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Indian Ocean Kawakawa Assessment based on the Maldives Pole and Line CPUE Index

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Rishi Sharma (rishi.sharma@iotc.org, IOTC Secretariat, Seychelles)

Shijie Zhou (CSIRO, Melbourne, Australia)

Abstract

CPUE data derived from the Kawakawa CPUE standardization was used in Surplus Production model assessment. Non-informative priors were used on r, and K, assuming the population was at K when the catch time-series begins in 1950. Catch data was used from 1950 and key reference points, namely S_{MSY} & MSY were estimated using the SIR algorithm. Since there is limited information on the CPUE dataset, the range of estimates on reference points is large. Results obtained though similar to the posterior based stock reduction method only based on catch series presented by Zhou et. al. (IOTC 2013), differ in their interpretation towards the latter half of the time-series. The stock status appears to be healthy and not overfished based on the time-series used, though the model has convergence issues, and has a high degree of confounding in r and K estimates. Informative priors help the model converge, though the model is influenced to large extent by these priors. Due to the lack of contrast in the index of abundance data over the period, the model has difficulty estimating SMSY, though can still be useful for evaluating stock status and optimal yield targets. However, these should be used cautiously, and to a large extent the relative status of the stock is still highly uncertain.

Introduction

Although primarily distributed in the central Pacific, Indian Ocean Kawakawa (*Euthynnus affinis*) is an important fishery for numerous countries in the Indian Ocean region, namely Iran, Indonesia, India, Malaysia, and Thailand. Numerous other countries also catch the species (Figure 2). The species is primarily caught by Purse Seine and gillnets, but other gears (Figure 2) are also used to catch the species.

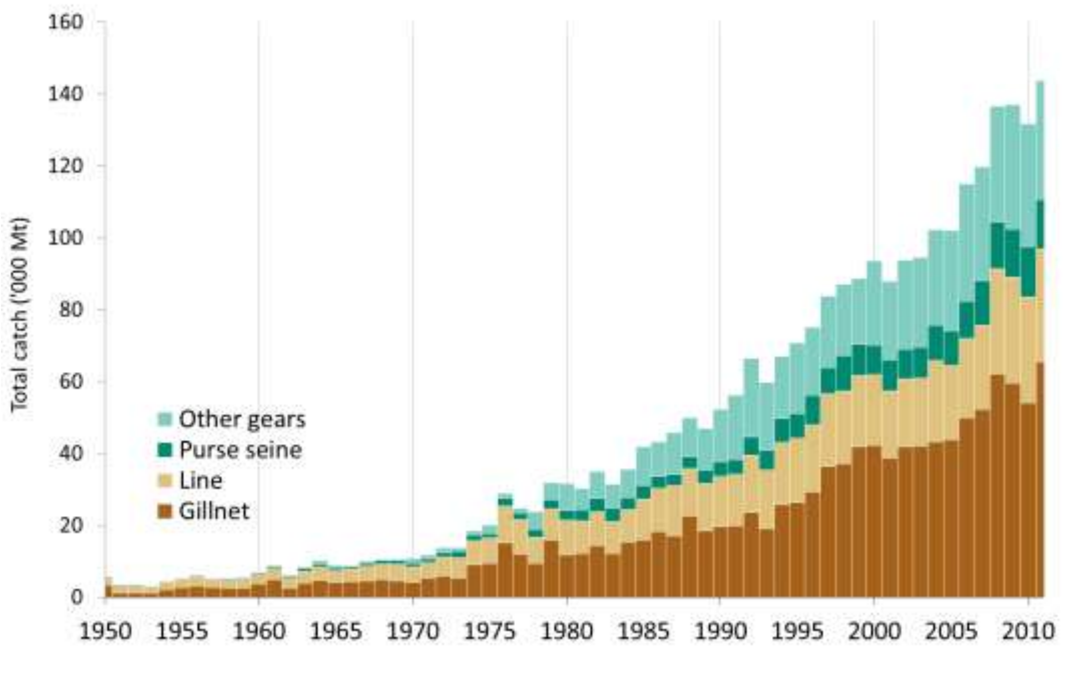

Figure 1. Annual catches of kawakawa by gear recorded in the IOTC database (1950–2011)

The countries that are the primary users of the resource are India, Indonesia and Iran. An attempt to re-estimate the catches across the region (Guillermo Moreno personal communication), is being undertaken in the Indian Ocean region, and it is likely that some of the numbers reported will be revised (Figure 4, Table 1).

