CONTINUITY RUNS OF THE ANDRADE (2016) BAYESIAN STATE-SPACE SURPLUS PRODUCTION MODEL ASSESSMENT OF INDIAN OCEAN BLUE MARLIN (*MAKAIRA NIGRICANS*) STOCK USING *JABBA*

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SUMMARY

Continuity between consecutive stock assessments is fundamental to tracking stock status over time. Here we attempt to create a continuity assessment of the 2016 Bayesian State-Space Surplus Production Model assessment of the Indian Ocean blue marlin (*Makaira nigricans*) documented in Andrade (2016) using the open-source stock assessment tool JABBA. All JABBA scenarios produced B/B_{MSY} trajectories that steadily declined from the mid 1970's to around 2008 before increasing to the 2015 B/B_{MSY} estimates and all scenarios produced F/F_{MSY} trends that steadily increased from 1980 to 2015. The Schaefer informative JABBA scenario indicated that the stock was "subject to overfishing" in 2015 but not overfished - the WPB14 decided that the equivalent Andrade (2016) scenario would be used to provide management advice. The point estimates between the models were comparable B/B_{MSY}: *JABBA = 1.13; Andrade = 1.11* and F/F_{MSY}: *JABBA = 1.26; Andrade = 1.18*. Thus, JABBA was able to accurately recreate the Andrade (2016) assessment of Indian Ocean blue marlin. Notwithstanding severe data conflict in recent years (2016-2018), a 2019 blue marlin assessment using JABBA should provide results comparable to projections from previous assessments. This is important to evaluate the efficacy of previous management recommendations to the IOTC Commission.

KEY WORDS

Stock status, CPUE fits, diagnostics, process error, stochastic biomass dynamics

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1. Introduction

In 2016, the Indian Ocean Commission (IOTC) carried out an assessment for blue marlin (*Makaira nigricans*) by employing three different model types; the Surplus Production Model (SPM) software ASPIC (Prager 1994) without process error, customized Bayesian State Space Production Model (BSPM) with process error (Andrade 2016), and the statistical age-structured model Stock Synthesis (Methot and Wetzel, 2013) . The assessment comprised catch and effort data through 2015 and estimated management reference points (IOTC, 2016).

Management advice was based on the results from the Bayesian State Space Production Model (BSPM) with a Schaefer-type production function, which indicated that the catches in 2016 (15,706 t) were above MSY and that the stock was overfished in the past and that currently it is "subject to overfishing". The WPB noted that the fluctuations in the Kobe trajectory were unusual, suggesting that the production model is too simple to adequately explain the data. Alternatively, the reason might be because the Kobe diagram plots the mean/median of B/B_{MSY} ratio against the mean/median of F/F_{MSY} ratio.

In 2019, the IOTC WPEB plans to reassess the blue marlin stock and we intend to provide an assessment using the Bayesian State-Space Surplus Production Model software 'JABBA' (Winker et al. 2018a; Just Another Bayesian Biomass Assessment) as an option. To ensure continuity with previous assessments, we recreate the 2016 BSPM assessment of the Indian Ocean blue marlin stock using JABBA. JABBA is implemented as a flexible, user-friendly open-source tool that is hosted on GitHub (https://github.com/jabbamodel) that has also been included in the ICCAT stock catalogue (https://github.com/ICCAT/software/wiki/2.8-JABBA), following a number a number of recent tuna RFMO stock assessments, including the 2018 striped marlin and black marlin assessments for the IOTC (Parker et al., 2018a &2018b).

2. Material and Methods

Data

The 2016 BSPM input data, in the form of time series of aggregated catches (1950-2015) and standardized catch-per-unit-effort (CPUE) from Japan (1971-2015) and Taiwan (1978-2015), were extracted from the IOTC stock assessment dataset repository of the 14th Meeting on of Working Party on Billfish (https://www.iotc.org/meetings/14th-working-party-billfish-wpb14). Details on the standardization procedure of CPUE indices are presented in Yokoi et al. (2016) and Wang (2016), respectively.

Model Scenarios

Andrade (2016) presented four scenarios for the BSPM model: two were based on non-informative priors for the intrinsic rate population increase *r* (NI) and the other two on informative lognormal priors for *r* (INF). The non-informative *r* priors were fitted with uniform priors over between 0 and 2, while in informative lognormal priors had a mean of log(0.4) and a standard deviation of 0.3. Each set of the two INF and two NI scenarios were fitted with a Fox and Schaefer model, respectively. The prior on the unfished biomass had been assumed to be uniform with bounds at 18000 t and 20 × 18000 t. Observation variance was assumed to be common for both time series and thus estimated as a single parameter. The state-space framework enables to simultaneously estimate the process and observation variance, which were both associated with the same inverse-gamma priors with scale and shape parameters of 8 and 0.1, respectively. This corresponds to a prior mean of 0.44^2, with a CV of 153%. Catchability parameters q_i for each CPUE index i were estimated separately assuming a wide uniform distribution.

