

Stock Assessment of Indian Ocean Narrow-Barred Spanish Mackerel (*Scomberomorus commerson*) using data-limited methods



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1. EXECUTIVE SUMMARY

In this stock assessment for narrow-barred Spanish mackerel (*Scomberomorus commerson*), a pelagic mackerel from the Scombridae, we have implemented the updated CMSY method (CMSY++; (Froese *et al.*, 2023)) that utilises both CMSY and a Bayesian Schaefer Model (BSM) separately, allowing for abundance indices to be incorporated if available, alongside gear creep (Froese *et al.*, 2023). We also implemented the JABBA model and one length-based method: the length-based spawning potential ratio model (LBSPR, (Hordyk *et al.*, 2015)). A separate analysis was completed to test a new Bayesian-based length-based model fishblicc (Fu, 2026; github.com/paulhmedley/fishblicc). Both length-based methods provide a useful monitoring tool for the stock in the final year of the assessment, rather than a time-series of stock status.

The assessment uses catch data from 1950 to 2024 and a standardised gillnet CPUE index from 2008-2017.

Estimates from the CMSY++ BSM model suggests that currently the stock of narrow-barred Spanish mackerel in the Indian Ocean is **not overfished** ($B_{2024} > B_{MSY}$) and is **not subject to overfishing** ($F_{2024} < F_{MSY}$). The estimates produced by the JABBA method, also suggest that the stock is **not overfished** ($B_{2024} > B_{MSY}$) and **not subject to overfishing** ($F_{2024} < F_{MSY}$).

The CMSY++ model estimated an average **MSY of ~ 155 000 t** which is lower than that estimated by JABBA (**168 000 t**). The 2024 catch (157 775 t) is close to that of MSY (from CMSY++) and higher than catches reported for the previous 10-15 years. The final year of catch is the highest ever recorded for narrow-barred Spanish mackerel in the latest iteration of the data, but it is lower than previous estimates of catch (e.g. 168 807 t were originally recorded for 2021 prior to revisions). It is likely that the revisions in catch data have driven the stock status to move towards a more optimistic outcome in 2026, given overall these have reduced long-term catches.

Estimates of stock status from the LBSPR method cannot be directly comparable to the catch-only models as they have made very different assumptions about target reference points. Nonetheless, the SPR estimated by the LBSPR method was below the SPR40% for gillnet fisheries, but above SPR40% for line fisheries, while fishing mortality is estimated to be much higher than F_{MSY} , in contrast to the result of the CMSY++ models.

Estimated spawning potential ratio throughout the time series is well below 0.4, indicating that the stock is depleted in relation to the risk-averse target (the SPR of 0.4 is often considered as a risk-averse target; see Hordyk *et al.* 2014a), and although the SPR increased 2009, mirroring the upward trend in the CPUE in the same time period, there has been a decrease in SPR from 2017 to 2024.

Based on a weight-of-evidence approach, it is likely that narrow-barred Spanish mackerel is, in 2024, **not overfished and not subject to overfishing** in the Indian Ocean. However, there are several caveats to this, stated below:

- a) Catch data have undergone significant revisions over time – the continued reduction in catch over time has moved the stock to a more optimistic status.
- b) The much higher reported catches in 2024 should be noted, as these represent catches very close to the estimated MSY, and are unlikely to be sustainable long term.



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- c) Length-based analyses suggest that the stock is likely to be overfished, however the representativeness of the length data in comparison to the entire Indian Ocean stock(s) needs to be fully evaluated.
- d) Recent work suggests there are likely several stocks of narrow-barred Indian Ocean Spanish mackerel, however catch, and length data are not reported at a fine-enough scale to capture individual stock dynamics. Additionally, representative abundance indices should be developed on a similar spatial scale to putative stocks.

2. INTRODUCTION

Assessing the status of the stocks of neritic tuna species in the Indian Ocean is challenging due to the paucity of data. There is a lack of reliable information on stock structure, abundance and biological parameters. Stock assessments have been conducted for Indian Ocean Narrow-Barred Spanish Mackerel (*Scomberomorus commerson*, COM) from 2013 to 2017, in 2020, and in 2023 using data-limited methods (Zhou & Sharma, 2013, 2014; Martin & Sharma, 2015; Martin & Robinson, 2016, Martin & Fu, 2017, 2020, 2023). In 2023, the CMSY method was used to assess the status of *S. commerson* using historical catches (Fu 2020). The 2023 assessment also explored several alternative methods including the Optimised Catch-Only method (Zhou *et al.*, 2018), Just Another Bayesian Biomass Assessment model (JABBA, (Winker, Carvalho and Kapur, 2018)), and the length-based spawning potential ratio model (LBSPR, (Hordyk *et al.*, 2015)). In addition to examining various population dynamic assumptions, these models allow for the evaluation of the usefulness of alternative data in determining the status of COM.

In this assessment, we have implemented the updated CMSY method (CMSY++; (Froese *et al.*, 2023)) that implements both CMSY and a Bayesian Schaefer Model (BSM) separately, allowing for abundance indices to be incorporated if available, alongside gear creep. The results were compared to an implementation of the CMSY method and were consistent, so we recommend using the CMSY++ method for following assessments.

We also implemented the JABBA model, although the model had difficulty fitting to the one abundance index available (a standardised gillnet CPUE index based on data from the Islamic Republic of Iran (I.R. Iran); Fu (2019)), possibly due to the short nature of the index compared to the catch data series, and the lack of representativeness of the index for the whole Indian Ocean population of Spanish mackerel.

We did not implement the Optimised Catch-Only method but did implement one length-based method: the length-based spawning potential ratio model (LBSPR, (Hordyk *et al.*, 2015)). A separate analysis was completed to test a new Bayesian-based length-based model fishblicc [Fu, 2026; github.com/paullmedley/fishblicc]. Both length-based methods provide a useful monitoring tool for the stock in the final year of the assessment, rather than a time-series of stock status.

The assessment uses catch data from 1950 to 2024 and a standardised gillnet CPUE index from 2008-2017.

2.1. Species Biology

Narrow-barred Spanish mackerel (*Scomberomorus commerson*) (Lacépède, 1800) are an epipelagic predatory mackerel from the Scombridae family. They are distributed widely in the Indo-Pacific region from shallow coastal waters to the edge of the continental shelf where they are found from depths of 10 – 70 m (McPherson, 1992). Spanish mackerel are relatively large for a neritic species with a maximum fork length of 240 cm, and within the Indian Ocean, they are primarily caught by gillnet fleets operating in coastal waters with the highest reported catches from Indonesia, India and the Islamic Republic of Iran (I.R. Iran, IOTC 2026). Most research has been focussed in these areas where there are important fisheries for the species, with the most common methods used to estimate growth being through length-frequency studies, although a few otolith ageing studies have also been undertaken (Brothers, 1990;

McPherson, 1992; Chale-Matsau, Govender and Beckley, 1999; McIlwain *et al.*, 2005; Lee and Mann, 2017).

Estimates of growth parameters for Spanish mackerel, using either length or age-based information, vary between geographic locations. Estimates of the growth parameter k in the von Bertalanffy growth model range from 0.12 (Edwards *et al.* 1985) to 0.78 (James *et al.*, 1993), with most studies suggesting relatively rapid growth of juveniles (IOTC 2015). Differences in studies are likely due to regional variation in growth patterns but may also be due to the different selectivity patterns of gears used to obtain the samples, as a variety of gears are used to catch Spanish mackerel in the Indian Ocean, such as drifting gillnets, hooks and lines, trolling and trawl gear.

Narrow-barred Spanish mackerel likely form several putative stocks within the Indian Ocean (Feutry *et al.*, 2025). Whether these stocks are from the same genetic population has not yet been elucidated. Due to the paucity of data available to the Secretariat relating to biological information (e.g. growth, age, age-at-length etc.), a lack of fine-scale fishery data, and one fishery-dependent index of abundance (standardised catch per unit effort, CPUE from the Iranian gillnet fishery), it is not possible to assess narrow-barred Spanish mackerel at a finer scale than the Indian Ocean currently. Future data collection, CPUE standardisation, and biological research could provide updated stock structure information, which would increase the potential of implementing spatially stratified stock assessments, alongside improved catch and effort data.

