Estimation of growth parameters and mortality rate of *Upeneus sulphureus* (Cuvier, 1829) in the Persian Gulf ecosystem

Vahabnezhad A.[1*]; Taghavimotlagh S.A.[1]; Salarpouri A.[2]

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Abstract

Population parameters were estimated for goatfish *(Upeneus sulphureus,* Cuvier, 1829) as a small size and abundant species in the Persian Gulf ecosystem. A method of Tropfish R package based on length frequencies analysis was used. A total of 520 fish samples were taken monthly from landing stations in the coastal area of Iranian Waters in the Persian Gulf (Bushehr coasts) from January 2017 to December 2018. The length (FL) of the captured fishes varied from 8.5 to 17 cm with an average (±SD) of 11.20 (±2.24) cm.

The values of the von Bertalanffy growth function fit length frequency data for *U. sulphureus* (combined sex) were estimated, as k = 1.2 per year, $L\infty$ =19.43 cm (*L*F). Total, natural and fishing mortality calculated, as Z=3.74 per year, M=2.21 per year and F=1.53 per year, respectively. The exploitation ratio (E) was estimated at 0.4.

The length-weight relationships of both sexes was estimated as, Log M_B = -1.707+3.00 log L_F (r = 0.92) which exhibited positive isometric growth. According to results, it could be concluded that goatfish (*Upeneus sulphreus)* is a relatively fast-growing and short-lived species. Although this species is not a direct target of fishermen, its ecological role in the Persian Gulf's food web due to their high abundance and high growth rate is undeniable.

Keywords: Growth, mortality rate, *Upeneus sulphureus*, Persian Gulf

1- Iranian Fisheries Science Research Institute (IFSRI), Agricultural Research Education and Extension Organization (AREEO), Tehran, Iran.

2- Persian Gulf and Oman Sea Ecological Research Center, Iranian Fisheries Science Research Institute, Agricultural Research, Education and Extension Organization, Bandar Abbas, Iran.

*Corresponding author e-mail: avn9400@gmail.com.

Introduction

Upeneus sulphureus (Mullidae family) is an endemic, small-sized fish which very abundant in the Persian Gulf ecosystem and commonly known as 'goatfish'. This species are distributed worldwide in tropical, subtropical and temperate waters (Lewis and Pring, 1986).Goatfishes distributed in a wide range of habitats and are associated to the bottom of the littoral, but some species of the Upeneus could be seen in deeper areas (Randall, 2004). All species of family Mullidae are benthic carnivores that 18 species of them have been detected in the Persian Gulf and Oman Sea and constitute one of the most important component of fish bycatch in the region (Kamrani and Daliri, 2018).

More than 90% of Iranian fishing in the Persian Gulf and Oman Sea comes from small scale fisheries (Shahifar, 2018). According to a study conducted by Hoveizavi *et al.* (2016), although the amount of fish bycatch landed by each vessel in the northwest of the Persian Gulf was low, but the high number of fishing vessels operating in this part of the Persian Gulf cause the high number of total fish bycatch , The study conducted by Eskandari *et al.* (2016) in the northwest of the Persian Gulf, showed that the highest amount of bycatch species in terms of weight per unit of effort were Belonging to *U. sulphureus* (18.41%) and the lowest value were belonging to Apogon family (0.03%). According to various studies, the ecological role of Goatfish in the food chain of the Persian Gulf is very important. Based on the Vahabnezhad (2015), most of the stomach contents of predatory fishes, like *Argyrops spinifer, Pomadasys kaakan and Trichiurus lepturus, Nemiopterus joponicus* and *Saurida tumbile,* consist of Goatfish species.

Additionally, Taghavi Motlagh (2019) pointed out that the composition of the catches in the coastal area of the Persian Gulf and Oman Sea are changed from high-value species to lower value species during the past two decades which might be attributed to overexploitation of high-value species with higher mean trophic level. Also, the results of fish survey (swept area method) in the Persian Gulf and Oman Sea revealed that the CPUA for Mullidae family had increased from 585 tons in 2003 to 5926.2 tons in 2018 (90 percent increase) (Valinassab *et al*., 2019).