To implement the JABBA continuity runs of the 2016 BSPM scenarios by Andrade (2016), we opted to match the original parameterization as closely as possible (Table 1). Just like the BSPM, JABBA is formulated based on the Bayesian state-space estimation framework proposed by Meyer and Millar (1999) and implemented in JAGS (Plummer, 2003). However, both models differ slightly with regards the implemented prior and variance parameterization user options in JABBA. Similar to the BSPM, JABBA permits the specifications of r and K priors as lognormal distributions or ranges. However, contrary to the BSPM, JABBA purposefully omits uniform prior distributions on K and r in favour of improved convergence properties and, instead, converts the input ranges into lognormal priors, with the lower and upper bounds of the range representing the 2.5^{th} and 97.5^{th} percentiles of the lognormal, respectively (See Eq. 13 in Winker et al. 2018). Whether the corresponding lognormal prior is informative or non-informative ("flat") depends on the width of the range. The larger the difference between lower and upper values, the less informative is the prior. Here, we adapted the same range for the K prior and the NI r priors as by Andrade (2016), whereas the INF r priors are chosen to be exactly the same.

Another difference is in the treatment of observation variance. JABBA provides additional flexible by enabling to decompose the observation variance into the externally estimated standard errors on CPUE, a minimum realistic fixed variance and an estimable "additional" variance, which can be set to be CPUE index specific or a single estimate as in Andrade (2016). However, other than in Andrade (2016), the JABBA prior for the estimable variance is by default a non-informative inverse-gamma prior with a scale and shape of 0.0001. To prevent adjusting the JABBA source code, we estimated the observation variance as the sum of estimable variance with a non-informative prior and a minimum fixed observation variance of 0.15^2, so as to closer resemble the higher central tendency of the informative observation variance prior. The JABBA prior choices for the process variance and q were those used by Andrade (2016).

Model fitting

The continuity runs were conducted with the most recently updated version (v1.5 Beta) of JABBA, available under: www.github.com/henning-winker/JABBAbeta. Each model was run for 30,000 iterations, sampled with a burn-in period of 5,000 for each of two chains and subsequently saving every 5th step to attain a joint posterior of 10,000 save values. Basic diagnostics of model convergence of the MCMC chains, including visualization of the MCMC chains throughout trace-plots, Heidelberger and Welch (Heidelberger and Welch, 1992) and (Geweke, 1992) and Gelman and Rubin (1992), indicated that all continuity had converged adequately, associated with a run time of under 2 minutes per scenario.

3. Results and Discussion

Nominal catches of blue marlin remained relatively low with stable inter-annual variability from the mid 1950's to 1980, thereafter increasing to the highest recorded catch of 14,739 tons in 2012 (Figure 1). Standardized catch rates based on the Japanese longline and on Taiwanese longline datasets were provided as input data for stock assessment models (Figure 2). The Japan CPUE decreased from 1970 to 2005, but there was a slight increasing trend after mid 2000's. In contrast, the Taiwan CPUE decreased from 1980 until the beginning of 1990's, thereafter it remains stable until 2010 when it increases sharply. Both CPUE time series were similar in the beginning and in the end of the time series, but data conflict was apparent between 1992 and 2005.

The MSY estimates derived from all four JABBA scenarios ranged between 10,538 (Schaefer NI) and 11,639 (Fox INF) (Table 2). The F/F_{MSY} estimates ranged from 0.9 (Fox INF) to 1.35 (Schaefer NI), and the B/B_{MSY} estimates ranged from 1.11 (Schaefer NI) to 1.5 (Fox INF) for the JABBA assessment. All four of the scenarios produced B/B_{MSY} trajectories that steadily declined from the mid 1970's to around 2008 before increasing to the 2015 B/B_{MSY} estimates. Similarly, all four scenarios produced F/F_{MSY} trends that steadily increased from 1980 to 2015.

The IOTC WPB14 decided that the Schaefer model with the informative prior from the Andrade (2016) model would be used to provide management advice. Results from the equivalent JABBA scenario (Schaefer INF) indicated that the stock was "subject to overfishing" in 2015 but not overfished, as did Andrade (2016). Furthermore, B/B_{MSY} *(JABBA = 1.13; Andrade = 1.11)* and F/F_{MSY} *(JABBA = 1.26; Andrade = 1.18)* estimates were comparable between models. Thus, JABBA was able to accurately recreate a continuity assessment of the Andrade (2016) assessment of Indian Ocean blue marlin. As point estimates were not available for scenarios other than the Schaefer informative in Andrade (2016), our comparison for alternative scenarios are largely based on the JABBA Kobe plot trajectories (1950-2015) of B/B_{MSY} and F/F_{MSY} (Figure 5) which closely follow those provided by the Andrade (2016) assessment (Appendix 1).