2.2. Fishery information

Disaggregated nominal catch data were extracted from the IOTC database for the period 1950–2024. Gillnet fleets are responsible for most of the reported catches of Spanish mackerel followed by line and purse seine gear, with most of the catch taken by coastal country fleets (Figure 1).

Indonesia, India and I.R. Iran together account for 64 % of catches in 2024. Figure 2 shows the total catch of narrow-barred Spanish mackerel since 1950, which increased to a peak of 152,502 t in 2016, then declined to 122,581 t in 2018, rising again to a peak in 2024 (157,775 t; Table 1). In 2019, IOTC endorsed the revisions of gillnet catch from Pakistan that introduced some changes in the catches of tropical tuna, billfish, as well as some neritic tuna species from 1987 (IOTC 2019). The Pakistani revision appears to have very minor effects on the Spanish mackerel nominal catch series since the last assessment (Figure 3).

Of major impact to fishery data has been the endorsed revisions of Indonesia’s catches for all historical data, with overall catches increased between 1950-2008 when compared to data used in 2020, after which the revised data shows much lower catches (Figure 3). In comparison to data used in 2023, catches are similar until the mid-1990s, when revised data has overall lower catches of narrow-barred Spanish mackerel in the Indian Ocean up to 2023. In 2024 a sharp increase in catch has been reported (Figure 3), mainly attributed to purse seine catches from Indonesia.

Fu *et al.* (2019) developed standardised CPUE indices for several neritic tuna species including Spanish mackerel from the I.R. Iran coastal gillnet fishery using the catch effort data collected from the port-sampling program. That analysis represented an effort to estimate a relative abundance index for neritic tuna stocks for potential use in stock assessments. The quarterly indices (2008–2017) for the Spanish mackerel tuna showed an increasing trend over time since 2011/12 (Figure 4), with a strong seasonal



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pattern driven mostly by the productivity cycle in the southern Gulf as well as market conditions (Fu et al. 2019). The annualised indices (by taking the average of the quarterly indices) were tested in the CMSY++ model but ultimately excluded from the reference model. The indices were included in the JABBA model (see Section 4.2).

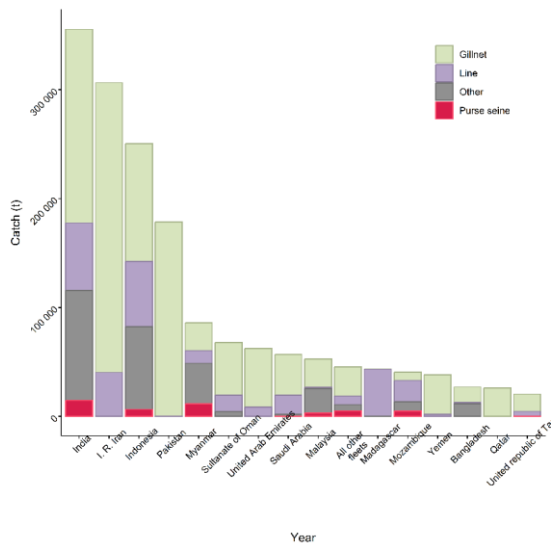


Figure 1: Average catches of narrow-barred Spanish mackerel (*Scomberomorus commerson*) in the Indian Ocean over the period 2012-2024, by country, and gear grouping.

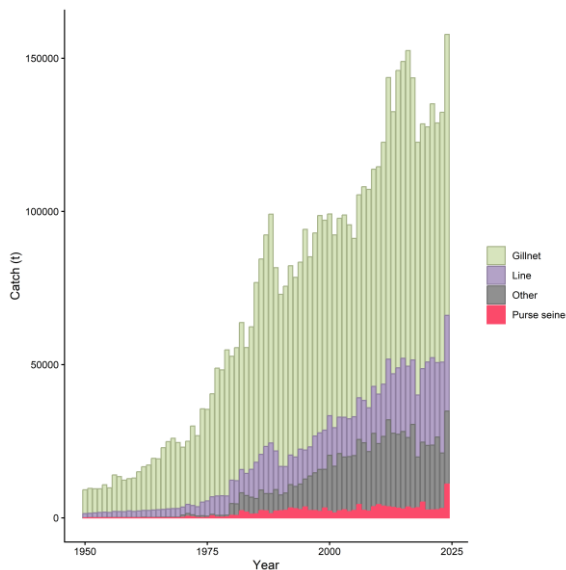


Figure 2: Total nominal catch of narrow-barred Spanish mackerel by gear grouping, 1950 – 2024 (IOTC database).

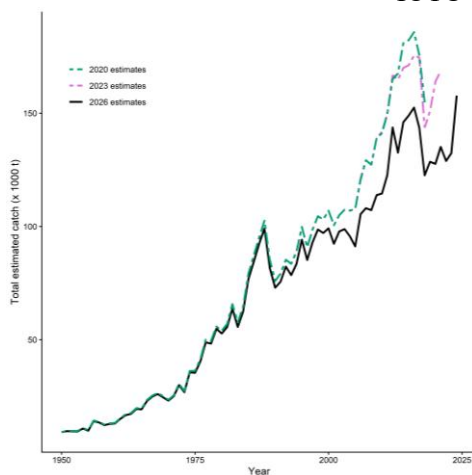


Figure 3: Revisions to IOTC nominal catch data for Spanish mackerel (datasets used for the 2020, 2023, and 2026 assessments, using data up to 2019, 2021, and 2024 respectively).

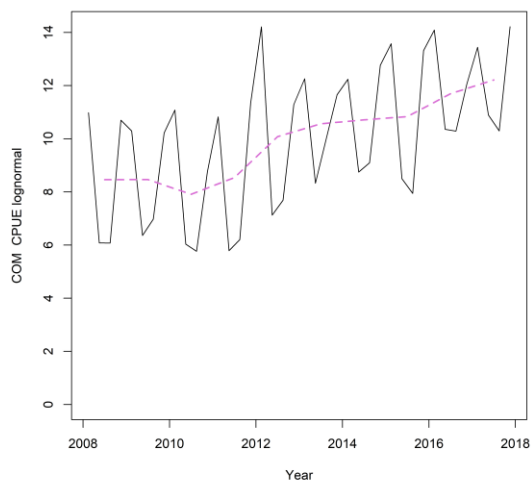


Figure 4: Standardised CPUE indices (year-quarter) for narrow-barred Spanish mackerel 2008–2017 from the GLM lognormal model. See Fu et al. (2019) for details. Purple dashed line represents the mean annual index.

Table 1. Catch data for narrow-barred Spanish mackerel (*Scomberomorus commerson*) in the Indian Ocean, 1950-2024 (source IOTC Database)

Year	Catch (t)	Year	Catch (t)
1950	9 155	1988	99 107
1951	9 635	1989	81 651
1952	9 498	1990	72 942
1953	9 475	1991	75 594
1954	10 793	1992	82 295
1955	9 798	1993	78 506
1956	14 013	1994	83 449
1957	13 475	1995	94 157
1958	12 288	1996	85 205
1959	12 811	1997	92 979
1960	13 000	1998	98 658
1961	15 044	1999	97 118
1962	16 684	2000	99 179
1963	17 245	2001	92 341
1964	19 405	2002	97 778
1965	19 238	2003	98 843
1966	22 914	2004	95 622
1967	24 880	2005	91 200
1968	25 983	2006	105 443
1969	24 580	2007	108 075
1970	23 064	2008	107 200
1971	24 994	2009	113 798
1972	29 964	2010	114 579
1973	26 817	2011	122 595
1974	35 570	2012	143 689
1975	35 406	2013	132 566
1976	40 490	2014	146 010
1977	48 850	2015	148 948
1978	48 278	2016	152 502
1979	54 802	2017	143 603
1980	52 749	2018	122 581
1981	55 549	2019	128 569
1982	63 749	2020	127 616
1983	55 600	2021	135 140
1984	62 347	2022	128 889
1985	76 786	2023	132 347
1986	84 491	2024	157 775
1987	92 337		

3. METHODS

3.1. CMSY

The CMSY method (Froese Rainer *et al.*, 2016) was applied to estimated reference points from catch, resilience and qualitative stock status information for narrow-barred Spanish mackerel (*Scomberomorus commerson*, hereafter Spanish mackerel, github.com/SISTA16/cmsy; version CMSY_2019_9f.R). The CMSY method represents a further development of the Catch-MSY method (Martell and Froese, 2013), with several improvements to reduce potential bias. Like the Catch-MSY method, The CMSY relies on only a catch time series dataset, which was available from 1950 – 2024, prior ranges of r and k , and possible ranges of stock sizes in the first and final years of the time series. The model does allow the addition of a biomass index, if one is available.

