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Size distribution and Colour pattern in the Freshwater Crab *Travancoriana schirnerae*

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Abstract
The present study analyzed the population size frequency distribution and colour pattern in the freshwater crab, *Travancoriana schirnerae* inhabiting the areca plantations of Mananthavady, Wayanad, Kerala for a period of two years (2009-2011). The population structure was evaluated by frequency distribution of size classes monthly and according to seasons. Results indicated that the size frequency distribution was bimodal in both the sexes. Juvenile crabs were present at higher proportion from June-November with peak in August, exhibited slight decrement during winter and was low during summer. Adult frequency remained more or less the same irrespective of seasons. In *T. schirnerae*, adult male and female crabs exhibited identical colour patterns and three morphotypes were recognized: yellow, intermediate and purple. The population was dominated by intermediate morphs (60%) followed by yellow (28%) and purple (12%). There was no evidence of a size difference between morphs. The frequency of morphotypes showed significant difference in the total collection, among and between the sexes.

Keywords: Colour pattern, Morphotypes, Size distribution, *Travancoriana schirnerae*

1. Introduction
The freshwater crab *Travancoriana schirnerae*, abundant in the wet lands of Mananthavady (Wayanad, Kerala), lives in burrows located on the embankments of paddy fields, banana and areca plantations and forms a cheap source of animal protein to the local tribe population. The genus *Travancoriana* now comprises six described species (*T. schirnerae*, *T. pollicaris*, *T. convexa*, *T. kuleera*, *T. charu* and *T. granulata*) with distribution restricted to the highlands of south Indian states of Kerala, Karnataka and Tamil Nadu Bahir MM *et al.* and Pati SK *et al.* [1, 2].

Size frequency distribution of a population is a dynamic characteristic that may fluctuate during the year, as a result of reproduction and larval recruitment Thurman CL [3]. In species which exhibit terminal moult, the size distribution may depend on factors that influence growth, survival and maturation of juveniles. Size distribution was extensively studied in spider crabs by Hartnoll *et al.* [4], Davis and Trundle [5] and Teixeira *et al.* [6]. Size structure in two intertidal grapsid species from Mar Chiquita lagoon, Argentina was analyzed by Spivak *et al.* [7]. Atar and Seçer [8] studied the size composition of the blue crab *Callinectes sapidus* population living in Beymelek lagoon lake, Turkey. Fransozo *et al.* [9] investigated the size distribution frequency of *Uca mordax* population from the south eastern coast of Brazil. The size structure and population parameters of the mud crab *Scylla serrata* were studied in Lowele Bay, Indonesia by La Sara [10]. Leite *et al.* [11] evaluated the frequency distribution of the size classes in the mangrove crab *Ucides cordatus*. However, scattered references exist on population size frequency distribution in freshwater crabs Arimoro FO *et al.* and Venancio FA *et al.* [12, 13].

Colour changes in animals may be triggered by a variety of social and environmental factors and may occur over a matter of seconds or minutes Detto T *et al.* [14]. The most dramatic changes in colour pattern are associated with moulting. Most of the studies on colour pattern of brachyurans have focused on marine and estuarine species Detto T *et al.* and Reid DG *et al.* and Silbiger N *et al.* and Baldwin J *et al.* and Krause-Nehring J *et al.* [14, 15, 16, 17, 18]. Brachyurid species have colouration patterns that vary among individuals, which are suggested to be the result of behavioural interactions between sexes Detto T *et al.* [19]. Colour changes in fiddler crabs have been thoroughly studied by a number of investigators, revealing its functional significance. Hemmi *et al.* [20] detailed the colour variations in *U. vomeris* in relation to their

Background and predation. Many studies have focused on the relationship between colour variation and mating success Takeda S [21] or colour variation as a function of thermoregulation Wilkens JL *et al.* [22]. Comparatively, very few have addressed the colour patterns in freshwater/land crabs Detto T *et al.* and Takeda S *et al.* [19, 23]. Stevens *et al.* [24] investigated the colour change and camouflage in the horned ghost crab *Ocypode ceratophthalmus*. The present study detailed the population size distribution and colour pattern in the freshwater crab *T. schirnerae*.

