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# Food, Growth and Mortality of Indian oil sardine (*Sardinella longiceps*) from Baluchistan coast, Pakistan

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## ABSTRACT

*The aim of this study was to estimate the growth, mortality and stock assessment of Indian oil sardine, Sardinella longiceps (Valenciennes, 1847, Family: Clupeidae) from Baluchistan coast of Pakistan. Monthly data of length and weight for Sardinella longiceps were measured in 2013. ELEFAN in the software package FiSATII was used to analyze the length frequency data. A total of 3032 individuals (male and female combined) ranging from 9 to 19 cm TL (Total length) (dominant length was 12 cm) and weight ranging from 14 to 73 g were examined. The von Bertalanffy growth parameter were, asymptotic length ($L_{\infty}$) = 19.95 cm, growth coefficient (K) = 1.00 year $^{-1}$. The theoretical age at length zero ($t_0$) and the growth performance index ($\varphi'$) were calculated as respectively -0.18 year and 2.60. Total mortality (Z) = 2.01 year$^{-1}$, natural mortality (M) = 1.96 year$^{-1}$, fishing mortality (F) = 0.05 year$^{-1}$ and exploitation ratio (E) = 0.02 were estimated respectively. The exploitation ratio (0.02) indicated that S. longiceps stock was exploited at managed.*

**Keywords:** *Indian oil sardine, Growth, Mortality, FiSAT, Pakistan.*

## INTRODUCTION

Fisheries sector is not only providing the cheap animal protein, but also playing a significant role in the national economy, human development and welfare, such as in terms of providing employment, production and trade. Employment in the fisheries sector has grown more rapidly, especially in Asia, where over 85% of the world's fisher folk live (FAO 2006; WHO/FAO, 2003). The fishing industry of Pakistan has importance in the foreign exchange earnings and employment. The Pakistani coastal belt is about 1 120 km long from the southeast Indian border to the northwest Iranian border (Fig. 1) and an EEZ (exclusive economic zone) is 2 40 000 km$^2$ with an additional continental shelf area of about 50 270 km$^2$. There were about 250 commercially important demersal fishes, 50 small pelagic, 15 medium-sized pelagic and 20 large pelagic fish species from Pakistani water (Bianchi, 1985; FAO, 2009).

Small pelagic fish are important in the food web of a marine ecosystem, playing a significant role in connecting the lower and upper trophic levels, because a substantial number predatory fish, seabirds and marine mammals feed on them (Rice, 1995; Bakun, 1996; Cury et al., 2000). These fishes are broadly distributed in the world seas and caught, canned and consumed globally (Lanier, 1981). Small pelagic fishes are mainly from family *clupeidae*, *engraulidae*, *scomboridae* and *carangidae*. The clupeoid fishes of genus sardinella comprise 21 recognized species all over the world, but there are 5 species reported from Pakistani waters, namely *Sardinella albella, S. gibbosa, S. longiceps, S. melanura, S. sindensis* (Bianchi, 1985; Fishbase, 2016). Indian oil sardine (*Sardinella longiceps* Valenciennes, 1847) is a highly migratory fish with huge level shoaling, found at a depth range of 20–200 m, located in the Indian Ocean, northern and western parts of Arabian sea, Gulf of Aden, Gulf of Oman and feed on planktons (Deshmukh et al., 2010; Fishbase, 2016). They are locally known as Tarli, Luar in Sindhi and Lugger, Luar in Baluchi language. Its maximum length is 23 cm

and the common length of 16 cm is found in Pakistan (Bianchi, 1985).

Indian oil sardine, *Sardinella longiceps* marks as a valuable commercial fish, is used for food, fish meal and oil (Deshmukh et al., 2010). Some studies are done from Indian waters such as in abundance (Longhurst and Wooster, 1990); on stock assessment (Annigeri et al., 1992: Rohit and Bhat, 2003); on reproductive biology (Deshmukh et al., 2010); on antibacterial activities of polyunsaturated fatty acid (Chitra Som and Radhakrishnan, 2011); on seasonal dynamics in amino Acid, vitamin and mineral composition (Kajal et al 2013); on chemical composition and amino acid profile (Shaji and Hindumathy, 2013). From Omani water work was done in biology (Al-Barwani et al., 1989); on age determination (Diana and Seelbach, 1990); on fecundity and gonado-somatic index (Al-Jufaili et al 2006); on age, growth, mortality, stock assessment (Al-Anbouri et al., 2011; Zaki et al., 2012;) on spawning pattern (Al-Anbouri et al., 2013). On population dynamics from Tawi-Tawi, Philippines (Aripin and Showers, 2000). However, there was no any work done on the Indian oil sardine (*Sardinella longiceps*) from Pakistani waters so this study will provide some basic information on population dynamics of the Indian oil sardine from Pakistani waters based on length and weight data. The results may be helpful for fish stock assessment and fishery management in Pakistan.

