Article

Length weight relationship and sexual dimorphism in snapping shrimp *Alpheus leptocheles* Banner and Banner, 1975 (Alpheidae) collected from Tamilnadu coast, India

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Abstract
This study describes the sexual dimorphism and morphometric relationships in compressed first pereopod snapping shrimp, *Alpheus leptocheles* (Banner and Banner, 1975). The shrimp were collected from the Mudasalodai landing centre, Cuddalore, Tamilnadu, India. Selected morphological characters were examined to find possible intersexual morphological differences in this species. The morphological observation and the statistical analysis showed a clear separation between the two sexes. Among the 19 characters, %CL (TL), %AL (TL), %TiL (AL), %NpH (NpL) and %NdL (NpL) were significantly ($p<0.05$) different in male and female. The slope value in carapace length-weight relationships and abdomen length-weight relationship in males and females of *A. leptocheles* showed the sexual dimorphism. The PC1 and PC2 showed more weightage for %CL (TL), %TiL (AL), and %NdL (NpL).

Keywords snapping shrimp; Alpheus; sexual dimorphism; morphometrics; length-weight relationship

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1 Introduction

Sexual dimorphism is a phenomenon in which males and females of the same species exhibit different characters among the animal kingdom (Shine, 1989; Fairbairn et al., 2007). The sexes often differ in body shape and size, but the degree to which sex specific traits expressionmay vary considerably among species and it is an essential component of biological diversity (Bertin et al., 2002; Chenoweth et al., 2008). Sexual selection and natural selection are the two major adaptive mechanisms have been proposed to explain the evolution of sexual dimorphism (Andersson and Simmons, 2006; Blanckenhorn, 2010; Safran et al., 2013). Sexual selection can be defined as the competition for mates (Shuker, 2010; Janicke et al., 2016). Natural selection can arise as a consequence of the different interactions like survival and fecundity and coexistence with their environment (Katsikaros and Shine, 1997; Lailvaux and Vincent, 2007).

Many body structures of caridean shrimps show clear morphological and meristic differences as sexual dimorphism (Hartnoll, 1985). The major sexual dimorphism like body size and weaponry in caridean shrimps is highly dependent on the mating system (Correa and Thiel, 2003; Bauer, 2004). Species in which males are significantly larger than females and possess hypertrophied weaponry (chelipeds) are characterized by mating, maintenance of their territory grounds and for female reproductive success (Correa and Thiel, 2003; Bauer, 2004; Bauer et al., 2014). In contrast, the selective pressures have led to small males and larger females in some species where the males do not guard the females (Correa and Thiel, 2003; Bauer, 2004).

Much biological information and analysis tools are available for sexual dimorphism, taxonomic, ecological, behavioral and evolutionary studies. The sexual dimorphism was studied in various crabs and shrimps (Ngrid et al., 2013; Christodoulou and Anastasiadou, 2017), but very few reports are available as in the case of Alpheid shrimps (Costa-Souza et al., 2019, Thangaraj et al., 2022). *Alpheus leptocheles* belongs to the family Alpheidae which is reported from India recently by Kajal and Thangaraj, (2024). These snapping shrimp shows a substantial sexual dimorphism is not bring out to biologists community so far. Here we have depicted the morphological characters posse sexual dimorphism and size relationship through statistics analysisin *A. leptocheles* of Indian waters.

2 Materials and Methods

2.1 Sample collection and preservation

In total, 84 individuals (49 male; 25 female) of *A. Leptocheles* (Figure 1) were collected during February to April 2022 from Mudasalodai landing centre (Lan. 11° 29' N; Lat. 79°46' E), Tamil Nadu, India. The samples were immediately kept in the ice box and brought to the laboratory. The morphological characteristics and colour pattern of male and females were noted before preservation and storage. Ten samples were preserved in 95% ethanol solution for molecular studies.

