

Age, growth and stock assessment of the Indian oilsardine *Sardinella longiceps* Valenciennes 1847 off Mahout coast, Sultanate of Oman

N. JAYABALAN*, S. ZAKI, F. AL-KIYUMI AND L. AL-KHARUSI

Marine Science and Fisheries Centre, Ministry of Fisheries Wealth, P. O. Box 427, P. C. 100, Muscat Sultanate of Oman

*Advanced Aquatic Environmental Research Services, P. O. Box 834, P. C. 130, Muscat, Sultanate of Oman
e-mail: maljaya2@yahoo.com

ABSTRACT

A study on the age, growth and stock assessment of the Indian oilsardine *Sardinella longiceps* was conducted between September 2007 and September 2009 from Mahout along the Arabian Sea coast of Oman. The size of the fish in commercial catches varied from 161 mm to 228 mm total length (TL). The length-weight relationship for both males and females can be expressed as $W = 0.00005 \cdot L^{2.914659}$. The estimated growth parameters L_{∞} , K and t_0 were 230 cm, 1.33 y^{-1} and -0.09 y respectively and most of the fish caught were in 1+ year of age. The annual total mortality (Z), natural mortality (M) and fishing mortality (F) rates were 3.661, 2.21 and 1.451 respectively. The exploitation rate (E) was 0.396. The estimated standing stock was 1,473 t and the annual stock stood at 7,311 t. The MSY estimated by Thompson and Bell analysis was equal to 5,552 t. The study indicates scope for additional catches of Indian oilsardine from the Mahout coast.

Keywords: Age, Growth, Mortality, MSY, Oman, *Sardinella longiceps*

Introduction

The fisheries sector of the Sultanate of Oman is second in importance in the economy of the country and is based mainly on artisanal fisheries consisting of about 37,520 coastal fishermen using small boats numbering about 14,769 to fish in the traditional grounds all along the Omani coast. Of the total fish production of the country, nearly 84% of catches come from the artisanal fisheries (GoSO, 2009) and the Indian oilsardine is the main targeted species among the small pelagic fishes. The fish is caught in beach seines, boat seines, gillnets and cast nets and the catches range from 12,000 t to 20,000 t annually (Abdessaalam, 1995; GoSO, 2010). The fish is marketed fresh for human consumption or sundried to use as fertiliser or cattle feed. The oilsardine is also used as live-bait for fishing larger species.

In spite of its economic importance, studies on the Indian oilsardine from Oman are few and fragmentary. While Al-Barwani *et al.* (1989) studied the biological characteristics of the oilsardine from Oman; few aspects of age and growth have been reported by Diana and Seelbach (1990). Siddeek *et al.* (1994) studied the reproductive dynamics and recruitment pattern of oilsardine exclusively from Al-Azaiba in the Sea of Oman. Al-Jufaili *et al.* (2006) estimated the fecundity and GSI of *S. longiceps* from Muscat region. It appears that *S. longiceps* of Oman is represented by a unit stock (Shaklee and Shaklee, 1990).

The Indian oilsardine has population doubling time of less than 15 months (Froese and Pauly, 2011). As the fish has short life-span, judicious use of the resource to their fullest potential is required. Successful development and management of fisheries depends on the availability of reliable stock estimates. The length frequency data collected during 2007-2009 were used for age, growth and stock assessment of *Sardinella longiceps* from the coast of Mahout, Oman.

Materials and methods

A total of 3,286 fish were collected at random from Mahout (Al-Wusta region) along the coast of Arabian Sea (Fig. 1) landed by the artisanal gears such as beach seines, boat seines, gillnets and cast nets on monthly basis between September 2007 and September 2009. The fish were measured for the total length (TL) in the field to the nearest 1 mm using a fish measuring board.

For estimating length-weight relationship, a sample of fish was brought to the laboratory and each fish was measured for total length (TL) to the nearest 1 mm and the total wet weight (TW) was recorded to the nearest 1 g using an electronic balance. The length-weight relationships in males, females and for sexes-pooled fish were estimated separately using the equation, $W = aL^b$; where, W is the TW, L is the TL and 'a' and 'b' are the constants to be determined. Analysis of covariance



Fig. 1. Map showing sampling location

(ANCOVA) (Snedecor and Cochran, 1967) test was used to find out the significant difference if any, between the relationships of males and females.

