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Length-Weight, Length-Length Relationships and Condition Factor of Moon Wrasse *Thalassoma lunare* (Linnaeus,1758) from the Indian Coast

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Abstract

The moon wrasse *Thalassoma lunare* has an attractive colour pattern that makes it a favourite and economically valuable species in marine aquarium fish trade. This study was conducted to determine length-weight and length-length relationships and condition factor (K) of *T. lunare*. A total of 51specimens caught by a non-return valve trap net and gill nets formed the material of the study. The logarithmic regression equations of length-weight relationships were found to be Log TW= -1.507+2.6596 Log TL, Log TW= -1.6769+2.789Log TL, and Log TW= -1.6087+2.7349Log TL for primary males, females, and combined sexes, respectively. The 'b' values were significantly lower than the critical isometric value (3), indicating a negative allometric growth pattern. Regression analysis of total length and standard length also showed a positive regression coefficient 'b' values of 0.926, 0.9025, and 0.8987 for primary male, female, and for combined sexes, respectively. The values of condition factor and relative condition factor of combined sexes were recorded 2.516±0.58 and 1.00±0.11, respectively, indicating a state of well-being for *T. lunare* in natural water. This study provides a vital tool in fishery management as the first reference of LWR equation parameters and Kn of *T. lunare* in Vizhinjam Bay, India.

Keywords: Length-weight relationship, Condition factor, *Thalassoma lunare*, Vizhinjam Bay, Fishery Management

1. Introduction

The moon wrasse *Thalassoma lunare* has an attractive colour pattern, and this wrasse derives its name from the crescent-shaped caudal fin. This species is distributed throughout the tropical Indo-Pacific, and it is carnivorous, feeding on fish eggs and small benthic invertebrates (Froese, and Pauly, 2019). The fish resides on coral reefs, lagoons, coastal reefs, and surrounding areas at depths up to a depth of 20 m, and are active fish in the marine 'cleaning stations' (Araujo et al., 2020). The maximum length can moon wrasse reach is 45 cm (Myers, 1991; Randall *et al*., 2000; Allen et al., 2012). *T. lunare* is diandrous; both primary and secondary males present in the same population (Choat, 1969). All "Gaudy" individuals are secondary males, and a duller "Drab" may be either females or primary males (Robertson *et al*., 1974). The change in length or weight or both with increasing age, often referred to as growth, happens due to an increase in size due to the conversion of the food into building matter (Gokhale *et al*., 2015). The growth rate defers between fishes, and it depends upon their genetic makeup, food resources available, and the environmental conditions in which they live and grow. For the estimation of growth, both length and weight are used as two fundamental parameters in the species biology at individual and population levels (Khajuria *et al.*, 2014).

Length-weight regression is useful for predicting weight from length because the direct weight measurements are consuming the time in the field (Ayo-Olalusi, 2014; Jin *et al*., 2015; Sabido-Itzá *et al.*, 2016). Length-length relationships (LWRs) are beneficial for the conversion of different lengths measurements of the body, such as standard length (SL) to total length (TL). (Klassen *et al.*, 2014). Length-length relationships (LLRs) are essential for comparative growth studies under various environmental conditions (Moutopoulos and Stergiou, 2002; Nazir and Khan, 2017). Equation of Le Cren (1951) allows comparing and describing populations of a particular species over time or between regions through its parameters 'a' and 'b' (Khristenko *et al*., 2017).

The condition factor (CF) is an indicator that shows the degree of the well-being of the fish in their habitat, and it is known as the length-weight factor or coefficient of condition. This factor is important for understanding various ecological and biological factors such as gonad development, degree of fitness, and the suitability of the environment with regard to the feeding condition (Macgregor, 1959; Nehemia *et al.*, 2012). The decrease in condition factor shows depletion of energy reserves because there are factors such as nutritional status and organo-somatic indices positively related to muscle and liver energy content; this also reflects recent feeding conditions as well as its reproductive status (Ayo-Olalusi, 2014; Khajuria *et al.*, 2014). Increasing in condition factor value reflects that the fish has attained a better condition and many factors influence the value of condition factors such as stress, sex, season, availability of feeds, and other water quality parameters (Khallaf *et al.*, 2003).

