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RESEARCH ARTICLE Indian Journal of Animal Research

Length-weight Relationship and Condition Factors of Seven Penaeus Shrimp Species along the Southeast Coast of Tamil Nadu (Southern India)

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10.18805/IJAR.B-5218

ABSTRACT

Background: The present study of the length-weight relationship and condition factors of seven shrimp species on the southeast coast of Tamil Nadu between July (2022) and February (2023) also estimated the coefficient of determination (r^2).

Methods: For shrimp species, the length-weight relationship shows some species have significant positive coefficients which have a determination by (r^2>0.5) like *Penaeus indicus*, *Penaeus mergiuensis, Penaeus canaliculatus, Penaeus latisulcatus, Penaeus monodon*, some species have shown negative as (r^2>0.5) value like *Penaeus japonicas* and *Penaeus semisulcatus.*

Result: All shrimp species have heterogeneity evident in intercept (a). The growth exponent (b) varied between 0.278 and 2.289 and it significantly (p=0.05) deviated from the value of <3 which denoted negative allometric growth for all Penaeus shrimp species.

Key words: Allometric growth, Condition factor, Length-Weight relationship, Penaeus shrimp.

INTRODUCTION

Around the world, coastal waters with warm temperatures and tropical climates gather the expensive seafood known as shrimp. In many parts of the world, shrimp fisheries provide economic assistance (Khademzadeh and Haghi, 2017; Olawusi *et al.,* 2014; Ajani *et al.,* 2013). The penaeid shrimp is found in a large area, from the west and east coasts of India to Hong Kong, to the waters of Malaysia and Indonesia, to tropical Australia and New Guinea. Most species are in the Indo-Pacific region, from the Persian Gulf through India, the east coast of Africa, Japan and Australia. These species are found in shallow inshore seas where spawning adults are frequently seen and they are also primarily fished in shallow coastal areas (Amani *et al.,* 2015). India has a sizable marine fishing industry contributes significantly to the national economy and has provided millions of people living in our nation with subsistence and employment opportunities in coastal communities (Rao *et al.,* 2023). In addition to fish, prawns play a significant ecological and economic role in capture fisheries. The foundation of the seafood export business is the penaeid prawn, which also generates most of the sector's foreign exchange earnings. Millions of people, directly and indirectly, depend on the fishery sector for their livelihood (Johnson, 2010; Joseph and Jayaprakash, 2003; Devaraj and Vivekanandan, 1999; George *et al.,* 1981). The crustacean fisheries resources around Palk Bay's shore are mostly harvested using four different types of gear: bottom-set gillnet, gillnet (a specialised gillnet for prawns) and thalluvalai (pushnet), which is used in the artisanal sector. Trawling is the mechanised sector. For the past few decades, Palk Bay's inshore waters have been used for thalluvalai operations aimed at prawn harvesting (Rajamani and Palanichamy, 2009). As a result, all species members of the Penaeidae family are referred to as "prawns" in this research. In Indian water, the Penaeidae family has 17 genera and 78 species. Most of the penaeid prawn species in Indian water belong to the genus Penaeus, which is of commercial significance

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How to cite this article: Mohale, H.P., Jawahar, P., Jayakumar, N., Oli, G.A., Ravikumar, T., Bhosle, R.V., Ananda, S.N., Kadam, R.V. and Sonwal, M.C. (2024). Length-weight Relationship and Condition Factors of Seven Penaeus Shrimp Species along the Southeast Coast of Tamil Nadu (Southern India). Indian Journal of Animal Research. doi: 10.18805/IJAR.B-5218.

Submitted: 09-08-2023 **Accepted:** 21-01-2024 **Online:** 01-03-2024

(Chanda, 2017). The main commercial shrimp species landed from the genera Metapenaeus, Parapenaeopsis and Penaeus. The procedure uses prawn trawl nets with a cod end mesh size of 10-20 mm in both the northern and southern orientations. With a crew of six, these trawlers can hold two to three tonnes of fish (Maheswarudu *et al.,* 2015). The primary tool used to exploit almost 90% of the penaeid prawn along the east coast is a trawl net. There are various varieties of trawlers based on the boat's size, engine capacity and gear size. These boats are Sona (13.1 m), Sorrah (11.4 m), Pablo (9.14 m) and Royya (9.75-10 m). The principal landing grounds and fishing harbours, which serve as the foundation for trawler operations, include Tuticorin, Mandapam, Kakinada, Digha, Paradeep, Visakhapatnam and Diamond Harbour. In addition to these trawlers, the coast of Tamil Nadu is home to Halluvalai (Sreeram *et al.,* 2014).

