

Changes in length-weight relationship and condition factor of Talang queenfish (*Scomberoides commersonnianus*) in the north-west Persian Gulf

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Abstract

The present study, which was conducted on *Scomberoides commersonnianus* as one of the commercially important fishes of Carangidae, seeks to investigate changes of length-weight relationships in different sexes, seasons and length classes and to calculate condition factor of Talang queenfish. In this study, 563 specimens (292 males, 247 females, and 24 of unknown sex) were collected from the north-west of the Persian Gulf from Oct. 2011 to Jan. 2013. Length-weight relationships and condition factor were determined for each sex in four length classes within different seasons. In general, the growth pattern in this fish was negatively allometric and the length-weight relationship in combined sexes amounted to $W=2.9109FL^{-1.8424}$. The growth pattern of combined sexes was negatively allometric in spring and autumn and isometric in summer and winter. Also, growth pattern was positively allometric in 8-31 class, negatively allometric in the 31-54 cm and 54-77 cm classes and isometric in the 77-100 cm class among all specimens. Also, the condition factor in males exceeded that of females in spring, autumn and winter; however, it was greater in females than in males during summer. In this season, females were in better condition owing to an increase in the weight of ovaries. The results demonstrate that growth pattern and condition factor vary in different seasons, lengths and sexes probably because of change in feeding intensity and the time of reproduction.

Keywords: *Scomberoides commersonnianus*, Length-weight relationship, Condition factor, Persian Gulf

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Introduction

The family Carangidae, which is represented by 50 species (Valinassab, 2013) is a dominant finfish group found in the Persian Gulf and the Oman Sea. The term “queenfish”, a common name for *Scomberoides* as a genus in this family, refers to a group of tropical pelagic fish species which are widely distributed throughout the Indo-West Pacific and inhabit estuaries and reefs both inshore and offshore (Griffiths *et al.*, 2005). This group consists of four species: Talang or giant queenfish (*Scomberoides commersonianus*), lesser queenfish (*Scomberoides lysan*), barred queenfish (*Scomberoides tala*), and needle skin queenfish (*Scomberoides tol*). These species constitute an ecologically significant part of the ecosystem in coastal and tropical areas. Talang or giant queenfish, the largest of the four species named above, are one of the most ecologically important components forming tropical inshore ecosystems, especially the estuaries, primarily because of their relatively large size, high biomass and predatory nature (Griffiths *et al.*, 2005).

S. commersonianus (Talang queenfish) grows to a maximum size of 120 cm TL (Smith-Vaniz, 1984) and 16 kg (International Game Fish Association, 2001). They are mostly found on banks and shelf slope habitats at depths of 80-200 m throughout much of its range, but in some regions juveniles and sometimes adults may also frequent the shoreline (Fischer and Bianchi, 1984). Talang queenfish are

voracious predators which consume a range of prey items, but the most dominant (in terms of biomass) include teleosts (90%), crustacean (5%) and cephalopods (3%) (Griffiths *et al.*, 2005).

The study of length-weight relationships serves a crucial role in fishery biological investigations. Length-weight relationship can be used to find the variations in expected weight from the known length groups, which are indicative of fatness, the estimation of standing-crop biomass when the length frequency distribution is known (Pettrakis and Stergiou, 1995), the conversion of growth-in-length equations to growth-in-weight for prediction of weight-at-age and for use in stock assessment models, the calculation of condition factor, (Zafar, 2003; Froese, 2006) and morphological comparison between populations of the same or various fish species (Kulbicki *et al.*, 1993), breeding and feeding state and their suitability to the environment (Saha *et al.*, 2009). New research has shown that the determination of length-weight relationships and the calculation of condition factor appear to be helpful in the management of fisheries and in research about fish population dynamics (Asadi *et al.*, 2017).

The condition factor which shows the degree of well-being of the fish in their habitat is expressed by ‘coefficient of condition’ also known as length-weight factor. This factor is a measure of various ecological and biological factors such as degree of fitness, gonad

development and the suitability of the environment with regard to the feeding condition (Mac Gregor, 1959).

The biological characteristics of *S. commersonianus* have been described in several different studies. Griffiths *et al.* (2005) investigated the age, growth and reproduction of this fish in northern Australia. Taghavi Motlagh *et al.* (2005) examined its growth parameters and mortality rate in the southeastern coastal waters of Iran. Mbaru *et al.* (2010) studied the length–weight relationship of 39 selected reef fishes, including this fish, in the Kenyan coasts. Panhwar *et al.* (2014) conducted research on stock estimates of this species from the Arabian Sea coast of Pakistan. Masoomizadeh *et al.* (2014) investigated food composition and the effects of season, sex, maturity and length on gastro-somatic index of queenfish in the northwest of Persian Gulf (Khuzestan waters).

Due to the fact that the calculation of length-weight relationships is really important and no studies have been conducted as to the patterns of growth and length-weight relationships in *S. commersonianus* in the south-west coast of the Persian Gulf, this study deals with the analysis of length-weight relationships in this type of fish in various size classes and different seasons among both sexes.

Materials and methods

In the present study, sampling from landing centers in the North-west Persian Gulf lasted for 15 months (from Oct. 2011 to Jan. 2013) and 563

specimens were collected. Queenfish were captured using hook, trawl and net (Fig. 1).

