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Age, growth and stock assessment of the Indian mackerel *Rastrelliger kanagurta* (Cuvier, 1817) along the Sohar coast of Oman

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ABSTRACT

A study on age, growth and stock characteristics of the Indian mackerel *Rastrelliger kanagurta* (Cuvier) was made from Sohar coast between 2007 and 2009. The length-weight relationship for the species can be expressed by the common formula, $W = 0.0035TL^{3.3881}$. The growth parameters of *R. kanagurta* were L_{∞} = 3 4.00 cm, K = 0.86 y^{-1} and t_0 = -0.06 y. The total mortality (Z) was 2.84 y^{-1}, the natural mortality rate (M) and fishing mortality (F) were 1.58 and 1.26 respectively. The exploitation rate (E) was less than 0.5. The estimates of MSY stood at 1512 t by Cadima's formula. The predictive Thompson and Bell analysis indicated scope for marginal increase in Indian mackerel landings and the estimated MSY and corresponding F were 1,576 t and 1.4 respectively.

Keywords: Age, Growth, Oman, *Rastrelliger kanagurta*, Stock assessment

Introduction

The Indian mackerel *Rastrelliger kanagurta* (Cuvier) is a pelagic shoaling fish that forms commercial fisheries along the coasts of the countries bordering the Red Sea, Oman Sea, Arabian Gulf, Pakistan, India, Sri Lanka, Bangladesh, Myanmar, Thailand and Malaysia (Fischer and Whitehead, 1974; Collette and Nauen, 1983; Fischer and Bianchi, 1984). Studies on the biology and stock assessment of Indian mackerel from various coasts are available (Dhulkhed and Annigeri, 1983; Fischer and Bianchi, 1984; Sanders *et al*., 1984; Sousa and Gislason, 1985; Sivasubramaniam, 1987; Gopakumar *et al*., 1991; Noble *et al*., 1992; Devaraj *et al*., 1994; Rohit *et al*., 1998; Mehanna, 2001; Rohit and Gupta, 2004; Moazzam *et al*., 2005; Abdussamad *et al*., 2006, 2010; Krishnakumar *et al*., 2008).

In Omani waters, Indian mackerel is harvested by the artisanal fishers using gill-nets and seines (Randall, 1995; Al-Abdessalaam, 1995). The contribution of Indian mackerel to the total marine fish production of Oman varied from 1.9 to 6.9% between 1998 and 2009 (GoSO, 2007; 2009). The estimated catches that stood at 1,994 t in 1998 had risen to 10,124 t in 2009 registering about five-fold increase in landings (GoSO, 2009). In spite of its economic importance, there has been no attempt to study the biology and stock characteristics of the Indian mackerel from the Omani waters. Hence, the present study was undertaken on the age, growth and stock characteristics of the Indian mackerel from the coast of Sohar (Al Batinah region) between 2007 and 2009.

Materials and methods

A total of 3,318 fish collected from Sohar (Fig. 1) were measured for the total length to the nearest 1 mm between October 2007 and September 2009. The monthly length frequency data for sexes pooled were used for age and growth

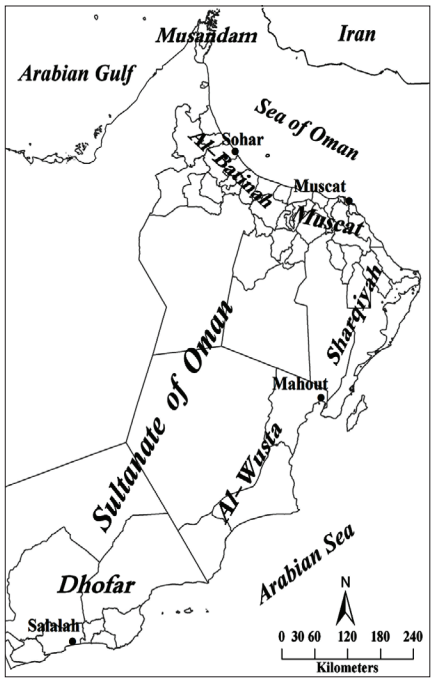

Fig. 1. Map showing Sohar (Al-Batinah) coast

estimations. The length-weight relationships were estimated from the length and weight data of fresh fish using the equation, $W = aL^b$, where, W is the total weight in g, L is the total length in cm and 'a' and 'b' are the constants to be determined which were fitted separately for males, females and sexes pooled samples. Analysis of covariance (ANCOVA) (Snedecor and Cochran, 1967) test was used to find out the significant difference if any, between the relationships of males and females at 5% level.

