The Journal of Basic and Applied Zoology

RESEARCH Open Access

Length–weight relationship of *Charybdis callianassa* Herbst, 1789 (Decapoda: Brachyura) in relation to sex and carapace length along the Mumbai coastal water, India

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Abstract

Background: The present study was performed to determine carapace length–body weight relationship of *Charybdis callianassa*. In fisheries biology, length–weight relationships are important as they allow for the calculation, by creating a mathematical equation between the two, of the total weight of the fish in a particular group in fish. Such information is helpful for fishery scientists to research the dynamics of development and populations and for public agencies that can maintain and preserve these resources sustainably.

Results: A study on the carapace length–body weight relationship of *Charybdis callianassa* (Herbst, 1789) was made on the northwest coast of India for the first time. The study was based on experimental trawl fishing conducted fortnightly from August 2019 to March 2020. A total of 479 specimens, including 262 males and 217 females from fishing trawler, were examined for their carapace length and total weight. The carapace length ranged from 2.69 to 3.54 cm, and the total weight from 5.26 to 7.36 g. This analysis revealed that the crabs exhibited negative allometric development, as shown by average exponents 'b' = 2.71 for pooled data with high coefficient (r) = 0.91 and r^2 = 0.83.

Conclusions: The carapace length–body weight relationship of *Charybdis callianassa* in relation to sex and carapace was studied in the Mumbai coastal water, India. We found major differences in the average "r^{2}" values of species reported for males (0.89), females (0.79) and pooled data (0.83). Such kind of study is essential for fisheries biology to comprehend the differences in circumstances in small and large specimens that vary with environmental conditions and seasons.

Keywords: Carapace length, Experimental fishing, Negative allometry, Northwest coast

Background

The true crabs of the Infraorder Brachyura are among the most popular and well-known species. The Decapoda, the most diversified group of crustaceans today, is comprised of Brachyuran crabs (Ng & Davie, 2002). Around 4.4% of the crustaceans including prawns, lobsters and crabs are the most important resources in terms of their availability in the world's seafood industry. In India, marine fishing is primarily export-oriented, and crustaceans represent approximately 45% volume and 75% value among seafood products exported from the country (Dey et al., 2005). The genus *Charybdis* is the most common species on the West Coast (Roy, 2013). Decapod crustaceans are vastly diverse and well adapted to life on land, belonging to the phylum Arthropoda. During the years 1975–1981, an average of 21,310 tonnes were obtained (Sakthivel & Fernando, 2012), which accounted for 10.4% of the overall crustacean landings on the Indian coast. It is estimated that 43,000 tons of crab stocks have

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been exploited in Indian Sea, which is half its availability (Ravichandran & Kannupandi, 2007). Current crustacean fishing production in India contributes 455,379 tons, having contributed to 13% of India's marine production and 57,354 tons of crab (CMFRI, 2018–2019). The Gulf of Mannar (Jobling, 2002), Puducherry Mangrove Forest (Serène, 1968) and Parangipettai Coast (Jones, 1986) have been mentioned by a range of authors in different sections of the Chennai Coast (Kuronuma, 1974; Le Cren, 1951; Sakai, 1976; Tirmizi & Siddiqui, 1996). The weight change to the carapace length ratio is used in a given geographic location for observing an evolving and dynamic ecosystem. In terms of the evaluation of fish and crustacean species, the relation between length and weight is considered more important. Furthermore, data on length and weight both seem valuable and the findings of standardized data collection studies are numerous. Crustacean is a significant benthic group since the resources and the functionality of tropical habitats are supported by more organisms in relation to human consumption and a wider diversity of small species (Hendrickx, 1995). They are all located at depths of 6000 m to the coastline and occupy estuarine environments, which can differ daily with salinity and temperature (Ng & Davie, 2002). In tropical and subtropical regions, there are more forms of crabs than in temperate and cold regions (Boschi, 2000; Fransozo & Negreiros-Fransozo, 1996). Brachyuran crabs, which are distributed worldwide, constitute approximately 700 genera and approximately 5000–10,000 species (Kathirvel, 1983), among which 2600 have been identified in Indo-West Pacific (Michael Apel & Spiridonov, 1998), and approximately 705 brachyuran crab species, 28 families and 270 genera have been reported (Kathirvel, 1983; Moutopoulos & Stergiou, 2002; Ng & Davie, 2002; Oluwatoyin et al., 2013; Sukumaran & Neelakantan, 1997; Sukumaran & Neelakantan, 1997) from Southeast Asian region, and the northern Australian part from Moreton Bay (Queensland) at the East Coast to Exmouth Gulf (West Australia) at the West Coast (Josileen & Menon, 2005; Stephenson, 1962). The *Charybdis callianassa* is a sublittoral swimming crab with some parts of its distribution regions. This crab will easily plunge into soft sediment (Bauer, 1989). During this study, many aspects of biology, including evidence on similarities between length and weight and size–frequency distributions, were analyzed from samples obtained. In fishes, the weight, the "fatness" or "well-being" are associated with a position that is based on a hypothesis that more large fishes on a given amount of water are in superior condition (Thangaraj Subramanian, 2001). On the contrary, crustacean growth is a discontinuous development as successive molts remove the solid exoskeleton per year. Every ecdysis is done, and the size of the body is easily increased until molten water is consumed (Hartnoll & Bryant, 2001). A morphometric study supports the recognition of genetic and environmental resources and weight–carapace length proportions of community and is important for determining population sizes for exploitation (Cadrin, 2000). The research on the length–weight relationship of marine aquatic species is commonly used to identify the trends of growth in the context of its evolution. Crabs (Portunidae) swim in mostly shallow waters that exist. Marine brachyuran crabs have a compressed or cephalothorax carapace, with the abdomen hidden behind the majority of the carapace, and the cephalothorax has five pairs of walking legs (Fischer, 1978). Apparently, the anterolateral boundary is reduced to six points (Garth & Abbott, 1980). The 1st to 5th segments are trunked, and the distance decreases from head to foot. Chelipeds are somewhat different and have pubescent surface and anterior border with two meri (Shen, 1937).

