STOCK ASSESSMENT OF BILLFISH SPECIES IN THE INDIAN OCEAN: BLACK MARLIN AND SAILFISH

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Abstract

We conduct stock assessments for Indian Ocean sailfish and Black marlin. We used a catch-based stock reduction analysis method. The method is based on a classical biomass dynamics model, requires only catch history but not fishing effort or CPUE. Known population growth rate will improve the assessment result. In this paper, we assume that the two species analysed, in the whole Indian Ocean belong to a single stock and the population size in 1950 is the virgin biomass, and is also equal to their carrying capacities. We use recently updated catch data in the analysis.

For Black marlin, the geometric mean virgin biomass was about 37.4 to 142 thousand tonnes, and the intrinsic population growth rate is about 0.56 (0.25-1.3 95% CI). The entire stock can support a MSY of nearly 10.2 thousand tonnes. Catch levels in recent year may have been too high, and likely overfishing is occurring on the stock.

Similarly, for sailfish the geometric mean virgin biomass was about 104 to 320 thousand tonnes, and the intrinsic population growth rate is about 0.595 (0.26-1.33 95% CI). The entire stock can support a MSY of nearly 27.2 thousand tonnes. Catch levels in recent year may have been too high, and likely overfishing is occurring on the stock.

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Introduction

In standard stock assessments conducted in the IO region, a index of abundance is essential to capture trends in biomass over time. However for Black Marlin and Sailfish in the Indian ocean no such data is available. Methods developed by CSIRO (draft report "Quantitatively defining biological and economic reference points in data poor fisheries" by Zhou et. al. 2013) highlights some methods developed for data poor fisheries using data rich fisheries as a testing platform. The primary method that is of use there is a technique called Stock reduction Analysis (Zhou et. al. 2012,Walters et. al. 2006, Martell and Froese 2012, Kimura and Tagart 1982) making assumptions about initial state of the Biomass, assumptions of what the biomass is at the middle of the time series, and what the biomass depletion levels range for the last year. The technique builds on simple surplus production models (like Shaefer, 1954), that use removal data and some estimate of carrying capacity and k. Ideally, these models should have some measure of the changes in abundance over time, but as shown in Martell and Froese (2012), and Walters et. al. 2006, a narrow range of r-K parameter can be obtained through simulation techniques that maintain the population, so that it neither collapses or exceeds the carrying capacity, K. This is the primary basis of the method developed and used here.

Black Marlin (*Makaira indica*)

Basic Biology

This species is basically oceanic, usually found in surface waters above the thermocline, often near shore close to land masses, islands and coral reefs in tropical and subtropical waters of the Indian and Pacific oceans. They feed on fishes, squids, cuttlefishes, octopods, large decapod crustaceans and mostly on small tunas when abundant (Nakamura 1985). Occasionally stray individuals migrate into the Atlantic Ocean by way of the Cape of Good Hope, but are not seen as a distinct breeding population there (www.fishbase.net).

Indian Ocean Sailfish (*Istiophorus platypterus*)

Basic Biology

The species is oceanic and epipelagic species usually found above the thermocline. This is mostly distributed in waters close to coasts and islands (Frimodt1995, Nakamura 1985). These fish most likely school by size, and undergo spawning migrations in the Pacific (Nakamura 1985). The species feeds mainly on fishes, crustaceans and cephalopods. The distribution is primarily in the tropical waters of the Indian and Pacific oceans and the species is differentiated from the Atlantic sailfish populations (www.fishbase.net).

Catch data for the two species show increasing trends in catches, in much the same manner as other billfish species.

Table 1: Catch data on IO Blue, Black, Striped Marlin, Swordfish and Sailfish from 1950-2013 (source IOTC Database)

