

## Reproductive biology of the freshwater crab, *Travancoriana schirnerae* Bott, 1969 (Brachyura: Gecarcinucidae)

A. R. SUDHA DEVI AND M. K. SMIJA

Department of Zoology, Mary Matha Arts and Science College, Mananthavady, Wayanad- 670 645, Kerala, India  
e-mail: arsudhadevi@yahoo.co.in.

### ABSTRACT

The reproductive biology of the freshwater crab *Travancoriana schirnerae* was studied with respect to the following traits: mating pattern, gonadosomatic index (GSI), vas deferens factor (VD factor), breeding period and fecundity, during the period from June 2009-October 2011. A total of 3605 individuals were collected, of which 2168 (60%) were males and 1437 (40%) females. The population was divided into juvenile males (15.3%), adult males (45%), juvenile females (9.3%), adult non-ovigerous females (27.9%), ovigerous females (0.6%) and juvenile carrying females (1.9%). Mating occurred between postmoult females and hard intermoult males and the mating period extended from June-October. The GSI peaked in March for females and decreased after spawning in April. For males, the maximum values for GSI and VD factor were recorded in July. The breeding season extended from February-May and the highest frequency of ovigerous females was observed in March. The mean fecundity was  $222 \pm 43$ . Juvenile carrying females appeared in the population from April-July, with the highest percentage in May. The mean egg diameter was  $2.38 \pm 0.33$  mm. Average number of juveniles carried by females was  $204 \pm 40$ . Recruitment of juveniles to the population was recorded at the onset of rainy season in June.

Keywords: Breeding period, Fecundity, Gonadosomatic index, Mating, *Travancoriana schirnerae*, Vas deferens factor

### Introduction

Reproductive biology plays an imperative role in the population dynamics and life history strategies of crustaceans. For species of commercial importance, in particular, this knowledge is highly pertinent for successful fisheries management. *Travancoriana schirnerae* Bott, 1969 is abundant in the wet lands of Mananthavady (N 11° 46.116', E 075° 58.971', altitude 2417 feet), Wayanad, Kerala, India. They live in burrows, located on the embankments of paddy fields, banana and areca plantations. This crab species coexists with two other species *Barytelphusa cunicularis* (Westwood, 1836) and *Cylindrotelphusa* sp. (Alcock, 1909). *T. schirnerae* is edible and forms a cheap source of animal protein to the poor malnourished local tribes. The genus *Travancoriana* Bott, 1969 now comprises five described species viz., *T. schirnerae* Bott, 1969; *T. pollicaris* (Alcock, 1909); *T. convexa* (Roux, 1931), *T. kuleera* Bahir and Yeo, 2007 and *T. charu* Bahir and Yeo, 2007, with distribution restricted to southern Indian states of Kerala, Tamil Nadu and Karnataka (Bahir and Yeo, 2007). Only *T. schirnerae* has been reported from Wayanad. In spite of abundance and commercial importance of the species, there appears to be no published work on any aspect of the genus except taxonomic descriptions by Srivastava (2005) and Bahir and Yeo (2007).

Though ample literature is available on population and reproductive biology of marine, intertidal and estuarine crabs (Sukumaran and Neelakantan, 1996; Sallam, 2005; Henmi and Koga, 2009; Omolara, 2010), limited published work is available on the population and reproductive biology of freshwater, semiterrestrial or land crabs (Liu and Jeng, 2007; Wehrtmann *et al.*, 2010). This paper is an attempt to provide information on the key parameters of reproductive biology viz., mating pattern, gonadosomatic index (GSI), vas deferens factor (VD factor), breeding as well as fecundity of *T. schirnerae* of the Mananthavady population. Basic knowledge on reproductive biology of the species could help in attempting captive reproduction and aquaculture production of the species in future.

### Materials and methods

The present investigation was carried out at the areca plantations near the Mary Matha Arts and Science College campus, Mananthavady, Wayanad (part of Western ghats), Kerala. Samples were hand picked from inside as well as outside the burrows. Efforts were made to collect small specimens by searching under aquatic vegetation. Sampling was done thrice in a month. Each sample comprised a minimum of 40-50 crabs.

The carapace width (CW), body weight, moult stage and sex were recorded for all the specimens collected.

Moult stages were identified by noting the changes in the exoskeleton, observing the setae of pleopods in females and maxilliped epipodites in males. The tips of the pleopods and epipodites were cut out, mounted in water on clean glass slides and observed under light microscope. The total collection was divided into six size classes: 0-1, 1.1-2, 2.1-3, 3.1-4, 4.1-5, 5.1-6 cm CW. After recording the necessary data, specimens were released unharmed to the field. A few were retained for dissection for determining the status of gonads to calculate GSI and VD factor. Not all data were recorded for all the specimens collected. For certain parameters, data was recorded from subsamples.

#### Mating pattern

The CW of males and females in the mating pairs were recorded during the mating season. The number and percentage of postmoult females were also recorded since their incidence in the population indicated mating season. Students' t test was performed to find out whether there was any significant relationship between CW of male and female in the mating pairs.

