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Age and growth of Sind sardine (*Sardinella sindensis*) using otolith from Qeshm Island (Persian Gulf)

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Abstract

This is the first study of growth and age of *Sardinella sindensis* from coastal waters of Qeshm Island (Persian Gulf) based on the sectioned otolith reading method. In total, 128 fishes were collected randomly from purse seine commercial nets during March 2011 to February 2012. The annual formation of the growth rings were determined by counting the opaque and translucent zones occurrence at the outer margin of the otolith. The peak of opaque and translucent zones formation occurred in June and January, respectively. There was no significant differences between the sex ratio of males to females (p>0.05). The total length and body weight for both sexes ranged between (7.9-18.6 cm) and (3.98-55.69 g). In total, four age classes were determined, and the maximum age was recorded as 3.5 years. The most abundant individuals were counted in 1^+ age class, while the least number of fishes belonged to the 3^+ age class. The non-linear regression relationship between the length and age for combined sexes were fitted in Von Bertalanffy growth equation, and described as: $TL= 20.8\ (1-e^{-0.54(t+\ 0.54)})$. There was a strong relationship between the body weight and total length of the fishes (p>0.05), indicating that the growth type of *S. sindensis* is isometric. From the results of this study we concluded that *S. sindensis* is a fast-growing species with a short-life span. In order to obtain more reliable results about the age and growth of this species, we suggest that different methods of age determination should be used, combined with the evaluation of the factors affecting its growth for the management of optimum exploitation of the resources of this fish.

Keywords: Age, Growth, Otolith, *Sardinella sindensis*, Persian Gulf

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Introduction

Sind sardine, *Sardinella sindensis*, is a small pelagic fish that living in coastal waters of the Western Indian Ocean, Arabian Sea, Gulf of Aden to the Oman Sea, Persian Gulf and Bombay (Whitehead, 1985). Small pelagic fishes specially; sardines are one of the world's main marine resources (Nansen 1981; Devaraj and Martosubroto 1997; Duhamel, 2006; FAO, 2011). *S.sindensis*, now is the dominant species of commercial catches in coastal waters of Iran and Pakistan (i.e. Persian Gulf and Oman Sea), so that, the small-scale purse seiners of Iran were landing about 500 tons per year (FAO, 2011). Thus, the study of various aspect of the biology of *S.sindensis* for fishery management purposes is essential.

There are much information about the biology, growth and age of this species (Lazarus, 1981; Sivakumaran *et al*., 1989; Bennet *et al*., 1992; Salarpouri *et al*., 2008; Salarpouri *et al*., 2009; Farkhondeh *et al.*, 2010), but age determination of *S.sindensis* by sectioned otolith has not been done yet.

Age determination and growth of fishes play a fundamental and critical role in the analysis and management of fish populations, so, the ability to estimate and analyze individual growth records is a key factor in answering many questions of interest of fisheries scientists (Chamber and Miller, 1995; Bellido *et al.*, 2000). The standard method of determining the age of fish is reading and interpreting the growth zones of calcified structures such as: otolith, scale, fin ray and other bony structures (Payan *et al*., 2002; Mendoza 2006). Otolith growth patterns not only provide a chronological record of early life history, stock structure, growth parameters and migration, but can also record ambient environmental information, such as water temperature, sunlight intensity, and food supply (Li *et al*., 2009).

Given the importance of *S.sindensis*, for stock assessment and management decisions to optimal and sustainable exploitation, age and growth rate determination by sectioned otoliths is essential. The objectives of the present study are to estimate the age structure of the population and growth rate of *S.sindensis*, samples which were collected from the coastal waters of Qeshm Island (Persian Gulf) during March 2011 to February 2012.

Materials and methods

Area of study

This study was performed in the southern coastal waters of the Qeshm Islnad (26°41′43″N 55°37′06″E) (Fig. 1). Qeshm Island is the largest island in the Persian Gulf which is located opposite the port cities of Bandar Abbas and Bandar Khamir. Persian Gulf possess tropical climate conditions, which is divided into warm season (spring and summer) and temperate season (autumn and winter).

Figure 1: The study area and location of sampling, Qeshm Island, northern Persian Gulf.

