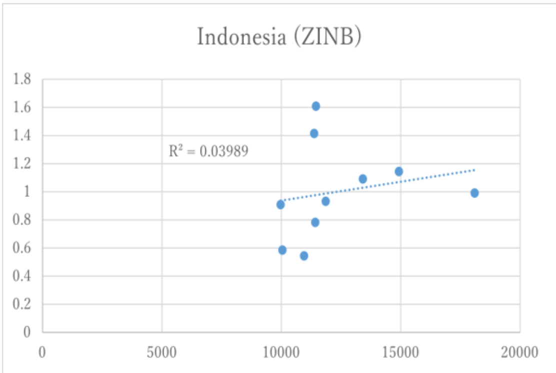
(JPN2)



(TWN)



(IND1)



(IND2)

Fig. 3 relation between catch and standardized CPUEs.

(3) Consideration of JPN2 and TWN standardized CPUE

Fig. 4 shows JPN2 and TWN standardized CPUE. They show similar trends thus we use average standardized CPUE for JPN2+TWN (1979-2015) for ASPIC (Fig. 5). Fig. 6 shows the relation between catch and combined standardized CPUE showing the strong negative (plausible) correlation.

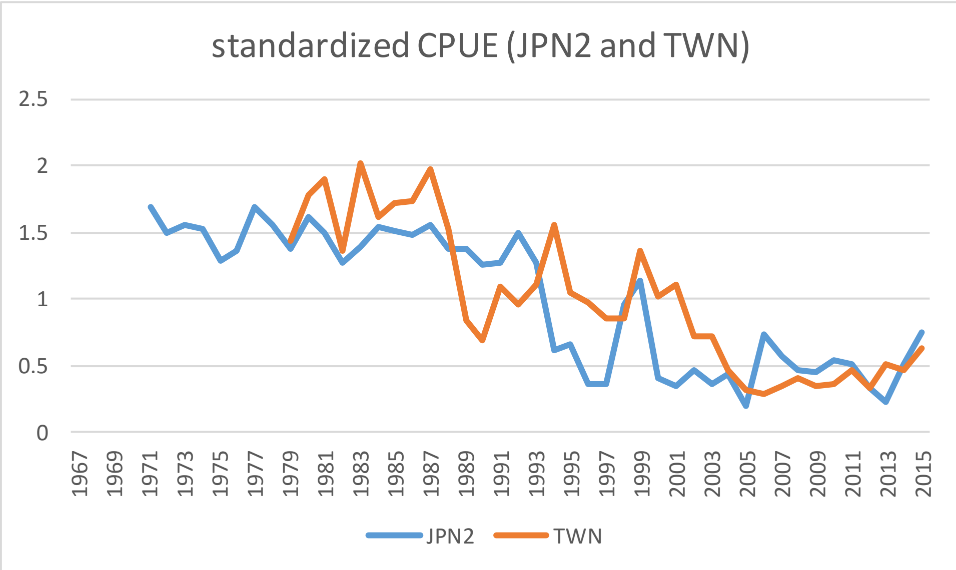


Fig. 4 standardized CPUE (JPN2 and TWN)

