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A preliminary stock assessment of Kawakawa (*Euthynnus affinis*) in the Indian Ocean

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Summary

This study conducted a preliminary assessment for the Indian Ocean Kawakawa by DCAC and CMSY methods. Monte Carlo simulation was used to integrate the uncertainty of some key parameters and potential assumptions. The results indicated that Kawakawa productivity was high, with the intrinsic rate of increase *r may larger than 1; The results are sensitive to the final depletion level, and most scenarios reveal that the average of the last three-year catch is higher than MSY, and stock status is also very close to overfished. Given the high uncertainty in the catch series, future assessments need to consider more date-limited methods based on the different sources of data and improve the statistics of abundance index data.*

Input Data

The nominal catch of Kawakawa collected by IOTC for 1950-2020 was selected in this study. The age and growth of Kawakawa have not been intensively investigated. Mann (2013) and Fishbase provided the record of longevity (t_{max}) of 6 years for Kawakawa in the South African water. We considered two empirical methods to calculate constant natural mortality(M) based on life-history information: (1) Then's (2015) method, i.e.,$M = 4.899{t_{max}}^{-0.916}$; (2) Hewett and Hoenig's (2005) method, i.e., $M = 4.22/t_{max}$. Zhou (2019) also provided the mean of M = 0.78 based on the review of the literature.

$$M = 4.899{t_{max}}^{-0.916} \quad (1)$$

$$M = \frac{4.22}{t_{max}} \quad (2)$$

Table 1. Natural mortality for Kawakawa in the Indian Ocean

Mean of M	Longevity	Methods	Resource
0.7		$M = \frac{4.22}{t_{max}}$	(Then et al, 2015)
0.78	6 Years	From literature	(Zhou et al, 2019)
0.95		$M = 4.899{t_{max}}^{-0.916}$	(Hewitt and Hoenig, 2005)

Methods

Most DLMs can be generally divided into three categories as follow: (1) Catch only methods (data-poor methods) which only rely on the catch time series; (2) Abundance-based methods (data-moderate methods) which additionally require relative abundance index. (3) length/age-based methods which fix the model with historical catch and length-frequency data without abundance. Given the lack of length-frequency data and representative abundance index data, The Commission recognized to use of data-poor, catch-based methods for neritic tunas stock assessment. Thus, we chose two catch-only models, DCAC (MacCall, 2009) and CMSY (Froese et al., 2017), as the probe in this trial study.

Depletion Corrected Average Catch (DCAC) model calculates a catch limit (Y_{sust}; intended as an MSY proxy) based on the average historical catch while accounting for the windfall catch that got the stock down to its current depletion level (D).

The method calculates the sustainable Yield (Y_{sust}) as:

$$Y_{sust} = \frac{\sum Catch}{n + \Delta B_0/Y_{pot}} = \frac{\sum Catch}{n + \frac{\Delta}{0.4cM}}$$

Where

$$\Delta = \frac{B_{FYR} - B_{LYR}}{B_0}$$

$$Y_{pot} = 0.4cMB_0$$

and $Catch$ is the historical catches. c is the ratio between F_{MSY} and M, and equal to 0.4 for most teleost. For the depletion (Δ), we assumed three different levels to cover the uncertainty in the model and followed a Monte Carlo simulation. We assumed a normal distribution with 0.3 standard deviations and a lognormal distribution with 0.05 standard deviation for key parameter Δ and M respectively. A total of 9 scenarios were considered in our case by the DCAC method(Table 2).