In fishery biology, ecology and fish stock assessment, the length-weight relationship (LWR) and length-length relationship (LLR) of shrimp are significant instruments (Karna, 2017). For comparing growth studies in fisheries management, length-weight connections are crucial. It aids in determining the two variables' mathematical relationship, allowing the conversion of one variable to characterise the growth in the wild to identify potential variations among several stocks of the same species, delineates the stocks and facilitate comparative growth research (Das *et al.,* 2021; Ahmadi, 2018). The length-weight connection can be a good indicator of environmental factors that may affect how energy is taken in and used by marine fish and crustaceans (Das *et al.,* 2021). An animal's physical health is frequently measured using Fulton's condition factor (K), which is also a helpful addition to a crustacean's growth estimate (Li *et al.,* 2016). Shrimp feeding intensity, age and growth rates may all be monitored using the condition factor, which is also beneficial. Both biotic and abiotic ecological circumstances heavily influence it and can be used as a gauge for the health of the aquatic habitat where fish reside (Prajapati and Ujjania, 2021; Solanki *et al.,* 2020; Uddin *et al.,* 2016). Fish and crustaceans' variations in the length-weight relationship are good predictors of energy absorption and allocation changes (Kop *et al.,* 2019; Qadri *et al.,* 2017). Further differences are influenced by various circumstances, including food, stress brought on by crowding, or the reproductive cycle (Oyebamiji *et al.,* 2008). The current study aims to add and complement already-existing knowledge about the shrimp growth pattern (Siddique *et al.,* 2022). To manage shrimp resources sustainably and also give relevant information on the length-length, length-weight connection (growth patterns) and condition factor on shrimps caught in coastal waters from the southeast coast of Tamil Nadu (Suryanti *et al.,* 2018; Olawusi *et al.,* 2014).

MATERIALS AND METHODS

The present study was conducted from July to February 2022-2023 at the sampling site from Thoothukudi (Station I), Nagapattinam (Station II), Mandapam (Station III) and Palk Bay (Station IV) on the southeast coast of Tamil Nadu (Fig 1). Every month, shrimp samples were taken at depths of 100 to 150 meters in the Gulf of Mannar (Tamil Nadu). Samples were collected once or twice a month during the shrimp landing period from the sampling sites in Thoothukudi, Mandapam and Nagapattinam using a commercial bottom trawler and bottom set gillnet. The net's mesh size measured 20.2 mm at the cod end and 30.9 mm in the net body. Before being transferred to the Fisheries College and Research Institute, Laboratory of the Thoothukudi, the samples were promptly refrigerated in ice on board and treated with 5% formalin. They were identified using FAO Species Identification Sheets (Volume VI). Based on the presence of thelycum in females and petasma in males, all obtained specimens were sexed. The overall length (from the tip of the rostrum to the edge of the telson) was measured using a graded measuring board and the weight was determined using an electronic weighing balance.

Characters for diagnosis: Small to large, with a body length ranging from 2.5 to 35 cm. All five pairs of legs are fully formed, with the first three generating pincers that aren't huge abdomen with the front portion of the subsequent pleura covered by the posterior part (lateral plates). A huge copulatory apparatus is on the first pair of pleopods in males (petasma) and on the posterior thoracic sternites in females (thelycum). The females do not hold the eggs on their abdomens; instead, they release them straight into the water (Josileen, 2022; Abdulraheem *et al.,* 2021; Das *et al.,* 2021; Rao *et al.,* 2013; Rajkumar *et al.,* 2015). Among the many different sizes of crustaceans, shrimps range from tiny to approximately 35 cm in length. Shrimps often have a lengthy abdomen longer than their head or carapace, a compressed and toothed rostrum and an almost invariably laterally compressed body. Generally speaking, the antennae and antennules are big and plate-like. Typically, pereiopods have slim legs, but some species have robust legs, either a single or a pair and some end in pincers or chelae. Except in a few species, all five anterior abdominal segments have well-developed pleopods or abdominal appendages utilised for swimming (Piratheepa *et al.,* 2016).

