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LENGTH-WEIGHT RELATIONSHIP IN ADULT *SCOMBEROMORUS GUTTATUS* (BLOCH & SCHNEIDER, 1801) FROM KARACHI COAST, PAKISTAN

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ABSTRACT

The length-weight relationship (LWR) of adult *Scomberomorus guttatus* (Bloch & Schneider, 1801) fish samples (N = 278) collected from August, 2006 to December, 2011 from Karachi Coast was determined. The largest fish (51.15 ± 0.673 cm) were recorded in winter (2006-2007). The fish were heaviest (721 ± 11.087 g) in 2008-2009. The relationship between length and weight of *S. guttatus* was given by an equation, $W = 0.167229.L^{2.121411} \pm 0.02045$, (r = 0.8487) indicating a negative allometry between length and weight. The weight of fish was equally well-defined by linear equation, W = -755.30127 + 28.56385L (cm) ± 19.248, (r = 0.8476). The power model ($W = a.L^b$) exhibited merely 0.19% higher explanatory value over the linear model (W = a + bL), if viewed on the basis of adj. r^2 associated with these models.

KEYWORDS: Length-weight relationship, *Scomberomorus guttatus*, Karachi Coast, Pakistan.

INTRODUCTION

Length-weight relationships (LWRs) have extensively been studied the world over in numerous fishes e.g., to cite a few, *Acanthopagrus berda* (Hameed *et al.,* 2013), *Arius maculatus* (Wu-Chan *et al.,* 2012), *Carianius heudelotii* (Ndome *et al.,* 2012), *Channa punctata* (Datta *et al.*, 2013; Haniffa *et al.*, 2006), *Channa deplomgrama, C. manulius and C. strata* (Ali *et al.*, 2013), *Cirrhinus mrigala* (Parmar and Bhatia, 2014), *Hilsa ilisha* (Shafi and Quddus, 1974), *Limanda limanada* (Htun Han, 1978), *Megalaspis cordylla* (Ahmed *et al*., 2013), *Perca fluviantis* (Le Cren, 1951), *Pomadasys maculatus* (Khan *et al.,* 2013), *Sardinella albella* and *S. gibbosa* (Sekhran, ND), *S. longiceps* (Saud, 2011), *Scomberomorus maculatus* (Wigley *et al.,* 2003), *S. guttatus* (Rashid *et al.,* 2010; Datta *et al.*, 2012; Zarochman, 2012), several Black Sea fish species (Kosapoglu and Duzgunes, 2013), *Synodontis schall* (Akomo *et al.,* 2014, etc.), several Australian fishes (Willing and Pender, ND) and many commercial fishes (Bedford *et al.,* 1986) with a view to estimate fish weight from fish length because of technical difficulties and the amount of time required to record weight in the field (Sinovacic *et al.,* 2004). LWR is the most commonly used analysis in fisheries data *(Mendes et al., 2004).* Furthermore, standing crop biomass can be estimated more easily through regression equations (Morey *et al.,* 2003). The seasonal variations in fish growth can also be easily tracked this way (Richter *et al.,* 2000). LWR in fishes is important for fish stock assessment as regression parameters ‘a’ and ‘b’ can be employed for length-weight conversion. The publications of Mutto *et al.* (2000) for São Paulo Brazil; Lawson *et al.* (2013) for Ogudu Creek Nigeria; Mutanda Aaura *et al*. (2011) for deep Sea fishes of Nigeria; Mendes *et al.* (2004) for Portuguese waters; Ferreira *et al.* (2008) for demersal fishes of Madeira Archipelago; Maci *et al*. (2014) for fishes of non-tidal lagoon of Adriatic Sea of Italy; Ismen *et al.* (2009) for Aegean Sea sharks; Abdurahiman *et al.* (2004) for Karnataka (India) fishes; and Wigley *et al.* (2003) for fishes captured in bottom trawl of continental shelf extending from Cape Hatteras, N. Carolina to Nova Scotia) are some of the very useful ones in this connection.