2. Materials and methods

The present investigation was carried out from June 2009-June 2011 in the areca plantations (which were once paddy fields) near the College campus, Mananthavady, Wayanad. Specimens were handpicked or collected during daytime from burrows using baits and brought immediately to the laboratory. The carapace width (CW), body weight (BW), colour and sex were recorded for all the specimens collected.

2.1 Size distribution

In order to study size distribution, the total collection was divided into juvenile males, adult males, juvenile females, adult females, ovigerous and juvenile carrying females and into six size classes: 0-1, 1.1-2, 2.1-3, 3.1-4, 4.1-5, 5.1-6 cm CW. Monthly size class-frequency distribution histogram using 1cm class interval was constructed. Seasonal variation in the juvenile and adult frequencies in the overall population was compared through ANOVA.

2.2 Colour pattern

The carapace width and colour were recorded for all the individuals collected. In addition, colour was recorded for chelate and walking legs. Based on the colour of the carapace, three morphotypes were identified. The frequency of morphotypes in the total collection, among and between the sexes and among sizes classes were recorded. The difference in frequency of morphotypes in the total collection, among and between the sexes was analyzed through ANOVA.

3. Results

3.1 Size distribution

From June 2009-June 2011, *Travancoriana* population was surveyed to determine monthly and seasonal changes in size distribution. A total of 3605 crabs were collected of which 2168 males (60.3%) and 1437 females (39.7%). The population was divided into juvenile males (15.3%), adult males (45%), juvenile females (9.3%), adult non-ovigerous (27.9%), ovigerous (0.6%) and juvenile carrying females (1.9%).

Size of crabs varied significantly between months and seasons. According to monthly distribution of individuals into size classes, juvenile crabs were present at higher proportion from June-November (34-47%) with peak in August as the young ones were recruited at the beginning of monsoon in June. Crabs of all size classes were available in the population from July-August. In both the sexes, juveniles <0.5 cm CW dominated the population during June; 0.5-1cm during July-August and 1.1-2 cm during September-November. From January-June, there observed an increase in the percentage of individuals of the adult size classes (3.1-4, 4.1-5 and 5.1-6 occurred at an average of 32%, 55% and 13%, respectively). Throughout the period of study, 4.1-5 cm size class predominated (51 % of the total collection) the population (Fig. 1).

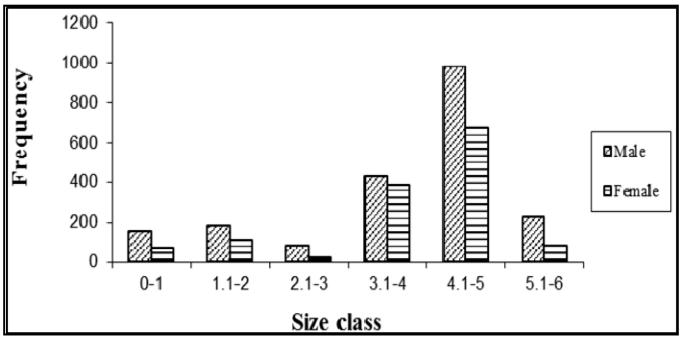

Fig 1: Frequency distribution histogram of size classes in *Travancoriana schirnerae* population

Males reached larger sizes than females as evidenced by the largest male (6.1 cm CW) and female (5.8 cm) in our collection. This was also evidenced by the fact that the larger size classes (3.1-4, 4.1-5 and 5.1-6) comprised a higher proportion of males (47.96%) than females (33.45%). The 4.1-5 cm size class was considered as the modal class of the population with the highest percentage of males (28.69%) and females (19.74%) followed by the 3.1-4 cm size class (12.54% males, 11.26% females). In both the sexes, the modal size class is near the middle of the mature size range (3.1-6 cm CW).