After the collection of specimens, they were transported to the shore and then to a laboratory in ice powder and kept in a freezer (Almeida, 2003; Hajisamaea *et al.*, 2003; Griffiths *et al.*, 2005) for laboratory tests. The weight and length of the fish were measured up to the nearest 0.1 g and 1 mm, respectively in the laboratory after defrosting. Afterwards, the specimens were cut on the ventral part and their sexes were determined.

The length-weight relationship was estimated through the equation: $W=aL^b$, where W =weight, L =forked length, a and b =intercept and slope, respectively. The data were converted on natural log to fit linear or straight line of log length and log weight. The equation can be demonstrated logarithmically as $\text{Log } W = \log a + b \log L$ (King, 1995). Coefficient of determination (R^2) was adopted in order to determine the strength of the relationship in the linear regression.

Deviation of the estimated ' b ' value from the isometric value of 3 was tested using t test:

$$t = \frac{sd \log L}{sd \log W} \cdot \frac{|b-3|}{\sqrt{1-r^2}} \cdot \sqrt{n-2}$$

Where $sd \log L$ is the standard deviation of the log Forked Length values, and $sd \log W$ is the standard deviation of the log W values, n being the number of fish used in the computation. The value b is different

from 3 if t is greater than the table value of t for $n - 2$ df (Pauly, 1983).

“Fulton’s coefficient of conditions” or simply the condition factor (K) is used to investigate the seasonal and habitat differences in condition. For an allometrically growing species, the condition factor (K) was computed from the equation: $K=W/L^b \times 100$ (Venkataramanujam and Ramanathan, 1994).

Where W =mean weight (Total weight-viscera weight) (g), L =mean length in cm (Forked length), b =an exponent, and K =the condition factor.

The regression of log weight on log length, growth pattern and K were calculated independently for male, female and combined sexes and then calculated for seasons and different sizes for males, females and total fishes.

LM_{50} was calculated for the mature fish in order to estimate the changes in the length-weight relationship and condition factor before and after maturity.

The mean length at first reproduction or mean length at sexual maturity (L_m) may be defined as the length at which 50% of all individuals are sexually matured, e.g. the length at which 50% of all females mature, or the length at which 50% of all females have ovaries in an advanced stage of development. The $L_{m50\%}$ was estimated by using the following formula (King, 1995) and least square method (Solver Tools in Microsoft Excel ver. 2010).

$$P = L/[1+\exp(-rm(L-L_{m50}))]$$

Where, rm is the slope of curve, L_m is the mean fork length (mm) at sexual maturity, L is mean carapace width (mm) and P is probability of presence mature fishes.

Results

In this study, the maximum total length and fork length were 107.2 cm and 96.9 cm and their minima measured 9.4 and 8.6, respectively. The maximum weight was 10380.0 g. and the minimum equaled 4.9. In the whole sample, 292 specimens were male, 247 were female and 24 were unknown in sex.

The monthly means of fork lengths are shown in Fig. 2. The mean fork-length measured was less than 35 cm between November and March, but it increased considerably in April and reached 63 cm in January. It demonstrated a decline in August and another rise in September. However from October onward, it decreased gradually. In fact, the mean fork-length increased in the warm season and decreased in the cold season. Because fish with shorter lengths were caught in August, the mean fork-length in this month was lower than that of other warm months

Kolmogorov-Smirnov test was used to assess the normality of length and weight data.



Figure 1: Sampling locations of *Scomberoides commersonnianus* in the north-western coasts of Persian Gulf.

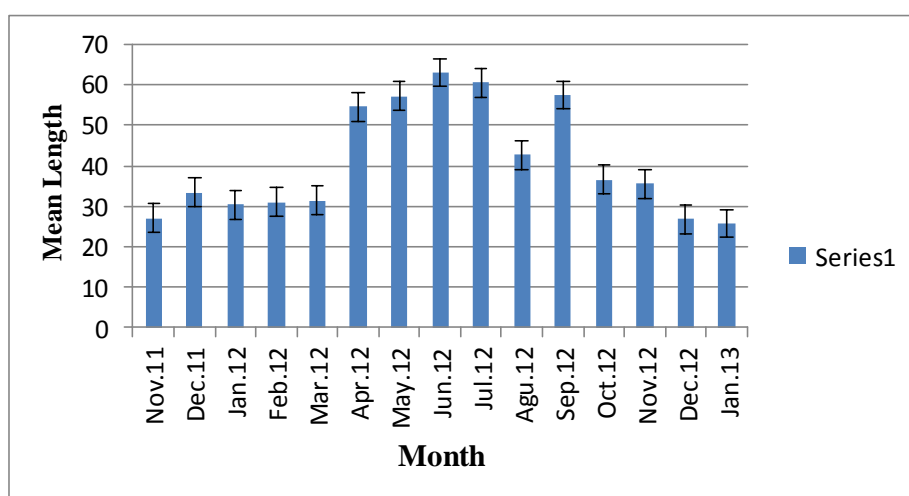


Figure 2: Monthly mean fork length (\pm S.D) distribution of *Scomberoides commersonnianus* in the north-west Persian Gulf.

As the data were not normal, the Mann-Whitney U test was adopted which indicated significant differences in length and weight of fish between the cold and warm seasons.

(Length: Mann-Whitney U= 9194.000, Sig= 0.000, Z= -15.564).

Mean FL warm season \pm S.E= 57.1 \pm 1.16

Mean FL cold season \pm S.E= 31.2 \pm 0.46

(Weight: Mann-Whitney U=9516.000,

Sig= 0.000, Z= -15.396).

