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Indian Ocean Striped Marlin Assessment based on the CPUE indices derived from the Japanese and Taiwanese Longline fleets

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Abstract

CPUE data derived from the Japanese LL fleet catching Striped marlin is used in a Bayesian Surplus production model with non-informative 'priors' and informative priors. 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} and MSY were estimated using the markv Chain Monte Carlo MCMC or Sample Importance Resample (SIR) algorithm. Results indicate the stock is overfished and at very low abundance levels relative to historic abundance (4% of virgin biomass ($0.04B_0$)). Fishing mortality rates are also excessively high (>1.5 F_{MSY} levels) and unless a substantial reduction in catch levels occur in the near future, the stock is unlikely to recover to MSY levels. The results are consistent when examining sensitivities to 'prior' choice. Additional runs using the Japanese LL CPUE indicated the stock is still overfished where stock size is $0.6B_{MSY}$ and experiencing fishing mortality levels that are >1.5 F_{MSY} levels.

Introduction

Although primarily distributed in the Pacific, in the Indian Ocean, fish are more densely distributed in equatorial regions with higher concentrations off eastern Africa, in the western Arabian Sea, the Bay of Bengal and off northwestern Australia (Figure 1, Pillai and Ueyanagi, 1977). Numerous countries catch the species (Figure 1a). The species is primarily caught by Longlines, but other gears (Figure 1b) are also used to catch the species.

Note, that for fitting purposes the Taiwanese LL CPUE data provided (Sheng-Ping pers. com) was used for the assessment. This data was analysed by 3 areas based on Longhurst areas in the Indian Ocean, and then collapsed into a single index as shown in Figure 2. For further details look at IOTC–2015–WPB13–XXX.

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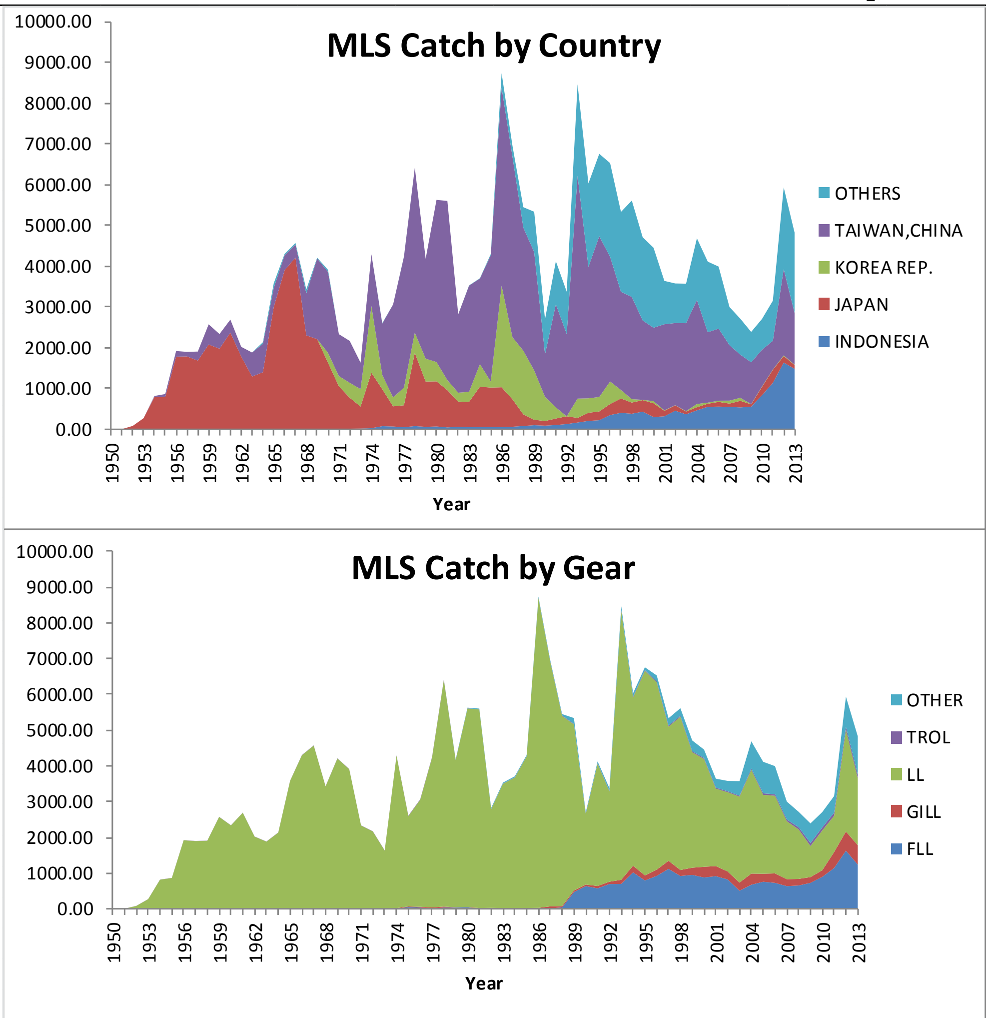

Figure 1. a.) Annual catches of MLS by country recorded in the IOTC database (1950–2011), b) Annual catches by primary gear in IOTC database.

