Spatial variations in the length – weight relationship and Fulton's condition factor of two commercially important fish species: *Lethrinus olivaceus* (Valenciennes, 1830) (family Lethrinidae) and *Lutjanus lutjanus* (Bloch, 1790) (family Lutijanidae), in Sri Lankan waters

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Abstract

Fulton's condition factor (*K*) and length-weight relationship (LWR) are widely used in fisheries biology for comparing the condition, fatness, well-being of fish and to determine the growth characteristics. The present study aimed to understand the spatial variation in the LWRs and the *K* of *Lethrinus olivaceus* (Valenciennes, 1830) and *Lutjanus lutjanus* (Bloch, 1790) in Sri Lankan waters. The samples of *L. olivaceus* (n=288) and *L. lutjanus* (n=181) were collected from the ecosystem survey conducted in Sri Lankan coastal waters by R/V Dr Fridtjof Nansen from 24thJune to 16thJuly, 2018. The LWRs and *K* were estimated for populations of two species in six different regions. The estimated LWRs for *L. olivaceus* populations in the Northeast, Centraleast, Southeast, South, Southwest and Northwest regions were $W=0.02L^{2.87}$, $W=0.02L^{2.88}$, $W=0.02L^{2.85}$, $W=0.01L^{3.23}$, $W=0.01L^{2.87}$ and $W=0.02L^{2.97}$ respectively. The estimated LWRs for *L. lutjanus* populations in Southeast, South, Southwest regions were $W=0.02L^{2.84}$, $W=0.02L^{2.89}$ and $W=0.02L^{2.97}$ respectively. The mean *K* values of the *L. olivaceus* populations in above regions were 1.39 ± 0.14, 1.32 ± 0.10, 1.31 ± 0.17, 1.32 ± 0.09, 1.24 ± 0.06 and 1.25 ± 0.15 respectively. The mean *K* values of the *L. lutjanus* populations in above regions were 1.57 ± 0.13, 1.43 ± 0.15 and 1.50 ± 0.18 respectively. The *L. olivaceus* populations in Northeast, Centraleast, Southeast regions and all *L. lutjanus* populations exhibited negative allometric growth. *L. olivaceus* populations in Southern region exhibited positive allometric growth while populations in Southwest and Northwest region exhibited isometric growth. The *L. olivaceus* populations in Centraleast, Northeast regions and *L. lutjanus* populations in Southeast regions likely having better condition/well-being.

Key words: Isometric growth, allometric growth, well-being, long face emperor, bigeye snapper

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Introduction

The status of the fish stocks is largely dependent on some of their biological parameters such as length and weight (Hampton, 2000; Fromentin and Fonteneau, 2001).The Length-Weight Relationship (LWR) and different condition factors are important biological parameters to assess the condition of the fish stocks (Bagenal and Tesch, 1978; Hossain, 2010).

The importance of determining LWRs in fish has been emphasized by many studies. LWRs provide information about the growth pattern, general health, habitat conditions, life history, fish fatness and condition, as well as morphological characteristics of the fish (Schneider *et al*., 2000; Froese, 2006). Length and weight measurements together with age data can give information on the stock composition, size at maturity, life span, mortality, growth, and production (Diaz *et al*.,2000; Froese,2006). Furthermore, LWRs are used for deriving the weight from length as direct weight measurements can be difficult and time-consuming in the field (Fafioye and Ayodele, 2018; Mehanna and Farouk, 2021). Apart from this, the LWRs can also be used for deriving comparisons between different stages in life history and between fish populations from regions or habitat groups (Petrakis and Stergiou, 1995; Gonçalves *et al*., 1997). LWRs are expressed in a formula, which allows the estimation of the fish weight (W) using a particular length (L). Values of the exponent '*b*' of that equation provide information on fish growth. When $b = 3$, isometric growth i.e., growth of all body parts at equal rates, is assumed. When the value of '*b*'significantly different from 3, growth is allometric (positive if $b > 3$, negative if $b < 3$) (Froese, 2006; Nehemia *et al*., 2012).