A modified Schaefer surplus production model (Schaefer, 1954) is used (Equation 1). This model combines the classic Schaefer surplus production model with a simple recruitment model to account for reduced recruitment at severely depleted stock sizes (Equation 2; Figure 5), where B_t is the biomass in time step t , r is the population growth rate, B_0 is the virgin (unexploited) biomass (equal to carrying capacity, k), and C_t is the known catch at time t . Annual biomass quantities can then be calculated for every year based on a given set of r and k parameters.

$$B_{t+1} = \left[B + r \left(1 - \frac{B_t}{K} \right) B_t - C_t \right] \quad \text{if } \frac{B_t}{K} > 0.25 \quad (1)$$

$$B_{t+1} = \left[B + 4 \frac{B_t}{K} r \left(1 - \frac{B_t}{K} \right) B_t - C_t \right] \quad \text{if } \frac{B_t}{K} \leq 0.25 \quad (2)$$

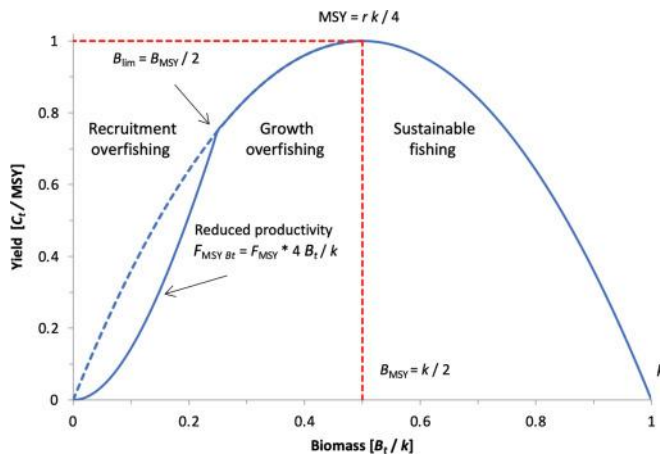


Figure 5: A schematic representation of the modified Schaefer surplus production model used by CMSY (Figure 2 from Froese *et al.*, 2023), that highlights the reduced productivity of a stock under recruitment overfishing where F_{MSY} reduces linearly with a decline in biomass.

The prior range for r was estimated using the life-history module (github.com/cttedwards/lhm) developed by C.T.T. Edwards. The model implements Monte Carlo Markov Chain (MCMC) sampling of life history parameter distributions, with iterated solving of the Euler-Lotka equation (McAllister, Pikitch and Babcock, 2001). The population parameters of Spanish mackerel (including growth, natural mortality, maturity, and length-weight relationship) are based on values collated and recommended by the IOTC (2015).

Froese (Froese *et al.*, 2023) proposes a classification of the stock resilience levels (SEE TABLE X) where stocks with a very low resiliency are allocated an r value of 0.05 – 0.5; medium resiliency $r = 0.2 – 1$ and high resiliency $r = 0.6 – 1.5$. Based on the FishBase classification (Froese and Pauly, 2025), Spanish mackerel has a high level of resilience, and so the r prior was set to 0.6–1.5. The LHM method produced similar values for r , and therefore for the CMSY / CMSY++ analyses, the prior range of r was set to 0.6 – 1.5.

The prior range of k was determined using the following (Equation 3):

$$k_{low} = \frac{\max(C_t)}{r_{high}}, k_{high} = \frac{4 \max(C_t)}{r_{low}} \quad (3)$$

Where k_{low} and k_{high} are the lower and upper lower bound of the range of k , $\max(C)$ is the maximum catch in the time series, and r_{low} and r_{high} are lower and upper bound of the range of r values.

The ranges for initial, intermediate, and final depletion levels were assumed to be based on one of possible three biomass ranges: 0.01–0.4 (low), 0.2–0.6 (medium), and high (0.4–0.8), using a set of rules based on the trend of the catch series (see Froese *et al.* (2023) for details). For the current assessment, it was decided to adopt the high range of biomass (0.4 – 0.8) assumption for the final depletion level (e.g. lower depletion) in the reference model, considering the continuing increase in total catches throughout the assessment period, with no decline in catches, or catch rates. The same level of biomass was assumed in the intermediate year, and the intermediate year was set to 2016, as this is the year the highest catches were observed (bar the very high catches reported in 2024), before a general decline in catches. This may signal a fundamental change in the fishery.

A sensitivity run was conducted using the previous model's use of 0.2-0.6 (medium biomass) for the final depletion level, along with alternative values for the intermediate years, as misspecification of this parameter can result in erroneous stock status (Froese *et al.*, 2023). The prior ranges used for key parameters are specified in Table 2.

CMSY estimates biomass, exploitation rate, maximum sustainable yield (MSY) and related fisheries reference points from catch data and resilience of the species. Probable ranges for r and k are filtered with a Monte Carlo Markov Chain (MCMC) approach to detect 'viable' r - k pairs. The model worked sequentially through the range of initial biomass depletion level and random pairs of r and k were drawn based on the uniform distribution for the specified ranges. Equation 1 or 2 is used to calculate the predicted biomass in subsequent years, depending on biomass, and each r - k pair at each given starting biomass level is considered variable if the stock has never collapsed or exceeded carrying capacity and that the final biomass estimates fall within the assumed depletion range. All r - k combinations for each

starting biomass which were considered feasible were retained for further analyses. The search for viable r - k pairs is terminated once more than 1000 pairs are found.

The CMSY package was implemented in R (version 4.5.2 (2025-10-31 ucrt) -- "[Not] Part in a Rumble") using RStudio (2026.01.1 Build 403 "Apple Blossom" Release (0e924abb, 2026-02-04) for Windows). Code to run the models can be provided by the IOTC Secretariat on request.

3.2. CMSY++

The CMSY++ approach was applied to the *S. commerson* data. CMSY++ [github.com/SISTA16/cmsyPlusPlus; Froese et al., (2023)] represents an update of the CMSY method above, using an advanced state-space Bayesian method for stock assessment, using the same modified Schaefer surplus production model as used in CMSY. An Artificial Neural Network (ANN) is used to select objective priors for relative stock size, based on patterns from 400 catch time series used to train the model. The main differences between CMSY++ and CMSY are documented in the paper by Froese et al., (2023) but briefly, are: (i) the use of a full Bayesian approach with MCMC modelling for the CMSY analysis; (ii) the use of the ANN to predict default biomass priors from catch; and (iii) the introduction of multivariate lognormal priors for r and k , replacing the uniform distributions in CMSY. Additionally, gear creep can also be included in the parameters, as implemented in (Palomares and Pauly, 2019).

Additionally, the CMSY++ package allows for the running of retrospectives, where sequential years of data are removed from the analysis, to understand the impact of the final years of catch data on the stock status. This analysis was completed for narrow-barred Spanish mackerel. Both a catch-only model were developed, and a model incorporating the CPUE index. Management quantities were taken from the Bayesian Schaefer Model (BSM) as is default in CMSY++.

The CMSY++ package was implemented in R (version 4.5.2 (2025-10-31 ucrt) -- "[Not] Part in a Rumble") using RStudio (2026.01.1 Build 403 "Apple Blossom" Release (0e924abb, 2026-02-04) for Windows). Code to run the models can be provided by the IOTC Secretariat on request.

Table 1: Parameters used for narrow-barred Spanish mackerel in the setup of CMSY and CMSY++ reference model

	Initial rel. biomass	Intermediate rel. biomass	Final rel. biomass	r	Resilience
Year	1950	2016	2024		
Value	0.5 – 0.9	0.4 – 0.8	0.4 – 0.8	0.6 – 1.5	High

3.3. JABBA

Both CMSY (and CMSY++) models impose strong assumptions on the stock abundance trend. Although the estimates of MSY from catch-only models are generally robust, estimates of other management quantities can be sensitive to the assumed level of stock depletion, although running sensitivities on this did not result in significant deviations in management quantities.

