Iran J Sci Technol Trans Sci (2017) 41:313–319
DOI 10.1007/s40995-017-0259-0

RESEARCH PAPER

Population Dynamics of the Sparid Fish, *Argyrops spinifer* (Teleostei: Sparidae) in Coastal Waters of the Persian Gulf

Mehri Ghanbarzadeh[1] · Yazdan Keivany[1] · Nasrollah M. Soofiani[1]

Received: 30 March 2015 / Accepted: 29 November 2015 / Published online: 5 June 2017

Abstract Some of the population characteristics of *Argyrops spinifer* collected from the coastal waters of Bushehr province (Persian Gulf) were investigated from June 2010 to May 2011. A total of 622 specimens were taken from Bushehr harbor and transferred to the laboratory on ice for further consideration. Total length, body weight and sex were recorded for each specimen and their sagittal otoliths were removed for age determination. Some of the otoliths were cut and age reading was performed by three investigators to assure the accuracy of the readings and age validation. In males, total length ranged between 15 and 61.2 (24.04 ± 6.62 SD) cm and total weight between 77.09 and 3450.00 (325.20 ± 320.45) g. In females, total length ranged between 13.50 and 64.20 (24.61 ± 7.86) cm and total weight ranged between 52.48 and 4162.00 (369.66 ± 465.03) g. Sex was determined in 532 mature specimens, among which about 44% were males and 56% were females. The age of males and females ranged from 2+ to 25+ and 2+ to 21+ years, respectively, indicating it is a long-lived species. The estimates of asymptotic length (L_∞) and the growth coefficient (K) of males were 67.90 cm and 0.082 per year, respectively. Females asymptotic length was 82.10 cm and their growth coefficient was 0.061 per year. Length–weight relationship was described as $W = 0.060\ \mathrm{TL}^{2.648}(r^2 = 0.98)$ for males and $W = 0.054\ \mathrm{TL}^{2.681}(r^2 = 0.98)$ for females, indicating a negative allometric growth pattern in both sexes ($p < 0.05$). The condition factor was 2 ± 0.14 for all the specimens.

Keywords Age determination · Asymptomic length · Growth · Sex ratio

1 Introduction

Population characteristics and age composition of a fish stock are important parameters used in stock assessment models in fisheries management. The age profile of a stock gives an indication on how healthy the stock is Metin and Ilkyaz (2008). Age determination in fish can be carried out with direct (observation on hard structures) or indirect (marking and recapture, length–frequency analysis, etc.) methods (Morales-Nin 1992). Age determination in bony fish can be carried out using the sagittal otoliths which are the largest otoliths in most bony fishes (Platt and Popper 1981; Gauldie 1988). Because of their accretionary growth and species (sometimes population) specific shape, they can be used in fish aging (Karlou-Riga 2000), determination of stock relationships and stock identification (Cardinale et al. 2004). Depositions of annual growth rings formed in this tissue are caused by seasonal changes in the environment (İlkyaz et al. 2011). By determining the age of a large number of individuals, it is possible to build up a picture of the age structure of the whole population. Knowledge of the age structure provides an indication of how the stock is measuring up to exploitation (Metin and Ilkyaz 2008).

Fishes of the family Sparidae, commonly known as seabreams, are among the most important fishes and contain many species of commercial and recreational importance throughout their range and some that are used for aquaculture (Smale and Buxton 1985; Foscarini 1988; Kailola et al. 1993; Sommer et al. 1996; Ingram et al. 2002). The king soldier bream *Argyrops spinifer* (Forsskal

✉ Yazdan Keivany
keivany@cc.iut.ac.ir

[1] Department of Natural Resources (Fisheries Division), Isfahan University of Technology, Isfahan 84156-83111, Iran

1775) is a large sparid fish that is distributed throughout the Western Indian Ocean extending eastward to the Indo Malayan archipelago and northern Australia (Sommer et al. 1996). Although some data on population characteristics and age of *A. spinifer* have been published in the last three decades (El-Sayed and Abdel-Bary 1995; Grandcourt et al. 2004; Al Mamry et al. 2009; Al-Kiyumi et al. 2013; Ghanbarzadeh et al. 2014a, b), currently, very little is known about this species in the northern Persian Gulf. The objective of this study was to determine the population characteristics of *A. spinifer* such as growth parameters and age composition to provide information required for their management in this region.