Success of a fish population in a habitat can also be estimated through different condition factors (Richter, 2007). The condition factor of fish has been shown to reflect information on the physiological state of the fish in relation to its welfare (Ighwela *et al*., 2011). It also gives information when comparing two populations living in certain feeding, density, climate, and other conditions; when determining the period of gonadal maturation and when following up the degree of feeding activity of a species to verify whether it is making good use of its feeding source (Wootton,

1990; Ndiaye *et al*., 2015). Among the various versions of the condition factor, the Fulton's condition factor (*K*) is widely used in fish biology and fisheries. It is based on the principle that individuals of a given length, exhibiting higher weight, are in a better condition. It is used for comparing the condition, fatness, or well-being of fish (De Giosa *et al*., 2014). This factor is calculated from the relationship between the weight of a fish and its length, with the intention of describing the "condition" of that individual (Froese, 2006).

The coastal fishery sector in Sri Lanka plays a significant role in the country's economy as it contributes about 48% to the total annual fish production (Ministry of Fisheries, 2020). In the coastal fishery, demersal fish are of major interest both for local consumption and for export market (Ministry of Fisheries and Aquatic Resources, 2020). Species of family Lethrinidae (emperor fish) and family Lutijanidae (snappers) are two of the dominant groups in the demersal fish catch (Maldeniya, 2011; Dalpathadu, 2020). Despite the importance in coastal fisheries, some of the fundamental biological information such as LWRs and condition factor are limited for the fish species of family Lethrinidae and family Lutijanidae in Sri Lankan waters. This study was conducted with the aim of estimating and spatial comparison of the LWRs and Fulton's condition factor (*K*) for different populations of *Lethrinus olivaceus* (Valenciennes, 1830) (family Lethrinidae) and *Lutjanus lutjanus* (Bloch, 1790) (family Lutijanidae) in Sri Lankan waters.

Materials and Methods

The samples were collected from the ecosystem survey conducted in Sri Lankan coastal waters by R/V Dr Fridtjof Nansen from 24th June to 16thJuly, 2018. The territorial waters of Sri Lankan were divided in to six regions: Northwest, Southwest, South, Southeast, Centraleast and Northeast (Figure 1). A total of 288 specimens of *L. olivaceus* and 181 specimens of *L. lutjanus* were recorded during the survey (Table 1). The biological samples for the study were obtained from the ''Super Gisund'' bottom trawl attached to the research vessel. Species identification was done on-board using Allen (1985), De Bruin *et al*. (1994) and Munro (2000). The total length (TL)

(to the nearest 1.0 cm) and total weight (TW) (to the nearest 0. 5 g) of each specimen were measured on-board by respectively the electronic measuring board and the electronic balance mounted in the laboratory of the research vessel.