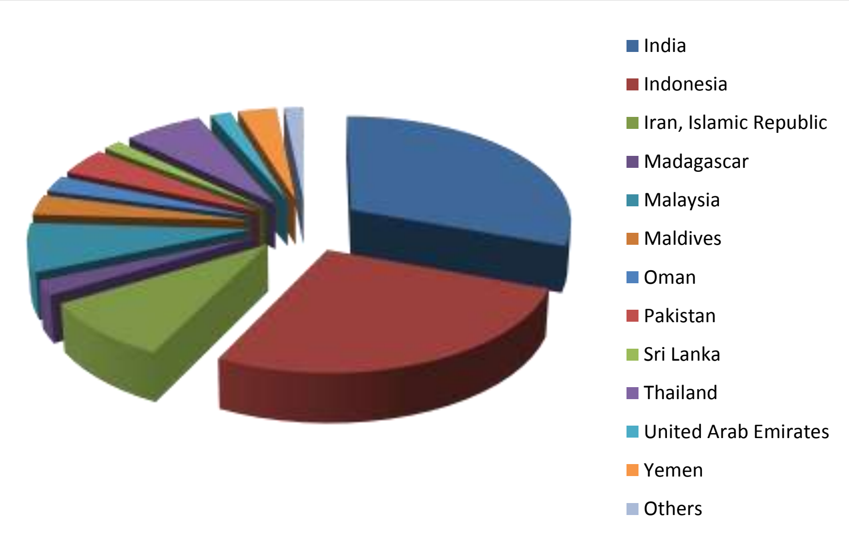

Figure 2: Proportion of the Catch accounted (1950-2011) for the Indian Ocean countries

As is evident from the figures, catch trends have increased in recent years primarily due to increases in effort by Iran and Indonesia. In recent years due the effect of piracy off the coast of Somalia, effort has been concentrated and redirected from Tropical Tunas to local neritic's by the countries of Iran, Pakistan and other Arabian gulf countries.

Although Maldives is not one of the major fleets catching Kawakawa. They consistently take between 5-10% of the catch and maybe a useful indicator to use for an index of abundance. This is the 1st attempt to use the Maldives CPUE data along with the catch data for conducting a surplus production assessment for the Indian Ocean. One of the big assumptions used in this approach is that the Maldives CPUE is representative of what is happening in the Indian Ocean on this stock, and that there is only one stock of kawakawa over its entire range. The CPUE data that is extracted from Maldives and used over time is shown in Figure 3a (by monthly variation) and 3b (annual variation) over 2004-2011. Since the catch data is collected at an annual time step, the model developed and used an annual time step and used the CPUE data in the fitting procedure on an annual basis.

