



Stock assessment of the Indian mackerel *Rastrelliger kanagurta* (Cuvier, 1817) from Muscat coast, Oman

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ABSTRACT

Assessment of age, growth and stock parameters was carried out for the Indian mackerel *Rastrelliger kanagurta* (Cuvier) along the Muscat coast of Oman between October 2007 and September 2009. The length-weight relationship of the fish indicated the 'a' value as 0.0101 and 'b' value as 3.0589. The length based von Bertalanffy growth (VBG) parameters L_{∞} , K and t_0 estimated were 37.54 cm, 1.0 y^{-1} and -0.17 y respectively. The estimates of mortality rates showed the annual total mortality (Z) to be 2.98, the natural mortality (M) 1.62 and fishing mortality (F) 1.36. The MSY estimated by Cadima's estimator was 859 t and the predicted value by yield analysis stood at 1,273 t. The calculated exploitation rate (E) was 0.46. The Yw/R at F = 1.6 was 48 g. Estimates of higher MSY than the current yield, lower fishing mortality than natural mortality and lower E indicate scope for increase in yield of *R. kanagurta* from Muscat region.

Keywords: Age, Growth, Muscat coast, *Rastrelliger kanagurta*, Stock assessment

Introduction

Sultanate of Oman is endowed with a coastline of 3,165 km bordering the Arabian Sea, Oman Sea and Arabian Gulf and has about 533,180 km² of EEZ. The fisheries sector of Oman is mainly traditional subsistence oriented one, contributing less than 1% of GNP, but is second next to oil contributing to the economy of the country. Fish production in Oman registered a remarkable growth from 94893 t in 1985 to 158789 t in 2009 and the value rose from RO 25 million (1 RO = 2.6 USD) to an all-time high of RO 104.6 million in the corresponding years (GoSO, 2009). Of the total fish production of the country, nearly 84% of catches come from the artisanal fisheries and the rest contributed by licensed industrial fleet (GoSO, 2009).

The contribution of small pelagics to the annual total fish landings of Oman varied from 21.4 to 51.3% between 1995 and 2009 (GoSO, 2009). Among the small pelagics of Oman, the Indian mackerel *Rastrelliger kanagurta* (Cuvier, 1817) is an important species (Randall, 1995). Its contribution to the total marine fish production of Oman varied from 1.9 to 6.9% between 1998 and 2009 and the annual average catch for the years 2000-2009 stood at 5334 t (GoSO, 2007; 2009). This indicates that the Indian mackerel fishery is developing in the country and requires judicious resource use to the fullest potential.

Indian mackerel is caught from the Sea of Oman by artisanal gears such as gillnets (of various mesh sizes up to 75 mm), seine nets (cod end mesh 9-12 mm) and castnets (mesh size 21 mm) using small boats (5 to 9 m LOA) fitted with outboard engines and the fishing activity is primarily confined to a depth up to 50 m. Along the coast of Sea of Oman, Muscat is an important fish landing centre and the estimated annual landings of *R. kanagurta* from this coast for the period 2000-2009 varied from 419 t in 2002 to 1025 t in 2007 (GoSO, 2009). Though the fish is caught almost the year round during south-west monsoon months (June-August/September), the fishery operates at a low key due to rough seas. Information on the stock of *R. kanagurta* from Sohar coast bordering the Sea of Oman is available (Jayabalan *et al.*, 2014). However, no attempt has been made to study the stock characteristics of *R. kanagurta* from the Muscat coast. As reliable stock estimates are needed for successful development and management of Indian mackerel fisheries along the Muscat coast, the present study on age, growth and stock assessment was undertaken for two years during 2007-2009.

Materials and methods

Altogether, 3804 specimens of *R. kanagurta* captured from Muscat coast (Fig. 1) during October 2007-September 2009 were brought to the laboratory and the total length (± 1 mm) of each specimen was measured