Indo-Pacific king mackerel [*Scomberomorus guttatus* (Bloch & Schneider, 1801] is a marine, brackish, pelagic-neritic and oceanodromous fish distributed in African, Asian and Australian coastal waters. It is locally called ‘Surmai’. All *Scomberomorus* spp. are primarily coastal fish inhabiting coastal waters depths between 15-200 m - sometimes entering turbid estuarine waters. The size of this fish at maturity in Southern India ranges between 48 and 52 cm total length and about 40 cm total length in Thailand. It is less migratory than *S. commerson* (FAO, 1983). It is usually found in small schools. It is predominantly piscivorous and feeds mainly on small schooling fishes (especially sardines and anchovies), squids, panaeids and crustaceans (Collette, 2001; McPherson, 1987). *S. guttatus* has no swim bladder (*Fishbase.sinica.edu.tw/summary/Scomberomorus-guttatus.html*). Siddeek (ND) has reviewed the fisheries biology of *Scomberomorus* and *Acanthocytrium* spp. *S. guttatus* is an economically important fish and has been studied in length and weight context in India, Bangladesh, Indonesia and Australia but LW relations in this species have never been, to our knowledge, published from Pakistan waters. The objective of the present research is to provide LWR data for adult *S. guttatus* from the Karachi coast, Pakistan. This is pertinent in view of the fact that the length-weight parameters of the same species may vary in different populations because of their geographic location, age, feeding, reproductive activities and fishing etc.

MATERIAL AND METHODS

Samples of adult *Scomberomorus guttatus* were collected seasonally (autumn, winter, spring, summer) from Karachi coast, Fish Harbour West Wharf Karachi. Fishes were collected during autumn (September and October), winter (November, December and January), Spring (February and March) and summer (April, May, June and July) between 2006 and December 2011 to total 278 i.e. 51 samples were collected in 2006-2007, 57 in 2007-2008, 62 in 2008-2009, 54 in 2009-2010 and 54 in 2010-2011. Total length (cm) of each fish was measured from the tip of the snout (mouth closed) to the extended tip of the caudal fin using a measuring board. Body weight (fresh) was recorded to the nearest gram using a top loading Metler balance. The length (L) and weight (W) relationships (LWRs) were determined statistically for various models (Zar, 1984; Ricker, 1973) with untransformed and logarithmically transformed length and weight data. The values of constant 'a' and 'b' were estimated from the log transformed values of length and weight for equation, log W = log a + b log L. or power model, $W = a.L^b$, to test the cube model of fish growth (Hile, 1936, Le Cren, 1951). The deviation of regression coefficient b from 3 was tested by calculating t value, $t = (b-3) / S_b$, where Sb was given as:

$S_b = \sqrt{[(SW / SL) - b^2] / n-2}$, where SW is the variance of the body weight, sL, the variance of the total length and n the sample (Lawson *et al.*, 2013).

RESULTS AND DISCUSSION

A Total of 278 samples of *Scomberomorus guttatus* were collected from Karachi Fish Harbour during August 2006 to December 2011. The samples were dominated by female individuals (188, 67.63%). There were 78 (28.06%) male and 12 (4.32%) unsexed individuals. The female: male ratio was 2.41. The mean length of *S. guttatus* was generally higher in winter (51.15 ± 0.673, 51 ± 0.652, 50.5 ± 0.72 cm in 2006-2007, 2007-2008, 2008-2009, respectively). The lowest mean length (48.5 ± 0.61, 48.75 ± 0.45 cm) was measured in spring (2006-2007, 2008-2009) (Fig. 1).
The maximum mean weight of fish, 721 ± 11.09, 708 ± 26.23 and 697 ± 33.21g, was obtained in winters of 2007-2008, 2008-2009 and 2009-2010, respectively. The lowest mean weight of 623 ± 21.72, 629 ± 13.55 and 636 ± 9.92g was recorded in spring of 2006-2007, 2007-2008 and 2010-2011, respectively (Fig. 2).

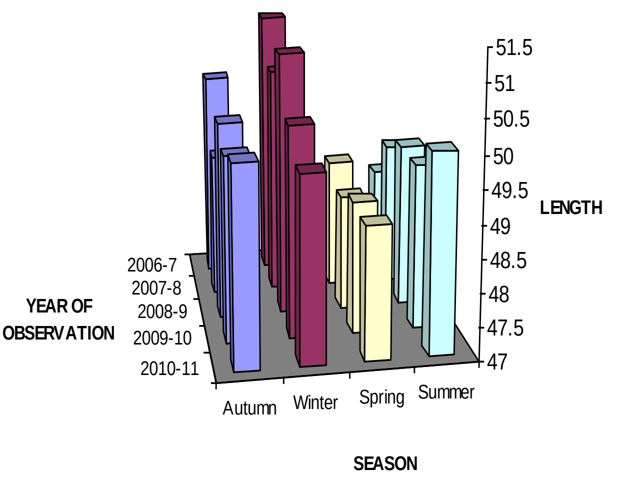


Fig. 1.Average total length (cm) of fishes collected during various seasons of the study years.