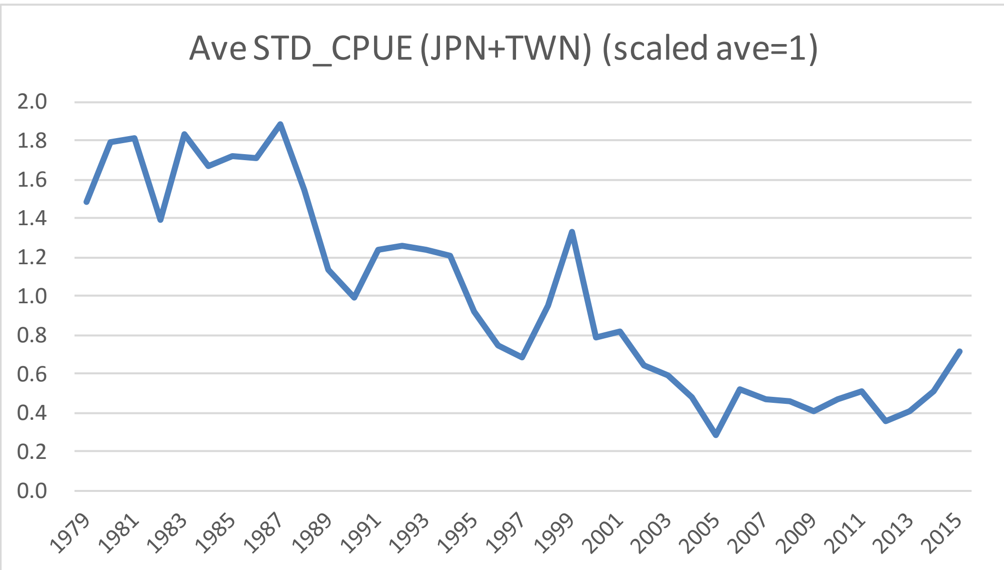


Fig. 5 Average standardized CPUE (JPN2 and TWN)

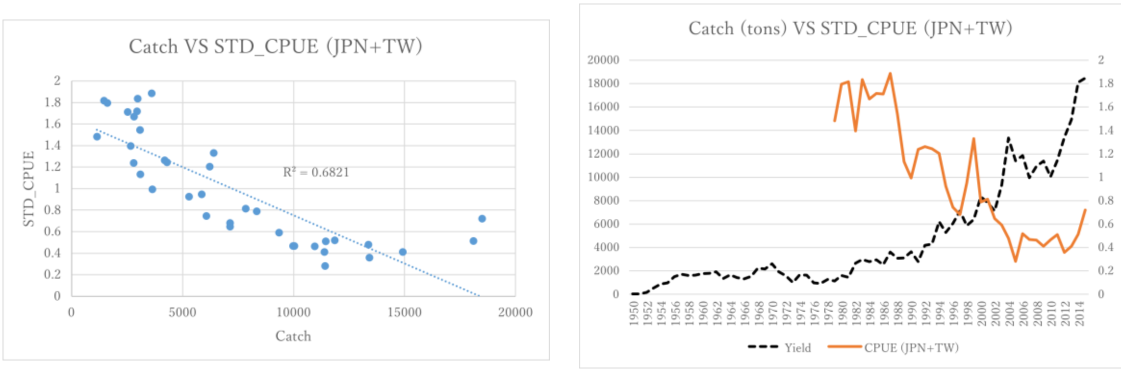


Fig. 6 relation between catch and standardized CPUE (JPN+TW).

4. ASPIC

4.1 Initial ASPIC runs

Initially we attempted ASPIC to estimate all parameters (K, B1/K, MSY and q) using Schaefer and Fox models. However, we could not get any conversions.

4.2 Second (final) ASPIC runs and results

Then, we conducted ASPIC by varying number of plausible K values with also two models (Schaefer and Fox model) (36 different runs). Tables 1 shows results by Schaefer model and Fox model.

We consider that the best scenario is B1/K closed 1 as it is likely the virgin stock and also with higher R2 and lower RMS (Root Mean Square). When K=75,000 (run 11) and K=80,000 (run 12) with the Schaefer model, we have B1/K= 0.98 and 1.02 respectively closest to B1/K=1. As for the Fox model results, with K=50,000 (run23), we have B1/K=1.031 closest to 1. Based on R2 and RMS among runs 11, 12 and 23, we selected with the Fox result (run23) as it shows the best goodness of fitness. Regarding r (intrinsic growth rate), it was estimated as 0.68. As the 0.58 (0.25-1.3) is plausible range (Sharma, 2014), 0.68 is considered to be the reasonable estimate. Box 1 shows the results in details for run 23.