We explored the use of JABBA (Winker, Carvalho and Kapur, 2018) which also incorporates the available CPUE indices. The JABBA model was implemented as a Bayesian state-space estimation model that was fitted to catch and CPUE. The model allows for both observation and process errors (see (Winker, Carvalho and Kapur, 2018) for details). The prior range for r and k used for the Bayesian estimation were the same as in CMSY++ (see Table 2). A lognormal likelihood with a CV of 0.2 was assumed for the CPUE index, however this was reduced to 0.1 in the final reference model to improve the fits to the index. The prior range for the initial and final depletion can be applied optionally. The reference model made no assumption on the depletion level. To explore the effect of the depletion constraint on model results, an additional model was conducted which penalise the final depletion outside the range of 0.2–0.6. The model also estimates the catchability scalar which relates the abundance index and estimated biomass trajectory and is calculated as a set of most likely values relative to the values of other parameters.

3.4. LBSPR

The LBSPR method (Hordyk *et al.*, 2015) estimates the Spawning Potential Ratio (SPR) of a stock directly from the size composition of the catch. The SPR of a stock is defined as the proportion of the unfished reproductive potential (often approximated by spawning biomass) left at any given level of fishing pressure (Hordyk *et al.*, 2015) and is commonly used to set target and limit reference points for fisheries. The $F_{40\%}$, i.e., the fishing mortality rate that results in SPR at 40% of unfished level, is considered risk adverse or precautionary for many species.

The LBSPR method uses maximum likelihood methods to estimate relative fishing mortality (F/M) and selectivity-at-length that minimize the difference between the observed and the expected length composition of the catch and calculates the SPR (Hordyk *et al.*, 2015). The LBSPR model requires the following parameters: an estimate of the ratio M/k (i.e., the individual values of the M and k parameters may be unknown), L^∞ (and associated variance), and maturity-at-size. These parameters for *S. commerson* were obtained from previously used figures (IOTC (2015)).

The length frequency data (IOTC-DATASETS-SF-COM-1987-2024-WIDE-FORMAT) used includes length samples by fleet, gear, year, month, and region. The majority of the Spanish mackerel samples come from the Iranian/Pakistani gillnet fishery from 2009 to 2024 (earlier samples are also available, although there is more variation in sample size and quality). The length distribution of samples from the gillnet fisheries (Figure 6) is comparable to that of the line fishery (Figure 7). We used the approach on both sets of data.

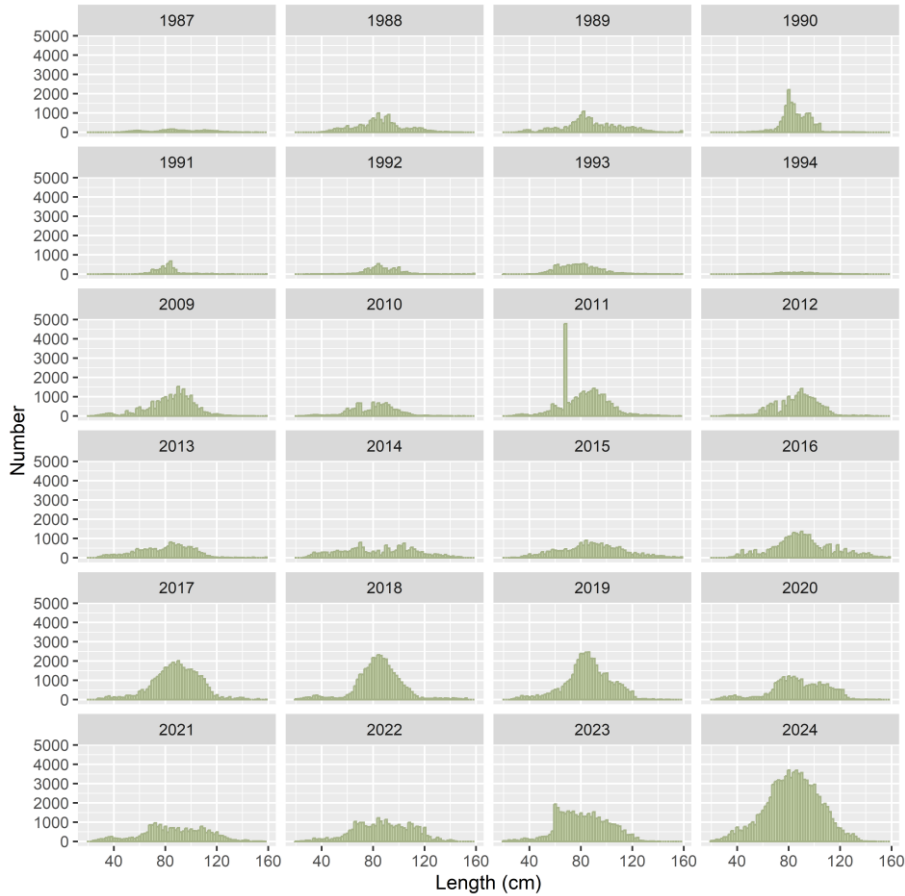


Figure 6: Length frequency data for narrow-barred Spanish mackerel available in 2026 for the assessment (data up to 2024) from gillnet fisheries in the Indian Ocean. Data are aggregated to a “fishery grouping” level and represent data reported to the IOTC from several fisheries across the Indian Ocean. Data were used from 2009 to 2024 in the LBSPR analyses.

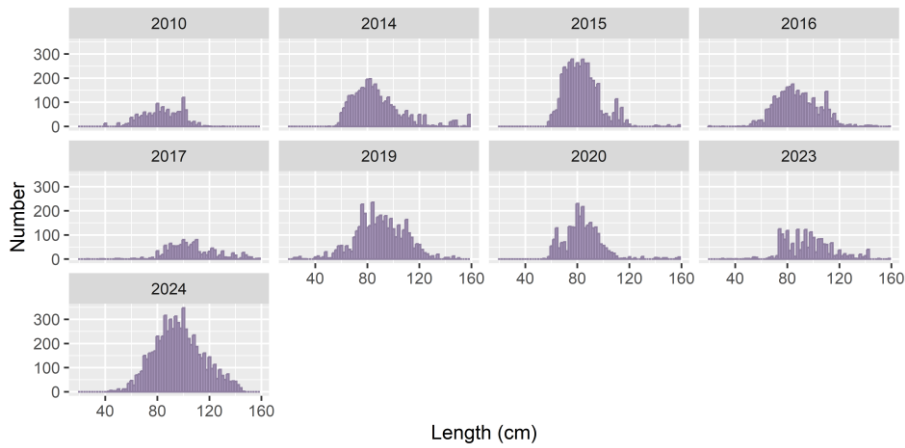


Figure 7: Length frequency data for narrow-barred Spanish mackerel available in 2026 for the assessment (data up to 2024) from line fisheries in the Indian Ocean. Data are aggregated to a “fishery grouping” level and represent data reported to the IOTC from several fisheries across the Indian Ocean. Data were used from 2010 to 2024 in the LBSPR analyses.

4. RESULTS

4.1. CMSY

Both the CMSY and CMSY++ models were fitted to the available catch data for narrow-barred Spanish mackerel. As the models produced very similar outputs, and the CMSY++ model represents an improvement in methodology, this was taken forward in the analyses. For a comparison of the model outputs from the reference model using CMSY and CMSY++, see [FIGURE X in the APPENDIX](#).

The reference model for narrow-barred Spanish mackerel did not include the CPUE index, as this did not provide any meaningful information to the model, and the model was unable to fit to the index satisfactorily. The following results are from the Bayesian Shaefer Model component of CMSY++ as the default setting in the package. The reference model used 2016 as the intermediate year as this is the final year of highest mean catches prior to the terminal year of the assessment. As such this represents a change in the fishery dynamics, from a fishery that is undergoing consistent increases in catches, to one where the maximum sustainable yield may have been caught (noting the final year of catch data are substantially higher than all previous years).

Figure 8 shows the results of the CMSY++ analysis – there are six panels in the figure, providing different outputs.

Panel A shows the time series of catches in black and the three-years moving average in blue with indication of highest and lowest catch. The use of a moving average is to reduce the influence of extreme catches.

Panel B shows the explored r - k values in lognormal space and the r - k pairs found to be compatible with the catches and the prior information.

Panel C shows the most probable r - k pair and its approximate 95% confidence limits. The probable r values were close to the full prior range (0.60 – 1.5), ranging from 0.64 – 1.21 (mean = 0.97) while probable k values ranged from 495 000 – 914 000 t (mean = 635 000 t). Given that r and k are confounded, a higher k generally gives a lower r value. CMSY++ implementation allows for viable r - k pairs to be estimated from information from 400 stocks (Froese *et al.*, 2023).