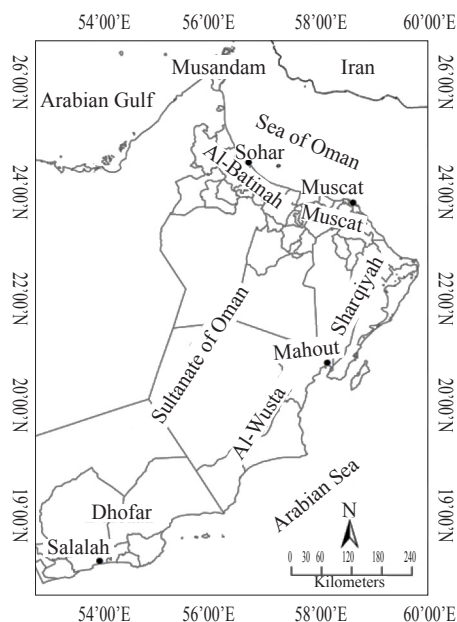


Fig. 1. Map showing the Muscat coast

using a fish measuring board. To estimate the length-weight relationships of males and females, 810 specimens (406 females and 404 males) were used employing the equation, $W = aL^b$ (Jayabalan *et al.*, 2014). While the size of females ranged from 17.3 to 34.5 cm and weight from 54 to 476 g, the size of males varied from 17.5 to 33 cm and weight from 41 to 448 g. The length-weight relationships of males and females were tested with Analysis of Covariance (ANCOVA) (Snedecor and Cochran, 1967) for significant difference at 5% level.

von Bertalanffy growth (VBG) parameters such as L_{∞} , K and t_0 were estimated for the monthly length frequency data (sexes pooled) by fitting the equation, $L_t = L_{\infty} [1 - e^{-K(t-t_0)}]$ for non-seasonal VBG curve using the ELEFAN 1 technique available with LFDA ver. 5.0 of FMSP- Fish Stock Assessment Software (Hoggarth *et al.*, 2006). The overall growth performance index (Phi prime) of the fish was estimated empirically (Munro and Pauly, 1983). The size at first capture was calculated by plotting cumulative percentages of sizes against size groups.

The length converted catch curve method (Pauly, 1983) and Beverton-Holt technique (Beverton and Holt, 1956) were adopted to estimate total mortality (Z) employing the routines in the LFDA version 5.0 of FMSP software and the average Z of both the methods was considered for stock assessment.

Natural mortality coefficient (M) of fish was determined using the empirical method (Pauly, 1980) considering 26°C as the mean surface water temperature in the Omani waters (Thangaraja, 1995). The difference

between Z and M was taken as the fishing mortality (F). The exploitation rate (E) and exploitation ratio (U) were determined by the formulae F/Z (Sparre and Venema, 1992) and $F/Z(1-e^{-Z})$ (Ricker, 1975) respectively.

From the annual average yield (Y) of Indian mackerel for the years 2005-2009 in the Muscat region calculated at 735 t (GoSO, 2010), the standing stock (Y/F) and total stock (Y/U) were calculated.

The maximum sustainable yield (MSY) was determined by Cadima's estimator (Traodec, 1977). To estimate the predicted yield and biomass for the F values ranging from 0 to 5 and the likely F for MSY, the YIELD software in FMSP package was used (Hoggarth *et al.*, 2006). All the input parameters required for the software were taken from the present study and equilibrium yield-per-recruit (Y_w/R), total biomass-per-recruit (TB/R) and stock spawning biomass-per-recruit (SSB/R) were estimated for F -values ranging from 0 to 5.

The value of SSB_0 was allocated considering the length at first maturity of *R. kanagurta* along the Muscat coast (Zaki *et al.*, 2011) and occurrence of various length groups in the catches during 2009. Beverton and Holt stock recruit relationship (SSR) was adopted.

Results and discussion

Catches and length frequency distribution

The estimated landings of Indian mackerel from Muscat coast during 2000 - 2009 are given in Fig. 2. The catch ranged from 419 t in 2002 to 1025 t in 2007 and the annual average catch stood at 735 t.

The total length of fish in the commercial catches during 2007-2009 ranged from 12.1 to 34.5 cm (Fig. 3). There were two peaks in the sizes, the minor peak at 14-15 cm and the major at 27-28 cm. Fish in the size groups from 23-24 cm to 30-31 cm contributed to about 71.4% in the total catches and the average size of fish at capture was calculated at 26.4 cm.