## MATERIALS AND METHODS

A total of 3032 fish samples was collected and measured from the fisherman catches using gill nets, at random, from the Baluchistan coast of Pakistan in 2013. The total length (TL) of each fish was taken to the nearest 1.0 cm using measuring board. The weight (W) of each fish was weighted to the nearest 1.0 g. The samples were male and female combined.


**Figure1.** *Map shows major landing sites along Baluchistan coast, Pakistan*.

The length frequency data were analyzed using FiSAT-II (Gayanilo et al., 2003). In this study, we estimated parameters such as mortality rate and biological reference point, length-weight relationship, growth.

The relationship between length and weight of *Sardinella longiceps* was established by using a power equation (Froese, 2006):

$$W=aL^{b}$$

Where, W= weight of fish in grams and L= Total length of fish in centimeter, a= constant condition factor and b= an exponent slope or allometric parameter.

The parameters of growth for *Sardinella longiceps* was calculated by using von Bertalanffy growth function the von Bertalanffy equation for growth in length according to Haddon (2011) is: $Lt = L_{\infty}\ (1–exp\ (-K\ (t– t_0)))$, where $L_t$ was the length at the predicted time $t$, $L_{\infty}$ was the asymptotic length, $K$ was the growth coefficient and $t_0$ was the hypothetical age or time where length was equal to zero. Additional estimated value of $t_0$ was obtained by the empirical equation by Pauly (1983) as: $log_{10}\ (-t_0) = -\ 0.3922 – 0.275\ log_{10}\ L_{\infty} -\ 1.038\ log_{10}\ K$

The estimation of instantaneous total mortality (Z) for *Sardinella longiceps* during 2013, the length converted catch curve method by Pauly (1983) was used. Additional parameters of M and F (natural mortality and fishing mortality) were also calculated. The regression formula for Z is: Ln ($N_t$) =Ln ($N_0$)-Zt, where $N_t$ is the

population size at age t, $N_0$ is population size at age 0.

The equation by Pauly (1980) was used for natural mortality (*M*) from $log_{10}\ M = 0.0066 - 0.279\ log_{10}\ L_\infty + 0.654\ log_{10}\ K + 0.4634\ log_{10}\ T$. Where $T = 27^oC$ was average annual sea surface temperature of Pakistani waters. The *F* (Fishing mortality) was estimated by using the relationship of subtracting $F = Z-M$. The exploitation ratio (E) was obtained by the relationship of Gulland (1971a): $E = F/Z = F/(F+M)$.

Biological reference points of the optimum fishing mortality were calculated by Gulland (1969) method as: $F_{opt} = M$

*Using* $L_\infty$ and *K* were used to determine the growth performance index (φ') (Pauly and Munro, 1984): $\varphi' = Log_{10}K + 2Log_{10}\ L_\infty$

## RESULTS

A total of 3032 pairs of length weight data of Indian oil sardine were measured during in this study. The minimum length was 9 cm and the maximum was 19 cm with the dominant length of 12 cm of total length (TL), weight ranging were measured from 14 to 72 g (Figure 2). The length-weight relationship of both sexes combined was: W= 0.0929* L2.299 (R2 =0.97) (Figure 3).