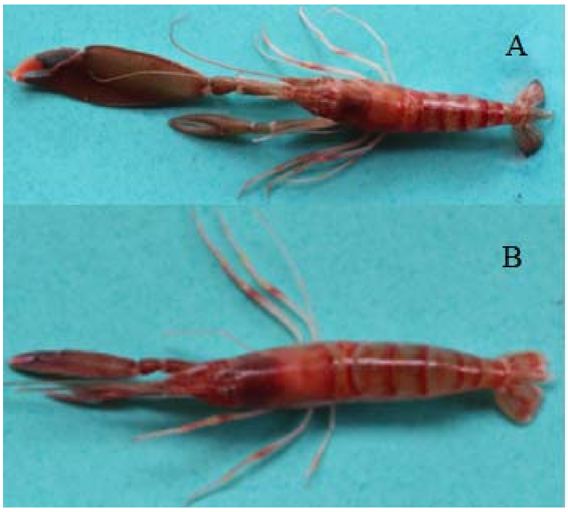

Fig. 1 Male (A) and female (B) *A. Leptocheles*.

2.2 Morphometric measurements

Morphometric characters were measured in all the specimens and analysed as per Thangaraj et al. (2022). The following measurements were performed: Total length (TL) = the distance from the tip of the rostrum to the posterior end of the abdomen, excluding telson; carapace length (CL) = the distance from the tip of the rostrum to the posterior end of the carapace middorsally; abdominal length (AL) = the length of the abdomen, excluding telson; ocular hood width (OW); antennal spine length (ASL); lengths of the first, second, and third antennular segments (AIl, AI2, AI3, respectively); telson length (TIL); telson width at the distal end (TID); telson width at the proximal end (TIP); propodus length of the major chela (MpL); maximum propodus height of the major chela (MpH); dactyl length of the major chela (MdL); height of the hand of the major chela with the dactyl closed (MhH); propodus length of the minor chela (NpL); propodus height of the minor chela (NpH); and dactyl length of the minor chela (NdL). Morphometric measurements were taken using a digital calliper (Mitutoyo, Japan) with 0.1mm accuracy. Body weight (W) was measured in milligram(mg).

2.3 Data analysis

All the morphometric data of the male and female were analysed using univariate analysis of variance (ANOVA; Zhang and Qi, 2024), with Tukey HSD (for unequal) post-hoc comparison texts to investigate significant morphometric differences (Tukey, 1949). Tests were considered significant at $p<0.05$. Principal Components Analysis (PCA) of covariance matrices was used on the morphometric variables to determine variability among and within the samples. The use of covariance matrices follows the suggestion of Wiley (1981) for data composed of the same kind of measurements. Morphometric measurements were then log transferred to preserve allometrics, standardize variance and produce a scale invariant covariance matrix before analysis. To ensure comprehensive analyses of the data for more powerful discrimination between species, loadings of PC1 were scattered against the PC2 in PAST (V3.0).

3 Results

3.1 Sexual dimorphism

The morphometric measurement values of *A. leptocheles* are given in Table 1 and the significance variance data between male and female in Table 2.

Table 1 Morphometric variables male (n=49) and female (n=25) *A.leptocheles*.