Year	BLM	SFA	SWO	BUM	MLS		Year	BLM	SFA	SWO	BUM	MLS
1950	49	336	43	1	1		1982	2163	4140	3908	3427	2596
1951	48	317	41	6	6		1983	2410	2738	4026	4775	3338
1952	179	359	44	396	85		1984	2188	2988	3946	4925	3306
1953	535	428	65	1268	274		1985	2094	2884	4997	5276	4106
1954	876	577	212	3009	817		1986	2233	3244	5846	5647	6252
1955	985	804	271	3510	861		1987	2475	3401	7147	6902	5428
1956	1484	1009	594	4945	1912		1988	2310	4692	9189	5072	3853
1957	1683	787	414	3778	1890		1989	2343	4472	8249	6027	3266
1958	1569	697	617	4175	1891		1990	2254	4730	8560	5116	1876
1959	1558	1014	622	4506	2498		1991	2471	4886	9457	5441	3043
1960	1737	1305	715	3887	2288		1992	3669	6418	15859	7811	2903
1961	1768	1258	920	3436	2675		1993	4077	8053	26125	8682	7005
1962	1903	1180	1081	3302	1993		1994	5951	10334	27593	8590	5413
1963	1318	1054	983	2198	1812		1995	5059	11781	32201	8363	6254
1964	1613	1047	1204	3467	2042		1996	5924	12988	36363	9892	6190
1965	1394	1048	1306	3721	3486		1997	6859	13383	36067	11404	4737
1966	1307	1226	1379	3558	4264		1998	5608	11097	38464	11929	4925
1967	1506	1346	1817	4083	4536		1999	6172	11729	36361	10765	4087
1968	2162	1389	1775	3661	3321		2000	8012	14555	35726	10395	3849
1969	2094	1119	2019	3276	4067		2001	7600	14028	32701	7428	3112
1970	2416	1026	2631	3892	3581		2002	6986	13403	33599	8694	3123
1971	1718	1206	2166	3094	2030		2003	8914	16198	38377	10175	2989
1972	1303	1003	2060	3038	1724		2004	12887	19668	40463	11395	4251
1973	812	860	1646	1919	1207		2005	10782	15608	35807	11045	2951
1974	1391	1166	1948	2238	2605		2006	11273	16905	33408	9591	3086
1975	1253	1379	2258	2780	2063		2007	9407	19449	30750	7865	2251
1976	665	1541	1980	1802	2605		2008	10504	27356	25177	7888	2216
1977	662	1585	1890	1964	4067		2009	10996	29180	24952	7964	2050
1978	790	1534	2393	3413	6106		2010	9420	32183	24446	7657	2289
1979	748	1538	2588	4085	3848		2011	10766	33914	21728	9029	2473
1980	1350	2341	2672	3792	5349		2012	11392	32309	26386	14327	4664
1981	1105	1793	2689	3366	5441		2013	11443	34481	28934	11838	3713

Methods

We use a newly developed stock assessment method in this paper. This method is based on catch data and does not require fishing effort or CPUE data. The method involves several steps. It applies a simple population dynamics model, starts with wide prior ranges for the key parameters, and includes the available catch data in the model. Then the model systematically searches through possible parameter spaces and retains feasible parameter values. Mathematically and biologically unfeasible values are excluded from the large pool of data. We progressively derive basic parameters, and carry out stochastic simulations using these base parameters to get biomass trajectories and additional parameters. Finally, we project to future biomass to explore alternative harvest policies.

We use following Graham-Shaefer surplus production model (Shaefer 1954):

$$B_{t+1} = B_t + rB_t\left(1 - \frac{B_t}{B_0}\right) - C_t \qquad (1)$$

Where B_t is biomass in time step *t*, *r* is the population growth rate, B_0 is the virgin biomass equal to carrying capacity K, and C is the known catch.

This simple model has two unknown parameters, r and K. We set reasonably wide prior range, for example, *K* between C_{max} and 500 * C_{max}. We used the approach proposed in Martell and Froese (2012) for “resiliency” estimates that tied to the productivity parameter r (low resiliency levels indicated r between 0.05-0.5, medium resiliency indicated a r between 0.2-1, and high between 0.5-1.5). These were compared to values obtained in the literature and alternative methods.

We run model (1) to find all mathematically feasible *r* values by searching through wide range of Ks for all depletion levels. If the feasible choice of r and k chosen meets the intermediate (0.1 and 1 level of depletion in 1980), and last point depletion levels (the range specified was 0.3-0.7 level of depletion for these billfish stocks) it is kept. The summary of all runs which meet these criteria are then used, and geometric mean values are reported to be the better representation of yield targets (Martell and Froese 2012). Biological parameters, including K, r, MSY, are derived from the retained pool of [r, K] values. The geometric mean values of these are then used to assess the stock dynamics over time and reported using a phase plot.