Table 2 Model setting of DCAC method for Kawakawa in the Indian Ocean

Scenarios	M	Δ	SD
DCAC_20_M1	0.7	0.2	0.3
DCAC_40_M1	0.7	0.4	0.3
DCAC_60_M1	0.7	0.6	0.3
DCAC_20_M2	0.78	0.2	0.3
DCAC_40_M2	0.78	0.4	0.3
DCAC_60_M2	0.78	0.6	0.3
DCAC_20_M3	0.95	0.2	0.3
DCAC_40_M3	0.95	0.4	0.3
DCAC_60_M3	0.95	0.6	0.3

CMSY is used as an alternative method for this assessment. We used estimated M to conduct an informative prior distribution for intrinsic rate of increase r, where $r = 2\omega M$ and ω equal to 0.87 for teleost. Besides, we also assumed a uniform distribution of U[0.2, 0.8] for parameter r as the non-informative prior. For the carrying capacity K, we used the 95% confidence interval of the prior information as the bounds of r (r_{low} and r_{high})and highest catch (Max_{catch})to generate a prior of K with uniform distribution.

$$K_{low} = \frac{Max_{catch}}{r_{high}}, K_{high} = \frac{4Max_{catch}}{r_{low}}$$

We assumed the almost unfished condition at the beginning of the assessment, where B_{sta}/B_0 followed a uniform distribution of U[0.7, 1]. For the last year in the assessment, we used the CMSY rule based on the ratio of last year to the highest year. Given the ratio is higher than 0.7, we assumed a uniform distribution of U[0.5, 0.9] for B_{last}/B_0 and an alternative distribution of U[0.2, 0.6]. A total of eight scenarios were considered in our CMYS model(Table3).

Table 3 Model setting of CMSY method for Kawakawa in the Indian Ocean

Scenarios	*M*	*r*	K_{low}	K_{high}	B_{sta}/B_0	B_{last}/B_0
CMSY_1	0.7	norm[1.22,0.2]	202071	2309386	U[0.7,1]	U[0.2,0.6]
CMSY_2	0.78	norm[1.36,0.2]	183701	1999880	U[0.7,1]	U[0.2,0.6]
CMSY_3	0.95	norm[1.65,0.2]	159268	1551907	U[0.7,1]	U[0.2,0.6]
CMSY_4	-	U[0.2,0.8]	404142	9699420	U[0.7,1]	U[0.2,0.6]
CMSY_5	-	U[0.6,1.5]	215542	3233140	U[0.7,1]	U[0.2,0.6]
CMSY_6	-	U[0.6,1.5]	215542	3233140	U[0.7,1]	U[0.5,0.9]

Results

DCAC method can not provide the status for the stock, but it can usually suggest more rigorous advice in some rebuilding plans if needed. Given the limited exploitation before the 1990s in Indian Ocean Karankawa, a relatively low average historical harvest lead to a pessimistic result while the median of Y_{sust} ranged from 75,497t to 82,087 t in all the scenarios.

For the CMSY method, the potential assumption of final depletion (B_{last}/B_0) caused the most uncertainty, and this parameter can perhaps affect the decision of stock status directly. For most scenarios (except CMSY_6), the geometrical mean of MSY ranged from 128,125 to 151,853, and all of them are lower than the mean Catch from 2018 to 2020($C_{2018\text{-}2020}$ = 157,008). Similar to the result of fishing mortality, the result based on biomass also indicated the status is or close to overfished. In general, two scenarios (CMSY_4 and CMSY_5) indicated the stock status is overfishing and overfished, and three scenarios (CMSY_1, CMSY_2, and CMSY_3) indicated the stock status is overfishing but not overfished. Given the high final depletion, the posterior distribution of CMSY_6 prefers a large and flat tail of the carrying capacity, but it would exceed the bound of the prior.

Table.4 Summary of sustainable yield for Kawakawa in the Indian Ocean (t)

Scenarios	Mean	Median	95%CI upper	95%CI lower
DCAC_30_M1	79793	81272	63228	87073
DCAC_50_M1	75875	78268	54587	83289
DCAC_70_M1	72552	75497	45916	81527
DCAC_30_M2	80239	81549	65193	86579
DCAC_50_M2	76537	78717	55830	83437
DCAC_70_M2	73338	76112	48083	81757
DCAC_30_M3	81013	82087	68717	86420
DCAC_50_M3	77838	79779	59705	83670
DCAC_70_M3	74904	77470	51346	82210

Table.5 Summary of biological reference points of CMSY methods for Kawakawa in the Indian Ocean (t)