Observations on seasonal variations in the frequencies of juveniles of the total population revealed that juveniles were more abundant during rainy season followed by winter and scarce during summer ($F=4.011$, $P<0.05$). Adult frequencies remained the same irrespective of seasons. ANOVA test for comparison of adult frequencies between seasons did not differ statistically ($F=0.271$, $P>0.05$) (Fig. 2).

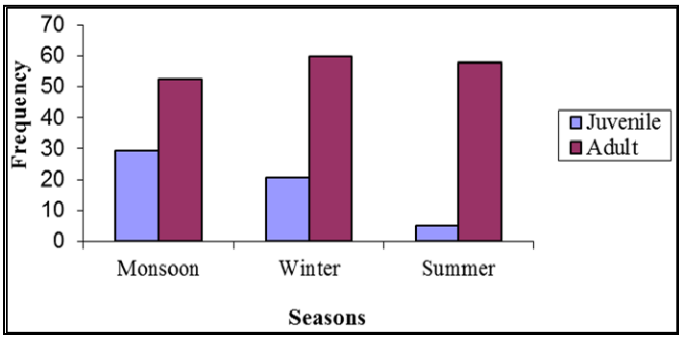

Fig 2: Seasonal variations in juvenile and adult frequencies of *Travancoriana schirnerae* population

3.2 Colour pattern

In *T. schirnerae*, adult male and female crabs exhibited identical colour patterns and three morphotypes were recognized which were yellow, intermediate and purple. Juveniles generally have uniform colouration (dark or dull colouration) for carapace, chelate and walking legs. The variation in adult colour pattern seemed to start appearing above 2.5 cm CW. Colour variation was complete among individuals above 3 cm CW in both the sexes. The yellow morphs have pale yellow colouration at the margin, dark purple towards the centre of the carapace and chelae appeared pale yellow. Intermediates have dark purple colour towards the middle and light blue distributed symmetrically on either side of the margin of the carapace; chelae pale yellow with blue tinge. Purple morphs have uniformly distributed purple coloured carapace and chelae showed pale yellow colour with blue tinge oriented along the sides. For all the morphs, abdomen appeared pale yellow and walking legs showed dark colouration.

The frequency of morphs was examined and analyzed in relation to sex. Overall, intermediate morphs were dominant comprising 60% of the population. The yellow morphs made up 28% and the purple 12% (Fig. 3). There was no evidence of a size difference between morphs. In both the sexes, the minimum and maximum carapace widths were similar for the three morphotypes. The frequency of intermediates remained the same (60%) for both the sexes. However, there was a difference between the sexes in the frequency of yellow and purple morphs. The yellow morphs were correspondingly less frequent in males (26%) than females (30%) while purple morphs were less frequent in females (10%) than males (14%). There was variation in colour pattern between size classes. In all the size classes, intermediate morphs showed the highest percentage and purple the least (see Table 1 and Figs. 4, 5).