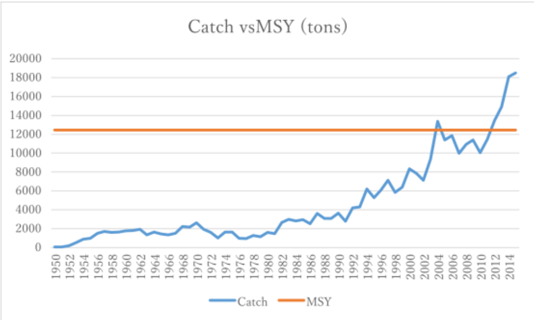
Table 1 Results of 36 ASPIC runs

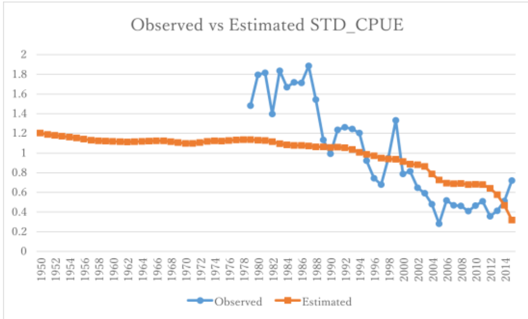
scenario	model	K	R2	RMS	B1/K	r	MSY	q	Bmsy	Fmsy	B/Bmsy	F/Fmsy
1	Schaefer	30000	0.281	0.4662	1.10	1.88	14090	3.52E-05	15000	0.9394	0.5791	1.8
2	Schaefer	35000	0.306	0.4591	0.62	1.53	13350	3.06E-05	17500	0.763	0.5279	2.025
3	Schaefer	40000	0.329	0.4521	0.96	1.27	12730	2.71E-05	20000	0.6366	0.4936	2.234
4	Schaefer	45000	0.349	0.4457	0.73	1.09	12230	2.44E-05	22500	0.5435	0.4743	2.411
5	Schaefer	50000	0.365	0.4402	0.77	0.95	11820	2.21E-05	25000	0.4728	0.4651	2.555
6	Schaefer	55000	0.378	0.4355	0.81	0.83	11480	2.03E-05	27500	0.4173	0.462	2.671
7	Schaefer	60000	0.389	0.4316	0.86	0.74	11170	1.87E-05	30000	0.3724	0.4616	2.774
8	Schaefer	65000	0.398	0.4283	0.90	0.67	10900	1.74E-05	32500	0.3354	0.4629	2.865
9	Schaefer	70000	0.406	0.4255	0.94	0.61	10640	1.62E-05	35000	0.3041	0.4631	2.959
10	Schaefer	75000	0.413	0.423	0.98	0.55	10400	1.52E-05	37500	0.2773	0.4642	3.048
11	Schaefer	80000	0.419	0.4209	1.02	0.51	10170	1.43E-05	40000	0.2541	0.4649	3.138
12	Schaefer	85000	0.424	0.419	1.05	0.47	9938	1.35E-05	42500	0.2338	0.4652	3.229
13	Schaefer	90000	0.429	0.4173	1.09	0.43	9716	1.28E-05	45000	0.2159	0.4655	3.322
14	Schaefer	95000	0.434	0.4157	1.13	0.40	9498	1.22E-05	47500	0.2	0.4654	3.419
15	Schaefer	100000	0.438	0.4143	1.16	0.37	9284	1.16E-05	50000	0.1857	0.4653	3.518
16	Schaefer	105000	0.443	0.413	1936.00	0.35	9072	1.11E-05	52500	0.1728	0.4648	3.62
17	Schaefer	110000	0.446	0.4117	4298.00	0.32	8862	1.06E-05	55000	0.1611	0.4642	3.727
18	Schaefer	115000	0.45	0.4106	3793.00	0.30	8655	1.02E-05	57500	0.1505	0.4634	3.839
19	Fox	30000	0.378	0.4355	1.109	1.32	14540	3.75E-05	11040	1.318	0.694	1.528
20	Fox	35000	0.4	0.4286	0.5875	1.08	13880	3.26E-05	12880	1.078	0.6483	1.678
21	Fox	40000	0.42	0.4221	0.9794	0.91	13320	2.89E-05	14720	0.9053	0.6179	1.812
22	Fox	45000	0.437	0.4164	0.9076	0.78	12850	2.59E-05	16550	0.7763	0.5999	1.925
23	Fox	50000	0.451	0.4116	1.031	0.68	12460	2.36E-05	18390	0.6772	0.5906	2.019
24	Fox	55000	0.462	0.4075	0.9155	0.60	12110	2.16E-05	20230	0.5987	0.5866	2.098
25	Fox	60000	0.47	0.4042	0.88	0.54	11810	1.99E-05	22070	0.535	0.5857	2.166
26	Fox	65000	0.477	0.4015	0.8691	0.48	11530	1.84E-05	23910	0.4823	0.5865	2.228
27	Fox	70000	0.483	0.3992	1.89E+23	0.44	11270	1.72E-05	25750	0.4378	0.5878	2.287
28	Fox	75000	0.488	0.3974	1.33E+07	0.40	11030	1.61E-05	27590	0.3997	0.5894	2.345
29	Fox	80000	0.491	0.3958	0.914	0.37	10810	1.51E-05	29430	0.3672	0.5951	2.387
30	Fox	85000	0.497	0.3943	2.06E+30	0.34	10560	1.43E-05	31270	0.3377	0.5911	2.466
31	Fox	90000	0.502	0.3928	6.96E+32	0.31	10330	1.35E-05	33110	0.3119	0.5897	2.536
32	Fox	95000	0.508	0.3912	3.23E+35	0.29	10090	1.29E-05	34950	0.2888	0.586	2.618
33	Fox	100000	No Convergence									
34	Fox	105000										
35	Fox	110000										
36	Fox	115000										