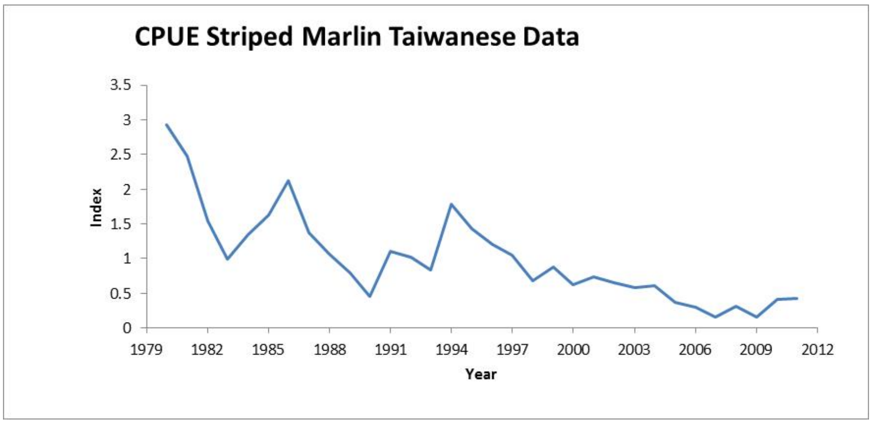

Figure 2. Taiwanese standardized CPUE data by yearly increments based on the 3 area (Longhurst area recommendations made in WPB08, held in 2010)

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.

$$B_{1950} = K \quad (1)$$

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

$$B_t = \frac{I_{t,f}}{q_{t,f}} \quad (3)$$

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

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

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):

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

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 MCMC algorithm (Metropolis Hastings XXXX) to estimate the uncertainty in r, K and derived parameters of MSY/Yield. In addition we computed two ratios, B_{2013}/ B_{MSY} and F_{2013}/F_{MSY} to evaluate the current status of the stock relative to these target reference points.

Results

We ran the MCMC algorithm with uniform priors on r and K; r ~ U [0, 2] and K ~ U [0, 70k]. Based on these values, the following was generated for the IO MLS stock (Figure 3).