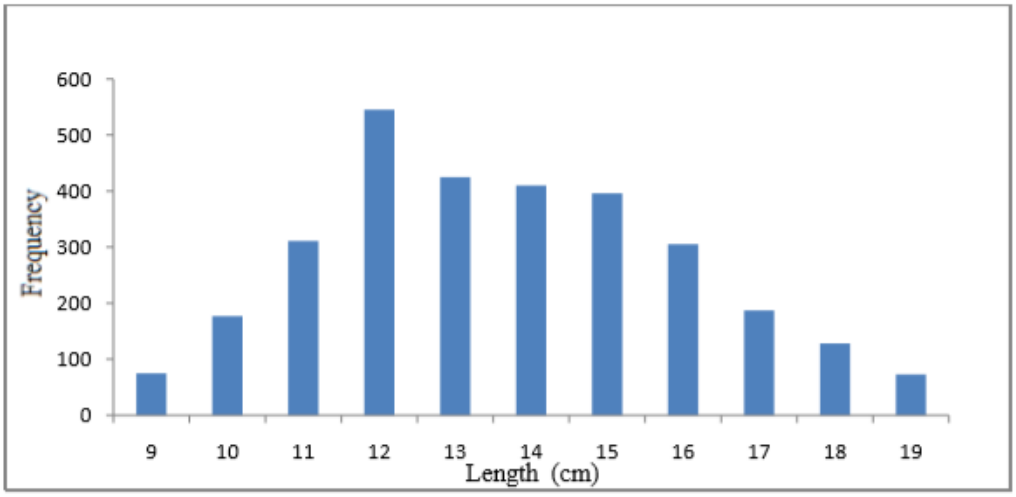


**Figure2.** *Length frequency distribution of Indian oil sardine from Baluchistan coast of Pakistan.*

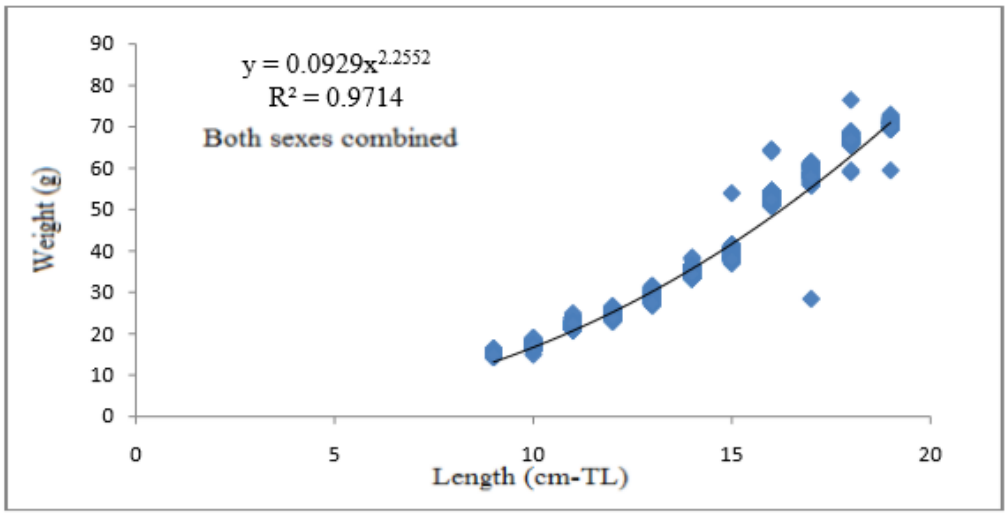


**Figure3.** *Length-weight relationship of both sexes combined of S. longiceps length and weight ranging from 9 to 19 cm (TL), 14 to 73g respectively.*

Growth parameters for Indian oil sardines were estimated using the ELEFAN method in a FiSATII computer software package. The von Bertalanffy growth parameters for Sardinella longiceps were L∞= 19.95 (TL-cm) and K=1.00 year-1 (Figure. 4) with the goodness of fit model at Rn =0.232, the t0 values were calculated by Pauly's equation as -0.18year-1

