Length-weight relationships of Indian squid, *Uroteuthis duvaucelii* and Bigfin reef squid, *Sepioteuthis lessoniana* from the coastal waters of Langkawi Island, Malaysia

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Abstract. Studies on the length-weight relationship (LWR) are crucial for understanding the growth, health, and ecological dynamics of fish and cephalopod populations. This study investigates how weight varies relative to its length. There have been limited studies on LWR in cephalopods, especially in Malaysia. This research aimed to explore the size frequency, length-weight relationship and relative condition factor of *Uroteuthis duvaucelii* and *Sepioteuthis lessoniana* in Langkawi Island. The samples were caught using squid cast net with a mesh size of 1.0 to 1.5 inch. Linear regression analysis was used to established the LWR of the species. Maximum mantle length for *U. duvaucelii* was recorded to be 213 mm long, and 98 mm for *S. lessoniana.* The growth coefficient *b* values calculated for *U. duvaucelii* and *S. lessoniana* were 2.068 and 2.3839, respectively, indicating negative allometric growth in this region. The mean relative condition factor (K_n) obtained for *U. duvaucelii* and *S. lessoniana* was similar, approximately 1.0 ± 0.1 suggesting favorable life conditions. The findings from this study are valuable in managing and conserving these species in Langkawi Island, Kedah.

1 Introduction

Uroteuthis duvaucelii (Indian squid) and *Sepioteuthis lessoniana* (bigfin reef squid), both from the family Loliginidae, inhabit the waters around Langkawi Island, Kedah. Among these, *U. duvaucelii* is the most frequently captured species by local fishermen using cast net with surface lamps as fish aggregating devices (FADs). Artisanal fishermen in this region primarily target these species, relying on their year-round availability for their main source of monthly income. In 2022, the production of *U. duvaucelii* and *S. lessoniana* were 1,116 and 239 mt respectively [1] which contributed about 60% of the total production of these squid in Malaysia. These indicates that Langkawi Island serves as a significant

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reproduction area for squid, underscoring its ecological and economic importance. Consequently, it is imperative to conduct comprehensive studies on the length-weight relationship (LWR) of these species to enhance understanding of the available stock.

The LWR is a standard method that provides robust biological insights by establishing a mathematical correlation between length and weight. This study demonstrates deviations from expected weight within defined length groups, indicating variations in fatness, general wellbeing, gonad development, and environmental suitability for the fish [2]. The relative condition factor serves as an index reflecting the interplay between biotic and abiotic factors on the physiological state of fish, providing insight into the population's welfare throughout different life stages [3].

There were studies on LWR of squid in north coast of Java [4], southern Gulf of Thailand [5], India [6-7] coastal waters of Bangladesh [8] and currently in west coast of Malaysia [9]. However, no record of LWR were available for *U. duvaucelii* and *S. lessoniana* specifically in Langkawi Island to represent the stock of both species in the area. Therefore, the present study was conducted to study the size frequency, length-weight relationship and relative condition factor (K_n) of these two species. Given that the LWR and K_n are precise indicators for assessing fish and squid welfare, this study will furnish essential information for the sustainable management of the subject species.

2 Materials and method

The study was conducted in Zone A (one to five nautical miles from shore) waters off Langkawi Island, Kedah (Fig. 1) and were carried out from November 2023 to January 2024. The fishing method involved was using squid cast net and surface lamps. Green light was used to attract squid for 8-11 hours overnight. With the help of yellow and red supporting light, the squid was caught using cast net from time to time. The cast nets used were made up of nylon and weighed between 6.4 and 7.6 kilograms with a mesh size of 1.0 to 1.5 inch. The total length of cast net was 4.05 m with nylon strand diameter range from 0.28 mm to 0.35 mm. The LWRs were established using linear regression analysis (least square method). LWRs parameters were determined by utilizing the following equation [2]:

$$W = aL^b \quad (1)$$

Upon applying a logarithmic transformation to the length-weight data, the resulting equation can be represented as:

$$\log W = \log a + b \log L \quad (2)$$

where:

W = Weight of the squid
L = Length of the squid
a = A constant that represents the weight for a unit length
b = An exponent that describes how weight changes with length

The coefficient b values were analyzed using standard assumptions: isometric for $b = 3$, negative allometric for $b < 3$, and positive allometric for $b > 3$.

The relative condition factor, K_n was calculated using this formula [2]:

$$K_n = W/W' \quad (3)$$

where:

W = Observed weight of the fish.