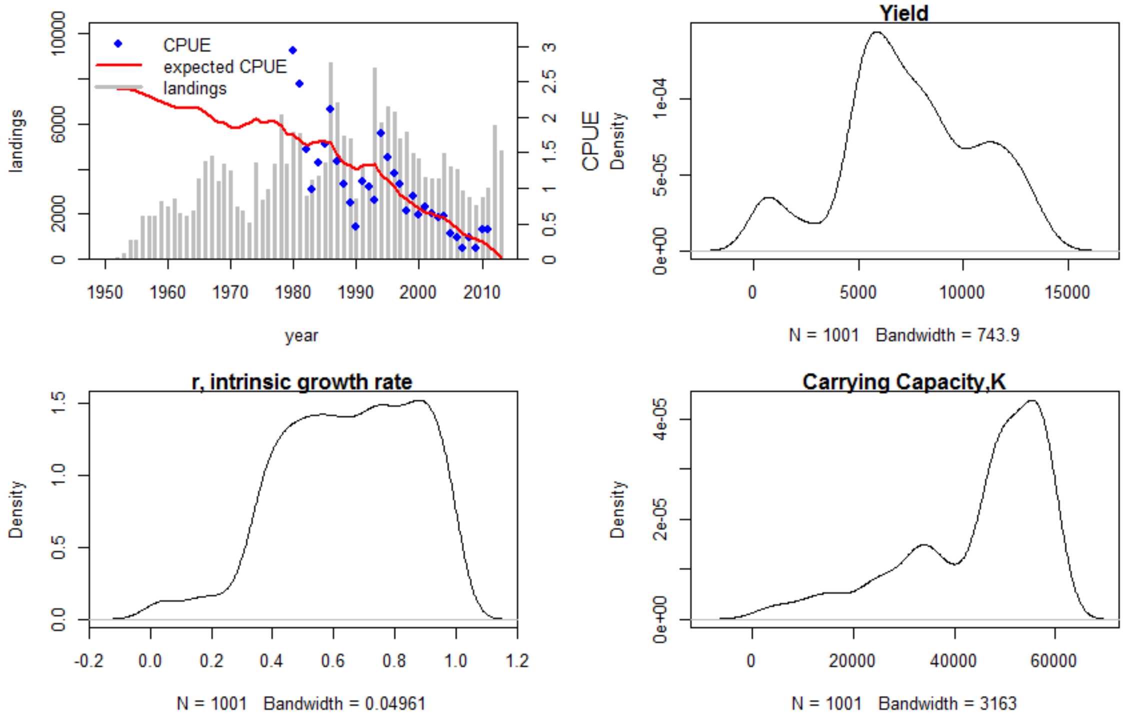

Figure 3. Maximum Likelihood Estimate (MLE) solution and estimates of r, K and optimal Yield of the stock.

While, optimal yield and the level of fishing relative to that can be estimated fairly well, we have relatively no information on r. Uncertainty in current stock status levels is shown in Figure 4, and it's clear that the stock status indicator shows that the stock is ***subject to overfishing***. MCMC runs appear to diverge from MLE solution of the assessment (Figure 3 above). Median estimates of yield were around 9.5K with K around 90K, and r=0.35, indicating the stock status was quite healthy. A range of posteriors were examined, but the results all seemed quite optimistic.

As such, we constrained the model to give results consistent with the MLE solution (Figure 4) using the SIR algorithm. Key reference points and uncertainty in parameter estimates is shown in Table 1.

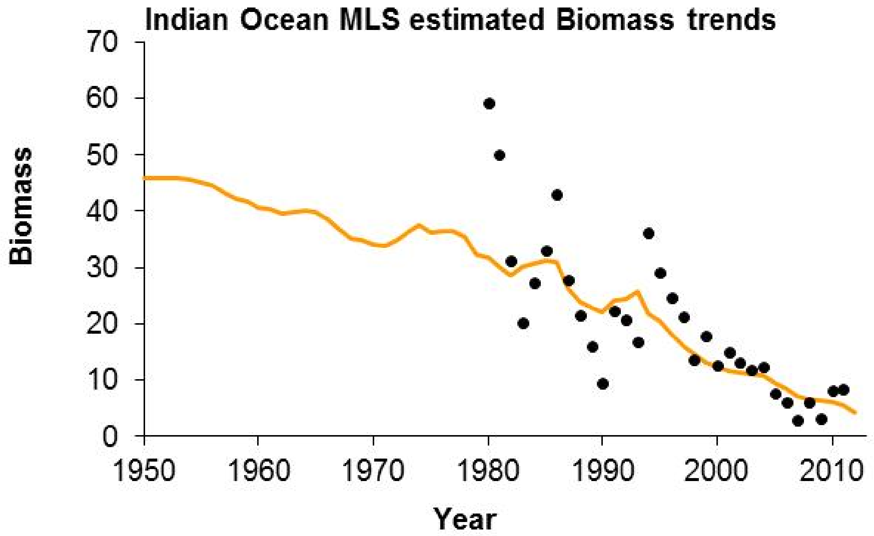

Figure 4. MLE solution (similar to panel 1 a) showing Biomass Trends over time fitted to the estimated CPUE over time by estimating catchability using the closed form solution trends

Table 1. Uncertainty in estimates of Stock status of MLS and other key parameters (intervals are 95% intervals based on bootstraps from priors)

Parameters	MLE	Lower	Upper	CV
r	0.40	0.34	0.62	0.15
K	46.01	30.24	49.27	0.12
B_{msy}	23.01	15.12	24.64	0.12
Yield	4.60	2.20	7.46	0.28
fmsy	0.18	0.16	0.27	0.13
Sratio	0.04	-	2.16	1.02
Fratio	9.67	-	13.76	0.82
B_{2013}	1.00	-	48.38	1.14

Note, projections were run based on catch levels in 2013 (Table 2) and posterior estimates of r and K (Figure 5) to generate uncertainty in the stock status trajectory shown in Kobe plot (Figure 6).