To estimate the von Bertalanffy growth (VBG) parameters (L_∞, K and t_0) of *R. kanagurta*, the pooled TL (total length) frequency data were grouped into 1 cm class interval to fit the equation, $L_t = L_{\infty *}[1 - e^{-K_*(t - t_0)}]$ using the LFDA version 5.0 of FMSP- Fish Stock Assessment Software (Hoggarth *et al*., 2006) and ELEFAN 1 with non-seasonal version of VBG curve were fitted to the TL data to calculate VBG parameters. The overall growth performance index (Phi prime) for the fish were calculated empirically (Munro and Pauly, 1983) using the formula, Phi prime = log10 K + 2 $\log_{10} L_\infty$, where, K is expressed on annual basis and L_∞ in cm. Length at first capture was estimated by plotting cumulative percentages of length against length classes.

The instantaneous total mortality rate (Z) was estimated using the length converted catch curve method (Pauly, 1983) and Beverton-Holt method (Beverton and Holt, 1956) using the routines provided in the LFDA version 5.0 of FMSP software and the average of both the techniques was taken for subsequent analyses. Natural mortality coefficient (M) of fish was estimated by the empirical method of Pauly (1980) using ln M = -0.0152 - 0.279 * ln L_∞ + 0.6543 log * k + 0.4634 * ln T, where T indicates the annual mean temperature (°C) of the surrounding water in which the fish lives. In the present study, the T value was taken as 26°C as this value represents the mean surface water temperature in the Omani waters (Thangaraja, 1995). The value of fishing mortality (F) was computed by subtracting natural mortality from total mortality as, F = Z – M. The exploitation rate (E) was computed as, E = F/Z (Sparre and Venema, 1992) and exploitation ratio (U) was estimated as, $U = F / Z (1-e^{-z})$ (Ricker, 1975).

The average annual yield (Y) of *R. kanagurta* from Sohar region for the years 2005-2009 was calculated at 1,346 t (GoSO, 2010). The standing stock was estimated by weight using the formula, Standing stock = Y/F, where Y is the yield and F, the fishing mortality. The total stock in weight was estimated using the relation between yield and exploitation ratio as: Total stock = Y/U, where Y is the annual yield and U is the exploitation ratio.

The maximum sustainable yield (MSY) was estimated by Cadima's estimator (in Traodec, 1977) and Thompson and Bell analysis. Using the 'YIELD" software available with FMSP package (Hoggarth *et al*., 2006), the predicted yield and biomass for a range of F values (F= 0 to 5) were estimated to obtain the probable F at which the MSY was obtained. All the required input parameters for the YIELD software were obtained from the present study. The value of SSB0 was assigned based on the length at first maturity (Zaki *et al*., 2011) and the contribution of various size groups in the commercial catches during 2009. For the stock recruit relationship (SSR), Beverton and Holt SRR was adopted.

The per-recruit analyses were conducted using the 'YIELD' software (Hoggarth *et al*., 2006). The estimations of equilibrium yield-per-recruit (Yw/R), total biomass-per-recruit (TB/R) and stock spawning biomass-per-recruit (SSB/R) for a range of F-values from 0 to 5 were made.

Results and discussion

Fishery

The estimated landings of Indian mackerel from Al-Batinah coast for the period 2000 - 2009 are given in Fig. 2. The catches ranged from 658 t in 2001 to 1981 t in 2007 and the annual average catches of Indian mackerel stood at 1,305 t.