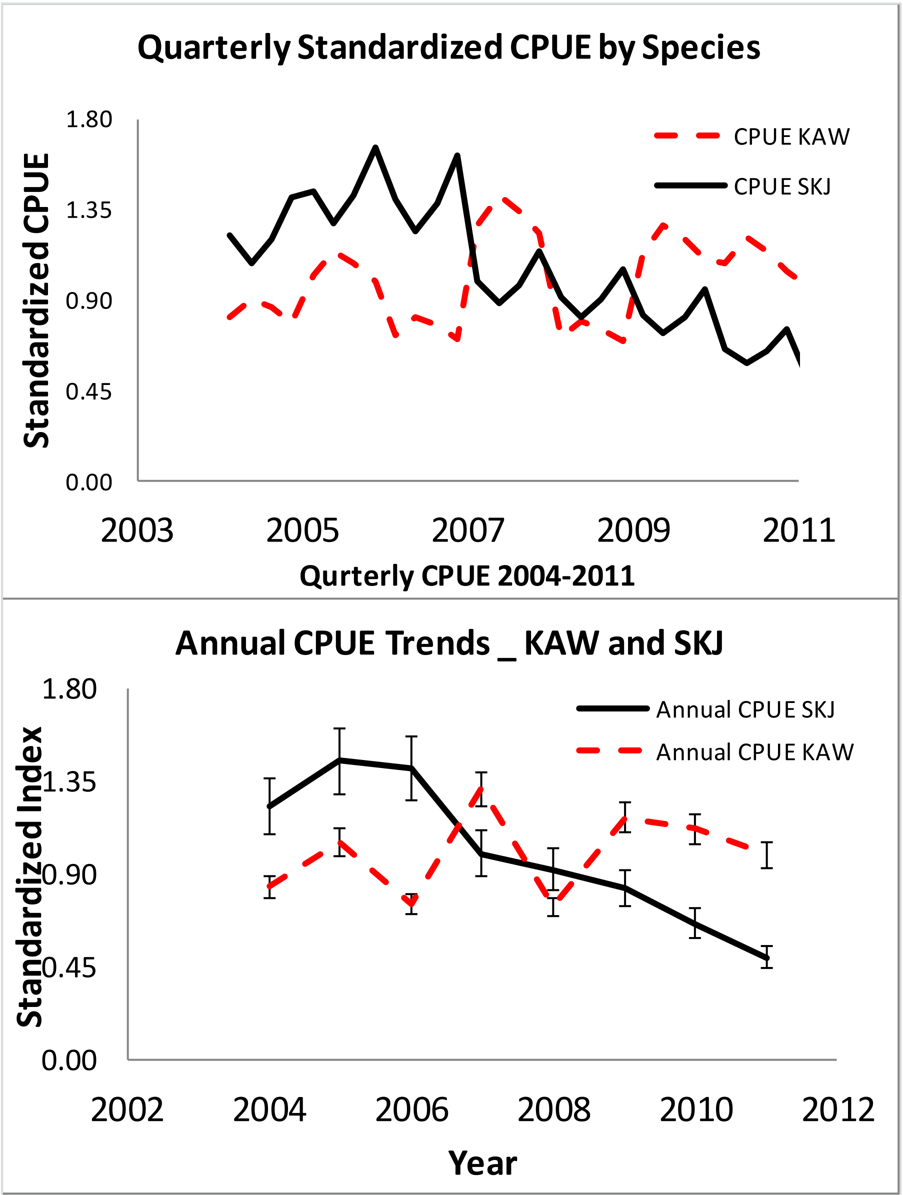

Figure 3: Maldives standardized CPUE data by quarterly and yearly increments

Methods

The model developed is a simple Surplus Production model (Logistic Model, Schaeffer 1954), and estimates two parameters r and K (eq. 1, Haddon 2011, Hilborn and Walters 1992) fit to estimated Biomass.

$$B_{1950} = K \tag{1}$$

$$B_{t+1} = B_t + \left(rB_t\left(1 - \frac{B_t}{K}\right) - C_t\right) \tag{2}$$

$$B_t = \frac{I_{t,f}}{q_{t,f}} \tag{3}$$

Closed form solution of q was used (eq. 4)

$$\hat{q}_{t,f} = \exp\left(\frac{\sum_1^n ln\left(\frac{\hat{B}_t}{I_t}\right)}{n}\right) \tag{4}$$

Where q is the catchability in the fleet, r is the intrinsic growth rate, and K is the carrying capacity assumed when the time series begins in 1950. The state variables are Biomass (B) and this is a function of r and K. The parameter, r, k and q are estimated by fitting the estimated Biomass using equation 2 to the observed index of abundance, based on the catch and series.

The Likelihood Equations used a log-normal error structure for the catch and normal error structure for the Index of abundance (eq. 5):

$$-\ln L(\underline{\theta} \mid I_{t,f}) = \sum_{f=1}^{n} \ln(\sigma_f) + \frac{\ln((B_{t,f}) - \ln(\hat{B}_{t,f}))^2}{2\sigma_f^2} \tag{5}$$

where $\underline{\theta}$ is the set of parameters, namely (r, K, and q, which may be fishery and block specific) that are estimated to get the best fit by minimizing the negative log-likelihood function (eq. 6 above) fitting to the Biomass using the index of abundance, and q.

