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# STOCK ASSESSMENT OF INDO-PACIFIC SAILFISH IN THE INDIAN OCEAN

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## Abstract

A catch-based stock reduction analysis method was used for an Indo-Pacific sailfish stock assessment. The method is based on a classical biomass dynamics model, requires only catch history but not fishing effort or CPUE. A known population growth rate would improve the assessment result. For this study, it is assumed that the two species examined (IP sailfish and swordfish as a comparison), belong to a single Indian Ocean-wide stock and the population size in 1950 is the virgin biomass, equal to their carrying capacities. We use recently updated catch data in the analysis. For sailfish the geometric mean virgin biomass was about 104 to 320 thousand tonnes, and the intrinsic population growth rate is about 0.588 (0.26-1.33 95% CI). The entire stock can support a MSY of nearly 23.9 thousand tonnes. Catch levels in recent year may have been too high, and likely overfishing is occurring on the stock.


## Introduction

In standard stock assessments conducted in the Indian Ocean, an index of abundance is essential to capture trends in biomass over time. However for black marlin and Indo-Pacific sailfish in the Indian Ocean no such indices are 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 (i.e. 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.

## Indo-Pacific Sailfish (SFA: *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).

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Catch data for the species show increasing trends in catches, in much the same manner as other billfish species. The most recent information considered by the IOTC Scientifc Committee for this species may be found in the IOTC Executive Summary, available from the IOTC website: http://iotc.org/science/status-summary-species-tuna-and-tuna-species-under-iotc-mandate-well-other-species-impacted-iotc

**Table 1.** Catch data on blue marlin (BUM), black marlin (BLM), striped marlin (MLS), Swordfish (SWO) and Indo-Pacific sailfish (SFA) from 1950-2013 (source IOTC Database)

| yr | BUM | BLM | MLS * | SWO | SFA* |
|---|---|---|---|---|---|
| 1950 | 1 | 49 | 1 | 43 | 336 |
| 1951 | 6 | 48 | 6 | 41 | 317 |
| 1952 | 396 | 179 | 85 | 44 | 359 |
| 1953 | 1268 | 535 | 274 | 65 | 428 |
| 1954 | 3009 | 876 | 819 | 212 | 577 |
| 1955 | 3510 | 985 | 867 | 271 | 804 |
| 1956 | 4945 | 1484 | 1922 | 594 | 1009 |
| 1957 | 3778 | 1683 | 1900 | 414 | 787 |
| 1958 | 4175 | 1569 | 1908 | 617 | 697 |
| 1959 | 4506 | 1558 | 2575 | 622 | 1014 |
| 1960 | 3887 | 1737 | 2338 | 715 | 1305 |
| 1961 | 3436 | 1768 | 2691 | 920 | 1257 |
| 1962 | 3302 | 1903 | 2024 | 1081 | 1180 |
| 1963 | 2198 | 1318 | 1884 | 983 | 1054 |
| 1964 | 3467 | 1613 | 2137 | 1204 | 1047 |
| 1965 | 3721 | 1394 | 3583 | 1306 | 1048 |
| 1966 | 3558 | 1307 | 4302 | 1379 | 1226 |
| 1967 | 4083 | 1506 | 4571 | 1817 | 1346 |
| 1968 | 3661 | 2162 | 3429 | 1775 | 1389 |
| 1969 | 3276 | 2094 | 4210 | 2019 | 1119 |
| 1970 | 3892 | 2416 | 3912 | 2631 | 1026 |
| 1971 | 3094 | 1718 | 2334 | 2166 | 1206 |
| 1972 | 3038 | 1303 | 2169 | 2060 | 1003 |
| 1973 | 1919 | 812 | 1636 | 1646 | 860 |
| 1974 | 2238 | 1391 | 4290 | 1948 | 1166 |
| 1975 | 2780 | 1253 | 2606 | 2258 | 1470 |
| 1976 | 1802 | 665 | 3063 | 1980 | 1656 |
| 1977 | 1964 | 662 | 4240 | 1890 | 1700 |
| 1978 | 3413 | 790 | 6415 | 2393 | 1706 |
| 1979 | 4085 | 748 | 4181 | 2588 | 1717 |
| 1980 | 3792 | 1350 | 5626 | 2672 | 2475 |
| 1981 | 3366 | 1105 | 5600 | 2689 | 1966 |
| 1982 | 3427 | 2163 | 2819 | 3908 | 4325 |
| 1983 | 4775 | 2410 | 3530 | 4026 | 3048 |
| 1984 | 4925 | 2188 | 3706 | 3946 | 3204 |
| 1985 | 5276 | 2094 | 4299 | 4997 | 3202 |
| 1986 | 5647 | 2233 | 8730 | 5846 | 3572 |
| 1987 | 6902 | 2475 | 6952 | 7147 | 3658 |
| 1988 | 5072 | 2310 | 5446 | 9189 | 4938 |
| 1989 | 6027 | 2343 | 5335 | 8249 | 4985 |