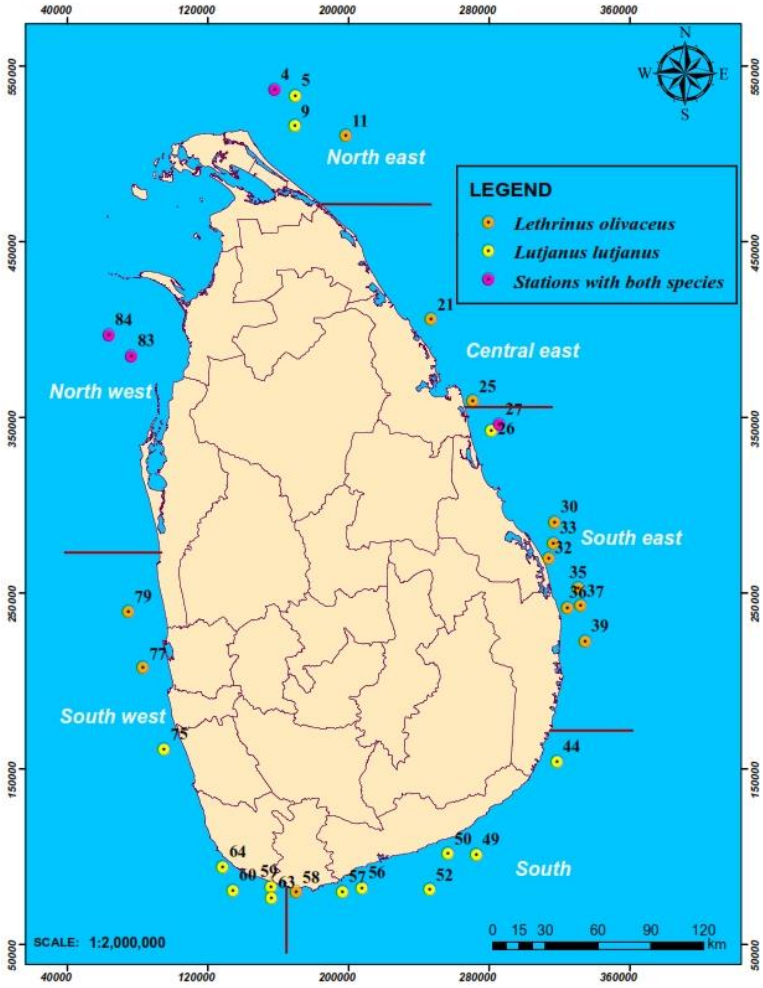

Fig.1. Six regions in Sri Lankan waters and the sampling stations where *L. olivaceus* (LO) and *L. lutjanus* (LL) recorded during the RV Dr Fridtjof Nansen Survey Programme 2018, Leg 3.1. (Regenerated after Krakstad *et al*., 2018).

Table 1. The summery of sample collection of *L. olivaceus* and *L. lutjanus* and average towing time in Sri Lankan waters during the survey.

Region		**North East**	**Central East**	**South East**	**South**	**South West**	**North West**
Species (n)	*L. olivaceus*	45	99	117	11	11	05
	L. lutjanus	_	_	62	89	30	_
Average towing time (min)± SD		30.05	39.08 ± 14.02	26.24 ± 4.89	24.00 ± 3.97	26.55 ± 3.08	22.97 ± 1.70

The LWRs were estimated from the following formula (Le Cren, 1951),

$W = aL^b$ ----------1

where W is total body weight (g), L is the total length (cm), *a* and *b* are the regression coefficients between W and L (Beckman, 1948; Ricker, 1973). The values of constants *a* and *b* were estimated by the least-square linear regression from the log-transformed values of length and weight (Zar, 1984; Fafioye and Ayodele, 2018; Mehanna and Farouk, 2021) given below.

$log\ W = log\ a + b \log L$ ----------2

To confirm whether the values of *b* obtained in the linear regressions were significantly different from the isometric value (i.e.,*b* = 3), the confidence interval (CI) at 95% was estimated (Bagenal and Tesch, 1978). In addition, Student's t-test (Zar, 1984) was used to see if parameter *b* is significantly different from 3 and to identify the type of growth.

The Fulton's condition factor (*K*) which shows the degree of well-being of the fish in their habitat was determined for the populations in each region by using the Equation 3 (Htun-Han, 1978);

$K = 100W/L^3$ ----------3

where W = the weight of the fish (g) and L = the total length of the fish (cm).
Non-parametric Kruskal-Wallis test (*H*) was used to determine the significance of the resulted *K* values of populations in different regions. Post-hoc comparisons were conducted using Wilcoxon rank Tests and Benjamini-Hochberg test with adjusted *p* value. In order to analyse the data and prepare the graphs and charts, Microsoft office 2013 Excel, R studio (version 4.1.3), and SPSS 20.0 software packages were used.