The length-weight relationship was calculated by the following formula, $W = a*L^b$, *i.e.*, log W= log a + b log L was estimated by linear regression analysis (Ricker, 1973) where is intercept (a) and (b) is the slope of linear regression on the log-transformed weight (g) and length data (cm) respectively (Froese, 2006; Froese *et al.,* 2011). The pattern of growth, *i.e.*, negative showing allometry ($b<3$), isometry ($b=3$), or positive allometry ($b>3$), was tested by using regression analyses (ANOVA) and setting a significance level of 0.05, p-value. The attributed data error and extreme outliers were excluded from the calculations. Using the least square residuals method, the optimized values of "a and b" were computed (Haddon, 2011). The statistical significance, 95% confidence intervals (CIs) of the parameters a, b and coefficient of determination (r^2) were also estimated. The length-length relationships (LLRs) between TL and CL were also established using linear regression analysis:

$$CL = a + b \times TL$$

The Fultons condition factor (CF) of shrimp species was calculated as the body weight expressed as a percentage of the cube of the Total length following the formula (Pauly, 1983).

$$\text{Condition factor (K)} = \frac{100W}{L^3}$$

Where:
K = Condition factors.
L = Total length (cm).
W= Weight of shrimps (gm).

RESULTS AND DISCUSSION

Table 1 displays the length-weight relationship and the estimated coefficient of determination (r^2) for all seven shrimp species (Fig 2). The length-weight connection demonstrated a statistically significant positive coefficient of determination (r^2>0.5) like *Penaeus indicus*, *Penaeus mergiuensis, Penaeus canaliculatus, Penaeus latisulcatus, Penaeus monodon and* some species have shown negative as (r^2>0.5) value like *Penaeus japonicas* and *Penaeus semisulcatus.* All shrimp species have heterogeneity evident in intercept (a). The growth exponent (b) varied between 0.278 and 2.289 and it significantly (p=0.05) deviated from the value of <3, which denotes negative allometric growth for all species, as mentioned in (Table 2), whichis shown in Fig 3-9 the length-weight graphs for each species of shrimp. The

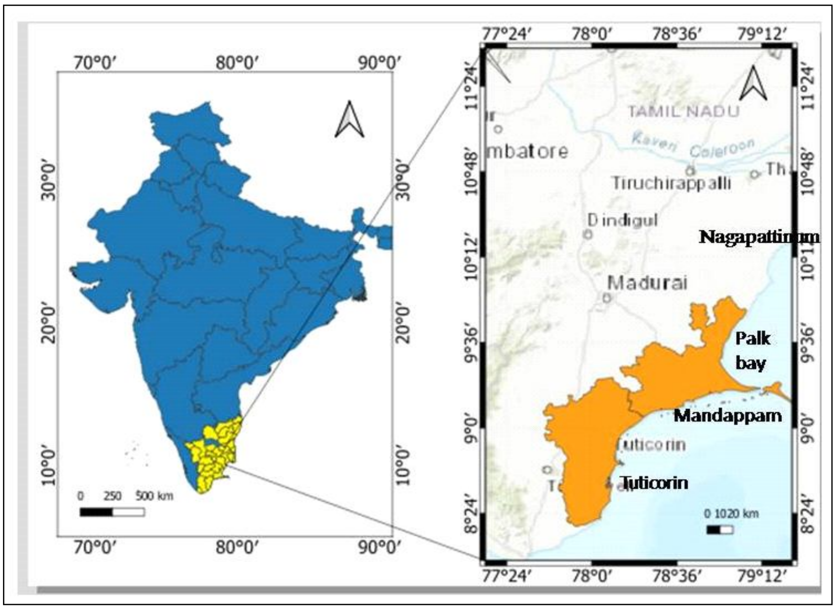

Fig 1: Study area of southeast coast of Tamil Nadu.

Table 1: The length-length relationships of seven Penaeus Shrimp species from the marine coast of Tamil Nadu.

	Length-length characters			
Species	Equation	a	b	r^2
Penaeus indicus	CL= a+b×TL	0.268	0.932	0.886
	BL= a+b×TL	3.878	0.282	0.459
Penaeus mergiuensis	CL= a+b×TL	0.678	0.433	0.53
	BL= a+b×TL	0.62	0.924	0.915
Penaeus japonicus	CL= a+b×TL	0.190	0.842	0.827
	BL= a+b×TL	0.698	0.802	0.912
Penaeus canaliculatus	CL= a+b×TL	0.663	0.437	0.609
	BL= a+b×TL	0.207	3.390	0.775
Penaeus latisulcatus	CL= a+b×TL	0.787	0.370	0.551
	BL= a+b×TL	2.271	0.381	0.721
Penaeus monodon	CL= a+b×TL	0.715	0.474	0.856
	BL= a+b×TL	2.677	0.333	0.572
Penaeus semisulcatus	CL= a+b×TL	0.268	0.932	0.886
	BL= a+b×TL	4.048	0.266	0.410