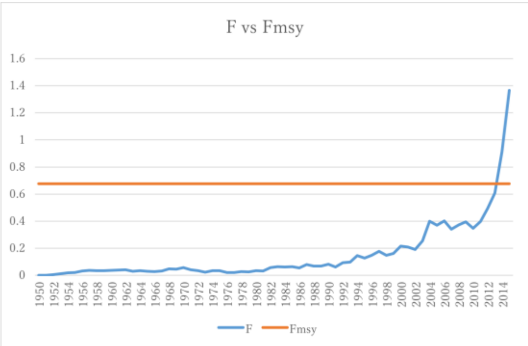
Table 2 Black marlin: Key management quantities from the ASPIC assessment for the Indian ocean

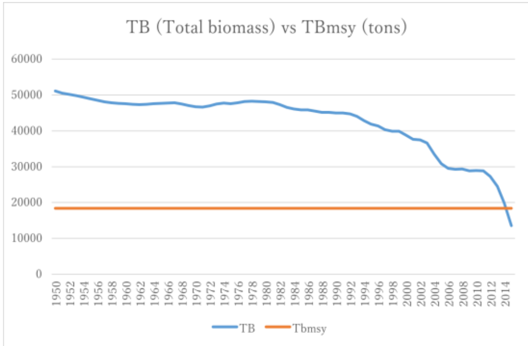
Management Quantity	**Aggregate Indian Ocean**
2015 catch (t)	18,490
Mean catch from 2011–2015 (t)	15,276
MSY (1000 t) (80% CI)	12,460 (11,750-14,680)
Data period (catch)	1950–2015
F_{MSY} (80% CI)	0.68 (0.64-0.80)
B_{MSY} (80% CI)	18,390 (n.a.)
F_{2015}/F_{MSY} (80% CI)	2.02 (1.08-3.42)
B_{2015}/B_{MSY} (80% CI)	0.59 (0.28-1.08)
SB_{2015}/SB_{MSY} (80% CI)	(n.a.)
B_{2015}/B_{1950} (80% CI)	n.a. n.a.
SB_{2015}/SB_{1950} (80% CI)	n.a.
$B_{2015}/B_{1950,\ F=0}$ (80% CI)	n.a.
$SB_{2015}/SB_{1950,\ F=0}$ (80% CI)	n.a.