Results

According to the results of the LWRs (Table 2) all the *b* values were significantly different ($p< 0.01$) from the value for the isometric growth of 3, except for the *L. olivaceus* populations thrived in the South west ($t_{(9)} = -1.05$, $p = 0.32$) and North west regions ($t_{(3)} = -1.99$, $p = 0.14$). Accordingly, all the populations of *L. lutjanus*, and the populations of *L. olivaceus* in the Northeast, Centraleast and Southeast regions exhibited a negative allometric growth pattern. The *L. olivaceus* populations in the Southwest and the Northwest regions exhibited an Isometric growth pattern while *L. olivaceus* population in the South region exhibited a positive allometric growth at least during the study period.

Table 2. Biometrics, LWRs, Growth pattern and *K* of *L. olivaceus* and *L. Lutjanus* in six different regions of Sri Lankan waters.

Species	**Region**	**Max TL (cm)**	**Min TL (cm)**	**Mean TL±SD (cm)**	**Max TW (g)**	**Min TW (g)**	**Mean TW±SD (g)**	**LWRs**	**Growth pattern**	***K*±SD**
L. olivaceus	Northeast	45.0	10.0	26.81 ± 6.25	1060.0	10.0	297.56 ± 177.64	$W=0.02L^{2.87}$	-A	1.39 ± 0.14
	Centraleast	65.0	17.5	28.95 ± 9.11	3840.0	84.0	418.15 ± 640.39	$W=0.02L^{2.88}$	-A	1.32 ± 0.10
	Southeast	82.0	15.0	32.09 ± 14.68	6700.0	51.0	694.67 ± 1142.82	$W=0.02L^{2.85}$	-A	1.31 ± 0.17
	South	75.0	51.0	67.18 ± 8.00	6310.0	1710.0	4190.91 ± 1450.38	$W=0.01L^{3.23}$	+A	1.32 ± 0.09
	Southwest	58.0	34.5	46.00 ± 9.31	2500.0	530.0	1339.09 ±759.16	$W=0.01L^{2.87}$	A	1.24 ± 0.06
	Northwest	54.0	25.5	38.30 ± 12.29	1891.0	240.0	854.20 ± 709.93	$W=0.02L^{2.97}$	A	1.25 ± 0.15
L. lutjanus	Southeast	22.0	13.0	15.81 ± 1.72	170.0	40.0	64.03 ± 23.92	$W=0.02L^{2.84}$	-A	1.57 ± 0.13
	South	26.0	13.5	17.56 ± 3.00	224.0	34.0	83.43 ± 43.55	$W=0.02L^{2.89}$	-A	1.43 ± 0.15
	Southwest	30.0	22.0	26.42 ± 2.35	420.0	150.0	283.20 ± 77.17	$W=0.02L^{2.97}$	-A	1.50 ± 0.18

TL – Total Length; TW – Total Weight; SD – Standard deviation; *K* – Fulton's condition factor

The scatter plots between $\log_{10}$TW and $\log_{10}$TL of the LWRs of all populations (Figures 2, 3) showed that there was a strong positive linear relationship between the two parameters, which was confirmed with a coefficient of determination (r^2) of greater than 0.80.