Table 2. Projections based on 2013 catch levels (60,80,100,120,140% of 2013 catch levels of 4825t)

Projected Values	**60%**	**70%**	**80%**	**90%**	**100%**	**110%**	**120%**	**130%**	**140%**
$B_{2016} < B_{MSY}$	27%		27%		27%		28%		28%
$F_{2016} > F_{MSY}$	55%		55%		55%		58%		71%
$B_{2023} < B_{MSY}$	55%		55%		55%		66%		81%
$F_{2023} > F_{MSY}$	54%		55%		55%		70%		87%

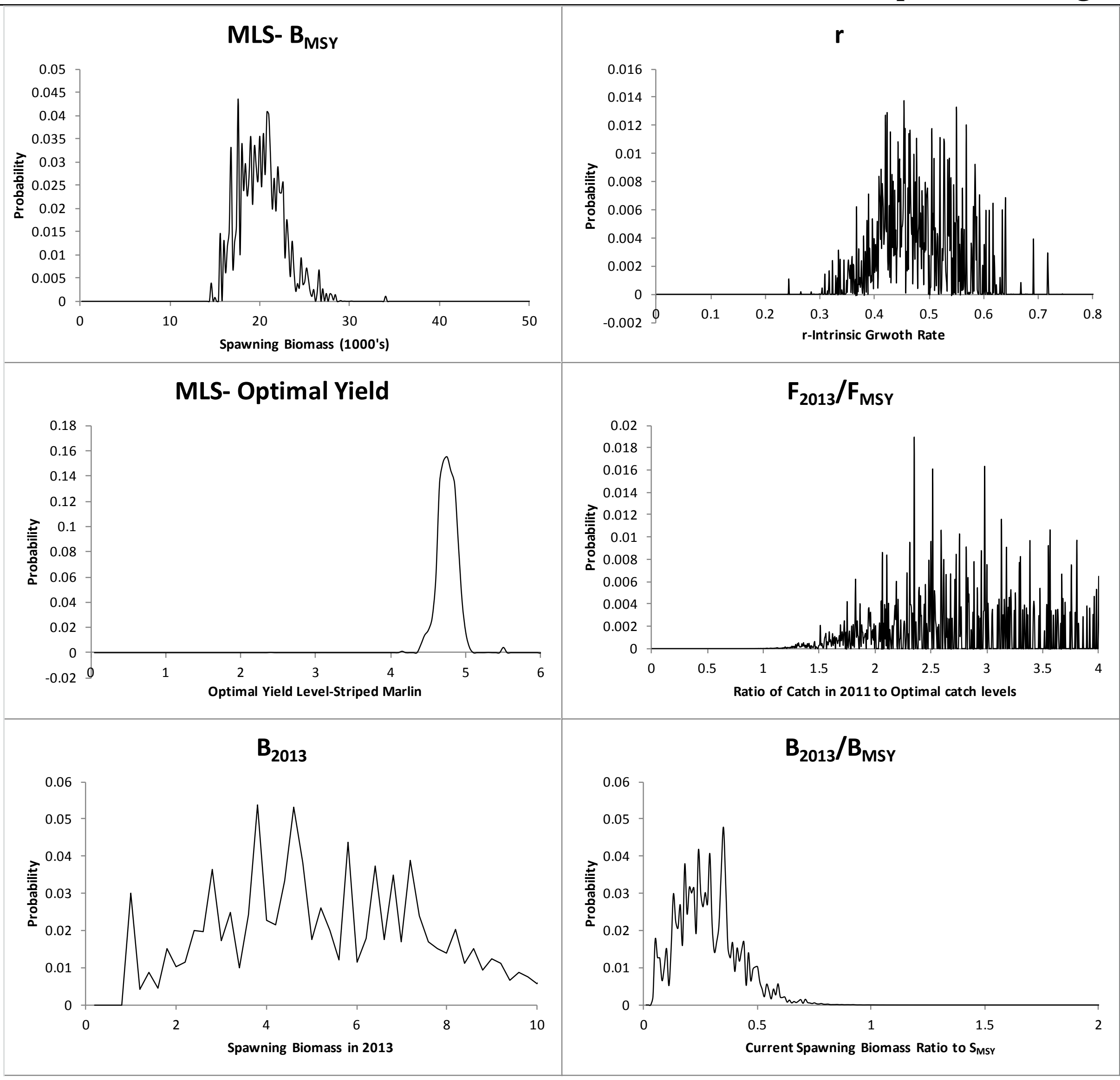

Figure 5. Derived reference points and parameters estimated using the SIR algorithm. Normal Priors on r were used N(0.5, 0.1) and on K, N (40,7.5)

