

Sexual system and Sexual dimorphism in the shrimp *Arete indicus*, symbiont with the sea urchin *Echinometra mathaei* in the Persian Gulf, Iran

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Received 20 September 2017; revised 20 November 2017

The sexual system and sexual dimorphism of the shrimp *Arete indicus* are described. The following were measured for all shrimp under stereomicroscope to the nearest ± 0.01 mm: carapace length (CL), merus length (ML) and carpus length (CrL) of the largest of the first pair of chelipeds, pleural width of the second abdominal segment (PW), and propodus length (PL) of the second (larger) pair of chelipeds. Sex determinations were based on presence of the appendix masculina on the base of the endopod of the second pleopods. With a view to determine whether or not a linear relationship exists between the CL, PL, ML, CrL and PW, the allometric model $y = ax^b$ was used. A correlation was found between CL and ML in both sexes of *Arete indicus*. The status of allometry differed among various body parts of both sexes, and degree of allometry differed among various body parts between the sexes. According to ANCOVA, PW, PL, and ML of females are not larger than that of males at any given body size. The CL of *Arete indicus* females was not larger than the males. Due to observation a few of males with tiny appendices masculina, also based on earlier literature worked on *Arete indicus*, we believe this species is partially protandric.

[**Keywords:** Sexual system, Sexual dimorphism A, Shrimp, *Arete indicus*, Symbiosis]

Introduction

Sexual systems are diverse in caridean shrimps, but they are unstudied¹ in most caridean shrimps. Many species of shrimps are gonochoric with gender expressing only one sex during their life time (e.g. *Hippolyte williamsi*²; *Pontonia margarita*³; *Periclimenes brevicarpalis*¹). In some decapod infraorders, including Anomura, Caridea, and Penaeoidea, we can find functional protandrous hermaphroditism. Protandry was first recorded in *Athanas kominatoensis* (Family Alpheidae), a symbiont of an endemic Japanese sea urchin⁴. Individuals with strict protandric hermaphroditism undergo sex change from male to female with increases in size age⁵. For example, in *Lysmata seticaudata* all individuals function first as male before changing to female. In other species, not all individuals are sex changers. Partial protandry occurs when some individuals are females, some are males, and some start as males and change to females. Partial protandry has been reported in *Thor manningi* and *Athanas indicus*^{1,4,6}.

Conspicuous sexual dimorphism is a common phenomenon in the animal kingdom, as males may be

brightly colored whereas females are dull (e.g. most birds, reptiles and mammals⁷⁻⁹). Males may possess some appendages that are absent in females^{4,10,11}. Many studies have examined sexual dimorphism in terms of sexual selection and reproductive fitness¹². Sexual dimorphism is also observed in some species of caridean shrimps (e.g. Family Alpheidae) and is related to the reproductive biology of the species¹³.

Arete indicus is widely distributed in the Pacific Ocean, Red Sea and Western Indian Ocean from Somalia to Mozambique, including the Seychelles and Madagascar¹⁴. This species lives among spines of the sea urchin *Echinometra mathaei*⁴. The aim of the work is the determination of the extent of sexual dimorphism to reveal the sexual system of *Arete indicus*.

Materials and Methods

The study areas were located in Bandar-e Lengeh (26° 32' 28" N, 54° 52' 28" E; water depth: 0.5–1 m) and Bandar-e Dayyer (27° 50' 3.57" N, 51° 53' 49.39" E; water depth: 0.5–1 m), Iran, two small inlets along rocky shores with a highly diverse fauna of macro-invertebrates in the northern part of the Persian Gulf.

The survey of the sexual system was conducted on a total of 94 individuals of *Arete indicus*. Measurements were made of carapace length (CL), merus length (ML) and carpus length (CrL) of the largest of the first pair

of chelipeds, pleural width of the second abdominal segment (PW), and propodus length (PL) of the second (larger) pair of chelipeds using a graduated ocular micrometer to the nearest 0.1 mm under stereomicroscope. Sex determination was based on presence of appendices masculina on the base of the endopod of the second pleopods (with masculina)¹⁵.

To determine whether or not a linear relationship exists between the CL, PL and pleura, the allometric model $y = ax^b$ was used¹⁶. Whenever $b > 1$, the growth is positive, and when $b < 1$ the growth is negative¹⁷. In addition, investigation of difference of each measured body dimension between the sexes was subjected to an independent analyses of covariance (ANCOVA)^{1,18}.

Results

A total of 34 out of the 94 examined *Arete indicus* were males (Figure 1). All the males had appendice masculina on the endopod of the second pair of pleopods. The remaining 47 individuals were females (Fig. 1) based on their lack of appendices masculina on the endopod of the second pair of pleopods. Thirteen individuals had no sex determination due to their small body size ($CL < 2.1\text{mm}$). Four individuals had tiny masculina and were classified as males. These shrimps can be 'transitional' individuals, or individuals with a combination of male and female external and/or internal characters.