#### Gonadosomatic index and vas deferens factor

Every month, 5-10 male (CW 4.0-5.5 cm) and female specimens (CW 3.8-5.5 cm) were dissected out. For males, the size, colour, wet weight of testes and vas deferens were recorded monthly to calculate the GSI and VD factor respectively. For females, the colour, size and wet weight of ovaries were recorded to calculate the GSI. The VD factor was calculated using the formula:

VD factor = weight of the vas deferens / (CW)<sup>3</sup> x 100 (Adiyodi, 1988)

#### Breeding period and fecundity

Period of appearance of ovigerous females, females with mature/spent ovaries were recorded since their presence in the population give a clear indication of the breeding period. Ovigerous females (n = 23, CW 3.7-5.3 cm; weight 20.66-48.31 g) had their eggs carefully removed and counted. From each ovigerous female, 50 eggs were chosen randomly for measuring egg diameter and weight, to determine whether the size of the egg is increased with the size of the crab. Ovigerous females were grouped into two: those with partial broods (CW 3.7-5.3 cm, upto 150 eggs) and those with complete broods (CW 4.2-5.3 cm, above 150 eggs). In this study, ovigerous females with 58-150 eggs were considered to have partial broods and those with above 150 eggs (161-281) were considered to have complete broods.

A total of 72 juvenile carrying females (CW 3.8-5.5 cm, weight 20.420-50.510 g) were observed. The young ones from each female were carefully removed and counted. A subsample of 20 juveniles was selected from each female

for measuring CW and weight. Only ovigerous females with complete broods and females bearing juveniles above 150 were considered for calculating average fecundity and average number of juveniles (mean  $\pm$  SD).

Regression analyses were carried out to find out any significant relationship between female CW/body weight and fecundity; CW and partial brood/complete brood; CW and egg diameter/egg weight; CW and total number of juveniles carried. Analysis of variance (ANOVA) was used to compare fecundity and number of juveniles carried between size classes; egg number of partial and complete brood; fecundity and juvenile number.

## Results and discussion

#### Mating pattern

Mating season extended from June-October. Mating takes place between postmoult (soft) females and intermoult (hard) males. A total of 42 mating pairs were collected from burrows during June 2009-October 2011 (Fig. 1). Postmoult females were available in the population from June-October. It is difficult to ascertain the peak mating season of crabs in the natural population. Hence the mating

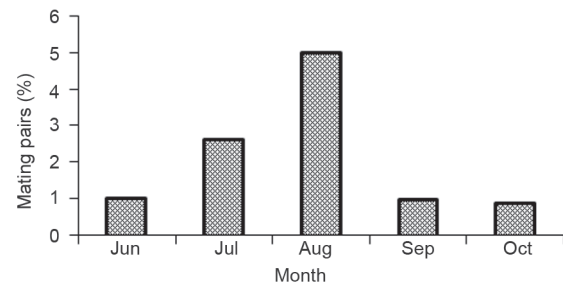


Fig. 1. Monthly percentage of mating pairs recorded during June 2009-October 2011 in *T. schirmerae*

period was determined from the prevalence of mating pairs and postmoult females in the population. Many postmoult females were collected during July-August (31 and 40% of the monthly collections respectively) and a few during June, September and October (5, 14 and 13% respectively). From these observations it is ascertained that the mating season extended from June-October with peak in August. Males were found involved in precopulatory mate guarding as confirmed by the presence of premoult ( $D_1$ ) females in male burrows. Males were always found at the entrance of the burrows and females deep down the burrows. Males were more aggressive during this period as a part of mate guarding. Pair formation takes place just before mating when females enter late premoult ( $D_3$ ). No postcopulatory mate guarding was noticed. The mean CW of males and females in mating pairs were  $5.0 \pm 0.31$  (4.3-5.6 cm) and  $4.08 \pm 0.43$  (3.2-4.8 cm) respectively. Students' t test showed significant difference in mean CW between males and females in mating pairs ( $t = 8.9$ ,  $p < 0.05$ ).

Pattern of mating in *T. schirnerae* basically corresponds with the pattern for brachyurans (Hartnoll and Smith, 1979); generally occurred between hard males and soft females as in portunids (Sukumaran and Neelakantan, 1996) and stone crabs (Savage, 1971). Most aquatic crabs copulate just after the females have moulted (Greenspan, 1982). Although mating between hard shelled males and soft shelled females in Brachyura is common, it is not universal (Hartnoll and Smith, 1979). Terrestrial and semiterrestrial crabs are known to copulate even in intermoult periods as long as the female's genital opening is not calcified. In *Dotilla sulcata*, copulation takes place when females are hard shelled (Sallam, 2005). Elner and Beninger (1995) reported that the females of the snow crab *Chionoecetes opilio* can copulate in either soft or hard shelled condition.

In *T. schirnerae*, usually males will be larger than females in the mating pairs. The possible reason for this may be that large males with bigger major chelipeds are more successful at acquiring mates (Wilber, 1987) and in handling females during copulation (Hartnoll, 1982). Similar reports were made in fiddler crabs and stone crabs (Crane, 1975; Wilber, 1989). On the other hand, in the intertidal dotillid crab *Ilyoplax deschampsii*, there was no significant relation between body size and mating pairs (Henmi and Koga, 2009).

Our observations revealed precopulatory mate guarding in *T. schirnerae* which is common in burrow mating fiddler crab species (Muraiet al., 2002). In *T. schirnerae*, males copulate with the females they guard and do not guard the females they do not mate with, as documented by Wilber (1987) in stone crabs.

In *T. schirnerae*, females usually remain seized in male burrows before mating as evidenced by the presence of mating pairs in burrows. Such burrow-mating systems are more advantageous to monogamy. The reason for monogamy found among females may be the difficulty to associate with other males because their partners may fend off their potential enemies (Wittenberger and Tilson, 1980). On the contrary, polyandry has been observed in some anomuran crabs (Sastry, 1983).