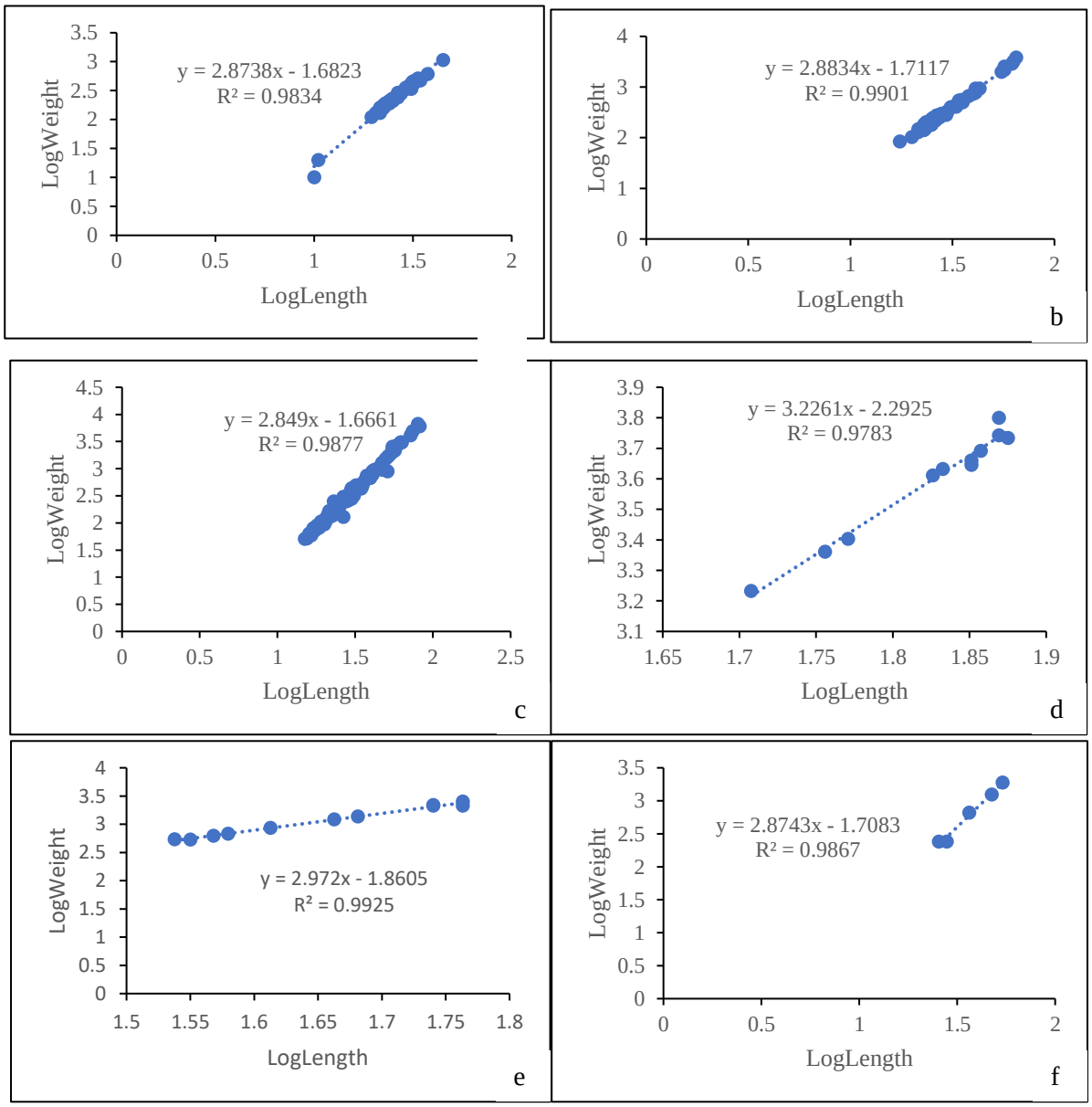

Fig. 2. The graphs of linear regressions obtained from the log- transformed values of total length and total weight for *L. olivaceus* in (a) Northeast region; (b) Central east region; (c) Southeast region; (d) South region; (e) Southwest region; (f) Northwest region of Sri Lanka