A correlation was found between ML of the second (larger) pair of chelipeds and CL in males ($p < 0.05$). A correlation was found between ML of the second (larger) pair of chelipeds and CL in females ($p < 0.05$). A correlation was found between PW and CL in females ($p < 0.05$). A correlation was found between C & L and CL in females ($p < 0.05$). The status of allometry differed among various body parts of both sexes, but the degree of allometry differed among various body parts of both sexes (Table 1, Figure 2-5). An analysis of covariance (ANCOVA) demonstrated a significant effect of sex ($F = 6.928$, $df = 2,76$; $p = 0.010$) and CL on CL, whereas no significant effect of sex found in PW, PL, and ML on CL (Table 2). This indicates that PW, PL, and ML of females are not larger than that of males at any given body size. The CL of *Arete indicus* females was not larger than

the males (Mann-Whitney U Test; $Z = 0.23924$, $P = 0.40517$ (Table 2)

Discussion

Great diversity of sexual systems is observed in the infraorder Caridea. Most caridean shrimps are gonochoric, while the second most common system is

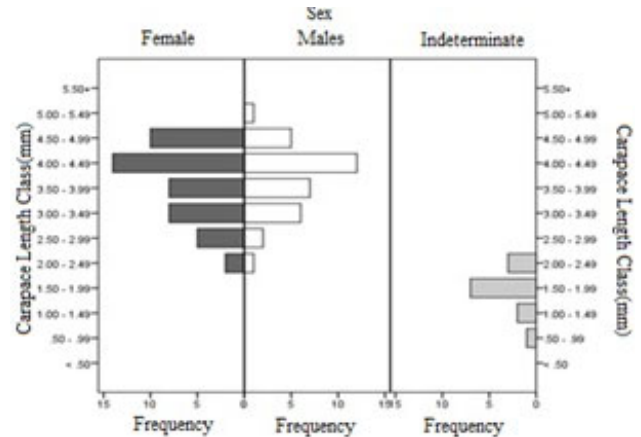


Fig. 1 — The distribution of carapace lengths of *Arete indicus* in males, females and indeterminate sex

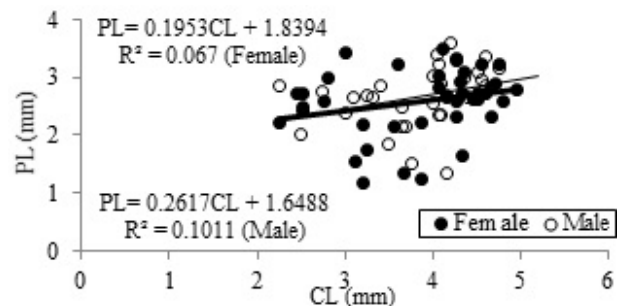


Fig. 2 — Relative growth propodus length of major cheliped as a function of carapace length in males and females of *Arete indicus*

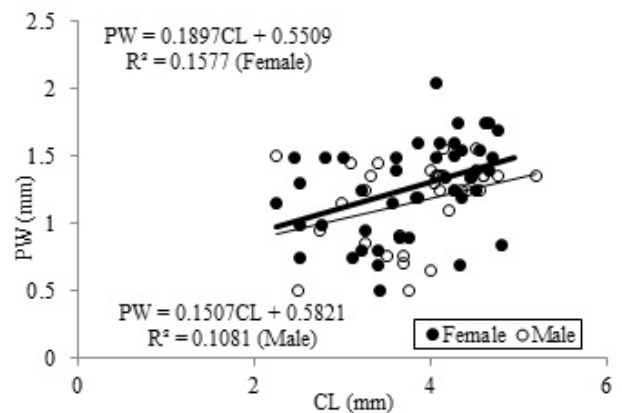


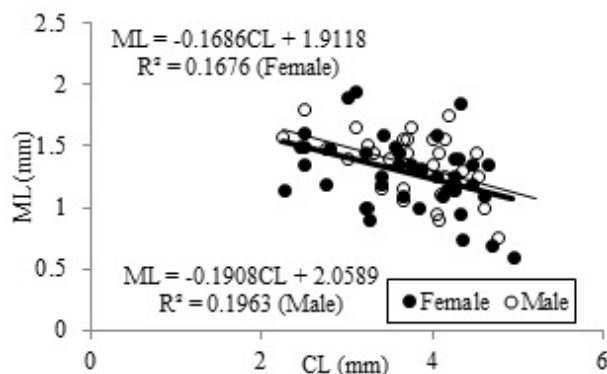
Fig. 3 — Relative growth of pleura as a function of carapace length in males and females of *Arete indicus*