| | | | | | |
|---|---|---|---|---|---|
| 1990 | 5116 | 2254 | 2697 | 8560 | 4974 |
| 1991 | 5441 | 2471 | 4121 | 9457 | 5120 |
| 1992 | 7811 | 3669 | 3375 | 15859 | 7480 |
| 1993 | 8682 | 4077 | 8457 | 26125 | 8370 |
| 1994 | 8590 | 5951 | 6029 | 27593 | 10629 |
| 1995 | 8363 | 5059 | 6755 | 32201 | 12077 |
| 1996 | 9892 | 5924 | 6527 | 36363 | 13358 |
| 1997 | 11404 | 6859 | 5331 | 36067 | 14062 |
| 1998 | 11929 | 5608 | 5609 | 38464 | 11486 |
| 1999 | 10765 | 6172 | 4709 | 36361 | 12155 |
| 2000 | 10395 | 8012 | 4454 | 35726 | 15055 |
| 2001 | 7428 | 7600 | 3640 | 32701 | 14544 |
| 2002 | 8694 | 6986 | 3577 | 33599 | 13929 |
| 2003 | 10175 | 8914 | 3572 | 38377 | 16626 |
| 2004 | 11395 | 12887 | 4684 | 40463 | 20009 |
| 2005 | 11045 | 10782 | 4112 | 35807 | 16070 |
| 2006 | 9591 | 11273 | 3991 | 33408 | 17302 |
| 2007 | 7865 | 9407 | 2999 | 30750 | 19715 |
| 2008 | 7888 | 10504 | 2713 | 25177 | 20990 |
| 2009 | 7964 | 10996 | 2389 | 24952 | 25155 |
| 2010 | 7657 | 9420 | 2707 | 24446 | 27887 |
| 2011 | 9029 | 10766 | 3154 | 21728 | 29522 |
| 2012 | 14327 | 11392 | 5934 | 26386 | 27398 |
| 2013 | 11838 | 11443 | 4825 | 28934 | 29657 |

* Only datasets updated since 2014

**Methods**

We use a newly developed stock assessment method in this paper. The 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**

**Indo-Pacific sailfish**

Indo-Pacific sailfish also show increasing catch trends in recent years. The stock is in healthy status though recent catch trends may indicate that the stock may be ***subject to overfishing*** (Figure 1, Table 1). Stock trajectories show how the stocks are experiencing excess fishing pressure in recent years (Figure 2), and further catches at this level may cause the stocks to deplete to levels that indicate it is ***overfished***.