condition factor (K) analysis has demonstrated that female shrimp typically have higher K-values than male shrimp. The K-value varied from 0.38 (*P. semisulcatus*) to 1.79 (*P. japonicus*). The outcome suggested that heavier shrimps of a particular length are in better shape. Also, the study discovered that the condition factor varied between shrimp sexes and that female shrimp generally had higher K-values than male shrimp, as mentioned in (Table 3). The maximum condition factor of *P. japonicus* males (K=1.56) and the lowest value of *P. semisulcatus* (K=0.38) were found in December 2022 and February 2023, respectively. In the case of Females, shrimp in *P. semisulcatus* had the lowest condition factor in January 2023 (K=0.58) and the highest condition factor in September (K=1.79) *P. japonicas.*

The results of the length-weight relationship (LWR) of shrimps in marine water revealed a strong and substantial connection between the overall length and weight of shrimp (r^2= 0.015-0.953) similarity observation found by Aye *et al.* (2019). In other words, shrimp growin length and weight similarly. The species-specific coefficient of determination

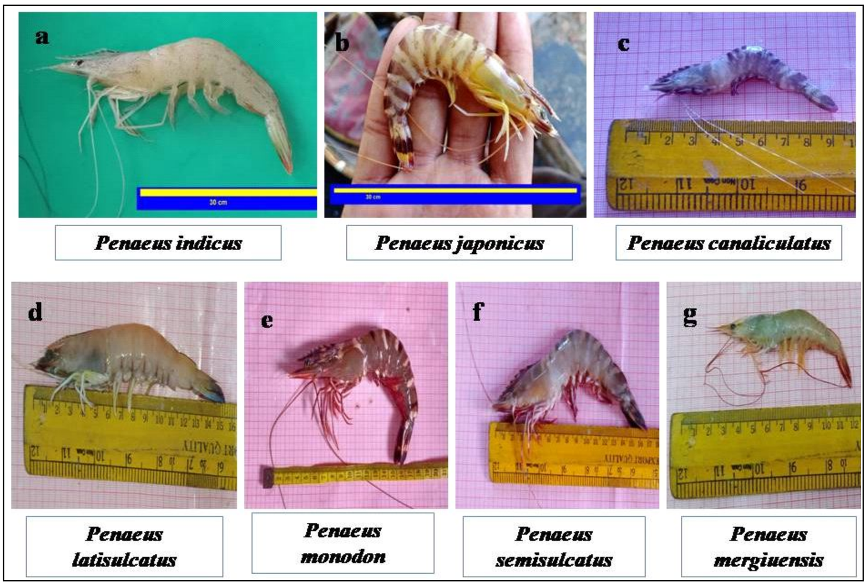

Fig 2: Collected shrimp sample from the southeast coast of Tamil Nadu.

Table 2: The length-Weight relationship of Penaeus Shrimps from the marine coast of Tamil Nadu.

Species	N	a	b	r^2	Growth pattern
Penaeus indicus	106 (F)	0.169	1.595	0.630	(-) Allometric
	70 (M)	0.143	1.705	0.773	(-) Allometric
	176 (C)	0.156	1.645	0.688	(-) Allometric
Penaeus mergiuensis	115 (F)	0.103	1.817	0.885	(-) Allometric
	26 (M)	0.139	1.676	0.940	(-) Allometric
	141 (C)	0.109	1.790	0.893	(-) Allometric
Penaeus japonicus	105 (F)	0.330	1.531	0.414	(-) Allometric
	36 (M)	4.19	0.278	0.015	(-) Allometric
	141 (C)	0.451	1.377	0.341	(-) Allometric
Penaeus canaliculatus	106 (F)	0.606	1.212	0.573	(-) Allometric
	46 (M)	0.586	1.234	0.563	(-) Allometric
	152 (C)	0.600	1.219	0.569	(-) Allometric
Penaeus latisulcatus	73 (F)	0.543	1.260	0.544	(-) Allometric
	28 (M)	0.533	1.268	0.556	(-) Allometric
	101 (C)	0.540	1.262	0.547	(-) Allometric
Penaeus monodon	52 (F)	0.037	2.289	0.953	(-) Allometric
	22 (M)	0.046	2.194	0.942	(-) Allometric
	74 (C)	0.040	2.259	0.949	(-) Allometric
Penaeus semisulcatus	111 (F)	0.470	1.296	0.161	(-) Allometric
	33 (M)	0.580	1.107	0.463	(-) Allometric
	144 (C)	0.482	1.261	0.179	(-) Allometric

