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MD. MOSHIUR RAHMAN

NUR ASMA ARIFFIN

YING GIAT SEAH

TUN NURUL AIMI MAT JAAFAR

AHASAN HABIB

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Length-weight relationships and relative condition factors of three coral-associated *Lutjanus* species from Terengganu waters of the South China Sea, Malaysia

Md Moshiur RAHMAN[1,2], Nur Asma ARIFFIN[1], Ying Giat SEAH[1,3], Tun Nurul Aimi MAT JAAFAR[1], Ahasan HABIB[1,*]

[1]Faculty of Fisheries and Food Science, Universiti Malaysia Terengganu, Terengganu, Malaysia
[2]Faculty of Fisheries, Sylhet Agricultural University, Sylhet, Bangladesh
[3]Fish Division, South China Sea Repository and Reference Centre, Institute of Oceanography and Environment, Universiti Malaysia Terengganu, Terengganu, Malaysia

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Abstract: The present study offers the first report of length-weight relationships (LWRs) and relative condition factor (K_n) of coral-associated snapper fishes namely: *Lutjanus johnii, L. quinquelineatus*, and *L. xanthopinnis* collected from Pulau Kambing fish landing port, Terengganu waters of South China Sea, Malaysia. This study also offers a new maximum total length of 26.8 cm (standard length of 21.3 cm) for *L. xanthopinnis*. A total of 861 specimens were collected monthly from March 2022 to February 2023 that were caught by using different types of fishing gear such as gill nets (mesh size 45–48 mm), hooks (numbers 9–12), and trawl nets (cod end mesh size 38 mm). In LWRs the growth coefficient b value was calculated at 2.602, 2.962, and 3.051, and the coefficient of determination r^2 value 0.948, 0.906, and 0.961 for *L. johnii*, *L. xanthopinnis*, and *L. quinquelineatus*, respectively. The student's t-test showed *L. johnii* had a negative allometric growth pattern. On the other hand, *L. quinquelineatus* and *L. xanthopinnis* showed an isometric growth pattern. The K_n values for *L. johnii*, *L. quinquelineatus*, and *L. xanthopinnis* were 1.005, 1.030, and 1.024 which indicates they are in a state of healthy growth. LWRs data for three *Lutjanus* species from the Malaysian South China Sea can be used for fisheries research and management of stocks.

Key words: Marine fishes, snappers, new maximum length, length-weight relationships, condition factor

1. Introduction

Fisheries assessments extensively rely on length-weight relationships (LWRs) and relative condition factors (K_n) because of their insights into fish growth, health, and efficiency in their natural marine ecosystem (Jisr et al., 2018; Dinh et al., 2022). The LWRs are of significant relevance in fisheries sciences and management (Mouludi-Saleh et al., 2023), revealing fish growth trends and facilitating future studies of fish populations and stocks (Mehanna and Farouk, 2021). In addition, LWRs are a vital tool for stock distinction, ecological models, yield, and biomass prediction (Froese, 2006) and contribute baseline data for conservation measures (Ortega-Garcia et al., 2017). The condition factor is an additional significant indicator of fish that is used to determine the degree of well-being status (Bagenal and Tesch, 1978) and also indicates the suitability of water bodies for fish growth (Yousuf et al., 2023). This article assessed the relative condition factor originating from length-weight analysis (Le Cren, 1951). K_n evaluates the divergence of a living being from the sample's average weight to assess the favorable marine environment for the growth of fish (Mensah, 2015). K_n value equal to or nearly 1, it is considered that fish species have a general level of fitness (Ragheb, 2023). Generally, several biotic and abiotic factors, including food availability, water quality, age, size, sex, and gonad development stage, affect LWRs and condition factors (Kuriakose, 2014).

LWRs of fisheries resources have drawn more consideration inside the broad South China Sea (Perkins et al., 2019) including Terengganu waters, Malaysia (Habib et al., 2021). Terengganu is one of the major fish-landing states, located east of the Malay Peninsula and facing the South China Sea (Sulaiman and Saat, 2017). Yet, there is a lack of biological data on fish in this region. However, LWRs and well-being data on the *Lutjanus* species are rare in Malaysia. Therefore, acquiring information or data related to fish growth types, such as LWRs, is necessary to make

* Correspondence: a.habib@umt.edu.my

fisheries stock assessments. This data is crucial for fisheries management and conservation. Hence, all examined specimens are considered the least concern (LC) per IUCN Red List except *L. xanthopinnis,* which is data deficient (DD).