*Gonadosomatic index and vas deferens factor*

The GSI was calculated every month for males and females. It was found to be maximum for females with ripe gonads just before spawning in the months of February (3.50 ± 0.89) and March (4.54 ± 1.18); minimum (0.160 ± 0.014) after spawning by April (Fig. 2). This indicated that the females utilised on an average 3.50-4.54% of their body weight for egg production. Gonadosomatic indices were practically constant and very small during May-September (previtellogenic period); showed a slight increase in

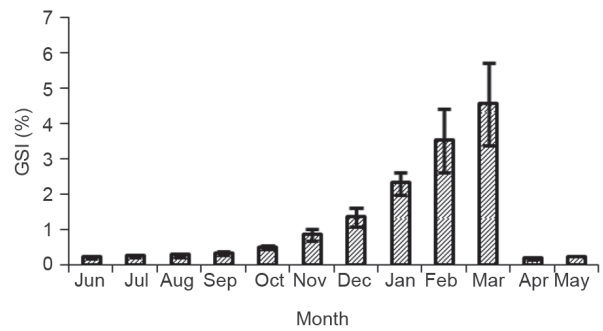


Fig. 2. Monthly distribution of female gonadosomatic index in *T. schirnerae* recorded during June 2009-May 2011

October (primary vitellogenic period). From November (beginning of secondary vitellogenesis) onwards, pronounced increase is observed, until it peaked in February-March (tertiary vitellogenic period). This observation indicated that the maturation and spawning activity takes place in the period from November-March.

In males, maximum values for GSI and VD factor were recorded in July (0.213 ± 0.03 and 242.19 ± 29.55 respectively); thereafter the values remained constant from August to October (mating period); showed a gradual decline with minimum in December (0.074 ± 0.01 and 75.13 ± 9.8 respectively). From January onwards, these values increased gradually until it reached the peak (Fig. 3 and 4).

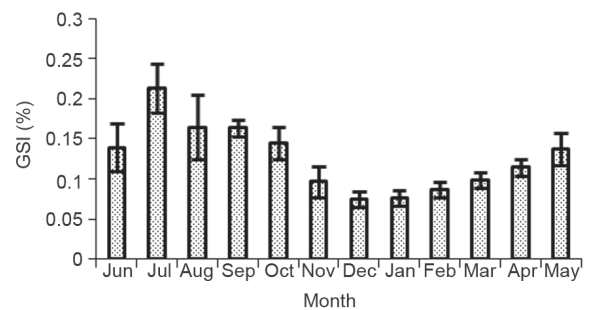


Fig. 3. Monthly distribution of male gonadosomatic index in *T. schirnerae* recorded during June 2009-May 2011

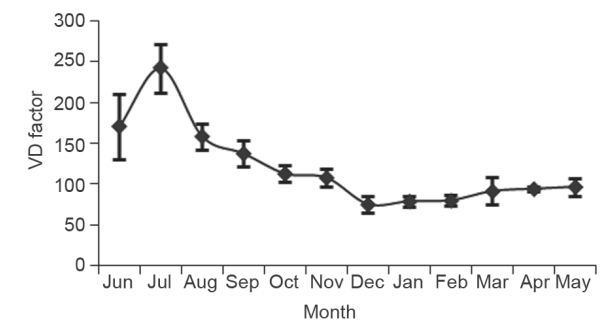


Fig. 4. Monthly distribution of vas deferens factor in *T. schirnerae* recorded during June 2009-May 2011

Gonadosomatic index represents the reproductive condition of a population (Pillay and Nair, 1971). In the present investigation, the GSI was not related to female size and this finding is in accordance with the results reported for the land crab, *Johngarthia lagostoma* (Hartnoll *et al.*, 2010). Freshwater/land crabs converted a low percentage of their body weight for egg production (Nordhaus *et al.*, 2006). Females of *T. schirnerae* convert on an average only 3.50-4.54% of their body weight for egg production whereas *Macrobrachium carcinus* females converted 8-16% of their body weight for egg production (Lara and Wehrmann, 2009).

In spite of the smaller egg number, the greater egg size of *T. schirnerae* resulted in a GSI value of 4.54%, very similar to 5% of *Gecarcinus ruricola* (Hartnoll *et al.*, 2007) and *J. lagostoma* (Hartnoll *et al.*, 2010). These values are small in comparison to the mean value of 10% determined for marine species (Hines, 1982). The possible reasons for low values of GSI in freshwater/land crabs include the difficulty in accumulating resources for ovarian maturation on a low energy and low nitrogen diet of predominantly plant material (Nordhaus *et al.*, 2006).

In the present investigation, the analysis of GSI and ovigerous females confirmed the results found in the breeding season. Monthly evaluation clearly showed that the GSI peaked in March, followed by decreasing values suggesting the occurrence of oocyte extrusion as documented for *Munida subrugosa* (Tapella *et al.*, 2002).

In the present investigation, male GSI and VD factor remained high during June-October with peak in July which corresponded to the mating season. The accumulation of sperm materials in the vas deferens might have occurred during May-June. In adult male *Paratelphusa hydrodromus*, the vas deferens factor reaches its highest value during the mating period (Adiyodi, 1988). In contrast, in male patagonian stone crab *Platyxanthus patagonicus*, the highest GSI value was observed during winter, which coincided with a non-mating period (Jimena *et al.*, 2009).

#### Breeding period

The occurrence of ovigerous females, females with fully mature or spent ovaries in the monthly samples and monthly mean GSI values were considered to determine the breeding season. Ovigerous females ( $n = 23$ , CW 3.7-5.3 cm; body weight 20.66 - 48.31 g) were scarce in our collection, comprised of only 0.6% of the total population and 1.6% of the total females collected. Ovigerous females were observed in the population between end of February and May in the first year (2010) and March-April of the second year (2011). In both the years, the peak was in March (9 and 19% respectively of the monthly females collected). Fewer samples were

collected during February 2010 (5%). The April collections comprised of 5 (2010) and 6% (2011) respectively and very few in May 2010 (2%) (Fig. 5). These observations indicated that this crab species is an annual breeder and the breeding season extended from February-May with peak in March. Of the total ovigerous females collected, maximum (68%) belonged to the 4.1-5 cm size class (modal size class); remaining 26% belonged to the 5.1-6 cm size class and 4% to the 3.1-4 cm size class. Ovigerous/juvenile carrying females were not found at a CW above 5.5 cm, which indicated an aging population. The average size of ovigerous/juvenile carrying females ( $4.61 \pm 0.39$ ) was higher than that of non-ovigerous/non-juvenile carrying females ( $4.55 \pm 0.42$ ).