r^2>0.5 results demonstrated the model's suitability for this investigation. The slenderness or stoutness of the shrimp could be attributed to dimensional discrepancy observed in shrimps living in maritime environments. The shrimp gets skinny as it grows longer, showing negative allometric growth. As a result, an analysis of the length-weight relationship offers a crucial tool for assessing shrimp population stock and production potential. Positive allometric

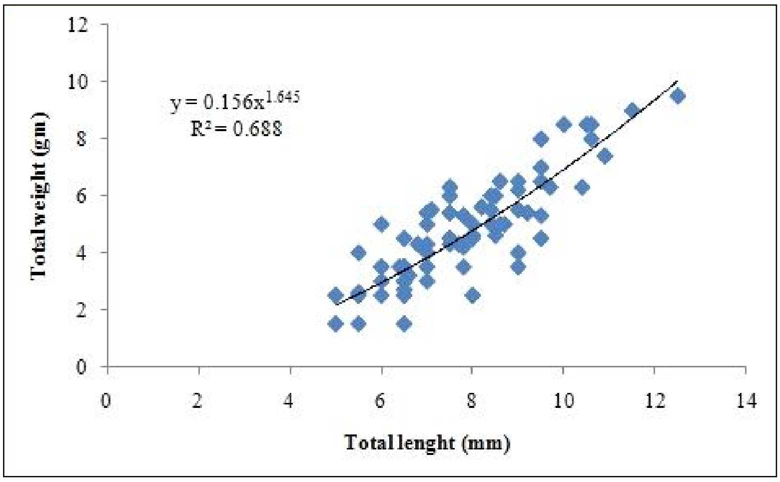

Fig 3: The graph of the length-weight relationship for combined sex of *P. indicus.*

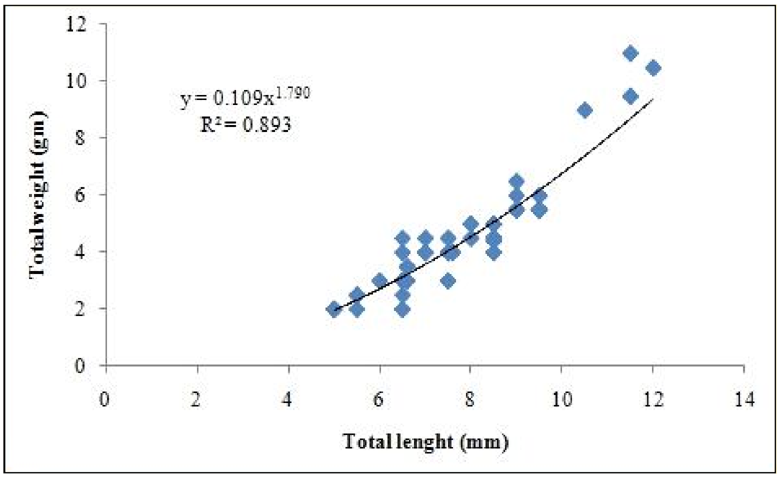

Fig 4: The graph of the length-weight relationship for combined sex of *P. mergiuensis*.

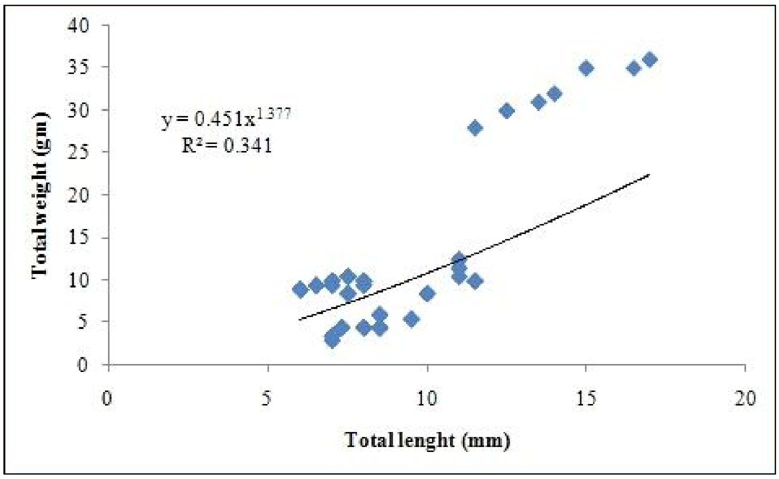

Fig 5: The graph of the length-weight relationship for combined sex of *P. japonicas*.