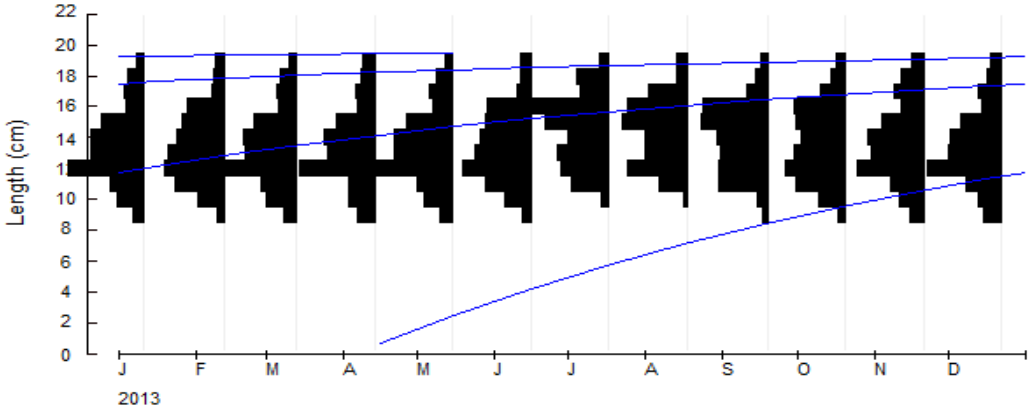


**Figure4.** *Length-frequency distribution data and the growth curves estimated using ELEFAN for Indian oil sardine in Pakistan in 2013.*

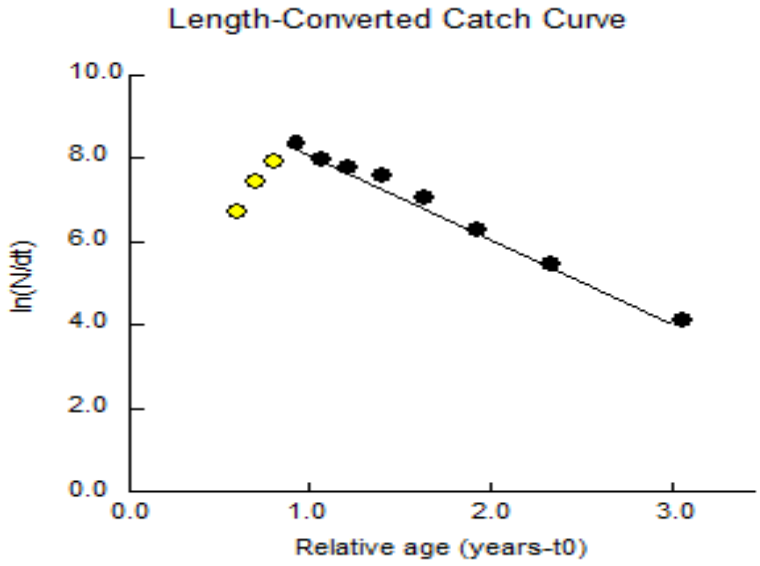


**Figure5.** *Length-converted catch curve for Indian oil sardine in Baluchistan in 2013 for the pooled data of one year ($L_\infty$ = 19.95cm and k=1.00 year$^{-1}$).*

Applying VBGF growth parameters above and using the length converted catch curve analysis, the total mortality rate was estimated at Z = 2.01 year-1 (Figure 5). Natural mortality was calculated as M =1.96 year-1 (Pauly's empirical formula) at an average annual sea surface temperature of 27 °C. The fishing mortality was calculated as F=Z-M= 0.05 year-1 and the exploitation ratio (E) was calculated from F/Z = 0.02. The growth performance index (φ') was estimated 2.60 for Indian oil sardine from Pakistani waters based on length frequency data.

## DISCUSSION

### Length-Weight Relationship

The length-weight relationship is a useful measurement which makes easy for the estimations of metamorphosis, gonad maturity and rate of feeding of fish (Le Cren, 1951) which is considered as an important parameter in fishery biology and fish stock assessment (Abdurahiman et al., 2004). In this study, the value of slope b of S. longiceps was estimated 2.25 (R2 =0.97) from the Baluchistan coast of Pakistan in 2013, which shows the negative allometric growth (King, 1995).

Because, when the b value is lower than 3 it determines the negative allometric growth, greater than 3 is positive allometric and when equal to 3 is isometric growth. When the b value is less than 3 it is categorized as light, greater than 3 is heavy and when the b value is equal to 3 the fish is categorized as isometric growth (Smith, 1996; Bal and Rao, 1984). The estimated value of slope b

was compared with the results obtained from different countries of the same species (Table 1), the b values were 3.21, 3.00, 2.92, 2.86 from Indian waters (Dhulkhed, 1963; Antony Raja, 1967; Kurup et al., 1989; Rohit and Bhat., 2003) 2.94, 3.02 from Omani waters (Al-Jufaili, 2011; Zaki et al., 2013) 3.2 from the Gulf of Aden (Edwards and Shaher, 1991).

