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Population biology of some species of crabs along Goa, west coast of India

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The population biology of brachyuran crab species namely *Leptodius exaratus*, *Epixanthus frontalis*, *Metopograpsus frontalis* and *Heteropanope glabra*, were examined at monthly interval from March, 2014 to August, 2015 along the five intertidal habitats of Goa. Out of 4068 crab samples, 46 % were males and 54 % females, of which 22 % were ovigerous females. The maximum carapace width (21.6 mm) was observed in *E. frontalis* and minimum (9.0 mm) in *H. glabra.* Seasonally, the *L. exaratus*, *M. frontalis* and *H. glabra* were abundant during the pre-monsoon season whereas, *E. frontalis* was abundant in the post-monsoon season. The sex-ratio revealed that males and females were abundant during monsoon whereas gravid females were found in plenty during both pre-monsoon and post-monsoon seasons. In overall size – frequency distribution, the males exceeded the females in *L. exaratus*, *M. fontalis* and *H. glabra*. The Chi-square test revealed a significant ratio of male and female, only in *L. exaratus* and *H. glabra*. The fecundity index was highest in *M. frontalis* (3630) and least in *H. glabra* (648).

[**Keywords**: Brachyuran crabs, Fecundity, Ovigerous females, Population biology, Sex ratio, Size frequency]

Introduction

Population biology determines the understanding of sexual maturity, reproductive period, fecundity and several other aspects of an organism[1]. A structural representation of the population is necessary for the conservation of natural assets[2]. Crabs are one of the ecologically important assets of littoral environments. The biological aspects of these organisms, however, are less understood as only a few studies have been conducted in the estuaries and along the coastal area. These areas have a significant impact on the eco-biology and life habits (behavioral) of crab population. The study on the reproductive aspect is considered essential for a better understanding of the population dynamics and biology[3-5].

Brachyuran crabs inhabiting inter-tidal ecosystem, live in extreme environment and still demonstrate a great diversity due to their reproductive strategies that maximize the survivorship of the offspring and help maintaining population stocks at adequate levels[6]. Fecundity is an integral part of the reproductive biology which determines the reproductive potential of species and stock size of the population, and this varies within and between the species and is influenced by various environmental factors and population attributes such as food and feeding habits, size, growth, etc.[7,8]. The present study attempts to focus on the population biology of four brachyuran crab species occurring along the different estuarine habitats of Goa, central west coast of India with an emphasis on the size frequency distribution of male, female and gravid females, their seasonal fluctuation, sex ratio, and fecundity.

Materials and Methods

Monthly sampling was carried out during low tide from the period of March 2014 to August 2015 in five estuarine beaches along the coast of Goa (Fig. 1) namely, Verem (15°29.747' N, 073°48.200' E), Odxel (15°27.255' N, 073°49.534' E), Cacra (15°27.059' N, 073°50.243' E), Siridao (15°26.584' N, 073°51.465' E), and Cortalim (15°24.525' N, 073°54.466' E). The study area comprises of Mandovi-Zuari estuarine system, which exhibit an annual cycle of varying hydrographical features[9]. It is influenced by semi-diurnal tides with a range of 0.5 to 2.9 m[(ref. 10)]. Among the five stations, Cacra, Verem, Odxel, and Siridao are rocky in nature whereas, Cortalim is inhabited partially by mangrove vegetation. Of the five sampling stations, four are situated in Zuari estuarine system while Verem lies in the adjoining estuary (Mandovi). The distance between the stations varies from 800 m to 3 km. The stations are located on the northern bank of Zuari estuary while Verem is located on the northern bank of the Mandovi estuary, Goa, on the central west coast of India.