The commercial importance of moon wrasse lies in their popularity as aquarium fish. Still, there is no information on its length-weight and length-length relationship, in

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addition to condition factors. Hence, the present study aimed to provide information on LWR, LLR, and CF of the moon wrasse, *T. lunare* inhabiting Vizhinjam Bay, Southwest coast of India for the first time.

2. Materials and Methods

The samples of *T. lunare* were collected from Vizhinjam Bay in Kerala, Southwest coast of India (latitude 8º22'35.30 N; longitude 76º59'30.80 E) using a non-return valve trap net and gill net between December 2018 and March 2020. A total of 51specimens of moon wrasse comprising 20 primary males and 31 females formed the material for the present study. The samples were brought to the lab and photographed fresh and then preserved in 10% neutral buffered formalin solution for further analysis. The specimens were dissected in the lab to determine the sex and divided into three groups, primary male, female, and combined primary male and female. Total length and standard length were measured to the nearest 0.01 cm using a digital calliper. Fish were also weighted to the nearest 0.01g after removing the adhered water, and other particles from the surface of the body and its weights were recorded, using a digital electronic balance sensitive up to 0.001g.

The length-weight relationship (LWR) was estimated using the formula of Le Cren (1951):

$$W = a\,L^{b}$$

where 'W' is the body weight in grams (g), 'L' is the total length in centimeter (cm), 'a' is a constant, and 'b' is a growth exponent. For getting a linear relationship rather than a curved relationship, this equation was log-transformed as:

$$\text{Log } W = \text{Log } a + b \text{ Log } L$$

Where 'W' is body weight in grams (g), 'L' is the total length in centimeter (cm), 'Log a' is the intercept of the regression line, and 'b' is the slope of the regression line. When 'b' = 3, the increase in weight is isometric, and when the value of 'b' is other than 3, the weight increase is allometric (positive if b > 3, negative if b < 3). The same regression method was also used to establish a relationship between total length and standard length. The equation is as:

$$\text{Log TL} = \text{Log } a + b \text{ Log St.L}$$

Where 'TL' is the total length in centimeter (cm), 'St.L' is the standard length in centimeter (cm), 'Log a' is the intercept of the regression line, and 'b' is the slope of the regression line. The correlation coefficient 'r' was determined in addition to the coefficient of determination 'R^2'.

The condition factor, which shows the degree of fitness or well-being of the fish in their habitat, was determined by using the equation:

$$K = \frac{W \times 100}{L^{b}}$$

Where 'K' is the condition factor, 'W' is the weight of the fish in gram (g), 'L' is the total length of the fish in centimeters (cm) and 'b' is the value obtained from the length-weight equation.

Relative condition factor 'Kn' (Le Cren 1951) was estimated using the equation:

$$Kn = \frac{W}{W}$$

Where 'W' is the observed weight of fish in gram (g) and 'W' is the calculated weight from the length-weight relationship logarithmic equation.

Both the Statistical Package for Social Sciences (SPSS, version 16) and Microsoft Office Excel software were used in the analysis of this study. All the statistical analyses were considered at a significance level of 5% ($p<0.05$).

3. Results

The growth rate of moon wrasse *T. lunare* from Vizhinjam Bay, Southwest coast of India in Kerala was assessed based on the length-weight relationship. The logarithmic regression equations of total length (TL), total body weight (TW), and their correlation coefficient 'r' derived for males, females, and combined (males and females) are given in Table 1. The length-weight relationship of *T. lunare* registered a significant linear relationship with negative allometric growth patterns for primary males, females, and for combined (primary males and females) (Fig. 1A, 1B, 1C). The regression coefficient registered 2.6596 for primary males whereas it was 2.789 and 2.7349 in females and combined population (primary males and females) respectively (Table 1; Fig. 1A, 1B, 1C) and the coefficient of determination (R^2) was significant (Table 2; Fig. 1D, 1E, 1F).