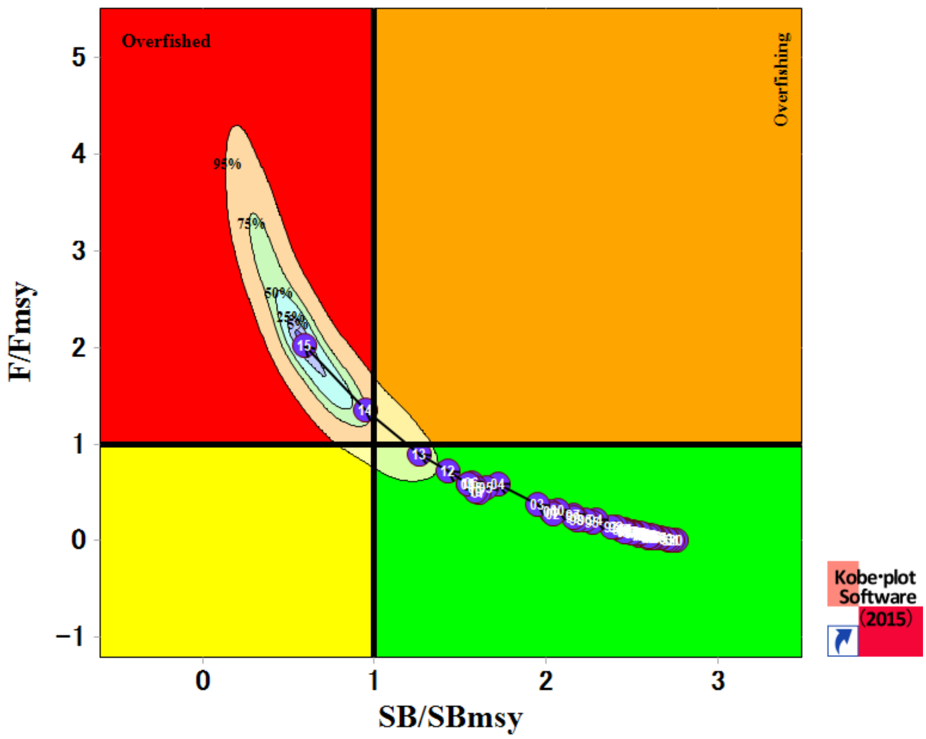
Box 1 Results of ASPIC run (Base case)











Kobe Plot

4 Discussion

The stock status in the last stock assessments (Sharma, 2014) based on Stock Reduction Analyses (SRA) using the data to 2011, are similar to this time to 2011 (Kobe plot in Fig. 6 and in Box 1). However, catch sharply increased from 2011-2013 (average 13,300t) to 2014-2015 (average 18,300 t) (38% increase), the stock status change to the overfished stage in 2015 (red zone in Kobe plot) (Box 1) from the overfishing stage in 2011 (orange zone in the Kobe plot) (Fig. 7). This sharp increase is likely caused by the cease of the piracy activities in 2011. This means that a number of longliners, gillnetters and other fleets resume operations in black marlin hot spots off Somalia (Fig. 8) (Yokoi et al, 2016) which made the sharp increase of the catch level.

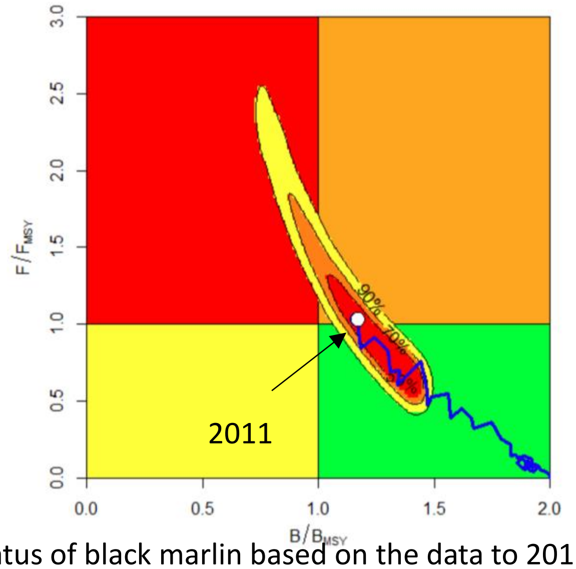


Fig. 7 Stock status of black marlin based on the data to 2011 (Sharma, 2014)