The length–weight relationship is known to be the strongest method for measuring crustacean populations and fish in the region (Dulcic & Kraljevic, 1996; Ikhwanuddin et al., 2010). The behavior of Charybdis callianassa was not studied in detail, but this crab can plunge itself quickly into soft sediment (Bauer, 1989). Physical parameters are considered to have a strong influence on the distribution of organisms into soft sediments. Several observational experiments found that large-scale variations in the abundance of organisms are also related to changes in grain sediment and grain size (Gray, 1981). A number of researchers have been working on portunid crabs so far, which involve those from various areas of water bodies, including Kuwait, Saudi Arabia (Apel & Turkay, 1992), Abu Dhabi and Umm al-Quwain (U.A.E.), and the Hormozgan Province (Iran) (Bahmani, 1997). The color of Charybdis callianassa is recorded by Chhapgar (1957). Keeping in mind significant ecological role and paucity of information on carapace length–weight relationship of this crab species, the present study aimed at studying the carapace length–weight relationship as tools to help conservation and will enhance management and comparisons among group and communities of the same species.

Methods

Fieldwork was carried out from September 2019 to March 2020. A study was performed using experimental fishing carried out on CIFE's M.F.V NARMADA (IV) in the traditional Mumbai coastal waters fishing grounds (Fig. 1). Much of all the trawling activities were conducted during the daytime, and similar shooting and hauling practices were followed in the entire experiment fishing. The depth of the water has also been manually measured using a graduated nylon rope with an iron