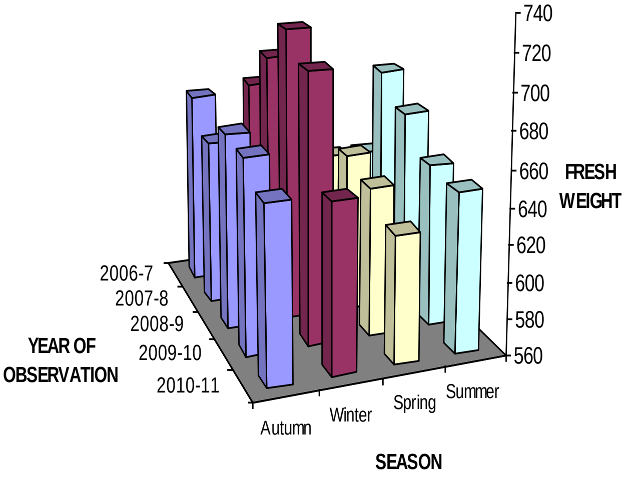


Fig. 2. Average fresh weight (g) of fishes collected during various seasons of the study period.

The distribution of the yearly data on length and weight for *S, guttatus* is presented in Fig. 3 supported by the location-dispersion parameters in Tables 1 and 2, respectively. The total length of fish for all the years of observation was skewed and deviated significantly from normal distribution (Fig. 3 and Table 1). The length varied not more than 2.7% for any year of observation. The weight of the fish also didn't follow normal distribution for any of the year of the observation. It varied not more than 6.32% for any year of observation (Table 1). The overall length for a sample of 278 fishes averaged to 49.82 ± 0.064 cm (Q2 = 49.8 cm) and varied by 2.16% only. It significantly deviated from normalcy (KS-z: 1.678, $p < 0.007$). The average fresh weight of the fish was 667.867 ± 2.172 g (Q2 = 667.0) and varied by 5.42%. Weight like length of fish deviated significantly from normal distribution (KS-z; 1.775, $p < 0.004$). Length and weight were positively skewed and platykurtic (Fig. 4).

The weight / length ratio of the fish studied varied through the years of the observation (Fig. 5). The mean W/L ratio of adult *S. guttatus* appeared to be 13.3975 ± 0.03013. It was, however, comparatively higher during the period of 2007-2010 (mean: 13.5310; varying from 13.4893-13.6075) than that during 2006-7 or 2010-2011 (Fig. 5). It appears that environmental conditions were relatively better for growth of this species during 2007-2010.

Table 1. Dispersion and location of length (cm) of *Scomberomorus guttatus* fishes for various years of collection.

Year	N	Mean	SE	CV	Min	Max	Q_2	g_1	Sg1	g_2	Sg2	KS-z	p
2006-07	51	49.93	0.167	2.39	48.2	52.0	50.2	-0.109	0.333	-1.17	0.656	1.139	0.149
2007-08	57	48.73	0.114	1.77	48.5	51.5	49.8	0.864	0.333	-0.11	0.623	1.375	0.046
2008-09	62	49.86	0.123	1.95	48.2	52.0	50.0	0.115	0.304	0.45	0.599	0.976	0.314
2009-10	54	49.74	0.185	2.73	48.2	52.0	49.2	0.325	0.639	0.35	0.480	1.128	0.157
2010-11	54	49.94	0.184	2.71	48.0	52.3	49.2	0.529	0.325	0.33	0.639	1.794	0.003

Table 2. Dispersion and location of weight (g) of *Scomberomorus guttatus* fishes for various years of collection.