Since r and K are highly correlated, we used non-informative Uniform priors on each parameter and the SIR algorithm (Rubin 1988) to estimate the uncertainty in r, K and derived parameters of interest B_{2011}, B_{MSY} and MSY. In addition we computed two ratios, B_{2011}/ B_{MSY} and C_{2011}/ C_{MSY} to evaluate the current status of the stock relative to these target reference points.

Results

We initially fit the model using the MLE solution, but due to parameter confounding observed a surface that had a number of solutions that could best fit the data (Figure 4 below). Based on this r could be anywhere from 0.4-1.8 and K anywhere from 1.4 M tons to >2.6 M tons.

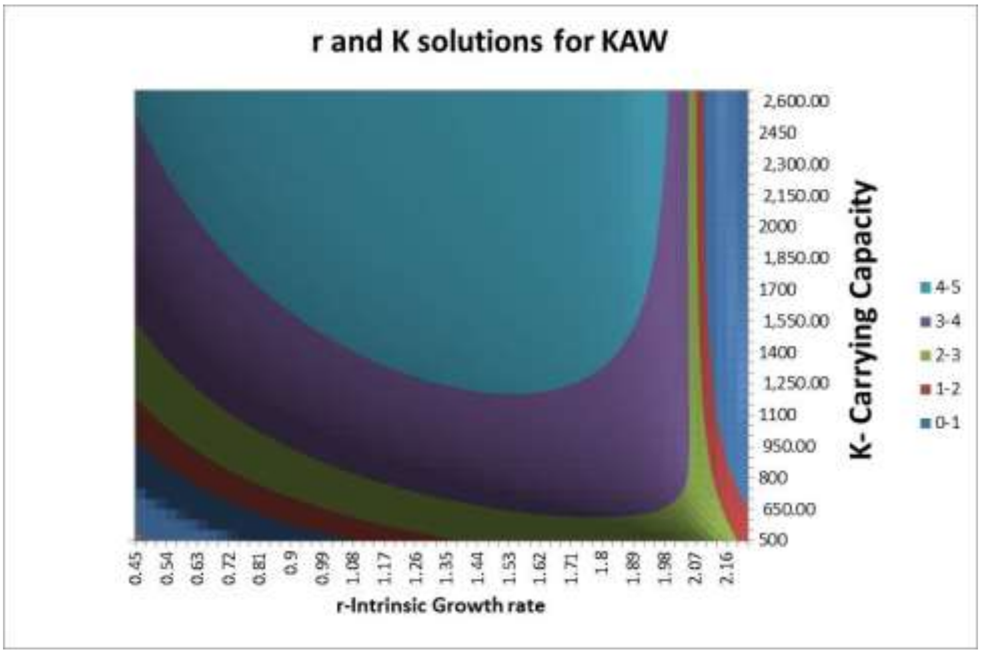

Figure 4: MLE surface for KAW based on r and K values

As a result, we ran the SIR algorithm with uniform priors on r and K; r ~ U [0.2, 2.2] and K ~ U [120k, 4.12 M]. Based on these values, the following was generated for the IO KAW stock (Figure 5).

While, optimal yield and the level of fishing relative to that can be estimated fairly well, we have relatively no information on r, K current Spawning Biomass or optimal Spawning Biomass targets (Figure 5, Table 1). From here, it is evident that very little is known about the Spawning stock size at optimal yield or stock sizes in the current year (2011). Optimal yield targets seem high for this stock with a yield target greater than 500k tons for the Indian Ocean. This is primarily due to the non-informative nature of the derived CPUE indices which indicate that we cannot estimate carrying capacity or r well, and therefore, the yield targets appear to be over-inflated.