The sampling was designed for 2 periods starting from January 2014 - December 2015. The trial

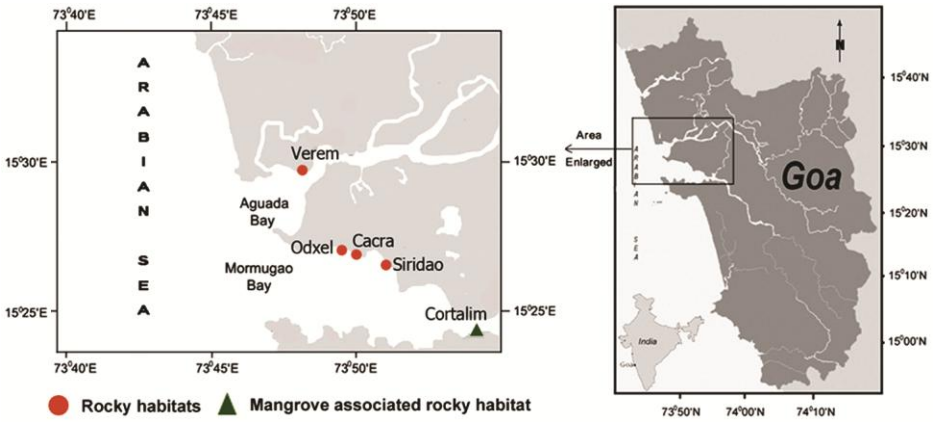

Fig. 1 — Map of the study area indicating the sampling sites

observation was carried out in the initial months of January 2014 and February 2014 to familiarize with observation, analysis and especially with the sampling which had to be carried out in different habitats at five different stations. Familiarization was necessary particularly at Cortalim wherein the habitat was not easily accessible. From September 2015 - December 2015, due to the excess catch of crab samples, the sampling efforts was reduced in an attempt to keep the sustainability of crabs.

To study the density of crabs, a 1 m^2 quadrate sampling method[11] was followed at three tidal levels *viz*. high, mid and, low tide levels at Cacra, Verem, and Odxel, and the number of crabs found within the quadrate was counted. At Cortalim a small beach exists wherein upper boundaries are limited by human inhabitation and the sandy surface encompasses the high tide level. Siridao comprise of fixed laterite boulders at mid and low tide and with sandy beach containing washed out broken shells at high tide level. Therefore the sampling at these two stations was done only at high tide level. To avoid any bias in sampling, a random sampling method was followed covering regions such as tide pools, areas underneath the rocks as well as rock crevices to study crab species diversity. The live samples were placed in plastic containers and brought to the laboratory for a detailed examination. Among the selected four crab species, *M. frontalis* was found to be actively mobile species hence the number of individuals moving out of the quadrate was noted.

At the laboratory, the samples were cleaned, photographed, subjected to morphometric and meristic analyses, and identified using available taxonomic literature[12-16]. These specimens were then stored in 5 % buffered formalin (buffered with hexamethylenetetramine) solution in transparent plastic vials. The four crab species namely *L. exaratus* (N = 1694), *E. frontalis* (N = 994), *M. frontalis* (N = 619) and *H. glabra* (N = 1029) were the most abundant crab species and frequently occurring throughout the year, hence were selected to study the size frequency, sex ratio and fecundity.

To study the fecundity, the Carapace Width (CW) was measured using vernier caliper (0.01 mm). The size frequency distribution graph was plotted using Grapher - version 8.4.696 software. The overall male and female sex ratios were tested using the Chi square test (X^2) for 1 degree of freedom (*df*) at a 5 % significance level[17]. A Sartorius CP124S analytical balance (0.01 g) was used to weigh the gravid crab along with eggs to study the fecundity of the crabs. Later the eggs were separated from the pleopods of crabs, weighed, and sub-sampled. The sub-samples were then weighed separately, placed on the counting slide and were counted under Olympus IX51 inverted fluorescence microscope[18,19]. The Analysis of Variance (ANOVA) of CW and fecundity relationship were statistically analyzed[17] at the critical value $\alpha = 0.05$. The reproductive period was determined on basis of monthly examination of the existence of gravid females during the course of the sampling period.