Year	N	Mean	SE	CV	Min	Max	Q_2	g_1	Sg1	g_2	Sg2	KS-z	p
2006-07	51	659.41	5.836	6.32	618	758	668	0.864	0.338	-0.105	0.656	1.715	0.006
2007-08	57	678.02	4.369	4.86	628	734	674	0.562	0.311	-0.847	0.623	1.579	0.014
2008-09	62	678.81	4.787	5.55	632	736	668	0.338	0.304	-1.25	0.590	1.497	0.023
2009-10	54	671.67	4.553	4.98	623	732	667	0.272	0.325	-1.19	0.639	1.360	0.049
2010-11	54	656.17	4.829	5.41	612	721	648	0.640	1.325	-0.948	0.639	1.511	0.021

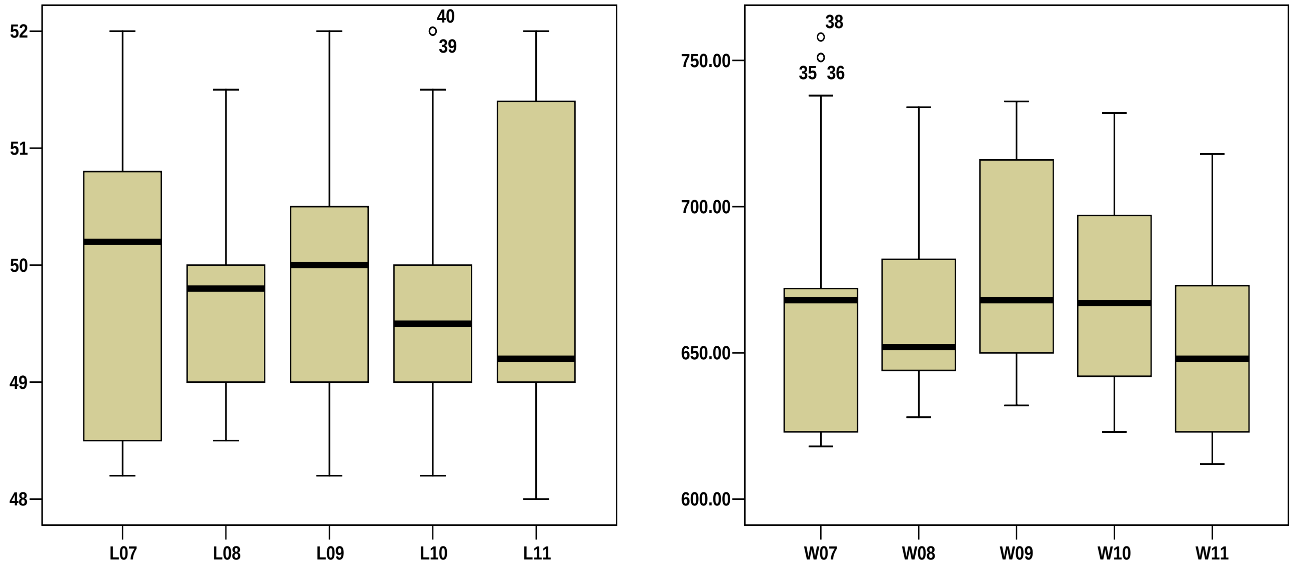
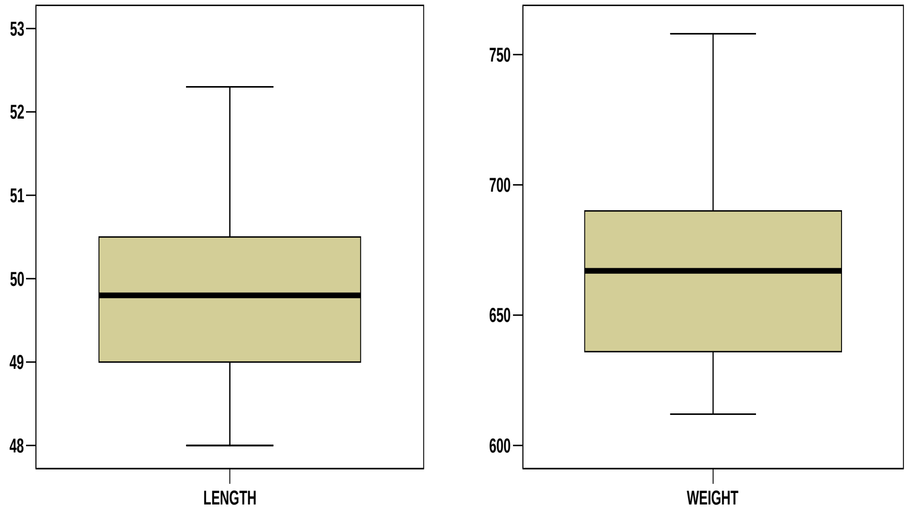


Fig. 3. Box plot representation of length (cm) and weight (g) of fishes captured during 2006-7 to 2010-11. Acronyms: L07 = Length 2006-7; L08 = Length 2007-8; L09 = Length 2008-9; L10, Length 2009-10 and L11, Length 2010-2011. W07 = Weight 2006-7; W08 = Weight 2007-8; W09 = Weight 2008-9; W10, Weight 2009-10 and W11, Weight 2010-2011.