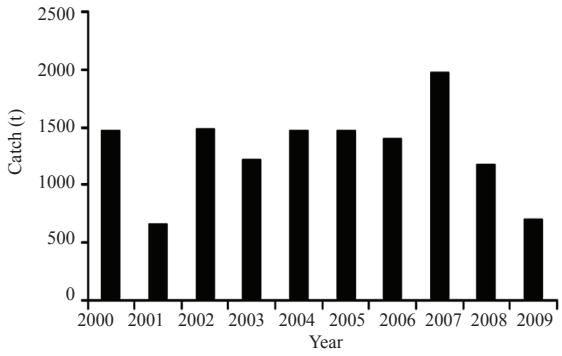

Fig. 2. Estimated catches of *R. kanagurta* from Sohar (Al Batinah) coast

Length frequency distribution

The length of fish in commercial catches in Sohar during 2007-09 ranged from 91mm to 332 mm of TL (Fig. 3). The smaller sized fish (91-130 mm) represented about 3.3%. Nearly 68% of fish were contributed by the size range 201-280 mm. However, narrow size ranges and smaller modal values of mackerel in the commercial catches from the Indian coasts bordering the Arabian Sea (range 110-150 mm; mode at 145 mm) and the Bay of Bengal (range 175-215 mm; mode at 195 mm) were reported (Yohannan and Sivadas, 2003). Generally, the average size of mackerel caught from Oman appeared to be

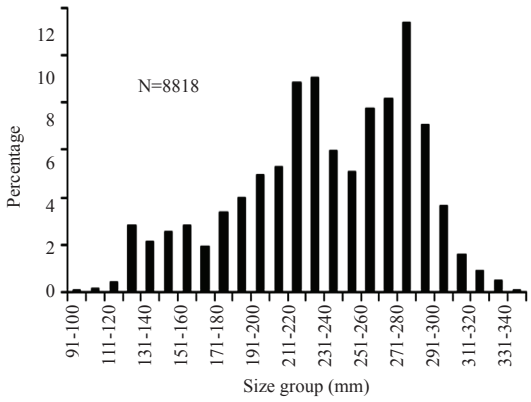

Fig. 3. Size frequency distribution of *R. kanagurta* in Sohar during 2007-2009

bigger than that from Indian waters (Noble *et al*., 1992; Rohit and Gupta, 2004; Abdussamad *et al*., 2006, 2010). From the cumulative percentage frequency, the average length at which 50% of fish caught in Sohar was estimated at 233 mm.

Length-weight relationship

The relationships showed the females were slightly heavier than the males measuring the same length. The ANCOVA test indicated no significant difference in the length-weight relationships of males and females. Hence, the equation for sexes pooled data would be ideal for the Indian mackerel in Sohar. The estimated length-weight relationship in *R. kanagurta* (Fig. 4) was, $W = 0.0035x^{3.3881}$ ($R^2 = 0.9808$). The length-weight relationships of *R. kanagurta* estimated from different regions indicated the 'b' values to fluctuate from 3.010 to 3.475 (Jones and Silas, 1962; Rafail, 1972 a; Luther, 1973; Sousa and Gislason, 1985; Tampubolon, 1988; Sanders and Morgan, 1989; Edwards and Shaher, 1991; Torres and Pauly, 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).

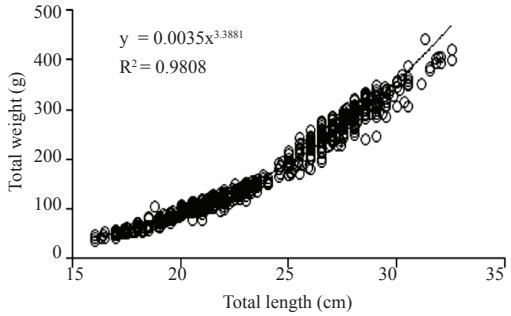

Fig. 4. Length-weight relationship in (sexes pooled) *R. kanagurta* in Sohar

Growth parameters

The VBG parameters, L_∞, K and t_o of Indian mackerel in Sohar were 34 cm 0.86 y^{-1} and -0.06 y respectively (Fig. 5) and these values are comparable with earlier studies (Table 1). The lengths of *R. kanagurta* in Sohar converted into age using the growth parameters (Fig. 6) showed growth at the end of first, second, third and fourth years as 19.7 cm, 27.4, 30.6 and 32.0 cm

