

Keywords: Reproductive biology; Pair of testes; Pair of ovaries; Pair of oviducts; *C. feriata*

Berried females are important to start a commercial hatchery, but berried females are not available throughout the year from the wild. So the production of berried females in a controlled condition is essential. Before that one should know the morphology of the reproductive system and reproductive biology of a particular crab is important [1-3]. Reproduction is the main mechanism to maintain species proliferation and continuity [4,5]. The recognition of biological data about reproduction is required for judicious management and exploitation of particular species resources. Hence in the present study an attempt has been made on the various aspects of reproductive biology of the male and female crabs of *C. feriata*, such as morphology of the reproductive tract, gonad development, gonado somatic index (GSI), size at maturity and fecundity.

The crabs for the present study were collected from Parangipettai landing centre (Lat.11°29'N; Long.79°46'E) and brought to the laboratory by using plastic container. The crabs were segregated as male and females. They were weighed individually and the size of the carapace width was measured. Sexes were determined by examining the abdominal morphology.

The pleopods and gonopores were analyzed to find out the mating and extrusion of eggs. Presence of the eggs or egg remnants or their absence on pleopods, colour of the egg mass was also noted. The crabs were dissected to study the morphology of the reproductive tract and stages of maturation, size, weight, colour of the gonads and

$$\text{GSI} = \frac{\text{Wet weight of the gonad}}{\text{Wet weight of the animal}} \times 100$$

Recently spawned females with bright yellow or orange coloured

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pair of ejaculatory ducts. The testes are connected with the vas deferens through a sho

on the inner side of the abdominal ab. The testes are flat and highly coiled roughly in the form of "H" located on the dorsal portion of the hepatopancreas sandwiched between the hepatopancreas and the hypodermis of the carapace, and continuing laterally to the stomach upto vas deferens. Just before the posterior stomach and anterior to the heart the left and right testis are bridged by a commissure.

The testes are connected with the vas deferens through a short small duct called vasa efferentia. Vas deferentia is a pair of elongated and coiled tubules which extend longitudinally from the posterior testes upto the posterior region of the body. The vas deferentia has been divided into three distinct regions, based on the morphological and functional criteria: Anterior (AVD), Median (MVD) and Posterior (PVD) vas deferens. The AVD are white, tightly coiled and lying on either side of the median line of cephalothorax posterior to the dorsal part of the stomach. The coils of the AVD increase in size postero-ventrally and lead into the middle vas deferens, which are milky-white meandering tubules of a higher caliber than both the testes and AVD. The posterior vas deferens are whitish in colour arising from the posterior end of the median vas deferens, which are massive for its proximal part, but gradually narrow before opening to the ejaculatory duct. Each posterior VD is connected with an ejaculatory duct, which is a smooth narrow duct extending between the musculature of the swimming peddles.

The ejaculatory duct leads into the slender weak tube like genital papilla (or) penis, which are located at the base of the swimming legs. Each penis passes into the two pairs of abdominal appendages called pleopods (or) gonopods situated in the inner side of the abdominal ab. The first pleopod is made up of two segments, the basal one is broad to the sternal wall and the terminal one is long tube-like and tapering towards the tip, which is actually inserted into the seminal receptacle of the female during copulation. The second pleopod helps in passing the seminal fluids from the penis into the funnel like portion of the first pleopod (Figure 1).

D REPRODUCTIVE SYSTEM OF IMMATURE CRABS

Observation: The gonads of the immature crabs are small and creamy in colour on either side of the stomach. Testes and vas deferentia are not clearly differentiated. Gonads of males measuring below 8.5 cm carapace width are in immature stage.

Remarks: Testes and vas deferentia are well developed and clearly differentiated and creamy white in colour. Testes are large coiled tube which spreading laterally and posteriorly to the stomach. Anterior vas

deferentia becoming enlarged middle and posterior vas deferentia straight and opaque extending to both the side of the heart.

Observation: Testes showed further enlargement as vas deferentia are coiled and very much swollen occupying full body cavity. The AVD and MVD are enlarged and milky white in colour, PVD enlarged and convoluted but still opaque. Gonads of males measuring above 10.5 cm carapace width are in mature stage.

D REPRODUCTIVE SYSTEM OF MATURE CRABS

The Gonadosomatic index of the male and female crabs was studied according to the size and weight of the crab. The GSI of the male crab (0.48) was increased from immature crabs to matured crabs (0.79). The size of the animals was ranging between 8.0 – 8.5 cm carapace width to 14.1–14.5 cm carapace width (Table 1).

