Draft

Stock assessments of striped marlin (*Kajikia audax*) in the Indian Ocean using A Stock-Production Model Incorporating Covariates (ASPIC) (1950-2015)

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ABSTRACT

To be completed

1. Introduction

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

2. Stock structure

Striped marlin is the large oceanic apex predator that inhabits tropical and sub-tropical 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.

Its distribution is different from other marlins in that it prefers more temperate or cooler waters however in the Indian Ocean it is common in tropical zone: off the east African coast (0-10oS), the south and western Arabian Sea, the Bay of Bengal, and north-western Australian waters. Several transoceanic migrations were reported in the Indian Ocean (the longest is from Kenya to Australia).

Therefore, we assume that striped marlin in the Indian Ocean is a single stock, which apparently is most appropriate for stock assessment and management

3. Data

To run ASPIC, we need total 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 WPB15 (Fig.1). According to Fig. 1, striped marlin is caught mainly using drifting longlines (72% of the total catch). The remaining catches are recorded under gillnets and troll lines.

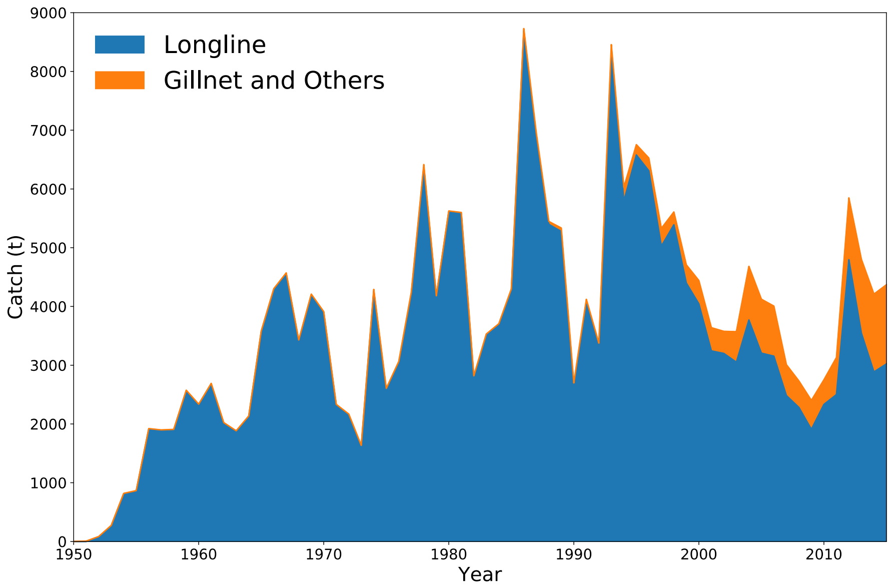


Fig. 1 Trend of nominal catch of striped marlin by fleet (1950-2015)

Striped marlin is generally considered to be a bycatch of industrial fisheries. Catch trends for striped marlin are variable, ranging from 2000 t to 8000 t per year; however, this may reflect the level of reporting.

Similarly, catches reported using drifting longlines are highly variable, with lower catch levels between 2009 and 2011 largely due to declining catches reported by Taiwan, China, deep-freezing and fresh-tuna longliners. The catches of striped marlin increased in 2012 and 2013, as longline vessels resumed their activities in the Western tropical Indian Ocean.

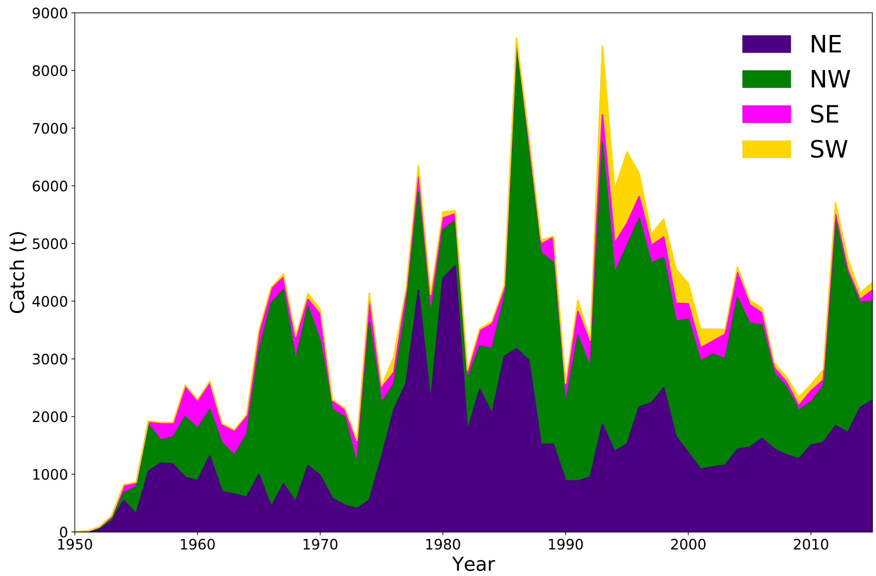


Fig.2 Trend of nominal catch of striped marlin by area (1950-2015)