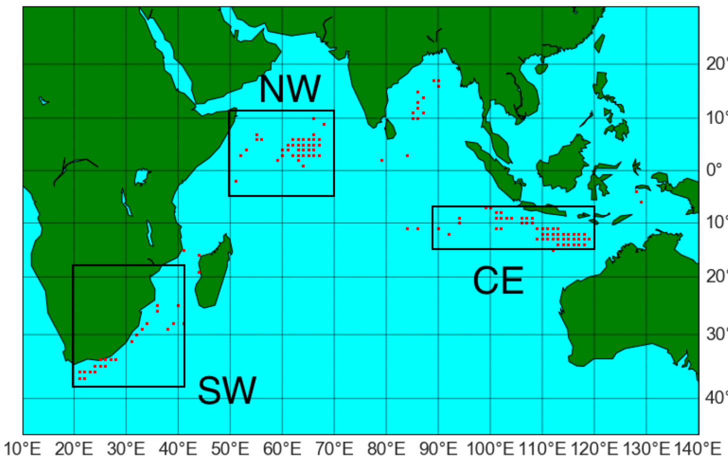


Fig. 8 Three hot spot areas of black marlin in the Indian Ocean (Yokoi et al, 2016)

4 RISK ASSESSMENTS (KOBE II)

We conducted risk assessments regulated by the IOTC scientific committee (IOTC, 2016). Table 3 and Figs 9-10 show results, which suggest that even we reduce 40% of the current catch level (17,171 tons, average of catch 2013-1015), we have high risks (more than 70%) to violate MSY level for both F/Fmsy and TB/TBmsy.

Table 3. Black marlin: ASPIC aggregated Indian Ocean assessment Kobe II Strategy Matrix. Probability (percentage) of violating the MSY-based reference points for nine constant catch projections (average catch level from 2013–15 (17,171t), ± 10%, ± 20%, ± 30% and ± 40%) projected for 3 and 10 years.

Reference point and projection timeframe	**Alternative catch projections (relative to the average catch level from 2013–15) and probability (%) of violating MSY-based target reference points ($B_{targ} = B_{MSY}$; $F_{targ} = F_{MSY}$)**								
Catch level	**60%**	**70%**	**80%**	**90%**	**100%**	**110%**	**120%**	**130%**	**140%**
Projected catch (tons)	10,303	12,020	13,737	15,454	17,171	18,888	20,605	22,322	24,039
$B_{2018} < B_{MSY}$	87%	89%	91%	93%	95%	97%	97%	98%	99%
$F_{2018} > F_{MSY}$	79%	87%	93%	97%	99%	100%	100%	100%	100%
$B_{2025} < B_{MSY}$	69%	79%	88%	95%	98%	99%	100%	100%	100%
$F_{2025} > F_{MSY}$	68%	78%	89%	97%	99%	100%	100%	100%	100%