D REPRODUCTIVE SYSTEM OF FEMALE CRABS

Observation: The gonads of the female crabs are small and creamy in colour on either side of the stomach. Testes and vas deferentia are not clearly differentiated. Gonads of females measuring below 8.5 cm carapace width are in immature stage.

Remarks: Testes and vas deferentia are well developed and clearly differentiated and creamy white in colour. Testes are large coiled tube which spreading laterally and posteriorly to the stomach. Anterior vas

visible in the eggs, the mean size of the eggs was $260.16 \pm 0.24 \mu\text{m}$ (Table 3).

Yellow to grey coloured egg mass, eyespots were observed, mean size of the egg was $290.2 \pm 0.31 \mu\text{m}$ (Table 3).

Deep grey to black coloured egg mass, eyespots and chromatophores

Small, flattened ovaries, white (or) translucent in colour, occupy small areas of the body cavity.

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Ovary is larger than previous one, light orange in colour, slightly nodulated not extending into hepatopancreatic region.

Larger ovaries yellowish or orange in colour, nodulated extending into hepatopancreatic region and occupies almost all the space of the body cavity.

Very large ovaries, dark yellow or orange in colour, highly nodulated, hepatopancreas is completely hidden or immersed, ovaries fill up all the spaces of the body cavity.

Small, translucent and greatly reduced ovaries unspawned ova are visible throughout the fibrous connective tissue.

The GSI in females were increased from immature crabs (1.95) to ripened crabs (3.97) however in spent crab has low value of GSI as similar to immature crabs (1.26) (Table 2).

Results and Discussion: Fifty percent of the female crabs attained sexual maturity when they reached the size of 9.1- 9.5 cm carapace width. Fifty percent of the male crabs attained sexual maturity when they reached the size of 9.5-10.0 cm carapace width. However, the smallest berried female attained sexual maturity in the present study was measured at 8.6 cm carapace width.

Observation: At the time of spawning the eggs from the ovary of female crabs were extruded through their gonopores and get attached to the cluster of long and very smooth setae on endopodite of the pleopods. Based on the change in colour, increase in the size and change in the shape of the berry eggs, three different stages of egg development was observed.

Pale yellow to deep yellow coloured egg mass, no eyespots was

C. bairdi [22]. However, they seem to be distributed along different groups of brachyura. Simeo et al. [23] studied that lobular testes are very common in portunid crabs. This is the reason why some brachyurans have a tubular testicular arrangement whilst others have a lobular one, is unknown [14,15,23]. The testes connected to the vas deferens by means of a small duct known as vas efferens has been described in *C. sapidus* [3,17] and *P. pelagicus* [8]. Vas deferens (VD) is a pair of elongated and convoluted tubules which extend longitudinally in the posterior region of the body [1, 24]. In *C. feriata* the vas deferens was divided into three distinct regions, the anterior, middle and posterior vas deferens as has been reported in other crabs based on their morphological and functional criteria in *P. sanguinolentus* [1,3], *C. sapidus* [11], *T. orientalis* [12] and *M. branchyactyla* [23]. However other studies characterized two in *G. cruentata* [9], four in *S. chacei* [25] and *D. puligator* into as many as eight regions [26]. Different criteria and different microscopic and macroscopic foci may account for this diversity [9]. The presence of diverticula in the VD of brachyura has been widely described [1,8,9,23] particularly in spider crabs, which present numerous ramified diverticula in the posterior region of the VD [10]. Diverticula play an important role in increasing the secretion, absorption and storage of spermatophores and seminal fluids [27,28]. The terminal portion of the reproductive system is the ejaculatory duct, which is a smooth duct extending between the musculature of the swimming pedals, as already described in brachyura [29]. Very few works have been described for the maturity stages in male crabs. Haefner [30] has described six maturity stages in the males of *C. irroratus* [31] observed five stages of maturation in *C. irroratus* based on a modified version of [30] who indicated six stages of gonad development. [32] indicated five stages of maturation in male crab *C. amnicola*. [33] reported four different morphometric categories of male gonads in *M. branchyactyla*. Boopathi, Anand and Sukumaran et al. [2,3,33] recognized three stages of maturation based on the testis development in *P. pelagicus* and *P. sanguinolentus*. In *P. pelagicus* three stages of maturation was reported based on the development of vas deferens by Lestang et al. [34].