2 Materials and Methods

This study was carried out in the northern Persian Gulf along the Bushehr coasts, Iran (28°55′19″N and 50°49′59″E) by monthly sampling intervals from June 2010 to May 2011. A total of 622 specimens of *A. spinifer* were collected from the fishermen just after the fishing and transferred to the laboratory on ice. Total length (TL) was measured to the nearest 0.1 cm and the total weight (TW) to the nearest 0.01 g for small specimens and 1 g for larger specimens. The individuals were sexed by macroscopic examination of the gonads. A cut was made just behind the eye and the Sagitta was removed with forceps. The otoliths were cleaned and stored dry in code-numbered envelopes. The age was determined by reading growth rings on the otoliths. First, otoliths were polished and then immersed in a solution of glycerin and read whole under a compound microscope using reflected light. Opaque rings from the nucleus to the margin were counted along the longest axis of the otolith. As a rule, each otolith was read three times and only coincident readings were accepted. Since the otoliths of *A. spinifer* are thick, to validate this method, some of them were sectioned and re-examined. For sectioning of otoliths, one otolith from a random subsample of 50 individuals was embedded in epoxy resin, acid (as fixing material) and cobalt by a proportion of 25:1:0.5, respectively. After cutting otolith sections, the specimens were mounted for polishing to reach approximately 0.5 mm in thickness. Otolith sections were then immersed in a solution of glycerin and read under a compound microscope at 12.5× magnification using reflected light (Campana and Neilson 1985). Results did not show differences between the two reading methods, thus age was estimated from whole otoliths for the rest of the specimens. Also, the age reading was performed by three investigators to assure the accuracy of the readings.

The condition factor was measured using Eq. (1)

$$C = W/L^3 \times 100. \quad (1)$$

Growth was modeled using the Von Bertalanffy (1938) growth equation (Eq. 2)

$$L_t = L_\infty \left[1 - e^{-K(t - t_0)}\right], \quad (2)$$

where L_t is the fish total length at age t, L_∞ the asymptotic total length, K is the growth coefficient and t_0 is the hypothetical age when fish would have been at 0 total lengths.

Parameters of the length–weight relationship were calculated for both sexes and for the whole sample, by fitting the power function to length and weight data (Eq. 3).

$$\mathrm{TW} = a \times \mathrm{TL}^b. \quad (3)$$

Pauly (1984) *t* test was used to determine if the slope of relationships was significantly different from 3. Statistical differences between the means were determined by independent-sample *t* test. To test for possible significant differences between the sex ratio from the 1:1, Chi-square test was used in SPSS.18 software.

3 Results

A total of 622 fish were collected for this study during a full year (Table 1), among which 231 (37%) were males, 301 (49%) females, 20 (3%) immature and 70 (11%) undetermined sex. The overall sex ratio was 1 M: 1.3 F which was significantly different from the expected ratio (Chi-square test, $p < 0.05$). The number, mean, maximum, minimum and SD values of the total length and weight for males, females and immature are presented in Table 2. No significant differences were found between males and females in mean length and weight ($p > 0.05$). The highest number of individuals in both sexes was observed in 20.1–25 and the least in the 45.1–50 size groups (Fig. 1).

Mean total length and weight of each age group is presented in Table 3. A pair-wise comparison of the mean length and weight-at-age of males and females showed that there was a significant variation between mean length and weight of age classes 1–6 in the two sexes ($p < 0.05$) (Table 4).

Only 532 sexed male and female fish were aged. The resulting sections showed a ring pattern that was very clear and the fish could be aged easily and the use of sagittal for age estimating of the king soldier bream proved straightforward, with distinct opaque and translucent bands surrounding a white opaque nucleus. The distance between bands became smaller from the core towards the outer margin of the otoliths. The ages of *A. spinifer* ranged from 2+ to 25+ years, with male fish attaining the oldest age (25+ years for males and 21+ years for females). The majority of fish were within a restricted age range of 2+ to 8+ years (Fig. 2).