**Table1.** *Comparison of value b of S. longiceps with previous studies from different areas of the world to present study from Baluchistan coast, Pakistani during 2013*

| Location | Slope "b" | Sources |
|---|---|---|
| Salalah coast, Oman | 3.02 | Zaki et al., 2013 |
| India | 3.21 | Dhulkhed, 1963 |
| Al-Aseeb Area, Oman | 3 | Al-Jufaili, 2011 |
| Mangalore-Malpe, Inda | 2.86 | Rohit and Bhat, 2003 |
| India | 3 | Antony Raja, 1967 |
| West coast of India | 2.92 | Kurup et al., 1989 |
| Al-Aseeb waters, Oman | 2.94 | Al-Jufaili, 2012 |
| Gulf of Aden | 3.2 | Edwards and Shaher, 1991 |
| Baluchistan coast, Pakistan | 2.25 | Present study |

The differences among the slope b values may be because of the changes in regions, seasonal fluctuations, environmental parameters and physical conditions of the fish at the time of sample collection, sex gonad development and nutritive conditions, number of individuals examine in study, different observed length ranges during the study etc. (Biswas, 1993; Wootton, 1998; Froese, 2006).

## Growth Parameters

VBGF parameters, i.e. asymptotic length L∞, growth rate K and the hypothetical age t0 were estimated from the length frequency data and were compared with the results in previous studies from the different areas (Table 2).

In the present study the ELEFAN method in the FiSATII computer software package was used to estimate the VBGF parameters. The asymptotic length L∞ and growth rate K was estimated at 197.2mm, 1.006 and 221mm, 0.75 from West coast of India (Kurup et al., 1989; Annigeri et al., 1992) in which the first one is similar to the present results while the second one is higher than the present values.

**Table2.** *Comparison of growth parameters of S. longiceps from present study with those from previous studies*

| *Location* | $L_\infty$ | *K* | $t_0$ | *Ó* | *Sources* |
|---|---|---|---|---|---|
| West coast of India | 221mm | 0.75 | - | - | Annigeri et al., 1992 |
| West coast of India | 197.2mm | 1.006 | -0.08 | - | Kurup et al., 1989 |
| Salalah coast, Oman | 23.02cm | 1.57 | -0.49 | 2.92 | Zaki et al., 2013 |
| Oman Sea, Muscat, Oman | 220mm | 1.209 | -0.01 | - | Al-Anbouri et al., 2011 |
| Mangalore-Malpe, India | 212-228mm | 0.85-1.09 | - | - | Rohit and Bhat, 2003 |
| Tawi-Tawi, Philippines | 26cm | 0.86 | - | 2.76 | Aripine and Showers, 2000 |
| India | 20.66 cm | 0.44 | -15.98 | - | Banerji, 1973 |
| Gulf of Aden | 23.8cm | 0.97 | -0.08 | - | Edwards and Shahar, 1987 |
| Gulf of Aden | 24cm | 0.55 | -0.09 | - | Edwards and Shaher, 1991 |
| southwest coast of India | 21 cm | 1.4 | - | - | Biradar, 1989 |
| Baluchistan coast, Pakistan | 19.95 | 1 | -0.18 | 2.6 | Present study |

$L_\infty$= asymptotic length (cm - FL); *K*= growth rate *year*$^{-1}$; φ'= growth performance index; $t_0$= hypothetical age at *which length of the fish is equal to zero*

They were 21 cm, 1.4 from the southwest coast of India (Biradar and GjΦosselig;ter, 1989) which are higher than the present results. They were 20.66 cm, 0.44 and 212─228mm, 0.85─1.09 from Indian waters (Banerji, 1973; Rohit and Bhat, 2003). L∞ and K were estimated as 220mm, 1.209 from Oman Sea, Muscat and 23.02cm, 1.57 from the Salalah coast of Oman (Al-Anbouri et al., 2011; Zaki et al., 2013) and 26cm, 0.86 from Tawi-Tawi, Philippines (Aripine and Showers, 2000) which are higher than the present values. L∞ and K were also estimated 23.8cm, 0.97 and 24cm,

0.55 from the Gulf of Aden, Yemen (Edwards and Shahar, 1987 and 1991) in which the L∞ is higher but K is lower than the present study.