3.2 Standardized CPUE

Standardized CPUE for Japanese LL (1976-1993, early period; 1994-2015, later period), Taiwanese LL (1979-2015) are available in the IOTC data set for WPB15 (Japan: Ijima 2017; Taiwan: Wang 2017). Fig. 3 and Fig. 4 shows Taiwanese CPUE and Japanese CPUE series, respectively. Taiwanese CPUE trends are similar in all area, while Japanese CPUE trends are different in the southwest and southeast area (later period) (Fig.5).

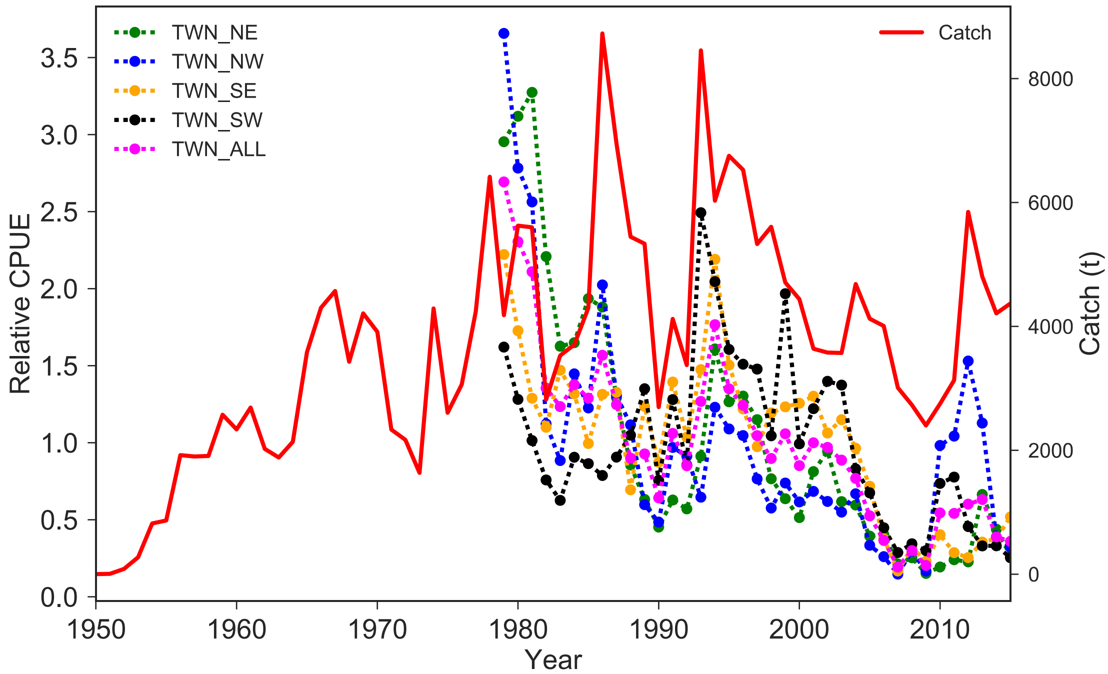


Fig. 3 Trends of striped marlins standardized CPUE (Tuna longline) (Taiwan)