Table 1 Mean observed length and weight-at-age (±SD) for different age classes of males and females of *A. spinifer* off the northern Persian Gulf coast (June 2010–May 2011)

Age (years)	Sex	No.	Mean observed length (cm)	Mean observed weight (g)
2	Male	94	19.02 ± 1.71	151.39 ± 39.17
	Female	44	16.88 ± 1.09	105.40 ± 20.15
3	Male	31	22.92 ± 0.89	255.16 ± 42.79
	Female	80	20.10 ± 1.28	176.30 ± 47.24
4	Male	27	25.82 ± 0.96	337.12 ± 41.52
	Female	56	23.07 ± 1.14	255.24 ± 43.35
5	Male	18	29.08 ± 0.81	451.75 ± 49.07
	Female	60	25.69 ± 1.16	338.53 ± 43.30
6	Male	16	32.25 ± 0.89	597.58 ± 66.83
	Female	21	29.45 ± 0.96	464.49 ± 56.47
7	Male	8	35.35 ± 1.02	734.34 ± 68.56
	Female	4	33.30 ± 1.45	636.25 ± 62.93
8	Male	6	37.72 ± 0.97	854.77 ± 26.74
	Female	15	36.19 ± 1.09	812.97 ± 91.99
9	Male	1	40.20 ± 0	980.00 ± 0
	Female	7	38.30 ± 1.41	971.31 ± 132.98
10	Male	2	42.30 ± 0.42	1292.00 ± 87.68
	Female	3	41.80 ± 0.53	1229.00 ± 105.76
11	Male	0	–	–
	Female	3	44.73 ± 0.64	1314.33 ± 125.72
12	Male	4	46.35 ± 0.51	1522.00 ± 80.72
	Female	2	46.25 ± 0.49	1570.45 ± 135.13
13	Male	4	48.78 ± 0.60	1661.50 ± 35.27
	Female	1	47.20 ± 0	1821.00 ± 0
14	Male	3	50.03 ± 0.35	1762.00 ± 60.56
	Female	0	–	–
15	Male	0	–	–
	Female	1	52.50 ± 0	2081.00 ± 0
16	Male	6	52.02 ± 0.21	2168.33 ± 8.31
	Female	1	54.20 ± 0	2275.70 ± 0
17	Male	0	–	–
	Female	0	–	–
18	Male	2	54.05 ± 0.35	2211.50 ± 16.26
	Female	0	–	–
19	Male	0	–	–
	Female	0	–	–
20	Male	0	–	–
	Female	0	–	–
21	Male	2	56.80 ± 0.28	2312.50 ± 3.54
	Female	3	63.90 ± 0.36	3829.67 ± 392.25
22	Male	0	–	–
	Female	0		
23	Male	2	59.05 ± 0.49	2523.00 ± 74.95
	Female	0		
24	Male	0	–	–
	Female	0		
25	Male	5	61.04 ± 0.32	3319.20 ± 154.88
	Female	0		

Table 2 Month sample size, mean length and mean weight for all fish of *Argyrops spinifer* off the northern Persian Gulf coast (June 2010–May 2011)

Month	No.	Length (cm)			Weight (g)		
		Mean	SD	Range	Mean	SD	Range
June 2010	47	19.64	2.35	16.3–25.4	147.25	49.50	85.06–273.98
July 2010	52	22.31	6.52	16.3–42.6	273.28	281.50	92.32–1354
August 2010	50	26	8.19	20–61.2	429.09	570.92	156.58–3450
September 2010	60	26.58	8.15	20.9–64.2	481.27	698.09	210.49–4162
October 2010	50	32.42	7.80	19.8–64	639.70	503.61	170–3397
November 2010	63	23.17	6.49	13.5–45.2	285.70	238.85	52.48–1400
December 2010	50	23.88	5.49	15.5–47.2	306.18	262.79	78.48–1821
January 2011	53	18.29	3.50	15–39.8	144.14	132.21	77.09–1037
February 2011	50	22.84	3	18.5–30.7	264.20	93.97	150.52–490
March 2011	49	23.12	7.50	15.5–47	315.31	328.31	80.27–1666
April 2011	51	23.16	7.37	16–39.5	305.10	264.59	92.41–937
May 2011	47	23.91	4.36	20–38.4	421.99	441.91	149–2921.04
Total	622						