The average of total length, standard length, total weight, condition factor, and relative condition factor of moon wrasse are given in Table 3. The mean total length and standard length registered for the total population in the present study was 16.26 ± 4.04 cm and 13.21 ± 2.98 cm, respectively, whereas the mean total weight recorded was 58.95±41.6g. The mean values of condition factor and relative condition factor were 2.516±0.58 and 1.00±0.11, respectively, for combined sexes. Comparisons of total length, total weight, and condition factor between primary male and female fishes by student's t-test (t) showed a highly significant difference ($P<0.01$). Standard length exhibited a significant difference at 5%level between primary males and females ($P<0.05$). Student's t-test (t) showed no significant variation between primary males and females in relative condition factor ($P>0.05$; $t = 0.131$) (Table 3). The values of observed weight registered overweight than calculated weight at length groups 22-22.9 and 23-23.9, respectively (Table 4; Fig. 2).

The values of condition factor (K) calculated for various length groups of combined sexes fluctuated between 2.23 and 3.08. The average value of the condition factor was 2.50 ± 0.02, and the highest value 3.08 in the length group of 22-22.9 cm. The values of the relative condition factor varied from 0.89 to 1.23 for the different length groups of *T. lunare* collected from Vizhinjam Bay (Fig. 3; Table 4). The difference in condition factors showed significant variation between monsoon and non-monsoon seasons ($P < 0.01$) and the variations in relative condition factors, however, were not significant between seasons ($P>0.05$). The condition factor of primary males in monsoon and