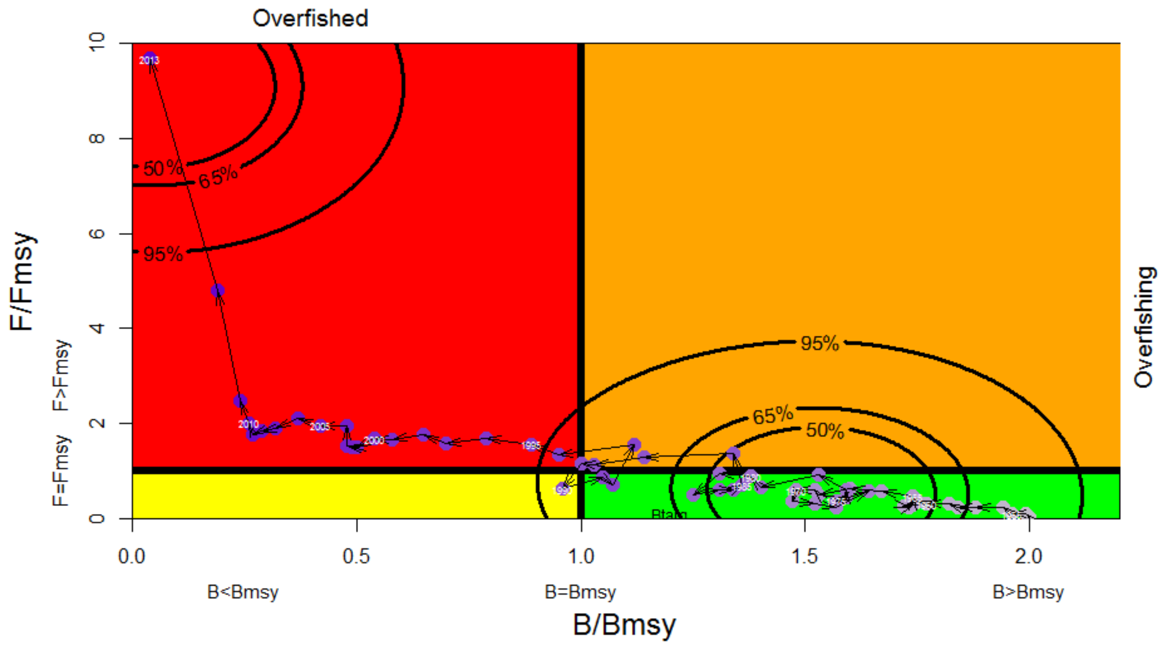

Figure 6. Phase plot of stock status and uncertainty in derived reference points

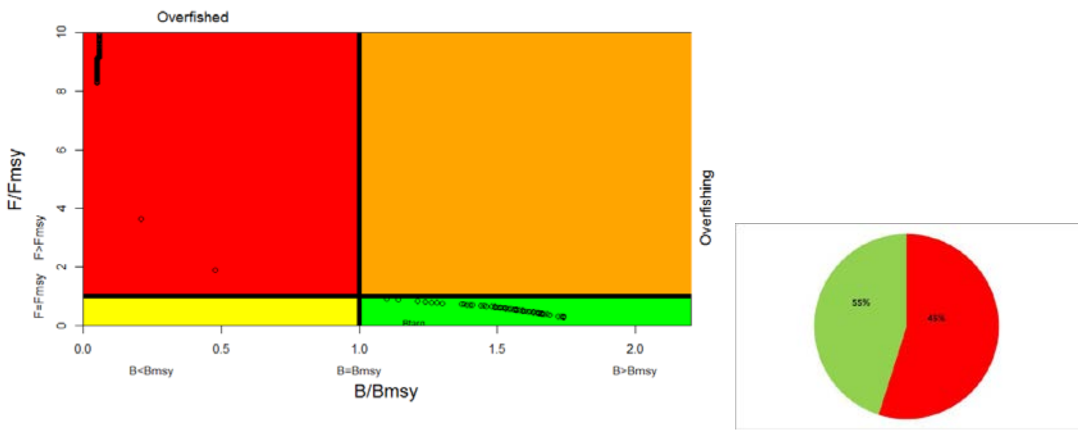

Figure 7. 500 points from Posterior resamples, showing status in 2013. As few points were chosen in the region in between, there are 2 modes in the distribution as shown in figure 6 else it would be one continuous distribution. Inset shows the number of bootstrap runs that indicate how many times the stock was in the green versus the red quadrant in 2013.

Sensitivity to Japanese LL CPUE series

Although, historically Japan was a major contributor of the catch of striped marlin, since 1985 (Figure 1a), catches declined substantially. Hence we chose to use the Taiwanese series for the main analysis. If CPUE data from 1970 was used model indicated that the population was extinct, which doesn't make much sense (Figure 8 below).