Characters (mm)	Male			Female		
	Min	Max	Mean ± SD	Min	Max	Mean ± SD
TL	21.30	27.22	24.39±1.48	19.69	31.14	24.37± 2.53
CL	8.77	11.83	10.31±0.73	7.95	12.69	10.00± 1.20
AL	12.53	16.34	14.08±0.84	11.74	18.45	14.36± 1.46
OW	1.89	2.48	2.20±0.16	1.83	2.89	2.19± 0.22
ASL	3.03	4.69	3.65±0.40	2.45	3.95	3.20± 0.33
Al1	0.74	1.12	0.89±0.10	0.61	1.01	0.77± 0.09
Al2	1.44	2.19	1.74±0.17	1.17	1.92	1.55± 0.16
Al3	0.66	1.11	0.91±0.09	0.62	0.98	0.81± 0.09
TiL	3.07	4.62	3.96±0.31	2.92	4.54	3.86± 0.38
TiD	0.99	1.39	1.20±0.09	0.91	1.43	1.18± 0.13
TiP	1.69	2.28	1.93±0.15	1.48	2.23	1.86± 0.17
MpL	13.95	25.37	19.88±2.82	6.75	13.00	10.81± 1.60
MpH	3.10	5.76	4.38±0.65	1.54	2.85	2.35± 0.36
MdL	5.27	8.95	7.29±1.01	2.61	4.79	3.94± 0.56
MhH	2.43	4.04	3.30±0.44	1.18	2.22	1.79± 0.25
NpL-1	7.77	11.64	9.62±0.98	6.12	10.64	8.26± 1.25
NpH-1	1.14	2.23	1.77±0.24	0.91	1.60	1.24± 0.17

NdL-1	4.98	7.52	6.23±0.66	3.75	6.65	5.24± 0.80
Weight (mg)	330	920	640±150	230	740	470± 130

Among the morphometric characters, carapace length (%CL), abdomen length (%AL), telson length (%TiL), propodus height of the minor chela (%MpH) and dactyl length of the minor chela (%NdL) showed significant variation in males and females. Most of the characters like %OW(AL),%AI2 (ASL), %AI3 (ASL), %TIP (TIL), %TID (TIL), %MdL(MpL), %MpH (MpL), %MhH (MdL), are showed no significant difference between sexes.The first and second principal component loading value for the males and females of *A.leptocheles* is given in Table 3. The PC1 and PC2 had more weightage for%CL (TL), %TiL (AL), and %NdL (NpL).

Table 2 Morphometric variance data in male and female of *A.leptocheles*.

Characters	Female	Male
%CL (TL)	59.19 ± 2.96^{a}	42.25 ± 1.11^{b}
%AL (TL)	68.10 ± 3.53^{a}	57.75 ± 1.11^{b}
%OW (AL)	15.30 ± 1.04^{a}	15.67 ± 0.89^{a}
%AL1 (ASL)	24.28 ± 1.62^{a}	24.59 ± 1.73^{a}
%AL2 (ASL)	48.72 ± 1.88^{a}	47.70 ± 2.05^{a}
%AL3 (ASL)	25.48 ± 1.89^{a}	25.02 ± 1.39^{a}
%TiL (AL)	27.02 ± 2.42^{a}	28.15 ± 1.94^{b}
%TiP (TiL)	48.21 ± 2.11^{a}	48.98 ± 2.11^{a}
%TiD (TiL)	30.65 ± 1.47^{a}	30.51 ± 1.37^{a}
%MdL (MpL)	36.59 ± 1.56^{a}	36.75 ± 1.68^{a}
%MpH (MpL)	21.82 ± 0.93^{a}	22.05 ± 0.79^{a}
%MhH (MdL)	45.59 ± 1.66^{a}	45.36 ± 1.85^{a}
%NpH (NpL)	15.11 ± 0.98^{a}	18.45 ± 1.91^{b}
%NdL (NpL)	63.41 ± 2.80^{a}	64.74 ± 2.49^{b}

Values in the row sharing the common superscripts are significantly not varied (P<0.05)

Table 3 Morphometric variable loadings for the first and second principal components of males and females of *A.leptocheles*

Characters	PC1 (21.34%)	PC2 (16.20%)
%CL (TL)	0.267	0.028
%AL (TL)	-0.267	-0.028
%OW (AL)	0.041	0.042
%AL1 (ASL)	0.170	-0.228
%AL2 (ASL)	-0.175	-0.022
%AL3 (ASL)	-0.162	-0.148
%TiL (AL)	0.566	-0.291
%TiP (TiL)	-0.304	0.476
%TiD (TiL)	-0.208	0.144
%MdL (MpL)	-0.040	0.156