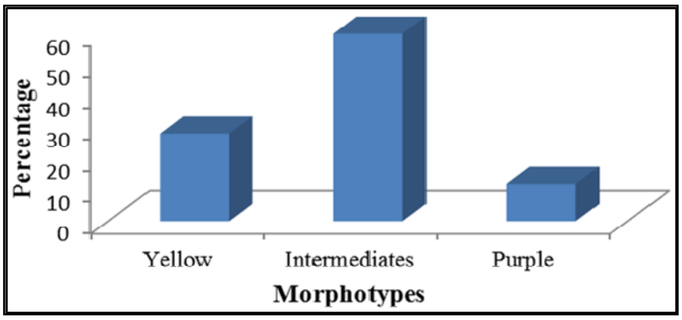

Fig 3: Percentage of morphotypes in the total population

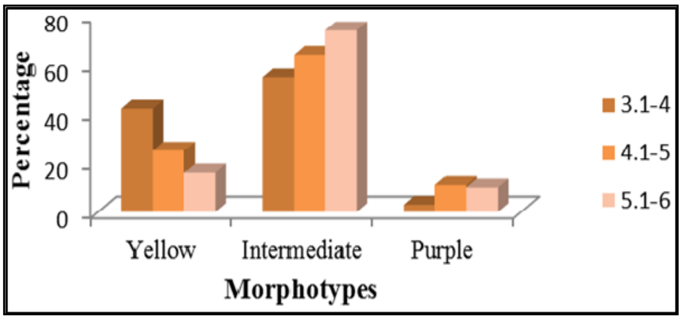

Fig 4: Percentage of morphotypes among adult size classes in male

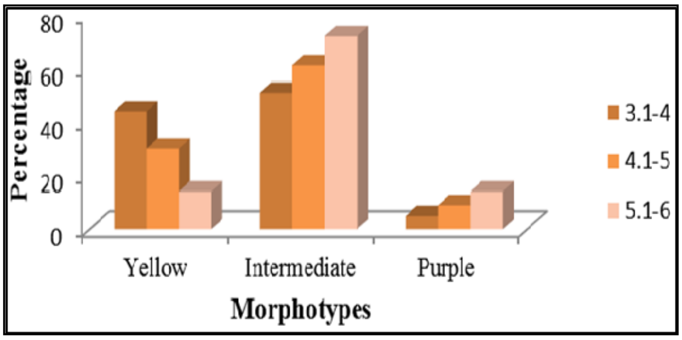

Fig 5: Percentage of morphotypes among adult size classes in females

Table 1: Percentage of morphotypes among adult size classes in *Travancoriana schirnerae* population

Size class	Male (%)			Female (%)		
	Yellow	Intermediate	Purple	Yellow	Intermediate	Purple
3.1-4	42	55	3	44	51	5
4.1-5	25	64	11	30	61	9
5.1-6	16	74	10	16	72	12

Statistical analysis using ANOVA showed that there is significant difference in the frequency of morphotypes in the total collection, among and between the sexes. In the total collection, the mean frequency of yellow morphs was estimated to be 20.62±8.11; intermediates 44.83± 19.51 and purple 9.16±7.51 (F=47.44, p<0.01). Among males, the frequency of yellow morphs was 23.66±7.52; intermediates 55.08±11.92 and purple 12.41±8.89 (F=63.31, p<0.01). In females, yellow morphs comprised of 17.58±7.79; intermediates 34.58±20.61 and purple 5.91±3.98 (F=14.91, p<0.01). Between the sexes, the frequency of yellow morphs showed no significant difference (F=3.78, p>0.05) while the intermediate and purple morphs displayed significant results (F=8.89 and 5.33 respectively, p<0.05).

4. Discussion

Generally, unimodal distribution is typical of stable populations which have continued recruitment and mortality rates constant over the life cycle and the number of individuals entering the population is equal to the number of individuals who leave Thurman CL and Díaz H *et al.* [3, 25]. Bimodal pattern of distribution reveals seasonality in reproductive and recruitment events Tsuchida S *et al.* [26]. In the present study, size frequency distribution of *T. schirnerae* population is bimodal revealing seasonality in reproductive and recruitment events. Population recruitment occurs on an annual basis with the onset of monsoon and the development takes about 10-12 months. Juvenile frequency was found high during rainy season (in coincidence with the recruitment of young ones at the onset of monsoon), followed by winter and low during summer. However, adult frequency remained more or less the same irrespective of seasons. Similar observations were reported from the boreal crab *Pisidia longicornis*, where the size frequency distribution of the population is bimodal Samuelsen T and Smaldon G [27, 28]. Conversely, unimodal population size structures have been observed for *Uca* population Castiglioni DS *et al.* and Litulo C and Benetti AS *et al.* [29, 30, 31]. In *U. thayeri*, juvenile crabs were more abundant during dry seasons and larger crabs were found mainly during rainy season Bezerra LEA *et al.* [32]. In *Neohelice granulata*, the size distribution was unimodal and recruitment occurs throughout the year, but more intensively in winter and summer months Gregati RA *et al.* [33]. In the freshwater crab *Sudanonautes floweri*, Arimoro and Orogun [12] indicated a unimodal distribution where the crabs were more abundant during wet season with peak in the months of June and July and lowest during February. In the freshwater prawn *Macrobrachium jelskii*, the length frequency distribution revealed a unimodal pattern for males and females Barros-Alves SP *et al.* [34].