Results

Black marlin

Based on information in Fish Base, Black Marlin appears to be a more resilient stock and therefore has not been subjected to overfishing till recent years. In contrast Blue Marlin (Sharma 2013) has a lower resiliency and in the late 1990's to early 200's catch levels may have been too high and caused the stock to decline (Sharma 2013). These trends are not apparent for Black Marlin (Figure1 and 2). Current catch levels are exceeding MSY targets, but within the 95% confidence interval.

Table 1: Key parameters associated with the stock production analysis for Black Marlin

Parameter	Lower 95% CI	Geometric Mean	Upper 95% CI
r	0.244	0.56	1.29
K	37454	72940	142049
MSY	7574	10233	13825
B_{MSY}	18727	36470	71025
B_{2013}/B_{MSY} *	1.13	0.73	1.53
F_{2013}/F_{MSY} *	1.06	0.39	1.73

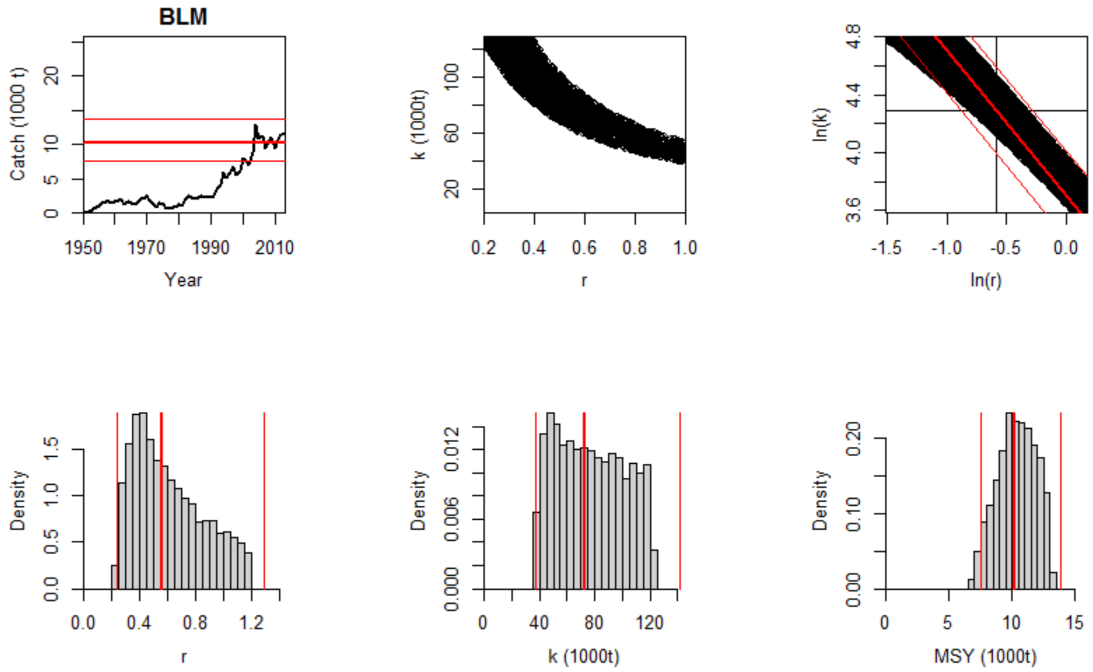
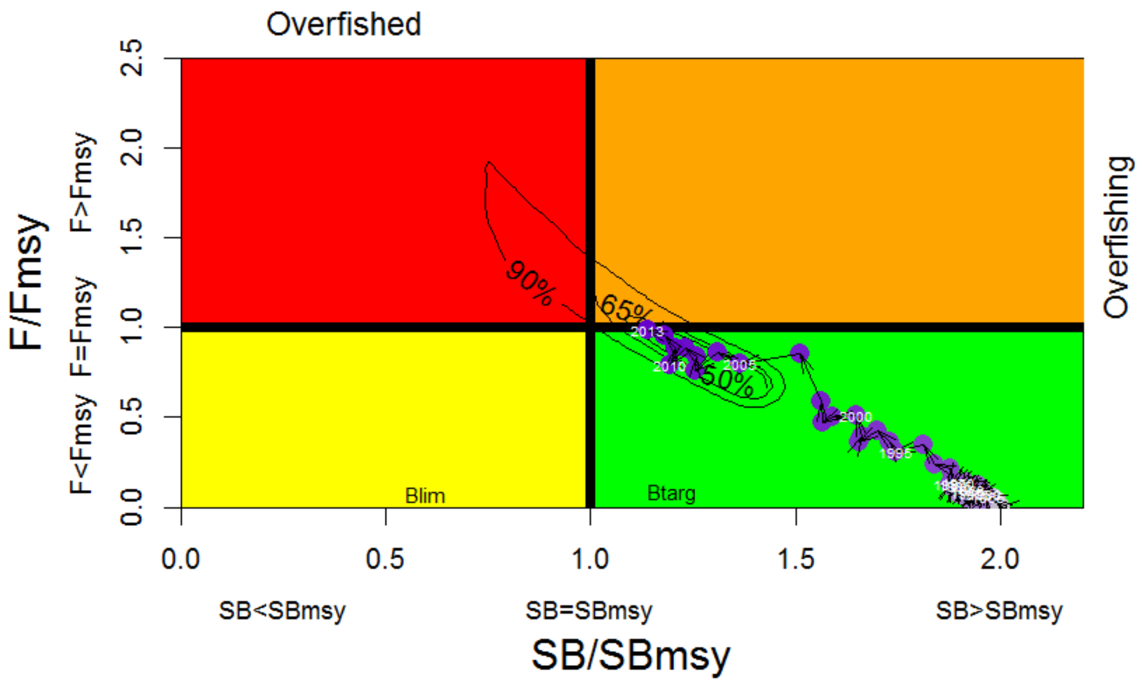