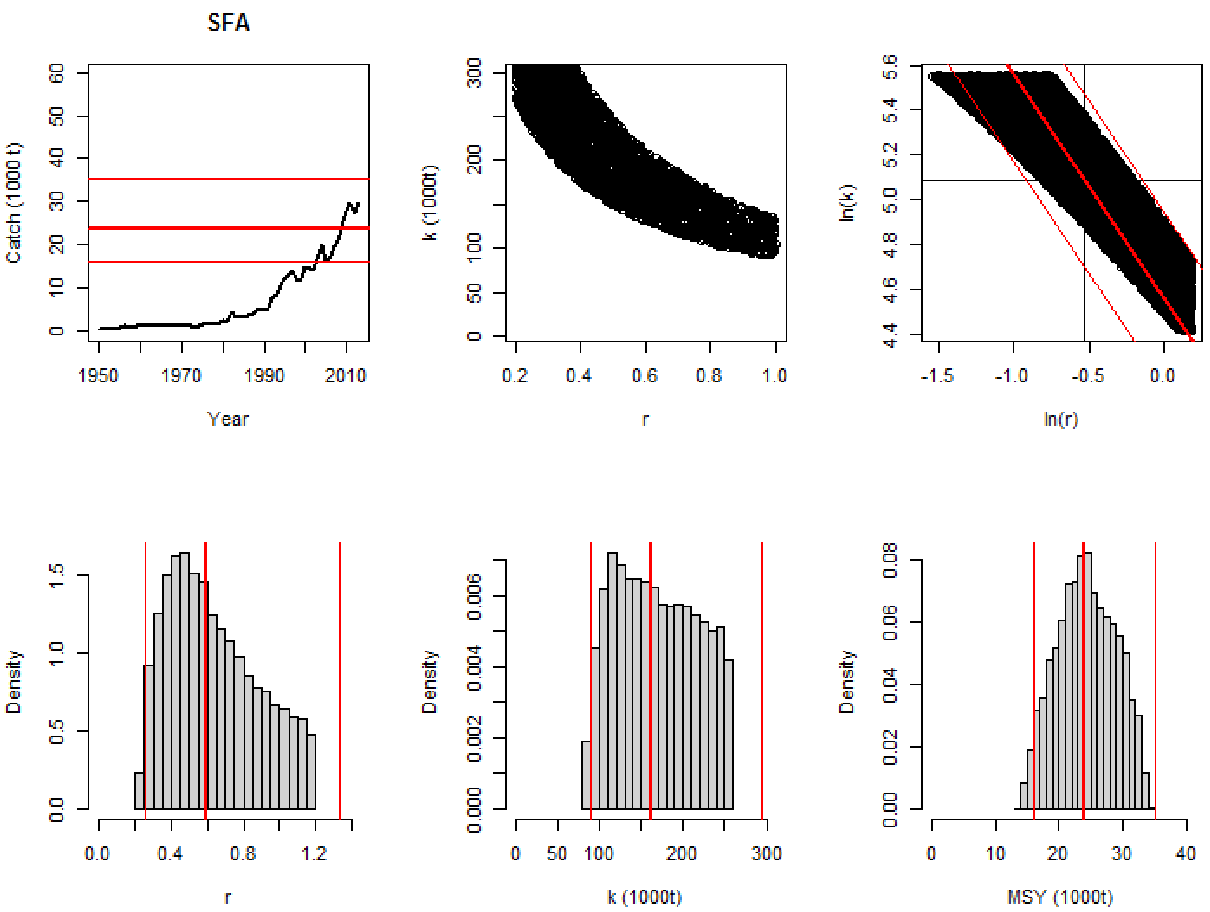


**Figure 1**. Stock trajectories of Sailfish and estimates of r and K that meet this criteria

**Table 1.** Key parameters associated with the stock reduction analysis for Indo-Pacific sailfish

| Parameter | Lower 95% CI | Geometric Mean | Upper 95% CI |
|---|---|---|---|
| r | 0.265 | 0.59 | 1.33 |
| K | 89413 | 162,298 | 294595 |
| MSY | 16182 | 23,857 | 35172 |
| $B_{MSY}$ | 54,741 | 92,814 | 139,837 |
| $B_{2013}/B_{MSY}$ * | 0.89 | 1.14 | 1.39 |
| $F_{2013}/F_{MSY}$ * | 0.64 | 1.08 | 1.66 |

*Arithmetic Mean not Geometric Mean

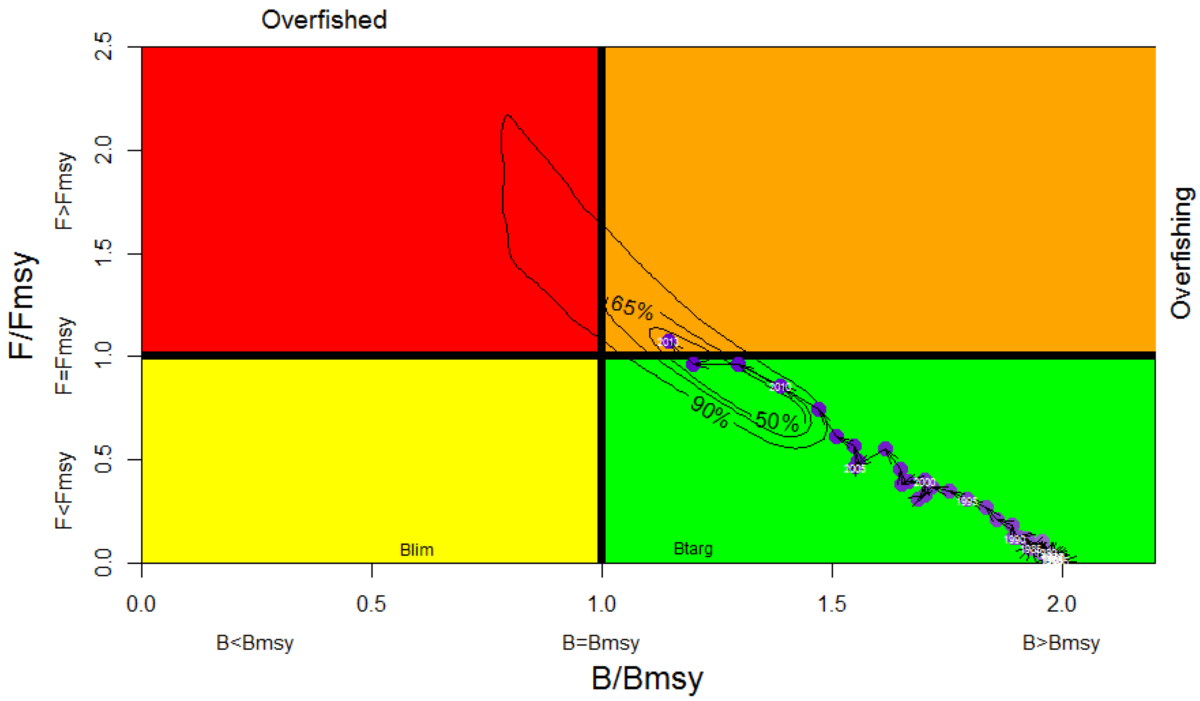


**Figure 2.** Phase plot of $S_{MSY}$ and $F_{MSY}$ trajectory for Indo-Pacific sailfish with contours showing the uncertainty

**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 4 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 t with a 95% confidence interval of 15K-41K t (Figure 3).