The two models compared differ in that JABBA purposefully translates prior ranges for *K* and *r* into lognormal priors, assuming that the bounds represent the lower and upper 10th and 90th percentile of lognormal (c.f. Meyer and Miller 1999). However, this change form uniform to 'flat' log-normal prior distributions seems to have little effect on the stock status, but may partially explain the satisfactory convergence of JABBA at only 10% of the MCMC thinning rate required for the BSPM by Andrade (2016).

These results indicate that JABBA is able to provide a suitable continuity assessment to the Andrade (2016) assessment. Notwithstanding severe data conflict in recent years (2016-2018), a 2019 blue marlin assessment using JABBA should provide results comparable to projections from previous assessments. This is important to evaluate the efficacy of previous management recommendations to the IOTC Commission.

4. References

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Yokoi H, Semba Y, Satoh K and Nashida T, (2016). Standardization of catch rate for blue marlin (*Makaira mazara*) exploited by the Japanese tuna longline fisheries in the Indian Ocean from 1971 to 2015. IOTC–2016–WPB14–22.

5. Tables

Table 1. Summary of JABBA prior specifications for the four continuity run scenarios of the 2016 Bayesian state-space production model assessment of Indian Ocean blue marlin (*Makaira nigricans*) by Andrade (2016). *denote ranges of minimum and maximum that were translated into lognormal distributions.

Scenario	Parameter	Prior	Specification
Fox NI	Pop. growth rate	lognormal*	$r \sim LN(\log(0.14),2.18)$; from range: 0.01 - 2
Fox INF		lognormal	$r \sim LN(\log(0.4),0.3)$
Schaefer NI		lognormal*	$r \sim LN(\log(0.14),2.18)$; from range: 0.01 - 2
Schaefer INF		lognormal	$r \sim LN(\log(0.4),0.3)$
All	Unfished biomass	lognormal*	$K \sim LN(\log(106557.8),0.75)$; from range: 18000 - 20×18000
All	Process variance	inv-gamma	$\sigma^2 \sim IG(0.001,0.001)$
All	Observation variance	inv-gamma	$\tau^2 \sim IG(0.001,0.001) + 0.15^2$
All	Catchability	uniform	$q \sim U(10^{-30},1000)$

Table 2. Summary of posterior quantiles denoting the 95% credibility intervals of parameter estimates for the Schaefer and the Fox models using informative (INF) and non-informative (NI) priors of intrinsic rate of population increase (*r*) for the JABBA assessment of blue marlin (*Makaira nigricans*) in the Indian Ocean.

		Fox NI			Fox INF	
Estimates	**Median**	**Median**	**2.50%**	**Median**	**2.50%**	**97.50%**
K	150002	73168	316010	97773	62158	187480
r	0.20	0.08	0.43	0.33	0.20	0.50
ψ (*psi*)	1.00	0.91	1.10	1.00	0.91	1.10
σ_{proc}	0.13	0.09	0.18	0.13	0.10	0.18
m	1	1	1	1	1	1
F_{MSY}	0.20	0.08	0.43	0.32	0.20	0.50
B_{MSY}	55210	26931	116312	35987	22878	69005
MSY	11008	7361	15856	11639	9355	17104
B_{1990}/K	0.99	0.76	1.29	1.00	0.75	1.30
B_{2016}/K	0.54	0.37	0.74	0.55	0.40	0.76
$B_{2016}/B_{\mathrm{MSY}}$	1.47	1.02	2.01	1.50	1.07	2.05
$F_{2016}/F_{\mathrm{MSY}}$	0.98	0.56	1.76	0.90	0.49	1.41
		Schaefer NI			**Schaefer INF**	
Estimates	**Median**	**Median**	**2.50%**	**Median**	**2.50%**	**97.50%**
K	170409	83823	444555	118179	71090	221870
r	0.25	0.07	0.53	0.37	0.22	0.61
ψ (*psi*)	1.00	0.91	1.10	1.00	0.91	1.10
σ_{proc}	0.13	0.09	0.18	0.13	0.10	0.18
m	2.00	2.00	2.00	2.00	2.00	2.00
F_{MSY}	0.13	0.04	0.27	0.19	0.11	0.31
B_{MSY}	85205	41911	222277	59089	35545	110935
MSY	10538	6114	15445	11046	8581	15722
B_{1990}/K	0.99	0.75	1.29	1.00	0.75	1.30
B_{2016}/K	0.56	0.36	0.76	0.57	0.42	0.76
$B_{2016}/B_{\mathrm{MSY}}$	1.11	0.73	1.52	1.13	0.83	1.53
$F_{2016}/F_{\mathrm{MSY}}$	1.35	0.78	2.76	1.26	0.75	1.93