Samples Collection

In total, 128 individuals of *S.sindensis* were randomly collected from commercial fishermen using purse seine fishing gear from March 2011 to February 2012. Samples stored in ice and transported to the laboratory of Persian Gulf and Oman Sea Ecological Research Center, Bandar Abbas. Before extraction of otoliths, total length (TL), fork length (FL) andstandard length (SL) were measured to the nearest 1mm, and body weight (BW) was measured to the nearest 0.01 g. The gonads were examined under stereomicroscope for sex determination.

Otolith Removal and Preparation

For removal and preparation of otolith and reading of opaque and translucent rings, the following methods were used described by (Giannetti and Donato, 2003; Easey and Millner, 2008). The extracted otoliths were cleaned, air dried, and stored in labeled tubes. The Sagitta otolith was used for age determination of sardines. Otolith length (OL) were measured Using (motic 2) Imaging Software to the nearest 0.01μm, and otolith weight (OW) were measured using digital balance to the nearest 0.0001g. In the next stage, otoliths embedded in epoxy resin, sectioned with an Isomet Low Speed Saw, then sectioned otoliths mounted on a glass slide with thermoplastic cement and polished with 400 – 600 grit wet sandpaper.

Reading of Annuli

For reading of annuli, otoliths were photographed under reflected light against a dark background at a magnification of 4x, using a stereo microscope coupled with motic digital camera. Under a stereoscopic microscope opaque rings appeared white, and translucent rings appeared black (Butler *et al.*, 1996). Opaque and translucent rings were counted twice at two different times by two readers independently (McFarlane *et al*., 2010). To verify the annuli periodicity of the rings formation, the frequency proportion of the opaque and translucent edges of the otoliths counted. Percentages of otoliths with opaque and translucent margins were plotted by month of capture for the whole survey period. Age classes were identified based on the number of annuli, without the knowledge of the length of the fish and date of collection. According to previous studies, the peak spawning season of *S.sindensis* in the coastal waters of Persian Gulf was reported in spring (Salarpouri *et al*., 2009).

Average percent error (APE) was used for comparisons of readings within readers and between readers, as used and suggested by Beamish and Fournier (1981), and percent agreement that is the traditional index of ageing precision (Campana, 2001) was also calculated. Average percent error is defined as:

$$APE = 100 x \frac{1}{R} \sum_{i=1}^{R} \frac{|Xij - Xj|}{Xj}$$

Where Xij is the ith age determination of the jth fish, Xj is the mean age estimate of the jth fish, and R is the number of times each fish is aged.

Growth

The sex ratio was calculated by the number of females and males. A chi-square test used to determine if the sex ratio was significantly different to the expected ratio of 1:1. The Von Bertalanffy growth function (Von Bertalanffy, 1957) was fitted to length and age data using non-linear least squares estimation method: $L_t = L_\infty (1-e^{-k(t-t0)})$, where Lt is the length at age t, L_∞ is the asymptotic length, k is the growth coefficient, t is the age (years from birth), and t_0 is the age at length zero. The parameters K, L_∞, and t_0 calculated by Solver program in Excel to minimize the residual sums of squares, that fitted to females, males, and combined sexes. Growth performance (φ′) was estimated for comparing the growth rates of this study to other studies using the empirical equation of (Pauly and Munro, 1984). $\varphi' = \log10\ k + 2 \log10 (L_\infty)$. Where, K and L_∞ are the growth parameters that were calculated by Von Bertalanffy equation described above.

Weight-Length relationship

Relationships between the BW and the TL were estimated using a power regression analysis, described as $W = a (L)^b$ Where W is weight (g), L is length (cm), and b are regression coefficients, Growth type (isometric and allometric) was determined by Student's t-test (Pauly and Munro, 1984).

Results

Sex ratio

Overall, 128 specimens were collected and dissected for sex determination (Fig. 2). The results showed 70 female and 58 male fishes. The frequency of females was slightly higher than males but Chi-square test was performed assuming equal sex ratio and the results with a degree of freedom, did not show any significant differences between the sexes (X^2= 1.125, df=1, p>0.05).