Many studies have been conducted on biology and population dynamics of goatfish in different marine regions of the world, but despite a relatively high abundance of this species in the Persian Gulf and Oman Sea, no studies have been carried out on this species in Iranian part of these two ecosystems. In the northern Persian Gulf, Iraqi waters, Mohamed and Saleh (2000) have been studied some aspects of the biology of goatfish.; Federizon (1993) in Philippines waters, Mohamed *et al.* (2004); Silvestre and Garces (2004); İşmen (2005); Mutlak and Mohamed (2006); Yousif *et al.* (2007); Mohamed and Resen (2010); Gumanao *et al*.

(2016); and Kochi (2017) in the Indian ocean.

Length frequency data were used to estimate the population parameters to fill the information gap on this species. As the goatfish is an abundant fish species in the Persian Gulf, the results of the present study could be used for further ecological analysis of its role in food web structure of the Persian Gulf.

Material and methods

The samples of *U. sulphureus* were collected from January 2017 to December 2018 (monthly) from Persian Gulf around Bushehr coast by weir locally named Gagoor and gill nets. (Fig. 1). Totally, the fork length of 520 individuals were measured randomly during seven months to estimate the size distribution, growth parameters, and mortality rates. During sampling events, the fork length (L_F, 1 cm), body weight (B_W, 0.1g) were measured.

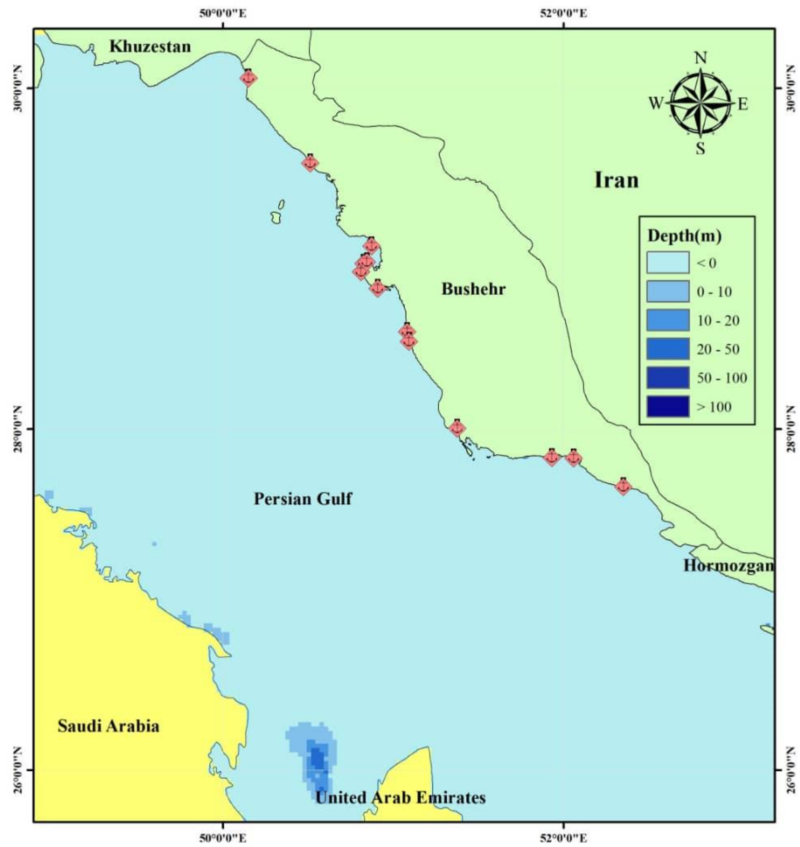

Figure 1: Map of the Persian Gulf showing fish landing sites along coasts (red dots).