Results and Discussion

Brachyuran crab population along the intertidal rocky shores of estuarine regions displays high diversity in their occurrence and abundance. These crabs play an important role in the eco-biological processes that regulate the ecosystem functions, facilitate the life processes and determine the population density. The present study attempts to

emphasize the reproductive habits of few selected brachyuran crab species from the heterogeneous habitats (sandy, rocky and muddy) of Goa.

A total of 4068 crabs were collected at monthly intervals over a period from March 2014 to August 2015. The observations revealed that among the collected crab samples, 1865 were males (46 %) and 2203 were females (54 %). Among the total females collected, 905 were gravid females (49 %).

The overall size-frequency distribution in CW of male, female and gravid female (Fig. 2) was also assessed among the different species collected from the study area. It was observed that males exceeded the total females up to 32.9 mm in the species, *L. exaratus* (Fig. 2a). In *E. frontalis* (Fig. 2b), the males and females showed no size variations whereas, in the species *M. frontalis* (Fig. 2c) and *H. glabra* (Fig. 2d) the overall CW of males exceeded that of females up to 35.5 mm and 20.0 mm, respectively.

The males tend to reach a larger size to perform the function of mate guarding to have greater efficiency for successful female copulation. Published reports[20,21] suggest that the larger sized males of these

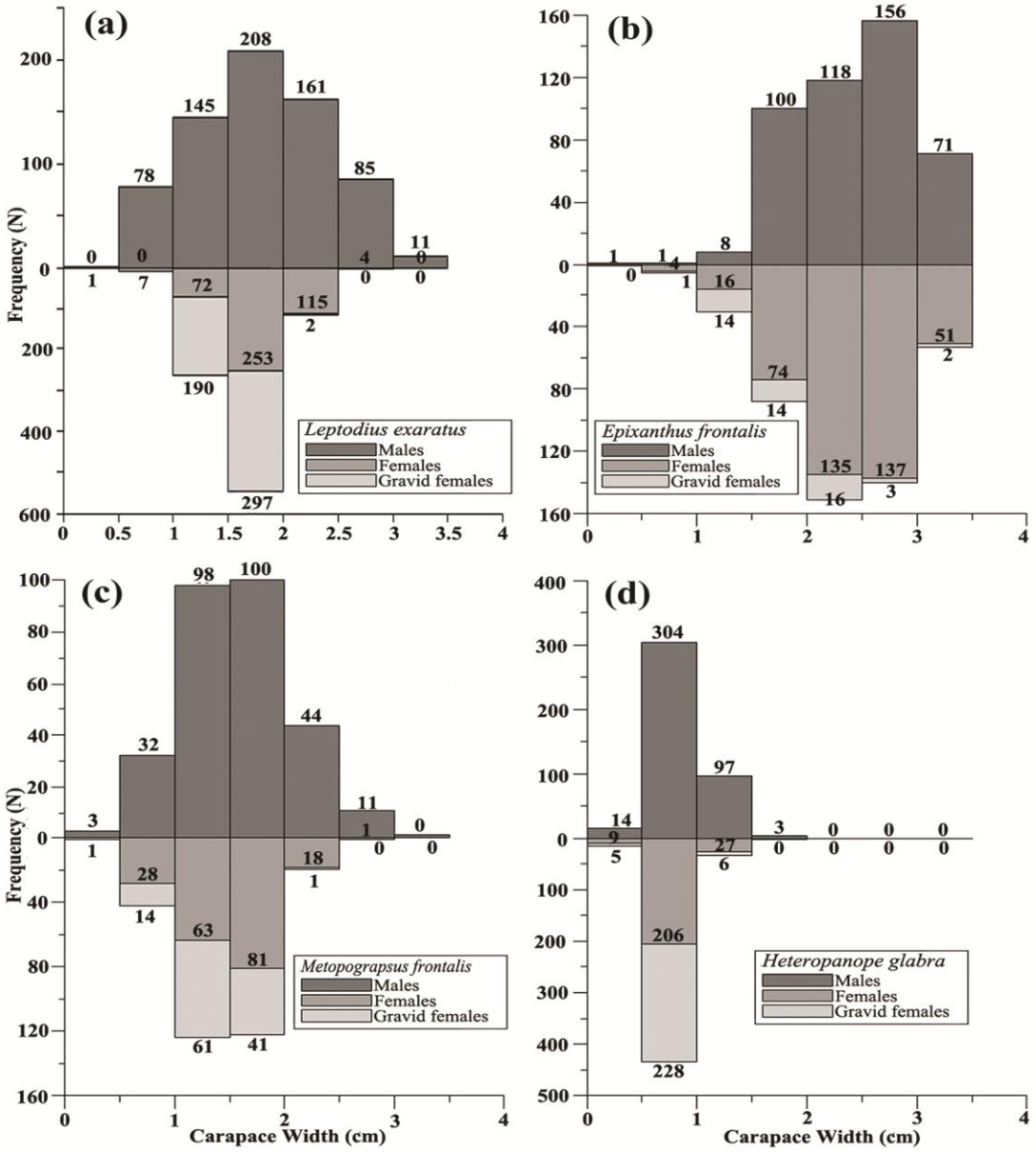

Fig. 2 — Size frequency distribution of male, female and ovigerous female of (a) *L. exaratus*, (b) *E. frontalis*, (c) *M. frontalis* and (d) *H. glabra*

crab species inhabiting in the inter-tidal habitats occupy larger sized females and display size-assortative mating resulting in the production of large clutches.

The largest CW was observed in *E. frontalis* compared to other species, with an average size of 21.6 mm (male) and 24.1 mm (female) whereas *H. glabra* showed a minimum size range with an average of 9.0 mm (male) and 8.3 mm (female). Comparing between males and females, *L. exaratus*, *M. frontalis* and *H. glabra* showed maximum size in males compared to females whereas *E. frontalis* showed no distinct size variation among males and females (Table 1).