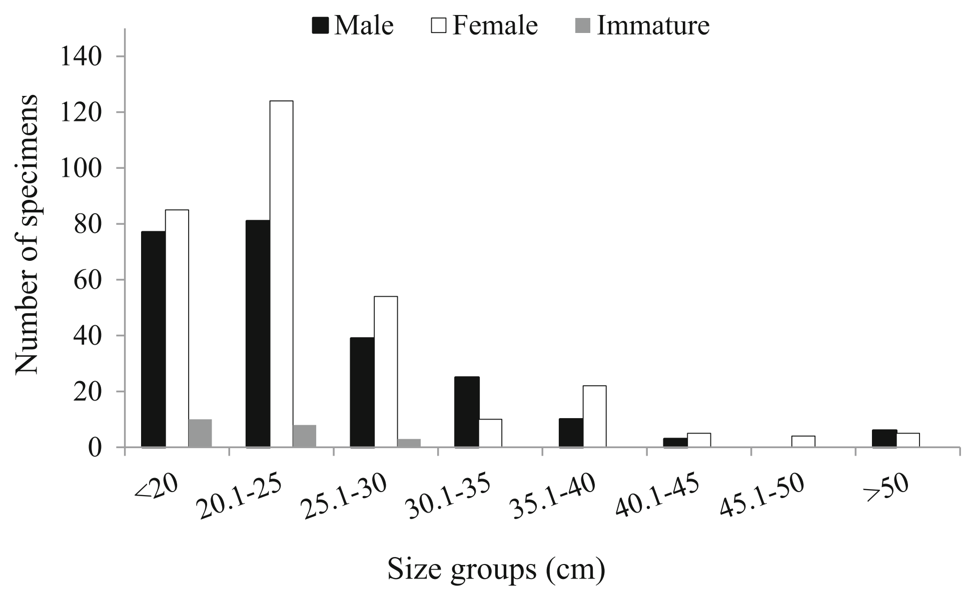

Fig. 1 Size group frequency distributions of males, females and immature *Argyrops spinifer* off the northern Persian Gulf coast (June 2010–May 2011)

Table 3 Number, range and SD values of the total length and total weight for males, females and immature *Argyrops spinifer* off the northern Persian Gulf coast (June 2010–May 2011)

	No.	Length (cm)		Weight (g)	
		Range	Mean ± SD	Range	Mean ± SD
Males	231	15.00–61.20	24.04 ± 6.62	77.09–3450.00	325.20 ± 320.45
Females	301	13.50–64.20	24.61 ± 7.86	52.48–4162.00	369.66 ± 465.03
Immature	20	15.10–25.10	19.38 ± 3.41	74.30–319.86	161.96 ± 73.48

4 Discussion

The total length of males and females ranged from 15–61.2 cm to 13.5–64.2 cm, respectively. Total length of males and females of *A. spinifer* in the Arabian Sea was reported as 20–68 cm and 24.5–70 cm, respectively (Al Mamry et al. 2009), slightly higher than those of present study. The maximum observed fork length reported by Mcilwain et al. (2006) in the Arabian Sea was 57.6 cm in males and 58.5 cm in females.

Mcilwain et al. (2006) reported the weight in males of *A. spinifer* from 169 to 3940 g and in females from 157 to 4020 g. The highest number of individuals in both sexes was observed in the 20.1–25 cm and the least in

Table 4 Mean observed length and weight-at-age (±SD) for different age classes of males and females of *Argyrops spinifer* off the northern Persian Gulf coast (June 2010–May 2011)