Growth parameter

TropFishR (Mildenberger *et al*., 2017) , an R package ver. 3.5.1 for tropical fisheries analysis, was used to estimate growth and mortality parameters. TropFishR has enhanced functions of the FAO-ICLARM Stock Assessment Tools II FISAT II (Gayanilo *et al*., 2005b). Monthly length-frequency data of the *U. sulphureus*, classified into 11 length classes of 0.5 intervals, were obtained from lfq Create function.

The bootstrapped ELEFAN with Simulated annealing (ELEFAN_SA) function (Mildenberger *et al*., 2017) was used for estimation of parameters L∞ and K of the von Bertalanffy equation. The simulated annealing algorithm begins with a highly randomized search, which gradually focuses on regions of the parameter search space with the highest Rn scores.

Growth was modeled based on von Bertalanffy growth function (VBGF) (Sparre and Venema, 1992):

$$L_t = L_\infty \left(1 - \exp^{[-K(t-t0) + S(t) - S(t0)}\right)$$

Where Lt is length-at-age t, L∞ is asymptotic length, K is the von Bertalanffy growth constant, and t_0 is the theoretical age when length equals zero. Usually t_0 is negative, resulting in a positive length at the time of recruitment (t = 0). $S(t)=(CK/2\pi)\sin 2\pi(t-ts)$, C is a constant indicating the amplitude of the oscillation, typically ranging from 0 to 1 (avalue >1 implies periods of shrinkage, which is rare), and ts is the fraction of a year (relative to the age of recruitment, t=0) where the sine wave oscillation begins (i.e. turns positive). In TropFishR, these additional oscillation parameters are written as C and ts. A seasonally oscillating VBGF was used to assess the growth parameters, which are attributed to changes in water temperature, precipitation and/or to the availability of food (Morales-Nin and Panfili, 2005).

The L∞ and K were used to calculate the growth performance index (Ø') = logK + 2logL∞ (Pauly and Munro, 1984).

The parameter t anchor indicates the fraction of the year where yearly repeating growth curves cross length equal to zero. T_{max} derived from Pauly *et al*. (1996) formula: T_{max}=3/K+t0.

Mortality and exploitation rate

The instantaneous total mortality coefficient (Z) was estimated using Powell-Wetherall method ($\bar{L}$)= a +b$\bar{L}$), where Lbar is the mean length and L' is the lowest length class of the collected samples, from which Z/K could be calculated from Z/K= -1-b/b. equation. This method allows estimation of L∞ and Z/K from a sample representing a steady-state population, as can be approximated by pooling a time series of length-frequency data (Pauly, 1990). The rate of natural mortality (M) was estimated according to the empirical equation as "Pauly_Linf" function (Pauly, 1990):

$$\mathrm{Log10\,(M)} = -0.0066 - 0.276\,\mathrm{log10\,(L\infty)} + 0.6543\,\mathrm{log10\,(K)} + 0.4634\,\mathrm{log10\,(T)}$$

Where T is the annual mean of sea surface temperature (*i.e.*, 26.5°C in the Persian Gulf (Ebrahimi *et al*., 2005)). Following the calculation of Z and M, fishing mortality (F) estimated using the functions; $F = Z - M$ and exploration rate (E) estimated using F/Z function (Sparre and Venema, 1992).

Length-weight relationship

The relationship between length and body mass for both sex was calculated using: $M_B = aL_F{}^b$, where a is scaling constant and b is allometric growth parameter (Hayes *et al*., 1995).

Using the linear regression of the log-transformed equation: log (M_B) = log (a) + b log (L_F), the parameters a and b were calculated with 'a' representing the intercept and 'b' the slope of the relationship. The significant difference of b values from the isometric threshold, *i.e.*, 3, was tested by the t-test (Pauly 1984).

Result

Growth parameters

Mean fork length (± SD) of the goatfish in the Persian Gulf over the study period was recorded 11.20 ± 2.24 cm. The weight of fish samples was (N= 520) varied between 11.73 to 91.89 g with the average of 29.19 ± 10.88 g.