W′= Expected weight (based on equation $W = aL^b$)

The K_n value signifies various conditions, where a K_n value greater than 1.0 indicates excellent life conditions, a K_n value equal to 1.0 signifies good life conditions, and a K_n value less than 1.0 indicates poor conditions. Both linear regression and relative condition factor (K_n) analysis were analysed using Microsoft Excel software.

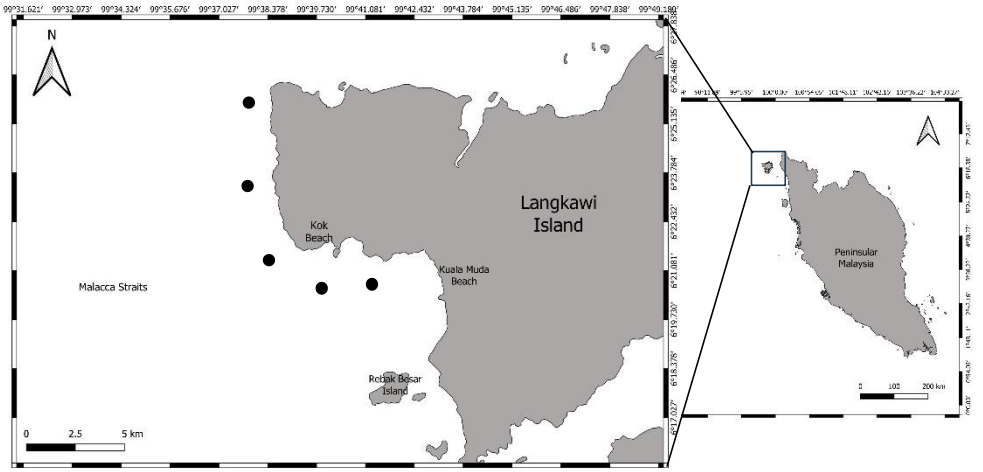

Fig. 1 : Sampling location in Langkawi Island, Kedah

3 Results and discussion

The observation of catch composition during the study period showed that a total of 997 squid samples were obtained, comprising 857 Indian squid, *Uroteuthis duvaucelii* and 140 Bigfin reef squid, *Sepioteuthis lessoniana*. The mean mantle length (±SE) of *U. duvaucelii* was 89.7 ± 1.2 mm, ranging from 35 – 213 mm with weight ranging from 3.4 – 134.3 g. The results indicated that 61 – 80 mm length class was numerically dominant and the largest *U. duvaucelii* caught was 213 mm long (Fig. 2). The maximum length of *U. duvaucelii* in the current study closely resembled the findings of prior studies conducted by [8, 10, 11]. In those studies, the recorded maximum lengths were 285 mm, 228 mm, and 163 mm, respectively.

While for *S. lessoniana*, the total mantle length ranged from 50 – 98 mm (mean 73.1 ± 0.9 mm) and the body weight ranged from 98 – 13.4 g. The largest *S. lessoniana* measured was 98 mm, with the length class 66 – 85 mm was numerically dominant (Fig. 3). Comparing to the study conducted by [12-14], it was observed that the maximum lengths of *S. lessoniana* captured exceeded those reported in the current study, measuring 290 mm, 244 mm, and 321 mm respectively. Differences in the maximum mantle length observed in the current study compared to the previous study could be due to a smaller sample size and the use of different sampling techniques.