Scenarios	CMSY_1	CMSY_2	CMSY_3	CMSY_4	CMSY_5	CMSY_6
r	1.53	1.71	1.99	0.61	1.25	1.25
*r*_CV	16.53	14.45	12.06	40.27	26.79	21.10
K	388163	350100	304886	842332	465766	697291
*K*_CV	16.27	14.36	12.13	32.06	24.07	20.72
MSY	148502	150013	151882	127654	145415	217720
B_{MSY}	194082	175050	152443	421166	232883	348645
B_{2020}_ B_{MSY}	1.00	1.01	1.03	0.94	0.98	1.49
F_{MSY}	0.77	0.86	1.00	0.30	0.62	0.62
F_{2020}/ F_{MSY}	1.09	1.06	1.03	1.35	1.13	0.50

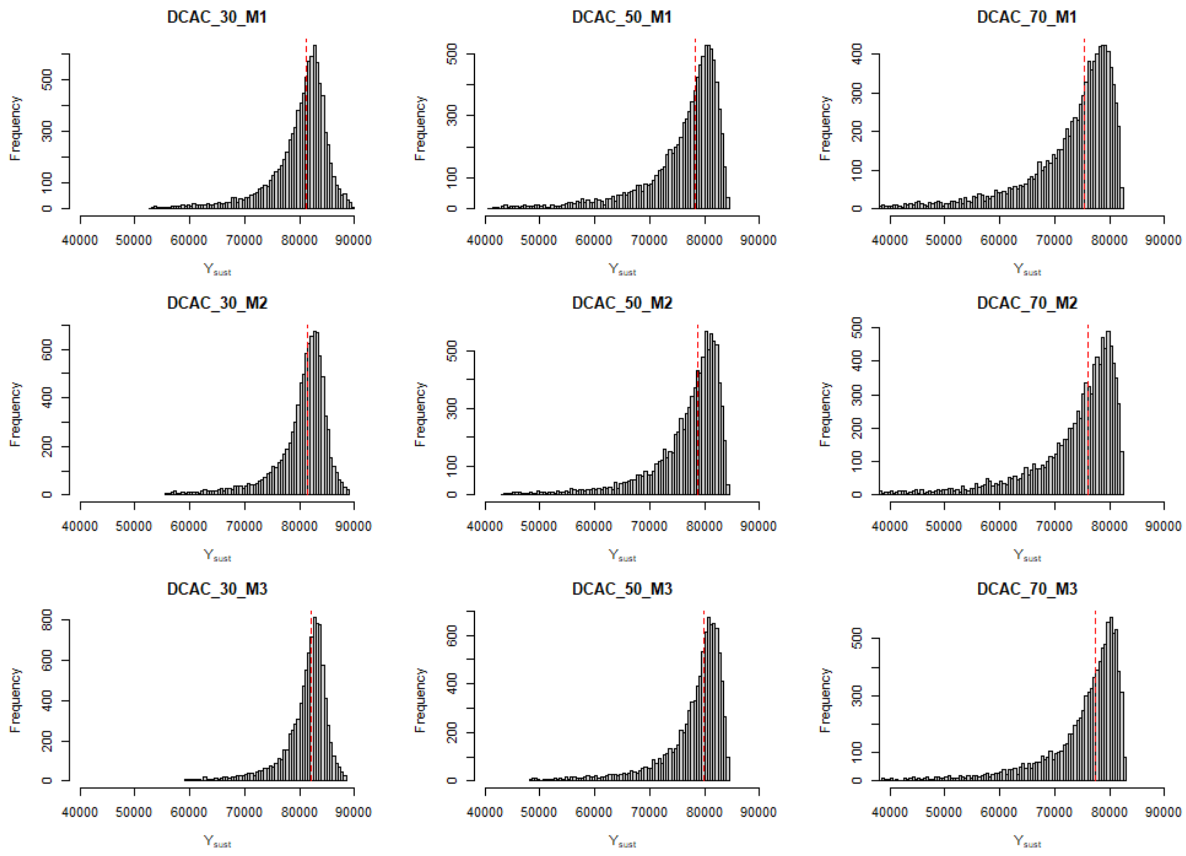

Figure 1 results from DCAC for Kawakawa in the Indian Ocean (red line indicate the median of sustainable yield)