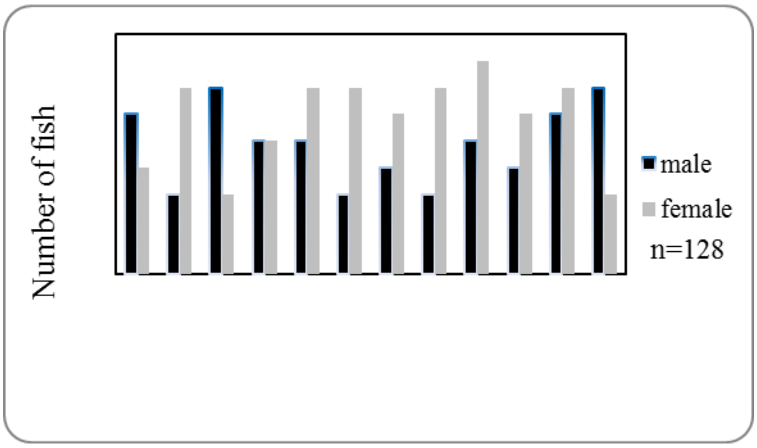

Figure 2: Number of *S.sindensis*, Persian Gulf (2011- 2012)

Length-weight composition

Total length and body weight were (7.9 -18.6 cm) and (3.98 to 55.69 g) for females, and (8.5- 17.7 cm) and (5.19 - 45.7 g) for males, respectively. The minimum and maximum abundance of length classes for combined sex were 7 cm and 14cm, respectively. Frequency of length classes for two sexes is shown in Fig. 3.

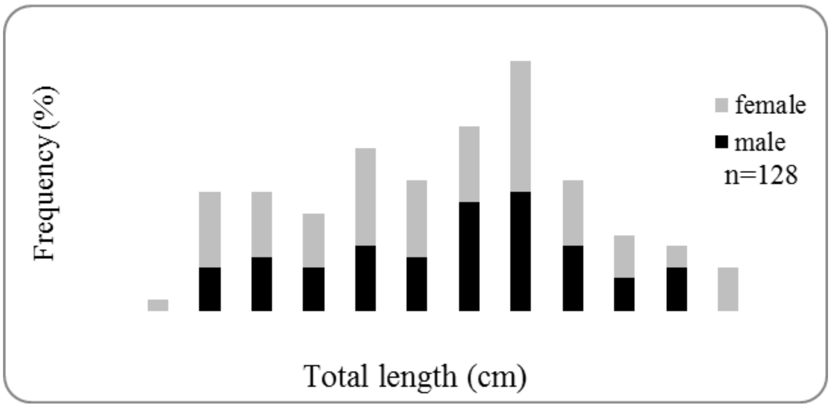

Figure 3:Total length frequency distribution for female and male of *S.sindensis*, Persian Gulf.

Weight-length relationship

Body weight-length relationships were calculated which showed a power correlation between total length and body weight for males and females.

BW= 0.0081 TL $^{3.0016}$ (r^2=0.94, n=58) for males and BW=0.009 TL$^{2.9653}$ (r^2=0.92, n=70) for females (Fig. 4). The slope was slightly higher than the theoretical value of 3 for males and the slope for females was slightly less than the theoretical value of 3, but t-test indicated no significant differences relative to value of 3 for males and females and combined sexes (p>0.05). Thus, growth type for both sexes was isometric.