%MpH (MpL)	0.006	0.030
%MhH (MdL)	-0.024	-0.019
%NpH (NpL)	0.233	0.652
%NdL (NpL)	0.505	0.370
Eigenvalue	9.55	7.25

3.2 Morphological relationship

The carapace length and weight of males showed a positive correlation (R^2 = 0.8579). The weight was increased with increasing carapace length and the regression equation was calculated as log weight = -1.5169 + 3.2702 Log CL (R^2 = 0.8579). In females also the carapace length and weight relationshiprevealed a positive correlation (R^2 = 0.9041) (Figure 2). The weight was increased with increasing carapace length and the regression equation was calculated as log weight = -0.8495 + 2.5049 log CL (R^2 = 0.9041).

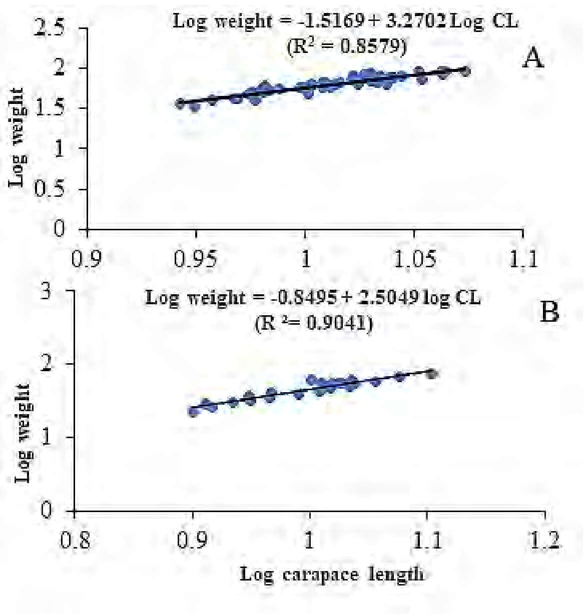

Fig.2 Relationship between log carapace length and log weight in *A.leptocheles* male (A), female (B).

The abdomen length and weight of males revealed a positive correlation (R^2 = 0.4646). The weight was increased with increasing abdomen length and the regression equation was calculated as Log weight = -1.5425 + 2.9057 log AL (R^2 = 0.4646). In female, the abdomen length and weight showed a positive correlation (R^2 = 0.6369) (Figure 3). The weight was increased with increasing abdomen length and the regression equation was calculated as Log weight = -1.2349 + 2.4964 log AL (R^2 = 0.6369).

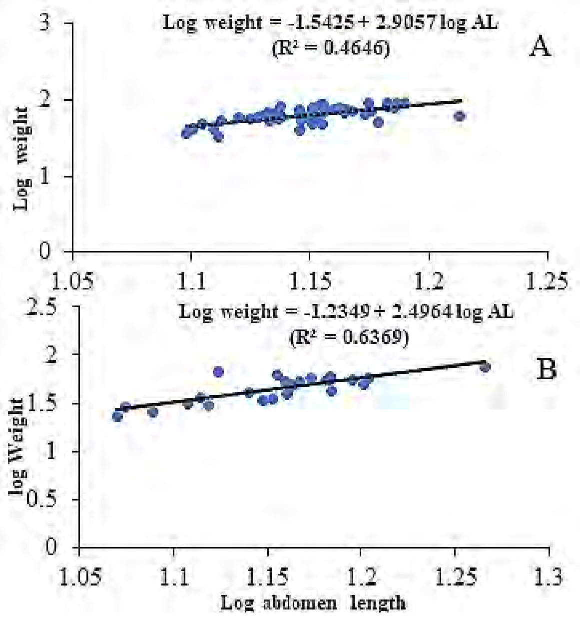

Fig. 3 Relationship between log abdomen length and log weight in *A.leptocheles* male (A), female (B).