The t0 = - 0.08 and t0 = - 0.09 from the Gulf of Aden by Edwards and Shahar, (1987) and Edwards and Shahar, (1991) respectively. From Oman Sea, Muscat t0 = - 0.01(Al-Anbouri et al., 2011) and from the Salalah coast of Oman t0 = - 0.49 (Zaki et al., 2013). From West coast of India t0 = - 0.08 (Kurup et al., 1989) which was close to our present study (t0 = - 0.18). The differences of those values in Table 2. May be because of their different sampling strategies, data sets, estimation methods, life patterns and ecological characteristics (Adam, 1980).

## Mortality Rate

The present study used length-converted catch curve analysis for estimation of the mortality rate of S. longiceps using input values of VBGF growth parameter and were compared with earlier studies from different countries of the world (Table 3).

**Table3.** Mortality rates of *S. longiceps* from the Baluchistan coast of Pakistan were compared with the other studies from different areas

| Area | Z | *M* | *F* | *E* | Sources |
|---|---|---|---|---|---|
| Salalah coast, Oman | 4.65 | 2.45 | 2.2 | 0.473 | Zaki et al., 2013 |
| Oman Sea, Muscat, Oman | 4.11 | 2.21 | 1.91 | 0.46 | Al-Anbouri et al., 2011 |
| West coast of India | 2.23 | 1.3 | 0.93 | 0.42 | Annigeri et al., 1992 |
| Southwest coast of India | 4.2 | 2 | 2.2 | 0.52 | Biradar and GjΦosselig;ter, 1989 |
| Tawi-Tawi, Philippines | 3.65 | 1.68 | 1.97 | 0.54 | Aripin and Showers, 2000 |
| Mangalore-Malpe, India | 1.95-4.58 | 1.77-2.06 | 0.18-2.52 | 0.08-0.55 | Rohit and Bhat, 2003 |
| West coast of India | 1.35-1.39 | 1.08 | 0.27-0.31 | 0.22 | Kurup et al., 1989 |
| Baluchistan coast, Pakistan | 2.01 | 1.96 | 0.05 | 0.02 | Present Study |

*Z= total mortality, M= natural mortality, F= fishing mortality, E=exploitation ratio*

The mortality values in the present study were lower than the values in the earlier studies (Tables 3). The total mortality (Z), natural mortality (M) and fishing mortality (F) were 4.11, 2.21, 1.91 and 4.65, 2.45, 2.2 from Omani waters Oman Sea, Muscat (Al-Anbouri., 2011) and Salalah coast (Zaki et al., 2013) respectively. The Z, M, F values were 4.2, 2, 2.2 from the Southwest coast of India (Biradar and GjΦosselig;ter, 1989) and 2.23, 1.3, 0.93 from West coast of India (Annigeri et al., 1992) which were higher than the present study. Z = 3.65, M = 1.68, F = 1.97 from Tawi-Tawi, Philippines (Aripin and Showers, 2000) in which the Z and F values were higher while the M values were smaller than the present study values. From Mangalore-Malpe, India the Z, M and F values were 1.95─4.58, 1.77─2.06 and 0.18─2.52 (Rohit and Bhat, 2003) and the present study values are 2.01, 1.91 and 0.05 for S. longiceps from Baluchistan coast of Pakistan. The different values from different areas of the world were because of unfavorable environmental conditions or commercial demand, which increased fishing efforts in that region. There are many causes for the mortality rates, such as fishing, pollution, diseases, predation and old age in the fish community (Nikolsky, 1969). Predation is a big cause of natural mortality for S. longiceps (Brandt et al., 1987; Laevastu and Favorite, 1988) which is sometimes higher than the fishing mortality (Christensen and Pauly, 1997)

## Growth Performance Index

The growth performance index is usually estimated from the VBGF parameters L∞ and K.If the value is higher it indicates faster and larger growth of the fish (Pauly and Munro, 1984; Sparre and Venema, 1998). In this study the growth performance index is 2.60. It was 2.97 from Salalah coast, Oman (Zaki et al., 2013) and 2.76 from Tawi-Tawi, Philippines (Aripine and Showers, 2000) which are higher but closer to the present study values. Ecological and environmental changes may cause the differences among the values of growth performance index (Devaraj, 1981; Jayaprakash, 2002).

## CONCLUSION

In the present study of mortality and growth parameters of Sardinella longiceps from the Baluchistan coast of Pakistan have indicated that the fishery is in a safe condition because the current exploitation ratio (0.02) of this specie is lower than the biological reference point (0.5). The growth rate and the growth performance index were found to be good in Baluchistan coast.

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