The data on crab abundance obtained on the seasonal occurrence of male, female and gravid females of the species *L. exaratus* (Fig. 3a), *M. frontalis* (Fig. 3c), *H. glabra* (Fig. 3d) indicated high values during pre-monsoon. However, *E. frontalis* was observed to be abundant during post-monsoon season. On the contrary, low abundance was noticed in *L. exaratus*, *H. glabra* and *E. frontalis* during monsoon season, whereas in *M. frontalis*, the low value was observed during post-monsoon. The observations made here suggest that salinity plays an important role in the abundance of these species in the inter-tidal habitats. It is noteworthy to mention that during the pre-monsoon period, high salinity is known to prevail along this region suggesting that saline waters are preferred by the species. The species showed high abundance during pre-monsoon and post-monsoon due to the prevalence of more saline waters during these seasons. Along this region, high salinity is known to occur during pre-monsoon and post-monsoon with a decrease in salinity during monsoon season due to the freshwater influence through precipitation[22,23]. The low density of these crabs during the monsoonal period suggests that influx of freshwater coupled with much of the sestonic material in suspension affects food availability thereby decreasing the abundance of these species[24].

Figure 3 also shows that, the gravid females in all the four species were observed to be less abundant during monsoon due to low osmoregulatory mechanism that leads to a low tolerance in changing salinity conditions. Further, it is also observed that these egg bearing females hide in deep burrows to prevent egg loss during low saline conditions[19]. However, the non-gravid females of *H. glabra* showed high abundance during monsoon. It appears that this species exhibit a high degree of tolerance to the low saline condition as it inhabits the mangroves habitat[25,26]. Published literatures[27,28] suggests that the changes in seasonal conditions like temperature and salinity during different seasons affect the abundance of crab seasonally. As in low salinity, the development of the ovary is delayed as the crustaceans have to spend much of their energy in osmoregulation, which leads to poor gonadal development[29]. However, temperature plays an

Table 1 —CW of male and female of four crab species

Sl. No	Crab species	Male CW (mm)				Female CW (mm)			
		Min	Max	Avg	Std. Dev	Min	Max	Avg	Std. Dev
1	*Leptodius exaratus*	2.9	32.9	18	6.1	4.8	25	17	3
2	*Epixanthus frontalis*	3.2	35.3	21.6	5.7	2.1	35	24	5.8
3	*Metopograpsus frontalis*	3.9	35	14.2	4.7	3.4	26	14	4.1
4	*Heteropanope glabra*	3.5	20	9	2.1	3.9	15	8.3	1.8