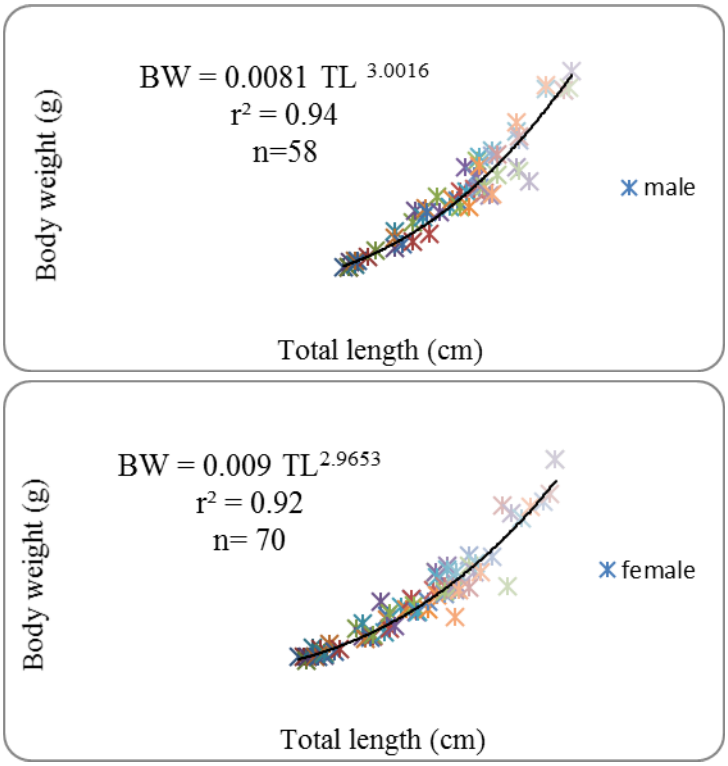

Figure 4: Relationship between total length and body weight in males and females of *S.sindensis*, Persian Gulf.

Annual formation of the rings

Amongst total 128 fish, only 119 otoliths were removed from fishes (about 93.0%), and 107 (89.9%) otoliths used for counting opaque and translucent zones at the margin of otolith, and for reading of annuli, 98 (82.4%) otoliths were used. For comparison of differences between right and left otoliths, 20 otoliths from the left and right sides were selected . The t-test indicated that no significant differences existed in length and weight of the left and right otoliths (paired t-test, p>0.05, n=20). Therefore, the left otoliths were used for ageing. The most frequency of opaque zones was observed during spring-summer (March to August) and those of translucent zones occurred in fall- winter (September to February). The results showed that the opaque zones peaked in May and the translucent zones peaked in November. This demonstrated that the formation of rings growth were annually (Fig. 5).

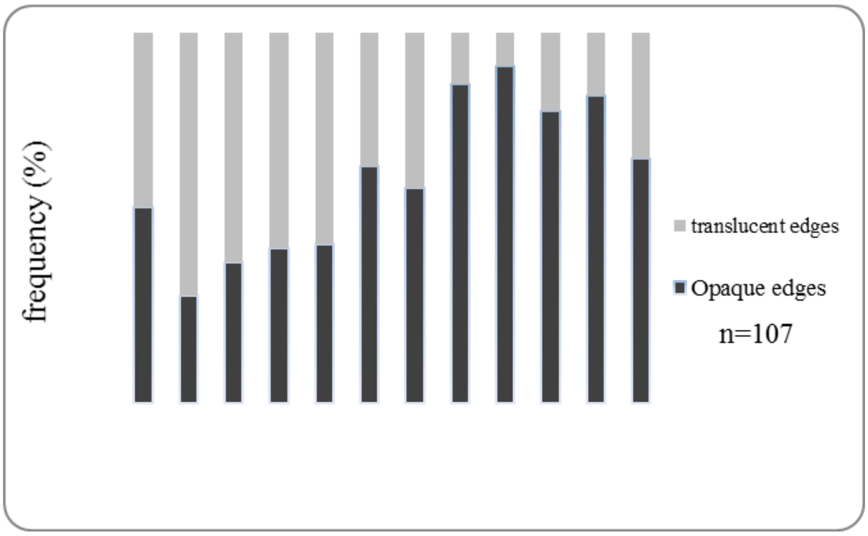

Figure 5: Monthly changes in the frequency of translucent and opaque zone occurrence at the outer margin of the otolith of *S.sindensis*, Persian Gulf.

Agreement Percent Readings

Agreement percent within reader 1 was 77% and agreement within 1^+ and 2^+ years was 94% and 100%, respectively. Average agreement within reader 1 was 4.4%. For reader 2, agreement percent without difference, 1^+ and 2^+ years difference was 86%, 98% and 100%, respectively, with 2.2% APE. Agreement percent between two readers was 76%, 96%, and 100%, and APE was 4.2%.

Age and growth

Opaque and translucent layers of otoliths were differentiable well. In total, 98 otoliths used for age determination. Four age classes including: 0^+, 1^+, 2^+, and 3^+ age classes were determined for males, females, and combined sexes (Fig. 6). Average age for males was 1.65 years (±0.49 SD) with 13.5 cm (±2.06 SD) average TL and for females was 1.62 years (±0.56 SD) with 13.3 cm (±2.20 SD) TL average. Minimum and maximum ages for males were 0.5 and 3.0 years, and 0.5, and 3.5 years for females (Table 1).