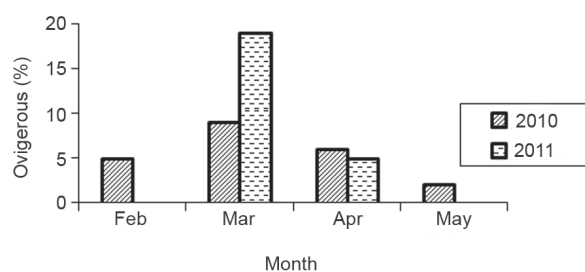


Fig. 5. Percentage of ovigerous females in *T. schirnerae* during the breeding season

In *T. schirnerae*, the breeding period is determined by the occurrence of berried females coupled with rise in mean GSI values and sudden rise in the incidence of mature/spent females in these months. Henmi and Kaneto (1989) reported that the presence of females with mature/spent gonads and percentage of ovigerous females over the year is the most common technique used to determine the reproductive period of a species. Several authors have based ovarian development to establish the reproductive period (Lopez-Greco and Rodriguez, 1999; Ituarte *et al.*, 2004).

Our observations indicated that *T. schirnerae* is an annual breeder with a short breeding season which extended from February end to May (summer) with peak in March. Breeding in summer months is thought to be advantageous to ensure embryonic development before rainy season (colder months). Such annual and seasonal breeding pattern has been observed in semiterrestrial and intertidal brachyuran crabs (Sastri, 1983; Henmi and Kaneto, 1989). On the contrary, *B. cunicularis*, which resides in brackishwaters of Maharashtra, is a continuous breeder (Pathre and Meena, 2010).

The low number of females with eggs or young ones in the collection examined by us suggested that these females were even more difficult for collection than females without eggs or young ones. Similar conclusion was made by Mansur and Hebling (2002) in neotropical freshwater crabs of Brazil. The reason for very low percentage of

ovigerous females in our collection during the breeding season may be attributed to the kind of behaviour of these females that they remain in their burrows during the entire incubation period and forage less.

In the present investigation, the pattern of breeding activity was different between 2010 and 2011. In both the years, the peak was in March, but it was of short duration and ovigerous females were more abundant in 2011. Like *T. schirnerae*, some gecarcinid crabs have short breeding season during summer (Hicks, 1985). On the other hand, species of *Cardisoma* (Gifford, 1962) and *Gecarcoidea lalandii* (Liu and Jeng, 2007) have long breeding seasons. The variation in reproductive pattern between 2010 and 2011 in the present study may be attributed to variations in environmental conditions that maximise reproductive success under favourable conditions.

**Fecundity**

*Travancoriana schirnerae* spawns once in a year. The smallest and largest female in our collection showing spawning had CWs of 3.7 and 5.3 cm respectively. The number of eggs spawned in the smallest crab was 115 and that in the largest was 281. The mean fecundity was found to be  $222 \pm 43$ . The diameter of eggs varied between 1.9 and 3.0 mm ( $2.38 \pm 0.33$ ). Colour of egg was bright yellow. There was no significant correlation between egg diameter/ weight and CW ( $r^2 = 0.03$  and  $0.04$  respectively) (Fig. 6). Females carried eggs at their first (diameter 1.9-2 mm, weight 6-6.5 mg) and second stages of development (diameter 2.5 mm, weight 8 mg) during February-March while eggs at their last stage of development (diameter 3 mm, weight 10 mg) occurred predominantly in April-May. It was difficult to determine the incubation period of eggs in the breeding season because, females quickly released their eggs from the abdomen under laboratory conditions..

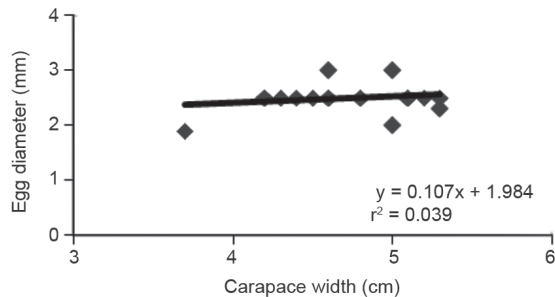


Fig. 6. Relationship between carapace width and egg diameter in *T. schirnerae*

There was no significant positive correlation between body size (CW/weight) and the number of eggs carried as shown by the regression values ( $r^2 = 0.271$  and  $0.260$  respectively) (Fig. 7). The ANOVA test for fecundity and size classes (4.1-5 and 5.1-6 cm) showed no significant

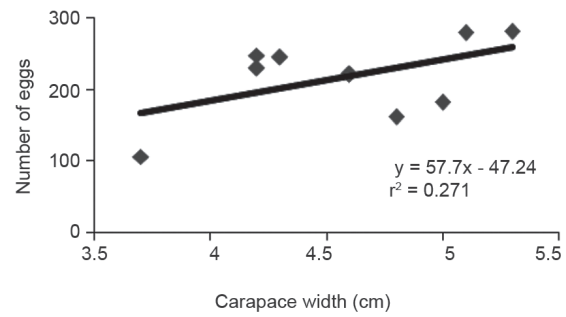


Fig. 7. Carapace width-fecundity relationship in *T. schirnerae*

difference in fecundity between size classes ( $p > 0.05$ ). There was a wide range in the number of eggs carried by crabs of any given CW and the range increased with CW. The greatest range was in crabs of CW 5.1 (119-279) and 5.3 cm (115-281).