As such, the range of derived management parameters such as optimal yield are in the ballpark and as such could be used for management.

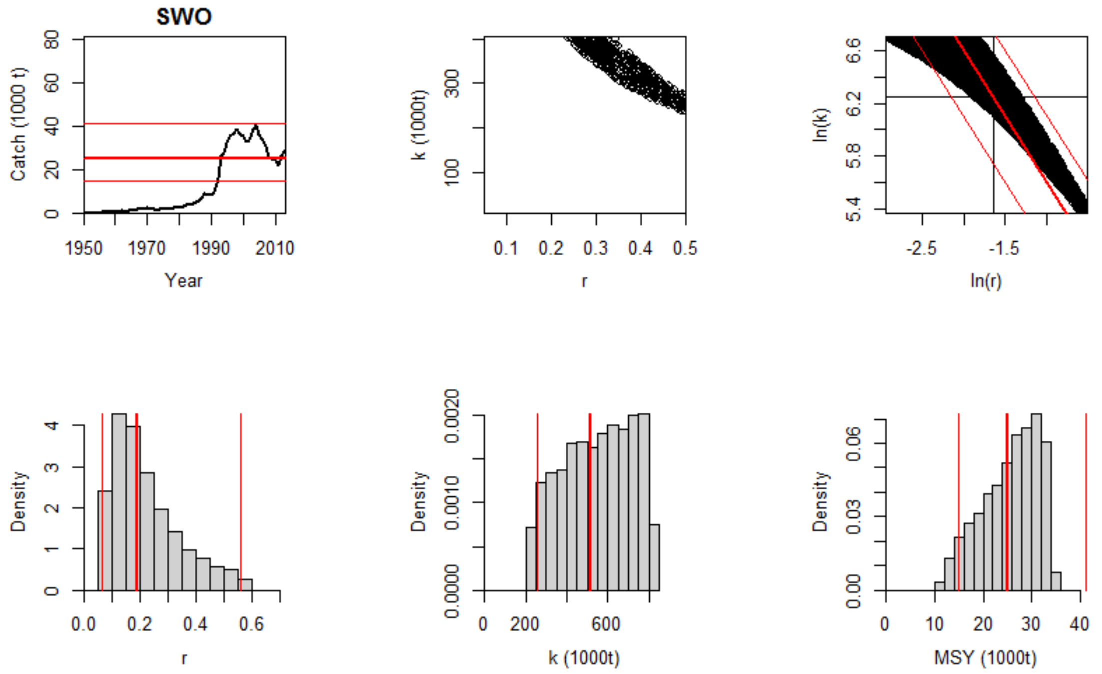


**Figure 3.** Stock trajectories of swordfish and estimates of r and K that meet this criteria

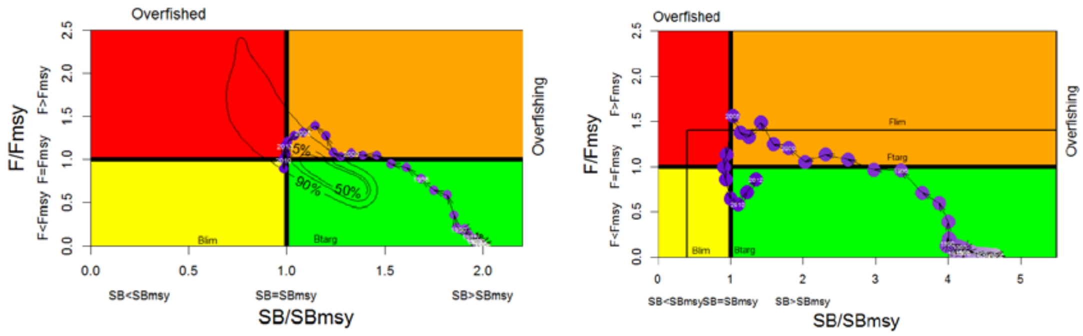


**Figure 4.** Comparisons of SRA approach on swordfish data using SRA (left panel) vs SS-III (right panel, based on Japanese CPUE only).

Thus, while being conservative in nature, this approach could provide some guideline for yield/bycatch levels in these fisheries. Based, on these simplistic models the following could be recommended as target yield levels on the Indo-Pacific sailfish species analysed that ***yield should not exceed 24k t.***

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