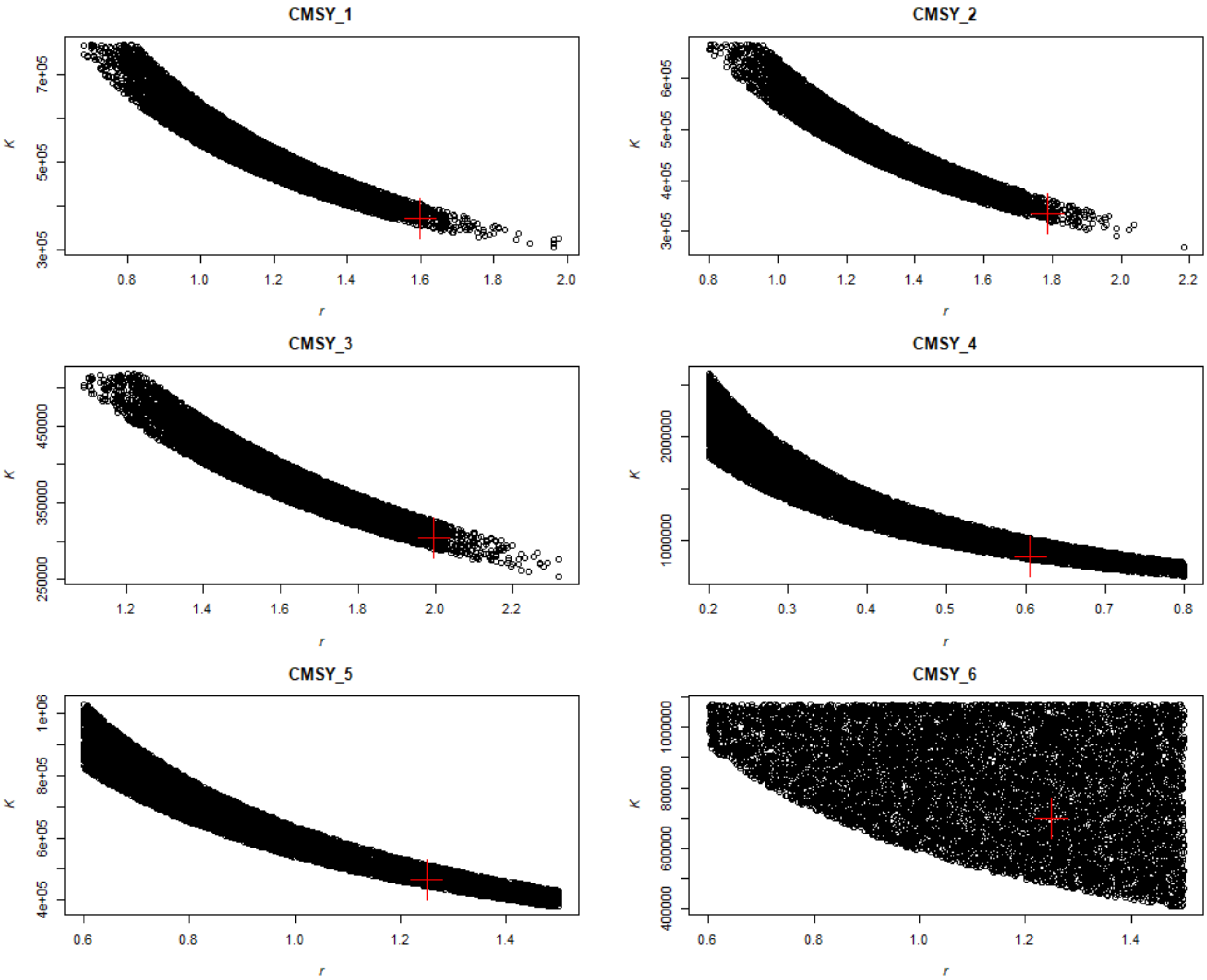

Figure 3. Posteriori distribution of *r*-*K* pairs in CMSY model

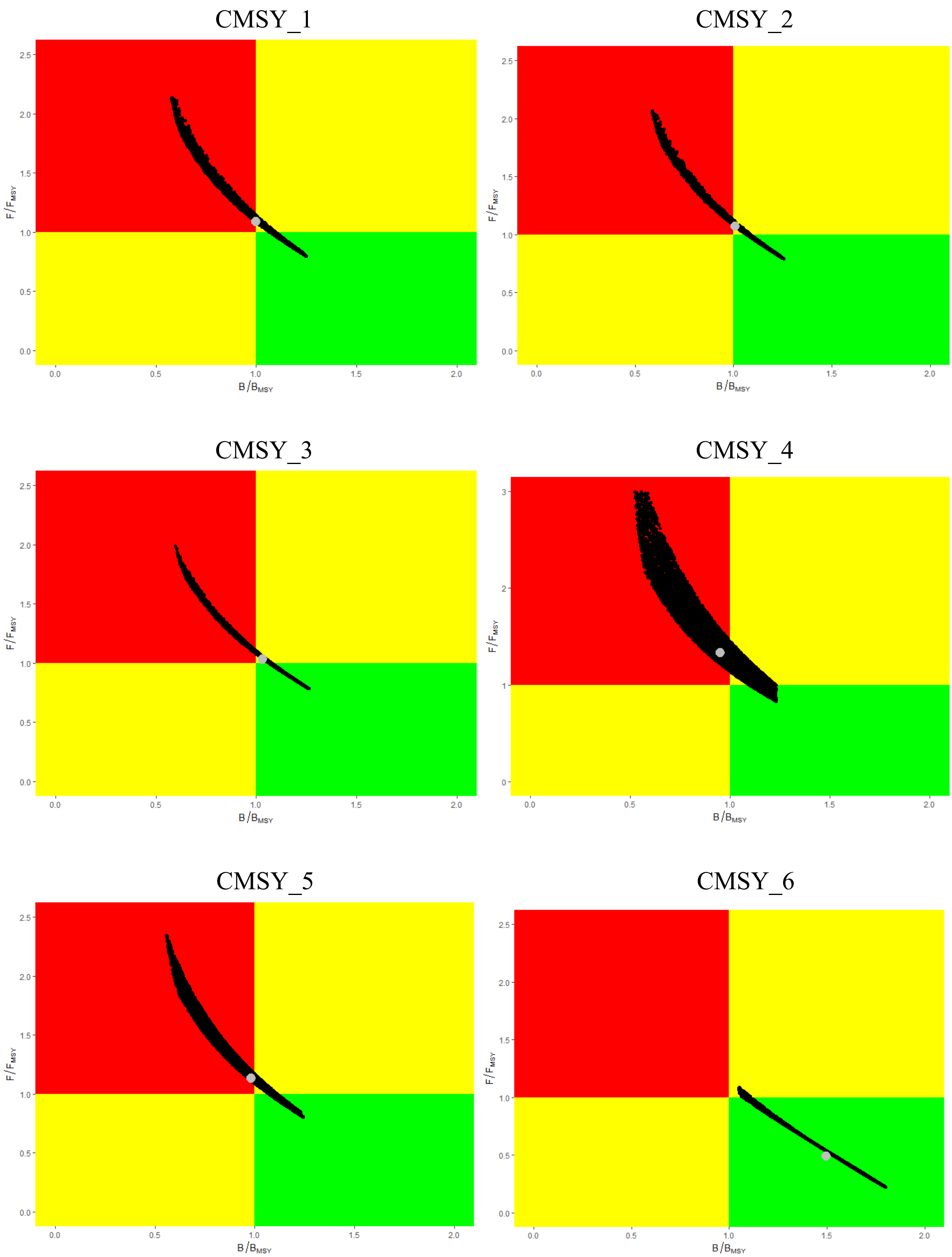

Figure 3. Kobe plot of CMSY method for Kawakawa

Acknowledgements

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