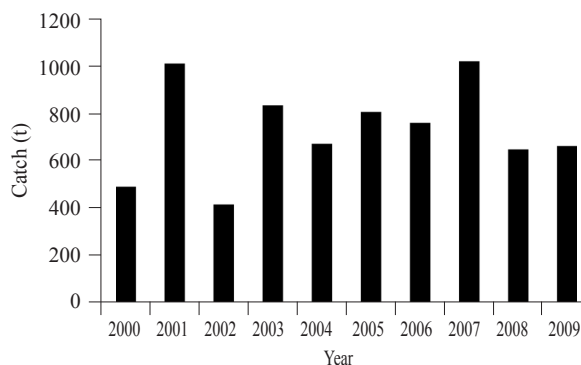


Fig. 2. Estimated catch of *R. kanagurta* from Muscat coast

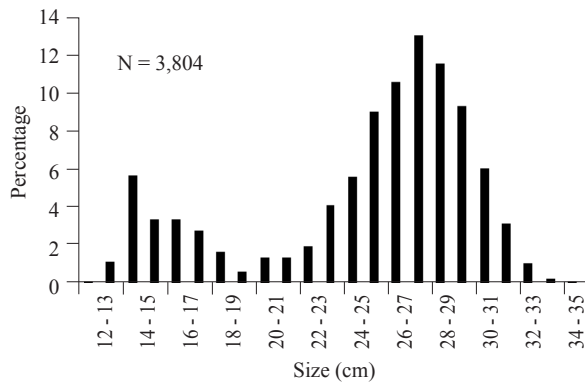


Fig. 3. Size frequency distribution of *R. kanagurta* in Muscat during 2007-09

The size of Indian mackerel in the commercial landings from the Sea of Oman ranged from 9.1 to 35 cm during 2007-2009 (Zaki *et al.*, 2011). The estimated average size of fish at capture from Muscat presently was found to be larger (26.4 cm) than from Sohar coast (23 cm) bordering the Sea of Oman (Jayabalan *et al.*, 2014). However, the average size of Indian mackerel landed at Mahout (28 cm) and Salalah (27 cm) were higher than from both Muscat and Sohar (Zaki *et al.*, 2011) indicating the occurrence of larger individuals in the Arabian Sea than in the Sea of Oman. In general, the average size of the Indian mackerel from the Indian coasts bordering the Arabian Sea and Bay of Bengal appeared to be smaller than from Omani coasts (Noble *et al.*, 1992; Yohannan and Sivadas, 2003; Rohit and Gupta, 2004; Abdussamad *et al.*, 2006, 2010, Jayabalan, 2014).

Length-weight relationship

Though, the length-weight relationships indicated females to be slightly heavier than males, no significant difference existed ($p > 0.05$) between the relationships. Hence, the common equation for *R. kanagurta* from Muscat (Fig. 4) can be expressed as: $W = 0.0101L^{3.0589}$ ($R^2 = 0.9158$).

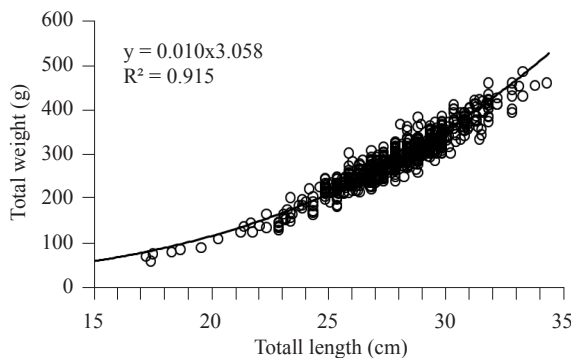


Fig. 4. Length-weight relationship in *R. kanagurta* in Muscat (Sexes pooled)

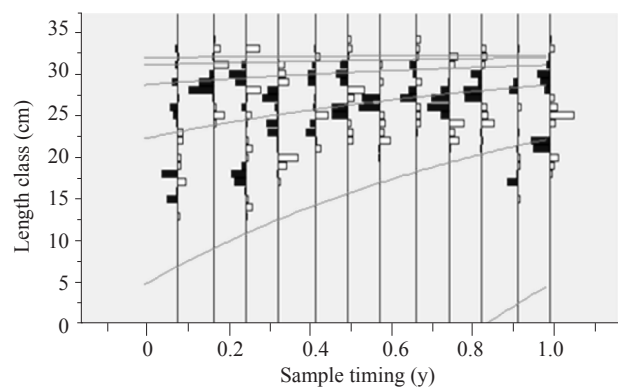
Common length-weight equations for males and females were proposed for *R. kanagurta* from Vizhijam in India (Gopakumar *et al.*, 1991) and from Sohar in Oman (Jayabalan *et al.*, 2014). However, separate length-weight equations were suggested for males and females of the Indian mackerel from the Kakinada coast in India (Abdussamad *et al.*, 2006).