Table 1: 90% credible intervals with Uniform non-informative priors on r and K for IO kawakawa

Parameters	5%	50%	90%
SMSY	296	1236	1900
MSY	178	622	1386
r	0.31	1.18	1.88
SB 2011	632	>2000	>2000
S2011/SMSY	1.55	1.88	1.95
C2011/CMSY	0.09	0.245	0.795

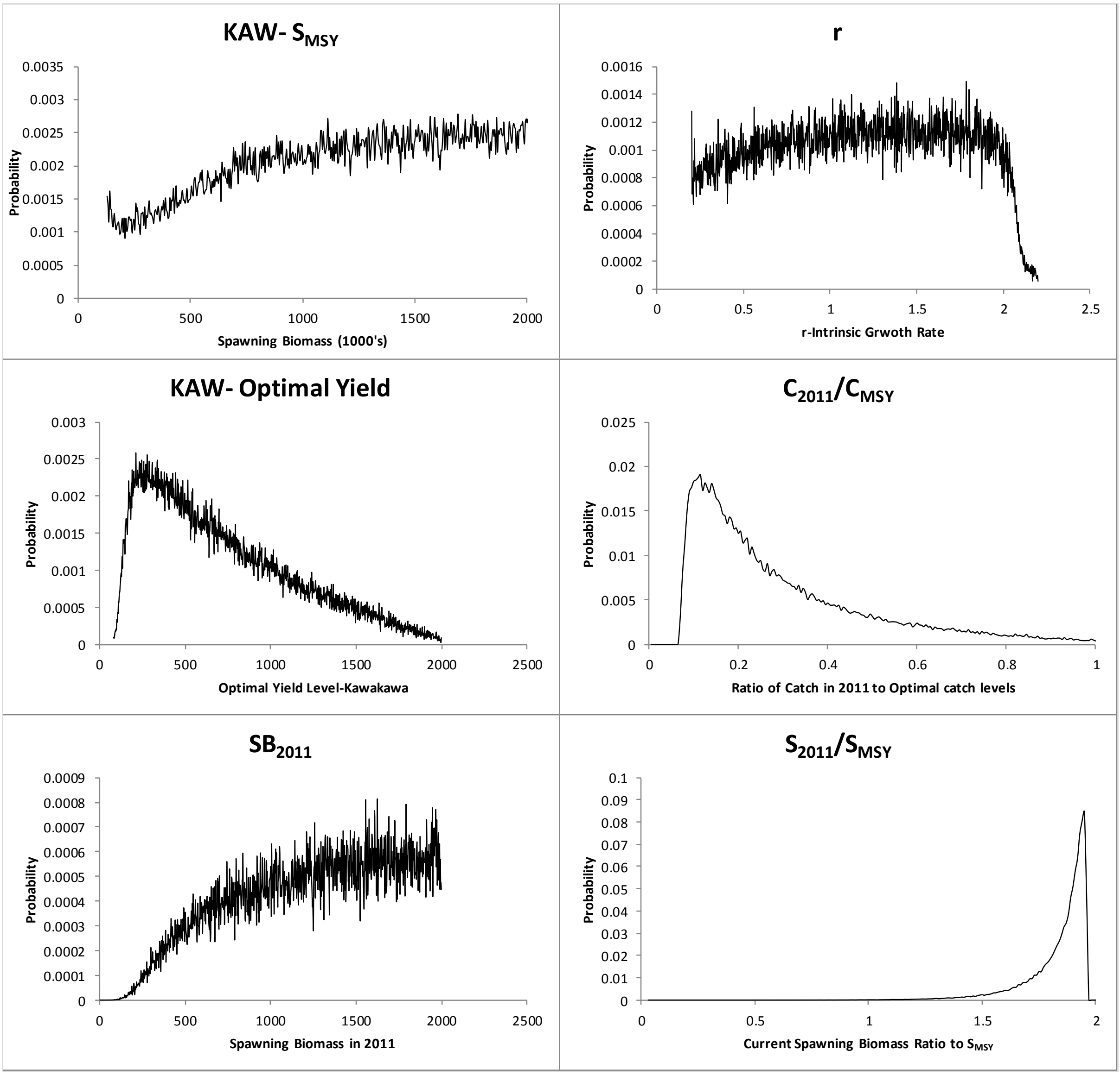

Figure 5: Derived reference points and parameters estimated using the SIR algorithm

If we use informative priors on r and K (r~N(1.2, 0.1) and K~N(800,200)) , we obtain a lot more precise idea on this stock, though now it is entirely driven by the priors, and hence still not entirely reliable (Figure 6). Now the derived parameters have a better resolution and we can say what r and K is with more reliability (Table2), though are almost entirely driven by the prior.