Mean weight in warm season \pm S.E=

1649.66 \pm 105.17

Mean weight cold season \pm S.E=

499.34 \pm 28.04

On the basis of the maximum and minimum fork lengths, 13 length classes were included.

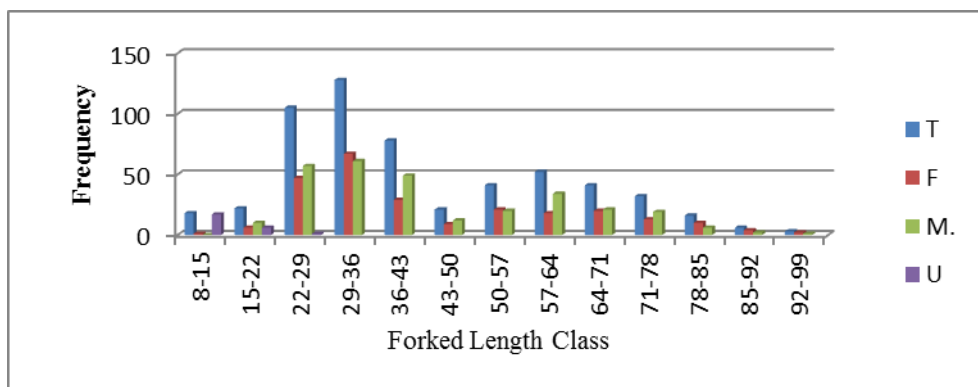


Figure 3: Frequency of fork length Class of *Scomberoides commersonianus*. T: Total number, F: Female number, M: Male number, U: Unknown number.

The frequency of each class for males, females, unknown sex and combined cases is shown in Fig. 3.

In the first three length classes, i.e. below 29 cm, the fish were of unknown sex. The fish with unknown sex were more frequent in lengths less than 15 cm. As the length increased and the gonads became clearer, it was easier to determine sex. Male and female fish were observed in all length classes. The maximum length frequency was found in the range between 22 and 43 cm. Due to the large number of length classes and the small number of specimens in some classes, the 13 length classes in Fig. 3 were reduced to 4 in order to show the differences between classes in a better way. The length-weight relationship in these four classes is shown in Table 1.

Length at first maturity

Length at first maturity or size at maturity of total fishes is 55.3 cm as shown in Fig. 4.

The maturity length of all the fish (55.3 cm) was calculated through Solver

method. Fig. 4 shows that all the fish beyond 70 cm are mature.

The comparison of mean length ($\pm S.E$), mean weight ($\pm S.E$) and condition factor ($\pm S.D.$) between males and females in each length class

The 8-31 cm length class: The mean lengths of males (26.1 ± 2.08) and females (26.6 ± 2.11) were the same and the mean weight of the females (222.2 ± 164.87) was slightly more than that of the males (214.8 ± 158.74). The condition factor (0.7795 ± 0.05) in males was more than that of females (0.7085 ± 0.15).

The 31-54 cm length class: The mean length of males (38.2 ± 1.71) and females (38.1 ± 1.87) were the same and the mean weight of the females (643.9) was slightly more than that of the males (624.7). The male condition factor (2.0234 ± 0.42) was greater than that of the females (1.2595 ± 0.29). Hence, the males were in a better condition than the females.

Table 1: Length- weight relationship and condition factor of *Scomberoides commersonnianus* in the north-west of the Persian Gulf at different lengths, FL: Fork length, SE: standard error, SD: standard deviation, Reg. R.: Regression relationship, R²: Coefficient of regression, K: Condition factor, C.t: Calculated t-test, t S: t-student, G.P: Growth pattern, F: Female, M: Male, U: Unknown, I: isometry, A⁺: Positive allometry, A⁻: Negative allometry.

Length	Sex	No.	Mean FL (cm)	SD FL	SE FL	Mean W (g)	SD Wei.	SE Wei.	Reg. R.	R ²	K	C.t	t S	p value	G. P
8-31	F	75	26.6	±18.39	±2.11	222.27	±1427.83	±164.87	Y=3.1286x - 2.135	0.9633	0.7085	1.908	2.000	p>0.05	I
	M	81	26.1	±18.72	±2.08	214.83	±1428.71	±158.74	Y=3.1011x - 2.087	0.8661	0.7795	0.823	2.000	p>0.05	I
	F+M	156	26.3	±18.38	±1.47	218.40	±1427.11	±114.26	Y=3.1031x - 2.0935	0.9148	0.7717	1.465	1.984	p>0.05	I
	F+M+U	180	24.6	±18.41	±1.37	193.14	±1426.73	±106.34	Y=3.1691x - 2.1905	0.9788	0.6863	5.192	1.984	p<0.05	A ⁺
31-54	F	94	38.1	±18.21	±1.87	643.94	±1470.77	±151.69	Y=2.9346x - 4.3158	0.9644	1.2595	1.135	1.990	p>0.05	I
	M	114	38.2	±18.28	±1.71	624.75	±1477.04	±138.33	Y=2.8967x - 1.67.57	0.9262	2.0234	2.572	1.984	p<0.05	A ⁻
	F+M	208	38.2	±18.21	±1.26	633.42	±1470.77	±101.98	Y=2.8741x - 1.7806	0.9464	1.5769	2.665	1.984	p<0.05	A ⁻
	F+M+U	215	38.0	±18.21	±1.24	626.15	±1470.77	±100.30	Y=2.882x - 1.7939	0.9473	1.5313	2.562	1.984	p<0.05	A ⁻
54-77	F	57	64.2	±18.08	±2.39	2727.53	±1577.98	±209.00	Y=2.9044x - 1.8272	0.8848	1.3783	0.695	2.021	p>0.05	I
	M	80	64.0	±18.00	±2.01	2552.17	±1564.64	±174.93	Y=2.6563x - 1.4022	0.8420	3.7747	2.539	2.000	p<0.05	A ⁻
	F+M	137	64.1	±18.08	±1.54	2625.13	±1577.98	±134.81	Y=2.7643x - 1.5876	0.8524	2.4149	2.374	1.984	p<0.05	A ⁻
77-100	F	18	83.9	±22.30	±5.25	5692.94	±1818.43	±428.61	Y=3.1636x - 2.3409	0.7800	0.4215	0.472	2.120	p>0.05	I
	M	13	81.8	±20.25	±5.61	5120.80	±1660.62	±460.57	Y=3.307x - 2.6249	0.9328	0.2133	1.326	2.201	p>0.05	I
	F+M	31	83.0	±20.25	±3.63	5453.01	±1660.62	±298.25	Y=3.2435x - 2.4983	0.8362	0.2904	1.094	2.045	p>0.05	I