growth was revealed by the growth coefficient for both sexes across all species, demonstrating that the rise in body length rate is not inversely correlated with the increase in body weight. The present study observed the negative allometric growth of all the Penaeus shrimp species, which means it grows longer than the stock population. Similar results were found by Torres *et al.* (2017) from the Gulf of Cadiz (Spain) and Ahmadi (2018) studied negative allometric growth in

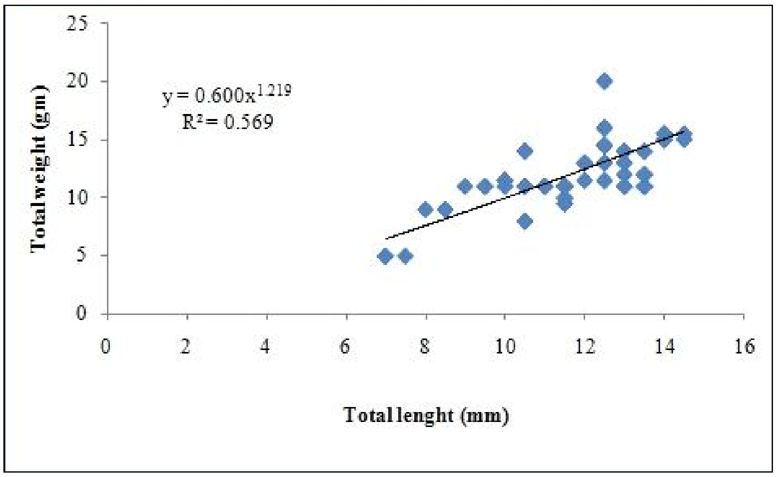

Fig 6: The graph of the Length-Weight Relationship for combined sex of *P. canaliculatus*.

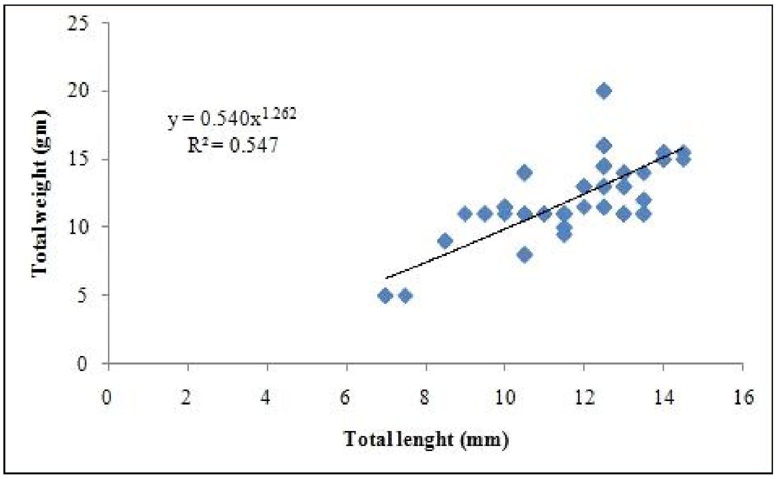

Fig 7: The graph of the length-weight relationship for combined sex of *P. latisulcatus*.

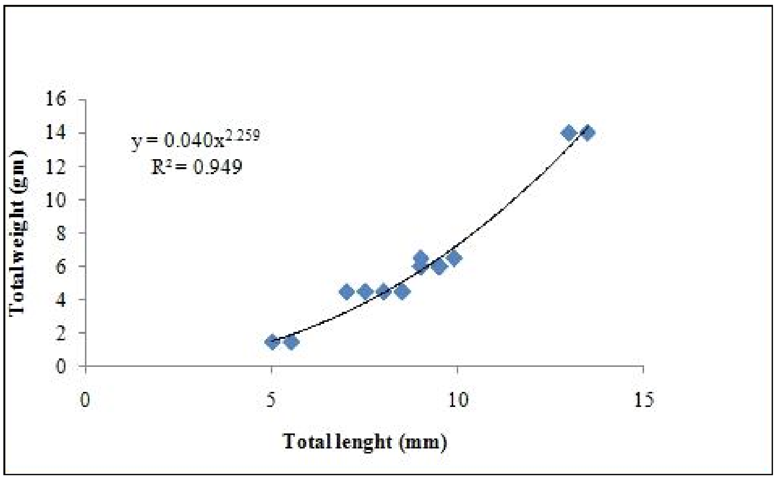

Fig 8: The graph of the length-weight relationship for combined sex of *P. monodon*.