Panel D shows the estimated biomass trajectory with 95% confidence intervals (vertical lines indicate the prior ranges of initial and final biomass). The method is highly robust to the initial level of biomass assumed (mainly due to the very low catches for the early part of series), while the final depletion range has a determinative effect on the final stock status. The biomass trajectory closely mirrors the catch curve with a rapid decline since the late 2000s, but a stable biomass in the last 8 years since the peak in 2016 (marked by the furthest left vertical line, representing the “intermediate” year).

Panel E shows the corresponding exploitation (harvest) rate from CMSY++ (F/FMSY) showing that although exploitation rates are increasing, currently they are below that of FMSY.

Panel F shows the modified Schaefer equilibrium curve of catch/MSY relative to relative biomass (B/k). However, we caution that the fishery was unlikely to be in an equilibrium state in any given year.

Figure 9 shows the estimated management quantities from the BSM model. The upper left panel shows catches relative to the estimate of MSY (with indication of 95% confidence limits), suggesting that

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catches have increased over time, but that they have not yet reached CMSY (based on the continuing increase in catches over time, with no substantial decrease or reduction in catches which would suggest that CMSY had been exceeded). The upper right panel shows the total stock size (biomass) relative to B_{MSY} , suggesting a decreasing stock size, but that the stock is still above B/B_{MSY} . The lower left panel shows the exploitation rate F in relation to F_{MSY} . The lower-right panel shows the trajectory of the stock in relation to the relative stock size (B/B_{MSY}) and relative exploitation (F/F_{MSY}).

Figure 10 is a retrospective analysis of the reference CMSY++ BSM model, that suggests that removing sequential years of catch data (left-hand panel) does not overly influence the trend in stock status (B/B_{MSY} , right-hand panel). The retrospective analysis suggests that although there has been a significant increase in catches in the final year of the assessment, this is not overly influencing the overall model fitting or outputs.

The IOTC target and limit reference points for narrow-barred Spanish mackerel have not yet been defined, so values applicable for other IOTC species are used. Management quantities (estimated means and 95% confidence ranges) are provided in Table 3, which show an estimated MSY of 155,000 t.

The KOBE plot (**Figure 11**) and management values indicate that based on the CMSY++ model results, Spanish mackerel is currently **not overfished** ($B_{2024}/B_{MSY} = 1.25$) and is **not subject to overfishing** ($F_{2024}/F_{MSY} = 0.79$). The average catch over the last five years (136,353 t) is lower than the estimated MSY (155,000 t). These results are more optimistic than the last assessment (which suggested the stock was subject to overfishing, due to increasing catches in the last few years that were above estimated MSY).

The improvement in stock status in 2026 is likely influenced by the following:

- a) The trend in reported nominal catch of Spanish mackerel over time in the Indian Ocean has been continuing to increase, therefore the catch-only models are estimating that (based on catch data alone), CMSY has not yet been reached, or breached.
- b) Revision of reported nominal catch data by Indonesia, which has reduced total catch of narrow-barred Spanish mackerel to levels lower than those in the previous assessment (see Figure 3). Additionally, the reduction in recent years brings the relative catch in the final years of the assessment to a lower proportion of that in the initial years of the fishery. This will reduce the overall fishing mortality (F).

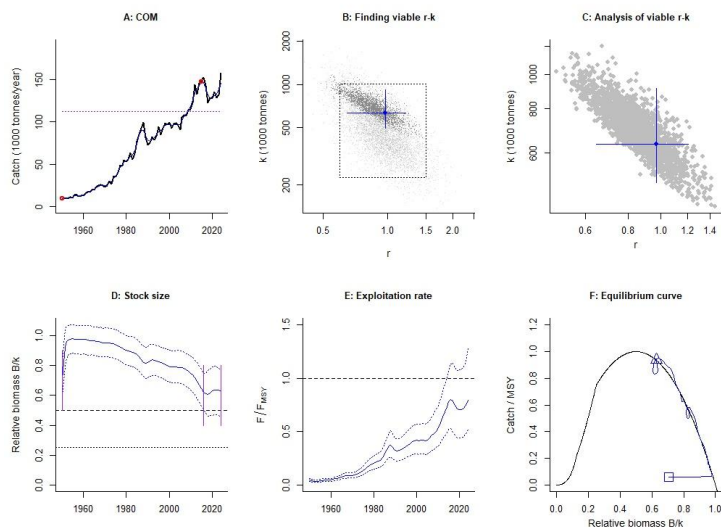


Figure 8. Results of CMSY model for Spanish mackerel. Each lettered panel represents a different output from the CMSY++ model. The red dot in panel A and the furthest left vertical line in panel D represent the intermediate year for the assessment (2016), chosen as this may represent a significant change in the fishery as it is the final year of high catches before a dip (barring the increase in catch in the final year of data).

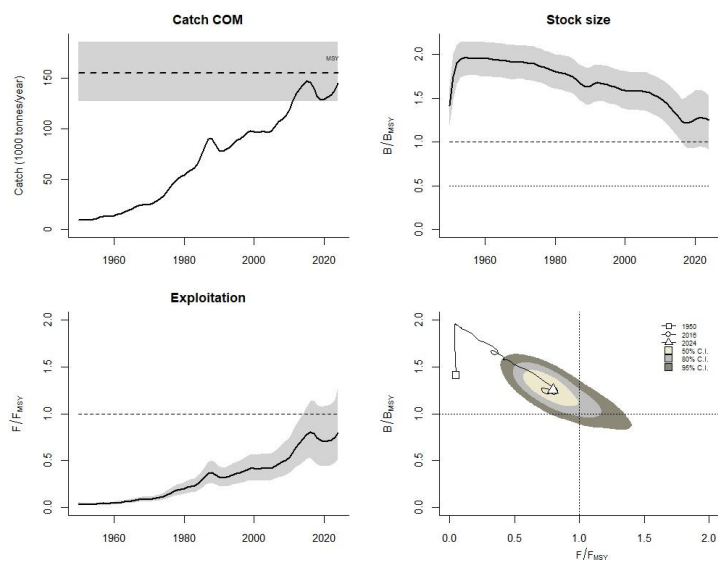


Figure 9. Management quantities from the CMSY++ model of Spanish mackerel.

Retrospective analysis for COM

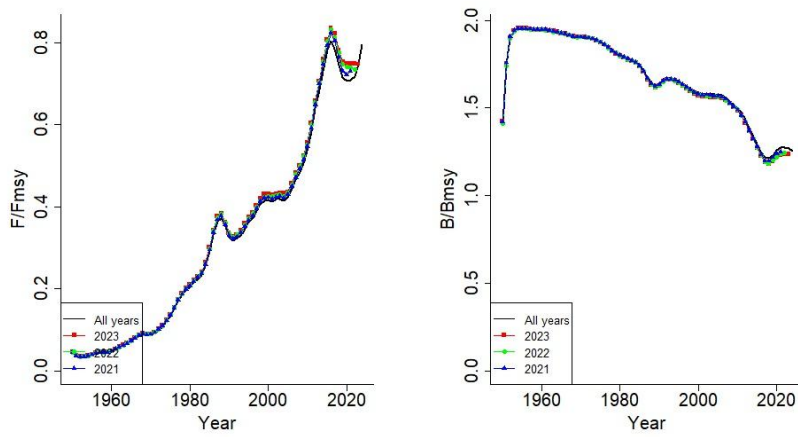


Figure 10. Retrospective analysis for the reference model for Spanish mackerel using CMSY++. Individual years of catch data are sequentially removed from the model. If the catch data in a specific year were significantly influencing the analysis, this analysis would reveal changes to the trajectory or trends in F/F_{MSY} and B/B_{MSY} .

