Length based data-limited methods: Application on the Narrow-barred Spanish mackerel, *Scomberomorus commerson* (Lace´pède, 1800) in the Persian Gulf & Oman Sea

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Abstract

Narrow – barred Spanish mackerel, *Scomberomorus commerson*, is a species of economic and artisanal importance throughout the Indo-West Pacific region. In this study a total of 2075 *S. commerson* were examined in a comprehensive study of length frequency structure from 2009 to 2024 and maturity assessment from 2022-23 along the northern Persian Gulf & Oman Sea. Length maturity 50% was estimated from length frequency data and maturity stages at 72.6 cm. LBSPR was used to analyze length frequency distributions from commercial gill net catches from 2009 to 2024. SPR estimates resulted in low values (below 40%) over the entire period (2009–2024), and in 2024, SPR was 31%, indicating that this stock is below proxies that would be consistent with ongoing recruitment fishing. The F/M ratio was substantially greater than 1 over the entire period except in 2009, 2014 to 2016, showing a decreasing trend in recent years, but still suggesting overfishing since current exploitation is generally above the optimum mortality (F = M). Based on the study periods, the LBSPR results presented a decreasing trend in SPR and an increasing one in F/M.

Introduction

Narrow- barred Spanish mackerel, *Scomberomorus commerson*, belongs to epipelagic species throughout the coastal tropical waters of the Indo- pacific (Mc pherson, 1992) and family of Scombridae with 15 genera and 49 species (Collette and Nauen, 1983). This fish is considered the most important commercial pelagic species (AL Hosni and Siddeek, 1999). This species is one of the endangered species of the neritic tuna which is controlled by RECOFI in the Persian Gulf & Oman Sea and IOTC in the whole distribution area competence in the Indian Ocean. RECOFI regulations include a recently introduced fishing ban period between 15 August and 15 October as well as mesh size regulations, minimum landing size and restrictions on the time at sea for different types of artisanal vessels. The Spanish mackerel has been captured with two types of gillnets (drifting & set) and three types of lines (longlines, handlines and trolling). Gillnets have been predominant in terms of landings in the RECOFI area (Roa- Ureta et al., 2019).

The last assessment by data – limited methods was conducted for narrow-barred Spanish mackerel in the Indian Ocean in 2023. Based on the CMSY assessment, the stock appears to be overfished and subject to overfishing (IOTC, 2024), but the Commission has not adopted limit reference points for this species. Since, at least 4 genetic populations of Spanish mackerel were identified within the IOTC area of competence which increases the uncertainty (IOTC-2024-SC27-R).

To determine the statue of the Spanish mackerel in the northern Persian Gulf & Oman Sea, a length-based approach was used following the description of Hordyk et al. (2015) who named it Length -based Spawning Potential Ratio (LBSPR). The spawning potential Ratio (SPR) in an exploited population is a function of the ratio of fishing mortality to natural mortality (F/M), selectivity and the two life history ratios M/K and $L_m / L\infty$, K is the von Bertalanffy growth coefficient, Lm is the size of maturity, and the L∞ is the asymptotic size (Hordyk et al.,2015). The inputs to the LBSPR are: M/K, L∞ and the size of maturity specified in terms of L50 and L95, the size at which 50% and 95% of a population are determined as matures as shown in Table 1.

A few studies have applied to *S.commerson* by Siddeek (1993) in Indian Ocean (Kedidi et al., 1993), Bertignac and Yesaki, (1993) Govender (1993) in Saudi Arabia, Oman and South Africa coastal waters. Some studies were carried out by Hosseini et al., 2000, Ghodrati shojaei et al., 2007, Taghavi Motlagh.et al., 2008, in the coastal waters of Iran.

The aim of this study was to assess and understand the stock status of *S. commerson* based on length frequency time series data and life history parameters by length - based assessment methods, LBSPR. These results could be relevant to the management of *S. commerson* and additionally offer insights on the application potential of different length-based assessment models in data-poor fisheries in Iranian waters of the Persian Gulf & Oman Sea.

Materials and Methods

The size frequency data were collected by gill net commercial catches of *S. commerson* made off the northern coast of the Persian Gulf & Oman Sea from 2009 to 2024 (Figs 1 & 3). 2075 specimens were selected randomly from landing sites; lengths were recorded using a measuring board to the nearest 1 cm fork length (FL) for LBSPR analysis. Biological data including maturity stages and length frequency were collected during the first weeks of each month in 2022-23 for length maturity and population dynamic parameters estimation.