Females with partial broods (CW 3.7-5.3 cm) had fewer eggs (58-120) attached to their pleopods than females (CW 4.2-5.3 cm) with complete broods (161-281). Regression analysis of CW with egg number of partial broods was found significant ( $r^2 = 0.655$ ) (Fig. 8) whereas no significant difference was found with complete brood ( $r^2 = 0.010$ ) (Fig. 9). The ANOVA test for comparison of

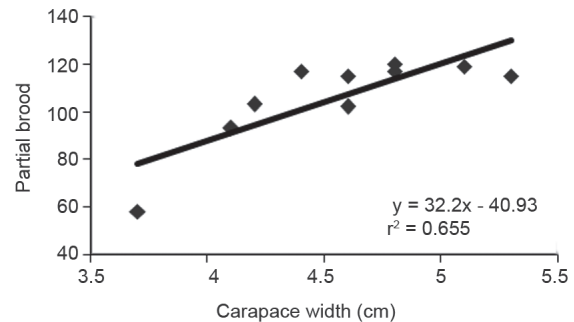


Fig. 8. Relation between carapace width and partial brood in *T. schirnerae*

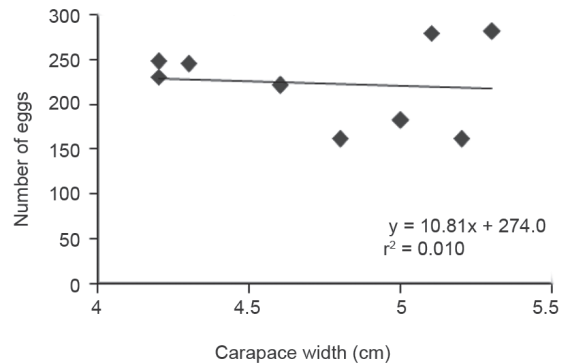


Fig. 9. Relationship between carapace width and complete brood in *T. schirnerae*

egg number of partial and complete broods provided highly significant results ( $p < 0.05$ ). In the early period of breeding season (February), usually the number of eggs borne by the crabs was less ( $118 \pm 1.3$ ) and was more ( $227 \pm 41$ ) as the season advanced (March) and decreased ( $120 \pm 36$ ) again towards the end of the season (April-May).

Juvenile carrying females ( $n=72$ , 1.9% of the total collection and 5.01% of the total females collected) were available in the population from April-July in 2010 and April-June of 2011 collection. Thirty one percent of the total females collected during April carried young ones in their brood pouch with the highest percentage in May (51%). The June and July collections comprised 11% (2010 and 2011 data) and 5% (2010 data) respectively (Fig. 10). The smallest and largest juvenile carrying females had CWs 3.8 and 5.5 cm respectively (include four generations : 3.5-4, 4.1-4.5, 4.6-5.0 and 5.1-5.5 cm). The mean CW and weight of juvenile carrying females were found to be  $4.62 \pm 0.37$  and  $34.16 \pm 7.7$  g respectively. The number of juveniles carried by females in their brood pouch ranged from 53-275 ( $204 \pm 40$ ). Regression analysis showed that the juvenile number was not significantly correlated with the CW of female ( $r^2 = 0.284$ ) (Fig. 11). The ANOVA test for comparison of egg number and juvenile number found

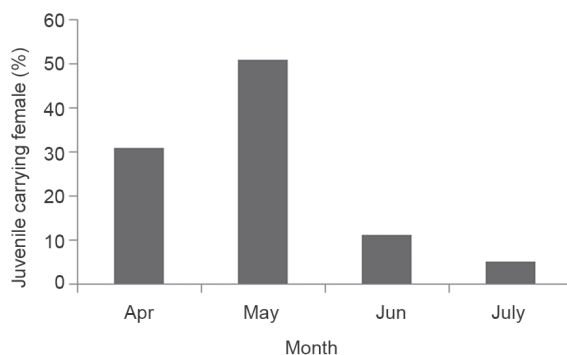


Fig. 10. Percentage of juvenile carrying females during the breeding season (2010 and 2011) in *T. schirmerae*

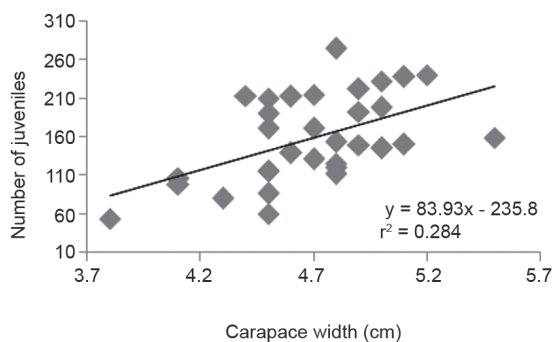


Fig. 11. Relationship between carapace width and number of juveniles carried by females of *T. schirmerae*

no significant results ( $p > 0.05$ ). Mean CW of juveniles was  $3.52 \pm 0.35$  (3.0-4.0 mm) while they were carried under the pleon of the female. The ANOVA test carried out for comparison of size classes and number of juveniles was not found significant ( $p > 0.05$ ).