N = 278,
Mean = 9.824
SE = 0.0644
Q2 = 49.80
CV = 2.16%
G_1 = 0.400
G_2 = -0.650
Min = 48.0
Max = 52.3
KS-z = 1.678
($p < 0.0007$)



N = 278,
Mean = 667.87
SE = 2.1717
Q2 = 667.00
CV = 5.42%
G_1 = 0.444,
G_2 = -0.865,
Min = 612.0,
Max = 758.0,
KS-z = 1.775
($p < 0.0004$)

Fig. 4. Distribution of total data set of length (cm) and weight (g) of fishes collected during the study period. Q2, Median; G1, skewness; G2, kurtosis; Standard error of skewness (Sg1) = 0.146 and standard error of kurtosis (Sg2) = 0.291.

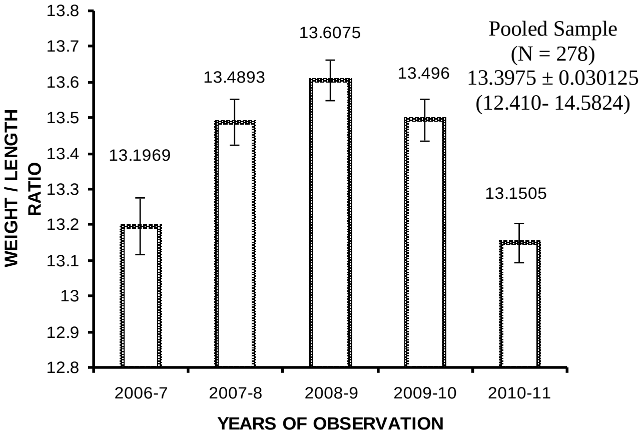


Fig. 5. Distribution of weight / Length ratio in the fishes sampled during various years.

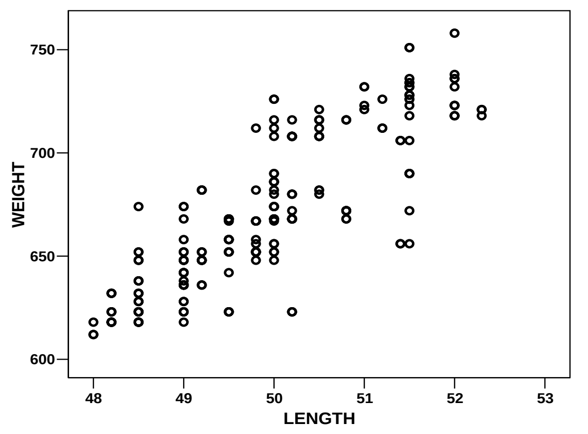


Fig. 6. Scatter diagram between length (cm) and weight (g) of *S. guttatus* (merchantable-sized) from Karachi coast (N = 278) captured during 2006-2011.

According to LWRs determined for yearly data (2006-2011) fish *S. guttatus*, exhibited negative allometric growth because b value was always smaller than 3 for each year of observation (Table 3). The length-weight scatter diagram for the pooled data (N = 278) is presented in Fig. 6 and correlation and regression analyses for the untransformed and transformed data appears in form of regression equations below (Eq. 1-8) for linear model with untransformed. data (Eq. 1), for semi-logarithmic models (Eq. 2-5), double logarithmic linear models (Eq. 6 & 7) and power model (Eq. 8). Within the size range of length: 48-52.3 cm and fresh weight: 617-758g, the adult *S. guttatus* appeared not to follow the cube law (b = 2.121411; Eq. 8). The value of b = 2.121411 was significantly lesser than 3 (t = 7.667, p<0.0001). The weight of the fish within this size range was equally well given by power model and the linear model. The power model ($W = a.L^b$) exhibited merely 0.19% higher explanatory value over the linear model (W = a + bL), if viewed on the basis of adj. r^2 associated with these models (comparing Eq. 1 and 8).