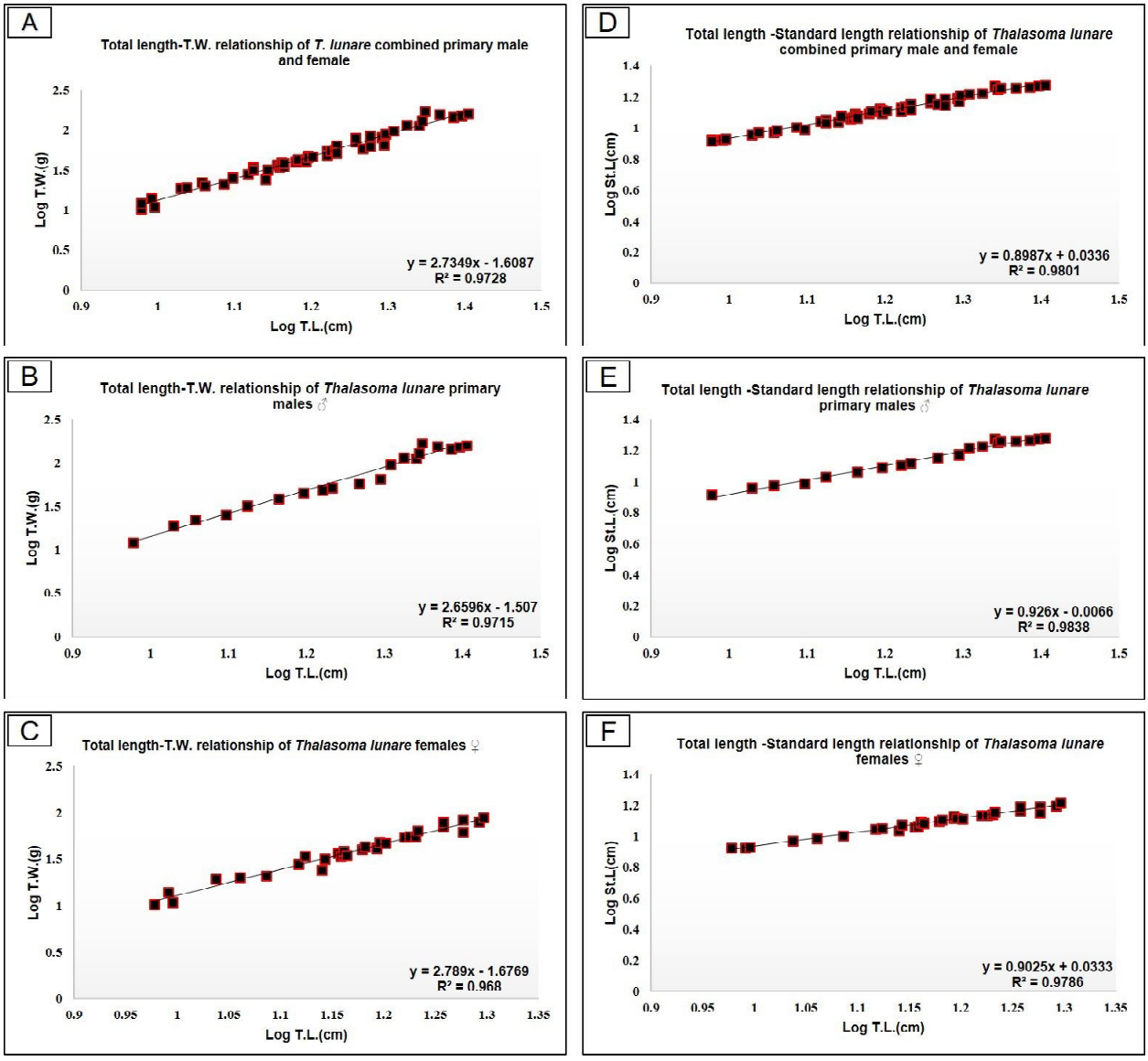

Fig. 1. Length-weight and Length-length relationship of moon wrasse *Thalassoma lunare*: A, B, C: Total length- total weight relationship of combined sexes, primary males and females respectively; D, E, F: Total length-Standard length relationship of combined sexes, primary males and female respectively.

Table 1. Linear regression of total length (TL) and total body weight (TW) relationship in moon wrasse *Thalassoma lunare*

Group	Logarithmic Regression Equation	Log a	b	R^2	r	Type of Growth
Combined (primary males and female)	Log TW= -1.6087+2.7349Log TL	-1.6087	2.7349	0.9728	0.9864	Negative Allometric
Primary Males	Log TW= -1.507+2.6596Log TL	-1.507	2.6596	0.9715	0.9857	Negative Allometric
Females	Log TW= -1.6769+2.789Log TL	-1.6769	2.789	0.968	0.984	Negative Allometric

Log a and b-the parameters of the length-weight relationship R^2-the coefficient of determination.

Table 2. Linear regression of total length (TL) and standard length (St.L) relationship in moon wrasse *Thalassoma lunare*

Group	Logarithmic Regression Equation	Log a	b	R^2	r
Combined (primary males and female)	Log TL= 0.0336+0.8987Log St.L	0.0336	0.8987	0.9801	0.99
Primary Males	Log TL= -0.0066+0.926Log St.L	-0.0066	0.926	0.9838	0.99
Females	Log TL= 0.0333+0.9025Log St.L	0.0333	0.9025	0.9786	0.98

Table 3. Comparison of weight, length, condition factor, and relative condition factor parameters between sexes of *Thalassoma lunare*

Parameters	Combined (primary males and female)	Primary Males	Females	p-values (comparing male and female)
	Mean ±SD	Mean ±SD	Mean ±SD	
TL (cm)	16.26±4.04	18.27±5.01	14.96±2.83	2.683**
St. L(cm)	13.21±2.98	14.51±3.77	12.38±2.15	2.292*
TW (gm)	58.95±41.6	82.93±54.7	43.47±21.66	3.071**
K	2.516±0.58	3.14±0.44	2.11±0.20	11.161**
Kn	1.00±0.11	1.00±0.14	1.00±0.09	0.131 NS

*P < 0.05; **P < 0.01; NS Not significant

Table 4. Observed weight, calculated weight, condition factor (K), and relative condition factor (Kn) of different length groups of moon wrasse *Thalassoma lunare*

Length Group (Cm)		Observed weight(g)	Calculated	Condition factors	
Size class	Mean ± SD.	Mean ± SD.	weight	K	Kn
9-9.9	9.6 ± 0.17	11.88 ± 1.38	12.46	2.38	0.95
10-10.9	10.8 ± 0.1	19.07 ± 0.27	16.84	2.82	1.13
11-11.9	11.4 ± 0.05	21.14 ± 0.97	19.76	2.67	1.06
12-12.9	12.3 ± 0.15	23.21 ± 2.21	24.31	2.38	0.95
13-13.9	13.4 ± 0.31	30.04 ± 3.51	30.89	2.42	0.97
14-14.9	14.4 ± 0.10	36.39 ± 1.94	37.6	2.41	0.96
15-15.9	15.5 ± 0.26	43.67 ± 2.91	45.62	2.38	0.95
16-16.9	16.6 ± 0.09	53.02 ± 3.15	55.23	2.39	0.95
17-17.9	17.0 ± 0.047	57.29 ± 5.03	58.93	2.42	0.97
18-18.9	18.5 ± 0.35	70.86 ± 9.66	73.49	2.4	0.96
19-19.9	19.7 ± 0	78.04 ± 9.84	87.29	2.23	0.89
20-20.9	20.3 ± 0	97.12 ± 0	94.76	2.55	1.02
21-21.9	21.5 ± 0.4	113.93 ± 0.93	110.9	2.56	1.02
22-22.9	22.2 ± 0.1	149.5 ± 20.5	121.07	3.08*	1.23*
23-23.9	23.3 ± 0	157 ± 0	138.2	2.83	1.13
24-24.9	24.6 ± 0.3	148.25 ± 4.25	160.35	2.308	0.92
25-25.9	25.4 ± 0	161 ± 0	175.03	2.29	0.91