Table 1: Age-length classes of Sind sardine, *S.sindensis* in Persian Gulf.

Age class(years)	Mean length(cm)	Minimum length(cm)	Maximum length(cm)	Number of fish	SD
0^+	9.2	8.1	10.6	24	0.80
1^+	12.8	9.9	14.6	42	1.32
2^+	15.9	14.7	17.5	27	0.89
3^+	18.2	17.9	18.6	5	0.44

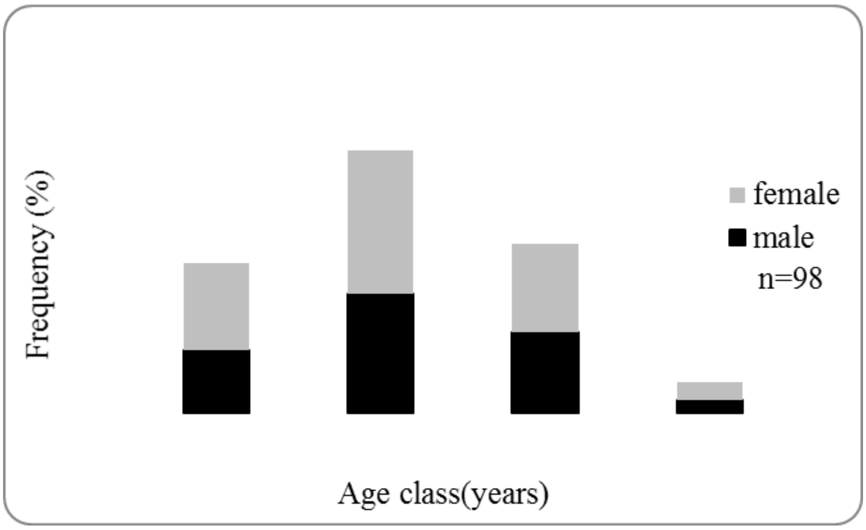

Figure 6: Age–frequency distribution for male and female of *S.sindensis*, Persian Gulf.

The Von Bertalanffy growth curves and equations for observed lengths at age of females, males and combined sexes are shown in (Fig. 7). Von Bertalanffy equations for *S.sindensis* was as: $TL(t)=20.8\ (1-e^{-0.54\ (t+0.54)})$ for combined sexes, $TL(t)=\ 20.7(1-e^{-0.55\ (t+0.50)})$ for females and $TL(t)=\ 20.6\ (1-e^{-0.57\ (t+0.49)})$. The Growth performance (φ′) for both sexes was calculated. The value of growth performance for males was 2.4 (years) and for females was 2.37(years). Growth parameters ($L\infty$ and K and growth performance (Ø) of this study were compared to the other studies on *Sardinella spp* in different areas (Table 2).