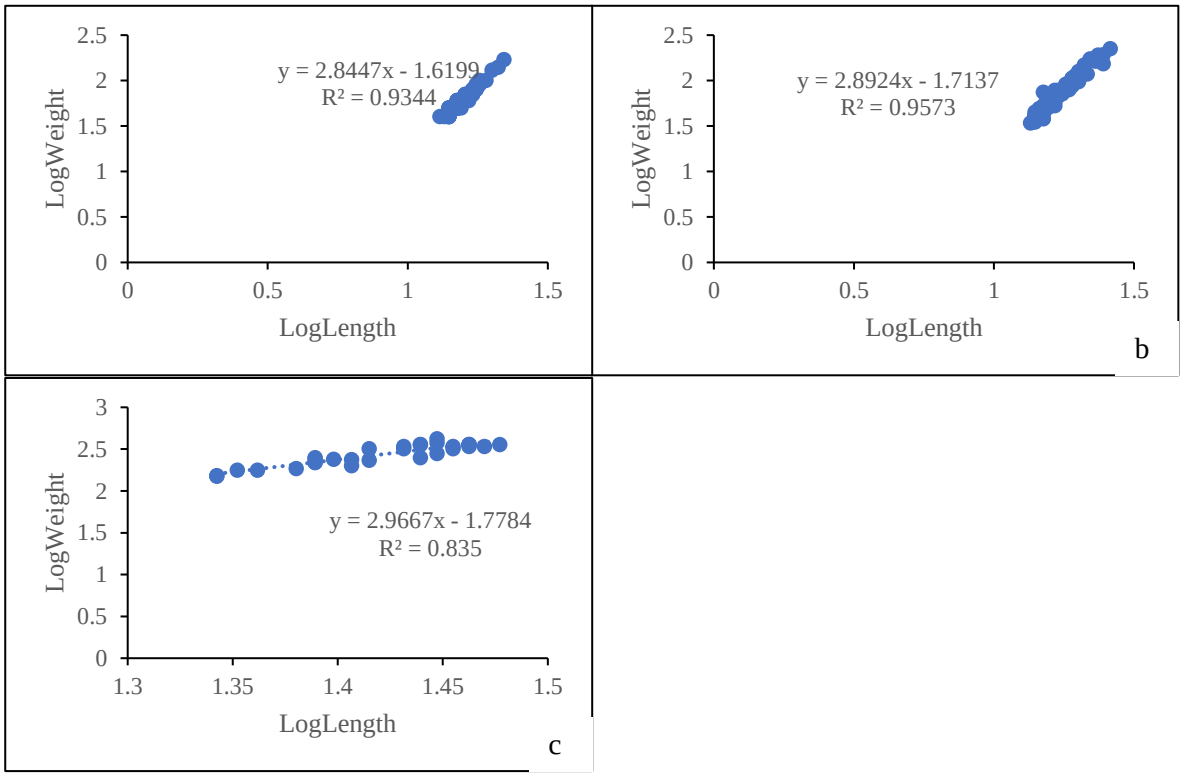

Fig. 3. The graphs of linear regression obtained from the log- transformed values of total length and total weight for *L. lutjanus* in (a) Southeast region; (b) South region; (c) Southwest region of Sri Lanka

There was a significant difference among the mean *K* values of six populations of *L. olivaceus* in Sri Lankan waters ($H_{(5)} = 25.19$, $p < 0.01$). A significant difference of mean *K* values were obtained for the *L. olivaceus* populations between the Southwest – Centraleast ($p = 0.02$), Southwest – Northeast ($p = 0.01$), Northeast – Centraleast ($p = 0.01$) and Northeast – Southeast ($p = 0.01$) regions. The mean *K* values between the populations in other region pairs were not significantly different (Table 3).

Table 3. Statistical comparison (*p* values) of the mean *K* values of six populations of *L. olivaceus* in Sri Lankan waters (significant *p* values are marked with * mark).

Region	Centraleast	Northwest	Northeast	South	Southeast
Northwest	0.3861	-	-	-	-
Northeast	0.0110*	0.1857	-	-	-
South	0.8220	0.3861	0.1247	-	-
Southeast	0.3861	0.4397	0.0073*	0.8789	-
Southwest	0.0224*	0.9130	0.0054*	0.0842	0.1247

Considering the *L. lutjanus* populations in the Sri Lankan waters, a significant difference among the mean *K* values of three populations was obtained ($H_{(2)} = 35.14$, $p < 0.01$). The mean *K* of population in the South region was significantly different than the population in the South east region ($p < 0.01$) while the differences in mean *K* was not significant for other populations (Table 4).

Table 4. Statistical comparison (*p* values) of the mean *K* values of three populations of *L. lutjanus* in Sri Lankan waters (significant *p* values are marked with * mark).