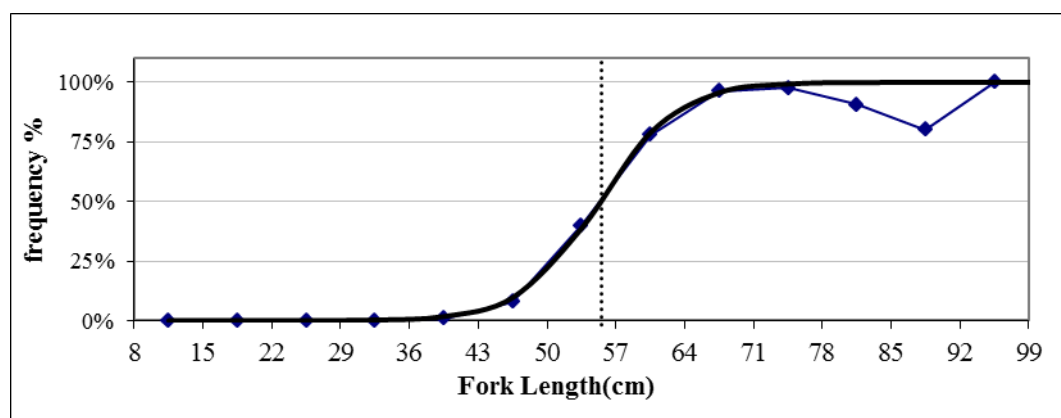


Figure 4: Size at maturity of *Scomberoides commersonnianus* in the North-west Persian Gulf.

The 54-77 cm length class: The mean length of males (64.0± 2.01) and females (64.2±2.39) were the same and the mean weight of the females (2727.5± 209.00) was slightly more than that of the males (2552.1±174.93). The condition factor (3.7747±0.72) in males exceeded that of females (1.37834±0.35). In this length class, the

males were in better condition than the females.

The 77-100 cm length class: The mean length of females (83.98±5.25) was slightly more than that of the males (81.8±5.61) and the mean weight of the females (5692.9±428.61) was slightly more than that of the males (5120.8±460.57).

The female condition factor (0.4215 ± 0.09) was more than that of males (0.2133 ± 0.07).

In this length class, the females were in better condition than the males.

As it can be seen in the data, it was only in the 77-100 cm length class that the condition factor in females (0.4215) was better than that in males (0.2133). In this length class, the fish either reached maturity or were in the period

after the release of ova. In the first three length classes, the male condition factor was more than that of the female.

Changes of mean length, mean weight and condition factor in males and females in all length classes in females:

As can be seen in Table 2, weight increased with the rise in length in all length classes.

Table 2: Length- weight relationship and condition factor of *Scomberoides commersonianus* in north- western of the Persian Gulf at different season, FL: Forked length, SE: standard error, SD: standard deviation, Reg.: Regression relationship, R²: Coefficient of Regression, K: Condition Factor, C.t: Calculated t-test, t S: t-student, G.P: Growth pattern, F: Female, M: Male, U: Unknown, I: isometry, A⁺: Positive allometry, A⁻: Negative allometry.