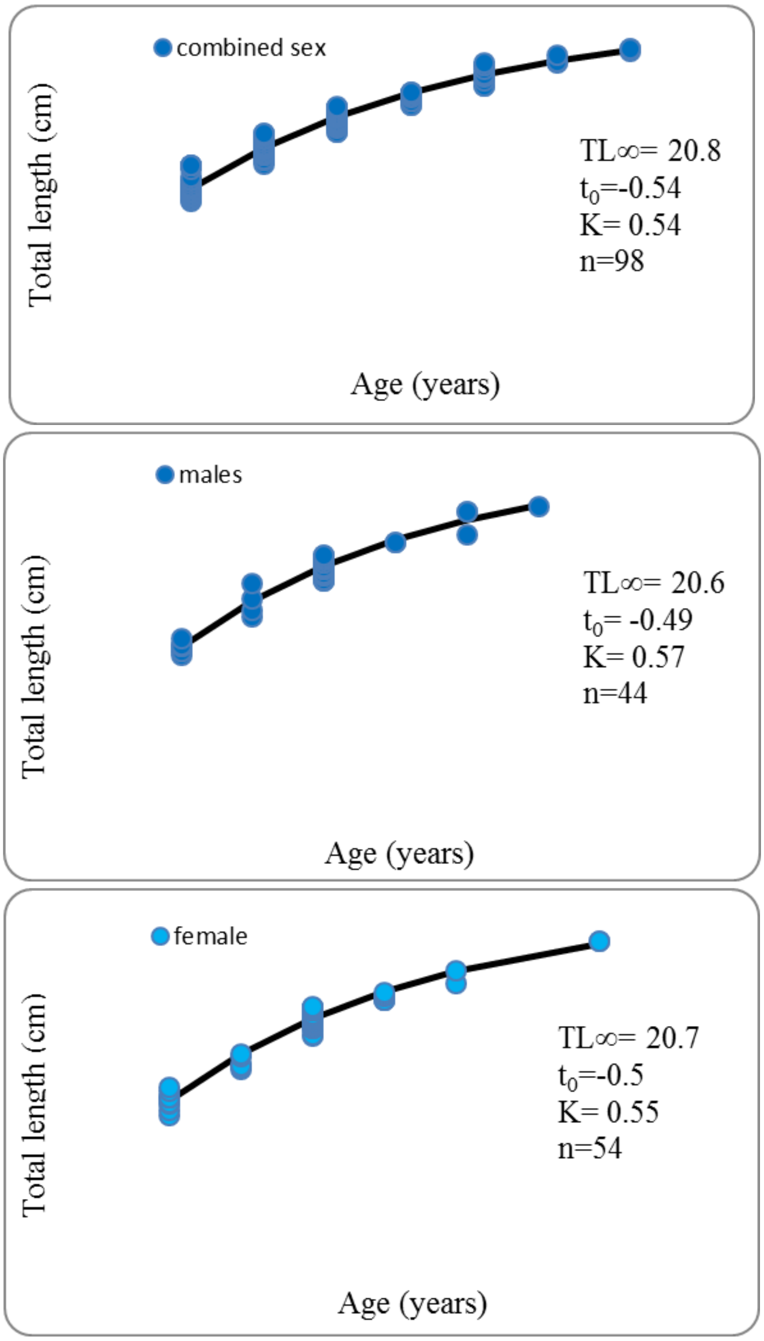

Figure 7: Total length at age and the fitted Von Bertalanffy growth curve for S.*sindensis*, Persian Gulf.

Discussion

Studies on *S.sindensis*, show that frequency of females is slightly higher than males, but sex ratio is without significant differences (Salarpouri *et al*., 2008a,b; Salarpouri *et al*., 2009). This is similar to some other species of sardines like *S.lemuru* in Western Australia (Gaughan and Mitchell, 2000), *Sardinops sagax* (Gaughan *et al*., 2008) and compared to *Sardinella longiceps* in the Oman Sea (Al-Jufaili, 2011; Zaki *et al*., 2012).

There was a high degree of correlation between weight and length.

Also, t-test for comparing the b-value of this study and the theoretical value of b (b=3) showed that growth pattern was isometric for both sexes. Although, the reported growth type in 2008 from the same area and coastal waters of Jask (Oman Sea) were isometric (Salarpouri *et al*., 2008 a,b). However, the value of regression coefficient was depended on the species, sex, age, sexual maturity of fish and season and fish feeding (Ricker, 1973).

Average APE (4.8%) calculated in this study was a little higher than the average APE obtained in many ageing studies (5.5% for APE) (Campana, 2001), and this valuewas acceptable and indicate that precision of present ageing is high.