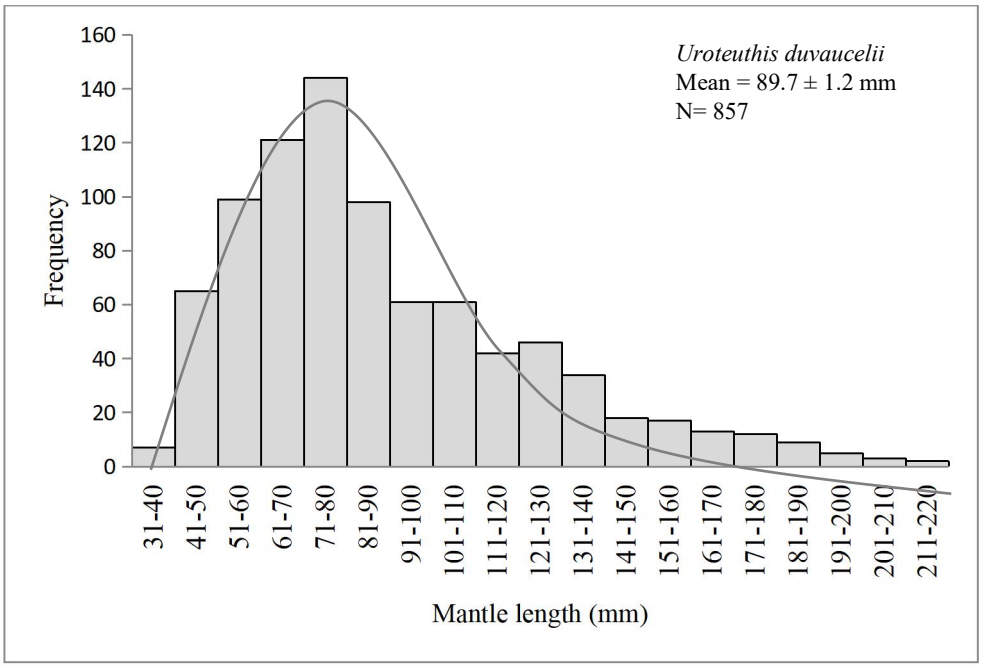

Fig. 2. Length frequency distribution of the Indian squid, *Uroteuthis duvaucelii*

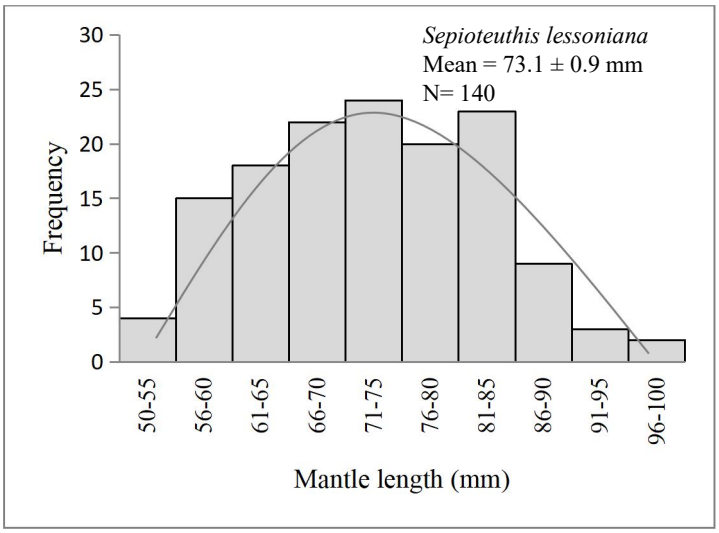

Fig. 3. Length frequency distribution of the Bigfin reef squid, *Sepioteuthis lessoniana*

The length-weight relationship analysis for combined sexes on both species were presented on a parabolic and logarithmic scale as shown in Figures 4 – 7. The regression equation for *U. duvaucelii* was estimated to be log W = 2.068 log L – 2.569 (r^2 = 0.9512). The parabolic equation obtained was $W = 0.0027\ L^{2.068}$. While the regression equation for *S. lessoniana* was estimated to be log W = 2.3839 log L – 2.921 (r^2 = 0.8888) and the parabolic equation derived for this species was $W = 0.0012\ L^{2.3839}$.