Figure 1: Black Marlin reference points derived from SRA Approaches



<u>Figure 2: Phase plot of SMSY and FMSY Trajectory for Black Marlin</u>

Sailfish

Sailfish also show increasing catch trends in recent years. The stock is in healthy status though recent catch trends may indicate overfishing (Figure 3, Table 3). Stock trajectories show how the stocks are experiencing excess fishing pressure in recent years (Figure 4), and further catches at this level may cause the stocks to deplete to levels that indicate it is overfished.

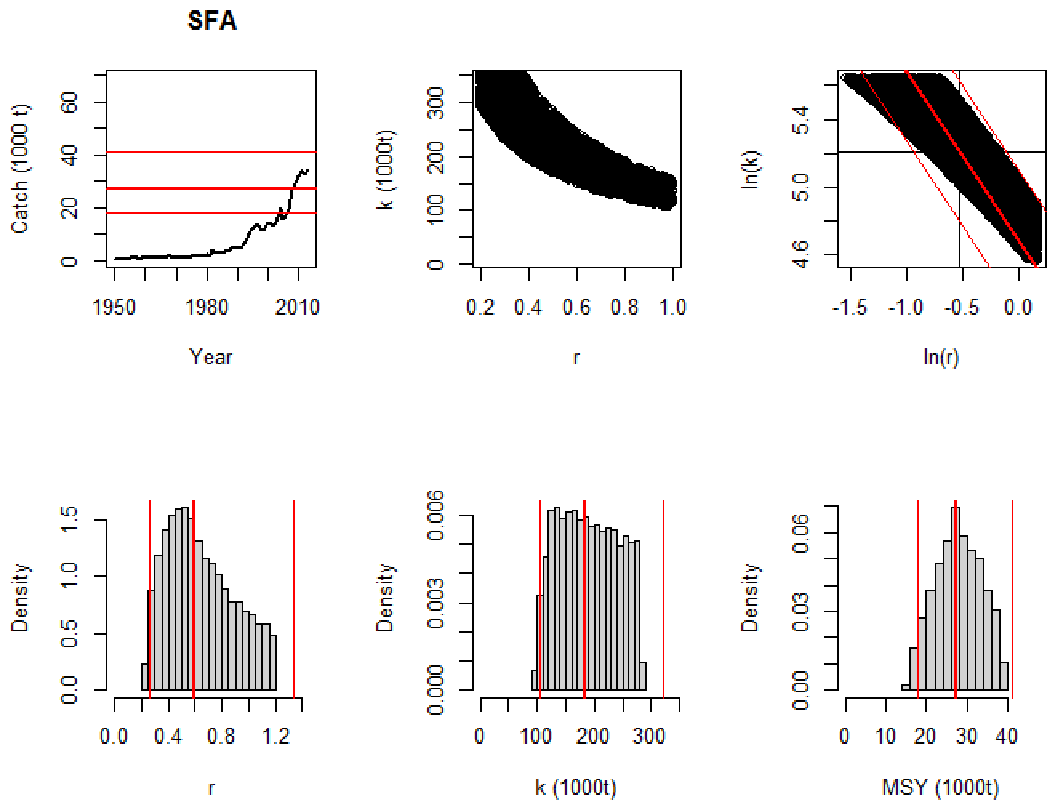


Figure 3: Stock trajectories of Sailfish and estimates of r and K that meet this criteria

