NOTE

https://doi.org/10.1590/s2675-28242020068317

OCEAN AND COASTAL RESEARCH

Age and growth of oriental sole, *Brachirus orientalis* (Bloch & Schneider, 1801), in the Persian Gulf (Soleidae)

Yazdan Keivany[1]*, Dima Alghada[1], Fatemeh Paykan-Heyrati[1]

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

*Corresponding author: Keivany@iut.ac.ir

The age and growth parameters are important biological indices in fish biology, fishery management, and aquaculture (Ghanbarzadeh *et al*., 2013, 2014, 2017). In practice, the age and growth parameters of fish are typically studied by examining catches at monthly intervals (Keivany *et al*., 2012; Keivany and Daneshvar, 2016).

Soleid fish (family Soleidae from the order Pleuronectiformes) is one of the important groups in the Persian Gulf, as they are consumed by people inside Iran and are also exported to the adjacent countries. However, there is little information on their biology. Seventeen species belonging to five families have been reported for the region (Yasemi *et al*., 2008). *Brachirus orientalis* (Figure 1) is widely distributed in the Persian Gulf and Makran Sea. They mostly live at depths of 10-200 m (Randall, 1995), reaching 40 cm in length and 1 kg in weight (Carpenter *et al*., 1997). Since soles are usually by-catch from shrimp trawls and other fishing nets, they have been neglected in biological studies in the region. Mohammadi and Khodadadi (2008) studied the growth parameters of *B. orientalis*, Bagherpour *et al*. (2011) examined the parasitic infections, and Moghdani *et al*. (2014) investigated the effects of petroleum pollution on nickel concentration in sole muscle tissue. Thus, this study aimed to obtain some information on the age and growth of soles in the Bushehr area in the Persian Gulf.

This study was performed from August 2015 to July 2016. The samples were obtained from commercial bottom trawls; 30 random samples were collected per month and transferred to the laboratory for further studies. The total (TL) and standard (SL) lengths were measured to the nearest 0.1 mm and total weight (TW) to the nearest 0.01 g. To determine the age, the fish otoliths were removed, washed in water, and dried and cut after embedding in resins (Campana and Neison, 1985).

The parameters of the length-weight relationship (LWR) were calculated for both sexes and for the whole sample by fitting the power function to the length and weight data using equation $W=aL^b$ (Pauly, 1984). The t-test was used to determine if the *b* value was significantly different from 3.

$$t = \frac{sd\ \mathrm{In}\ TL}{sd\ \mathrm{In}\ W} \times \frac{|b-3|}{\sqrt{1+r^2}} \times \sqrt{n-2}$$

The growth was modeled using the von Bertalanffy (1938) growth equation for length $L_t = L_\infty[1\text{-}e^{-k(t+t_0)}]$ and weight $W_t = W_\infty[1\text{-}e^{-k(t+t_0)}]$, where L_t is the total fish length at age *t*, L_∞ is the asymptotic total length, *K* is the growth coefficient, and t_0 is the hypothetical age when fish would have been at 0 cm total length, W_t is the total fish weight at age *t* and W_∞ is the asymptotic total weight. The maximum age (t_{max}) that a fish would reach, was calculated using von Bertalanffy growth function as $t_{max} = t_0 + 3/K$ (Taylor, 1958).