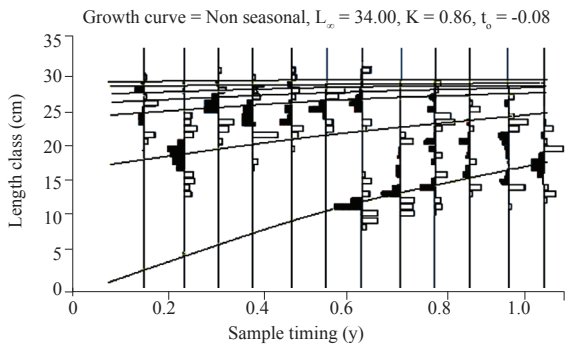

Fig. 5. VBG curves of *R. kanagurta* in Sohar by ELEFAN 1 technique

Table 1. Comparison of length-weight parameters of *R. kanagurta* from various studies

Country/ Region	a	b	Reference
India	0.000029	3.3087	Jones and Silas (1962)
India	0.000002164	3.2874	Luther (1973)
India	0.0000013848	3.3805	Gopakumar *et al*. (1991)
India	0.000000795	3.475	Noble *et al*. (1992)
India	0.000001385	3.3805	Rohit *et al*. (1998)
India	0.004457	3.29	Rohit and Gupta (2004)
India	0.005	3.261	Abdurahiman *et al*. (2004)
India	0.00000121	3.340179	Abdussamad *et al*. (2006)
Pakistan	0.00544	3.207	Moazzam *et al*. (2005)
Yemen	0.0170	3.010	Edwards and Shaher (1991)
Saudi Arabia	0.0040	3.33	Sanders and Morgan(1989)
Egypt	0.0043	3.2650	Rafail (1972 a)
Egypt	0.00548 (Male)	3.19870	Mehanna (2001)
	0.00607 (Female)	3.16818	
Malaysia	0.0067	3.090	Tampubolon (1988)
Indonesia	0.0039	3.19	Tampubolon (1988)
Indonesia	0.0061	3.174	Pauly *et al*. (1996)
Mozambique	0.0041	3.040	Sousa and Gislason (1985)
South Africa	0.0064	3.170	Torres and Pauly (1991)
Oman (Sohar)	0.0035	3.3881	Present study

respectively. The life span of fish would be around 4 years. The growth performance index was calculated at 2.97. In the commercial landings, the fish belonging to the age groups 1 and 2 years were dominant.

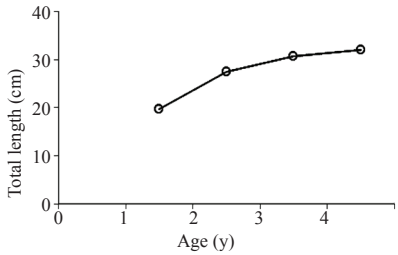

Fig. 6. Estimated length of fish for the given age of *R. kanagurta* in Sohar

The growth during the first and second years is in close agreement with the report of Abdussamad *et al*. (2010) from Tuticorin waters in the east coast of India. They have estimated the first year and second year growth of *R. kanagurta* as 25.4 cm and 30.3 cm respectively. Several studies have indicated lower growth rates at first, second, third and fourth year of age than the growth observed in the present study (George and Banerji, 1964; Rao *et al*., 1962; Seshappa, 1969; Luther, 1973; Rafail, 1972 b; Mehanna, 2001; Abdussamad *et al*., 2006).

Mortality and exploitation

The total mortality (Z) of *R. kanagurta* estimated by the length converted catch curve was 3.37 (SE=0.155) and by Beverton and Holt technique was 2.325 (SE=0.696). The average Z of 2.848 was taken for subsequent stock assessment. While, the estimated M was 1.58, the estimated fishing mortality (Z-M=F) stood at 1.268.