Figure 2 showed restructure of length-frequency histogram of *U. sulphureus* in the Persian Gulf. The following plot shows reconstructed frequencies, with negative and positive values as white and black colored histograms, respectively. The sum of the positive peaks were indicated with black bars (ASP) equal to 0.16. Three age groups (cohorts) were observed, the smallest one was in December 9-12 cm (MA = 7).

Figure 3 indicates seasonal oscillations of the growth rate. The parameter c, the "amplitude", takes value between 0 and 1. When inserting parameter c equal to 0 (c=0), the seasonality oscillations didn't appear in the von bertalanffy growth rate, but when c equal 1 (c=1), used the seasonal oscillations more pronounced, and growth rate appear to be zero (curve is horizontal) at the winter points (t_w) in 0.7 and 1.7 year.

The results of the Simulated annealing (ELEFAN_SA) analysis provided the best fit of growth model as, L_∞= 19.43 cm and K = 1.2 per year (Table 1 and Fig. 4). The values of t_0 and φ' were estimated as -0.15 year, and 2.65, respectively. Ageing analysis showed that the lifespan of goatfish in this area may reach 2.35 years.

Mortality rate

The natural mortality (M) estimated by Pauly's method, as 2.21 yr^{-1}. The annual rate of total mortality (Z) was derived from Power-Wetheral method as 3.74 $year^1$ (Fig. 5).

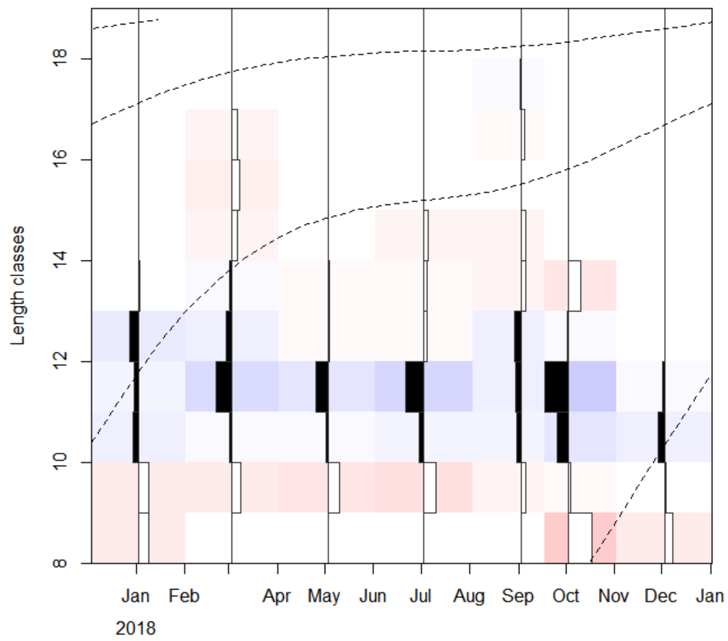

Figure 2: Restructure of length-frequency histogram of *U. sulphureus* in the Persian Gulf (2017-2018), the black and white bars are positive and negative deviations from the 'weighted' moving average.

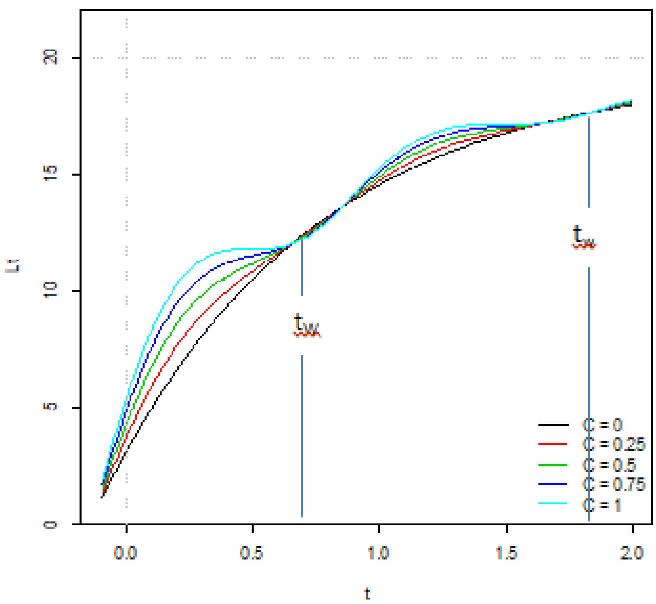

Figure 3: The seasonlaized von Bertalanffy growth of *U. sulphureus*. Note for c=1 (blue line) the growth rate is zero at the winter points.