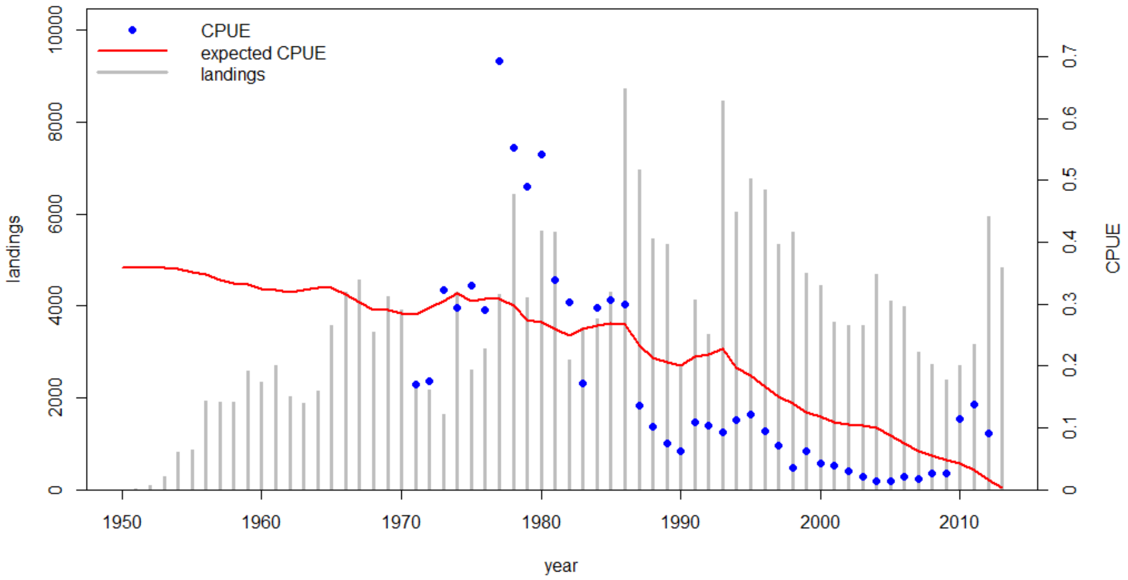

Figure 8. MLE solution from Japanese CPUE data used from 1970 (r= 0.39 and K=46,597)

Hence, we only used data from 1980 onwards that gave more sensible results. However, a sensitivity was run with the Japanese LL CPUE data, and the MLE obtained was, r. K was r=0.77 and K=26,500 (Figure 9 below). Carrying capacity estimates are substantially lower than that obtained from the TWN,China data