To estimate age and growth, the pooled TL 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 the technique of ELEFAN 1 with non-seasonal version of VBG curve was fitted to the length data. 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. The average Z value obtained from both the techniques was taken for subsequent analyses (Vivekanandan, 2005).

Natural mortality coefficient (M) of fish was estimated by the empirical method of Pauly (1980) following equation:

$\ln M = -0.0152 - 0.279 * \ln L_{\infty} + 0.6543 \log * k + 0.4634 * \ln T$; where 'T' indicates the annual mean temperature ($^{\circ}\text{C}$) 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 (Ricker, 1975; Sparre and Venema, 1992) as, $E = F/Z = F/(M+F)$. To estimate the exploitation ratio (U), the equation given by Ricker (1975) as, $U = F/Z (1-e^{-Z})$ was adopted.

The annual average catch of oilsardine for the period 2005 to 2009 from the region (GoSO, 2010) was considered as yield (Y).

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 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 and Thompson and Bell analysis. The MSY was calculated by the Cadima's estimator (Traodec, 1977) as, $MSY = 0.5 * (Y + M * B)$ where, Y is the total catch in a year, M is the natural mortality and B , the average biomass in the same year.

For Thompson and Bell analysis, the 'YIELD' software (Hoggarth *et al.*, 2006) was used to predict the yield and biomass for a range of F values ($F = 0$ to 5) and the probable F at which MSY would be obtained. The required input parameters of VBG, length-weight, natural mortality (M) and L_c were obtained from the present study. The values of length at first maturity ($L_m = 185$ mm) and SSB_0 (6200 t) were taken from the earlier study of the authors (Zaki *et al.*, 2011). Beverton and Holt stock recruitment relation (SSR) with $h=0.81$ 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), spawning stock biomass per recruit (SSB/R) and fishable biomass per recruit (FB/R) for a range of F -values from 0 to 5 were made.

Results and discussion

Length frequency distribution

The fish in commercial catches (2007-08 and 2008-09 pooled) ranged in size from 161 mm to 228 mm TL (Fig. 2). The fish measuring above 191 mm contributed to about 71.7%.

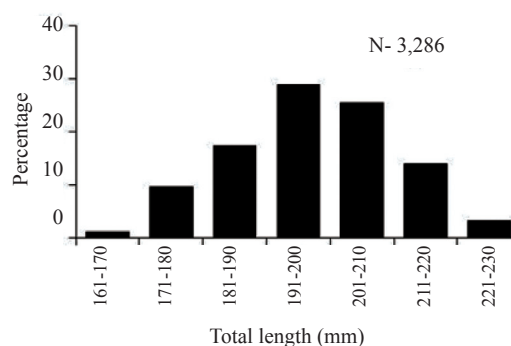


Fig. 2. Length-frequency of *S. longiceps* in commercial catches at Mahout during 2007-08 and 2008-09 (pooled)

Length at capture

The average length (L_c) of Indian oilsardine landed in Mahout was estimated at 193 mm. The Indian oilsardine would attain maturity at about 15-16 cm (Hornell and Nayudu, 1924; Devanesan, 1943; Chidambaram and Venkataraman, 1946; Antony Raja, 1967; Dhulkhed, 1967) and depending on the growth rate in the previous year of recruitment which might fluctuate according to the prevailing ecological conditions, the size at maturity may fluctuate around 150-170 mm (Antony Raja, 1969). As oilsardine attained maturity at 185 mm in Mahout (Zaki *et al.*, 2011), the length at capture (193 mm) in the present study indicates that majority of fish may spawn during the spawning season.

Length-weight relationship

The ANCOVA test indicated no significant difference between the length-weight relationships of males and females ($p > 0.05$). The estimated length-weight relationship for sexes pooled fish was:

$$W = 1E-05 * L^{2.914659} \quad (R^2 = 0.8898) \quad (\text{Fig. 3}).$$

Age and growth

While the minimum size of fish recorded was in the 161-170 mm size group, the maximum size recorded was in 221-230 mm group. The estimated growth parameters, L_∞ , K and t_0 by ELEFAN 1 technique (Fig. 4) stood at 230 mm, 1.33 y^{-1} and -0.09 y respectively.