The female reproductive system of *C. feriata* is more or less similar to that of other Portunid crabs. It is closely related with the structure observed by Ryan [1] and George [8] in *P. sanguinolentus*. Estampador EP [7] observed similar structure in *S. serrata* and [11] in *C. sapidus*. Boopathi [2] and George [8] noticed that the posterior prolongation of the right side ovary is shorter and narrower than the left side in *P. sanguinolentus*. This condition is also observed in *C. feriata* at the present study. George [35] in *C. pagurus* and Estampador [7] in *S. serrata* observed that the posterior prolongations of the ovary are connected at the posterior end. In *C. feriata* differ from such species by posterior prolongation of the ovaries are permanently separated. In many species of brachyurans, fresh mating female crabs are indicated externally by hardened mass of spermatozoa called sperm plug together with associated secretions producing from the vulva. Similar observation was made in the present study as well as the study of Estampador [36]. The mated females inhibit further copulation with other males [38,39] by prevent the loss of sperm or keep deleterious materials from entering the female reproductive tract [11].

Stages of ovarian development have been determined based on the morphological and histological analysis of the ovary. In the present study, the morphological analysis of the ovaries of *C. feriata* demonstrated that a gradual development of the ovaries confirmed the maturation into five maturation stages. Among different workers who have studied the maturation of ovaries in brachyuran's crabs, there is a little consistency as to the number of maturity stages recognized.

Six stages of maturation were recorded by Haefner [30] in rock crab *C. irroratus* and five stages in *Chaceon quinquegens*. Haefner [39] recorded five maturity stages in *P. pelagicus*; similarly [40] classified five ovarian developmental stages. Sukumara [41] was reported four maturity stages except the spent stage in *P. sanguinolentus*. In the deep sea golden crab, *C. feneri* the developmental stages were classified into six stages by Erdman [42]. The microscopical analysis of the ovaries of *C. feriata* in the present study demonstrated that a gradual development of the ovaries confirmed the maturation into five maturity stages. The examination of gonad is one of the most accurate techniques, but precise estimates rely on some previous knowledge about specific patterns of growth and reproduction to aid the interpretation of the results, as well as knowledge of short-term breeding cycle to avoid confusion between spent and immature specimens [43]. In the present study the GSI was studied only based on the size and weight of the crab but not in seasonal wise. The GSI has the great relationship with the size and weight of the crabs.

The reproductive capacity of certain crustacean species can be assessed by the study of sexual maturity [44]. The size at onset of sexual maturity in brachyurans can be evaluated considering different criteria, including growth allometry, gonad development stages, presence of spermatic bags or sperm in spermathecas, vestige eggs on the ovigerous areas or the presence of eggs in the abdomen as was analyzed by several authors [27,31,35]. Sexual maturity in brachyurans has been determined in various ways, based on the analyses of morphological maturity, relative growth criteria and physiological and functional maturity [45,46]. According to Parker [37], the consecutive changes observed during gonadal development are important because besides enabling and estimate of physiological sexual maturity [47,48]. In brachyuran crabs chela in males and abdomen in females are considered as secondary sexual characters because of their functions in reproduction [49]. The male crab uses its chela for territorial defence, combat, mating and courtship as well as in carrying and holding the female during copulation. The abdomen in adult females forms an incubation chamber for the developing eggs, which are attached to the setose pleopods. The increase in relative growth of the male chela and female abdomen at the puberty moult brings these structures to full functional size at sexual maturity. Hence the relative growth of chela in males and abdomen in females has been used to determine size at which puberty moult occurs or functional maturity attained. Pillai [50] from Cochin, west coast of India reported that the size of the smallest berried *P. sanguinolentus* as 8.5 cm CW and the size at maturity range was 8.1-9.6 cm. Sumpton [51] who worked out physiological maturity in both male and female *P. sanguinolentus* from Queensland, Australia, reported that the males and females attain sexual maturity at 8.3 and 7.4 cm respectively. Reeby [52] reported that male *P. sanguinolentus* attains full sexual maturity (meaning functional as well as physiological) at 8.1-8.5 cm CW from Karwar, west coast of India.

In south west coast of India the male and female may undergo a pupertal moult at a size ranging between 8.0-8.5 cm and 8.0-9.0 cm CW respectively. Rasheed and Mustaqim, (2010) reported that male and female attain full maturity at 8.3-8.9 mm CW and 8.1-9.3 mm CW, respectively. In the present study the smallest berried female attained sexual maturity at 8.6cm CW while the male and female crab attained sexual maturity when those reached the size of 9.5- 10.0 cm CW and 9.0-9.5 cm CW respectively. According to the present investigation it was observed that the functional and physiological maturities occur almost at the same size.

