Length-Weight Relationships and Condition Factors of Kawakawa *Euthynnus affinis* and Longtail Tuna *Thunnus tonggol* from Sarawak, Malaysia

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Abstract

Length-weight relationships (LWR) and condition factors (K) were determined for two neritic tuna species *Euthynnus affinis* and *Thunnus tonggol*, caught in Sarawak waters. Specimens were collected from five locations around Sarawak between 2016-2019. The r2 value of the LWR for each species re both close to 1 (>0.9), indicating a highly significant relationship attributed to the length and weight of the fish species . The K values are 1.94 and 1.97, and the values of b in the LW equation are 2.53 and 2.59 for *E. affinis* and *T. tonggol*, respectively. The b<3 values indicates negative allometric growth patterns, where the growth rate of body length is faster than the weight gain. These values fall within the published range of 2.50 to 3.50 for neritic tuna species in the region. The results of this study provide the basic life history parameters and the general condition of the two species, *E. affinis* and *T. tonggol*, useful for our tuna fish stock assessment efforts in Sarawak waters.

Keywords: Tuna fisheries, *Euthynnus affinis*, *Thunnus tonggol*, FiSAT, allometric growth, Sarawak

Introduction

The fisheries industry plays an essential role in the economy of countries globally, including Malaysia. Landings of marine fish increased from 1,482,900 tonnes (2013) to 1,455,446 tonnes in 2019 (DOFM, 2021). Landings slightly decreased in 2020 at 1,383,299 tonnes due to a lack of vessel operations, resulting from the restrictions on the re-entry of foreign labour (DOSM, 2021).

To date, Malaysia's per capita consumption is 46.9 kg per year, which is the second highest in the Southeast Asia region, behind only Cambodia (63.2 kg per year), but higher than the global average of 20.5 kg per year (Malay Mail, 2020). Therefore, the management and conservation of marine resources should be prioritised to ensure the fishing sector's sustainability and contribute to developing the target group's living standards, food safety, and the national economy. However, according to the Department of Fisheries Malaysia (DOFM) as reported by Goh et al. (2021), despite an increase in the fishing effort, where issued fishing licenses increased by 15% from 2009 to 2014, the number of fish landings remained constant. This suggests a depletion in the fish stock in the ocean. This was agreed to by Gambang et al. (2003), where marine fish production from captured fisheries has reached the maximum sustainable yield (MSY) in the West Coast and East Coast Exclusive Economic Zones (EEZ) in Peninsular Malaysia. According to Gambang et al. (2003), the East Malaysia EEZ, particularly in Sarawak, has a bright potential to be developed as a fishery resource.

The EEZ of East Malaysia has an approximate area of 250,000 km^2, whereas the EEZ of Sarawak has an estimated 160,000 km^2 (Hadil, 2007). Sarawak reported the highest biomass for fish, at 1,273,081 tonnes, with 340,013 tonnes of small pelagic yet to be exploited (JPLS, 2018). About 4.6% of Malaysia's marine fish landings in 2018 were contributed to by neritic tuna (Sallehudin et al., 2019). Neritic tuna species in Malaysia consist of the longtail tuna (*T. tonggol*), kawakawa (*E. affinis*), and frigate tuna (*Auxis thazard* and *Auxis rochei*) (Adnan et al., 2015). They are the second most abundant landed by purse seines, with the longtail tuna dominating the landings, followed by the kawakawa and frigate tuna in Kuala Perlis, Malaysia (Sallehudin et al., 2019).

Thunnus tonggol and *E. affinis* are distributed exclusively in the Indo-Pacific waters (Rohit et al., 2012; Kasim et al., 2020). *Thunnus tonggol* grows to a maximum size of 136 cm fork length and 35.9 kg (Collette & Nauen, 1983). It tends to form schools of different sizes, where fish, cephalopods and crustaceans are their common prey (Seafood Watch Consulting Researcher, 2015). *Euthynnus affinis* grows to a maximum fork length of 100 cm with a maximum weight of 13.6 kg (Collette & Nauen, 1983). *Euthynnus affinis* usually forms multispecies schools with small *Thunnus albacares*, *Katsuwonus pelamis*, *Auxis* spp. and *Megalaspis cordyla*, consisting of 100 to over 5,000 individuals (Sulistyaningsih et al., 2014). It is an opportunistic predator feeding on fish, shrimps and cephalopods (Collette & Nauen, 1983).