6. Figures

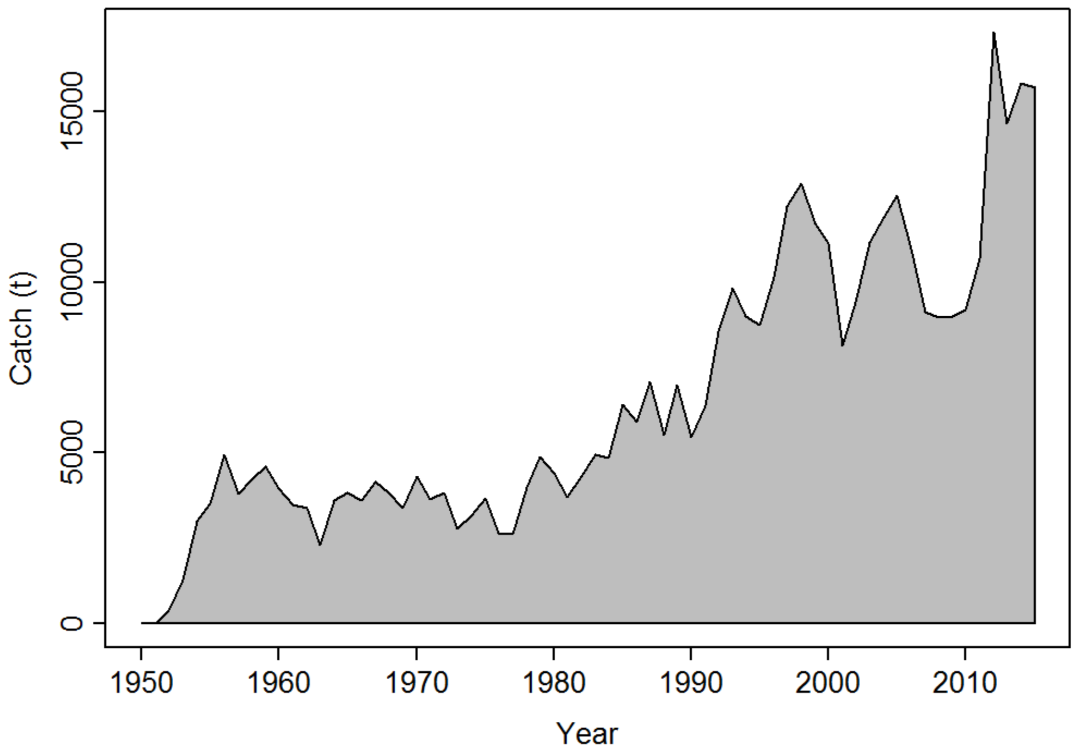


Figure 1. Time series of estimated catch in metric tons (t) for Indian Ocean blue marlin (1950-2015) used for the continuity assessment of the Andrade 2016 assessment.