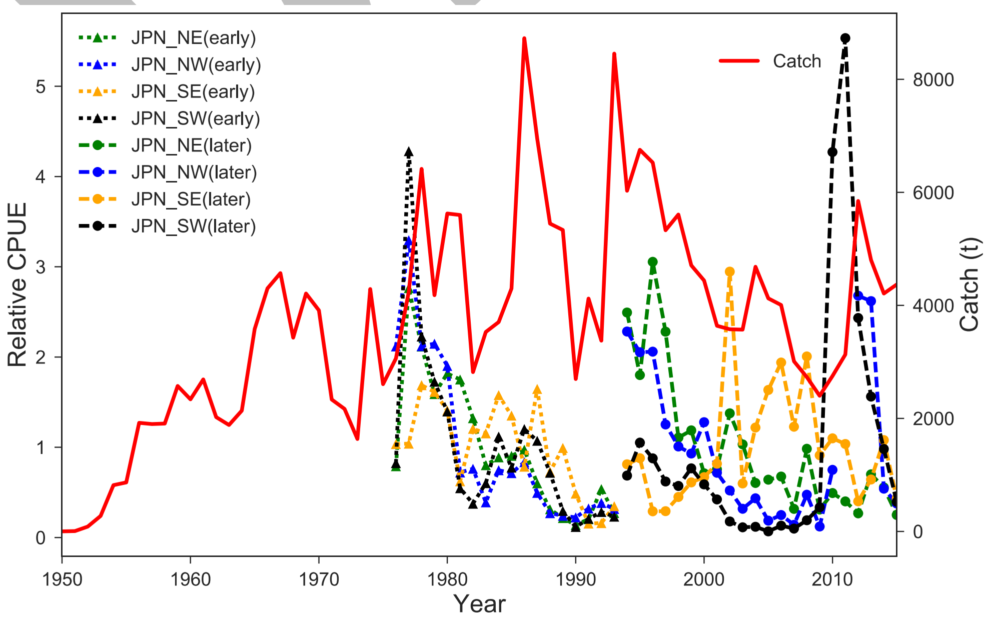


Fig. 4 Trends of striped marlins standardized CPUE (Tuna longline) (JPN)