Age (year)	Males			Females		
	No.	Mean observed length (cm)	Mean observed weight (g)	No.	Mean observed length (cm)	Mean observed weight (g)
2	94	19.02 ± 1.71	151.39 ± 39.17	44	16.88 ± 1.09	105.40 ± 20.15
3	31	22.92 ± 0.89	255.16 ± 42.79	80	20.10 ± 1.28	176.30 ± 47.24
4	27	25.82 ± 0.96	337.12 ± 41.52	56	23.07 ± 1.14	255.24 ± 43.35
5	18	29.08 ± 0.81	451.75 ± 49.07	60	25.69 ± 1.16	338.53 ± 43.30
6	16	32.25 ± 0.89	597.58 ± 66.83	21	29.45 ± 0.96	464.49 ± 56.47
7	8	35.35 ± 1.02	734.34 ± 68.56	4	33.30 ± 1.45	636.25 ± 62.93
8	6	37.72 ± 0.97	854.77 ± 26.74	15	36.19 ± 1.09	812.97 ± 91.99
9	1	40.20 ± 0.00	980.00 ± 0	7	38.30 ± 1.41	971.31 ± 132.98
10	2	42.30 ± 0.42	1292.00 ± 87.68	3	41.80 ± 0.53	1229.00 ± 105.76
11	0	–	–	3	44.73 ± 0.64	1314.33 ± 125.72
12	4	46.35 ± 0.51	1522.00 ± 80.72	2	46.25 ± 0.49	1570.45 ± 135.13
13	4	48.78 ± 0.60	1661.50 ± 35.27	1	47.20 ± 0	1821.00 ± 0
14	3	50.03 ± 0.35	1762.00 ± 60.56	0	–	–
15	0	–	–	1	52.50 ± 0	2081.00 ± 0
16	6	52.02 ± 0.21	2168.33 ± 8.31	1	54.20 ± 0	2275.70 ± 0
17	0	–	–	0	–	–
18	2	54.05 ± 0.35	2211.50 ± 16.26	0	–	–
19	0	–	–	0	–	–
20	0	–	–	0	–	–
21	2	56.80 ± 0.28	2312.50 ± 3.54	3	63.90 ± 0.36	3829.67 ± 392.25
22	0	–	–	0	–	–
23	2	59.05 ± 0.49	2523.00 ± 74.95	0	–	–
24	0	–	–	0	–	–
25	5	61.04 ± 0.32	3319.20 ± 154.88	0	–	–

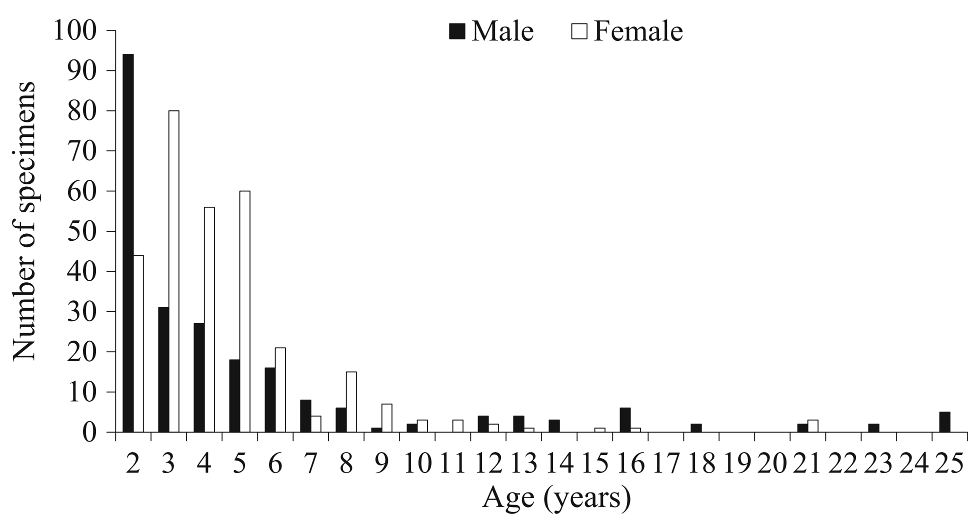

Fig. 2 Age-frequency ($n = 532$) distributions of male and female of *Argyrops spinifer* off the northern Persian Gulf coast (June 2010–May 2011)

45.1–50 cm size groups. Similar finding was recorded in the Arabian Sea for *A. Spinifer* (Mcilwain et al. 2006). The most frequent size class of males reported by Al Mamry et al. (2009) was in >60 cm size class and in females was in 50–54.9 size class. It appears that observed differences in linear distribution of these populations are related to differences in applied fishing gears, mesh size, skewness in sampling, different ecological conditions, different seasons, different habitats and interspecific differences, as observed in other fish species (Keivany et al. 2012, 2014; Alavi-Yeganeh et al. 2011; Daneshvar et al. 2013; Ghanbarifardi et al. 2014; Hasankhani et al. 2013, 2014; Asadollah et al. 2017).