Despite their significant contributions and growing demands in recent years, the population dynamics study, such as growth, spawning season, recruitment and mortality, were still lacking in Sarawak waters. Management and conservation of marine resources should be prioritised to ensure that the fishing industry remains sustainable and contributes to developing the target group's living standards and the national economy. Therefore, the length frequency distribution, the length-weight relationship (LWR) of the two species, and the condition factors were assessed in this study. These parameters will act as a preliminary fisheries management and conservation assessment.

Materials and Methods

Sampling area

Five sampling locations, namely Sematan, Lundu, Kuching, Bintulu and Miri, were identified to represent this study (Figure 1).

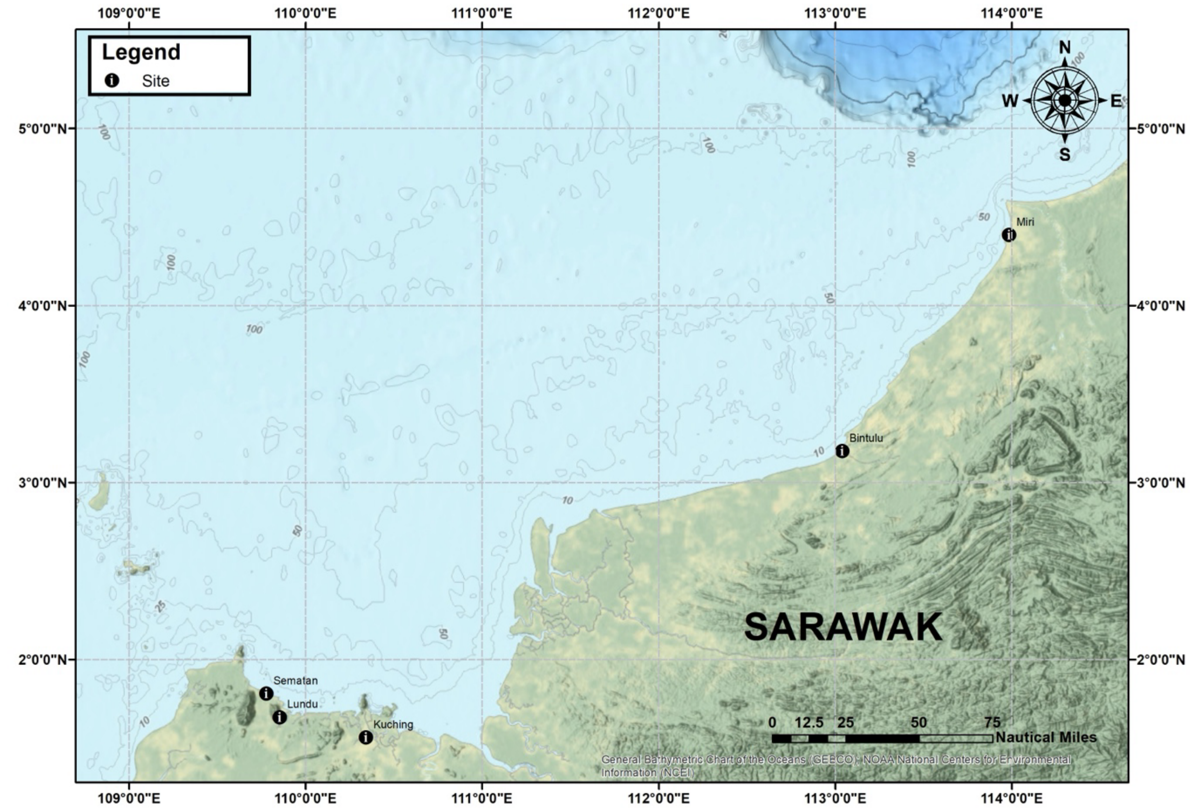

Figure 1. Sampling locations for *E. affinis* and *T. tonggol* from Sarawak, Malaysia

Fish sampling

Samplings of the fish were conducted at the specified locations, and the data was pooled between 2016 to 2019. The fish were caught by Sarawak-registered commercial fishermen using various fishing gears, such as the drift net, the purse seine and the beam trawl. A total of 2,154 *E. affinis* and 2,605 *T. tonggol* were examined across five locations.