Table 3: The mean length, weight and condition factor (K) for the Penaeus Shrimp species from the marine coast of Tamil Nadu.

Species	Female				Male				Combine sex			
	N	TL (cm) X±SE Min - Max 95% CL	TW (g) X±SE Min - Max 95% CL	K	N	TL (cm) X±SE Min - Max 95% CL	TW (g) X±SE Min - Max 95% CL	K	N	TL (cm) X±SE Min - Max 95% CL	TW (g) X±SE Min - Max 95% CL	K
P. indicus	106	7.83±0.15 5-12.5 0.298	4.70±0.16 1.5-9.5 0.330	1.08	70	7.87±0.31 5-12.5 0.420	5.04±0.23 1.5-9.5 0.465	1.03	176	7.84±0.12 5-12.5 0.242	4.84±0.13 1.5-9.5 0.272	1.05
P. mergiuensis	115	7.91±0.16 5-12 0.321	4.66±0.19 2-11 0.387	0.99	26	7.81±0.35 5-12 0.731	4.35±0.38 2-10.5 0.797	0.96	141	7.89±0.14 5-12 0.290	4.64±0.17 2-11 0.344	0.97
P. japonicus	105	8.91±0.24 6-17 0.493	11.00±0.82 3-36 1.640	1.79	36	8.11±0.25 6-11.5 0.516	8.00±0.45 3-12.5 0.914	1.56	141	8.71±0.19 6-17 0.391	10.23±0.63 3-36 1.256	1.71
P. canaliculatus	106	11.71±0.16 7-14.5 0.330	2.18±0.27 5-20 0.546	0.86	46	11.69±0.26 7-14.5 0.52	12.40±0.44 5-20 0.904	0.82	152	11.70±0.13 7-14.5 0.276	12.25±0.23 5-20 0.463	0.81
P. latisulcatus	73	11.75±0.19 7-14.5 0.394	12.36±0.35 5-20 0.703	0.82	28	11.76±0.30 7-14 0.634	12.37±0.55 5-20 1.143	0.80	101	11.75±0.16 7-14.5 0.329	12.36±0.29 5-20 0.588	0.80
P. monodon	52	8.95±0.27 5-13.5 0.557	6.08±0.44 1.5-14 0.890	0.85	22	8.95±0.46 5-13.5 0.968	6.18±0.73 1.5-14 1.530	0.84	74	8.95±0.23 5-13.5 0.473	6.11±0.37 1.5-14 0.753	0.82
P. semisulcatus	111	15.60±0.28 10-19.5 0.566	20.91±1.67 7-68 3.311	0.58	33	15.48±0.55 10-19.5 1.136	12.80±1.38 7-55 2.821	0.38	144	15.57±0.25 10-19.5 0.501	19.05±1.35 7-68 2.678	0.53
Total	668 (71.90%)				261 (28.09%)				929			

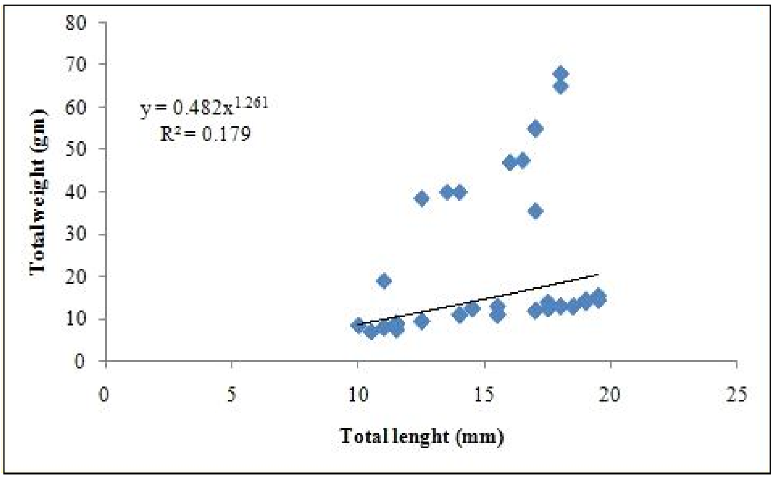

Fig 9: The graph of the length-weight relationship for combined sex of *P. semisulcatus*.