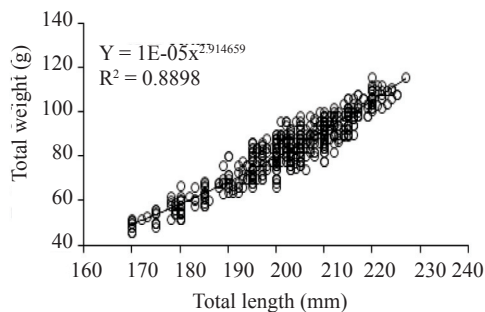


Fig. 3. Length-weight relationship in *S. longiceps* at Mahout

The estimated growth of *S. longiceps* in Mahout showed that the fish grew faster during the first year of its life and attained a length of 182 mm. The growth of the fish for 0.5, 1, 1.5 and 2 and 2.5 years were estimated as 125 mm, 182 mm, 202 mm, 216 mm and 223 mm respectively. In Mahout, most of the fish caught were of 1+ year of age. The value of K for *S. longiceps* in Mahout was estimated at 2.97. However, the growth parameters of *S. longiceps* from different countries and even from different regions of a country indicate the parameter values to differ considerably (Table 1).

In an earlier study from Oman along the coast of Al-Azaiba bordering the Sea of Oman, lower L_∞ (197 mm) and K (0.99 y^{-1}) values were reported (Siddeek *et al.*, 1994) compared to the values obtained in the present investigation from the Arabian Sea coast. On the other hand, a lower L_∞ (145 mm TL) and a very high K (5.62) were reported in Indian oilsardine from the Gulf of Aden based on daily growth increments in otolith (Dayaratne and Gjøsæter, 1986). However, the above estimates were found to be erroneous as the electron microscopic studies on the daily growth increments in the otolith of fish suggested L_∞ as and K to be 193 mm and 1.22 y^{-1} respectively (Morales-Nin, 1988).

The growth performance index of *S. longiceps* in Mahout ($\phi = 2.85$) was within the range reported from

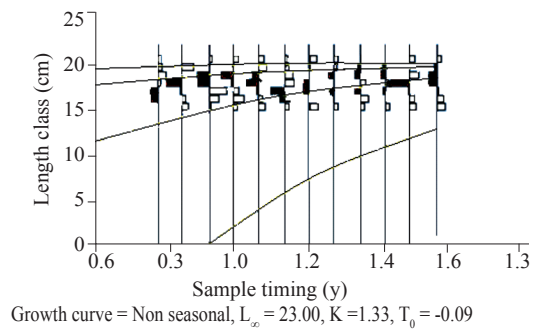


Fig. 4. VBG curves of *S. longiceps* from Mahout by ELEFAN technique

Table 1. Comparison of growth parameters of *S. longiceps* from various studies

Country/Region	L_∞ (mm)	K (y^{-1})	t_0 (y)	Reference
India	210	0.6	-1.12	Antony Raja (1972)
India	207	0.53	-1.33	Banerji (1973)
India	197	1.01	-	Kurup <i>et al.</i> (1987)
India	221	0.75	-	Annigeri <i>et al.</i> (1992)
India	200	2.1	-	Yohannan <i>et al.</i> (1998)
India (Karwar)	204	1.6	-	Ganga (2000)
India (Visakhapatnam)	216	1.5	-	Ganga and Pillai (2006)
India (Malabar)	200	2.1	-	Ganga and Pillai (2006)
Sri Lanka	163	2.77	-0.025	Dayaratne and Gjøsæter (1986)
Gulf of Aden, Yemen	145	5.62	-0.027	Dayaratne and Gjøsæter (1986)
Gulf of Aden, Yemen	238	0.97	0.7	Edwards and Shaher (1987)
Gulf of Aden, Yemen	193	1.22	-	Morales-Nin (1988)
Oman (Al-Azaiba)	197	0.99	-	Siddeek <i>et al.</i> (1994)
Mahout	230	1.33	-0.09	Present study

Indian waters where the values ranged from 2.36 to 2.92 (Antony Raja, 1972; Banerji, 1973; Kurup *et al.*, 1987; Annigeri *et al.*, 1992; Yohannan *et al.*, 1998; Ganga, 2000).