Data Analysis

Population parameters

The *E. affinis* and *T. tonggol* population growth were estimated based on the length frequency and length-weight relationships. Upon landing at the jetty, the fork length (FL) of each fish was measured in centimetres and weighed to the nearest 0.1 g (body weight, BW) using an electronic balance (Model: Camry EK 3250). The length at the first maturity (L_m) was estimated using Equation 1 adapted from Binohlan and Froese (2009):

$$\log(L_m) = -0.1189 + 0.9157 * \log(L_{max}) \qquad \textbf{(Equation 1)}$$

Where, L_m is the length at first maturity, and L_{max} refers to the maximum length. The length-weight relationship (LWR) was analysed using the FAO-ICLARM Fish Stock Assessment Tools (FiSAT II) software to obtain a regression analysis (Quinn & Deriso, 1999). The LWR equation is stated as in Equation 2:

$$W = aL^b \qquad \textbf{(Equation 2)}$$

Where, W is the weight of the fish, L is the total fish's length, and 'a' and 'b' are constants. The values of the constants were estimated using the least square linear regression using a log-log transformed data (Equation 3):

$$\log_{10}W = \log_{10}a + b\log_{10}L \qquad \textbf{(Equation 3)}$$

The value of b, ideally 3.0, represents an isometric growth due to environmental conditions or the fish' condition (Ricker & Carter, 1958). When b is less than 3.0, the fish is slimmer with an increased length and is known as a negative allometric growth factor. When b is more than 3.0, the fish becomes heavier. Thus, it demonstrates a positive allometric growth, reflecting the optimum growth conditions. The coefficient of determination (r^2) was used to indicate the quality of the linear regression. A 95% confidence limit for the parameters and the statistical significance level of r^2 was estimated.

Fulton's condition factor

Fulton's condition factor (K) (Equation 4) was used to estimate the fish's body conditions. The condition factor was analysed according to the equation (Froese, 2006):

$$K=\left[\frac{W}{L^3}\right]\times 100 \qquad \textbf{(Equation 4)}$$

Where, K is the Fulton's condition factor, W is the weight of the fish in grams, and L is the length of the fish in centimetres. A conditional factor ≥ 1 implies a good feeding level and suitable environmental conditions, while a conditional factor < 1 refers to no proper habitat conditions for this species in the region.

The analysis was done by combining the data of each species from across the five sampling stations.

Results and Discussion

A total of 2,154 tails of *E. affinis* and 2,605 tails of *T. tonggol* were collected in this study.

Length frequency

A preliminary analysis of the size distribution of *E. affinis* (Figure 2) showed a length frequency distribution range between 17.0 – 90.0 cm with two modes. The highest size distribution was observed at 33.0 – 34.0 cm with 325 tails, followed by the size distribution range between 32.0 – 33.0 cm (305 tails). The average weight for this species was 911.0 g.