Submitted on: 7/March/2020
Approved on: 19/September/2020

Editor: Rubens M. Lopes

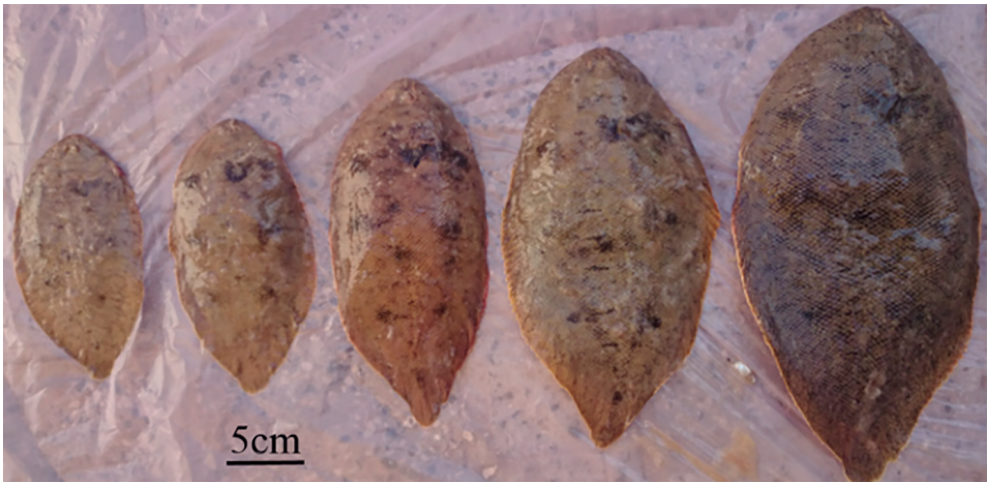

Figure 1. Photos of *B. orientalis* specimens as examples of different size classes.

The condition factor was measured using the equation $Cf=(W/L^3)\times 100$, where, W = weight of fish (g), L = length of fish (cm), a = intercept, and b = slope (Bagenal and Tesch, 1978). The growth performance index was calculated as $Ø= LnK+2LnL_\infty$. The Instantaneous growth rate was calculated by $G= (lnW_{t+1}–lnW_t)/\Delta t$ in females and males. The natural mortality rate was estimated based on Pauly's (1984) empirical equation at average temperature of 22°C for length as:

$$\log M = -0.0066 - 0.279 \log L_\infty + 0.6543 \log \mathrm{K} + 0.4634 \log \mathrm{T},$$

and for weight as

$$\log M = -0.2107 - 0.0824 \log L_\infty + 0.6757 \log \mathrm{K} + 0.4627 \log \mathrm{T}.$$

The statistical differences between the means were determined by *t*-test for independent samples. The chi-square test was used to test for deviation of the sex ratios from the expected 1:1 ratio. The relationship between length and weight was tested with a regression analysis and the degree of association between them given by the coefficient of determination (r^2). All the statistical analyses were performed at the 95% confidence level using Excel 2016 and SPSS 20 computer software.

Of the 300 individuals studied, 205 were females (68%) and 95 were males (32%), indicating a sex ratio of about 1M:2.2F (= 40.33, df= 1). The total length and weight of the specimens ranged between 14.1-38.5 (25.76±4.97 SD) cm and 50.45-757 (294.2±158.52) g for the whole sample, ranged from 16.2 to 38.5 (27.74±4.42) cm and 70.9 to 757 (353.26-152.45) g in females and from 14.1 to 29.1 (21.3±5.04) cm and 50.54 to 389.84 (166.75±73.97) g in males (Figure 2). There were significant differences in female and male lengths and weights ($p<0.05$).

The results of LWR indicated a negative allometric growth pattern for the females ($W= 0.02L^{2.933}$, $r^2 = 0.95$, *b* 95% CI: 2.880-3.728), males ($W= 0.02\ L^{2.918}$, $r^2 = 0.96$, *b* 95% CI: 2.702-3.442) and all the specimens ($W= 0.018\ L^{2.964}$, $r^2 = 0.97$, *b* 95% CI: 2.726-3.734) ($p<0.05$). The age of the specimens was 3^+-17^+ years and the dominant age groups were 6 and 7 years (Table 1).

The length-at-age analysis indicated the growth parameters as $L_\infty = 36.2$cm, $K= 0.177$ and $t_o = -0.569$ ($L_t= 36.174[1-e^{-0.177(t+5.569)}]$) in females and as $L_\infty = 33.86$cm, $K= 0.1467$ and $t_o = -0.433$ ($L_t= 33.86[1-e^{-0.1467(t+0.433)}]$) in males. The weight-at-age analysis indicated the asymptotic mean weight as $W_\infty = 744.4537$g ($W_t= 744.4537[1-e^{-0.1419(t+0.569)}]^{2.933}$) in females and as $W_\infty = 581.643$g ($W_t= 581.643[1-e^{-0.1467(t+0.433}]^{2.918}$) in males. The mean condition factor was 2.07 in females and 2.22 in males.