This present study aims to offer first-time and updated data on LWRs and K_n of three coral-associated *Lutjanus* species collected from Terengganu waters.

2. Materials and methods

Specimens of the three coral-associated snappers viz., *L. johnii, L. quinquelineatus*, and *L. xanthopinnis* were sampled monthly from March 2022 to February 2023 from Pulau Kambing fish landing port, Terengganu waters of the South China Sea, Malaysia (Figure). Fresh specimens were collected using various types of fishing gear, i.e. gill nets, hooks and trawl nets. Gill nets are composed of nylon netting with a mesh size of 45 to 48 mm used in 5 to 20 m depth range to catch fish like *L. quinquelineatus* and *L. xanthopinnis*. At the same time, anglers in this region use hooks with numbers 9 through 12 to angling for *L. johnii* in water deeper than 50 m. In addition, some samples of studied fishes were taken with trawl nets having 38 mm cod end mesh at depths of 20 to 40 m. The obtained samples were stored in iced and transported to the Fisheries Science Laboratory, Universiti Malaysia Terengganu (UMT) for further analysis and identified using multiple systematic features mentioned by Allen (1985) and Iwatsuki et al. (2015).

The total length, from mouth to the tip of the caudal fin was measured on the board to the nearest 0.1 cm and was weighted with a digital electronic balance to the nearest 0.1 g.

The power equation, $BW=a \times TL^b$, (Le Cren, 1951) for estimating the correlation between length and weight; where BW is the total body weight (g), TL is the total length (cm), **a** is the regression intercept, **b** is the growth coefficient (Froese, 2006). The growth coefficient b represents fish health and growth. When b = 3, the fish's length and weight increase isometrically (Santos et al., 2002). If b > 3 (positive allometric) weight rises with length, making the fish larger; and if b < 3 (negative allometric)