The total length and major propodus lengthof males revealed a positive correlation (R^2 = 0.3707). The major propodus lengthwas increased with increasing total length and the regression equation was calculated as Log MpL = -0.7525 + 1.476 Log TL (R^2 = 0.3707). In females, the total length and major propodus lengthshowed a positive correlation (R^2 = 0.5955) (Figure 4). The major propodus lengthwas increased with increasing total length and the regression equation was calculated as Log MpL = - 0.6225 + 1.1926 log TL (R^2 = 0.5955).

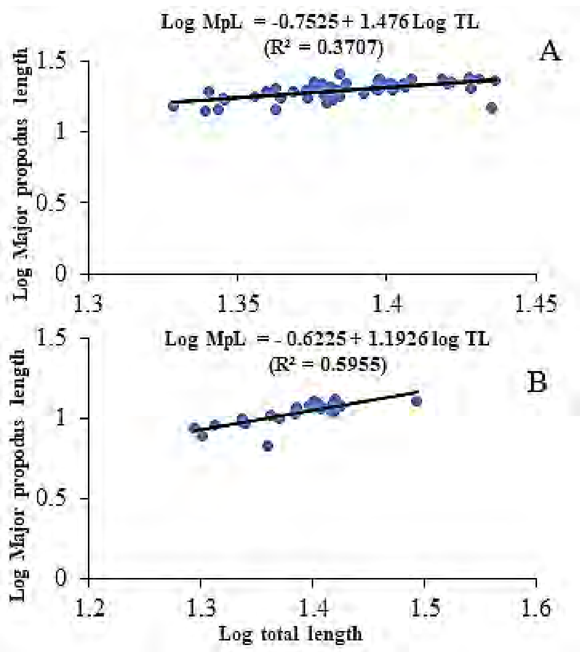

Fig.4 Relationship between log total length and log major propodus length in *A. leptocheles* male (A), female (B).

The total length and minor propodus lengthof malesshowed a positive correlation (R^2 = 0.3787). The minor propodus lengthwas increased with increasing total length and the regression equation was calculated as Log NpL = - 0.4539 + 1.0351 log TL (R^2 = 0.3787). In females, the total length and minor propodus lengthshowed a positive correlation (R^2 = 0.6401) (Figure 5). The minor propodus lengthwas increased with increasing total length and the regression equation was calculated as Log NpL = - 0.7475 + 1.1988 log TL (R^2 = 0.6401).

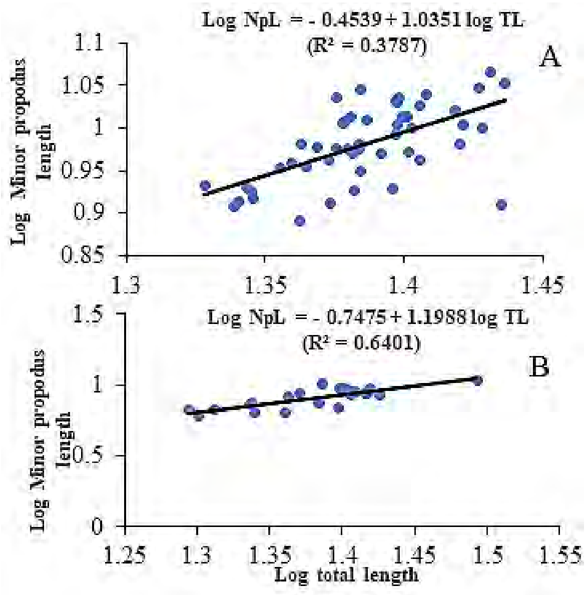

Fig. 5 Relationship between log total length and log minor propodus length in *A. leptocheles* male (A), female (B).