A total of 840 fish were sexed through macroscopic examination of the gonads which were dissected out to estimate length of maturity .The maturity development stages were assessed according to the five stages (Grandcourt et al., 2005).The mean size at first maturity (Lm) was estimated for female by fitting the logistic function to the proportion of mature fish in 20 cm (LF) size categories and determined as the size at which 50% of individuals were mature (King, 2007). The growth parameters $L\infty$, k, and t_0 and natural mortality values are estimated (King, 2007), which are used as the prior values for length-based model (Table 1).

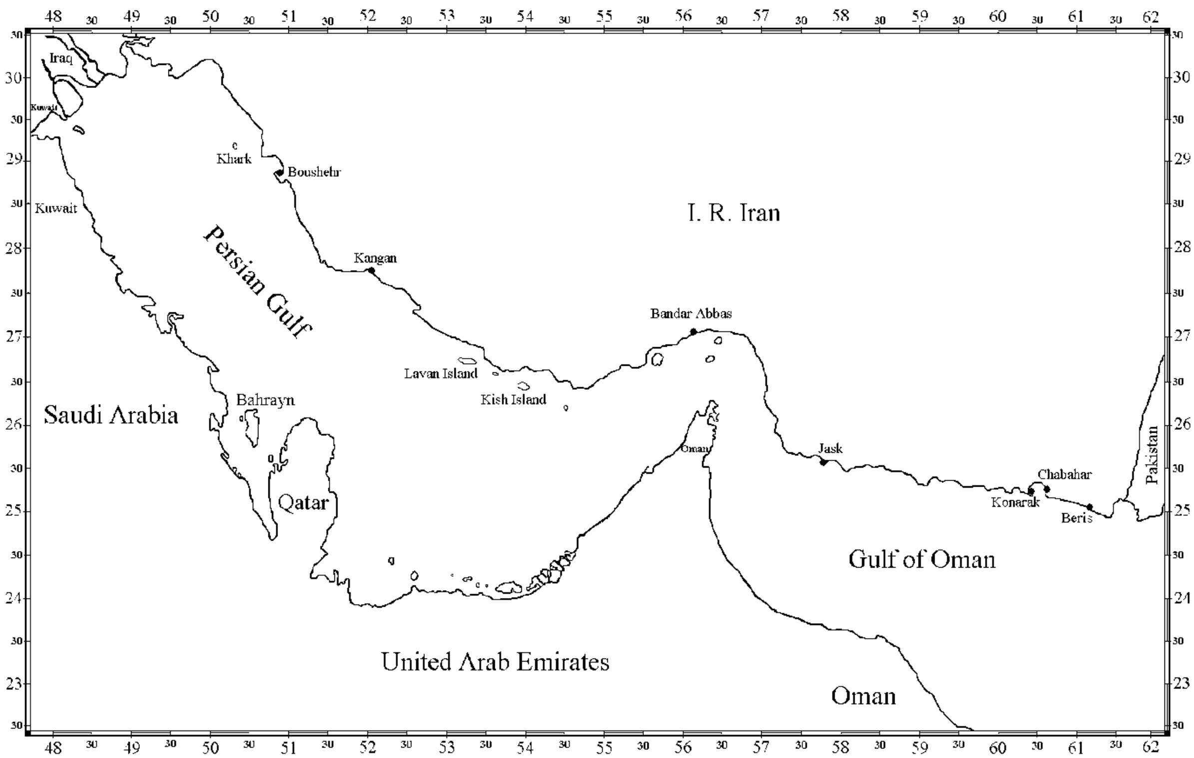

Fig. 1. Sampling sites of *S. commerson* in the Iranian coastal waters of the Persian Gulf and Oman Sea

Table 1: Input of life history parameters to assess the stock status of *S. commerson* in the Northern Persian Gulf & Oman Sea waters using length- based data-limited method, (data for 2022-23).

parameter	value	model
K	0.24 ($year^{-1}$)	LBSPR
L∞	158 cm (FL)	LBSPR
M	0.49	LBSPR
Lm50	72.6 cm (FL)	LBSPR
Lm90	78 cm (FL)	LBSPR

The LBSPR method is sensitive to the underestimation of the asymptotic size (L∞). Moreover, the accuracy of the model estimations can be influenced by the data-collection techniques employed. In cases where data are insufficient, biological data from robust studies of similar geographical locations and related taxa can be used.

The LBSPR model is based on the life history parameters (Table 1) and length frequency distribution of an exploited population. It estimates the spawning potential ratio (SPR), which reflects the reproductive capacity of a population under fishing pressure compared to its unfished state. In other words, SPR is calculated by comparing the equilibrium spawning biomass under current fishing pressure to the equilibrium spawning biomass without fishing pressure (Hordyk et al., 2015).