Bagenal and Braum (1978) reported that fecundity studies give data relating to population stability and yearly class fluctuations which may be major factors determining discrepancies in production from year to year. As documented for *Callinectes amnicola* (Omolar, 2010) and a few *Cancer* species (Shields, 1992), in *T. schirmerae* there was a low correlation between fecundity and body size in contrast to the strong size-fecundity relationship found in brachyuran families (Hines, 1982; Hartnoll, 1985). Garziani *et al.* (1993) reported that the differences in fecundity are controlled by variation in female size as well as temperature, food quality and quantity which may vary along the longitudinal range of the distribution of the species. In the present investigation, the possible reason pointed out to the lack of relationship between body size and fecundity may be shortage of food or nutrients for the developing females. Thurman (1985) described that both size and number of eggs produced appear to correspond to environmental conditions and that the apparent cost in producing an egg brood in semiterrestrial species is not greater than that of other species which carry a large number of smaller eggs. Additionally in freshwater crabs, the size of egg mass is limited by provision of an adequate oxygen supply to the developing embryos in its abdomen. In marine crabs, oxygen levels can fall within the egg mass and the females show behaviour to detect and remedy the problem (Baeza and Fernandez, 2002).

*T. schirmerae* females produced relatively few but large eggs typical for species with an abbreviated or direct development (Mc Edward, 1997). Similar report was made in *Kingsleya* sp. (Wehrmann *et al.*, 2010). The neotropical freshwater crabs from Brazil produced relatively less number of eggs which was within the range in the present study (Mansur and Hebling, 2002).

Freshwater crabs generally produce on an average between 100 and 300 eggs (Corey and Reid, 1991) which is in agreement with our present investigation. On the other hand, the mean fecundity was found high in land crabs like *Johngarthia lagostoma* (Hartnoll *et al.*, 2010), *Gecarcinusururicola* (Hartnoll *et al.*, 2007). A mean fecundity of 3.2 million eggs was documented by Guillory *et al.* (1996) for blue crabs.

In the present investigation, females with partial broods were available in the population at the beginning and towards the end of the breeding season. The occurrence of partial brood at the beginning of the breeding season was reported in *Munida subrugosa* (Tapella *et al.*, 2002). The cause of the wide range in fecundity (partial and

complete brood) of *T. schirnerae* is unknown. The possible reason attributed to this condition may be shortage of food or nutrients for the developing females.

In freshwater crabs, females incubate their eggs which remain attached to the pleopods, beneath the abdomen from spawning to hatching (Wehrtmann *et al.*, 2010). In *T. schirnerae*, there was no evidence of substantial incubatory loss of eggs or juveniles as evidenced by our observations on the average fecundity and number of juveniles carried by females. Similar conclusion was made in the case of *Kingsleya ytipora* (Magalhães, 1986) by Wehrtmann *et al.* (2010). In *T. schirnerae*, we assume that the parental care diminishes the loss of eggs or juveniles as reported for *J. lagostoma* by Hartnoll *et al.* (2010). Such behaviour is often highly developed in species inhabiting extreme environments and in species which produce only a limited number of offsprings (Thill, 2003).

The presence of juveniles attached to the female has already been reported for several freshwater crabs (Disney, 1971; Wehrtmann *et al.*, 2010). In *T. schirnerae*, the presence of two size groups of juveniles attached to females seems to indicate that juveniles are attached to the mother for a prolonged time period. Similar reports were made in *K. ytipora* (Wehrtmann *et al.*, 2010). The exact duration of the attachment of the offspring to the mother cannot be established from our data and for this further laboratory studies are needed. In the case of *Candidopotamon rathbunae* (De Man, 1914), brooding females carry their juveniles between 9 and 16 days (Liu and Li, 2000).

#### Egg diameter

In *T. schirnerae*, egg diameter was in the range 2-3 mm, independent of female size and fecundity. The size of the eggs in decapods is under genetic control and associated with the type of larval development (Herring, 1974). Freshwater decapods which present an abbreviated larval development produce larger eggs (Nazari *et al.*, 2003). Exact data on egg size of freshwater crabs are rare. All available information indicates that the egg diameter of these crabs is in the range of 2-3 mm, independent of female size and fecundity. Egg size in decapods tends to increase during the incubation period (Wehrtmann and Lopez, 2003) and this increase is typically related to the incorporation of large amounts of water (Pandian, 1970). In contrast, Mansur and Hebling (2002) mentioned that the egg size in *Dilocarcinus pagei* and *Sylviocarcinus australis* did not vary during embryogenesis.

Reproduction is one of those aspects of biology that is most crucial to farming. Efficient management of crab fisheries requires knowledge of the reproduction and life history of the exploited population. Knowledge of reproductive biology, including aspects of mating, GSI, VD

factor, breeding and fecundity is of paramount importance in the commercial utilisation of a species. The information gathered from this study may be utilised for aquaculture practices of this species as well as a baseline data for more comprehensive research in the future. An understanding of breeding period may also help reduce fishing efforts on ovigerous/juvenile carrying females to protect the spawning part of the population.

#### Acknowledgements

The authors wish to thank Dr. Sanal George from Rajiv Gandhi Centre for Biotechnology for species identification. This research was funded by the grant support from Kerala State Council for Science, Technology and Environment.