4 Discussion

Morphometrically, the snapping shrimp, *A. leptocheles* did shows substantial sexual dimorphism in some traits. The length, width of the major chela and the thickness, length of the minor chela contributed major differentiation in males and females. As per earlier observation by Costa-Souza et al. (2019) there was no significant difference between males and females in three species such as *A. angulosus*, *A. buckupi* and *A. carlae* and in the other species (*A. bouvieri*, *A. estuariensis* and *A. nuttingi*), the difference was small and idiosyncratic.This finding is consistent with other studies, for example, in the populations of *A. estuariensis* from Bahia and *A. brasileiro* from São Paulo, males and females were similar in size (Costa-Souza et al., 2018; Pescinelli et al., 2018), whereas in *A. carlae* from São Paulo (Brazil), and *A. normanni* and *A. heterochaelis* from North Carolina (USA), males were slightly larger (Nolan and Salmon, 1970; Mossolin et al., 2006). Other related species in *Alpheus* genusmostly did not show sexual dimorphism in body size, which can be explained by its social and reproductive behaviour that may include social monogamy (Davanso et al., 2017). In monogamic species, the size difference between sexes is minimal and often absent (Correa and Thiel, 2003). Body size is a crucial in paired males and females as observed in *A.brasileiro* by Davanso et al. (2017).

In *A. Leptocheles* the major cheliped in males is much large and stronger than females. This finding is consistent with studies of other Alpheus species such as *A. angulosus*, *A. buckupi*, *A. nuttingi*, *A. carlae*, and *A. estuariensis* were dimorphic regarding the size of the major chelipeds (Costa-Souza et al., 2019). Male chelipeds are more robust indicating that this appendage has a higher adaptive value for these species. However, the size of the major cheliped did not differ between the sexes in *A. bouvieri* (Costa-Souza et al., 2019). In some brachyuran crabs and caridean shrimps, the conspicuous sexual dimorphism of the chelipeds is related to behavioral and functional differences (Saito, 2002; Araújo et al., 2012). Males are usually more aggressive and more cautious about their territory and use their appendages in disputes for breeding females or for space, and to grasp the female during the mate-guarding (Jormalainen, 1998; Pinheiro and Hattori, 2006). The triggering mechanisms and other functions of the major cheliped are the same in both sexes (Anker et al., 2006). The dimorphism observed in this study suggests that males exhibit an expressive dominance and aggressiveness towards females and other competing males, which can be tested in behavioral studies ex situ. Moreover, Hughes et al. (2014) suggested that robust chelipeds may increase the cost of locomotion of ovigerous females.

Commonly, crustaceans maintain dimensional equality and the length-weight slope value less than three which indicate that the animal becomes slender as it increases in length. But somewhere the slope having value greater than three represents stoutness indicating allometric growth (Kurup et al., 2000, Lalrinsanga et al., 2012). The parameters of carapace length-weight relationships, abdomen length-weight relationship in males and females of *A. Leptocheles* estimated in the present study were within the ranges and also demonstrated by several workers (Nahavandi et al., 2010; Lalrinsanga et al., 2012; Mohanty et al., 2015). The slope value in carapace length-weight relationships (3.2M and 2.5F) and abdomen length-weight relationship (2.9M and 2.4M) in males and females of *A. leptocheles* showed the sexual dimorphism. The major propodus length and total animal length relationship in male and female also indicated sexual dimorphism.The degree of overlap as shown in score plot in males and females attests to their morphological similarity. Morphometric sexual dimorphism in *A.leptocheles*is due largely to the relative thickness of the minor chela propodus height and width.

5 Conclusion

Alpheus leptocheles show sexual dimorphism in terms of chela of major and minor first pereopod, carapace length (%CL), abdomen length (%AL), telson length (%TiL), propodus height of the minor chela (%NpH) and dactyl length of the minor chela (%NdL).The morphometric and statistical analyses provide here are consistent discrepancy of male and female in this species. The observationsmay be useful in future studies on taxonomy and population structure of Alpheid shrimps.

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