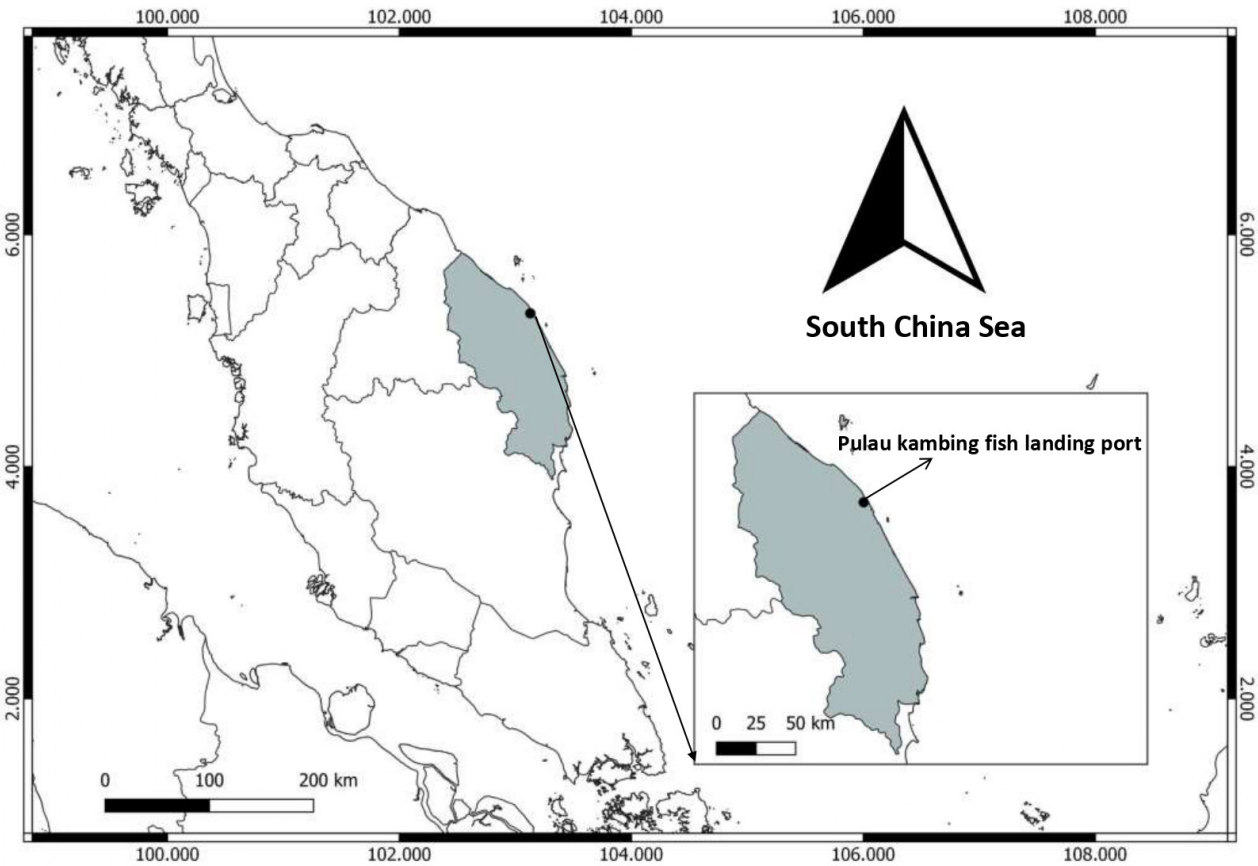

Figure. Map of sampling sites PulauKambing, Terengganu waters of South China Sea, Malaysia.

fish will be narrower (Jones et al., 1999). In the present study, r^2 (value around 1 implies a more efficient model) and K_n was also assessed. The K_n was estimated using the formula developed by Le Cren (1951), which is stated as follows: where W = observed weight (g) of studied fish and W_c = calculated fish weight resulting from LWRs. This study uses K_n to determine the species condition because when K_n is above or equal to one, the fish is in healthy growth status; when it is less than one, it is in bad growth status. The student's t-test was used to determine whether the actual b-value deviates from the predicted value of 3 (i.e. $b = 3$, $p < 0.05$). Regression analysis was used to determine the 95% confidence intervals for 'a' and 'b'. All statistical analysis was carried out using Excel 2010 and PAST 4.09 (Hammer et al., 2001).

3. Results

A total of 861 fish specimens were sampled. Descriptive statistics with sample size, length and weight range of each species, estimated length-weight variables of a and b, coefficient of determination (r^2) and K_n of three coral-associated snapper fish from Terengganu waters of South China Sea, Malaysia are summarized in Table 1. This study offered first time LWRs data for *L. johnii*, *L. quinquelineatus*, and *L. xanthopinnis* from Malaysia. In addition, a maximum TL for *L. xanthopinnis* of 26.8 cm (standard length of 21.3 cm) reported in this study as per FishBase database (Froese and Pauly, 2022). In the current study, calculated a, b, and r^2 values were 0.066, 0.014, 0.017; 2.602, 3.051, 2.962; and 0.948, 0.906, 0.961 for *L. johnii, L. quinquelineatus*, and *L. xanthopinnis*, respectively. Lastly, the mean K_n value for *L. johnii, L. quinquelineatus*, and *L. xanthopinnis* was 1.005, 1.030, and 1.024.

4. Discussion

Information on the LWRs and condition factors of the *Lutjanus* species in Malaysian South China Sea is scarce. This is the first comprehensive report of the LWRs for *L. johnii*, *L. quinquelineatus*, and *L. xanthopinnis* from Malaysia. The r^2 values were more than 0.9 (Table 1) for all studied specimens, indicating the reliable regression analysis model. The growth coefficient values b of LWRs were 2.5 to 3.5, which was anticipated by Carlander (1969) and Froese (2006) for every species. Regarding the pattern of growth; *L. johnii* showed negative allometric growth, it implies that fish become slenderer as their weight increases, but on the other hand *L. quinquelineatus* and *L. xanthopinnis* showed isometric growth that reveals fish length and weight increase isometrically (Table 1). The value of b varies due to several extrinsic (season, habitat, food availability, etc.) and intrinsic (sex, age, gonad maturation, diet, level of stomach fullness, genetic makeup, etc.) factors (Ali et al., 2016; Hanif et al., 2020). The present study findings are consistent with previous studies conducted in different regions (Table 2) (Alavi-Yeganeh et al., 2016; Mehanna et al., 2017; Velamala et al., 2020) except *L. xanthopinnis*.