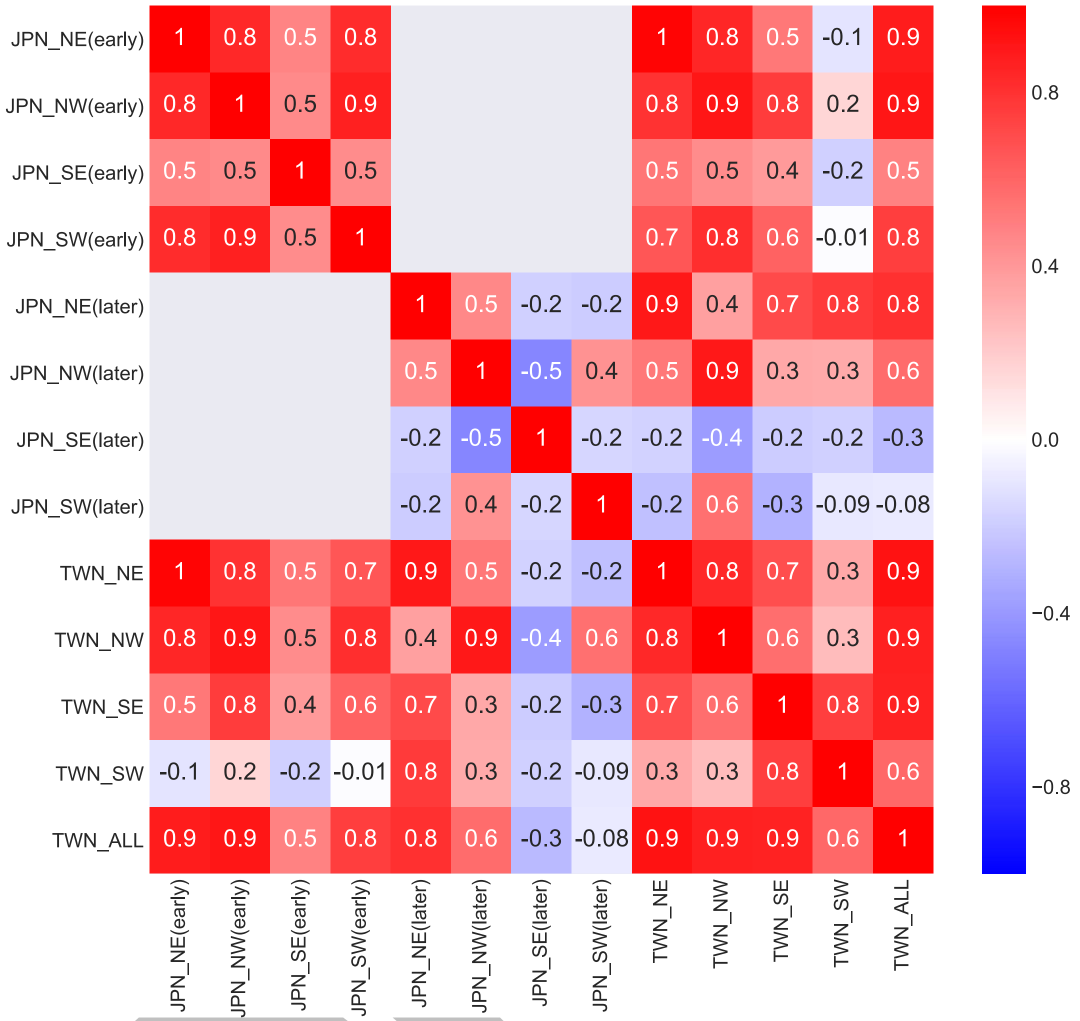


Fig. 5 Correlation between the standardized CPUEs (Tuna longline)

4. ASPIC

We conducted ASPIC by combining CPUE and B1/k setting with also two models (Schaefer and Fox model) (48 different runs). Tables 1 shows results by Schaefer model and Fox model.

We consider that the best scenario is similar to previous assessment result on B/Bmsy (0.65). We selected with Schaefer model (run3) on Japanese CPUE. Box 1 and Table 2 summarize relevant results. Fig. 6 shows the Kobe plot.

Table 1 Results of ASPIC runs for 48 scenarios

JPN_NW

			Results						
Scenario number	Production Model	B1/K	RMSE	B1/K	MSY	Fratio	TBratio	K	r
1	Schaeffer	Estimated	0.7693	0.9741	5445	2.436	0.26	17950	1.21
2		1	0.7581	1	5448	2.495	0.2501	17900	1.22
3		0.9	0.7596	0.9	5400	1.324	0.6217	18890	1.14
4		0.8	0.7581	0.8	5448	13.14	4.5E-22	17900	1.22
5	Fox	Estimated	0.7191	0.1685	5147	2.606	0.2878	24950	0.56
6		1	0.7217	1	5280	1.845	0.4426	21190	0.68
7		0.9	0.7053	0.9	5233	3.184	0.2055	22450	0.63
8		0.8	0.7053	0.8	5238	3.264	0.1968	22320	0.64

TWN_NW

			Results						
Scenario number	Production Model	B1/K	RMSE	B1/K	MSY	Fratio	TBratio	K	r
9	Schaeffer	Estimated	0.5029	1.03	5361	2.382	0.281	19780	1.08
10		1	0.4955	1	5349	2.375	0.2837	20040	1.07
11		0.9	0.4955	0.9	5360	2.388	0.2799	19790	1.08
12		0.8	0.4955	0.8	5360	2.388	0.2801	19790	1.08
13	Fox	Estimated	0.4996	1.072	4934	1.94	0.4428	32070	0.42
14		1	0.4922	1	4934	1.94	0.4428	32070	0.42
15		0.9	0.4922	0.9	4942	1.94	0.442	31780	0.42
16		0.8	0.4922	0.8	4942	1.94	0.4421	31780	0.42

JPN_NW-JPN_NE

			Results						
Scenario number	Production Model	B1/K	RMSE	B1/K	MSY	Fratio	TBratio	K	r
17	Schaeffer	Estimated	0.7394	1.942	952.3	1.68	0.2498	16290	0.23
18		1	0.7096	1	5391	3.914	0.1085	19100	1.13
19		0.9	0.7096	0.9	5390	3.907	0.109	19110	1.13
20		0.8	0.7094	0.8	5413	3.915	0.1058	18630	1.16
21	Fox	Estimated	No convergence						
22		1	0.676	1	5180	4.243	0.1269	23960	0.59
23		0.9	0.6712	0.9	5076	4.884	0.1043	27190	0.51
24		0.8	0.6708	0.8	5104	4.856	0.1031	26290	0.53

TWN_NW-TWN_NE

			Results						
Scenario number	Production Model	B1/K	RMSE	B1/K	MSY	Fratio	TBratio	K	r
25	Schaeffer	Estimated	0.5548	1.377	1240	1.19	0.2765	18560	0.27
26		1	0.5194	1	5363	2.895	0.2025	19730	1.09
27		0.9	0.5202	0.9	5311	2.935	0.2043	20970	1.01
28		0.8	0.5196	0.8	5350	2.924	0.2007	20040	1.07
29	Fox	Estimated	No convergence						
30		1	0.5118	1	4881	3.115	0.2446	34020	0.39
31		0.9	0.5113	0.9	4964	3.078	0.2415	31010	0.44
32		0.8	0.5114	0.8	4925	3.091	0.2434	32400	0.41