Mortality rates

The total mortality (Z) estimates of fish in Mahout were 4.87 (SE = 0.182) and 2.452 (SE = 1.089) by length converted catch curve technique and Beverton and Holt technique respectively. The average Z of both the techniques worked out to be 3.661. Pauly's empirical method (Pauly, 1980) indicated the natural mortality (M) of *S. longiceps* from Mahout to be 2.21 and the F estimated was 1.451.

Exploitation rate (E) and Exploitation ratio (U)

In Mahout, the exploitation rate (E) and exploitation ratio stood at 0.396 and 0.386 respectively. The fishing mortality rate less than the natural mortality, and exploitation rate (E) less than 0.5 indicate scope for higher catch.

Yield, standing stock, total stock and MSY

The estimated annual yield for the period 2005-2009 from Mahout was 1,901 t. While, the estimated standing stock was 1,311 t, the annual stock stood at 4,925 t.

The MSY estimated by Cadima's formula was equal to 2,399 t and the current yield is about 79% of MSY. The MSY estimated by Thompson and Bell analysis showed a higher value of 5,552 t than the Cadima's estimator for *S. longiceps* in Mahout (Fig. 5). The MSY would be obtained at an F of 1.90 with the corresponding total biomass (TB) and spawning stock biomass (SSB) being 4,501 t and 2,528 t respectively.

In the absence of fishing, the TB and SSB were estimated at 9,159 t and 8,122 t respectively and these values declined to 6,057 t and 4,258 at $F = 1$ with the yield of 4,402 t. The declining trend in yield, TB and SSB values continued with the increase in F beyond MSY level and at $F = 5$, the TB stood at 992 t.

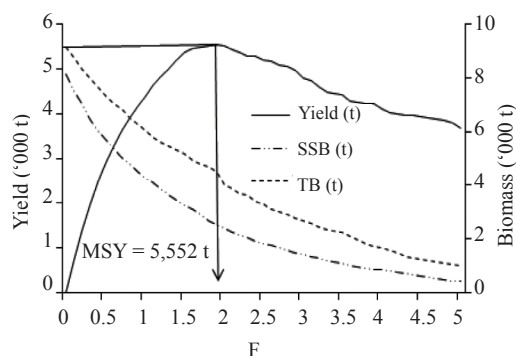


Fig. 5. Yield and biomass of *S. longiceps* in Mahout against F

Per-recruit analysis

The estimated Yw/R (g), SSB/R (g), FB/R (g) and TB/R (g) of *S. longiceps* against a range of F showed the Yw/R (g) to increase from initial low value to higher value with the increase in F ; while, TB/R , SSB/R and FB/R decreased with the increase of F (Fig. 6).

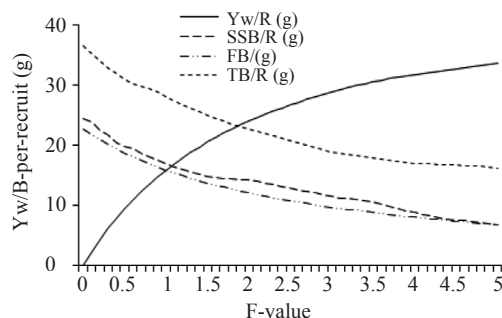


Fig. 6. Yield and biomass-per-recruit in *S. longiceps* at Mahout against F

At $F = 1$, the Yw/R was equal to 15.82 g which increased to 24.03 g, 28.9 g, 31.793 g and 23.64 g at the F values of 2, 3, 4 and 5 respectively. The SSB/R that stood at 24.5 g at $F = 0$ decreased to 16.85 g at $F = 1$. At $F = 1$, the FB/R and TB/R stood at 15.82 g and 28.12 g respectively.

In the present study, the estimated annual yield of *S. longiceps* for the period 2005-2009 was 1,901 t. As the MSY estimates by Cadima's estimator (2,399 t) and Thompson and Bell analysis (5,552 t) are higher than the current yield, there is possibility for increase of yield from the artisanal fishing sector.