In this model, SPR is determined by the interaction between fishing mortality relative to natural mortality (F/M) and the two life history ratios (LHRs).The first LHR considers the natural mortality (M) and Von Bertalanffy growth coefficient (K), (M/K). In contrast, the second LHR accounts for the ratio of the size of maturity when 50% of a population matures into adults ($L50$) and the asymptotic length ($L\infty$), ($L50/L\infty$). To employ the LBSPR model, additional inputs beyond species length data are necessary, including the parameters listed in Table 1. Using these inputs, the model calculates the SPR, fishing pressure (F/M), and net selectivity (SL) by applying the maximum likelihood method.

Analyses were performed using R statistical software (version 4.4.0; R Core Team, 2024) with source codes provided in the following link: R code for LBSPR (https://cran.r-project.org/web/packages/LBSPR).

Results & Discussion:

Length maturity

A total of 840 female specimens were collected, ranging in size from 35 to 154cm FL (83.99± 23.08 cm). The mean size at first sexual maturity (Lm50 %) was estimated 72.6 Cm (Fig.2). The smallest mature female specimen was 59 cm.

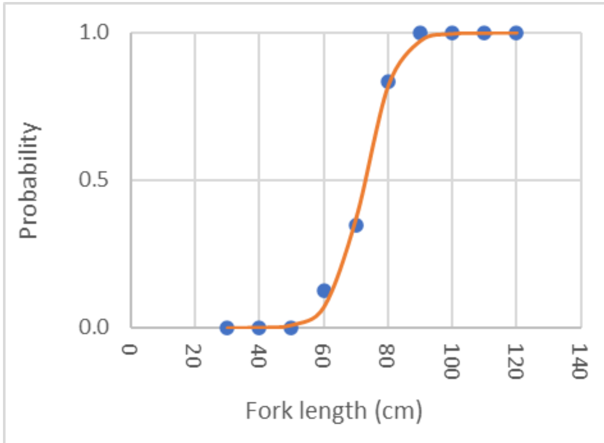

Fig. 2. Cumulative relative frequency of the length at first maturity *S. commerson* (female) in the Persian Gulf & Oman Sea (Oct.2022- Sep. 2023)

Devaraj (1983) estimated the size at first sexual maturity 75 cm FL in the northern Indian Ocean, compare to the estimated size at spawning of 75-80 cm FL given by Dudley et al.,1992 for males and females combined off Oman. Claereboudt et al., 2005 estimated the size at first sexual maturity (also off Oman) at 80.4 cm FL for females. *S. commerson* has been found to mature between 70-80cm FL off Madagascar, Papua New Guinea, Fiji and north eastern Australia (Collete and Russo, 1979; McPherson, 1993). The mean size at first sexual maturity of this species was also found in our study 72.6 cm FL for females which can be compared with the published values of size at first maturity in the region (Table 2).

Table 2: Length of maturity of *S. commerson* reported by various studies

Length frequency range	L_m 50% (cm)	Region	Reference
?	79	Australian Coast	Mcpherson ,1993
40-170	70.7	Arabian Sea	Claerboudt et al.,2005
40-170	80.7	Oman Sea	Claerboudt et al.,2005
44.1-155.2	86.3	Southern Persian Gulf	Grandcourt et al.,2005
29-154	83.6	Northern P.G & O. S	Kaymaram et al.,2010
17-152	85	Northern Persian Gulf	Niamaimandi et al., 2017
?	78.7	Southern Persian Gulf	Francis et al.,2020
46.5 - 148	68	Western Pacific Ocean	Weng et al., 2020
35-154	72.6	Northern P.G & O. S	Present study

Conclusions on sources of variation in maturity sampling

Sampling time, locations and levels are the main considerations when maturity determination is one of the main goals. Is the timing of the sampling suitable for distinguishing mature fish from immature fish?

Uniformly distribution of the stock in space is one of the key questions. If spawning takes place in localized areas, it is necessary to sample both on and off the spawning grounds. Information on the sampling locations is then essential and commercial data might be unsuitable.

Is it necessary to sample in a length stratified way? Random sampling avoids many problems with raising the data, but might require higher sample sizes than length stratified sampling. For many stocks, commercial data are not appropriate and existing surveys are in the wrong period.