Region	South	Southeast
Southeast	<0.01*	-
Southwest	0.064	0.062

Discussion

The present study has demonstrated the spatial variations in the Fulton's condition factor (*K*), growth pattern and the length-weight relationship of the commercially important two fish species: *L. olivaceus* and *L. lutjanus* in Sri Lankan waters. The *b* values of both species in all studied regions in Sri Lankan waters were within the expected range of $2.5 < b < 3.5$, suggesting that the results of this study are valid

(Froese, 2006). The estimated *a* and *b* values of the LWR and the growth pattern for *L. olivaceus* in this study were in agreement with other studies conducted by Matthews *et al*. (2019); Kamikawa *et al*. (2015) and Ontomwa *et al*. 2018. Considering *L. lutjanus*, the estimated values were in agreement with other studies conducted by Yamagawa (1994) and Letourneur *et al*. (1998).

The *K* is an indicator of the healthy status of the fish over time and hence acts as an index reflecting interactions between biotic and abiotic factors in the physiological condition of fishes (Lizama *et al*., 2002; Tesfaye and Tadesse, 2008).The significantly higher *K* values of the populations of *L. olivaceus* in the Central east and North east regions while *L. lutjanus* population in the South east regions might attributed to the better environmental conditions which could enhanced the well-being of the populations of the two species in those regions (Le Cren, 1951; Ontomwa *et al*., 2018).Some studies have proven that the *K* could be lower in the larger/older fishes of the same species due to some health problems and increasing sensitivity to ambient surroundings (Percin and Akyol, 2009; Jin *et al*., 2015). Considering the mean TL and the mean TW of the populations with significant *K* values, relatively smaller sized fish could be identified in the samples (Table 2). Thus, the availability of high proportion of smaller/younger fish in the sample might be another possible reason for resulting a significantly higher *K* values for the population of *L. olivaceus* in the Central east and North east regions while *L. lutjanus* population in the South east regions. However, it should be noted that some other factors such as fullness of the stomach (Percin and Akyol, 2009), food supply and parasitism (Le Cren, 1951) may also affect the *K* of fish populations.

The parameters of LWRs indicate the allometric growth as well as isometric growth of the *L. olivaceus* populations while only allometric growth for the *L. lutjanus* in the studied regions (Table 2). Tesch (1971) stated that the difference in the growth behaviours of a fish species might be attributed to the observed length ranges of the specimens considered. As the mean TL of the populations of each species differed from each other, the differences in the TL of the specimens may be the reason of having different growth patterns for the *L. olivaceus* and *L. lutjanus* populations in

the spatial scale. Furthermore, the variations in the '*b*' of the LWRs of a fish species within a season could be attributed to the combination of one or several factors such as fish physiology, growth phase, sex, sexual maturity, stomach fullness, sampling size, habitat, feeding rate, diet, and health (Le Cren, 1951; Wooten, 1998; Froese *et al*., 2011; Mondol *et al*., 2017).

Conclusion

The population of *L. olivaceus* in the Central east and North east regions and *L. lutjanus* populations in the South east regions likely having better condition/well-being than their counterparts who lived in other regions in Sri Lankan waters. The populations of *L. olivaceus* exhibited all three growth patterns; negative allometric, positive allometric and isometric growth while all the *L. lutjanus* populations exhibited only negative allometric growth in same sampling period in Sri Lankan waters. The study attempted to address the issues of lacking the basic parameters of *L. olivaceus* and *L. lutjanus* in different regions in Sri Lankan waters and growth phases over those regions. The findings of the study related to *L. olivaceus* and *L. lutjanus* would be beneficial for fishery biologists and conservationists to impose adequate regulations for sustainable fishery management and conservation of biodiversity in respective regions. Although basic information on LWRs and *K* values are provided, the reasons behind the variations of such parameter values require further studies; the explicit relationship between morphological characteristics and environmental changes is yet to be revealed.

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