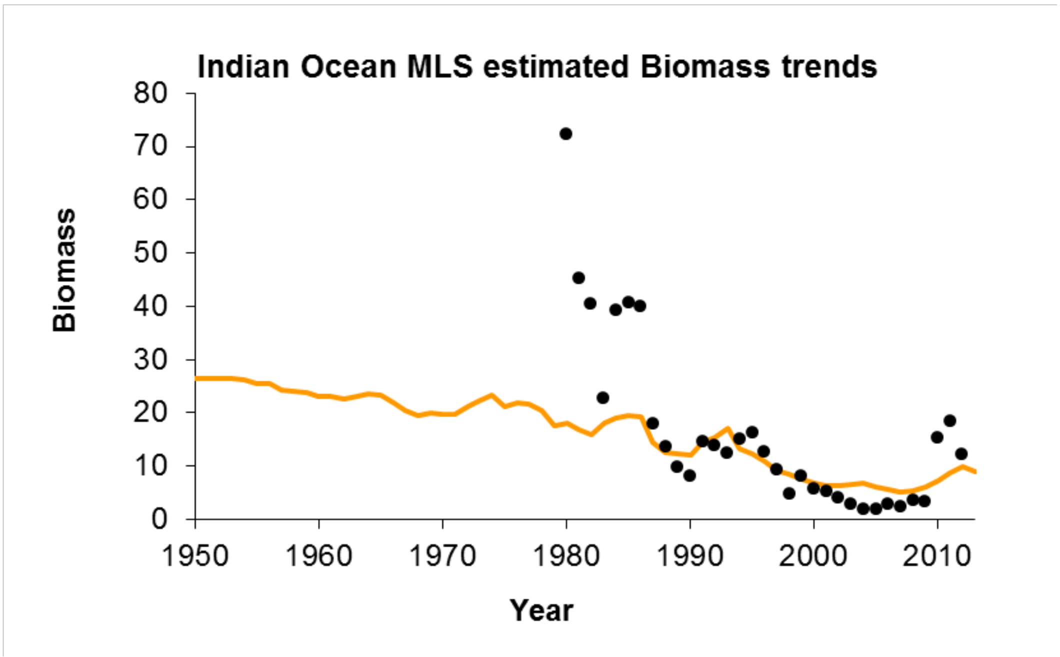

Figure 9. MLE solution from Japanese LL CPUE data only used after 1980

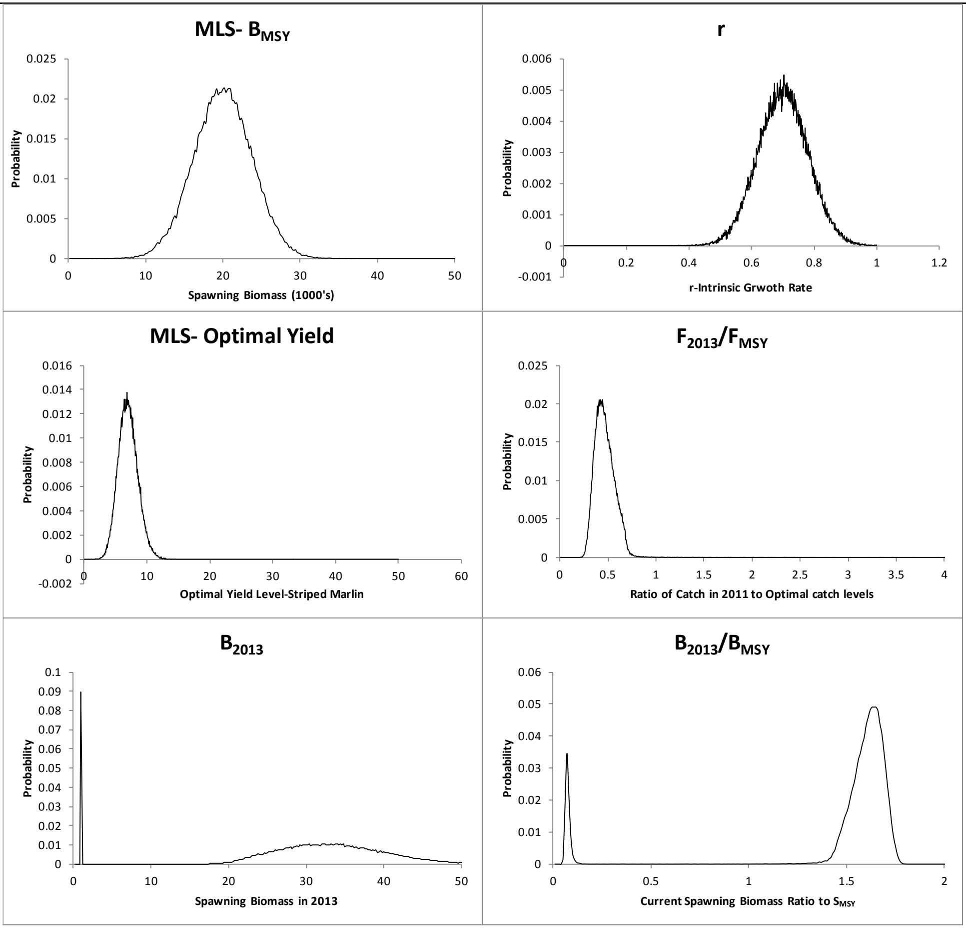

Figure 10. Posterior distributions on MLS using Priors on r were used N(0.7, 0.1) and on K, N (40,7.5)

Derived and reference parameters based on this series are shown below (Table 3), and projections based on a Bootstrap based on the posteriors is shown in Table 4. Stock status indicators are shown in Figures 11 and 12 respectively. Surfaces were not clear as there appear to be two modes giving equally good solutions (Figure 12) which can give quite a different picture on stock status.

Table 3. Key parameters derived from bootstraps run from distributions shown in Figure 10 above. Limits are based on 80th percentiles.

Parameters	MLE	Lower	Upper	CV
r	0.78	0.55	0.85	0.11
K	26.20	25.49	54.20	0.18
B_{msy}	13.10	12.75	24.61	0.18
Yield	5.14	3.10	11.17	0.29
fmsy	0.33	0.24	0.36	0.10
Sratio	0.64	0.34	2.47	0.39
Fratio	1.38	0.00	5.85	1.67
B_{2013}	8.32	4.11	46.01	0.47

Table 4. Striped marlin: 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 (4825 t ± 10%, ± 20%, ± 30% and ± 40%) projected for 3 and 10 years.