However, all results related to length – based data limited analysis should be taken with caution as there are many different sources of uncertainty in these types of models. Remarkably, most of these models suggest that selectivity is asymptotic by default (Hordyk et al., 2015) If large or small fish are absent, the model assumes that they do not exist in the population. The logistic selectivity assumption is generally violated in highly size-selective fisheries, such as the case of the gillnet, which is the main gear deployed by the Iranian fishermen operating in the studied area. Consequently, it is recommended to carry out future sampling programs on other fishing gears such as line fishing to cover large specimens.

International fisheries management employs spawning potential ratios (SPRs) of 20% and 30–40% to measure the status of fish stocks. When the SPR falls below 20%, it indicates overfishing and a weak reproductive capacity, designating 20% SPR as a limit reference point (LRP). A 30–40% SPR is considered the SPR target. Generally, an SPR above 20% suggests that the fish population can self-replenish effectively, indicating an ample population of spawners to sustain the continuity of the species over generations while reducing the risk of recruitment failure and stock collapse. Management authorities can set different reference points based on the status of the species. In this study, we utilized the LRP of 20% and SPR target of 40%.

On the other hand, an F/M value < 1.0 implies that the fishing pressure on the fish stock is sustainable. However, interpreting the F/M value along with the observed SPR and estimates of the net selectivity is crucial. Occasionally, an $F/M > 1.0$ may not necessarily signify a declining stock but rather serve as an alert to unsustainable fishing practices.

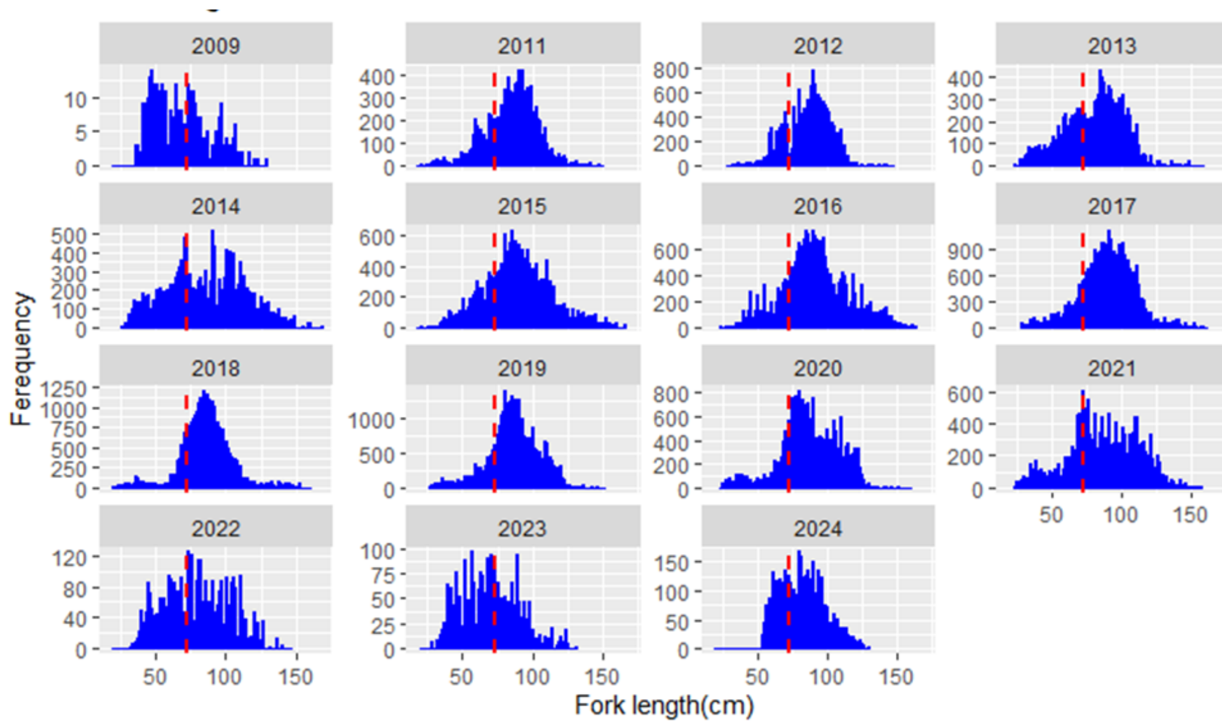

Fig. 3. Length frequency distribution of *S.commerson* from 2009 to 2024.the dashed red line indicates the length of maturity 50% (Lm_{50} = 72.6 cm)

The LBSPR results for the reference points SPR and F/M and selectivity parameters SL50 and SL95 are estimated. The parameters SL50 and SL95 were substantially lower than Lm50 in most years, suggesting that the fishery targeted undersized individuals (Fig 4). SPR estimates resulted in low values (below 40%) over the entire period (2009–2024), and in 2024, SPR was 31%, indicating that this stock is below proxies that would be consistent with ongoing recruitment fishing. The F/M ratio was substantially greater than 1 over the entire period except in 2009, 2014 to 2016, showing a decreasing trend in recent years, but still suggesting overfishing since current exploitation is generally above the optimum mortality (F = M). Based on the study periods, the LBSPR results presented a decreasing trend in SPR and an increasing one in F/M (Fig, 4).