Linear Model (Untransformed)

Weight (g) = -755.30127 + 28.56385L (cm) ± 19.248
t_a = -14.08 (p<0.00001; t_b = 26.54 (p<0.00001)
r = 0.8476; r^2 = 0.7184; Adj. r^2 = 0.7174; F = 704 (p < 0.00001) Eq. 1

Semi-Logarithmic Models

Log_{10}Weight (g) = 1.906823 + 0.018409 L ± 0.01237
t_a = 55.03 (p<0.00001; t_b = 26.61 (p<0.00001)
r = 0.8482; r^2 = 0.7195; Adj. r^2 = 0.7185; F = 707.99 (p<0.00001) Eq. 2

Weight (g) = - 4917.7722 + 3290.8204 Log_{10} L ± 19.2307
t_a = -23.40 (p<0.00001; t_b = 26.57 (p<0.00001)
r = 0.8479; r^2 = 0.7190; Adj. r^2 = 0.7179; F = 706.02 (p<0.00001) Eq. 3

Log_e Weight (g) = 4.390644 + 0.042689 L ± 0.02849
t_a = 55.30(p<0.00001; t_b = 26.61 (p<0.00001)
r = 0.8492; r^2 = 0.7195; Adj. r^2 = 0.7185; F = 707.99 (p<0.00001) Eq.4

Weight (g) = - 4917.7722 + 3290.8204 Log_e L ± 19.2307
t_a = -23.39 (p<0.00001; t_b = 26.57(p< 0.00001)
r = 0.8479; r^2 = 0.7190; Adj. r^2 = 0.7179; F = 706.016 (p<0.00001) Eq. 5

DOUBLE LOGARITHMIC MODELS

Log_{10}Weight (g) = -0.776693 + 2.121411 Log_{10} L ± 0.01235
t_a = -5.75 (p<0.00001; t_b = 26.66 (p<0.00001)
r = 0.8487; r^2 = 0.7204; Adj. r^2 = 0.7193; F = 710.94 (p<0.00001) Eq.6

Log_e Weight (g) = -1.788401 + 2.121411 Log_e L ± 0.02845
t_a = -5.75 (p<0.00001; t_b = 26.66 (p<0.00001)
r = 0.8487; r^2 = 0.7204; Adj. r^2 = 0.7193; F = 710.94 (p<0.00001) Eq. 7

POWER MODEL

Weight (g) = 0.167227.L (cm) $^{2.121411}$ ± 0.02045
t_a = 3.25 (p<0.0015; t_b = 26.6 (p<0.00001)
r = 0.8487; r^2 = 0.7204; Adj. r^2 = 0.7193; F = 710.9 (p<0.00001) Eq. 8

Table 3.length (L) –weight (W) relationship (W = a.L ^{b}) in 648 *Scomberomorus guttatus* fishes from Karachi coast for various years of collection.

Year	N	a	b	t_a	t_b	r^2	SE	F	p
2006-07	51	0.1009	2.2462	1.40	12.34	0.7565	0.3080	152.21	0.00001
2007-08	57	0.1066	2.2391	1.10	9.63	0.6333	0.0299	92.79	0.00001
2008-09	62	0.0721	2.3406	2.00	18.32	0.8484	0.0194	335.74	0.00001
2009-10	54	0.0705	2.3449	1.92	17.63	0.8566	0.0189	310.73	0.00001
2010-11	54	0.5195	1.8265	2.47	17.66	0.8571	0.0203	311.90	0.00001