Based on reading of the annuli of sectioned otolith, opaque zones peaked in spring-summer (March to August) which was the spawning season and times of the fast growth in the tropical waters, due to food richness and translucent zones occurred in fall-winter (September to February), the seasons with poor food, consequently with slow growth. Therefore, formation of rings were annuali that was very similar to many previous studies on *Sardinella* spp (Mendoza *et al*., 1994; Gaughan and Mitchell, 2000; Mehanna and Salem, 2011). The opaque and translucent rings formed from nucleus to margin of otoliths as sequence, the width of annuli decreased from nucleus to external ring, suggested that as age increases, the growth has been slow (Giannetti and Donato, 2003). Distinction of the rings in 0^+ and 1^+ years of sardine was easier, but in older years, the rings were close together, although we have found some checks specially in older fish, so counting of annuli was difficult, that was similar to other studies. For example McFarlane *et al* (2010) reported that second annuli were usually easily identified in younger fish. In older fish, as deposition occurs across the entire otolith surface, and otolith thickness increases, identification of annuli near the focus became increasingly problematic as it may be more difficult to distinguish checks. In addition, annuli near the edge of otoliths from older fish were close together, and might be fainted due to increased deposition on the exterior surface of the entire otolith (McFarlane *et al*., 2010). In the present study, four age classes identified for *S.sindensis* in Persian Gulf. Minimum and maximum age was 0.50 and 3.50, respectively. Oldest species (3.50 years) belonged to female. Age classes for two sexes were similar. The findings demonstrated that *S.sindensis* is a short-lived species, similar to the other studies on this species based on length-frequency in Persian Gulf and Oman Sea (Salarpouri *et al*., 2008a.b; Farkhondeh *et al*., 2010). Other researches on *S.sindensis* in Persian Gulf and Oman Sea showed that maximum age of Sind sardine in coastal waters of Qeshm Island and Jask were estimated as 2.75 years and 2.50 years respectively, which were slightly less than the results of the present study. These differences might be because of differences in the frequency of lengths class. The most abundant year class was found to be less than a year and the most abundant length class ranged from 8 to 10 cm. Cailliet and Goldman (2004) reported that growth model estimates are greatly affected by the lack of very young or old individuals. Because there was not individuals smaller than 7.9 cm, while in other study by (Salarpouri *et al*., 2008a), the minimum length was 4.5 cm which were very young and fast-growing fishes. Therefore, it could be suggested that growth estimations are affected by lack of very young or old individuals (Cailliet and Goldman, 2004). Estimated growth parameters by Von Bertalanffy equation in our study showed that growth rates (k) contrast to those reported by Salarpouri *et al*., (2008); Farkhondeh *et al*., (2010) based on length-frequency methods. This relatively high differences may be due to using different methods that have been found in other studies, too (Mendoza *et al*., 1994).We suggested that estimation of growth and age based on rings of hard structures contrast to those based on the length- frequency, result in different values. Based on Table 2, Growth performance (φ′) of present study are similar for those of other studies on growth of *sardinella* spp, indicating that growth estimation is reliable (Bellido *et al.*, 2000).

Table 2: Growth parameters (L∞ and K) and performance growth (φ′) of *Sardinella* spp this study and others studies based on different methods of age determination.

φ′(year)	K(yr^{-1})	L∞(cm)	Method	Source	Region	Species
2.65	1.11	17.8	Length frequency	Salarpouri *et al*., 2008a	Qeshm(Iran)	*S. sindensis*
2.65	1.18	19.5	Length frequency	Salarpouri *et al*., 2008b	Jask(Iran)	*S. sindensis*
2.75	1.40	20	Length frequency	Farkhondeh *et a*l., 2010	Jask(Iran)	*S. sindensis*
--	1.21	22.0	Length frequency	Al-Anbouri *et al*., 2011	Oman	*S. longiceps*
_	0. 60	16.6	Otolith	Gaughan and Mitchell, 2000	Australia	*S.lemuru*
2.95	1.26	26.6	Otolith	Mendoza, 1994	Venezuela	*S.aurita*
2.56	0.55	25.6	Otolith	Mehanna and Salem, 2011	Egypt	*S.aurita*
__	1.50	21.6	Length frequency	Gnga and Pillai, 2006	India	*S. longiceps*
2.37	0.54	20.8	Otolith	Present study	Qeshm(Iran)	*S. sindensis*

Readings of the annuli of the otolith of *S. sindensis* were carried out and overall, four age groups with maximum age of 3.5 (years) were determined for *S.sindensis*. Results of age determination and growth parameters estimation demonstrated that *S.sindensis* is a fast growing and short-lived fish. Finally, we propose in order to achieve more accurate and reliable results, broad-scale sampling at several years-ranges should be done. In addition, different methods should be applied simultaneously to determine the age and growth of the fish in order to obtain reasonable results. Other factors such as temperature, food availability, competition within and between species, and human activities also have impacts on the fish life which are to be considered simultaneously. These are essential for management decisions for optimal and sustainable exploitation and preservation of the sardine stocks which are of economical and ecological important species.

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