Season	Sex	No.	Mean FL (cm)	SD FL	SE FL	Mean W (g)	SD Wei.	SE Wei.	Reg. R.	R ²	K	C.t	t S	P value	G. P
Spring	F	69	60.5	±11.06	±1.33	2561.76	±1364.49	164.26±	Y=2.8808x - 1.7769	0.9671	1.7804	1.832	2.000	p>0.05	I
	M	80	57.2	±11.02	±1.23	1997.30	±1358.72	±151.91	Y=2.8468x - 1.7361	0.9374	1.8101	1.838	2.000	p>0.05	I
	F+M	149	58.7	±11.03	±0.90	2258.69	±1360.23	±111.04	Y=2.8808x - 1.7869	0.9536	1.6787	2.290	1.984	p<0.05	A ⁻
Summer	F	38	57.7	±21.80	±3.53	2590.03	±1664.75	±270.05	Y=2.9105x - 1.8626	0.9961	1.7696	2.882	2.042	p<0.05	A ⁻
	M	45	64.9	±22.11	±3.29	3008.81	±1740.43	±259.44	Y=2.902x - 1.8598	0.9937	1.5159	2.607	2.021	p<0.05	A ⁻
	F+M	83	61.6	±22.11	±2.42	2817.08	±1740.43	±191.03	Y=2.901x - 1.8526	0.9951	1.6565	4.276	1.990	p<0.05	A ⁻
	F+M+U	97	54.7	±22.11	±2.24	2414.78	±1740.43	±176.71	Y=2.9844x - 2.0028	0.9972	1.5661	0.942	1.990	p>0.05	I
	F	69	34.3	±18.52	±2.23	568.05	±1446.81	±87.45	Y=2.7888x - 1.636	0.9812	2.9581	4.305	2.000	p<0.05	A ⁻
	M	87	33.2	±18.15	±1.94	462.09	±1447.73	±155.21	Y=2.7499x - 1.5817	0.9731	2.6048	4.841	1.999	p<0.05	A ⁻
Autumn	F+M	156	33.7	±18.52	±1.48	508.95	±1447.73	±115.91	Y=2.7698x - 1.6097	0.9770	2.5614	6.464	1.984	p<0.05	A ⁻
	F+M+U	164	32.5	±18.52	±1.44	484.74	±1446.08	±112.91	Y=2.9123x - 1.8285	0.9877	1.6895	3.348	1.984	p<0.05	A ⁻
Winter	F	72	29.6	±18.99	±2.37	307.47	±1485.20	±175.03	Y=2.9486x - 1.8951	0.9817	1.2744	1.010	2.000	p>0.05	I
	M	81	30.0	±18.98	±2.22	317.13	±1487.60	±165.28	Y=2.8057x - 1.6779	0.9049	2.0566	1.804	2.000	p>0.05	I
	F+M	137	29.8	±18.99	±1.62	312.62	±1485.20	±126.88	Y=2.8841x - 1.7968	0.9457	1.5796	1.955	1.984	p>0.05	I

The condition factor rose from 0.7085 in the first class to 1.2595 and then 1.3783; however, in the 77-100 cm class the condition factor fell to 0.4215.

In males: Weight increased with the increase in length in all length classes. The condition factor rose from 0.7795 in the first class to 2.0223 and then

3.7747; however, in 77-100 cm class the condition factor fell to 0.2123.

In all specimens: Weight increased with an increase in length in all length classes. The condition factor rose from 0.6863 in the first class to 1.5769 and then 2.4149; however, in 77-100 cm class the condition factor fell to 0.2904.

The maximum condition factor in males (4.0658) and in females (1.5344) was found in 54-77 cm length class.

The analysis of growth pattern in various length classes

In the 8-31 cm length class in males, females and the total of both sexes, the growth pattern is isometric, but in total cases (F+M+U) it is positively allometric. In the 31-54 cm and 54-77 cm length classes, the growth pattern is isometric only in females, but it is negatively allometric in males and in the total specimens of both sexes. In the 77-100 cm length class, the growth pattern is isometric in males, females and the total specimens of both sexes.

In females, the growth pattern was isometric in all length classes and did not change. In males, the growth pattern was isometric in the 8-31 and 77-100 cm length classes, but it was negatively allometric in the other two classes. The growth pattern in the total specimens of both sexes was negatively allometric in the 31-54 and 54-77 cm classes, but it was isometric in the 77-100 cm class. In the 8-31 cm length class, where there are specimens with unknown sex, the growth pattern of the total males, females and the sexually unknown ones appeared to be positively allometric.

On the whole, growth was positively allometric in the 31-88 cm class, negatively allometric in the 31-54 cm and 54-77 cm classes and isometric in the 77-100 cm class among all the specimens.

The changes of length-weight relationship in different seasons for each sex are shown in Table 2.

The comparison of mean length (\pm S.E.), mean weight (\pm S.E.) and condition factor (\pm S.D.) between males and females in each season

In spring: The mean length (60.5 \pm 1.33cm) and mean weight (2561.7 \pm 164.26g) in females were greater than mean length (57.21 \pm 1.23 cm) and mean weight (1997.3 \pm 151.91 g) in males, yet the condition factor in males (1.8101 \pm 0.38) was more than that in females (1.7804 \pm 0.23), which indicated better condition among males during spring (Table 2).

In summer: The mean length (64.9 \pm 3.29cm) and mean weight (3008.8 \pm 259.44g) in males were greater than mean fork-length (57.72 \pm 3.53 cm) and mean weight (2590.0 \pm 270.05 g) in females, but the condition factor in females (1.7696 \pm 0.46) was more than that in males (1.5159 \pm 0.30), which showed better condition among females during summer.

In autumn: The mean length (34.3 \pm 2.23 cm) and mean weight (568.0 \pm 87.45g) in females were greater than mean length (33.22 \pm 1.94 cm) and mean weight (462.0 \pm 155.21g) in males, yet the condition factor in males (2.6048 \pm 0.68) was more than that in females (2.7120 \pm 0.52), which demonstrated better condition among females during autumn.

In winter: The mean length (30.0 \pm 2.22 cm) and mean weight (317.1 \pm 165.28g) in males were greater than mean length (29.6 \pm 2.37 cm) and mean weight (307.4 \pm 175.03g) in females, but the condition factor in males (2.0566 \pm 0.12) was more than that in females

(1.2744±0.07), which indicated better condition among males during winter.