The life span or maximum age was calculated as 17.5 years in females and 20.8 years in males. The Ø value was calculated as 5.45 in females and 5.12 in males. The overall instantaneous growth rate was calculated as 0.04 in females and 0.06 in males. The natural mortality rate was estimated based on length as 0.49 in females and as 0.59 in males and based on

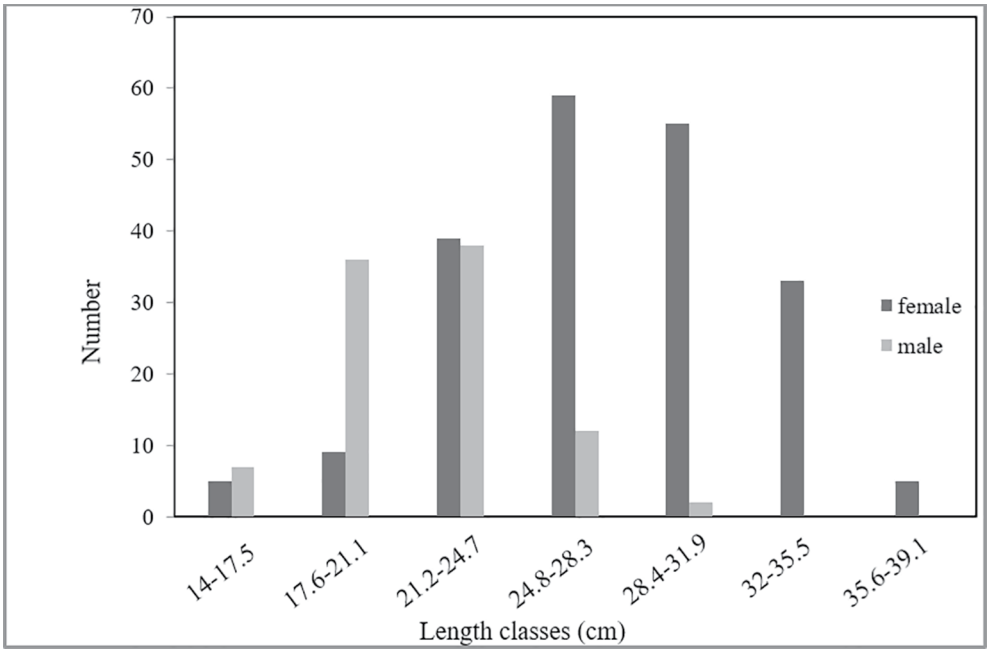

Figure 2. Distribution of length classes of males and females.

weight as 0.59 in females and as 0.53 in males at the average temperature of 22°C.

The maximum total length and weight for this species were 38.5 cm and 757 g in females. Yasemi *et al*. (2005) reported the maximum length and weight of this species as 27.6 cm and 696 g, and Mohammadi and Khodadadi (2008) reported the maximum length as 40 cm. There was a significant difference in the total length and weight of the males and females at different ages. The maximum age in this study was 17^{+} years and the most frequent age classes were 6 and 7 years (Table 1). There is no other age data for this species to compare. However, the differences and discrepancies in age composition could be due to fishing gears, different age determination methods, ecological conditions, and population differences (Evans, 1998; Kiani *et al*., 2016; Keivany *et al*., 2018).

The LWR implied that the growth was negatively allometric in all the specimens of this study. The different growth strategies are of influential factors on the LWR. The LWR was originally used to provide information on fish conditions and may help determine whether the somatic growth is isometric or allometric (Ricker, 1973). In *Cynoglossus arel,* the LWR was estimated as $W= 0.257TL^{1.8}$ in the Persian Gulf (Nasri and Taati, 2010). In *Pseutodes erumei*, it was reported as $W= 0.005TL^{3.284}$ (Azh *et al*., 2013). Generally, the *b* value lies between 2.5-3.5 and is affected by seasonal, geographical, feeding, and environmental conditions (Weatherley and Gill, 1987; Keivany *et al*., 2017).