Acknowledgements

The authors are thankful to H. E. Dr. Hamed Al-Oufi, the Under Secretary of Fisheries Wealth and Dr. Saoud Al-Habsi, the Director General of Fisheries Research, Ministry of Agriculture and Fisheries Wealth, Government of Sultanate of Oman, for their interest and encouragement during the study. Thanks are due to the Agriculture and Fisheries Development Fund, Government of Sultanate of Oman for financial support. The authors also thank their colleagues in the Marine Science and Fisheries Centre for the technical help

References

- Al-Abdessalaam, T. Z. S. 1995. *Marine species of the Sultanate of Oman*. Marine Science and Fisheries Centre, Ministry of Agriculture and Fisheries, Sultanate of Oman, Publication No. 46/95, 412 pp.
- Al-Barwani, M. A., Prabhakar, A., Dorr III, J. A. and Al-Mandhary, M. 1989. Studies of the biology of *Sardinella longiceps* (Valenciennes) in the Sultanate of Oman (1985-1986). *Kuwait Bull. Mar. Sci.*, 10: 201 – 209.
- Al-Jufaili, S. M., Al-Azri, A. R., Al-Shuaili, S. S. and Ambu-Ali, A. A. 2006. Observation on the fecundity

- and gonado-somatic index (GSI) of the Omani-Indian oilsardine *Sardinella longiceps* (Valenciennes, 1874). *Pak. J. Biol. Sci.*, 9(4): 700-702.
- Annigeri, G. G., Kurup, K. N., Kumaran, M., Madan Mohan, Luther, G., Nair, P. N. R., Rohit, P., Kulkarni, G. M., Gnanamuthu, J. C. and Rao, K. V. N. 1992. Stock assessment of oilsardine, *Sardinella longiceps* Val., off west coast of India. *Indian J. Fish.*, 39 (3&4): 125-135.
- Antony Raja, B. T. 1967. Some aspects of spawning biology of Indian oilsardine, *Sardinella longiceps* Val. *Indian J. Fish.*, 11A(1): 45-120.
- Antony Raja, B. T. 1969. The Indian oilsardine. *Bull. Cent. Mar. Fish. Res. Inst.*, No. 16, 128 pp.
- Antony Raja, B. T. 1972. Estimation of age and growth of the Indian oilsardine, *Sardinella longiceps* Val. *Indian J. Fish.*, 17: 26-42.
- Banerji, S. K. 1973. An assessment of the exploited pelagic fisheries of the Indian seas. *Proc. Symp. Living Resources of the Seas around India, CMFRI Special Publication*, p. 114-135.
- Beverton, R. J. H. and Holt, S. J. 1956. A review of methods for estimating mortality rates in exploited fish populations, with special reference to sources of bias in catch sampling. *Rapp. P.-V.Reun. CIEM*, 140: 67-83.
- Chidambaram, K. and Venkataraman, R. 1946. *Tabular statements on the natural history of certain marine food fishes on the Madras Presidency, West coast*. Government Press, Madras, p. 1-26.
- Dayaratne, P. and Gjøsaeter, J. 1986. Age and growth of four *Sardinella* species from Sri Lanka. *Fish. Res.*, 4: 1-33.
- Devanesan, D. W. 1943. A brief investigation into the causes of the fluctuation of the annual fishery of the oilsardine of Malabar, *Sardinella longiceps* Cuv. and Val., determination of its age and account of the discovery of its eggs and spawning grounds. *Madras Fish. Bull.*, 28(1): 1-38.
- Dhulkhed, M. H. 1967. Observations on the spawning behaviour of Indian oilsardine, *Sardinella longiceps* Valenciennes determined by ova diameter studies. *Indian J. Fish.*, 11A(1): 371-376.
- Diana, J. S., and Seelbach, P. 1990. *Age determination of Sardinella longiceps collected during 89-90 in the Sultanate of Oman*. Consultant's Report to the CIFAD/MSFC Institute for Fishery Research Michigan, Department of Natural Resource, Ann Arbor, Michigan. USA.
- Froese, R. and Pauly, D. 2011. *FishBase*. World Wide Web electronic publication. www.fishbase.org, version (02/2011).
- Ganga, U. 2000. Oilsardine fishery at Karwar- an update. *J. Mar. Biol. Ass. India*, 42(1&2): 112-123.
- Ganga, U. and Pillai, N. G. K. 2006. Comparison of the growth of oilsardine *Sardinella longiceps* Val., off Vishakhapatnam and Malabar coasts. *Indian J. Fish.*, 53(4): 449-453.
- GoSO (Government of Sultanate of Oman), 2009. *Fishery statistics book 2009*. Fisheries Statistics and Information Dept., Directorate General of Fisheries Research, Oman.
- GoSO (Government of Sultanate of Oman), 2010. *Fishery statistics book 2010*. Fisheries Statistics and Information Dept., Directorate General of Fisheries Research, Oman, 216 pp.
- Hoggarth, D. D., Abeyasekera, S., Arthur, R., Beddington, J. R., Burn, R.W., Halls, A. S., Kirkwood, G. P., McAllister, M., Medley, P., Mees, C. C., Pilling, G. M., Wakeford, R. and Welcomme, R. L. 2006. Stock assessment and fishery management - A framework guide to the FMSP stock assessment tools. *FAO Fisheries Technical Paper*, 487, Rome, Italy, 261 pp.
- Hornell, J. and Nayudu, M. R. 1924. A contribution to the life history of the Indian oilsardine with notes on the plankton of the Malabar coast. *Madras Fish. Bull.*, 17: 120-197.
- Kurup, K. N., Balan, V., Vijaya Raghavan, P. and Kumaran, M. 1987. Stock assessment of the Indian oilsardine (*Sardinella longiceps*) off the west coast of India. In: Venema, S. C. and van Zalinge, N. P. (Eds.), *Contributions to tropical fish stock assessment in India*. FAO/DANIDA/ICAR National Follow-up Training Course on Fish stock Assessment, Cochin, India, 2-28 November 1987, FI:GCP/TNT/392/DEN/1.
- Morales-Nin, B. 1988. Caution in the use of daily increments for ageing tropical fish. *ICLARM Fishbyte*, 6(2): 5-6.
- Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. *Journal du Conseil international pour l'Exploration de la Mer*, 39(2): 175-192.
- Pauly, D. 1983. Length converted catch curves. A powerful tool for fisheries research in the tropics (Part I). *ICLARM Fishbyte*, 1(2): 9-13.
- Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. *Bull. ish Res. Bd. Canada*, 191; 382 pp.
- Shaklee, J. B. and Shaklee, M. A. 1990. A biochemical genetic assessment of stock structure of Sardine (*Sardinella longiceps*) in Oman. In: Dorr III J. A. (Ed.), *Small pelagic final report, Appendix SP5*-submitted, University of Michigan.
- Siddeek, M. S. M., Al-Habsi, H. N., Al-Jufaily, S. M. and Al-Ghafry, I. N. 1994. Spawning cycle, recruitment pattern and maturity length of Indian oilsardine at Al-Azaiba in the Gulf of Oman. In: Chou, L. M., Munro, A. D., Lam, T. J., Chen, T. W., Cheong, L. K. K., Ding, J. K., Hooi, K. K., Khoo, H. W., Phang, V. P. E., Shim, K. F. and Tan, C. H. (Eds.), *The Third Asian Fisheries Forum Proceedings*, Asian Fisheries Society, Manila, Philippines, p. 484-487.
- Snedecor, G. W. and Cochran, W. G. 1967. *Statistical methods*. Oxford and IBH Publishing Co., New Delhi, 6th edn., 539 pp.