The comparison of condition factors between two sexes in each season showed that males were in better condition during spring, autumn and winter; however, in summer females enjoyed better condition.

Changes of mean length, mean weight and condition factor in males and females in all seasons

In females: As can be seen in Table 2 the mean length declined from spring to winter, but the mean weight rose until summer and decreased once again in fall and then in winter. The condition factor increased from spring to fall, but dropped during winter.

In males: The mean length and weight were greater in summer than in spring, but the condition factor declined in summer. In autumn, the mean length and weight showed a sharp decrease compared to spring and summer and the condition factor increased substantially (the reverse relationship between mean length, mean weight and condition factor). Although the mean length and weight dropped in winter compared to the autumn, the condition factor is less than that of the autumn.

In all specimens (males, females and the unknown): The mean length dropped steadily from spring to winter, but the mean weight did not display this constant reduction: it rose in summer but declined in fall and winter. Under such circumstances, the condition factor decreased in summer and increased in

autumn, but it dropped once again in winter.

On the whole, the maximum condition factors in autumn were 2.6048 and 2.7120 in males and females respectively.

The analysis of growth pattern in different seasons

In spring, both males and females demonstrated isometric growth, but on the whole they showed negatively allometric growth. In summer, negatively allometric growth could be observed among males, females and the total of both sexes, yet the total of all the males, females and unknown specimens showed isometric growth. In autumn, the growth pattern was negatively allometric in males alone, in females alone, in males and females together and also in males, females and the unknown all together. In winter, the growth pattern was isometric in males alone, in females alone, in males and females together and also in males, females and the unknown all together. On the whole, the growth pattern in all specimens was negatively allometric in spring and autumn and isometric in summer and winter.

In Table 3, the length-weight relationship and condition factor of *S. commersonianus* are given for each sex in north-west coasts of the Persian Gulf.

As can be seen in Table 3, the mean length was the same in males (44.1±1.10 cm) and females (44.3±1.20 cm), whereas the mean weight in females (1391.9±94.49g) was more than that in males (1258.0±88.53g). In this study, *t* which is calculated through Pauley method is greater than *t*-student; therefore, the growth in females,

males and the total specimens in the north-west of the Persian Gulf are not isometric, but rather allometric. The regression coefficient in males, females and total specimens is less than 3; thus, the growth of this fish is negatively allometric in both sexes as well as all the specimens.

Table 3: Length-weight relationship and condition factor of *Scomberoides commersonianus* in the north-west of the Persian Gulf in different sexes, FL: Forked length, SE: standard error, Reg. R.: Regression relationship, R²: Coefficient of regression, K: Condition factor, C.t: Calculated t-test, t S: t-student, G.P: Growth pattern, F: Female, M: Male, T: Total, A: Negative allometry S: sex, P: Parameter.

S/P	No.	Mean Forked length (cm)± SE	Length range(cm)	Mean weight(g)± SE	Weight range(g)	Relationship	R ²	K	C.t	t S	p value	G.P
F	247	44.3±1.20	12.6-96.9	1391.9±94.4	21.9-10380.0	W=2.8873FL-1.7977	0.9928	2.1598	6.662	1.984	p<0.05	A ⁻
M	292	44.1±1.10	17.2-94.9	1258.0±88.37	39.6-8745.5	W=2.8141FL-1.6855	0.9864	2.6070	9.039	1.984	p<0.05	A ⁻
T	563	42.5±0.79	8.6-96.9	1239.9±62.9	4.9-10380.0	W=2.9109FL-1.8424	0.9910	1.9712	7.607	1.984	p<0.05	A ⁻

Discussion

The increase in mean length in the warm seasons (57.1 cm) and its decrease in the cold seasons (31.2 cm) indicates that the fish caught in the warm seasons were larger in length than those caught in cold seasons. In other words, one can conclude from the maturity length in this fish (55.3 cm as shown in Fig. 4) that mature fish were more frequent in the warm seasons, whereas immature fish were dominant in the cold seasons. It seems that mature fish migrate to deeper areas or other regions in the Persian Gulf, yet immature fish do not migrate and live in relatively shallow areas. Caudal fin in immature fish is fork-shaped, but it is lunate in mature ones. This change in the shape of caudal fin provides evidence for this migration because the

lunate fin is used for speedy swimming and can be found in fishes such as Carangidae and Scomberidae, which migrate. On the basis of the statistically significant differences in weight and length of fish in warm and cold seasons, it is concluded that the mature fish migrate to other regions in cold seasons, whereas the immature ones do not. Therefore, the mean length and weight of the fish differ between warm seasons and cold seasons. The dominance of immature fish in coastal waters can be seen in other species of Carangidae such as the adults of *Chloroscomberus chrysurus*, whose distribution occurs from coastal waters to open ocean, while larvae might be dominant in shallow waters, particularly close to estuaries and bays (Pena Rivas *et al.*, 2013).

On the whole, the mean weight in females (1391.9g) was greater than that in males (1258.0g), which was probably because of the weight difference at the time of reproduction as the mean weight of females increases in this period due to the larger contents of the abdomen.

