Length-Based Age, Growth and Stock Assessment of the Indian Oil Sardine
Sardinella longiceps Val. from the Salalah Coast, Sultanate of Oman

S. Zaki, N. Jayabalan, F. Al-Kiyumi, L. Al-Kharusi, S. Al-Habsi and Shejaibi

1Marine Science and Fisheries Centre, Ministry of Agriculture and Fisheries Wealth, P.O. Box 427, P.C. 100, Muscat, Sultanate of Oman
2Advanced Aquatic Environmental Research Services, P.O.Box 834, P.C. 130, Muscat, Sultanate of Oman
3Fisheries Research Centre-Salalah, Ministry of Agriculture and Fisheries Wealth, P.O. Box 33, P.C. 217, Salalah, Sultanate of Oman

Abstract: A study on age, growth and stock assessment of the Indian oil sardine Sardinella longiceps was conducted between October 2007 and September 2009 from the Salalah coast of Oman. The length of the fish in catches ranged from 111 mm to 220 mm of TL. The common equation of length-weight relationship estimated for males and females was W=0.000007*L. The estimated von Bertalanfy growth (VBG) parameters of L∞, K and t0 were 23.02 cm, 1.57 y⁻¹ and -0.49 y respectively. The growth performance index was estimated at 2.92. The annual total mortality (Z), natural mortality (M) and fishing mortality (F) rates were 4.65, 2.45 and 2.2 respectively. The exploitation rate (E) and exploitation ratio (U) stood at 0.473 and 0.466 respectively. While, the estimated biomass was 1241 t, the MSY was equal to 2886 t.

Key words: Indian Oil Sardine - Age - Growth - Mortality - Exploitation - MSY - Per-Recruit Analyses - Oman

INTRODUCTION

Along the coasts of Oman, the Indian oil sardine Sardinella longiceps is the main targeted species among the small pelagic fishes. The fish is caught by beach seines, boat seines, gillnets and cast nets and the catches range from 12,000 t to 20,000 tons annually [1, 2]; however, fluctuation from year to year appears common [2, 3]. The fish is marketed fresh for human consumption or sundried to use as fertilizer or cattle feed. The oil sardine is also used as live-bait for fishing larger species.

The total annual catches of sardines of the genus Sardinella from the coasts of Oman ranged between 31,974 t and 58,959 t during 2000-2009 [2, 3]and the contribution of S. longiceps ranged from 26,772 t (2008) to 41,168 t (2001). In spite of its economic importance, studies on the Indian oil sardine from Oman are few and fragmentary[4-7]. The Indian oil sardine has population doubling time of less than 15 months [8]. Hence, for the judicious use of the resource and successful development and management of fisheries depends on the availability of reliable stock estimates.

As the study on age and growth of S. longiceps from Oman was conducted more than two decades back [9] and no investigation on the population parameters and stock assessment has been carried out, the present study was undertaken from Salalah along the Arabian Sea coast of Oman.

MATERIALS AND METHODS

A total of 4,453 fish were measured at random from Salalah along the coast of Arabian Sea (Fig. 1) landed by the artisanal gears such as beach seines, gillnets of various mesh sizes (24 mm to 42 mm) and cast nets every month between October 2007 and September 2009. The pooled length data from various gears were used for the estimations. The fish were measured for the total length (TL) in the field to the nearest 1 mm using a fish measuring board. As sexes could not be identified...
externally, both the sexes were treated together. Length at 50% of capture (Lc) was estimated from cumulative percentage of lengths against length classes.

To calculate length-weight relationship, the TL (mm) and total weight (W) of fish were recorded to the nearest 1 mm and 1 g respectively. After cutting open, the sex of the fish was identified and the length-weight relationships in males, females and for sexes-pooled fish were estimated separately using the equation, \( W = aL^b \) where, \( W \), the total weight; \( L \), the total length and, \( a \) and \( b \) the constants to be determined. The relationships of males and females were tested with Analysis of Covariance (ANCOVA) [10] for significant difference if any, between the relationships at 5% level.

To estimate age and growth of fish, length frequency data grouped into 1 cm class interval were fitted to the equation, \( L_t = L_\infty(1-e^{-K(t-t_0)}) \) using ELEFAN 1 technique incorporated in LFDA version 5 of FMSP-Fish Stock Assessment Software [11] with non-seasonal version of VBG curve.

Growth performance index (\( \phi' \)) of the fish was estimated with the empirical formula [12] as, \( \phi' = \log_{10} K + 2 \log_{10} L_\infty \) where, \( K \) is expressed on annual basis and \( L_\infty \) in cm.

RESULTS AND DISCUSSION

Fishery: The total landings of *S. longiceps* from the Omani coasts and exclusively from Dhofar region (Salalah) for the period 2000-2009 are shown in Fig. 2. The annual catches in Salalah varied between 1775 t (2002) and 6774 t (2000).

The size of fish in the commercial catches (Fig. 3) showed that the smaller size groups of fish (111-150mm) contributed to about 5.3% of the catch and about 72.1% of the landings were represented by the size classes of 171-210 mm.
Fig. 2: Estimated annual catches of *S. longiceps* in Oman

Fig. 3: Length-frequency of *S. longiceps* in commercial catches at Salalah during 2007-09

Fig. 4: Length-weight relationships in *S. longiceps* at Salalah
A: Male; B: Female; C: Sexes pooled

The average size at first capture (Lc) estimated from the pooled cumulative percentages of fish in different size groups stood at 185 mm. However, in a parallel study from Arabian Sea along Mahout coast larger sized fish ranging from 161-230 mm (Lc= 193 mm) were recorded [19].