Table 2: Key parameters associated with the stock reduction analysis for Indian Ocean Sailfish

Parameter	Lower 95% CI	Geometric Mean	Upper 95% CI
r	0.265	0.595	1.33
K	104,787	183,357	320,839
MSY	17,972	27,261	41,350
B_{MSY}	52,394	91,679	16,0419
B_{2013}/B_{MSY} *	1.12	0.75	1.50
F_{2013}/F_{MSY} *	1.19	0.37	2.01

*Arithmetic Mean not Geometric Mean

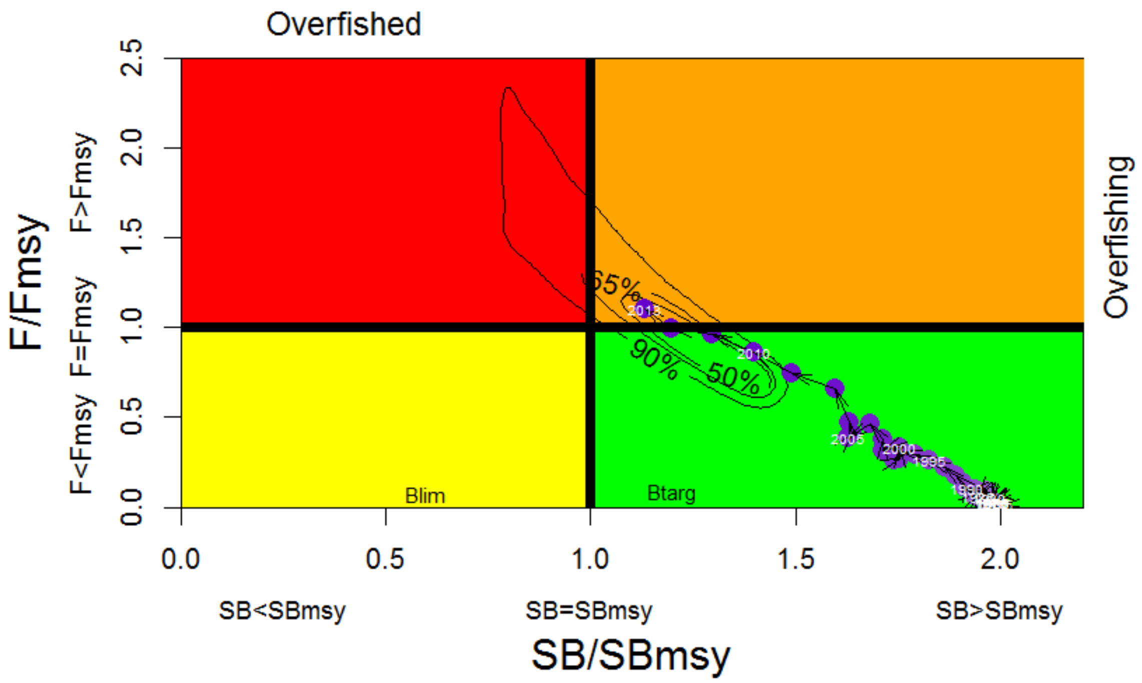


Figure 4: Phase plot of SMSY and FMSY Trajectory for Indo Pacific Sailfish with contours showing the uncertainty

Discussion

While these analyses are by no means conclusive, they still match the trends on stock trajectories and reference points that maybe useful for management (Figure 6 comparison of the SRA approach phase plot with the draft SS-III assessment, Sharma and Herrera 2014). A simple approach like this was compared to the complex programs for swordfish and gave very similar trajectories (left panel SRA approach vs. right panel SRA based approach). In terms of target yield levels, a range of 15.5 to 40K t using the age structured modelling approach developed by Sharma and Herrera. (2014). This approach which is a whole lot simpler, recommends target yield estimate of 25K Tons with a 95% confidence interval of 15K-41K Tons (Figure 5).