As regard to the cube law application in LWR of fishes, there are contradictory reports. For a size range of 16-59 cm, *Scomberomorus maculatus* (combined sexes, N = 159), has been reported to follow cube law of growth (b = 3.0242; r^2 = 0.9848) in continental shelf region from cape Hatteras, N. Carolina to Nova Scotia (Wigley *et al.*, 2003). Khan *et al*. (2013) also reported *Pomadasys maculatus* to follow cube law in the coastal water of Karachi, Pakistan and grow symmetrically and isometrically. LW relationship in most fish can be adequately described by W = a.L^b, where b is exponent usually lying between 2.5–3.5 (Carlander, 1969) or 2.5 to 4.0 (Hile, 1936). If value of b is 3, the fish grows isometrically, and if b is greater than 3, the fish exhibits positive allometry and if b is lesser than 3, the fish exhibits negative allometry (Tesch, 1968). For an ideal fish which maintains the same shape, b = 3, and this occasionally been observed (Allen, 1938). In the vast majority of instances where LWRs have been calculated, however, it has been found that the cube law is not obeyed and b ≠ 3. Most of the fishes change their shape as they grow (Martin, 1949) and so cube law relationship could hardly be expected. It may be assumed that in probable b ≠ 3. It has been found that while b may be different for fish from different location, different sexes or for larval, immature and mature fish (Le Cren, 1951). For instance, *Acanthopagrus berda* male (N = 233) and female (N= 280) samples from Karachi Coast of Pakistan have been shown to bear negative allometry (b = 2.638 and 2.636, respectively) but the pooled sample of male + female + unsexed individuals (N = 1074) followed cube law in LW relationship (Hameed *et al*., 2013).The b is often constant for fish similar in these respects. It may change with metamorphosis and or on onset of maturity (Frost, 1945). In 57 fish species of São Sebastião system of Brazil, Mutto *et al*. (2000) found the value of ranging from 2.746 to 3.617 (mean = 3.136). Of the 57 species, only 13 (26%) had b equal to 3. The rest of the 44 species (74%) had b ≠ 3 i.e. they didn't follow the cube law. The distribution of b of 57 species exhibited symmetry (g_1 = -0.7497, p<0.803) and normality in the mesokurtic curve (g_2 = 0.013, p<0.67). It was concluded by them that the cube law cannot be applied in most of the fishes of São Sebastião system. In theory one might expect b =3, because volume is a 3-dimensiopnal object roughly proportional to the cube of length for regular shaped solid. In fishes that have thin elongated bodies will tend to have value of b lower than 3 while fishes that have thicker bodies tend to have values of b that are greater than 3 (Brodziak, 2012). In 51 species studied, the value of b ranged between 1.94 (*Loligo duranceli*) and 3.62 (*Portunus pelagicus*). The mean value of b was 2.80 ± 0.32 (SD) and median 2.85. For male and female samples pooled (N=200) of *S. guttatus* admeasuring 32 to 51 cm in length, the value of a = 0.023 and b = 2.782 was reported for equation, W = a.L ^{b}, by Abdurahiman *et al.* (2004) from Karnataka, India.

Based on the data of *S. guttatus* in Airbangis waters west of Sumatra in 1985, length-weight was reported approaching an exponential curve (Y = 16.483 e $^{0.0785 X}$) on a level of close association of r^2 = 0.84. By this curve, acceleration occurred when length of fish reached 12.74 cm or weighing about 44.8g. At TL > 40.0 cm *S. guttatus* experience a significant acceleration of growth in an exponential manner. The maturity of gonads coincides with the end of rapid growth or hence starts spawning (Zarochman, 2012).For *S. guttatus* of Northern Bay of Bengal (mean length: 375.84 ± 80 mm and mean weight: 418.2 ± 15.3g, N=480), LWR was reported by Datta *et al*. (2012) to be W = 0.00001.L $^{2.894}$ (r^2 = 0.9915) i.e. a negative allometric relationship. In view of condition factor, 0.649 ± 0.003, it was concluded by them that the fish growth was poor, the weight not increasing with length. That is why it is elongated in shape. Pauly (1984) has also opined that with b value lesser than 3, fish becomes more slender as it increases in length. Our results of negative allometry in LWR of *S. guttatus* are in agreement with previous studies conducted in South Asia (Table 4).

In some cases the specific gravity (SG) of the fish may not be unity and variations in SG may take place (Tester, 1940). This may influence upon the condition or fatness of the fish as has been reviewed by Kesteven (1947). In demersal fishes, the density of the fish as a whole is maintained the same as in that of the surrounding water by the swim bladder and therefore changes in weight for length are due to changes in form or volume and not due to SG (Le Cren, 1951). *S. guttatus* is known to have no swim bladder.

Table 4. LWR equations reported for *S. guttatus* from different localities of Asia.

Country	LWR Equation	r^2	Allometry	Reference
Bangla Desh	$Y = 0.0101\ L.^{2.8622}$	1.0000	Negative	Rashid *et al*. (2010)
Southern Karnataka, India	$Y = 0.023\ L.^{2.782}$	0.9300	Negative	Abdurahiman *et al.* (2004)
West Bengal, India	$Y = 0.00001\ L.^{2.894}$	0.9915	Negative	Datta *et al.* (2012)
Karachi Coast, Pakistan	$Y=0.167227.L^{2.1214}$	0.7204	Negative	Present study

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