The overall sex ratio was in favor of females as reported in previous studies and explained as a result of protogynous hermaphroditism (Grandcourt et al. 2004; Al Mamry et al. 2009). Differences in sex ratio might be related to the interspecific differences in adapted population of a species to different ecological conditions, different in the date and time of capture, fishing gears, location, different growth rates, different mortality in males and females, migration of mature fishes from the region and different behavior in male and female fish species (Qasim 1966; Pitcher and Hart 1982; Rajaguru 1992; Keivany and Soofiani 2004; Soofiani et al. 2006; Asadollah et al. 2011; Abaszadeh et al. 2013; Tabatabaei et al. 2014; Keivany and Daneshvar 2015).

In many sparid species, age determination is difficult since their otoliths are very thick and cloudy so that light cannot pass through. This difficulty is also related to a consequence of the phenomenon of stacking zones towards the otolith edge, especially in older fish (Van Der Walt and Beckley 1997). Sparid fishes, in general, are long lived, displaying a steady and slow rate of growth (El-Sayed and Abdel-Bary 1995; Ghanbarzadeh et al. 2013, 2014a). The oldest age estimated in this study was 25 years as observed in Oman waters by Al Mamry et al. (2009). The maximum reported age for this species from Qatari waters as 18 years is more likely a mistake as suggested by El-Sayed and Abdel-Bary (1995), because ages were not validated and fish 70 cm in length were excluded. Al-Kiyumi et al. (2013) in studying growth, mortality and yield per recruit of the king soldier bream *A. spinifer* (Sparidae) in the Oman coast of the Arabian Sea refuted the maximum age determination of Al Mamry et al. (2009) as 25 years, however, their specimens hardly exceeded 61 cm in total length. The annuli formation pattern of otoliths of the king soldier bream of the northern Persian was consistent with those observed in other sparids and teleosts. Seasonal growth cycles might be related to physiological changes produced by the influence of temperature, feeding regime and reproductive cycle (Morales-Nin 1989). Longhurst and Pauly (1987) hypothesized that the formation of growth checks in structures used for ageing fishes may require seasonal changes in water temperature of at least 4 °C. The evidence presently available suggests that a seasonal temperature difference of 6 °C might be sufficient to cause ring formation (Nevman et al. 2000). Seasonal deposition of alternative rings has been demonstrated for this species in other regions such as the Arabian Sea by Al Mamry et al. (2009) and in the southern Persian Gulf by Grandcourt et al. (2004) and also in other sparid species such as *Diplodus sargus* (Pajuelo and Lorenzo 2002) and *Diplodus vulgaris* of the Canary Islands (Pajuelo and Lorenzo 2003).

In conclusion, the king soldier bream is a long-lived species, females are dominant, live longer and reach higher lengths and weights and the growth pattern in both sexes is negative allometric.

Acknowledgements We thank the staff of the ecology section at the Iranian Shrimp Research Center for their help in fish collection and Dr. S. A. Taghavi-Motlagh (Iranian Fisheries Research Organization) for his support during the study. This research was funded jointly by Isfahan University of Technology and the Iranian Fisheries Research Organization.

References

Abaszadeh A, Keivany Y, Soofiani NM, Falahatimarvast A (2013) Reproductive biology of the greater lizardfish, *Saurida tumbil* (Bloch 1795), in Bushehr coastal waters of Iran. Turk J Zool 37:717–722

Al Mamry JM, Mccarthy ID, Richardson CA, Meriem SB (2009) Biology of the kingsoldier bream (*Argyrops spinifer*, Forsskal 1775; Sparidae), from the Arabian Sea, Oman. J Appl Ichthyol 25:559–564

Alavi-Yeganeh MS, Seifabadi SJ, Keivany Y, Kazemi B, Wallis GP (2011) Comparison of length–weight relationships in different populations and sexes of Iranian thoothcarps. J Appl Ichthyol 27:1401–1403

Al-Kiyumi F, Mehanna SF, Al-Kharusi L (2013) Growth, mortality and yield per recruit of the king soldier bream *Argyrops spinifer* (Sparidae) from the Oman coast of the Arabian Sea. Iran J Fish Sci 12(4):737–748

Asadollah S, Soofiani NM, Keivany Y, Shadkhast M (2011) Reproduction of *Capoeta damascina*, a cyprinid fish, in Zayandeh-Rud River, central Iran. J Appl Ichthyol 27:1061–1066

Asadollah S, Soofiani NM, Keivany Y, Hatami R (2017) Age and growth of the mesopotamian barb, *Capoeta damascina*, in Central Iran. Iran J Fish Sci 16(2):511–521