The ‘b’ values of length-weight relationships of *R. kanagurta* vary between 3.010 and 3.475 in studies from various coasts of its distribution (Jones and Silas, 1962; Rafail, 1972; Luther, 1973; Sousa and Gislason, 1985; Tampubolon, 1988; Sanders and Morgan, 1989; Edwards and Shaher, 1991; Gopakumar *et al.*, 1991; Noble *et al.*, 1992; Pauly *et al.*, 1996; Rohit *et al.*, 1998; Mehanna, 2001; Abdurahiman *et al.*, 2004; Rohit and Gupta, 2004; Moazzam *et al.*, 2005; Abdussamad *et al.*, 2006; Jayabalan *et al.*, 2014). The ‘b’ value obtained in the present study lies within the range reported from earlier studies. As minor variation in the length-weight parameters would largely influence the stock structure, coast specific estimates of length-weight parameters are necessary for stock assessment.

Age and growth

The estimated L_{∞} , K and t_0 values of *R. kanagurta* from Muscat were 37.54 cm, 1 (y^{-1}) and -0.17 y respectively (Fig. 5). The L_{∞} and K values are higher in Muscat than in Sohar coast in Oman (Jayabalan *et al.*, 2014). Growth parameters of *R. kanagurta* from earlier studies indicated that the parameters not only differed between the countries; but also, in different regions of the country and periods of study (Table 1). The present estimates of growth parameters are well within the ranges reported from earlier studies (Table 1).

Based on the VBG parameters, the expected lengths for different ages of *R. kanagurta* indicated higher growth



Growth curve = Non-seasonal, $L_{\infty} = 37.5$, $K = 1.00$, $t_0 = -0.17$

Fig. 5. VBG curves of *R. kanagurta* from Muscat by ELEFAN technique

Table 1. Comparison of growth parameters of *R. kanagartha* from various studies

Country/Region	L_{∞} (cm)	K (y^{-1})	t_0 (y)	Reference
India	31.6	0.6	-	Rao <i>et al.</i> (1962)
India	39.0	0.74	-	Luther (1973)
India	26.5	2.4	-	Yohannan <i>et al.</i> (1998)
India	28.17	1.233	-	Rohit <i>et al.</i> (1998)
India (east coast)	28.35	1.7	-	Yohannan <i>et al.</i> (2002)
India (west coast)	28.50	1.78	-	Yohannan <i>et al.</i> (2002)
India	30.7	1.8	-	Rohit and Gupta (2004)
India	28.63	1.89	-0.0023	Abdussamad <i>et al.</i> (2006)
India	33.28	1.634	0.0018	Abdussamad <i>et al.</i> (2010)
Philippines	38.0	0.8	-	Guanco (1991)
Seychelles	31.7	0.64	-	Lablache <i>et al.</i> (1988)
Yemen	32.3 (FL)	0.67	-0.69	Edwards and Shafer (1991)
Egypt	42.0	0.29	-0.95	Rafail (1972)
Egypt	40.0	0.23	-	Sanders <i>et al.</i> (1984)
Egypt	32.15	0.57	-0.053	Mehanna (2001)
Oman (Sohar)	35.00	0.93	-0.45	Jayabalan <i>et al.</i> (2014)
Oman (Muscat)	37.54	1.00	-0.17	Present study

during first year (27.7 cm); while, the growth at 2nd, 3rd and 4th years were 33.9, 36.2 and 37.1 cm respectively. However, lower growth rates for first, second, third and fourth year of age were reported from various coasts than in the present study (George and Banerji, 1964; Rao *et al.*, 1962; Seshappa, 1969; Luther, 1973; Rafail, 1972; Mehanna, 2001; Abdussamad *et al.*, 2006; Jayabalan *et al.*, 2014).

The estimated phi-prime index stood at 3.15. This indicates comparatively faster growth in fish in Muscat than in Sohar (2.97) (Jayabalan *et al.*, 2014). In the commercial catches in Muscat area, the fish in 0 year and 1+ year were dominant.

Mortality and exploitation rates

Table 2 shows the estimates of Z, M, F, E and U of *R. kanagartha* from Muscat coast and all the values were comparable with the estimates reported earlier from the coast of Sohar (Jayabalan *et al.*, 2014).

The annual M values of *R. kanagartha* varied from 1.00 to 2.61 in the Indian waters (Noble *et al.*, 1992; Rohit *et al.*, 1998; Rohit and Gupta, 2004; Abdussamad *et al.*, 2006; 2010) and the present M value is well within the above range. In Muscat, the estimated F was lower than M and the E value (0.46) was less than 0.5 (Gulland, 1971). These show that the stock is not harvested to its optimum level from the coast and hence there is scope for higher yield.