Generally, natural mortality is influenced by several biological and environmental parameters and hence, it would be difficult to obtain an accurate estimate of M in fishes (Pauly, 1980; Cushing, 1981; Liu and Cheng, 1999). Moreover, the estimates of M for *R. kanagurta* vary greatly in earlier studies conducted in the region. While the M values ranged from 1.00 to 2.61 y^{-1} in Indian waters (Noble *et al*., 1992; Rohit *et al*., 1998; Rohit and Gupta, 2004; Abdussamad *et al*., 2006; 2010), lower M values for male (0.26 y^{-1}) and female (0.25 y^{-1}) were reported from Egypt (Mehanna, 2001).

The estimated E stood at 0.45, while U stood at 0.42. For optimal exploitation of a stock, it is assumed that E ≈ 0.5 which in turn is under the assumption that the sustainable yield is optimised at F = M (Gulland, 1971). As the exploitation rate (E) was 0.45 and the fishing mortality was lower than the natural mortality, the stock was not exploited to its potential along the coast of Sohar.

Stock assessment

The estimated standing stock and annual stock were 1,062 t and 3,212 t respectively. The MSY calculated by the Cadima's estimator stood at 1,512 t. The Thompson and Bell analysis indicated the MSY to be 1,576 t (Fig. 7). In the absence of fishing, total biomass stood at 5,057 t. When the F value increased from initial 0, the yield also increased and an MSY of 1,576 t was obtained at F of 1.4 and the corresponding total biomass was equal to 2,399 t. Thereafter, the yield decreased with increase of F and when F value reached 4, the remaining total biomass was 850 t. The initial SSB stood at 3,100 t which was about 61% of the total biomass. When the MSY was obtained at F equal to 1.4, the SSB was reduced to 1,042 t which was equal to about 34% of the total biomass. The SSB further decreased with increase of F and at F values of 2, 3 and 4, the corresponding SSB values stood at 739 t, 455 t and 264 t respectively.

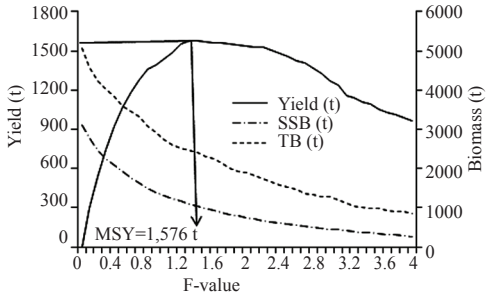

Fig. 7. Predicted yield, total biomass and SSB of *R. kanagurta* in Al-Batinah coast against F

The MSY values estimated by the Cadima's formula (1,512 t) and Thompson and Bell analysis (1,576 t) were comparable and both indicated scope for marginal increase of catches. The calculated E (0.45) also supports this conclusion. The Yw/R with the current fishing mortality (F = 1) was equal to 28.9 g which can be increased to 33.2 g if the F is increased to 1.4 (Fig. 8). The TB/R and SSB/R decreased with the increase of F. At the current F, the TB/R and SSB/R are 50.2 g and 21.1 g respectively which decreases to 38.4 g and 10.6 g at F = 2. At F = 4, the Yw/R, TB/R and SSB/R are 42.1 g, 26.2 g and 3.7 g respectively.

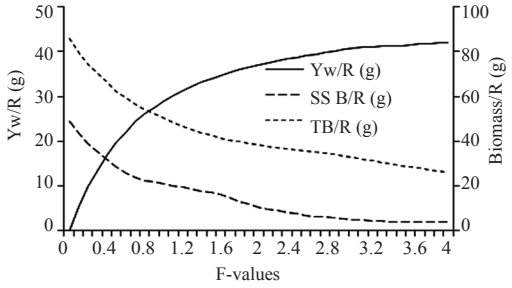

Fig. 8. Yield and biomass-per-recruit in *R. kanagurta* in Al-Batinah coast against F

As plankton feeder, Indian mackerel plays significant role in utilising the primary and secondary production in the coastal waters and sustains effective link in the food chain with larger carnivores (Yohannan and Sivadas, 2003). The instances of large quantities of smaller sized *R. kanagurta* landed by seine nets from the Indian coasts has affected the fishery resources in two ways, (i) in the underutilisation of the primary production and (ii) food scarcity to larger carnivorous fish (Yohannan and Sivadas, 2003). In Omani waters, as the size at capture is higher than the size at maturity, there is no management concern perceivable from the present study.

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