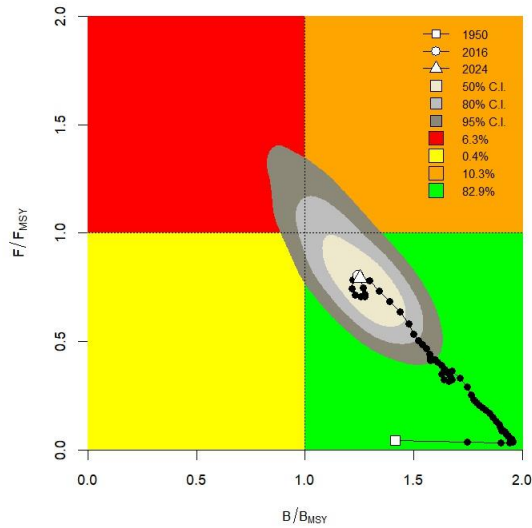


Figure 11: KOBE plot for narrow-barred Spanish mackerel from the output of the CMSY++ reference model.

Table 3. Key management quantities from the CMSY++ stock assessment for Indian Ocean narrow-barred Spanish mackerel. Geometric means (and plausible ranges across all feasible model runs). Previous assessment results are provided for comparison, but note that between models, significant revisions in catch data mean that results are unlikely to be comparable between assessments (see Figure 3).

Management Quantity	2020	2023	2026
Most recent catch estimate (year)	154 785 (2018)	168 807 (2021)	157 775 (2024)
Mean catch (t) – most recent 5 years ³	175 891 (2014 – 2018)	160 351 (2017 – 2021)	136 353 (2020 – 2024)
MSY (t) (95% CI)	166 000 (126 100 – 218 000)	161 000 (132 000 – 197 000)	155 000 (127 000 – 186 000)
Data period used in assessment	1950 – 2018	1950 – 2021	1950 - 2024
F _{MSY} (95% CI)	0.60 (0.48 – 0.74)	0.60 (0.48 – 0.74)	0.49 (0.32 – 0.60)
B _{MSY} (95% CI)	277 000 (194 000 – 396 000)	271 000 (197 000 – 373 000)	318 000 (248 000 – 457 000)
F _{current} /F _{MSY} (95% CI)	0.97 (0.78 – 2.14)	1.07 (0.88 – 2.38)	0.79 (0.51 – 1.29)
B _{current} /B _{MSY} (95% CI)	0.96 (0.44 – 1.19)	0.98 (0.44 – 1.19)	1.25 (0.91 – 1.52)
B _{current} /B ₀ (95% CI)	0.48 (0.22 – 0.60)	0.49 (0.22 – 0.60)	0.97 (0.64 – 1.20)

Commented [DF1]: B_{current} is close to B₀? Is this correct?

³ Data at time of assessment

4.2. JABBA

The model was fitted to the short CPUE index from I.R. Iran, and catch data, however the initial model struggled to fit to the CPUE index. The initial abundance estimates were quite uncertain, (see **Figure 12**). Estimates were uncertain, but in a similar range of estimates to those from CMSY++. The posterior estimates for k did not resolve into a single peak initially, suggesting the model had difficulty in estimating a carrying capacity, or initial biomass, given the data informing the model. This is partly due to the short CPUE index, and partly due to continually increasing catches (e.g. the model cannot estimate MSY accurately due to a lack of contrast in catch data). Additionally, the ‘intermediate’ year is not estimated well (the outputs estimate the intermediate year as 2002, however catches were still increasing at this time point, and the CPUE index had not started). Misspecification of this year is likely to cause issues with model fitting, and therefore the usability of the outputs.

Following methods in the previous assessment that improved the model, the final depletion was penalised outside the range of 0.2 to 0.6 (model 2), which then slightly lowered the uncertainty of abundance estimations, and the model fitted better to the CPUE index. The stock depletion pattern in this model is more plausible than the initial model 1. The model fitted better to CPUE index by assuming a much lower observation error for the index (reducing from 0.25 to 0.1, model 3; **Figure 13**), however, this is achieved by generating a somewhat increasing patterns in the process errors. Additionally, the k prior range was set to be narrow – forcing the model to have an estimated carrying capacity of ~ 900 000 t (similar estimate to CMSY++, model 7). Several iterations of ranges for the k prior were tested, and narrowing the range removed the multiple peaks in the posterior distribution. This also meant the model fitted well to the CPUE index and provided some realistic trends in the stock trajectory. However, the realism of the estimate of the initial carrying capacity requires further research.

Estimates of management quantities from model 7 are shown in **Figure 14**. The estimated stock status is more optimistic than the CMSY++ model (apparently driven by the CPUE index). The MSY varies between 168,000 and 262,000 t, with an average of 168,000 t which is lower than the estimates from CMSY++. According to the JABBA estimates, the biomass of the spawning stock in 2024 is 22 % higher than B_{MSY} , while the fishing mortality (F_{2024}) is 27% lower than the F_{MSY} ($B/B_{MSY} = 1.22$ (0.75 – 1.68), $F/F_{MSY} = 0.73$ (0.36 – 1.54)). Despite the addition of CPUE indices to provide information on relative abundance changes, the information is limited due to the relatively short time series.

The stock trajectory (**Figure 15**) and Kobe plot from the reference model (model 7; **Figure 16**) are shown and provide reasonable results, based on the information available at the time of the assessment. The stock is following the surplus production model in a reasonable way.

The JABBA model results suggest that the stock is **not overfished** and **not subject to overfishing** in 2024.

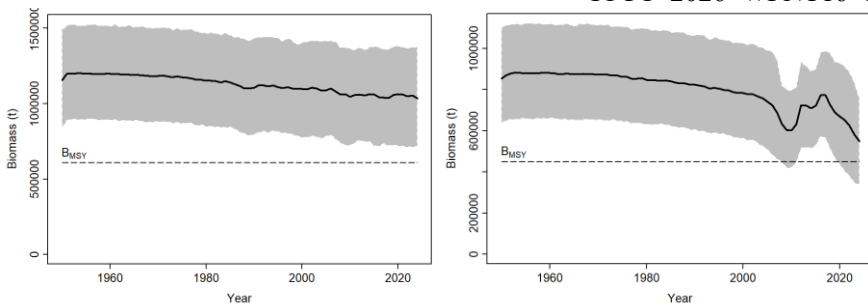


Figure 12: Biomass estimates (median and 95% CI) from JABBA model 1 (left, no prior on final depletion), and the reference model, model 7 (right, a normal prior on final depletion with mean of 0.4 and CV of 10%, corresponding to an approximate range 0.2 – 0.6). Dashed line indicates median B_{MSY} .

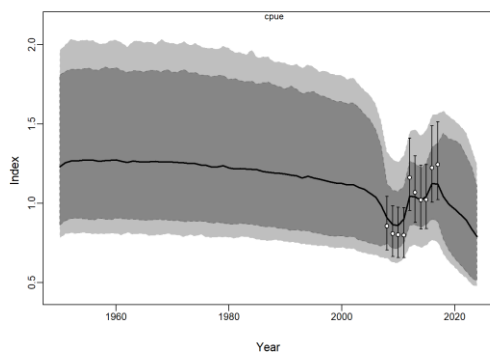


Figure 13: Fits to CPUE indices 2008–2017 from the JABBA reference model. Shaded areas indicate 50% and 95% CI, vertical lines indicate observation errors.

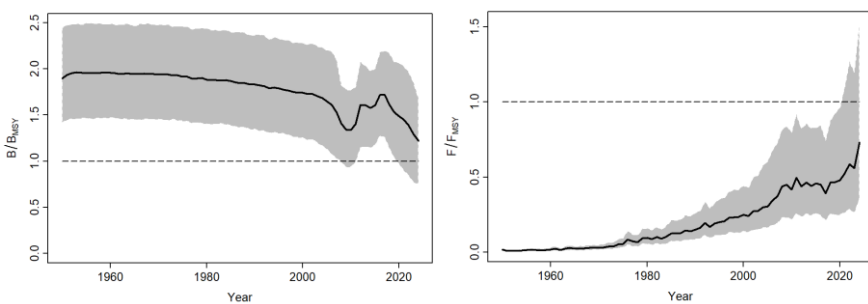


Figure 14: Estimates of management quantities from the JABBA reference model (B/B_{MSY} and F/F_{MSY}).