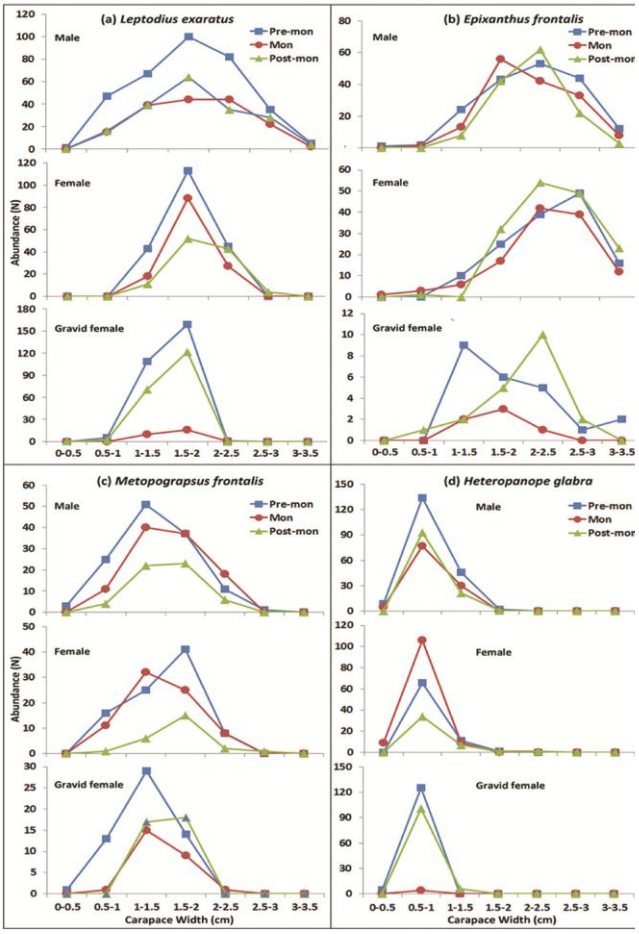

Fig. 3 — Seasonal fluctuation of male, female and ovigerous female of (a) *L. exaratus*, (b) *E. frontalis*, (c) *M. frontalis* and (d) *H. glabra*

important role in the incubation of egg, larval development and survival of offspring[30] which suggests that warm water and abundant food reduces the stress of the production of eggs and stimulates physiological maintenance.

The sex-ratio was computed to investigate the temporal variations in the male, female and gravid females in all the species. The analysis revealed that the overall sex ratio among *L. exaratus* (Fig. 4a), *M. frontalis* (Fig. 4c) and *H. glabra* (Fig. 4d) showed that males dominated during the monsoon season, whereas females were high during pre-monsoon and post-monsoon seasons. The non gravid females with respect to gravid females of species *L. exaratus* and *H. glabra* were higher in abundance during monsoon, whereas in *M. frontalis* such an observation was evident during pre-monsoon and monsoon seasons. The highest occurrence of males and females during the monsoon season suggests that the reproductive activity of these species is mainly determined by rainfall as during monsoon due to runoff the organic matter production is high[31]. Gravid females showed their occurrence during post-monsoon as the oocytes maturity is low during low temperature hence they need longer period of incubation[32]. As for *E. frontalis* (Fig. 4b), no distinct seasonal relationship on the dominance of males was seen. The ratio of the gravid females with respect to females showed the dominance of females, probably due to the hiding of gravid females in the rock crevices, holes of laterite rocks, and may even remain burrowed in the sediments.

The Chi-square test carried out for species *E. frontalis* and *M. frontalis* showed that computed values are less than tabulated values at 1 *df* at a 5 % significance level. Hence, there is no significant difference in the number of males and female. Whereas the sex ratio of species *L. exaratus* and*H. glabra* showed a significant difference for 1 *df* at a 5 % level of significance (Table 2 and 3).