Condition factor analysis among the four length classes between males and females demonstrates that in the first three length classes (8-31, 31-54 and 54-77 cm) the condition factor of the males was greater than that of the females; therefore, the males had better condition in comparison with the females. However, females enjoyed better condition in the 77-100 cm class. On account of the fact that all the fish in this class were mature (based on the maturity length of the fish, i.e. 55.3 cm), the better condition of females was probably due to the heavier ovaries, compared to testes. The rate of K changes in females and males as well as all the specimens (all the specimens in the last two classes are only males and females) in different lengths indicates that condition factor in the first three length classes was constantly increasing, but in the 77-100 cm class it declined. In this class, the fish did not have a good condition compared to other classes because of less feeding at the time of their reproduction and great loss of energy. Barnham and Baxter (1998) assert that condition factor decreases rapidly in females at the time of spawning. It was observed in the present study that condition factor declined in the last length class among

males, females and all the specimens. The maximum condition factor in males and females was found in 54-77 cm length class. In this class, it is more likely that most of the fish are mature; consequently, the condition factor in this class was greater than the others, owing to the increase in gonad weight. Also, comparing condition factor for both sexes in each season, the condition factor in males exceeded that of the females in spring, autumn and winter, whereas it was greater in females during the summer. The males appeared to have more intense feeding than the females during these seasons, while the increase in female gonad volume in summer was probably the reason for a rise in female condition factor, compared to males.

This is the result of a greater gonadal development, based on the consumption of fat reserves during the spawning period. The differences in the condition factor between females and males may result in different life history strategies of reproduction (King, 1995)

The maximum condition factor in males and females was found in autumn. In this season, most specimens were immature. Based on the maturity length (55.3 cm), mean length in females (34.3 cm) and that in males (33.2 cm) in autumn, most of the fish were not mature. The immature specimens had more intense feeding in order to increase their somatic growth. When condition factor is higher, it means that the fish has attained a better condition. The condition factor of fish can be affected by a number of factors

such as stress, sex, season, availability of feeds, and other water quality parameters (Khallaf *et al.*, 2003).

In the 8-31 cm length class, the growth pattern was positively allometric in all the males, females and the sexually unknown since all the fish whose sex was unknown were included in this length class and all these specimens had full stomachs and intense feeding, which turned the growth pattern of males, females and the total from isometry into positive allometry. In the 31-54 cm and 54-77 cm length classes, there was negative allometry, which indicated less growth in weight than in length. The 77-100 cm class demonstrated isometric growth. The negatively allometric growth in other classes was turned into isometric growth in this class due to an increase in the volume of gonads at the time of maturity or more intense feeding after spawning period.

Breeding periodicity was found to have a profound influence on the feeding rate in *Selaroides leptolepis* where the fish in maturing and spent recovering conditions fed more than the juveniles and matured groups (Sivakami, 1996). In *Alepes djedaba* also, highest feeding intensity was observed during the post spawning period (Sivakami, 1988).

In analyzing changes of growth pattern in various length classes, females were observed to have isometric growth in all length classes because they had a higher level of feeding before maturity for an increase in somatic growth. At the time of

maturity, their growth pattern did not change owing to maturity and a rise in the volume and weight of the gonads, although they had a lower rate of feeding due to stress. The growth pattern in males within the length classes of 8-31 cm (before maturity) and 77-100 cm (after maturity) was isometric. In fact, males probably had more intense feeding in comparison with the other two length classes before maturity to increase somatic growth and after reproduction to compensate for the lost energy and they showed isometric growth. Yet, in the 31-54 cm and 54-77 cm classes there was a lower level of feeding and the growth pattern was negatively allometric, probably because of maturity. In a large number of fish, feeding intensity and weight increased after the spawning period.

The growth pattern in all specimens was negatively allometric in spring and autumn and isometric in summer and winter. Although each sex showed isometric growth in spring, the growth of the total specimens was negatively allometric. In this season, there was a decrease in feeding rate among these fish, probably due to the onset of reproduction. Major carangids as a general rule were found to exhibit lesser feeding intensity during breeding season with a higher percentage of empty stomachs in mature specimens with the immature, developing and spent ones observed in an actively fed condition (Sivakami, 1996). In summer, the reproduction continued and the mean weight was lower due to the lower level of feeding. Also, the

increase in weight was less than the increase in length. Although males, females and the total of both had negatively allometric growth, all the specimens demonstrated isometric growth because of the sexually unknown ones, all of which had full stomachs. Therefore, they turned the overall growth pattern from negative allometry to isometry. The males, females, the total of both sexes and the total of all specimens showed negatively allometric growth in autumn. Most of the fish in this season, which included few mature fish as well as a large number of immature fish and those with unknown sex, had such a low level of feeding that the existence of sexually unknown ones with full stomachs did not change the growth pattern. In winter, nearly no mature specimens were observed. The fish had more intense feeding for somatic growth, so the growth pattern was isometric. In other words, the increase in weight was proportional to the

increase in length. Small-sized fish feed actively and more frequently than larger ones. This phenomenon has been recorded in the majority of fish species (Nikolsky, 1963). Feeding intensity in immature and juvenile fish is higher than the mature ones. This may be attributed to the very high food requirements in the young and fast growing fish (Kuthalingam, 1967; Pati, 1980; Armstrong *et al.*, 1992; Sivakami, 1996).

Most fish species change their shape as they grow and b-values may be different for larval, immature and mature fish. In most cases, growth in length appears to dominate in early life stages while growth in weight becomes relatively more important as fish reach adulthood (Arnason *et al.*, 2009).

Table 4 presents the length-weight relationships of *S. commersonianus* in coasts of Australia, Pakistan, southeastern coastal waters of Iran and Kenyan artisanal marine fishery.