Projected Values	60%	70%	80%	90%	100% (4,825 t)	110%	120%	130%	140%
$B_{2016} < B_{MSY}$	7%		7%		8%		7%		7%
$F_{2016} > F_{MSY}$	14%		14%		15%		14%		24%
$B_{2023} < B_{MSY}$	14%		14%		15%		17%		33%
$F_{2023} > F_{MSY}$	14%		14%		15%		20%		37%

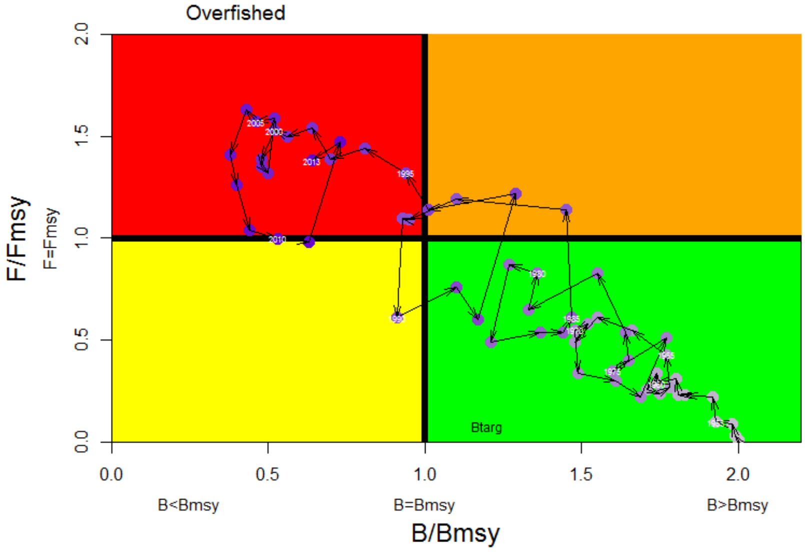

Figure 11. Stock Trajectory for Striped Marlin using the base run (MLE) and CPUE from Japan LL.

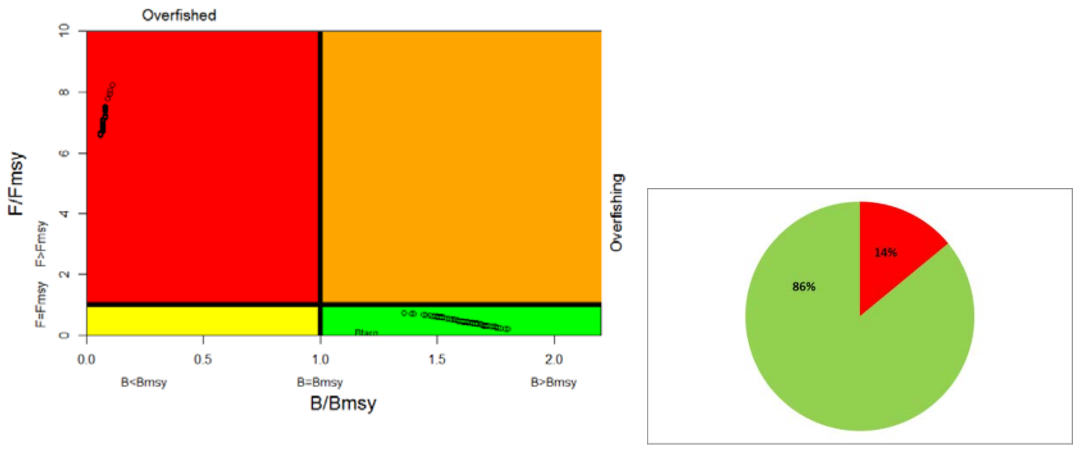

Figure 12. Final trajectory of all runs using Japanese LL series. There appears to be two clusters which indicate that the stock is in contrasting status. Inset shows the number of bootstrap runs that indicate how many times the stock was in the green versus the red quadrant in 2013.

Discussion

Striped Marlin are ***overfished*** irrespective of whether we use the Japanese LL or Taiwanese LL CPUE series. However, SP Models have problematic convergence issues, and appear to have two modes for the distribution based on a high r and low K value or a high K and low r value. Based on the assessments run in 2012, the catches indicated to be higher than those used in the last assessment for recent years, it is likely that the stock is ***overfished*** and ***subject to overfishing***. However, if we use the FishBase (www.fishbase.org) estimates of r, then the stock can be extremely productive (r=1.4), and could be indicative that the stock is healthy and not ***subject to overfishing*** or is not **overfished**. Both the Taiwanese LL data, and the Japanese LL data indicate that either conclusion is likely (~50% to be in either the red or green zone (Figure 7 and 11 respectively).

However, given the status of other Striped Marlin stocks in other oceans (Pacific), it is unlikely that the stock is not being overfished nor being subject to overfishing. Using the precautionary approach to management, we would recommend indicating that the stock is ***overfished*** and ***subject to overfishing***.

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