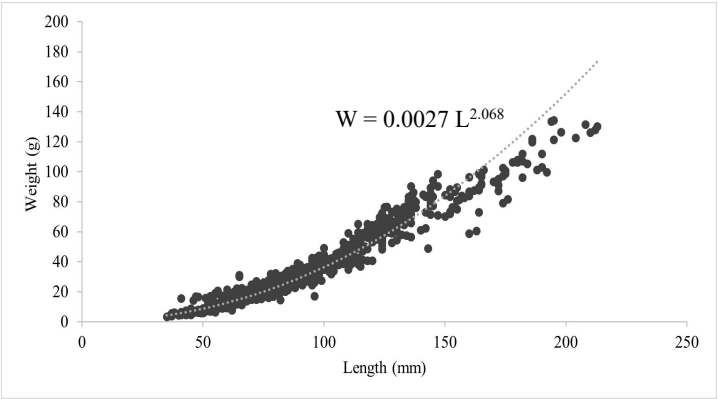

Fig. 4. Length-weight relationships of the Indian squid, *Uroteuthis duvaucelii*

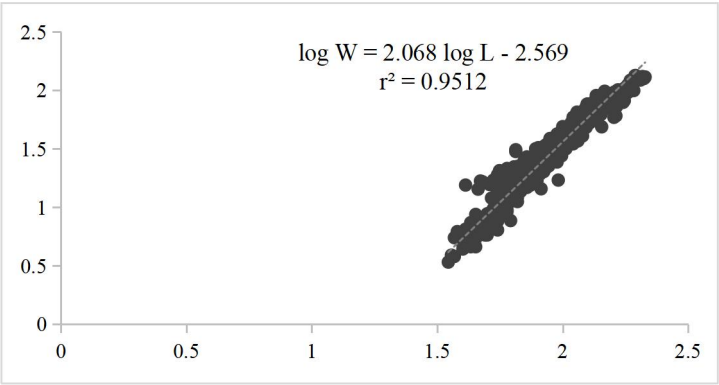

Fig. 5. Length-weight relationships of the Indian squid, *Uroteuthis duvaucelii* on logarithmic scale.

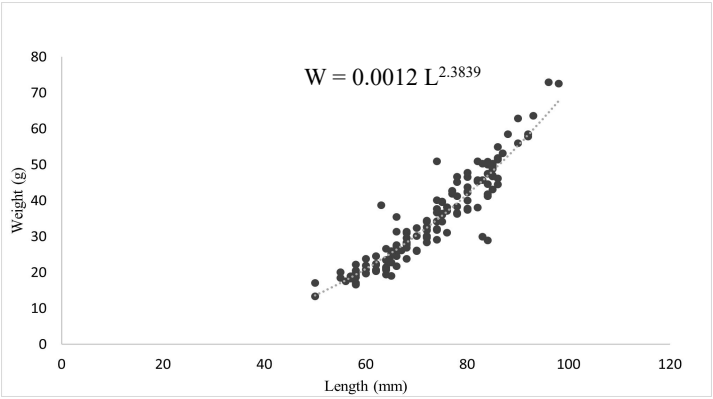

Fig. 6. Length-weight relationships of the Bigfin reef squid, *Sepioteuthis lessoniana*

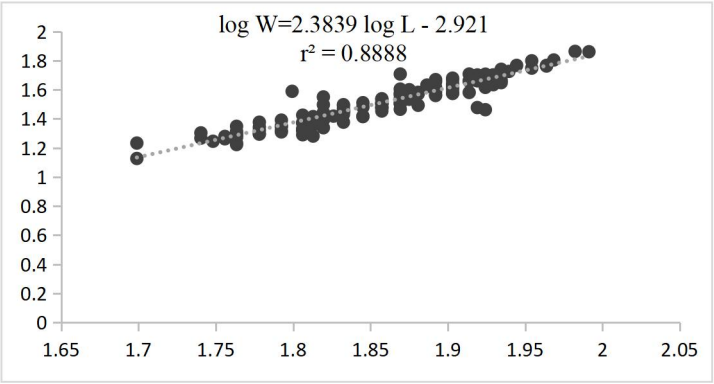

Fig. 7. Length-weight relationships of the Bigfin reef squid, *Sepioteuthis lessoniana* on logarithmic scale.

The LWR analysis revealed that combined sexes of *U. duvaucelii* exhibited a *b* value of 2.068 (b < 3), indicating negative allometric growth. This finding aligns with [6] and [15], reported *b* values were less than 3 showing patterns of negative allometric growth in *U. duvaucelii*. Furthermore, this study's findings also consistent with [8], who found a growth coefficient lower than ismoteric value which is *b* = 1.377 for the Indian squid, *U. duvaucelii*, signifying negatively allometric. In contrast, [16] reported a coefficient *b* value of 3.00, showing isometric growth in their study on Indian squid from Pakistani waters.

The LWR analysis for *S. lessoniana* yielded *b* values of 2.3839 (b < 3), also suggesting negatively allometric growth. This observation is consistent with earlier studies by [17] and [18], which reported *b* values of 2.84 and 2.459, respectively. The present study revealed that the *b* values obtained for both species *U. duvaucelii* and *S. lessoniana* significantly deviated from the ideal value of 3, denoting negative allometry, accompanied by a siginificant positive correlation between length and weight, r=0.9755 ($p < 0.005$) for *U. duvaucelii* and r=0.9408 ($p < 0.005$) for *S. lessoniana.* The departure of the *b* value from 3 suggests that the growth pattern for both *U. duvaucelii* and *S. lessoniana* becomes less robust as length increases. One factor contributing to the lower *b* values observed in squids is their body shape, which is more torpedo-like compared to fish [19]. Additionally, deviation in growth patterns may be influenced by seasonal fluctuations in environmental parameters, variations in food availability and differences in health conditions [8, 18].