**Length-Weight Relationship:** The relationships between the length and weight of males (Fig. 4A), females (Fig. 4B) and sex's pooled fish (Fig. 4C) were as follows.

Male: \( W = 1E-05*L^{2.916} \) (\( R^2 = 0.8056 \)) \[4, 20\]

Female: \( W = 6E-06*L^{2.0939} \) (\( R^2 = 0.8434 \))

Sexes pooled: \( W = 7E-06*L^{1.0272} \) (\( R^2 = 0.8392 \))

Though, the b value of females was slightly higher than in males, the ANCOVA test (Table 1) showed no significant difference between the slopes (\( P>0.05 \)); however, significant difference existed between the elevations (\( P<0.05 \)). This is in agreement with the observations from the Sea of Oman along the Muscat and Sohar coasts [19]. However, males had higher b value in fish from the Arabian Sea in the Mahout coast (Jayabalan et al., MS).

In earlier studies from Omani waters, the b values ranged between 3.00 and 3.83 [4, 20]. However, lower b values (2.341-2.7021) of *S. longiceps* recorded from the Arabian Sea coast of India [21, 22] indicate that
Table 1: Comparison of length-weight relationships between sexes of *S. longiceps* in Salalah

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>sx</th>
<th>sy</th>
<th>spxy</th>
<th>Reg.coef</th>
<th>d.f.</th>
<th>S.S.</th>
<th>M.S</th>
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<td>22.78758</td>
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<td>808</td>
<td>3.891541</td>
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*Significant at 5% level

Fig. 5: VBG curves of *S. longiceps* in Salalah by ELEFAN 1

*S. longiceps* in Omani waters are heavier for their length than in Indian waters. This may be due to the differences in the stock characteristics.

Age and Growth: The VBG parameters of *S. longiceps* estimated from Salalah were: L∞= 23.02 cm; K= 1.57 y⁻¹ and t₀=-0.49 y (Fig. 5).

The growth calculated for 1 year and 2 years were 20.8 cm and 22.6 cm respectively. This showed that the fish grew faster during the initial stages and the commercial fishery targeted mainly the individuals of 0 and 1+ years of age. As the Lm of fish was estimated at about 18 cm [19] and Lc at 18.5 cm, most of the fish would spawn atleast once before they are caught. The L∞ (19.7 cm) and K (0.99 y⁻¹) estimated in an earlier study from Al-Azaiba region in Oman [6] were lower than in the present investigation.

The L∞ and K values of *S. longiceps* ranged from 19.7 cm to 22.1 cm and from 0.3y⁻¹ to 2.1y⁻¹ respectively from different regions along the Indian coasts (Antony Raja, 1972 [23-29]. From Yemen, a low L∞ (14.5 cm TL) and maximum K (5.62) reported from the Gulf of Aden [30] were inaccurate and were estimated subsequently as 19.3 cm and 1.22 y⁻¹ respectively [31]. However, Edwards and Shaher [32] estimated L∞ as 23.8 cm and k as 0.97y⁻¹.

The growth performance index of *S. longiceps* was found to be 2.92 in Salalah. This agrees with the observation from Indian waters where the values ranged from 2.36 to 2.92 [23-28].

Mortality rates, Exploitation rate (E) and Exploitation Ratio (U): The total mortality of *S. longiceps* from the Salalah coast was estimated at 4.65 y⁻¹ (SE= 0.149). While, the natural mortality (M) was calculated to be 2.45 y⁻¹, fishing mortality (F= Z-M) was equal to 2.2 y⁻¹. The calculated exploitation rate (E) and exploitation ratio were 0.473 and 0.466 respectively.

The mortality parameters of *S. longiceps* reported from earlier studies in the region indicated no consistency. While in Yemen, low Z, M and F values (1.3, 1.05 and 0.35 y⁻¹ respectively) were reported [32], high Z values ranging from 2.23 to 6.34 y⁻¹, M from 1.3 to 4.91 y⁻¹ and F from 1.43 to 2.2 y⁻¹ were recorded from Indian waters [26, 28, 33]. The natural mortality was high (2.2 y⁻¹) in Salalah than from other coasts of Oman [19]. However, lower fishing mortality than the natural mortality and exploitation rate (E) less than 0.5 showed the stock was not overexploited.

Yield, Standing stock, Total stock and MSY: The average annual yield of Indian oil sardine for 2005-2009 from Dhofar coast (Salalah) was estimated at 2,732 t. The estimated standing stock and total stock were 1,241 t and 5,861 t respectively.
The commercial fishery of the Indian oil sardine in Oman during 2007-2009 consisted mainly of 0 and 1+ year age groups. However, few individuals of 2 years of age also occurred. This shows that majority of fish may spawn only once and few larger fish may get an opportunity to spawn for the second time. Hence, the success or failure of the fishery appears to be predetermined during spawning of the same season. This has to be verified by subsequent studies on the process of reproduction and in tracing the causative factors that influence the spawning success and better survival for recruitment.

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