Mean calculated K_n values for the *L. johnii, L. quinquelineatus*, and *L. xanthopinnis* were 1.005, 1.030, and 1.024 in this present study, as presented in Table 1, which indicates they are in a state of healthy growth. As per Anderson and Newmann (1996), and Muchlisin et al. (2010), it is recommended K_n values below 1.00 reveal high predator density or poor prey availability, whereas K_n values above 1.00 suggest low predator density or prey surplus. An additional claim made by Muchlisin et al. (2017) is that when K_n is 1, there is still a balance of prey and predators, the waterways are in a good state, and fish can grow. Jisr et al. (2018) also concluded that K_n is higher or equal to 1 when the fish has adequate food to grow at its best. Normally, the difference between K_n and 1 reveals something about food availability changes and the effects of physicochemical traits on fish species life cycles (Le Cren, 1951).

5. Conclusion

In conclusion, length-weight data is an essential component of FishBase. The current study provides the first data on LWRs and K_n for three coral-associated *Lutjanus* species from the Malaysian South China Sea. Also, it offers new LWRs data for previously misidentified species, i.e. *L. xanthopinnis*. All of this fundamental biological information will be highly beneficial for subsequent research on population dynamics and will guide fish biologists to manage the capture fisheries in this region.

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Table 1. Descriptive statistics, estimated length weight variables, and relative condition factor of three coral-associated *Lutjanus* species from Terengganu waters of South China Sea, Malaysia sampled during March 2022 to February 2023.

Species	N	Sex	IUCN status	TL (cm)	BW (g)	Regression parameters			CI of b	CI of a	Growth pattern	K_n	
				Range	Range	a	b	r^2				Range	Mean
Lutjanus johnii (*Bloch*, 1792)	129	C	LC	41.7–74.7	1015.2–5310.3	0.066	2.602	0.948	2.499–2.711	0.053–0.079	Negative Allometric	0.816–1.223	1.005
	61	M		41.7–70.9	1015.2–4261.1	0.115	2.460	0.946	2.302–2.612	0.099–0.129		0.822–1.182	1.011
	68	F		45.3–74.7	1310.9–5310.3	0.044	2.699	0.952	2.559–2.856	0.041–0.047		0.837–1.214	1.025
Lutjanus quinquelineatus (Bloch, 1790)	237	C	LC	14.3–26.7	38.6–316.8	0.014	3.051	0.906	2.920–3.174	0.011–0.017	Isometric	0.785–1.532	1.030
	119	M		14.3–26.7	38.6–316.8	0.014	3.063	0.936	2.913–3.209	0.011–0.017		0.797–1.363	1.003
	118	F		14.9–22.1	58.7–185.1	0.015	3.024	0.863	2.793–3.271	0.012–0.018		0.801–1.564	1.043
***Lutjanus xanthopinnis* Iwatsuki, Tanaka & Allen, 2015**	**495**	**C**	**DD**	**15.3–26.8**	**53.5–279.8**	**0.017**	**2.962**	**0.961**	**2.906–3.011**	**0.013–0.021**	**Isometric**	**0.869–1.209**	**1.024**
	284	**M**		**16.0–26.8**	**59.5–279.8**	**0.018**	**2.948**	**0.968**	**2.883–3.005**	**0.014–0.022**		**0.884–1.153**	**1.008**
	211	**F**		**15.3–25.2**	**53.5–279.4**	**0.015**	**2.991**	**0.940**	**2.892–3.099**	**0.012–0.018**		**0.906–1.265**	**1.066**

Descriptive statistics, estimated length weight variables, and relative condition factor of three coral-associated *Lutjanus* species from Terengganu waters of South China Sea, Malaysia (N: number of samples; C: combined sex; M: males; F: females; LC: least concern; DD: data deficient; TL: total length; BW: total body weight; a: exponent; b: growth coefficient; r^2: coefficient of determination; CI: confidence intervals; and K_n: relative condition factor. **Bold:** new maximum total lengths that exceed those in FishBase).

Table 2. The a, b, and r^2 values of LWRs of selected species from previous research conducted in different regions of the world.

Reference	Species	Length Type	Sex	a	b	r^2	Location
Alavi-Yeganeh et al., 2016	*L. johnii*	TL	Combined	0.039	2.73	0.96	Persian Gulf
Velamala et al., 2020	*L. johnii*	TL	Combined	0.045	2.74	0.97	India
Mehanna et al., 2017	*L. quinquelineatus*	TL	Combined	0.011	3.09	0.95	Egypt
Velamala et al., 2020	*L. quinquelineatus*	TL	Combined	0.004	3.49	0.99	India
Velamala et al., 2020	*L. xanthopinnis*	TL	Combined	0.035	2.71	0.96	India

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