Overall, the results of this study confirmed the prevalence of negative allometric growth patterns among these cephalopod species, as indicated by their respective *b* values in the length-weight relationships.

Table 1. Descriptive statistics, LWRs and Kn values for *U. duvaucelii* and *S. lessoniana*

Species	N	Total mantle length (mm)		Total body weight (g)		Regression parameters				Relative Condition Factor (Kn)	Gowth Pattern
		Min	Max	Min	Max	*a*	*b*	r	r^2		
Indian squid *Uroteuthis duvaucelii*	857	35	213	3.4	134.3	0.0027	2.068	0.9755.	0.9512	1.0 ± 0.01	Negatively allometric
Bigfin reef squid *Sepioteuthis lessoniana*	140	50	98	13.4	73	0.0012	2.3839	0.9408	0.8888	1.0 ± 0.01	Negatively allometric

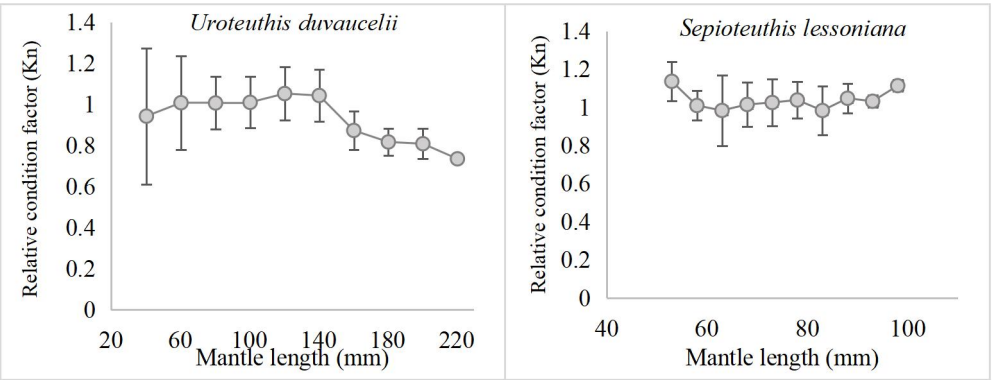

Fig. 8. Variation of relative condition factor (K_n) in different size classes in *U. duvaucelii* and *S. lessoniana*

Descriptive statistics, length-weight relationship and relative condition factors for *U. duvaucelii* as well as *S. lessoniana* are presented in Table 1. The results demonstrated that mean relative condition factor obtained for *U. duvaucelii* and *S. lessoniana* were similar with the value of 1.0 ± 0.1. Figure 8 illustrates the variation of relative condition factors across different size classes of *U. duvaucelii* and *S. lessoniana*. The lowest K_n values for *U. duvaucelii* and *S. lessoniana* were observed in the 211-230 mm and 81-85 mm size classes, respectively (Fig. 8). The reason behind this may be due smaller sample size of squid caught in the size class. According to [20], the fluctuation of condition factor in length class of both species could be attributed to gonadal maturation or other physiological changes. Despite this, the mean K_n values for both species were equal to 1, indicating that both populations are in good condition. According to [21], the condition factor serves as a key indicator of the well-being of a population throughout its life cycle stages. Typically, condition factor values assess the "plumpness" or "robustness" of fish and other aquatic species. The condition factor of a species is regarded as a comprehensive indicator, reflecting not only the biological attributes like growth, well-being, health and reproductive status, but also the environmental conditions, including water quality, ecosystem quality, and food availability [20, 22].

4 Conclusion

The growth patterns of both species exhibited negative allometric, indicating that length increases faster than weight, as evidence by *b* coefficients not equal to 3. Strong positive correlations were observed between length and weight (r = 0.9755 and 0.9408) for both species, and were in good condition, with relative condition factor (K_n) values equal to 1. The findings from this study are valuable in managing and conserving these species in Langkawi Island, Kedah. It is suggested that future work on improving larger sample sizes and impacts of environmental factors on LWR and K_n should be carried out in different regions to verify the growth pattern of the squid.

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