Table1: Summary of ELEFAN_SA analysis for *u. sulphureus*

Asymptotic length (L_∞)	Growth rate (K)	t_anchor	Phil	Rn_max
19.43	1.2	0.14	2.47	0.52

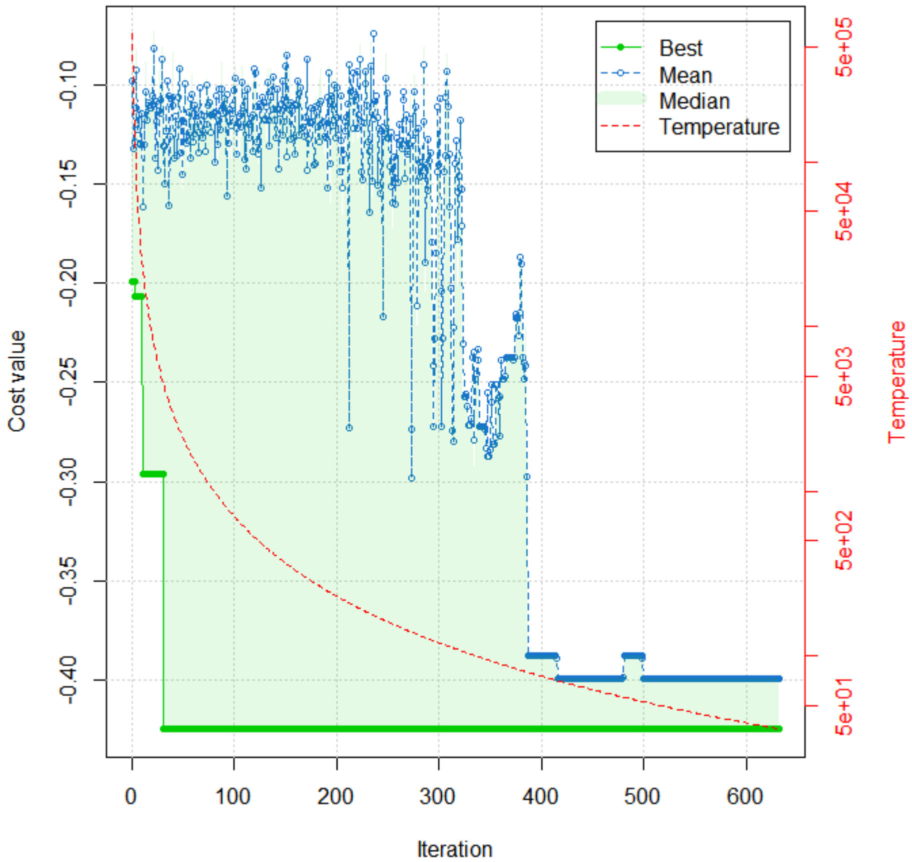

Figure 4: Refined searches using optimization algorithms with ELEFAN_SA analysis.