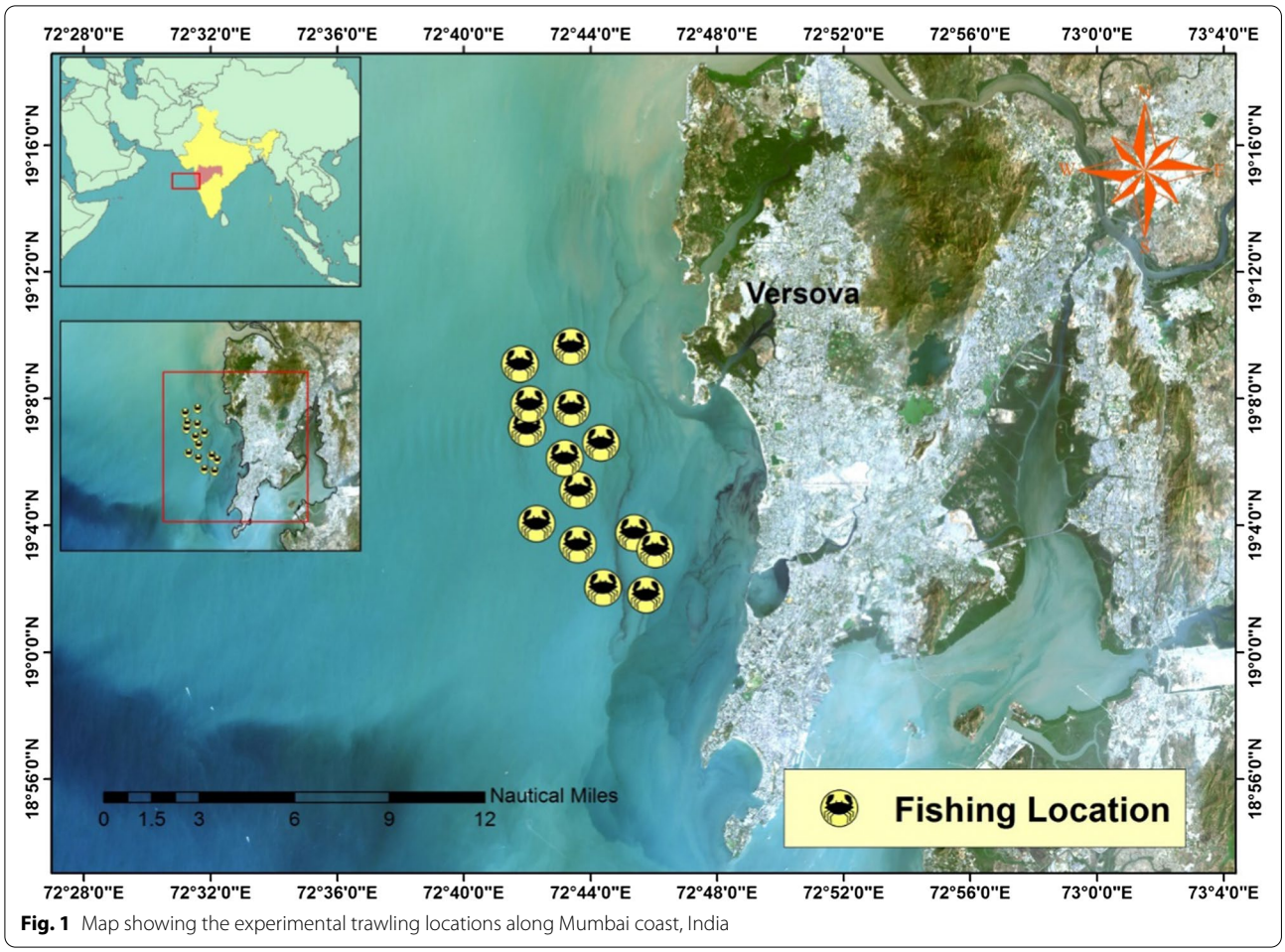

Fig. 1 Map showing the experimental trawling locations along Mumbai coast, India

sinker. A trawl net with the head-rope length of 35 m and foot-rope length of 40 m and mesh size of wing 200 mm, overhang 200 mm, belly 150 and 100 mm, throat 75 and 35 mm, and cod-end 30 mm was towed at 1.5 to 2.5 km. Fishing operations were conducted between 19°06′86″ N and 19°12′15.09″ N latitudes and from 72°41′23.20″ E to 72°48′50″ E longitudes, at a depth range of 6–21 m. The carapace length of crab was determined as a length between the ends of the longest lateral spines around the midline of the frontal nozzle and back margin, and the body weight was recorded to the nearest gram. The length and weight similarity of every species was calculated by means of the formula:

$$\mathrm{Log}W = \mathrm{Log}a + b\mathrm{Log}L$$

where W = crustacean weight in gm, L = length of the crab in cm, a is the intercept from Y axis, and b is an exponent that equals regression slope in line. The length–weight relationship has been separately measured for both males and females in the present analysis and for both sexes and pooling (males and females) results. Exponent b values inform about the organism's development. According to Bagenal and Tesch (1978), if the b value is not equal to 3, it implies that the weight gain is allometric with positive allometry if b reaches greater than 3 and has negative allometry if b is less than 3, while being an isometric if $b = 3$. The carapace length (CL) and body weight (BW) measurements were calculated and recorded. The data obtained were evaluated with statistical similarities in order to assess the intensity of the similarity with the statistical data and regression analysis available to estimate the relations between variables using basic MS Excel.