Table 2: 90% credible intervals with informative priors on r and K for IO kawakawa

Parameters	5%	50%	90%
S_{MSY}	284	420	584
MSY	164	252	354
r	1.04	1.2	1.37
SB_{2011}	416	712	1030
S_{2011}/S_{MSY}	1.45	1.69	1.79
C_{2011}/C_{MSY}	0.4	0.57	0.87

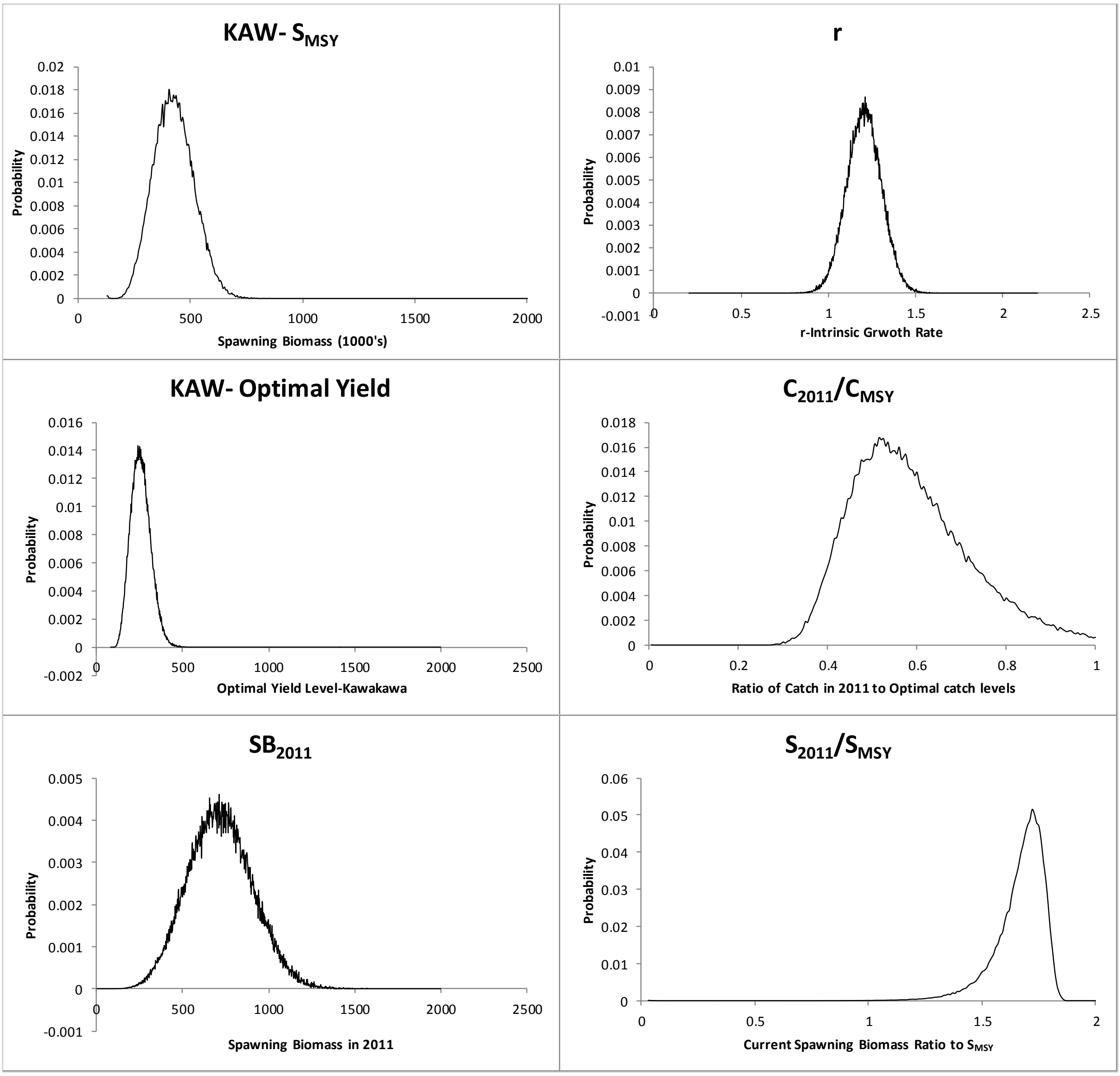

Figure 6: Derived reference points and parameters estimated using the SIR algorithm and informative priors on r and K