The highest value*

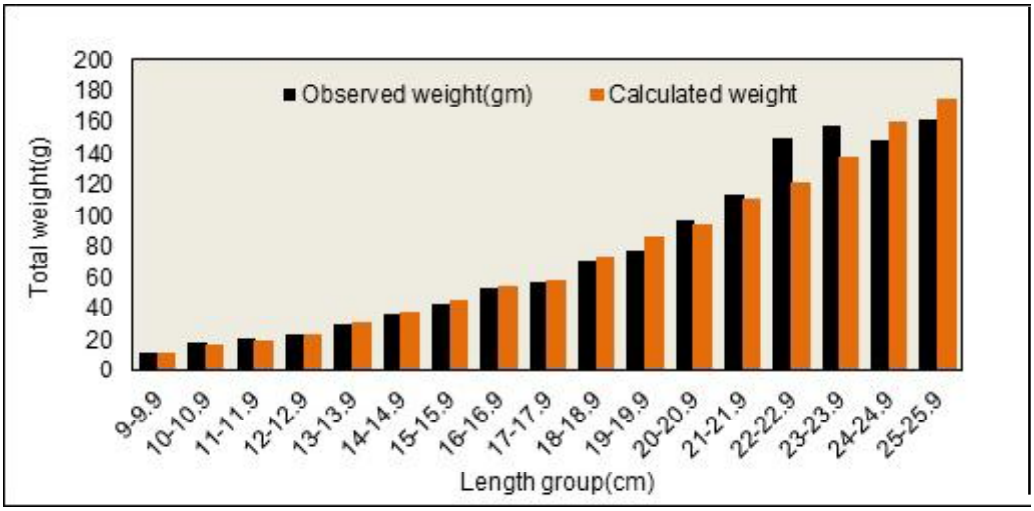

Fig. 2. Observed and calculated weight in different length groups of *Thalassoma lunare*

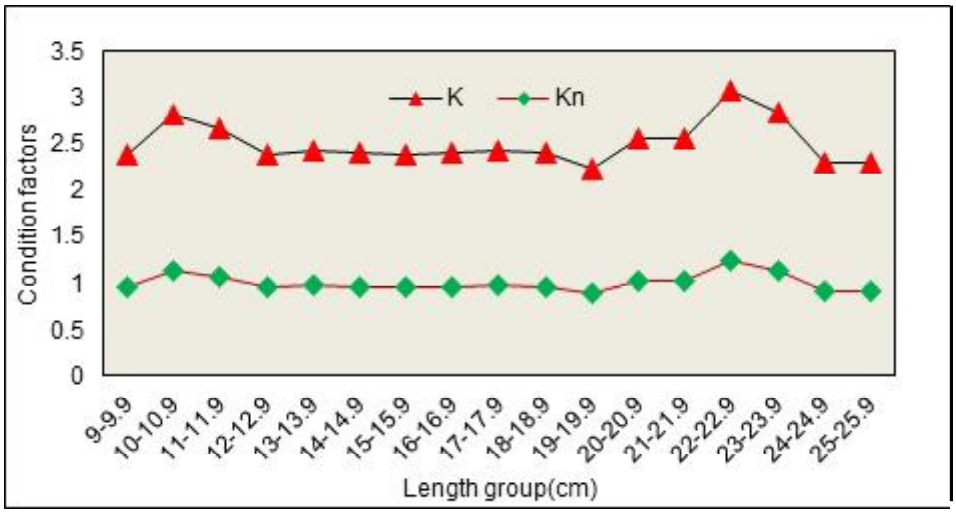

Fig. 3. Condition factor (K) and relative condition (Kn) factor in different length groups of moon wrasse *Thalassoma lunare*