In *T. schirnerae*, males exceeded females in size. The larger size reached by males is a consistent feature not only of freshwater/land crabs Hartnoll RG *et al.* and Micheli F *et al.* [23, 35] but indeed for many other crab species Litulo C and Clayton DA *et al.* [30, 36]. It is seen in the land crabs *Johngarthia lagostoma* Teixeira AL [37], *Gecarcinus ruricola* in the San Andres archipelago [38] and Saba [39], *Gecarcoidea natalis* on Christmas Island Hicks JW [40] and *Epigrapsus notatus* in Taiwan Liu HC *et al.* [41]. The possible reason is that the reproductive activity of females delays the somatic growth and consequently increases the number of females in some size classes especially in reproductive size classes Díaz H *et al.* [25]. Unique colour variations have been documented in individuals of a number of species of crustaceans. In brachyurans, the function of body colours can range from providing crypsis, mimicry and temperature control to social signalling Detto T *et al.* [19]. The present study documented the occurrence of three colour morphs in a population of *T. schirnerae*. Our observations revealed that the three morphotypes in *T. schirnerae* were associated with colour changes during the moulting process. Similar situation was reported in *Carcinus maenas* where the different colouration of the carapace was indicative of moult stages Reid DG *et al.* [15]. In the snow crab *Chionoecetes opilio*, green colour of the carapace is an indication of moulting Hoenig JM *et al.* [42]. In *U. capricornis*, carapace colouration is determined by ontogenic colour changes during moulting which provide information about the sex, size and reproductive status of the individual Liu HC *et al.* [14]. Ontogenic colour changes are common in many crustaceans, in response to the changing camouflage requirements associated with changes in habitat or behaviour [43]. Findings of Stevens *et al*. [24] showed that ghost crabs have a circadian rhythm of colour change to achieve effective camouflage under a range of environmental conditions. On the other hand, some fiddler crabs change colour as a thermoregulatory response to temperature changes Wilkens JL *et al.* [22] and to match the background Thurman CL [44]. Colouration patterns in semi-terrestrial crabs may change with growth Detto T *et al.* [19], seasonality Fingerman M *et al.* and Nakasone Y *et al.* [45, 46], stress Crane J and Zeil J *et al.* [47, 48] and endogenous rhythms Palmer JD [49].

In *T. schirnerae*, juveniles are dark and dull coloured and all three morphotypes are represented in adult size classes. A similar pattern of dark coloured juveniles and variously patterned adults was seen in *Cardisoma guanhumi* Gifford C [50]. The juvenile colour polymorphism in *Cancer productus* may reduce the vulnerability to visual predators and decrease the risk of predation during juvenile stages Krause-Nehring J *et al.* [18]. On the other hand in *J. lagostoma*, smaller individuals are normally red or purple and the largest individuals are normally yellow or orange Hartnoll RG *et al.* [38]. There is clear rationale for the juveniles to be dark coloured as they are exposed to a variety of predators and will benefit from cryptic colour.

5. Conclusions

To conclude, the Mananthavady population of *T. schirnerae* follows a bimodal pattern of size distribution indicated by seasonality in reproductive and recruitment events. The three morphotypes represented in the adult population were associated with the colour changes of the carapace during moulting process.

6. Acknowledgements

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