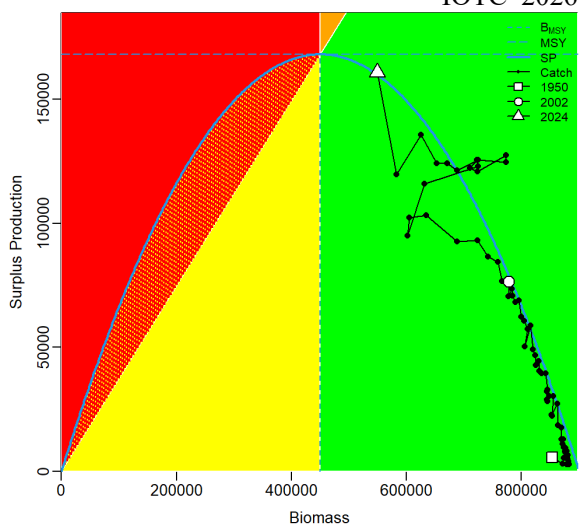


Figure 15: Trajectory of the stock against the Schaefer surplus production model from 1950 to 2024. The intermediate year (2002) has been estimated by the JABBA model.

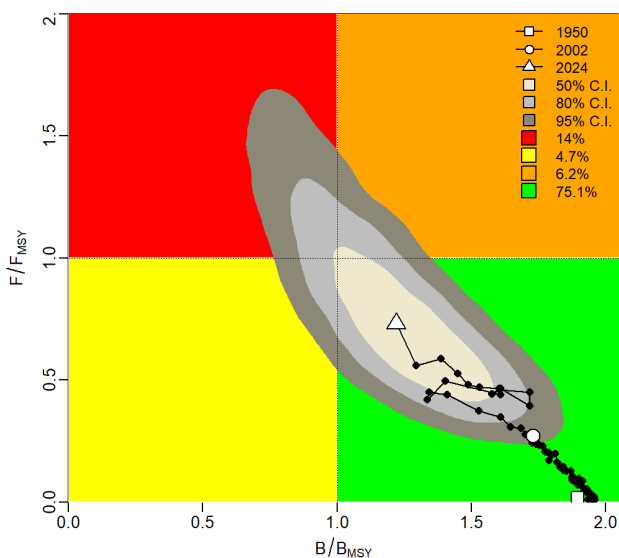


Figure 16: KOBE plot from the JABBA reference model, showing the stock trajectory. The stock is found within the green quadrant of the KOBE plot, which represents a fishery that is not overfished, and is not subject to overfishing. There is a 75.1 % likelihood that the fishery is not overfished and not subject to overfishing.

4.3. LBSPR

The length distributions from both the gillnet and line fisheries are well fitted (**Figure 17, Figure 18**).

4.3.1. Gillnet

Selectivity slightly decreased from 2009 to 2013 and then slightly increased after that (**Figure 17**) plateauing until 2024. The fishing mortality is estimated to have decreased (**Figure 17**) but was above the potential F_{MSY} (0.87 M was regarded a realistic approximation of F_{MSY} for teleosts, see (Zhou, Smith and Fuller, 2011)). Estimated spawning potential ratio throughout the time series is well below 0.4, indicating that the stock is depleted in relation to the risk-averse target (the SPR of 0.4 is often considered as a risk-averse target; see (Hordyk *et al.*, 2015)), and although the SPR has increased 2009, mirroring the upward trend in the CPUE in the same time period, there has been a decrease in SPR from 2017 to 2024. Note that there is considerable variation around the mean values.

4.3.2. Line

The estimated SPR was close to 0.4 in 2023 and 2024 when LBSPR was applied to length samples from line fisheries (**Figure 18**). Indeed, the mean SPR has been increasing through time, while selectivity has remained relatively constant, and fishing mortality has decreased, although it is still estimated to be above F_{MSY} .

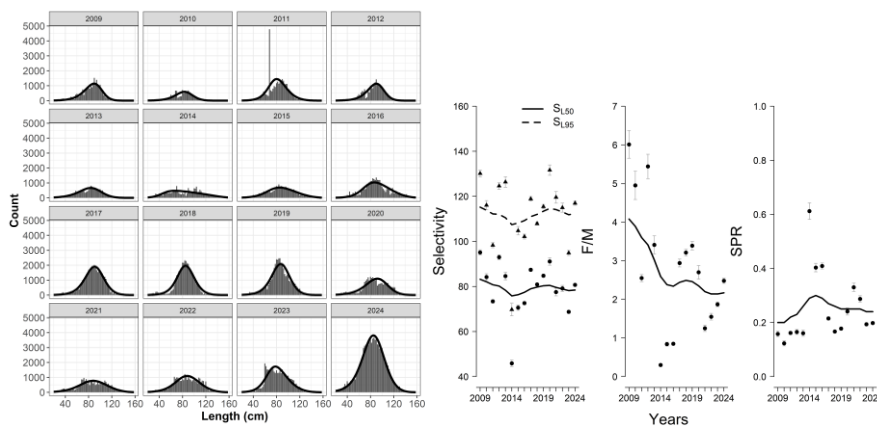


Figure 17: Results of LBSPR method applied to the length samples from the gillnet fishery for Spanish mackerel: Fits to the length frequency in 2009–2021 (black dots) right – estimates (with 95% CI) of annual logistic selectivity parameters (a_{50} and a_{95}), F/M , and spawning potential ratio (SPR) over time.

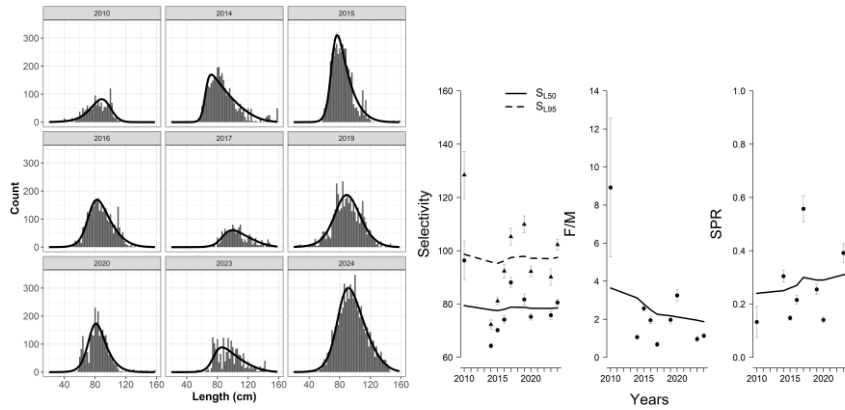


Figure 18: Results of LBSPR method applied to the length samples from the Line fishery for Spanish mackerel tuna: Fits to the length frequency in 1987–2020 (black dots) a; right – estimates (with 95% CI) of annual logistic selectivity parameters (a_{50} and a_{95}), F/M , and Spawning Potential Ratio over time.

5. DISCUSSION

The CMSY++, JABBA, and LBSPR methods have all been investigated in this report to evaluate the status of Indian Ocean narrow-barred Spanish mackerel. Only the catch series is needed as input for the CMSY++ method, which relies on an aggregated biomass dynamic model and uses simulations to find historical biomass that is plausible and supports the known catch history. Although there was the option to include a CPUE index, and indeed gear creep, this was trialled, but not included in the final model, as the model was unable to fit well to the CPUE index.

A time series of relative abundance (gillnet standardised CPUE index) was included into the JABBA model, together with model parameters and management quantities estimated in a Bayesian framework.

5.1. CMSY++ and JABBA

Estimates from the CMSY++ BSM model suggests that currently the stock of narrow-barred Spanish mackerel in the Indian Ocean is **not overfished** ($B_{2024} > B_{MSY}$) and is **not subject to overfishing** ($F_{2024} < F_{MSY}$). The estimates produced by the JABBA method, also suggest that the stock is **not overfished** ($B_{2024} > B_{MSY}$) and **not subject to overfishing** ($F_{2024} < F_{MSY}$).

The CMSY++ model estimated an average MSY of ~ 155 000 t which is lower than that estimated by JABBA (168 000 t). The 2024 catch (157 775 t) is close to that of MSY (from CMSY++) and higher than catches reported for the previous 10-15 years. The final year of catch is the highest ever recorded for narrow-barred Spanish mackerel in the latest iteration of the data, but it is lower than previous estimates of catch (e.g. 168 807 t were originally recorded for 2021 prior to revisions). It is likely that the revisions in catch data have driven the stock status to move towards a more optimistic outcome in 2026, given overall these have reduced long-term catches.

The CPUE data suggest increasing biomass, as the index is increasing, while over the same time period, catches are remaining constant (and high). As the previous assessment stated, it is likely that the stock is approaching being fished at MSY levels, and higher catches are unlikely to be sustainable. A precautionary approach to management is recommended, particularly with only one standardised index of abundance, that does not represent the entire Indian Ocean.