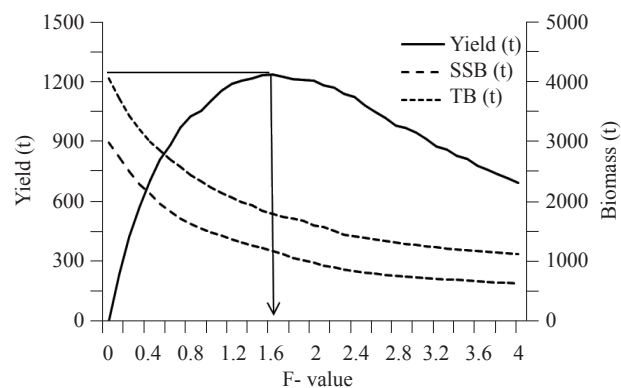
Table 2. Estimates of Z, M, F, E and U for *R. kanagartha* in the Sea of Oman

Centre	Z	M	F	E	U	Source
Sohar	2.848	1.58	1.268	0.45	0.42	Jayabalan <i>et al.</i> (2014)
Muscat	2.978	1.62	1.358	0.46	0.43	Present study

Stock assessment and per-recruit analysis

The standing stock and annual stock were estimated at 577 and 1,809 t respectively. The MSY calculated by Cadima's formula was 859 t. The yield analysis indicated an initial biomass of 4173 t and MSY of 1273 t (Fig. 6). The increase in F from 0 showed the yield to increase proportionately and the MSY of 1273 t was achieved at F = 1.6 and the corresponding biomass stood at 1854 t. Further increase in F showed the yield to decrease and at F = 4, the biomass was equal to 1153 t. The initial SSB of 3078 t reduced to 1206 t at the MSY level harvest. The SSB decreased further with increase in F and at F = 4, the SSB was just 651 t which was equal to 21% of the initial value. The average annual catch of 783 t in Muscat coast is lower than the estimated MSY. Further, the M (1.62 y^{-1}) was higher than F (1.358 y^{-1}), while E stood at 0.46. Hence, there is possibility for marginal increase in catches from the Muscat coast.

The Yw/R, TB/R and SSB/R of *R. kanagartha* in Muscat region are shown in Fig. 7. The Yw/R at F = 1.6 was 48.0 g. The TB/R, FB/R and SSB/R decreased with

Fig. 6. Predicted yield, biomass and SSB of *R. kanagartha* in Muscat against different F

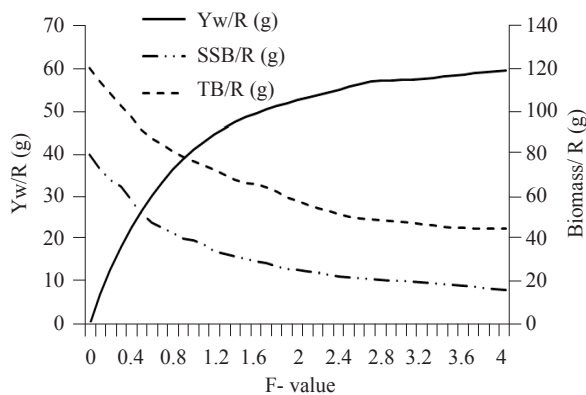


Fig. 7. Yw/R, TB/R, and SSB/R of *R. kanagurta* in Muscat against different F values

increase in F. At F = 1, the TB/R, FB/R and SSB/R were 74.2, 39.9 and 38.6 g respectively which decreased to 43.8, 14.4 and 16.0 g at F = 4.

Indian mackerel utilise both primary and secondary production as well as associate with larger carnivores in the food chain in the coastal waters (Yohannan and Sivadas, 2003). In the coastal upwelling areas, inter-annual variations in the abundance of plankton feeding small pelagic fishes are common (Krishnakumar *et al.*, 2008). Hence, the annual fluctuations in the catches of Indian mackerel would be related to fishery independent factors.

Along the Muscat coast, the length at first maturity (L_m) of *R. kanagurta* was calculated at 22.8 cm for males and 23.1 cm for females during 2007-08 and the corresponding values were 23.7 and 24 cm in males and females respectively during 2008-09 (Zaki *et al.*, 2011). Since, the average size of fish at capture in Muscat was calculated at 26.4 cm, there appears to be no fishery management concern at present. As the fish appears to grow to 27.7 cm at the end of first year, fish would attain maturity prior to the completion of first year of its life. Occurrence of mature fish for several months in the catches indicates that the fish is adapted to make use of any favourable environment for spawning in Omani waters (Zaki *et al.*, 2011).

Acknowledgements

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