female shrimp from the Barito River, Indonesia. One author from India also found that the negative allometric growth in both sexes of shrimp from the Digha coast of West Bengal has been studied by Uddin *et al.* (2016). Some other authors similarly study reported by (Das *et al.,* 2021; Ukpatu, 2021; Hasan *et al.,* 2020; Suryanti *et al.,* 2018; Khademzadeh and Haghi, 2017; Uddin *et al.* 2016; Amani *et al.,* 2015; Faye *et al.,* 2015; Fatima, 2001; Fontaine and Neal, 1971).

The variations may result from geographic conditions and regional shrimp growth patterns. The modest variance in b and r^2 values is acceptable given that a species' length-weight relationship may change depending on its environment and the time of year. The different physical traits shown in Table 3 clearly distinguish the sexes of shrimp in marine water. Many crustaceans have shown these alterations. Many species of commercially significant penaeid shrimp exhibit the same pattern of sexual dimorphism, in which the females are larger than the males. Compared to males of the same overall length, it was reported that females had longer carapaces and heavier bodies and this difference became more evident in larger-size groups. More weight and an increase in the number of moult cycles may contribute to larger female sizes. The condition factor (CF) can describe a shrimp's health or fatness. It varies based on sex, stage of development and season. The existence of gravid females or the larger size of the female gonads, which are absent in their male counterparts, may cause variances in the condition factor between males and females.

The greater K value for *P. japonicas* (K = 1.71) obtained in this study can be explained by the fact that this species grows bigger and quicker than other Penaeid shrimps, according to the usage of condition factor as an index of growth and feeding intensity. The lower k value for *P. semisulcatus* (K = 0.80) may be due to its high feeding rate, severe overexploitation and marine habitat. Ajani *et al.* (2013) conducted a similar investigation on two Penaeid shrimps from the coastal state of Lagos in South West Nigeria. Likewise, observations were made by (Suryanti, 2021; Solanki *et al.,* 2020). According to Silva *et al.* (2021), the condition factor is a sign of changes in food stores. The individual condition component, as it relates to the health and fatness of the organisms, may cause weight variations for all species of shrimp. The combined sex condition factors were K = 0.53 for *P. semisulcatus,* K = 0.80 for *P. latisulcatus*, K = 0.81 for *P. canaliculatus*, K = 0.82 for *P. monodon*, K = 0.97 for *P. mergiuensis*, K = 1.05 for *P. indicus* and K = 1.71 for *P. japonicus* differed from the record in the coastal waters of Tamil Nadu. According to a study present study, Olawusi-Peters *et al.* (2014) also reported the similarity condition factors value. These variations might result from oil reserves and the pollution level in Tamil Nadu maritime waters, which could impact the biotic integrity of the shrimp species. The condition parameters in Tamil Nadu thermal industries were also affected by pollution. The sex, maturity, season and environmental factors may all have a role in shrimp's length-weight relationship and condition factor.

CONCLUSION AND ACKNOWLEDGEMENT

The LWRs and condition factor (CF) of seven Penaeus shrimp from Tamil Nadu marine waters were assessed in the current study, exhibiting a negative allometric trend. The presentresearch is suggested to be in good condition based on an analysis of growth-related features and condition factors. The condition factor (K) analysis showed that female shrimp typically have higher K-values of 1.79 (*P. japonicus* than male shrimp of *P. semisulcatus* K-value was 0.38; the outcome suggests that shrimps of a particular length are heavier in better shape.

The author appreciates the continued support provided by the Dr. J. Jayalalithaa Fisheries University in Nagapattinam, Tamil Nadu and the dean of the Fisheries College and Research Institute in Thoothukudi, for his wise advice. I am pleased to convey my sincere appreciation and gratitude to Dr. P. Jawahar, my mentor and advisor at Tamil Nadu's Dr. J. Jayalalithaa Fisheries University in Nagapattinam. My work had only been finished because of his commitment to labour and assistance. His prompt counsel and careful inspection greatly aided me in completing this assignment.

Conflict of interest

All authors declared that there is no conflict of interest.

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