In this species, as in other related species (e.g., Türkmen, 2003), the L_{∞} was higher in the females. This difference can be due to older age at maturity and longer life span of females. The earlier maturity in the males leads to the slower growth of the somatic organs (Wootton, 1998; Keivany *et al*., 2014). However, they rarely reach the asymptotic length in the wild due to the natural causes such as predation, diseases, and fishing (Biswas, 1993).

The growth performance index was higher in females, indicating their faster growth rate. The higher growth rate means that the fish reaches the asymptotic length faster (King, 2007). These parameters are influenced by temperature, salinity, dissolved oxygen, and other environmental conditions, thus varying with these factors. Besides, as temperature increases, K increases logarithmically, and L_{∞} decreases (King, 2007). Also, K was higher in females than that in the males. $t_{0,}$ which depends on L_{∞} and K, was lower in females, indicating a faster growth rate (Sparre *et al.*, 1989(. The growth varies with temperature and feeding conditions, which affect the physiology of the fish (Grossman *et al*.,

Table 1. Frequency, mean length and mean weight by age class and sex.

Age classes	Sex	Frequency	Mean Length ± SD (cm)	Mean weight ± SD (g)
3+	M	1	14.1	50.54
	F	13	18.55-1.78	298.61-109.64
4+	M	4	15.85-0.64	65.09-11.92
	F	0	----------	----------
5+	M	13	17.98-0.56	94.92-11.58
	F	5	21.52-0.34	402.62-153.42
6+	M	24	20.08-0.66	126.68-15.32
	F	26	22.98-0.61	450.99-154.27
7+	M	28	21.88-0.53	164.46-16.19
	F	13	24.53-0.25	313.28-159.53
8+	M	13	24.21-0.49	217.51-25.01
	F	27	25.96-0.53	352.91-163.54
9+	M	8	26.13-0.57	281.12-35.08
	F	0	----------	----------
10+	M	3	27.96-0.51	375.63-12.94
	F	20	27.47-0.24	332.33-97.97
11+	M	1	29.1[a]	375.18
	F	48	29.38-0.86	373.79-145.97
12+	M	0	----------	----------
	F	15	31.42-0.28	465.64-76.59
13+	M	0	----------	----------
	F	16	32.35-0.23	338.27-180.11
14+	M	0	----------	----------
	F	10	33.52-0.23	182.38-66.53
15+	M	0	----------	----------
	F	7	34.52-0.34	261.06-144.64
16+	M	0	----------	----------
	F	3	36.3-0.60	280.18-79.21
17+	M	0	----------	----------
	F	2	38.45-0.07	177.44-82.84

1980; Bruton, 1990). This species reaches a larger size and older age in colder waters despite later maturity (Ross, 1988). The growth parameters are affected by biological production, genetics, and fishing gears (Pauly and Munro, 1984; Pajuelo and Lorenzo, 2003).

The mean condition factor was higher in females. The condition factor is an indicator of the effect of interaction between biological and non-biological factors on fish physiology and is used to compare different populations in different conditions and life cycles (Bagenal and Tesch, 1978; Asadollah *et al*., 2017). In general, *B. orientalis* is a relatively slow-growing species with a relatively long-life span compared to other fish.

ACKNOWLEDGEMENTS

We would like to thank S. Karimi, M. Pourmohammad, and S. Asadolla for their assistance in the laboratory. This study was financially supported by Isfahan University of Technology.

CONTRIBUTION AUTHORS

YK: Funding acquisition, Conceptualization, Writing – review & editing, Supervision,

DA: Formal analysis, Investigation, Writing – original draft

FP: Methodology, Project administration, Writing – review & editing

REFERENCES

ASADOLLAH, S., SOOFIANI, N. M., KEIVAN, Y. & HATAMI, R. 2017. Age and growth of the Mesopotamian Barb, *Capoeta damascina*, in central Iran. *Iranian Journal of Fisheries Sciences*, 16(2), 511-521.

AZH, Z., SOURINEJAD, I., KAMRANI, E. & SHOJAEI, M. G. 2015. Feeding habits of Indian halibut *Psettodes erumei* in the Persian Gulf (Hormozgan Province). *Journal of Animal Research*, 25(2), 125-135.