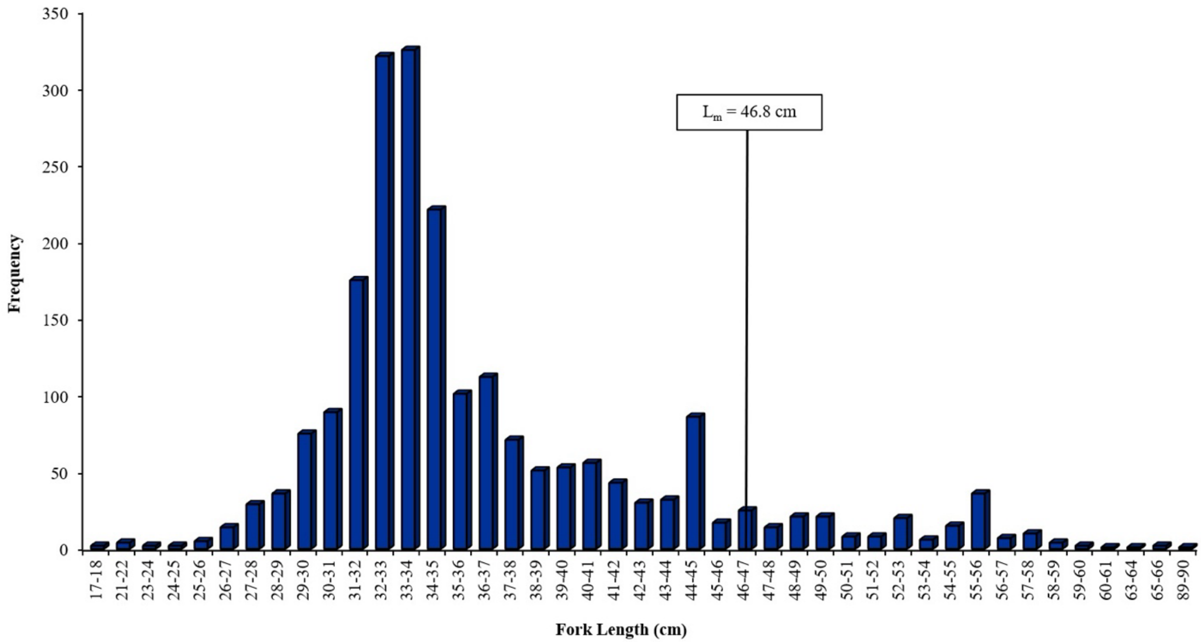

Figure 2. Length frequency graph for *E. affinis*

The size distribution of the *E. affinis* in present study was slightly larger. In northern Peninsular Malaysia, the *E. affinis* was 15.0 – 57.5 cm (Effarina et al., 2019). A similar study from Kuala Perlis indicated that the size distribution was around 13.0-59.0 cm (Adnan et al., 2015). In Tanjung Luar waters, Agustina et al. (2018) reported that the size range was between 24.0 – 71.0 cm. The significant catches in the present study were in agreement with the work by Effarina et al. (2019) and Adnan et al. (2015). Table 1 shows the size distribution of the *E. affinis* in other localities in Malaysia and Indonesia.

Table 1. Size distribution for *E. affinis* in different areas

Locality	Size distribution (cm)
Sarawak (Present Study)	17.0 – 90.0
Northern Peninsular Malaysia	15.0 – 57.5
Kuala Perlis, Peninsular Malaysia	13.0 – 59.0
Tanjung Luar Waters, West Nusa Tenggara, Indonesia	24.0 – 71.0

The length at first maturity (L_m) was 46.8 cm (Figure 2); about 92% of the *E. affinis* landings in the area were mostly juveniles. The result obtained in this study was slightly larger than the length at first maturity as reported in Kuala Perlis, 43.0 cm and in the Straits of Malacca, 41.0 cm (Sallehudin et al., 2016; Wagiyo et al., 2018). Both results showed that most of the *E. affinis* landed were caught before reaching first maturity.

As shown in Figure 3, the size range of *T. tonggol* landing was between 20.0 – 80.0 cm. The most common size caught was 41.0 – 42.0 cm, with 210 tails, followed by 39.0 – 40.0 cm, with 193 tails. The average weight of the *T. tonggol* was 1241.9 g, and the length at first maturity (L_m) was 42.1 cm.

A similar analysis for the *T. tonggol* size distribution in this study was slightly more prominent compared to other areas. In Kuala Perlis, the size ranged from 21.0 – 54.0 cm (Adnan et al., 2015). Other researchers, such as Griffiths et al. (2019) and Risti et al. (2019), recorded the catch size of the *T. tonggol* which ranged between 23.8-125 cm in Australian waters and 39.5 – 67.5 cm in Aceh Barat Daya waters. The most common size obtained in this study was in agreement with the work by Adnan et al. (2015). Table 2 presents the size distribution across different areas.

About 69% of the *T. tonggol* caught in Sarawak waters were juveniles. The length at first maturity (L_m) in this study was nearly identical to the L_m of *T. tonggol* caught in the Java Sea, 42.3 cm (Hidayat et al., 2020). *T. tonggol* was reported to attain a L_m of 41.1 cm in the South China Sea (Hidayat and Noegroho, 2018), and 51.1 cm in the Indian coast (Abdussamad et al., 2012).