Campana SE, Neilson JD (1985) Microstructure of fish otoliths. Can J Fish Aquat Sci 42:1014–1032

Cardinale M, Doering-Arjes P, Kastowsky M, Mosegaard H (2004) Effects of sex, stock, and environment on the shape of known-age Atlantic cod (*Gadus morhua*) otoliths. Can J Fish Aquat Sci 61:158–167

Daneshvar E, Keivany Y, Paknehad E (2013) Comparative biometry of the Iranian cichlid, *Iranocichla hormuzensis*, in different seasons and sexes. Res Zool 3:56–61

El-Sayed AM, Abdel-Bary K (1995) Population biology of sparid fishes in qatari waters: 4 growth and mortality of longspine seabream (*Argyrops spinifer*). Qatar Univ Sci J 15(2):457–461

Foscarini R (1988) A review: intensive farming procedure for red sea bream (*Pagrus major*) in Japan. Aquaculture 72:191–246

Gauldie RW (1988) Function, form and time keeping properties of fish otoliths. Comp Biochem Physiol 91A:395–402

Ghanbarifardi M, Ghasemian S, Aliabadian M, Pehpuri A (2014) Length–weight relationships for three species of mudskippers (Gobiiformes: Gobionellidae) in the coastal areas of the Persian Gulf and Gulf of Oman, Iran. Iran J Ichthyol 1:29–31

Ghanbarzadeh M, Soofiani NM, Keivany Y, Taghavi-Motlagh SA (2013) Determination of growth parameters of the king soldier bream (*Argyrops spinifer*), using the backcalculation method and otolith reading data in coastal waters of Bushehr Province, Persian Gulf. Iran Sci Fish J 21:75–84 **(in Persian with English abstract)**

Ghanbarzadeh M, Soofiani NM, Keivany Y, Taghavi-Motlagh SA (2014a) Use of otolith length and weight in age estimations of the kingsoldier bream, *Argyrops spinifer*, in the Persian Gulf. Iran J Ichthyol 1(1):1–6

Ghanbarzadeh M, Soofiani NM, Keivany Y, Taghavi-Motlagh SA (2014b) Feeding habits of the king soldier bream, *Argyrops spinifer* (Perciformes: Sparidae), in the northern Persian Gulf. J Appl Ichthyol 30:485–489

Grandcourt EM, Al Abdessalaam TZ, Francis F, Al Shamsi AT (2004) Biology and stock assessment of the Sparids, *Acanthopagrus bifasciatus* and *Argyrops spinifer* (Forsskål 1775), in the Southern Arabian Gulf. Fish Res 6:7–20

Hasankhani H, Keivany Y, Raeisi H, Pouladi M, Soofiani NM (2013) Length-weight relationships of three cyprinid fishes from Sirwan River, Kurdistan and Kermanshah provinces in western Iran. J Appl Ichthyol 29:1170–1171

Hasankhani M, Keivany Y, Daliri M, Pouladi M, Soofiani NM (2014) Length–weight and length–length relationships of four species (*Barbus lacerta*, *Pseudorasbora parva, Squalius lepidus* and *Oxynoemacheilus angorae*) from the Sirwan River, western Iran. J Appl Ichthyol 30:206–207

İlkyaz AT, Metin G, Kinacigil HT (2011) The use of otolith length and weight measurements in age estimations of three Gobiidae species (*Deltentosteus quadrimaculatus*, *Gobius niger*, and *Lesueurigobiu sfriesii*). Turk J Zool 35(6):819–827

Ingram BA, Mckinnon LJ, Gooley GJ (2002) Growth and survival of selected aquatic animals in two saline groundwater evaporation basins: an Australian case study. Aquac Res 33:425–436

Kailola PJ, Williams MJ, Stewart PC, Riechelt RE, Mcnee A, Grieve C (1993) Australian fisheries resources. Department of Primary Industries and Energy and the Fisheries Research and Development Corporation, Canberra, p 422

Karlou-Riga C (2000) Otolith morphology and age and growth of *Trachurus mediterraneus* (Steindachner) in the Eastern Mediterranean. Fish Res 46:69–82

Keivany Y, Daneshvar E (2015) Reproduction of an isolated Iranian cichlid, *Iranocichla hormuzensis*. Casp J Environ Sci 13:119–128