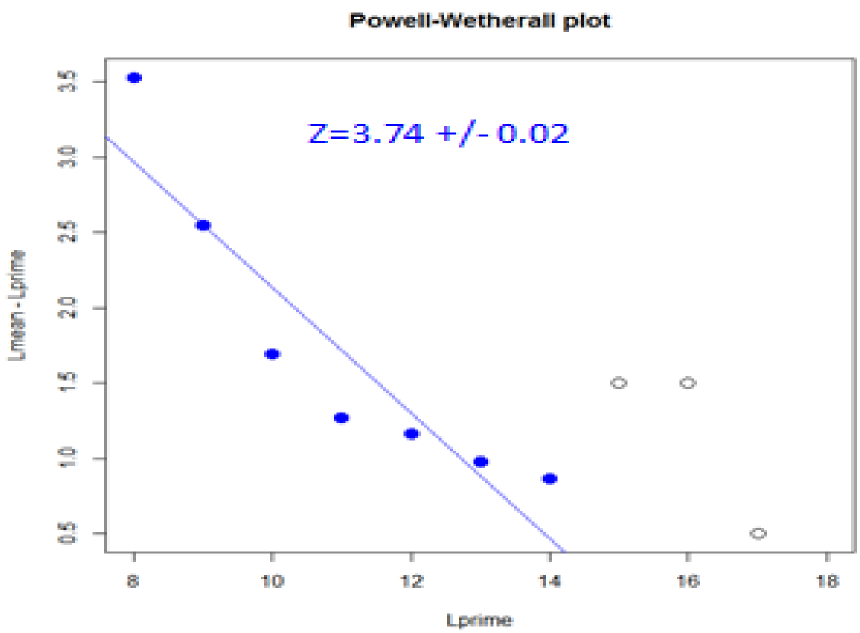

Figure 5: Estimation of total mortality using Powell-Wetherall method for *U. sulphureus.*

Using the value of Z and M, fishing mortality were calculated 1.53 year^{-1}. The exploitation ratio (E) was estimated as 0.4.

Length-weight relationship

The length-weight relationship and correlation coefficient (r) for both together presented in (Fig. 6).

The value of 'a' and 'b' were -1.707 and 3.00 respectively for both sex. The b value was not significantly different from 3 (t-test; p>0.05). The equation of the length-weight relationships were stated below:

$$\text{Log } M_B = -1.707+3.00 \log L_F \ (r = 0.92)$$

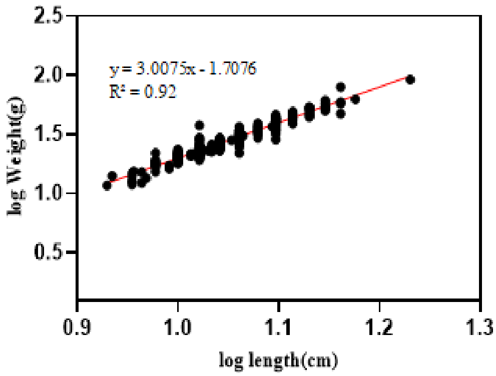

Figure 6: Length-weight relationship of *U. sulphureus* in the Persian Gulf.

Discussion

In the present study Length measurement has been used to estimate the key parameters of stock assessment and its population parameters like asymptotic length (L∞), growth coefficient (K), total mortality (Z), natural mortality (M) and fishing mortality (F). Length frequency data provide unique and valuable information for modeling growth (Laslett *et al*., 2004). In this study, length frequency data of goatfish in the Persian Gulf (Bushehr coastal water) were used to depict its growth model. The present study revealed that the highest growth oscillation occurred in January, with two peaks that each peak represents an age group. This could be due to active feeding before spawning time (January–March) according to Akter *et al*. (2020) reports. the von bertalanffy curve which does not reveal the oscillation of the growth, The oscillation curve shows the point where the growth of the fish is stop, which in the present study, showed that according to oscillation curve when we use c=1 it shows that growth of goatfish stop in age 0.7 and 1.7 years. The highest frequency was observed for length interval of 11-12 cm.

K is a curvature parameter that represents how fast the fish approaches its L∞. Based on calculated K (1.2 per year), goatfish could be classified as short-lived species which reaches L_{max} (18.50 cm) after 2 years. Table 2, present the comparison of the von Bertalanffy growth parameter estimated in the present study with previous investigations, which shows variability of growth parameters of Goatfish in different regions which could be attributed to various ecological condition of each ecosystem (Sparre and Venema, 1992).