The JABBA model utilised the standardised CPUE index to provide information on abundance trend, and as such, the model is less reliant on some of the subjective assumptions relating to k and r . However, for Spanish mackerel, there appears to be inconsistency between the CPUE indices, and the catch history, and productivity assumptions of the species. The increasing CPUE can be attributed to other (unknown) random variations in the population (e.g., process error) but there is a risk of overparameterizing the model (such that it has little predictive power). Furthermore, it remains to be seen whether CPUE indicators obtained from the Islamic Republic of Iran's coastal gillnet fishing fleets can index the abundance of Spanish mackerel stocks in the Indian Ocean, in addition to the various caveats even as a local indicator (see Fu et al 2019). Nevertheless, the availability of updated standardised CPUE indices as potential abundance indices and their inclusion in following assessments will be a useful step forward in the context of assessing data deficient neritic tuna stocks. CPUE indices should be regularly updated to be a reliable monitoring tool, potentially providing a longer and more informative time series. Standardised indices should also be developed for other fisheries/regions to ensure better spatial coverage of stock populations.

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A recent stock assessment by colleagues at the Offshore Fisheries Research Centre, I.R. Iran (Hashemi *et al.*, 2026) using a 26-year dataset (1997-2022) from catches in the Persian Gulf and Sea of Oman using the Transparent Analytical Framework (TAF) concluded that the stocks of narrow-barred Spanish mackerel within those waters showed 'low depletion rates' and were categorised as 'underutilised' or within a 'green' status.

5.2. LBSPR

Estimates of stock status from the LBSPR method cannot be directly comparable to the catch-only models as they have made very different assumptions about target reference points. Nonetheless, the SPR estimated by the LBSPR method was **below** the SPR_{40%} for gillnet fisheries, but **above** SPR_{40%} for line fisheries, while fishing mortality is estimated to be much higher than F_{MSY} , in contrast to the result of the CMSY++ models.

Estimated spawning potential ratio throughout the time series is well below 0.4, indicating that the stock is depleted in relation to the risk-averse target (the SPR of 0.4 is often considered as a risk-averse target; see Hordyk *et al.* 2014a), and although the SPR increased 2009, mirroring the upward trend in the CPUE in the same time period, there has been a decrease in SPR from 2017 to 2024. The LBSPR model assumes asymptotic selectivity, and it has been demonstrated that the results are sensitive to this assumption (the model interprets the absence of the large individuals from the size structure as evidence for a high level of exploitation). Although gillnets used to capture Spanish mackerel are size-selective, Spanish mackerel length samples from gillnet fisheries have similar size ranges or distributions to those from line fisheries (asymptotic selectivity), making it difficult to quantify the degree of possible doming in gillnet selectivity.

Additionally, the high variation in SPR around the mean line suggests that there are biases in the length frequency data (e.g. they do not necessarily represent a true sample of all fish sizes selected by fishing gear in the Indian Ocean). The spatial and temporal stratification of length frequency data for neritic species in the Indian Ocean should be well investigated to ensure that these biases are not unduly impacting stock assessment results.

6. CONCLUSIONS

Based on a weight-of-evidence approach, it is likely that narrow-barred Spanish mackerel is, in 2024, **not overfished** and **not subject to overfishing** in the Indian Ocean. However, there are several caveats to this, stated below:

- e) Catch data have undergone significant revisions over time – the continued reduction in catch over time has moved the stock to a more optimistic status.
- f) The much higher reported catches in 2024 should be noted, as these represent catches very close to the estimated MSY, and are unlikely to be sustainable long term.
- g) Length-based analyses suggest that the stock is likely to be overfished, however the representativeness of the length data in comparison to the entire Indian Ocean stock(s) needs to be fully evaluated.
- h) Recent work suggests there are likely several stocks of narrow-barred Indian Ocean Spanish mackerel, however catch, and length data are not reported at a fine-enough scale to capture



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individual stock dynamics. Additionally, representative abundance indices should be developed on a similar spatial scale to putative stocks.

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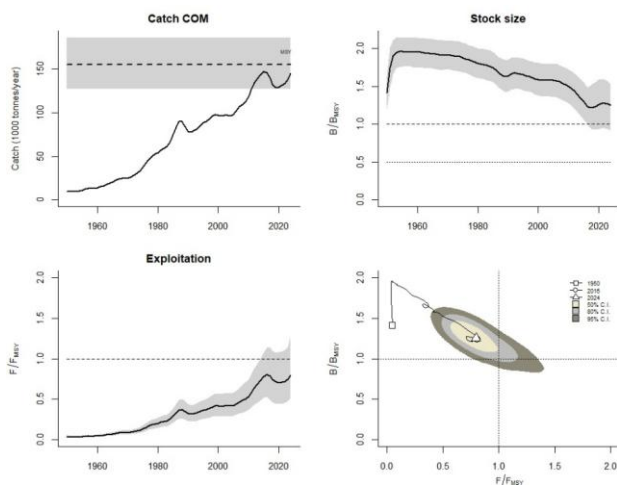
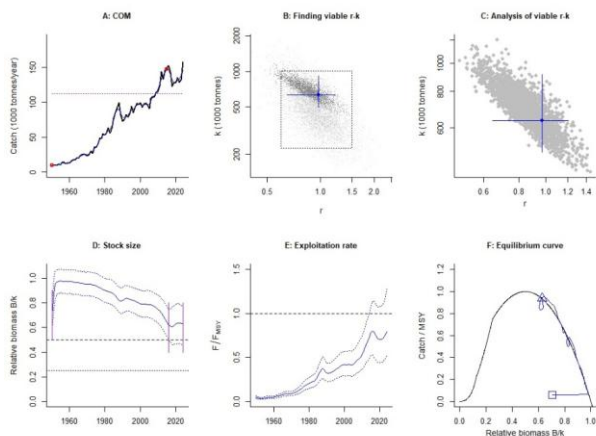
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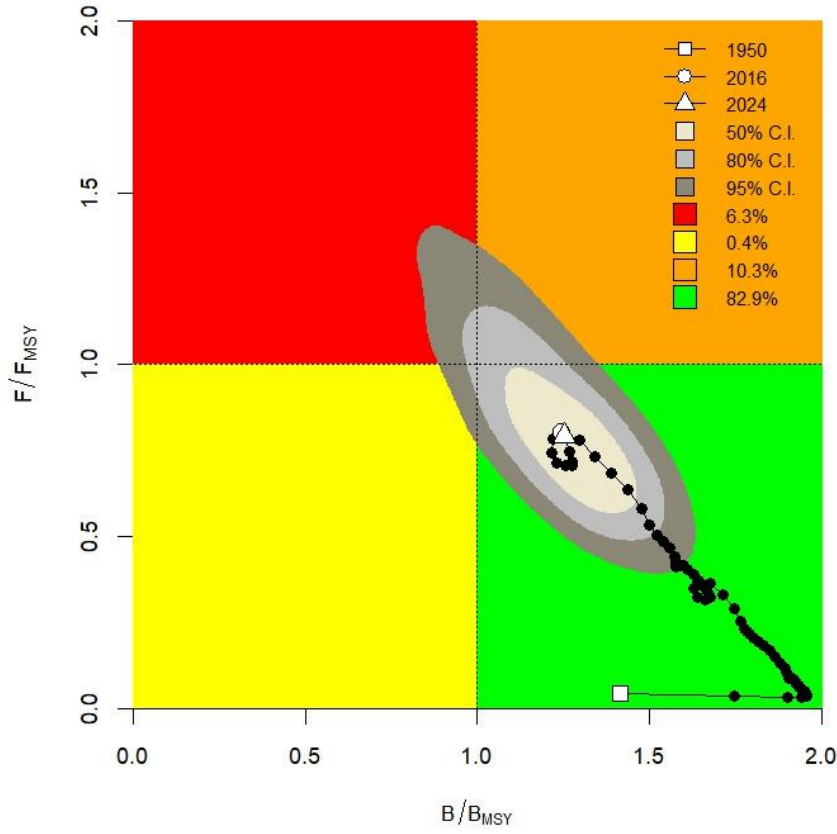
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8. APPENDIX

8.1. Comparison of outputs from the CMSY++ and CMSY reference models

1) CMSY++





2) CMSY++ (v9f)