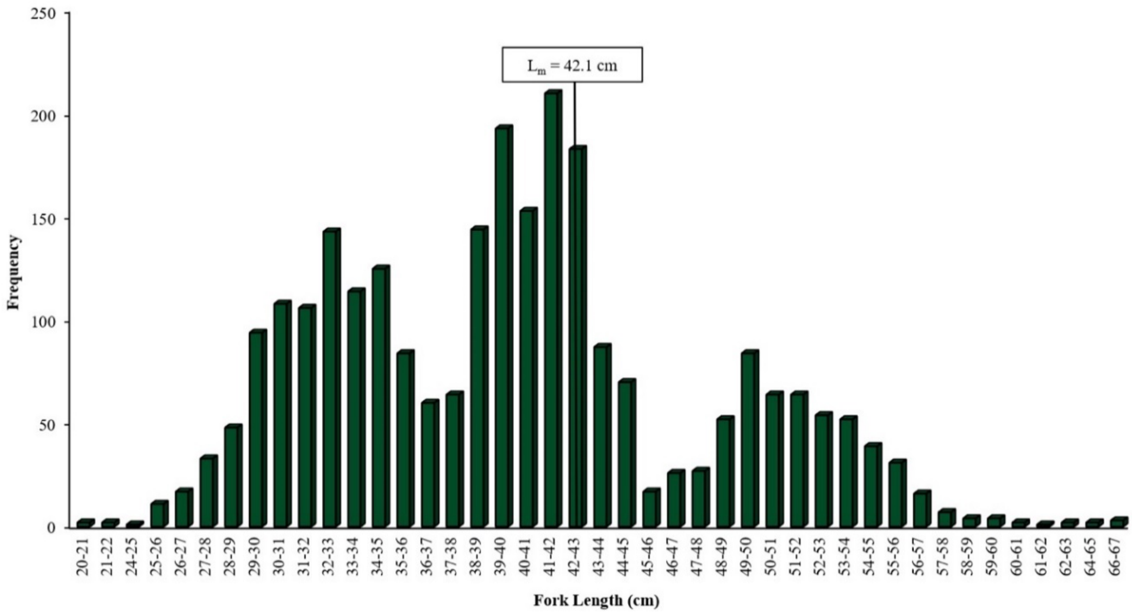

Figure 3. Length frequency graph for *T. tonggol*

Table 2. Size distribution for *T. tonggol* in different areas

Locality	Size distribution (cm)
Sarawak (Present Study)	20.0 – 80.0
Kuala Perlis	21.0 – 54.0
Australia	23.8 – 125.0
Aceh Barat Daya	39.5 – 67.5
Persian Gulf and Oman Sea	27.0 – 107.0

The results suggested that the size distribution for both species caught in Sarawak waters was bigger than in other areas. The L_m value obtained suggested that most of the caught fish were below the size of first maturity, indicating that they did not have the chance to spawn for the first time. The differences in size at maturity for the same species may be due to geographical factors, fishing pressure, stock density, and food and water temperatures (see Hidayat et al., 2020).

Length-weight relationship (LWR)

The results of the LWR analysis for both fish are depicted in Figure 4 (a and b). The intercept 'a' of the *E. affinis* (Figure 4a) was 0.0969, while the exponent b was 2.53, with a correlation coefficient of r^2 = 0.91. The LWR analysis of the *T. tonggol* (Figure 4b) recorded 0.0807 for the intercept 'a', whilst the exponent b was 2.59 with a correlation coefficient of r^2 = 0.94. A high value for the coefficient of determination (> 0.90) indicated a high degree of correlation and a better fit of the length-weight relationship.