#### References

- Adiyodi, R. G. 1988. Reproduction and development. In: Burggren, W.W. and McMahon, B. R. (Eds.), *Biology of the land crabs*. Cambridge University Press, Cambridge, p. 139-185.
- Bagenal, T. B. and Braum, E. 1978. Eggs and early life history. In: Bagenal, T. B. (Ed.), *Methods of assessment of fish production in freshwaters*, 3<sup>rd</sup> edn. Oxford, Blackwell Scientific, p. 165-201.
- Baeza, J. A. and Fernandez, M. 2002. Active broodcare in *Cancer setosus* (Crustacea: Decapoda): the relationship between female behaviour, embryo oxygen consumption and the cost of brooding. *Funct. Ecol.*, 16: 241-251.
- Bahir, M. M. and Yeo, D. C. J. 2007. The Gecarcinid freshwater crabs of Southern India (Crustacea: Decapoda: Brachyura). *Raffles Bull. Zool.*, 16: 309-354.
- Corey, S. and Reid, D. M. 1991. Comparative fecundity of decapods crustaceans I. The fecundity of thirty-three species of nine families of caridean shrimp. *Crustaceana*, 60: 270-294.
- Crane, J. 1975. Fiddler crabs of the World. Ocypodidae: Genus *Uca*. Princeton University, Princeton, New Jersey, USA, 736 pp.
- Disney, R. H. I. 1971. Notes on *Simuliumovazzae* Grenier and Mouchet (Diptera: Simuliidae) and river crabs (Malacostraca: Potamidae) and their association. *J. Nat. Hist.*, 5: 677-689.
- Elnor, R. W. and Beninger, P. G. 1995. Multiple reproductive strategies in snow crab *Chionoecetes opilio*: physiological pathways and behavioral plasticity. *J. Exp. Mar. Biol. Ecol.*, 193: 93-112.
- Garziani, C. A., Cheung, K. S. and Donato, M. D. 1993. Comportamiento reproductivo y fertilidad de *Macrobrachium carcinus* (Decapoda: Palaemonidae) en Venezuela. *Rev. Biol. Trop.*, 41: 657-665.
- Gifford, C. A. 1962. Some observations on the general biology of the land crab, *Cardisoma guanhumi* (Latreille) in South Florida. *Biol. Bull.*, 123: 207-223.

- Greenspan, B. N. 1982. Semi-monthly reproductive cycles in male and female of fiddler crabs, *Ucapugnax*. *Anim. Behav.*, 30: 1048-1092.
- Guillory, V., Prejean, E., Bourgeois, M., Burdon, J. and Merrell, J. 1996. A biological and fisheries profile of the blue crab, *Callinectes sapidus*. LA. *Department of Wildlife Fisheries Management Plan Series*. 8 (1): 210.
- Hartnoll, R. G. 1982. Growth. In: Bliss, D. E. and Abele, L. G. (Eds.), *The biology of crustacea*. Academic Press, New York, p. 111-196.
- Hartnoll, R. G. 1985. Growth, sexual maturity and reproductive output. In: Wenner, A. M. (Ed.), *Factors in adult growth*. Balkema, Rotterdam, p. 101-128.
- Hartnoll, R. G. and Smith, S. M. 1979. Pair formation in the edible crab *Cancer pagurus*, (Decapoda, Brachyura). *Crustaceana*, 36: 23-28.
- Hartnoll, R. G., Baine, M. S. P., Britton, A., Grandas, Y., James, J., Velasco, A. and Richmond, M. G. 2007. Reproduction of the black land crab, *Gecarcinus ruricola*, in the San Andres Archipelago, western Caribbean. *J. Crust. Biol.*, 27: 425-436.
- Hartnoll, R. G., Annette, C. B., Godley, B. J., Susanna, S., Pearson, M., Stroud, S. A. and Saunders, K. K. 2010. Reproduction in the land crab *Johngarthia lagostoma* on Ascension Island. *J. Crust. Biol.*, 30: 83-92.
- Henmi, Y. and Kaneto, M. 1989. Reproductive ecology of three ocypodid crabs I. The influence of activity differences on reproductive traits. *Ecol. Res.*, 4: 17-29.
- Henmi, Y. and Koga, H. 2009. Growth and reproduction of the intertidal dotillid crab *Ilyoplax deschampsii*. *J. Crust. Biol.*, 29: 516-522.
- Herring, P. J. 1974. Size, density and lipid content of some decapod eggs. *Deep-Sea Res.*, 21: 91-94.
- Hicks, J. W. 1985. The breeding behaviour and migrations of the terrestrial crab *Gecarcoidea natalis* (Decapoda: Brachyura). *Aust. J. Zool.*, 33: 127-142.
- Hines, A. H. 1982. Allometric constraints and variables of reproductive effort in brachyuran crabs. *Mar. Biol.*, 69: 309-320.
- Ituarte, R. B., Spivak, E. D. and Luppi, T. A. 2004. Female reproductive cycle of the Southwestern Atlantic estuarine crab *Chasmagnathus granulatus* (Brachyura: Grapsoidea: Varunidae). *Sci. Mar.*, 68: 127-137.
- Jimena, B. D., Norma, A. V., Gustavo, A. L. and Pedro, J. B. 2009. Fluctuations in the biochemical composition of the Patagonian stone crab *Platyxanthus patagonicus* A. Milne Edwards, 1879 (Platyxanthidae: Brachyura) throughout its reproductive cycle. *Sci. Mar.*, 73(3): 423-430.
- Lara, L. R. and Wehrmann, I. S. 2009. Reproductive biology of the freshwater shrimp *Macrobrachium carcinus* (Linnaeus) (Decapoda: Palaemonidae) from Costa Rica, Central America. *J. Crust. Biol.*, 29: 343-349.
- Liu, H. C. and Jeng, M. S. 2007. Some reproductive aspects of *Gecarcoidea lalandii* (Brachyura: Gecarcinidae) in Taiwan. *Zool. Stud.*, 46: 347-354.
- Liu, H. C. and Li, C. W. 2000. Reproduction in the freshwater crab *Candidopotamon rathbunae* (Brachyura: Potamidae) in Taiwan. *J. Crust. Biol.*, 20: 89-99.
- Lopez-Greco, L. S. and Rodriguez, E. M. 1999. Annual reproduction and growth of adult crabs *Chasmagnathus granulatus* (Crustacea, Brachyura, Grapsidae). *Cah. Biol. Mar.*, 40: 155-164.
- Mansur, C. B. and Hebling, N. S. 2002. Análise comparativa entre a fecundidade de *Dilocarcinus pagei* Stimpson e *Sylviocarcinus australis* Magalhães & Türkay (Crustacea, Decapoda, Trichodactylidae) no Pantanal do Rio Paraguai, Porto Murtinho, Mato Grosso do Sul. *Rev. Bras. Zool.*, 19(3): 797-805.
- Mc Edward, L. R. 1997. Reproductive strategies of marine benthic invertebrates revisited: facultative feeding by planktotrophic larvae. *Amer. Nat.*, 150: 48-72.
- Murai, M., Koga, T. and Yong, H. S. 2002. The assessment of female reproductive state during courtship and scramble competition in the fiddler crab, *Ucapara dussumieri*. *Behav. Ecol. Sociobiol.*, 52: 137-142.
- Nazari, E. M., Simão-Costa, M. S., Müller, Y. M. R., Ammar, D. and Dias, M. 2003. Comparison of fecundity, egg size, and egg mass volume of the freshwater prawns *Macrobrachium potiuna* and *Macrobrachium olfersi* (Decapoda, Palaemonidae). *J. Crust. Biol.*, 23(4): 862-868.
- Nordhaus, I., Wolff, M. and Diele, K. 2006. Litter processing and population food intake of the mangrove crab *Ucides cordatus* in a high intertidal forest in northern Brazil. *Est. Coast. Shelf Sci.*, 67: 239-250.
- Omolar, A. L. A. 2010. Reproductive biology of the blue crab, *Callinectes amnicola* (De Rocheburne) in the Lagos Lagoon, Nigeria. *Turk. J. Fish. Aquat. Sci.*, 10: 1-7.
- Pandian, T. J. 1970. Ecophysiological studies on the developing eggs and embryos of the European lobster *Homarus gammarus*. *Mar. Biol.*, 5: 154-167.
- Pathre, R. F. and Meena, P. 2010. Breeding cycle and fecundity of the freshwater crab, *Barytelphusa cunicularis* (Decapoda, Potamonidae). *World J. Zool.*, 5(2): 96-102.
- Pillay, K. K. and Nair, N. B. 1971. The annual reproductive cycles of *Uca annulipes*, *Portunus pelagicus* and *Metapenaeus affinis* (Decapoda, Crustacea) from the south-west coast of India. *Mar. Biol.*, 11: 152-166.
- Sallam, W. S. 2005. Population structure and biology of the crab *Dotilla sulcata* from Elgharqana Mangrove, South Sinai, Red Sea. *Egypt. J. Aquat. Res.*, 31: 314-325.
- Sastry, A. N. 1983. Ecological aspects of reproduction. In: Vernberg, F. J. and Vernberg, W. B. (Eds.), *The biology of crustacea*. Academic Press, New York, p. 179-270.