Results

A total of 479 specimens, including 262 males and 217 females, from fishing trawler were examined for their carapace length. The carapace length of males ranged from 2.76 to 3.19 cm, and the total weight varied from 5.30 to 6.70 gm, while the carapace length of females ranged from 2.69 to 3.54 cm and the weight varied from

5.26 to 7.36 gm. During the sampling, the highest number of samples was 138 specimens recorded in September (29%) and the lowest number was 48 specimens recorded in October (10%) as shown in Table 1. The sample size, carapace length range (cm), total body weight (W) range (g), variables of carapace length to weight (LWR), *a* and *b* length–weight relationships (LWR), their frequency and confidence intervals of 95% and the determination coefficient (r^2) are mentioned in Table 2. Both sex-wise and the pooled, the *b* values were calculated. Figure 2 depicts the length–weight relationship between males, females and pooled data. The *b* values recorded 2.87 for males, 2.58 for females and 2.71 for pooled. The length–weight relationship of this crab was represented by the curvilinear model ($W = a \times L^b$) with values for males, females and pooled sexes given in Table 3. The length–weight relationship parameters are intended by an average, minimum and maximum mean measurement of the total length (cm) and weight (gm) of crab given in Tables 2 and 3. The length–weight relationship of males and females was reported in allometric relations. The analysis of the present results also revealed that the male's sex-wise regression slope ($P > 0.01$) does not have any meaningful difference, and the relationship is highly significant ($P > 0.01$). This study on length–weight relationship (LWR) of crab species captured by the trawl highlights the growth patterns as indicator of state of the organism in terms of capacity for survival and reproduction. There were significant differences in the average r^2 values for males (0.89), females (0.79) and pooled data (0.83) in the r^2 values ($P > 0.01$) of crab species recorded.

Table 1 Monthly collection of *Charybdis callianassa* from Mumbai coast (September 2019–March 2020)

Months	Monthly specimen collected	Percentage (%)
September	139	29.0
October	48	10.0
November	67	14.0
December	64	13.4
January	58	12.1
February	53	11.0
March	50	10.5
Total	479	100.0

Discussion

In the present study, the resulting *b* value = 2.71 was measured for pooled data. However, the *b* value recorded 2.87 for males and 2.58 for females. All these values are negative allometry, but males are heavier than females according to Bagenal and Tesch (1978) for fishes and Thirunavukkarasu and Shanmugam (2011) for mud crabs *Scylla tranquebarica* (Fabricius, 1798) collected from the landings in Parangipettai, India. The range (Froese, 2006) of *b* value varies between 2.5 and 3.5. If the measured *b* value equals 3, it indicates an isometric increments in both length and weight, but if it is larger than 3, it is an indicator that the fish (or crustaceans) are plumper with the length, and if *b* is less than 3, it means species have a slimmer body as the length tends to increase (Bagenal & Tesch, 1978; Atar & Seçer, 2003). The carapace length to body weight ratio has been widely used to classify species development and assess species decline in a particular geographical area. The main environmental factors which can influence crustacean growth are temperature, quality and quantity of food (Kaestner, 1970). *Charybdis callianassa* is a relatively small species, reaching a maximum carapace length and width size of around 46 × 29 mm. The largest specimen reported (Mantelatto & Garcia, 2001) was a male from Malaysia measuring 38.3 × 24.9 mm, and the specimen from Pakistan (Tirmizi & Siddiqui, 1996) measured between 25 × 16 and 38 × 26 mm for the females and between 23 × 17 and 38 × 22 mm for the males. Maximum (cm) lengths of males in this sample varied from 2.76 to 3.19 cm and weight (gm) from 5.30 to 6.70 gm. The female ranged from 2.69 to 3.54 cm and 5.26 g to 7.36 gm as observed in the present study.

Table 2 Length–weight relationship of *Charybdis callianassa* species sampled during September 2019–March 2020 from Mumbai coast, India

Number of samples (*N*)	Sex	TL (cm)		BW (gm)		Regression parameters				
		Minimum	Maximum	Minimum	Maximum	*a*	95% CI of *a*	*b*	95% CI of *b*	r^2
262	M	2.76	3.19	5.30	6.70	0.0038	0.0017–0.0085	0.0038	2.7521–2.9901	0.90
217	F	2.69	3.54	5.26	7.36	0.0245	0.0074–0.0811	0.0245	2.4243–2.7772	0.80
479	P	2.69	3.54	5.26	7.36	0.0116	0.0065–0.0309	0.0116	2.436–3.098	0.83

r^2, coefficient determination; CI, confidence interval; TL, total length; BW, body weight in gm; *a* and *b*, parameters of length–weight relationship; *N*, sample size; M, male; F, female; P, pooled sex; *a*, anti-log