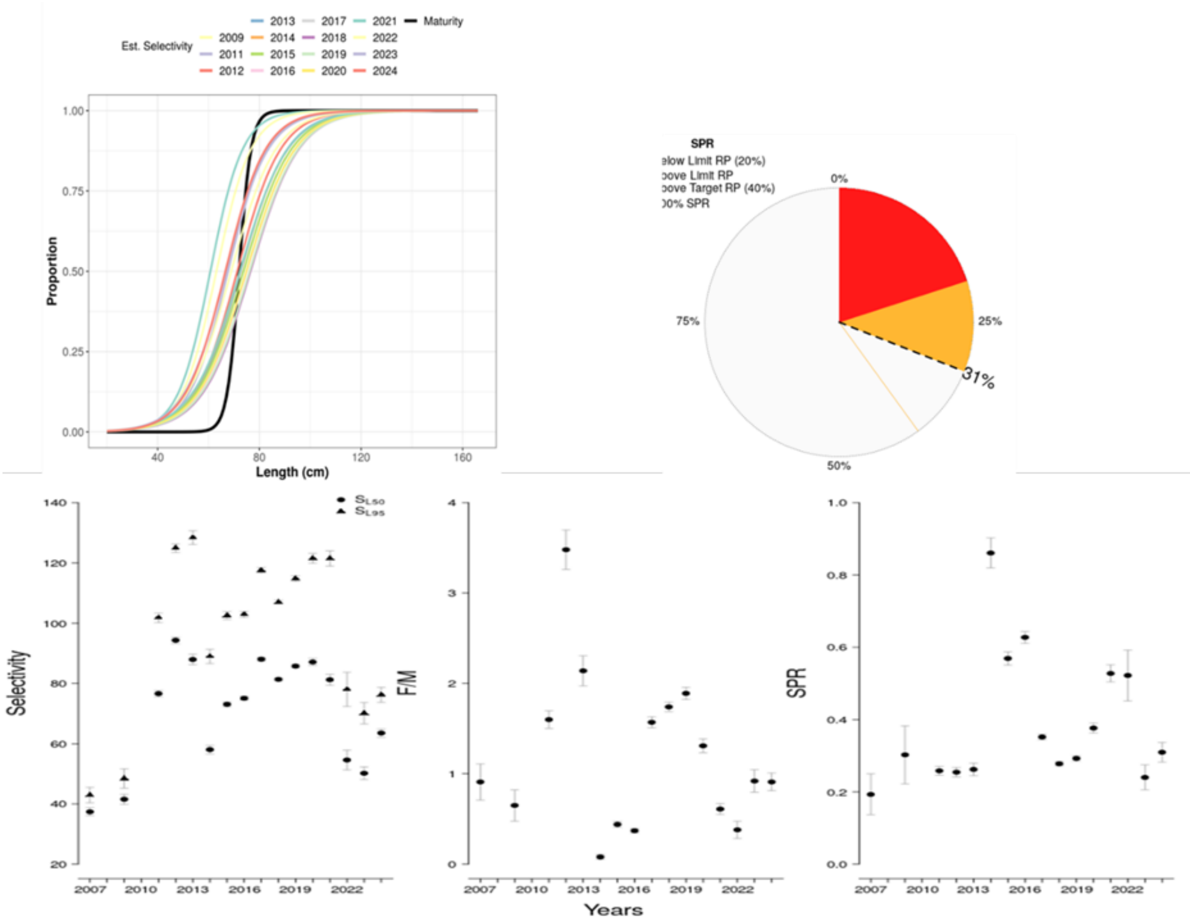

Fig .4. Outputs of the LBSPR model showing (A) maturity and selectivity curve from the fitted model when Lm50% = 72.6 cm and L95% =78 cm for all study years, (B) SPR for the last year of assessment (dotted line) according to reference point (RP), time series changes in (C) the distribution of mean selectivity parameters SL50% (solid black line) and SL95% (dotted line) across Lm50 (red solid line), (D) fishing mortality to natural mortality (F/M), and(E) SPR% with their standard deviations.

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