The fecundity analysis revealed that there was a linear relationship between the fecundity and CW in all four crab species with various coefficient of determinant (R^2) for each species (Fig. 5). The observation revealed that the maximum number of egg produced (6038 ± 3656) was found in *M. frontalis* and the minimum number of egg produced (822 ± 489) was found in *H. glabra* (Table 4). The low fecundity number in *H. glabra* is due to the result of its smaller body size[33]. The analysis of the fecundity index was carried out and showed that *M. frontalis* has the highest fecundity index number (3,630) and the lowest one was found

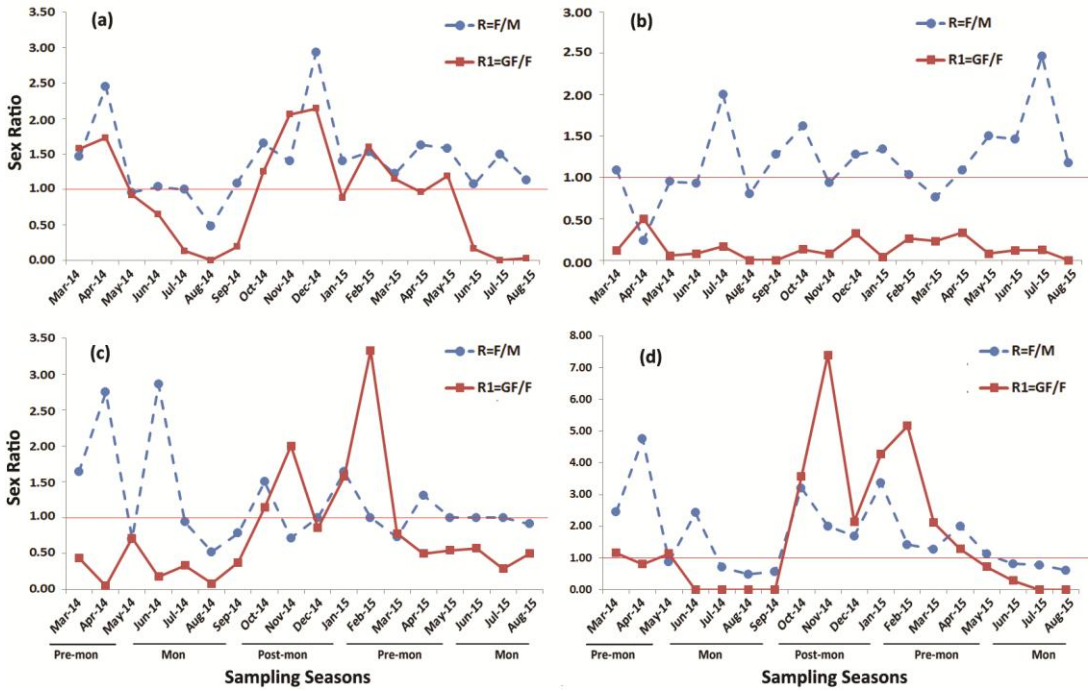

Fig. 4 — Sex-ratio between male with respect to female; and ovigerous female with respect to non-gravid female of species (a) *Leptodius exaratus*, (b) *Epixanthus frontalis*, (c) *Metopograpsus frontalis* and (d) *Heteropanope glabra*

Table 2 — Chi-square Test on Sex ratio of *Leptodius exaratus* and *Epixanthus frontalis*

-	*Leptodius exaratus*				*Epixanthus frontalis*			
Sex	Observed no.	Expected no.	Calculated X^2	Tabulated X^2	Observed no.	Expected no.	Calculated X^2	Tabulated X^2
Males	689	815	38.67	3.84	469	469	0.002	3.84
Females	940	815	-	-	468	469	-	-
Total	1629	1629	-	-	937	937	-	-

Table 3 — Chi-square Test on Sex ratio of *Metapograpsus frontalis* and*Heteropanope glabra*