- Savage, T. 1971. Mating of the stone crab, *Menippe mercenaria* (Say) (Decapoda, Brachyura). *Crustaceana*, 20: 315-316.
- Shields, J. D. 1992. The reproductive, ecology and fecundity of *Cancer* crabs. In: Wenner, A. M. and Kurts, A. M. (Eds.), *Crustacean egg production*. Crustacean issues 7, Balkema, Rotterdam.
- Srivastava, O. P. 2005. Freshwater crabs (potamonids) in the collection of the southern regional station, Zoological Survey of India, Chennai. *Rec. Zool. Surv. India*, 104: 115-122.
- Sukumaran, K. K. and Neelakantan, B. 1996. Spawning biology of two portunid crabs, *Portunus sanguinolentus* (Herbst) and *Portunus pelagicus* (Linnaeus) from the Karnataka coast. *The Fourth Indian Fisheries Forum Proceedings*, 24-28 November 1996. Kochi, p. 35-38.
- Tapella, F., Gustavo, A., Lovrich, M., Romero, C. and Thatje, S. 2002. Reproductive biology of the crab *Munida subrugosa* (Decapoda: Anomura: Galatheididae) in the Beagle Channel, Argentina. *J. Mar. Biol. Assoc. UK.*, 82: 589-595.
- Thill, M. 2003. Extended parental care in crustaceans - an update. *Rev. Chil. Hist. Nat.*, 76: 205-218.
- Thurman, C. L. 1985. Reproductive biology and population structure of the fiddler crab *Uca subcylindrica* (Stimpson). *Biol. Bull.*, 169 (1): 215-229.
- Wehrtmann, I. S. and Lopez, G. A. 2003. Effects of temperature on the embryonic development and hatchling size of *Betaeuse marginatus* (Decapoda: Caridea: Alpheidae). *J. Nat. Hist.*, 37: 2165-2178.
- Wehrtmann, I. S., Magalhaes, C., Hernaez, P. and Mantelatto, F. L. 2010. Offspring production in three freshwater species (Brachyura: Pseudothelphusidae) from the Amazon region and Central America. *Zoologia*, 27 (6): 965-972.
- Wilber, D. H. 1987. *The role of mate guarding in stone crabs*. Dissertation, Florida State University, Tallahassee.
- Wilber, D. H. 1989. Reproductive biology and distribution of stone crabs (Xanthidae, *Menippe*) in the hybrid zone on the northeastern Gulf of Mexico. *Mar. Ecol. Prog. Ser.*, 52: 235-244.
- Wittenberger, J. F. and Tilson, R. L. 1980. The evolution of monogamy: hypotheses and evidence. *Annu. Rev. Ecol. Syst.*, 11: 197-232.

Date of Receipt : 09.10.2012

Date of Acceptance : 01.03.2013