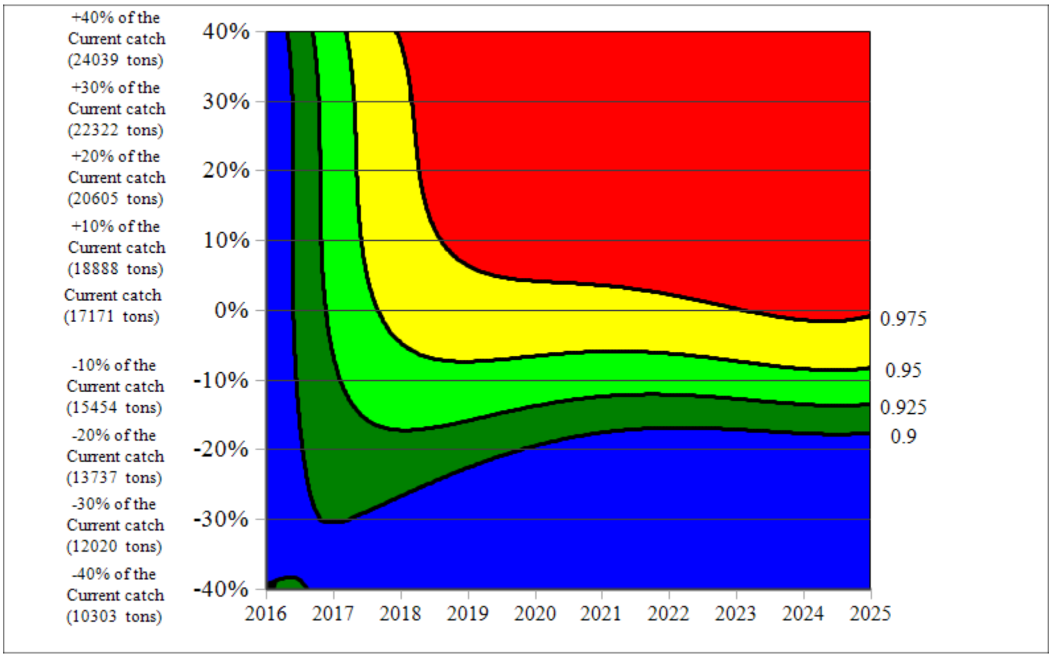


Fig. 9 Results of the risk assessments (TB/TBmsy)

Annual risk levels (probability in % violating MSY) by catch level (2016-2025)

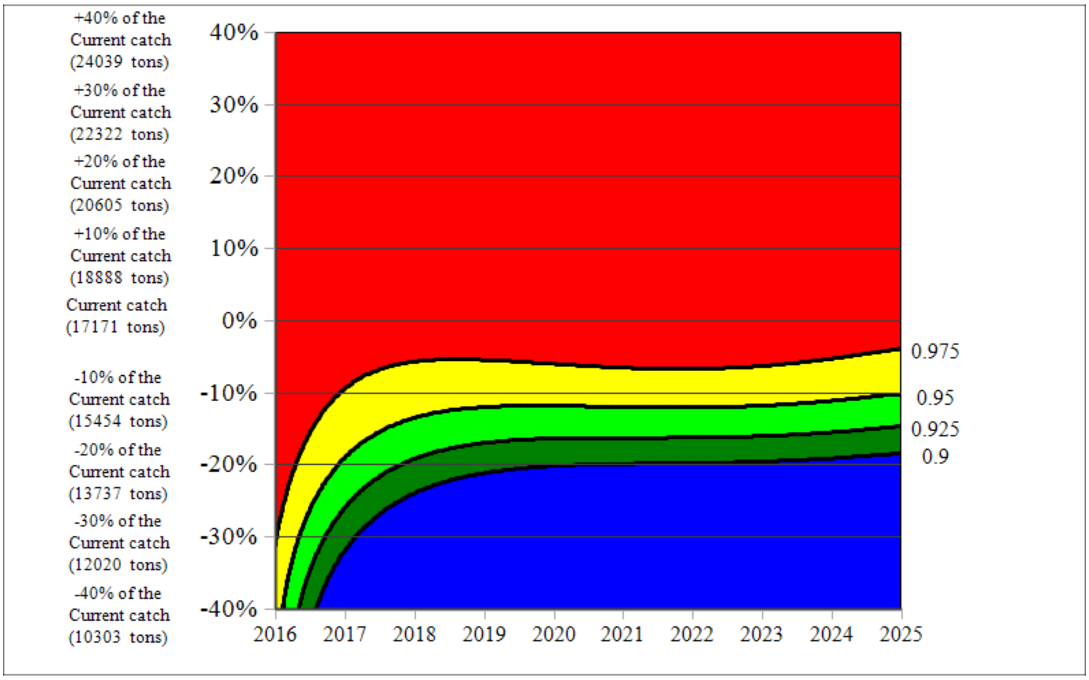


Fig. 10 Results of the risk assessments (F/Fmsy)

Annual risk levels (probability in % violating MSY) by catch level (2016-2025)

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