Table 5. Seasonal variations of condition factor (K) and relative condition factor (Kn) of *Thalassoma lunare*

Seasons	Parameters	Combined (Primary Males and female)		Primary Males		Females		p-values (comparing male and female)
		Mean	SD.	Mean	SD.	Mean	SD.	
Monsoon(wet)	K.	2.5	0.29	3.01	0.36	2.24	0.24	5.20**
	Kn.	1.01	0.12	0.96	0.11	1.06	0.11	-1.82 NS
Non-monsoon(dry)	K.	2.46	0.28	3.33	0.49	2.06	0.18	6.98**
	Kn.	0.99	0.11	1.07	0.16	0.98	0.08	1.94 NS

*P < 0.05; **P < 0.01; NS Not significant

non-monsoon seasons (3.01 and 3.33 respectively) was significantly high compared to that of females (2.24 and 2.06, respectively) (P < 0.01) (Table 5).

4. Discussion

This study reveals the first LWR and Kn data on *T. lunare* inhabiting Vizhinjam Bay, southwest coast of India. In this study, the LWR of *T. lunare* showed negative allometric growth, whereas 'b' values were 2.7349 for combined sexes, 2.6596 for primary males, and 2.789 for females. Variations in 'b' values of fish at various localities may be attributed to variations in the environmental conditions of the water body in different regions (Serajuddin *et al.*, 2013). The lack of studies of length-weight relation and condition factor of *T. lunare* makes it challenging to compare our results from Vizhinjam Bay with the same species in different localities. In this study, the 'b' value was slightly higher in females than primary males, and it was probably related to the higher weight of the gonads of females compared to primary males. This is in corroboration with the study of Lanés *et al.* (2012) who observed that the LWR and Kn in females were higher than those in males.

In this study, the total length-standard length relationship was highly significant between primary males and females, and the coefficient of determination (R^2) values range from 0.9786 to 0.9838. The positive correlation in the relationship suggests that the growth performance of *T. lunare* in Vizhinjam Bay was ideal though lack of studies on the length-length relationship for this species, including in Fish Base (Froese and Pauly, 2019), makes it difficult to draw a plausible conclusion.

The values of condition factor 'K' for *T. lunare* fluctuated between 2.23 and 3.08, while the values of relative condition factor varied from 0.98 to 1.23 for the different length groups. Similar results of relative condition factor were also observed by Jisr *et al.* (2018) for three selected fish species (*Liza ramada*, *Oblada melanura*, and *Epinephelus costae)* in two periods: warm (spring, summer) and cold (fall, winter) from Eastern Mediterranean city, Tripoli-Lebanon. In general, the mean value of the relative condition factor is one, indicating that the ecological conditions at Vizhinjam Bay are nearly suitable for the growth of this fish species; Le Cren (1951) reported that the deviation of Kn from one reveals information concerning the differences in food availability and consequence of physicochemical features on the life cycle of fish species.

The values of condition factor 'K' of *T. lunare* females recorded higher value (2.24) during monsoon; it decreased to 2.06 during non-monsoon, indicating loss of weight, and it may be attributed to the ovulation process. Furthermore, it is known that most fishes decrease their feeding activity and depend on their lipid reserves during spawning, which leads to a decrease in condition factor (Lizama *et al.*, 2002). On the other hand, the values of condition factor 'K' of *T. lunare* primary males recorded a lower value of 3.01 during monsoon, and 3.33 during

non-monsoon, which points that primary males gain more weight in the non-monsoon season and the gonads are ready for spermiation. This result is in agreement with the report of Ayoade and Ikulala (2007) who observed that the highest value of the mean 'K' factor (1.92) was recorded during the dry season for *Hemichromis bimaculatus* (Perciformes: Cichlidae). That value was statistically different from the rainy season 'K' factor. Seasonally, the fluctuations of 'K' and 'Kn' values were very negligible in combined (primary male and females). The present study provides essential information on LWR, LLR, and CF of moon wrasse *T. lunare* for fishery biologists for the first time, which could be a valuable contribution for the management of this commercial aquarium fish.

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