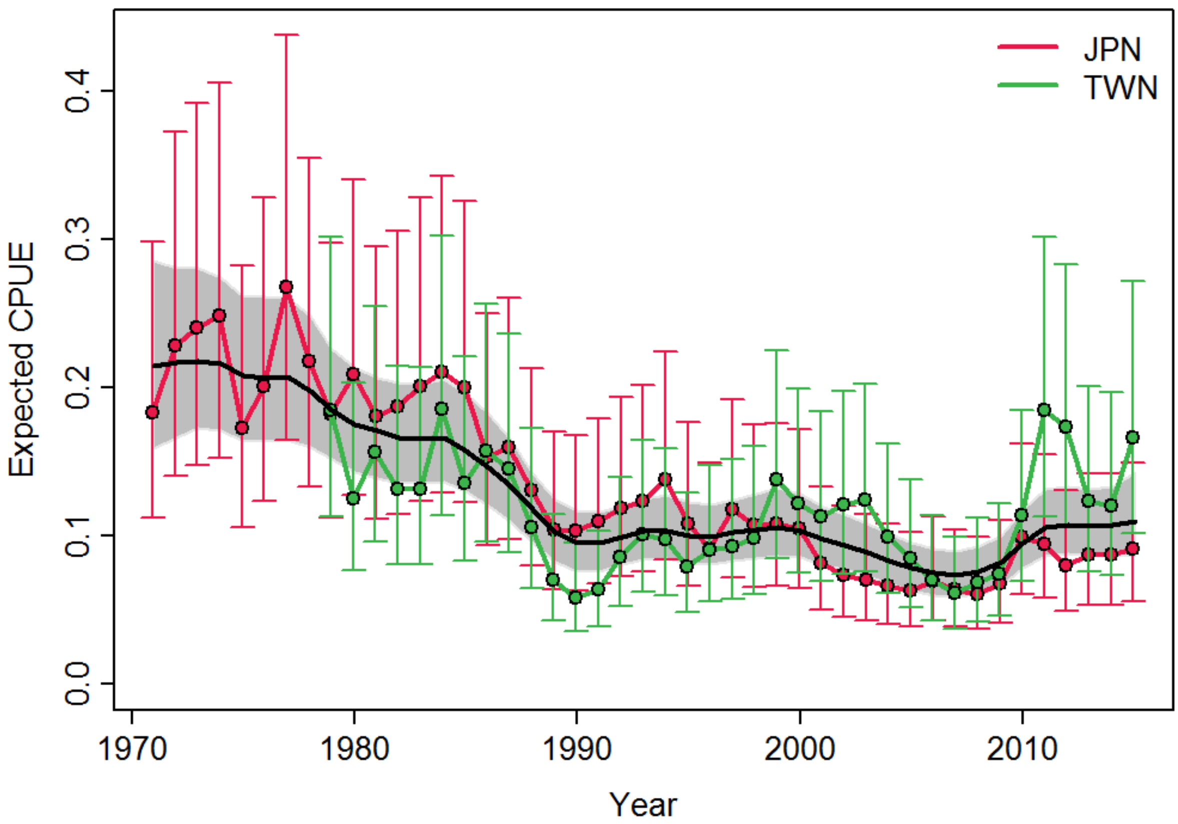


Figure 2. Time-series of two standardized CPUE series (JPN & TWN) for blue marlin in the Indian Ocean. The mean CPUE trend (solid black line) was produced using the state-space CPUE averaging tool implemented in JABBA. The underlying abundance trend is treated as an unobservable state variable that follows a log-linear Markovian process, so that the current mean relative abundance was assumed to be a function of the mean relative abundance in the previous year, an underlying mean population trend and lognormal process error term. The CPUE indices are aligned with the base index via estimable catchability scaling parameters.

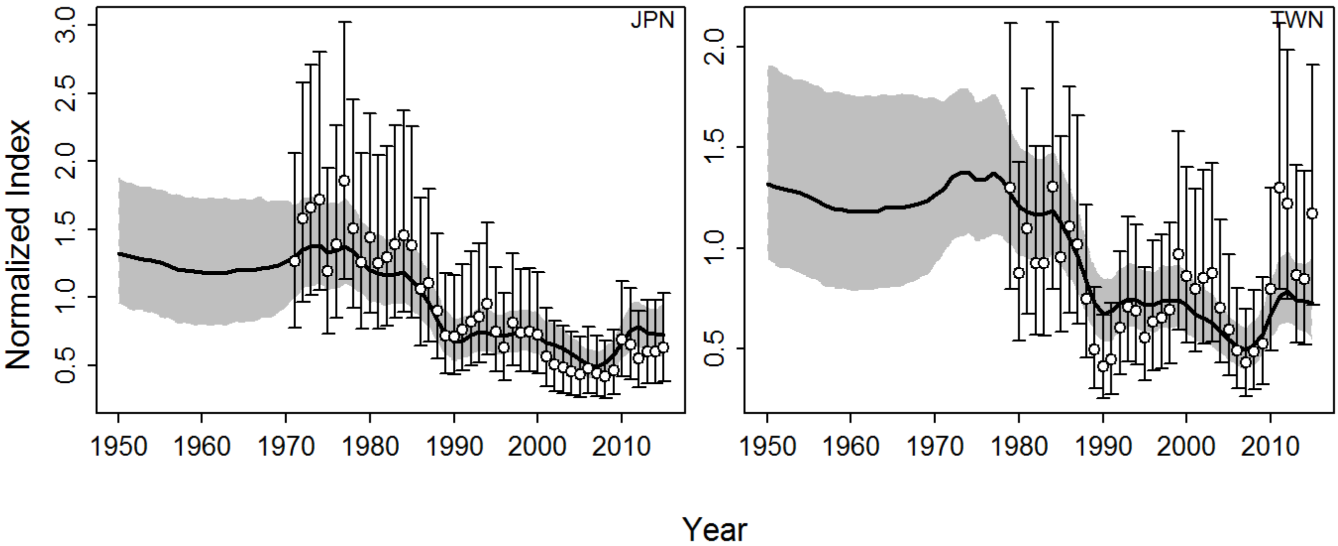


Figure 3. Time-series of observed (circle and SE error bars) and predicted (solid line) CPUE of blue marlin in the Indian Ocean for the Bayesian state-space surplus production model JABBA. Shaded grey area indicates 95% C.I.