Table 4: Length-weight relationship of *Scomberoides commersonianus* in the other regions. F: Female, M: Male, T: Total.

S/P	No.	Length range(cm)	Weight range	Relationship	b	R ²	Reference
F	162	-	-	$W=5e-05FL^{2.8130}$	2.8130	0.990	Griffiths <i>et al.</i> , 2005
M	165	-	-	$W=5e-05FL^{2.7629}$	2.7629	0.998	Griffiths <i>et al.</i> , 2005
T	563	233-921(mm)	0.157-8.210(kg)	$W=5e-05FL^{2.7915}$	2.7915	0.989	Griffiths <i>et al.</i> , 2005
T	2530	18-111(cm)	-	$W=0.014FL^{2.93}$	2.93	0.979	Taghavi Motlagh <i>et al.</i> , 2005
T	504	21.5-96.0(cm)	115.0-5158.0(g)	$W=6.722TL^{3.633}$	3.633	0.918	Mbaru <i>et al.</i> , 2010
T	1003	18-130 (cm)	30-15700(g)	$W=0.011TL^{2.88}$	2.88	0.952	Panhwar <i>et al.</i> , 2014

Taghavi Motlagh *et al.* (2005) showed that the growth of *S. commersonianus* was isometric in his study, the length and weight of 2530 fish were measured

and their mean length was reported to be 51.66 cm.

Length-weight relationships were presented for 39 major fish species in the Kenyan artisanal marine fishery.

Captures were made between the years 2001 and 2009. In the aforementioned study, the growth pattern of *S. commersonianus* was reported to be positively allometric (Mbaru *et al.*, 2010).

Also, the relationship between length and weight, growth and condition factor of *S. commersonianus* in waters of the Oman Sea were calculated by Panhwar *et al.* (2014) to determine the parameters of stock assessment, 1003 fish were collected from Karachi in Pakistan in the period between July 2012 and June 2013 and their length and weight were measured. The length-weight relationship indicated that the growth pattern of this fish was negatively allometric in these coasts ($R^2=0.90$, $b=2.88$, $a=0.011$). In the above-mentioned study, the growth pattern of this fish was reported to be negatively allometric.

Parameter b is the exponent of the arithmetic form of the weight-length relationship, and the slope of the regression line in the logarithmic form. If $b=3$, then small specimens in the sample under consideration have the same form and condition as large specimens. If $b>3$, then large specimens have increased in height or width more than in length, either as the result of a notable ontogenetic change in body shape with size, which is rare, or because most large specimens in the sample were thicker than small specimens, which is common. Conversely, if $b<3$, then large specimens have changed their body shape to become more elongated or

small specimens were in better nutritional condition at the time of sampling. (Froese, 2006). Karachle and Stergiou (2012) assert that when $b<3$ the fish grows faster in length than in weight, and when $b>3$ the fish grows faster in weight than in length.

In this study, the growth pattern of all the specimens was positively allometric only in 8-31 cm class. This result demonstrates that it was only in this class that weight growth was greater than length growth. In other words, the fish shapes in this class were wider than those in other length classes. However, the growth pattern was often isometric or negatively allometric in other seasons or length classes, which means that length growth was greater than weight growth (i.e. longer shape) or they were equal.

Froese (2006) analyzed 3929 weight-length relationships for 1773 species, and reported that b ranged between 1.96 and 3.94, with 90% of the cases falling inside the 2.7-3.4 range. The lowest values have been recorded for *Cepola macrophthalma*, whereas the highest for *Chaenocephalus aceratus*. In principle, these types of relationships are allometric (82%), with a trend towards positive allometry.

In the present study, the analysis of the maximum length in different areas demonstrates that the length (total and forked) as well as weight of this fish in coastal areas of the north-west of the Persian Gulf were greater than those in Australia and Kenyan artisanal marine fishery, but the forked length of this fish was more in southeastern coastal

water of Iran, as well as in coasts of Pakistan, compared to the north-west of the Persian Gulf. Also, the maximum weight found in this study exceeded that of Australia and Kenyan artisanal marine fishery, but it was less than the maximum weight in coasts of Pakistan.

The results indicate that the growth pattern varies among different seasons, length classes and sexes since it depends on several factors. In nature, the preservation of this growth pattern rarely happens during the lifetime. This phenomenon depends upon such factors as seasonal changes, geographical location, sex, the type of species, feeding intensity and environmental conditions of the species (Bagenal, 1978). In the present study, the value K varies in both sexes and among different seasons and length classes. The value of K is influenced by age of fish, sex, season, stage of maturation, fullness of gut, type of food consumed, amount of fat reserve and degree of muscular development. In some fish species, the gonads may weigh up to 15% or more of total body weight. With females, the K value will decrease rapidly when the eggs are shed (Barnham and Baxter, 1998).

But in some studies, it has been found that the seasonal changes and the gonadal development do not affect the growth patterns of such fish as mudskipper (*Boleophthalmus boddarti*) (Dinh, 2017) and *Ilisha melastoma* in Pakistan (Mahmood *et al.*, 2012).

All in all, the analysis of length-weight relationship in *S. commersonnianus* shows that the

growth pattern of this fish in the north-west of the Persian Gulf is negatively allometric, like Arabian sea coast of Pakistan (except for southeastern coastal waters of Iran and Kenyan artisanal marine fishery), and there is a high level of correlation between length and weight. Furthermore, males are in better condition than females. The growth pattern and condition factor vary in different seasons, length classes and sexes.

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