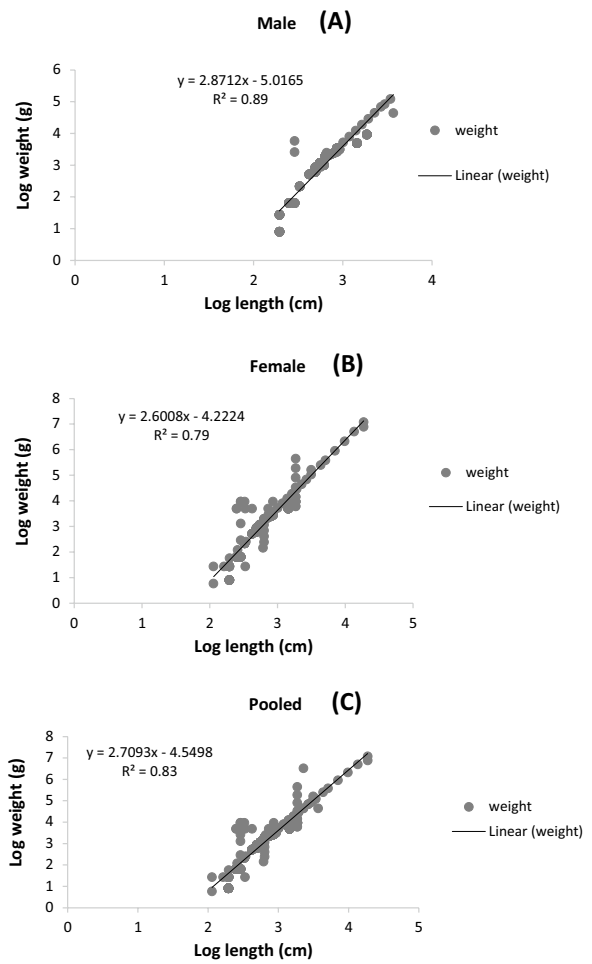

Fig. 2 The coastal areas of Mumbai, with the length–weight relationship of *Charybdis callianassa* between males and females recognized (**a** male, **b** female and **c** pooled sex)

Table 3 The curvilinear relationships of length and weight of pooled, male and female sexes of *Charybdis callianassa*

Sex	*b*	Pearson (*r*)	r^2	*a*	Log (*a*)
M	2.87	0.95	0.8967	− 2.41451	0.003850
F	2.58	0.89	0.7970	− 1.6091	0.024598
M + F	2.71	0.91	0.8360	− 1.93512	0.011611

Conclusions

This study concludes that *Charybdis callianassa* crabs, length–weight relationship along Mumbai coastal waters, India is as:

$$W = {}_{0.011611}\, L^{2.71}$$

In order to maintain a sustainable habitat and also provide fishermen with increased incomes, the enormous numbers and distribution of brachyuran crab stocks along the Indian coast play a significant part. The average condition and the disparity in condition between small and large specimens vary between areas, seasons and years, which is the result of various relationships between weight and volume. The mean status of the specimens and the differences between large and small specimens vary across various regions, seasons and years for similar weight and longitude connections. Sometimes, significant weight-length relationships within the species may differ based on locations, seasons or yearly environment. Crustacean creation is an unusual mechanism as the successive moulds extract the stiff exoskeleton slowly. The length–weight relation also provides details on the general well-being of individuals, the difference between sex and growth, the maturity of the first season, breeding and gonadal production. Long-term growth equations can be converted into weight equations, for use in stock assessment models. Crabs, as a source of rich protein food and excellent raw material for seafood products for export, are increasingly being recognized for the rising population in India, especially in the coastal region. The third main component of edible shellfish is crab edibility, with prawns and lobsters holding the first and second positions because of the demand in other markets.

Abbreviations

M.F.V.: Mechanized fishing vessel; ICAR: Indian Council of Agricultural Research; LT: Total length; LWR: Length–weight relationships; CL: Carapace length; BW: Body weight; CIFE: Central Institute of Fisheries Education.

Acknowledgements

The authors wish to express sincere thanks to the Director, ICAR-CIFE, Mumbai, for providing the necessary facilities to conduct the research work.

Authors' contributions

RNW and KKR conceived and designed the experiment and wrote the manuscript; SR contributed to material/analysis tools and helped in performing the experiment. NG helped to write the manuscript. All authors have read and approved the manuscript.

Funding

No funding.

Availability of data and materials

Data are available upon request.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors hereby declare that there are no conflicts of interest.

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Received: 30 April 2021 Accepted: 2 September 2021
Published online: 07 October 2021

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