Figure 4. Predicted trajectories of F/F_{MSY} and B/B_{MSY} for the Schaefer and the Fox models using informative (INF) and non-informative (NI) priors of intrinsic rate of population increase (*r*) for the JABBA continuity assessment of Andrade (2016) for blue marlin in the Indian Ocean. Grey shaded areas denote 95% CIs.

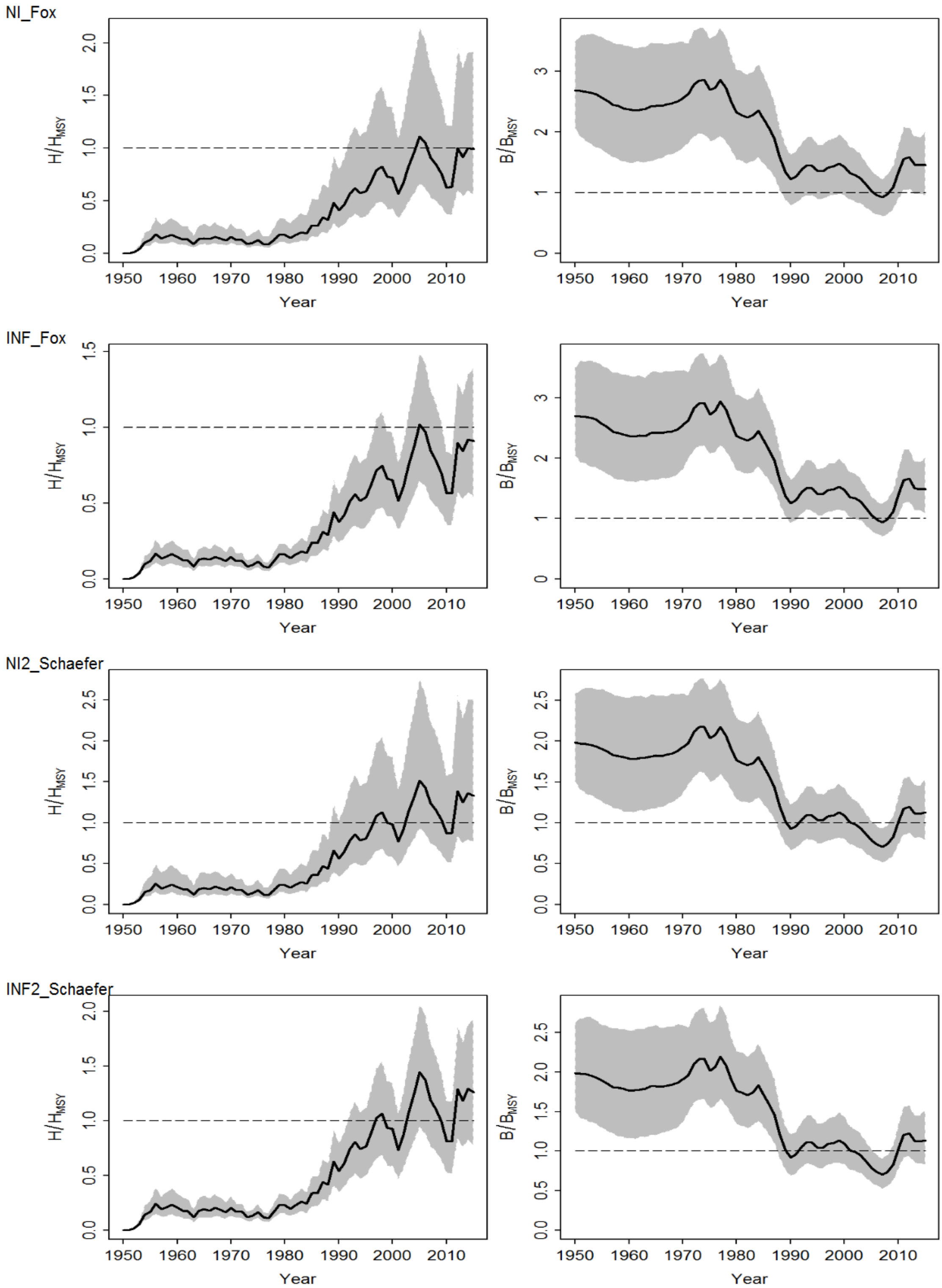
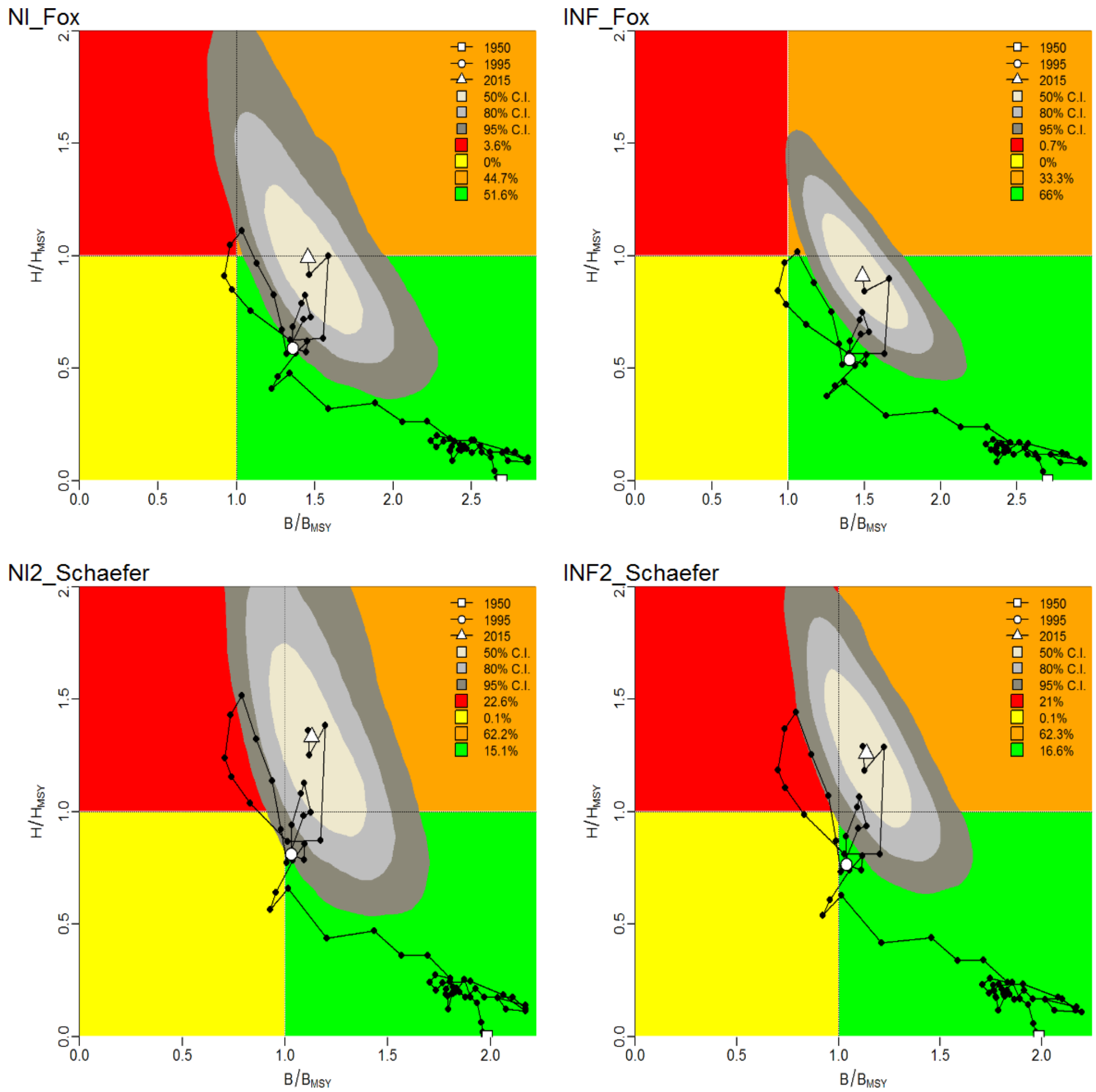