BAGENAL, T. B. & TESCH, F. W. 1978. Age and growth. In: BAGENAL, T. B. (ed.). *Methods for the assessment of fish production in fresh waters*. 3rd ed. Oxford: Blackwell Scientific Publications.

BAGHERPOUR, A., AFSHARNASAB, M., MOBEDI, I., JALALI, B. & MESBAH, M. 2011. Prevalence and intensity of internal parasitic helminthes infected black sole fish, *Brachirus orientalis* (Bloch and Schneider, 1801) in the Persian Gulf. *Iranian Journal of Fisheries Sciences*, 10(4), 570-584.

BISWAS, S. P. 1993. *Manual of methods in fish biology*. New Delhi: South Asian Publishers Ltd.

BRUTON, M. N. 1990. Trends in the life history styles of vertebrates: an introduction of the second ALHS volume. *Environmental Biology of Fishes*, 28, 7-16.

CAMPANA, S. E. & NEISON, J. D. 1985. Microstructure of fish otolithes. *Canadian Journal of Fisheries and Aquatic Sciences*, 42(5), 1014-1032.

CARPENTER, E. K., KRUPP, F., JONES, D. A. & ZAJONZ, U. 1997. *The living marine resources of Kuwait, Eastern Saudi Arabia, Bahrain, Qatar and the United Arab Emirates*. Rome: FAO Species Identification Field Guide for Fishery Purposes.

EVANS, D. H. 1998. *The physiology of fishes.* 2nd ed. Boca Raton: CRC Press.

GHANBARZADEH, M., SOOFIANI, N. M., KEIVANY, Y., ASADOLLAH, S. & TAGHAVI-MOTLAGH, S. A. 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. *Iranian Scientific Fisheries Journal*, 21(4), 75-84.

GHANBARZADEH, M., SOOFIANI, N. M., KEIVANY, Y. & TAGHAVI-MOTLAGH, S. A. 2014. Use of otolith length and weight in age estimations of the kingsoldier bream, *Argyrops spinifer*, in the Persian Gulf. *Iranian Journal of Ichthyology*, 1(1), 1-6.

GHANBARZADEH, M., KEIVANY, Y. & SOOFIANI, N. M. 2017. Population dynamics of the sparid fish, *Argyrops spinifer* (Teleostei: Sparidae) in coastal waters of the Persian Gulf. *Iranian Journal of Science and Technology,* 41, 313-319.

GRANDCOURT, E. M., AL ABDESSALAAM, T. Z., FRANCIS, F. & AL SHAMSI, A. T. 2004. Biology and stock assessment of Sparids, *Acanthopagrus bifasciatus and Argyrops spinifer* (Forsskal, 1775), in the Southern Arabian Gulf. *Fisheries Research*, 69(1), 7-20.

GROSSMAN, G. D., COFFIN, R. & MOYLE, P. B. 1980. Feeding ecology of the *Bay goby* (Pisces: Gobidae). Effects of behavioural, onto-genetic and temporal variation on diet. *Journal of Experimental Marine Biology*, 44(1), 47-59.

HOSSUCU, B., KAYA, M. & TAŞKAVAK, E. 1999. An investigation of growth parameters and otolith-total length relationship of *Solea solea* (l., 1758) (Pisces: Soleidae) in İzmir Bay. *Israel Journal of Zoology*, 45, 277-287.

KEIVANY, Y. & DANESHVAR, E. 2016. Contribution to the knowledge of the feeding and growth biology of the Iranian cichlid, *Iranocichla hormuzensis*. *Zoology and Ecology*, 26(2), 104-109.

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. *Research in Zoology*, 2(3), 7-14.

KEIVANY, Y., ABASZADEH, A. & SOOFIANI, N. M. 2014. A study on some growth parameters and feeding characteristics of the Lizardfish, *Saurida tumbil*, from the Iranian Persian Gulf coast. *Khoramshahr Journal of Marine Sciences and Technology*, 13(3), 51-60.

KEIVANY, Y., GHORBANI, M. & PAYKAN-HEYRATI, F. 2017. Age and growth of *Alburnus mossulensis* (Cyprinidae) in Bibi-Sayyedan River of Isfahan Province. *Iranian Journal of Fisheries Sciences*, 16(4), 1164-1177.