- Sparre P. and Venema, S. C. 1992. *Introduction to tropical fish stock assessment. FAO Fisheries Technical Paper, 306*, Rome, FAO, 376 pp.
- Thangaraja, M. 1995. *Hydrobiology off Oman*. MSFC, Ministry of Agriculture and Fisheries, Muscat, Sultanate of Oman, Research Report No. 95-1.
- Troadec, J. P. 1977. *Méthodes semi-quantitatives d'évaluation. FAO Circ. Pêches*, 701: 131-141.
- Vivekanandan, E. 2005. *Stock assessment of tropical marine fishes*. Indian Council of Agricultural Research, New Delhi, 115 pp.
- Yohannan, T. M., Balasubramanian, K. K. and Janaki, V. K. 1998. Comparison of the growth patterns of Indian mackerel and oilsardine. *J. Mar. Biol. Ass. India*, 40 (1&2): 205-209.
- Zaki, S., Jayabalan, N., Al-Kiyumi, F., Al-Kharusi, L., Al-Habsi, S. and Al-Marzouqi, A. 2011. Fishery, biology and population dynamics of three small pelagic fish species (Indian oilsardine *Sardinella longiceps*, Indian mackerel *Rastrelliger kanagurta* and Indian scad *Decapterus russelli*) from the Sultanate of Oman. *Project Final Report- Part I*. Ministry of Agriculture and Fisheries, Oman, 154 pp.