Keivany Y, Soofiani NM (2004) Contribution to the biology of Zagros tooth-carp, *Aphanius vladykovi*, in central Iran (Cyprinodontidae). Environ Biol Fishes 71:165–169

Keivany Y, Zare P, Kalteh L (2012) Age, growth and reproduction of the *Female Kutum*, *Rutilus kutum* (Kamensky 1901) (Teleostei: Cyprinidae), in Gorgan-Rud Estuary, Northern Iran. Res Zool 2:7–14

Keivany Y, Abaszadeh A, Soofiani NM (2014) A study on some growth parameters and feeding characteristics of the Lizardfish, *Saurida tumbil*, from the Iranian Persian Gulf coast. J Mar Sci Technol 13(3):51–60 **(in Persian with English abstract)**

Longhurst AR, Pauly D (1987) Ecology of tropical oceans. Academic Press, San Diego, p 407

Mcilwain J, Hermosa GV, Claereboudt M, Al Oufi HS, Al Awi M (2006) Spawning and reproductive patterns of six exploited finfish species from the Arabian Sea, Sultanate of Oman. J Appl Ichthyol 22:167–176

Metin G, Ilkyaz AT (2008) Use of otolith length and weight in age determination of poor cod (*Trisopterus minutus* Linn. 1758). Turk J Zool 32(3):293–297

Morales-Nin B (1989) Growth determination of tropical fishes by means of otolith interpretation and length frequency analysis. Aquat Living Resour 2:241–254

Morales-Nin B (1992) Determination of growth in bony fishes from otolith microstructure. FAO Fisheries Technical Paper NO 322, p 51

Nevman SJ, Cappo M, Williams DM (2000) Age, growth, mortality rates and corresponding yield estimates using otoliths of the tropical red snappers, *Lutjanus erythropterus*, *L. malabaricus* and *L. sebae*, from the central Great Barrier Reef. Fish Res 48:1–14

Pajuelo JG, Lorenzo JM (2002) Growth and age estimation of *Diplodus sargus cadenati* (Sparidae) off Canary Islands. Fish Res 59:93–100

Pajuelo JG, Lorenzo JM (2003) The growth of the common two-banded seabream, *Diplodus vulgaris* (Teleostei, Sparidae), in Canarian waters, estimated by reading otoliths and by back-calculation. J Appl Ichthyol 19:79–83

Pauly D (1984) Fish population dynamics in tropical waters: a manual for use with programmable calculators. ICLARM Stud Rev 8:1–325

Pitcher TJ, Hart PJB (1982) Fisheries ecology. Chapman & Hall, London, p 414

Platt C, Popper AN (1981) Fine structure and function of the ear. In: Tavolga WN, Popper AN, Fay RN (eds) Hearing and sound communication in fishes. Springer, New York, pp 3–38

Qasim SZ (1966) Sex ratio in fish populations as a function of sexual differences and growth rate. Curr Sci 35:140–142

Rajaguru A (1992) Biology of two co-occuring tongue fishes, *Cynoglossus arel* and *C. lida* (Pleuronectiformes: Cynoglossidae), from Indian waters. Fish Bull 90(2):328–367

Smale MJ, Buxton CD (1985) Aspects of the recreational skiboat fishery off the Eastern Cape, South Africa. S Afr J Mar Sci 3:131–144

Sommer C, Schneider W, Poutiers JM (1996) FAO species identification field guide for fishery purposes. The living marine resources of Somalia. FAO, Rome, p 376

Soofiani NM, Keivany Y, Shooshtari AM (2006) Contribution to the biology of the lizardfish, *Saurida tumbil* (Teleostei: Aulopiformes), from the Persian Gulf. Zool Middle East 38:49–56

Tabatabaei SN, Hashemzadeh-Segherloo I, Abdoli A, Milani M, Mirzaei M (2014) Age and growth of spirlins, *Alburnoides eichwaldii* and *A. namaki*, from the Caspian, Kavir and Namak basins of Iran. Iran J Ichthyol 1:266–273

Van Der Walt BA, Beckley LE (1997) Age and growth of *Sarpa salpa* (Pisces: Sparidae) off the east coast South Africa. Fish Res 31:241–248

Von Bertalanffy LUDWIG (1938) A quantitative theory of organic growth (inquiries on growth laws. II). Hum Biol 10(2):181–213