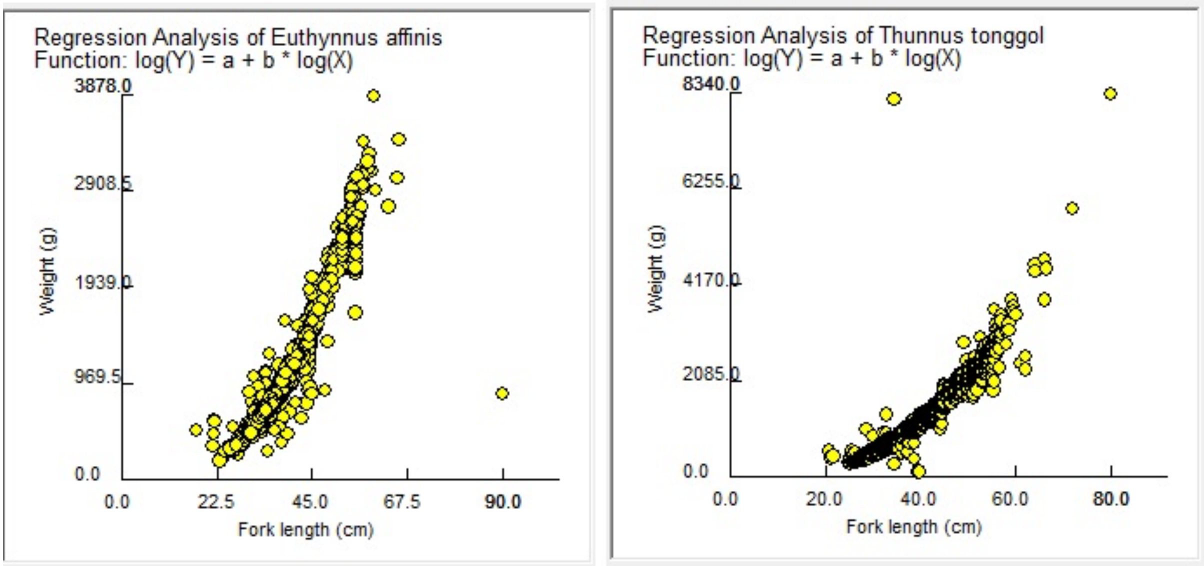

Figure 4a (left) & 4b (right). Length-weight relationship graph for (a) *E. affinis* and (b) *T. tonggol*

The constant value of 'b' depicted important information for the fish's growth. This value was crucial in assessing the well-being of the fish (Mohamad Radhi et al., 2017). The analysis showed that the exponent 'b' values referred to the negative allometric growth slightly deviating from the cube law, which stated that the ideal value was 3, i.e., an isometric growth value (Jisr et al., 2018). This showed that the increment in the weight of both fish was not proportional to its length, thus increasing the fish's length, resulting in a less rotund fish shape (Mohamad Radhi et al., 2017). However, according to Mariasingarayan et al. (2018), the acceptable range of 'b' value lies between 2.50 to 4.00, which agrees with our estimation. This was agreed to by Froese (2006), as cited in Yasemi et al. (2017), which also reported that the acceptable range of the 'b' value was between 2.50 and 3.50. The value of 'b' obtained in this analysis was small compared to different locations worldwide (Table 3). The negative allometric growth pattern for both species may be due to several parameters, for example, temperature, food supply, spawning conditions, dissolved oxygen contents in the water, sex, and age of the fish (see Mariasingarayan et al., 2018).

Condition factor

In fisheries ecology, standard practices are used to determine the individual fish species' conditions based on the analysis of the length-weight data. Conditional factors are seen as quantitative parameters indicating the fish's state (size, maturity, spawning gonadal development, and the general well-being of the fish). According to Asadi et al. (2017), the heavier the fish at a given length, the better the condition due to suitable environmental conditions. The conditional factor, K, for the *E. affinis* was 1.94; for the *T. tonggol*, a value of 1.97 was recorded. The internal and external parameters were subject to conditional factors. Sex, age, gonadal maturity rates, and the fish's well-being can be correlated with internal factors. Additionally, the availability of food and the environmental conditions of the water in which the fish thrive can be used as external factors (Jalil et al., 2020). Conditional factors are based on the hypothesis that the heavier fish of a given length are in much better condition. According to the results, it was ≥ 1 for both species, showing an acceptable condition for both species in this area. However, for the current data, we could not identify which parameters, among those stated above, contributed to these findings. Hence, further analysis is needed.

Table 3. Parameters of length-weight relationship (a and b) and growth pattern for *E. affinis* and *T. tonggol* in different locations

Locality	Species	a	b	Growth type	References
Kuala Perlis	*E. affinis*	0.00000843	3.1173	(+) Allometric	Ahmad Adnan et al. (2015)
Northern Part of Peninsular Malaysia	*E. affinis*	0.000025	2.9335	(+) Allometric	Effarina et al. (2019)
West Nusa Tenggara, Indonesia	*E. affinis*	0.000011	3.114	(+) Allometric	Agustina et al. (2018)
Central Java Indonesia	*E. affinis*	0.1509	3.0513	(+) Allometric	Prasetyo et al. (2019)
Kuala Perlis	*T. tonggol*	0.0000103	3.09	(+) Allometric	Ahmad Adnan et al. (2015)
Northern of the Persian Gulf and Oman Sea, Iran	*T. tonggol*	0.00003	2.82	(-) Allometric	Yasemi et al. (2017)
Northern of the Persian Gulf and Oman Sea (Iran, Hormozgan Province)	*T. tonggol*	0.00002	2.87	(-) Allometric	Darvishi et al. (2018)

Conclusion

This paper provided information on the size distribution, LWRs, and K values for the *E. affinis* and *T. tonggol* in Sarawak. This fundamental biological information will be helpful for further population and stock assessment studies for fishery management in Sarawak. Both species exhibited a negative allometric growth pattern and were predominantly immature. Steps must be taken to ensure the sustainability of the species, for example, enlarged mesh size to give the fish a chance to spawn. Further studies are needed to investigate the effects of the parameters against the K and LWR values.

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