-	*Metopograpsus frontalis*				*Heteropanope glabra*			
Sex	Observed no.	Expected no.	Calculated X^2	Tabulated X^2	Observed no.	Expected no.	Calculated X^2	Tabulated X^2
Males	289	299	0.66	3.84	418	452	5.12	3.84
Females	309	299	-	-	486	452	-	-
Total	598	598	-	-	904	904	-	-

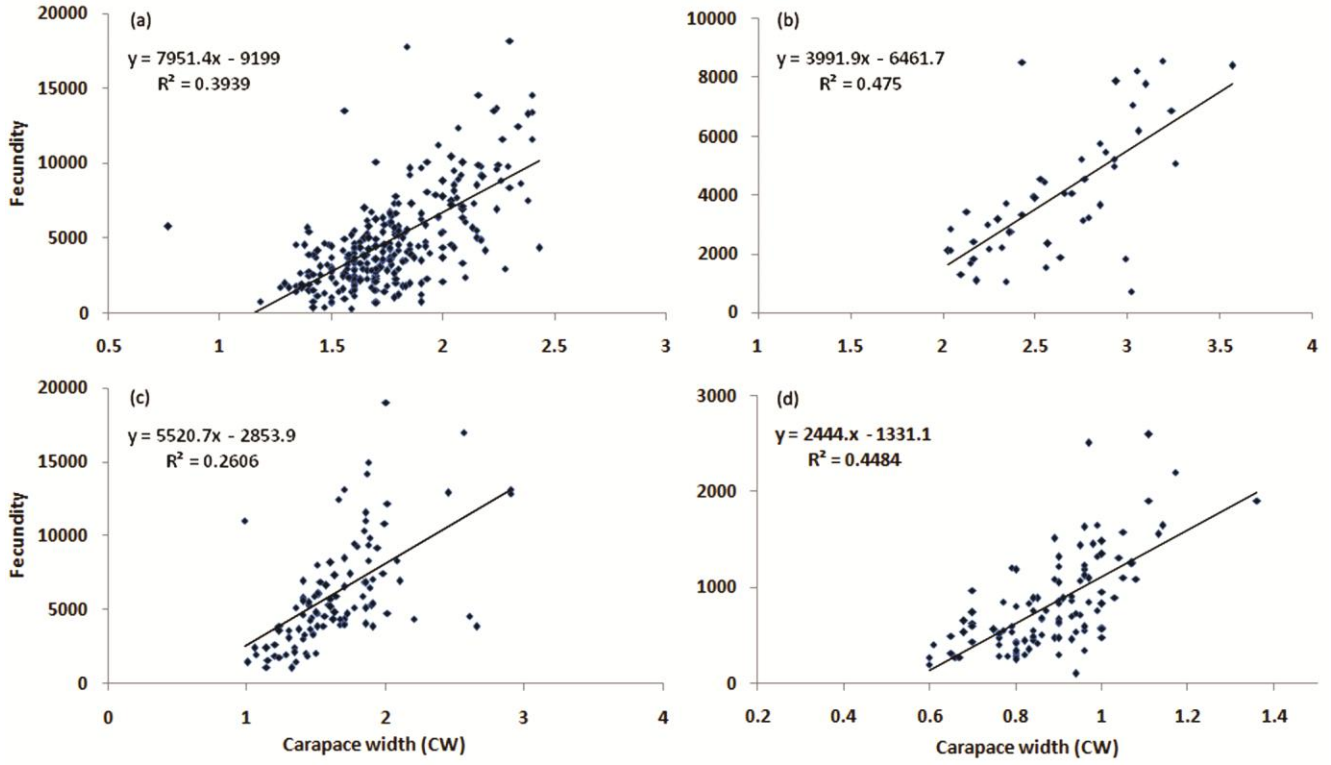

Fig. 5 — Relationship between CW and fecundity of: (a) *L. exaratus*, (b) *E. frontalis*, (c) *M. frontalis* and (d) *H. glabra*

in *H. glabra* (648) (Table 5). The variation in egg production in these intertidal species depends on several factors which influence the development of egg such as food availability, incomplete fertilization, multiple spawning, and water temperature[34,35]. It is important to note that in tropical habitats which are largely influenced by the spatio-temporal variations will alter the food availability and environmental conditions responsible for the wide spectrum in the number of egg produced. Moreover, the inter-tidal tropical habitats have a wide range of variability of environmental conditions, causing extreme environmental conditions at different times. This will result a partitioning of the energy affecting the fecundity.