Table 2: Growth parameters of *U. sulphureus* in various areas.

Reference	Linf	K	t_0	b	a	Ǿ	M	Area
Present study	19.43	1.2	-0.15	3.00	0.01963	2.65	2.21	Persian Gulf
(Rajkumar, 2004)	24.5	0.67	-0.14	-	-	2.60	4.06	Visakhapatnam
(Gumanao *et al*., 2016)	23.5	1.30	-	3.68	0.00550	2.85	-	Philippines
(Silvestre and Garces, 2004)	17	0.85	-	3.035	0.820	2.39	2.21	Philippines
(Kochi, 2017)	20.2	0.97	-	-	-	2.60	-	India
(Loychuen, 2010)	21.5	1.01	-	-	-	2.67	-	Thailand
(Chan and Liew, 1986)	23.0	1.01	-	-	-	2.76	-	Malaysia
(Federizon, 1993)	-	-	-	3	0.01930	-	-	Philippines
(Mohamed and Resen, 2010)	18.82	0.75	-	3.01	0.0621	2.36	1.85	Northwest Persian Gulf
(Prayitno *et al*., 2020)	-	-	-	3.12	0.0159	-	-	Java Sea

The value of growth performance index (Ǿ) (2.65) in the present study was similar to many previously published reports in Fish Base (Table 2). According to Gayanilo *et al.* (2005b), the growth performance index (Ǿ) is a species-specific parameter, i.e. its values are usually similar within related taxa and have small distributions. growth dissimilarity of Ǿ for a number of stocks of the same species or related species is an indication of the unreliability in the accuracy of estimated growth parameters .It must be realized however, that Ǿ can be used only to compare the growth performance of fish with similar shapes (Gayanilo *et al*., 2005a). Preliminary analyses of Moreau *et al.* (1986) suggest that the C.V. of Ǿ for several stocks of the same species should not exceed 5 percent, which may provide some guideline that values of Ǿ are credible or not (Gayanilo and Pauly, 1997). The coefficient of variation of 6.41% together with other measures of dispersion (range = 0.49, variance = 0.03, standard deviation = 0.16 and mean = 2.61) for Ǿ values presented in Table 2.

The b value of length-weight relationship for *U. sulphureus* was similar to those reported by other authors; like Mohamed and Resen (2010) and Federizon (1993).

The instantaneous rates of total (Z) natural (M) and fishing mortalities were 3.74, 2.21 and 1.53 year^{-1}, respectively. The value of natural mortality to growth coefficient (M/K) of *U. sulphureus* in the present study was 1.84. Beverton and Holt (1957) pointed out that the value of M/K is ranging from 1.5 to 2.5 and the best value is equal to 2.0. Any deviation from this value, the fish will be vulnerable and exposed to high natural mortality before reaching to a certain age (Gayanilo and Pauly, 1997).

The ratio of F/Z or exploitation ratio is a measure of the intensity by which a fish stock is exploited. The exploitation ratio (E) for this species in the Persian Gulf ecosystem was estimated to be 0.40, which was less than the optimum value of 0.50 suggested by Gulland (1971).The values of F and E obtained for *U. sulphureus* in the present study was similar to those reported by Mohamed and Resen (2010) in the Persian Gulf, whereas higher natural mortality rate was estimated by present study.

According to results of the Swept area surveys project, the abundance of Mullidae stock increased 90 % in past two decades in the Persian Gulf and the Oman Sea (Valinassab *et al*., 2019) which shows that the population of small-demersal fish species are become more abundant, which could be attributed to overexploitation of top predator in this area.

As many of the small demersal species in the bottom-trawl surveys in the Persian Gulf and Oman Sea was not recorded during survey period to see the abundance variation of these species group, therefore it is suggested to record the abundance and catch per unit area of all small demersal fish species, to quantify and trace the fluctuations of the abundance of this species in this region could draw out indicators to figure out the changes occurred in this ecosystem (Ouellet *et al*., 2016).

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