Figure 5. Kobe diagram showing the estimated trajectories (1950-2015) of B/B_{MSY} and F/F_{MSY} for the Schaefer and the Fox models using informative (INF) and non-informative (NI) priors of intrinsic rate of population increase (*r*) for the JABBA continuity assessment of Andrade (2016) for the Indian Ocean blue marlin stock.



7. Appendices

Appendix 1: Kobe plots from the Andrade (2016) assessment.

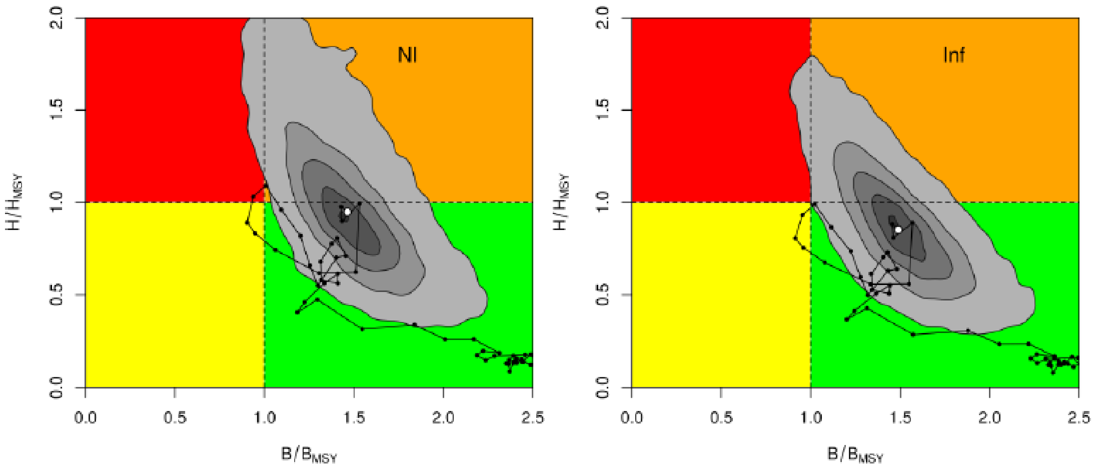


Figure 16 – Contour plots of posteriors of H/H_{MSY} and B/B_{MSY} calculated based on Fox type model. Solid lines and filled circles stand for the trajectories of marginal medians. NI – non-informative prior; Inf – Informative prior.

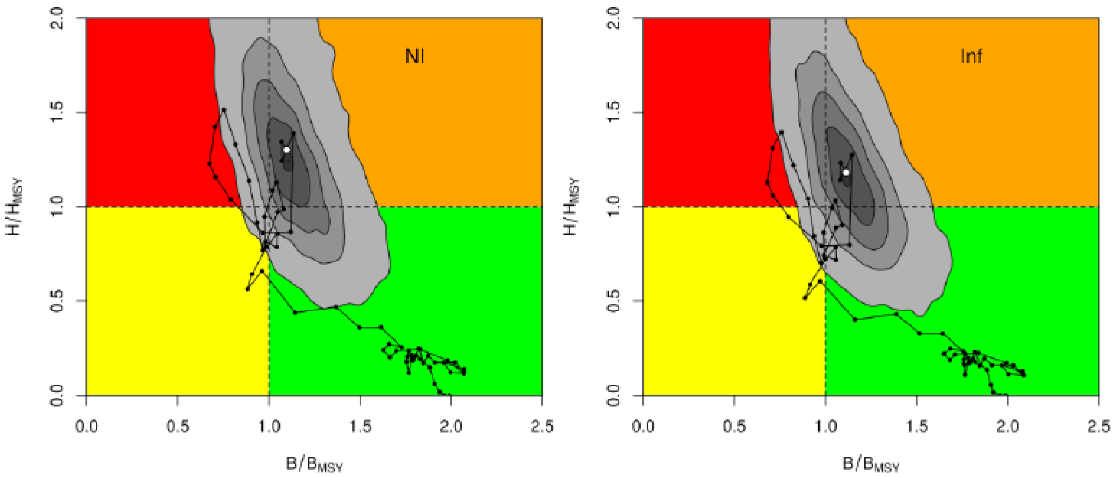


Figure 17 – Contour plots of posteriors of H/H_{MSY} and B/B_{MSY} calculated based on Schaefer type model. Solid lines and filled circles stand for the trajectories of marginal medians. NI – non-informative prior; Inf – Informative prior.

Appendix 2: Point estimates from the Schaefer informative scenario of the Andrade (2016) assessment.

Management Quantity	Indian Ocean
2015 catch estimate	15,706
Mean catch from 2011–2015	14,847
MSY (1000 t) (80% CI)	11.926 (9.232 – 16.149)
Data period used in assessment	1950 – 2015
F_{MSY} (80% CI)	0.109 (0.076 – 0.160)
B_{MSY} (1000 t) (80% CI)	113.012 (71.721 – 161.946)
F_{2015}/F_{MSY} (80% CI)	1.18 (0.80 – 1.71)
B_{2015}/B_{MSY} (80% CI)	1.11 (0.90 – 1.35)
SB_{2015}/SB_{MSY}	n.a.
B_{2015}/B_{1950} (80% CI)	0.56 (0.44 – 0.71)
SB_{2015}/SB_{1950}	n.a.
$B_{2015}/B_{1950,\ F=0}$	n.a.
$SB_{2015}/SB_{1950,\ F=0}$	n.a.