JPN_NW-TWN_NE

			Results						
Scenario number	Production Model	B1/K	RMSE	B1/K	MSY	Fratio	TBratio	K	r
33	Schaeffer	Estimated	0.6609	1.332	5468	2.931	0.1846	17480	1.25
34		1	0.655	1	5504	2.916	0.182	16810	1.31
35		0.9	0.655	0.9	5502	2.913	0.1825	16830	1.31
36		0.8	0.655	0.8	5503	2.92	0.1815	16810	1.31
37	Fox	Estimated	0.6279	1.153	5113	3.294	0.2052	26000	0.79
38		1	0.6874	1	5287	1.743	0.4746	21000	0.68
39		0.9	0.6236	0.9	5103	3.315	0.2039	26300	0.53
40		0.8	0.6238	0.8	5098	3.25	0.2109	26480	0.52

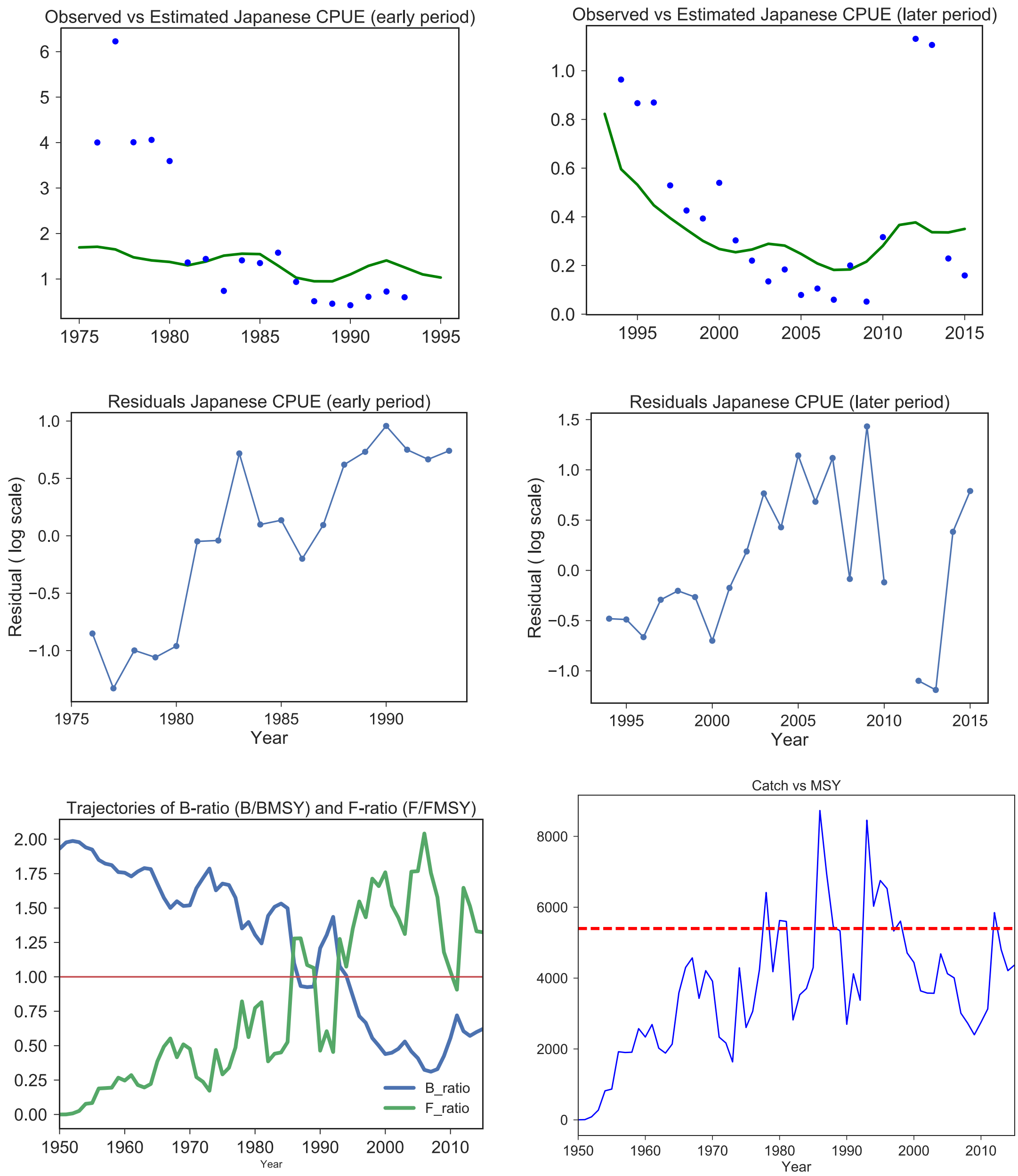
TWN_NW-JPN_NE

			Results						
Scenario number	Production Model	B1/K	RMSE	B1/K	MSY	Fratio	TBratio	K	r
41	Schaeffer	Estimated	0.6083	1.458	1574	9.961	0.2582	17300	0.36
42		1	0.5872	1	5212	3.867	0.133	23590	0.88
43		0.9	0.5871	0.9	5215	3.868	0.1326	23510	0.89
44		0.8	0.7712	0.8	7564	0.2928	1.972	156100	0.19
45	Fox	Estimated	No convergence						
46		1	0.571	1	4868	4.377	0.147	34530	0.38
47		0.9	0.5712	0.9	4791	4.364	0.1542	37510	0.35
48		0.8	No convergence						