Discussion

As is evident from Figure 4 and Figure 5, the CPUE index is not informative for this model, and thus the range of possible options on r and K can vary quite a bit (Figure 5). If we use informative priors based on what r (based of Fish Base) and K (based on IO areas), we get a better idea on what maybe going on with this stock, but this is driven entirely by the prior on r and K (Figure 6). Hence, we are sceptical of these results as well. Until more effort is taken to get a longer time series on KAW index of abundance, we can't say much about the stock status here as it is highly uncertain using standard assessment methods.

A range of 3 models are displayed below (Table 3), with fits to the last model (Figure 7). As is evident from the CPUE series (Figure 3 above), a whole range of models could possible fit this series as we don't have enough variation in the CPUE series for the model to estimate certain key parameters.

Table 3: Range of models with high and low r and K levels that could fit the standardized CPUE data.

Pars	Model 1 (low productivity)	Model 2 (Medium productivity)	Model 3 (High productivity)
r	0.250	0.650	1.100
k	1,600	1,200	800
Likelihood	1.39	3.01	2.97
SMSY	800	600	400
Yield	100.0	195	220
ratioS	1.16	1.58	1.63
ratioF	1.26	0.42	0.31
Prob	19%	41%	40%

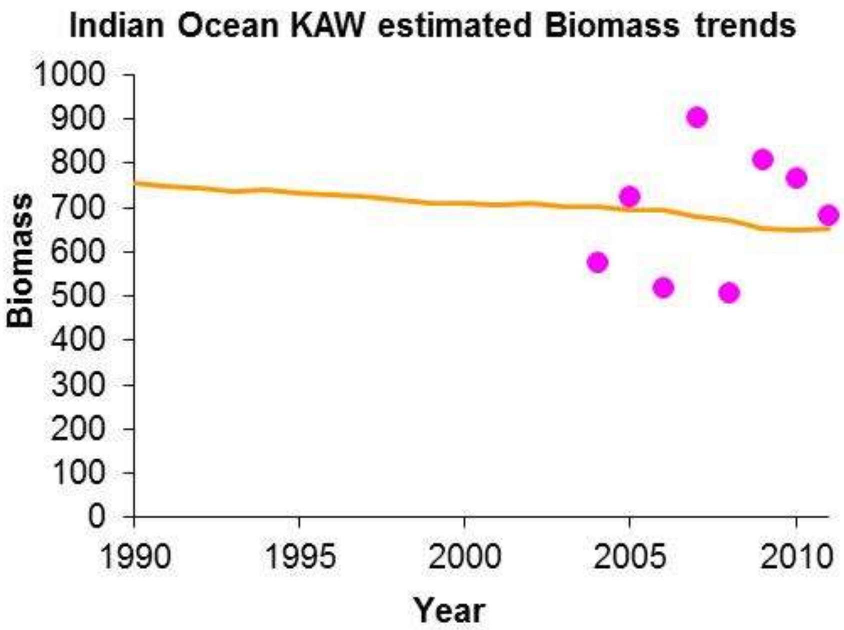

Figure 7: Fits to Model 3 (table 3 above) using high productivity estimates and fit to the standardized CPUE series used.

In addition, anchored FAD fishing predominates during this period and can be expected to cause hyper-stability in CPUE indices observed in the Maldives, and may not thus be representative of true abundance. Finally, the assumption that the Maldives CPUE series is assumed to represent all of the Indian Ocean is problematic as well. Further research and development must be made by the coastal countries to estimate standardized indices of abundance. Until, we proceed down that path, it will be difficult to use standard stock assessment procedures to estimate what maybe going on with these stocks.

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