KEIVANY, Y., MORTAZAVI, S. S. & FARHADIAN, O. 2018. Age and growth of brond-snout, *Chondrostoma regium* in Beheshtabad River of Chaharmahal & Bakhtiari Province of Iran (Teleostei: Cyprinidae). *Iranian Journal of Ichthyology*, 5(1), 30-42.

KIANI, F., KEIVANY, Y. & PAYKAN-HEYRATI, F. 2016. Age and growth of king nase, *Condrostoma regium* (Cyprinidae), from Bibi-Sayyedan River of Semirom, Isfahan, Iran. *Iranian Journal of Fisheries Sciences*, 15(3), 1214-1223.

KING, M. 2007. *Fisheries biology, assessment and management*. 2nd ed. Oxford: Blackwell Publishing Ltd.

MOGHDANI, S., PAZIRA, A. R. & ZADEH, N. J. 2014. Effects of oil contamination on nickel concentration in muscle tissues of *Brachirus orientalis* in Persian Gulf waters. *Journal of Biodiversity and Environmental Sciences*, 4(1), 141-148.

MOHAMMADI, G. & KHODADADI, M. 2008. Estimating growth, mortality and exploitation index of round sole (*Euryglossa orientalis*) in northwestern Persian Gulf. *Iranian Scientific Fisheries Journal*, 7, 1-10.

NASRI, T. M. & TAATI, R. 2010. Length-weight relationship in large-scale tongue sole (Cynoglossus arel) in the northern coasts of the Persian Gulf. *Journal of Marine Biology*, 2(6), 87-91.

PAJUELO, J. G. & LORENZO, J. M. 2002. Growth and age estimation of *Diplodus sargus* cadenati (Sparidae) off Canary Island. *Fisheries Research*, 59(1-2), 93-100.

PAULY, D. 1984. Fish population dynamics in tropical waters: a manual use with programmable calculators, International Center for Living Aquatic Resources Management. *ICLARM Studies and Reviews*, 8, 325-339.

PAULY, D. & MUNRO, J. L. 1984. Once more on the comparison of growth in fish and invertebrates. *ICLARM Fishbyte,* 2(1), 1-21.

RANDALL, J. E. & HOOVER J. P. 1995. *Coastal fishes of Oman*. Hawaii: University of Hawaii Press.

RICKER, W. E., 1973. Linear regressions in fishery research. *Journal of the Fisheries Board of Canada*, 30(3), 409-434.

ROSS, S. W. 1988. Age, growth and mortality of Atlantic croker in North Carolina, with comments on population dynamics. Journal of the American Fisheries Society. *American Fisheries Society*, 117, 461-473

SPARRE, P., URSIN, E. & VENEMA, S. C. 1989. *Introduction to tropical fish stock assessment. Part 2. Manual*. Rome: FAO Fisheries Technical Paper.

TAYLOR, C. C. 1958. Cod growth and temperature. *ICES Journal of Marine Science*, 23(3), 366-370.

TÜRKMEN, M. 2003. Investigation of some population parameters of common sole, *Solea solea* (L., 1758) from Üskenderun Bay. *Turkish Journal of Veterinary and Animal Sciences*, 27(2), 317-323.

VON BERTALANFFY, L. 1938. A quantitative theory of organic growth (inquiries on growth laws II). *Human Biology*, 10, 181-213.

WEATHERLEY, H. & GILL, H. S. 1987. *The biology of fish growth*. London: Academic Press.

WOOTTON, R. J. 1998. *Ecology of teleost fishes*. Dordrecht: Kluwer Academic Publications.

YASEMI, M., KEYVAN, A., VOSOUGHI, G. H., AHMADI, M., GOHAR, M. F., FATEMI, M. R. & MAHIANEH, A. A. H. 2007. Identification of the species of Pleuronectiformes order inhabiting in the Persian Gulf coastline area Bushehr province regarding morphometrics and meristics characteristics (parameters). *Pajouhesh and Sazandegi*, 20(376), 20-28.