The relationship between CW and fecundity in all four species was found to be better explained by linear relation (Fig. 5).

The variance of CW and fecundity were further analyzed statistically using a one-way analysis of variance (ANOVA). The value of F computed for all the four species was higher when compared to critical

Table 4 — Abundance of gravid females, egg range, average number of eggs and mean fecundity of four crab species

Sl. No	Crab species	Gravid female abundance (N)	Egg no.	Average no. of eggs	No. of eggs produced (X±SD)
1	*L. exaratus*	496	318 – 18,162	52,147	4,768 ± 3,154
2	*E. frontalis*	50	721 – 8,578	18,645	3,944 ± 2,224
3	*M .frontalis*	118	1,090 – 19,020	45,946	6,038 ± 3,656
4	*H. glabra*	241	100 – 2,590	41,733	822 ± 489

Table 5 — Fecundity index of four crab species.

Sl. No	Crab species	Fecundity index
1	*L. exaratus*	2781
2	*E. frontalis*	1331
3	*M. frontalis*	3630
4	*H. glabra*	648

Table 6 — Results of one-way analysis of variance (ANOVA) between CW and fecundity of *Leptodius exaratus*

Source of variance	*df*	*Sum of squares*	*Mean S.S.*	*Variance ratio (F)*
Between CW size range	3	4.43E+08	1.48E+08	3.02E+01
Error	81	3.97E+08	4897306	-
Total	84	8.4E+08	-	-

Table 7 — Results of one-way analysis of variance (ANOVA) between CW and fecundity of *Epixanthus frontalis*

Source of variance	*df*	*Sum of squares*	*Mean S.S.*	*Variance ratio (F)*
Between CW size range	3	96541637.3	32180546	10.2755071
Error	45	140929742	3131772	-
Total	48	237471379	-	-

Table 8 — Results of one-way analysis of variance (ANOVA) between CW and fecundity of *Metopograpsus frontalis*

Source of variance	*df*	*Sum of squares*	*Mean S.S.*	*Variance ratio (F)*
Between CW size range	3	3.12E+08	1.04E+08	1.29E+01
Error	56	451843631.3	8068636.3	-
Total	59	764283997.8	-	-

Table 9 — Results of one-way analysis of variance (ANOVA) between CW and fecundity of *Heteropanope glabra*

Source of variance	*df*	*Sum of squares*	*Mean S.S.*	*Variance ratio (F)*
Between CW size range	3	3.46E+06	1.15E+06	5.14E+00
Error	46	10318938.55	224324.75	-
Total	49	13776099.7	-	-

value (α (2): 0.05). Therefore, the hypothesis that there is no significance in variance in fecundity with respect to carapace is rejected. Thus, variance in fecundity with respect to CW is significant and hence CW is related to fecundity (Tables 6 – 9).

Conclusion

The above study illustrates that among the crab population a high degree of variability with regard to reproductive attributes exists and is largely influenced by environmental variables and temporal changes in tropical ecosystem. Moreover, it is evident from the data collected that the population is comprised especially of males, females and gravid females that tend to regulate the total population structure in these habitats. It is also observed that the crab population encompassed by observed species shows a wide range of CW, probably one of the significant factor that regulate the size frequency among these population.

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Conflict of Interest

There is no conflict of interest.

Author Cotributions

JV collected the samples and analysed and have prepared the initial draft of the manuscript; AAC analysed the data and subjected it to the statistical analysis to make interpretations; and CUR conceptualised and designed the study and has revised the manuscript.

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