Table 2 Blue marlin: Key management quantities from the ASPIC assessment based on the Fox model, for the Indian Ocean.

Management Quantity	Aggregate Indian Ocean
2015 catch (t)	4,369
Mean catch from 2011–2015 (t)	4,472
MSY (1000 t) (80% CI)	5,400 (-)
Data period (catch)	1950–2015
F_{MSY} (80% CI)	0.57 (-)
B_{MSY} (80% CI)	9,447 (-)
F_{2015}/F_{MSY} (80% CI)	1.32 (-)
B_{2015}/B_{MSY} (80% CI)	0.62 (-)
SB_{2015}/SB_{MSY} (80% CI)	(na)
B_{2015}/B_{1950} (80% CI)	0.32 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 Result of ASPIC run



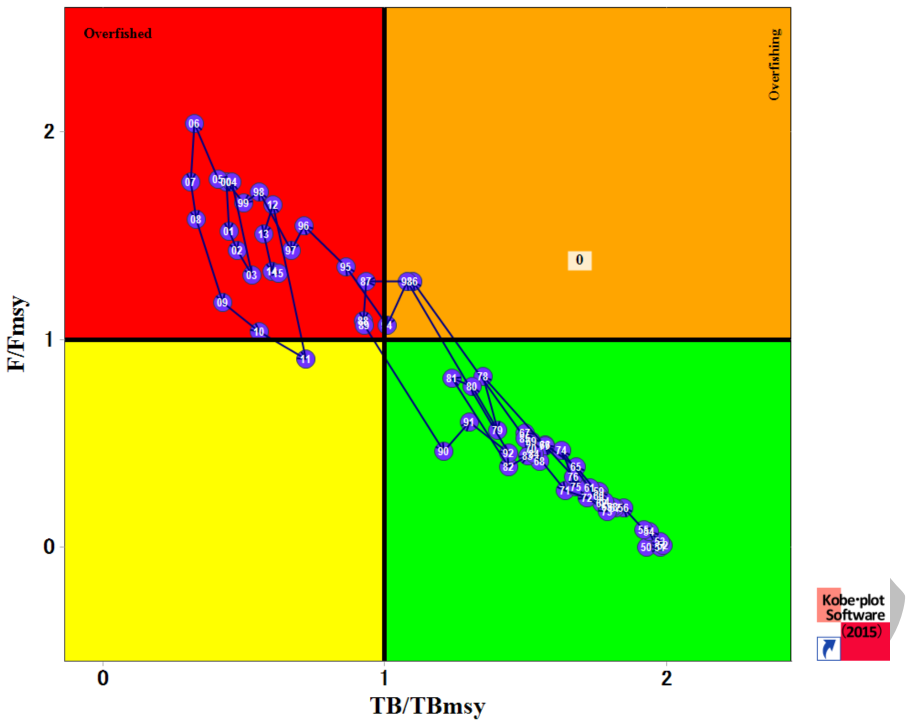


Fig. 6 Kobe plot

4.3 Discussion

To be completed

4.4

5. Risk assessments (Kobe II)

To be completed

Table 3. Blue 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 (xxxxx t), ± 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)									
$B_{2018} < B_{MSY}$									
$F_{2018} > F_{MSY}$									
$B_{2025} < B_{MSY}$									
$F_{2025} > F_{MSY}$									

Acknowledgements

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