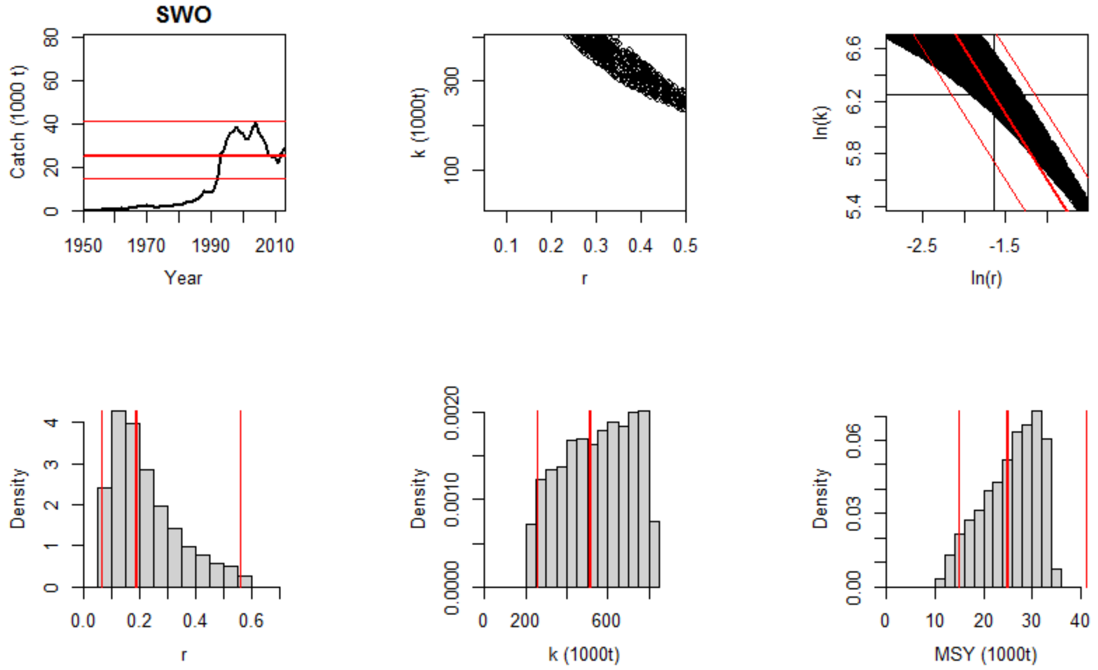


Figure 5: **<u>Stock trajectories of Swordfish and estimates of r and K that meet this criteria</u>**

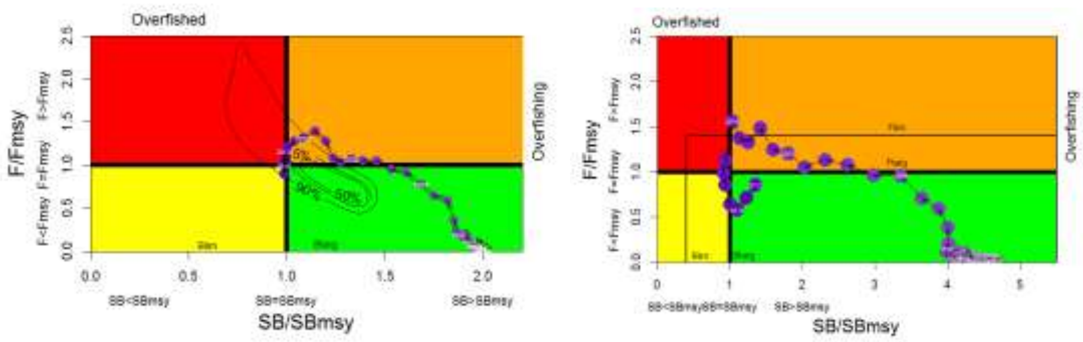


Figure 6: Comparisons of SRA approach on IO Swordfish data using SRA (left panel) vs SS-III (right panel, based on Japanese CPUE only).

Thus, while being conservative in nature, this approach could provide some guideline for yield/by-catch levels in these fisheries. Based, on these simplistic models the following could be recommended as target yield levels on the two billfish species analyzed:

<u>i) Yield not to exceed 10k Tons for Black Marlin and ii) yield not to exceed 25k Tons for Sailfish in the Indian Ocean Region.</u>

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