Table 1 — The relative growth of different body structures in males and females of *Arete indicus*

y	x	Regression	r ²	p	b	Allometry
Males						
PW	CL	y=0.2617x+1.6488	0.108	0.0582	0.2617	-
PL	CL	y=0.1507x+0.5821	0.101	0.0677	0.1507	-
ML	CL	y=-0.1908x+2.0589	0.196	0.0088	-0.1908	-
CrL	CL	y=-0.11x+1.3934	0.103	0.0650	-0.11	-
Females						
PW	CL	y=0.1953x+1.8394	0.157	0.0058	0.1953	-
PL	CL	y=0.1897x+0.5509	0.067	0.0799	0.1897	-
ML	CL	y=-0.1686x+1.9118	0.167	0.0044	-0.1686	-
CrL	CL	y=-0.1174x+1.2974	0.128	0.0137	-0.1174	-

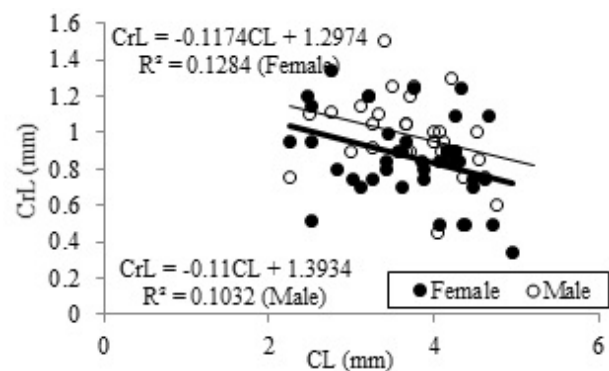
Table 2 — Analysis of covariance (ANCOVA) demonstrated a significant effect of sex in *Arete indicus*

Covariate	Independent variable	Dependent variable	F	df	p
CL	Sex	CrL	6.928	2,76	0.010
CL	Sex	PW	2.435	2,76	0.123
CL	Sex	PL	0.724	2,76	0.398
CL	Sex	ML	0.754	2,76	0.388

Fig. 4 — Relative growth merus length of major cheliped as a function of carapace length in males and females of *Arete indicus*

protandry¹⁹. The presence of males smaller than females in body size agrees with protandric hermaphroditism species in commensal shrimp²⁰. There was no significant difference in first chelipeds between males and females in *Arete indicus*.

The shape of the appendix masculina seems not to differ significantly among males in *Arete indicus* (true male and sex-change male)⁴. In our specimens, we observed some males with tiny masculina that were smaller than true males regarding masculina sizes (Table 1). No significant difference observed between sizes of appendix masculina in true males versus sex-change males, but figures in that paper suggest that there was a slight difference in sizes in appendix masculina length in true male and sex-changer male. Sexual dimorphism was not observed in sizes of *Arete indicus*⁴ which agrees with our data.

Fig. 5 — Relative growth carpus length of major cheliped as a function of carapace length in males and females of *Arete indicus*

The first case of potential protandry in shrimps in the hippolytid *Thor manningi*. Primary females can not recognized from female-phase hermaphrodites whenever the latter have completed their final change. Also, secondary sexual characteristics in the two male' types of *Arete indicus* are similar morphologically (e.g. masculina). Using absolute CL in *Arete indicus*, we cannot determine sex-changers morphologically⁶. Transition of small males to larger females in some gonochoric shrimps is facultative or not obligatory, as in *Odontonia katoi*. Moreover for gonochoric species (e.g. *O. katoi*)¹⁵ and strictly protandric species (e.g. *Thor amboinensis*)²¹, with mixed protandry¹⁵ is reported.

Conclusion

Arete indicus does not display sexual dimorphism in terms of body size. The lack of sexual dimorphism also

differs from other shrimps reported to be putatively promiscuous, such as *Palaemon pugio*²², *Pontonia mexicana*²³, *Odontonia katoi*¹⁵, or the polygamous *Macrobrachium* sp.^{24,25} and *Rhynchocinetes* sp.²⁶⁻²⁷.

Acknowledgements

The authors are grateful to Mr Rameshi for providing us with facilities at the Bandar-e Lengeh research station. A special acknowledgement is due to Dr. Mousa Keshavarz, Assistant Professor of Marine Biology, Department of Marine Science and Technology, University of Hormozgan, for his creativity and overwhelming enthusiasm in helping us with his valuable comments on *Echinometra mathaei* and plots. We also thank him for his reading of the entire paper and his valuable suggestions and comments. Authors wish to thank Dr. Nancy Knowlton, Dr. Floyd Hayes, Dr. Backwell and Mr. Rayner Pitt for comments as well as editing of the manuscript.

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