The size at which maturity occurs can vary with latitude or location

[53] and within individuals at any location. Hines [54] compared geographic variation in the size of sexually mature females in five species of crabs along the east and west coast of North America. Four of the five species show significant geographic variation in size at onset of maturity. The differences in size at maturity among population of the same species of crab may be attributed to variation in moult increment and in the number of moults [54]. Environmental factors such as temperature and salinity can also affect size at sexual maturity in crabs. Fisher [55] who investigated the effect of temperature and salinity on size at sexual maturity of female blue crab *C. sapidus* from nine Texas bay systems stated that size at maturity can vary along the Texas coast, as temperature and salinity vary from bay to bay. He also mentioned that seasonal and annual variation in temperature and salinity in the bay could also affect size at onset of maturity.

Egg bearing females occurs throughout the year with proportion of females bearing egg masses being peak during three different months August, January and March along Parangipettai coast [56], whereas November to March in South west coast [57], whereas December to May and July to August in Calicut coast [59]. Peaks of higher breeding intensity may be associated with variation in temperature, salinity, food availability, rainfall and photoperiod [59]. In brachyuran crabs inhabiting tropical waters usually breed throughout the year whereas those found in temperate waters breeds only in certain months. It is generally suggested that near the tropics reproduction occurs year round because environmental conditions are generally favorable for gonad development [60,61]. However both continuous and seasonal reproductive patterns are found in subtropical and tropical regions [62].

Fecundity is defined as the number of eggs produced by an individual female [63]. Fecundity is calculated as the number of eggs carried externally by the female [6]. In general the fecundity of decapod crustaceans is evaluated as the number of eggs or weight of eggs produced by a female in a single egg batch (Batch fecundity) and is positively correlated with body size (or) weight of females [45,64-66]. Fecundity is significantly related to the female crab's carapace width [44]. The larger females have potential to produce more eggs than smaller females [67]. Fecundity is a species specific character, not only regarding the number of eggs extruded in a single batch but also the frequency of brood production during the life cycle of crustaceans [68].

In general the fecundity of the similar species was varied between different locations. Ryan [1] reported that the fecundity in *P. sanguinolentus* was ranged between 9.6 lakhs to 22.5 lakhs. Sukumara [41] has reported that fecundity was ranged between 2, 68,400 to 6, 68,300 eggs from Mangalore [52] has been reported that the eggs ranged between 1, 58,608 - 7, 12,526 eggs from Karwar [46] reported that the fecundity from Karachi was between 2, 25,649 to 5, 24,456 eggs.

In general, Portunids lay around 1 to 6 million eggs per spawning. In the present investigation the fecundity of *C. feriata* was found to be ranging from 2, 83,963 to 9, and 67,293. Whereas, previous reports on the fecundity of the portunid species were reported to be more or less similar [50] reported 1, 51,780 to 3, 07,500 eggs (1.5 to 3.07 lakhs) and later [56] reported a total of 15,314 to 1, 48,800 eggs (0.15 to 1.48 lakhs). Contrastingly higher fecundity levels were observed by [33] - 2, 88,162 to 9, 20,510 eggs (2.88 to 9.20 lakhs). But the allied species *P. pelagicus* was reported to be having 52,025 to 20,22,500 eggs [69], 3,18,720 to 5,21,450 eggs in southwest coast [57] and 0.1 to 2.3 million eggs were reported by Srinivasagam [70]. The fecundity in *S. tranquebarica* and *S. serrata* was comparatively higher [57,69-73]. Several factors such as salinity, temperature, photoperiod, abundance of food in the

environment and intrinsic state of the animal have been attributed to both interspecific and intraspecific variability of fecundity. There has been considerable variation in the results obtained by various workers who studied fecundity of portunids from different regions [74,75]. In several crustaceans there is a linear relationship between the number of eggs per brood and the size of the female. This has also been observed for the freshwater prawn *Macrobrachium lamarrei* [77], the freshwater crayfish *Astacus leptodactylus* [78], the crayfish *Procambarus (Austrocambarus) ilamasi* [78] and the velvet swimming crab *Necora puber* [69,79] showed a similar direct relationship between size and fecundity in *S. serrata* to 3, 0a/Spainignecundiannnd 0rjEMC /e v/MCI

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58. Saradha PT (1998) Crab fishery of the Calicut coast with some aspects of the population characteristics of *Squilla* *sanguinolentus*, *Squilla* *fabia* and *Squilla* *fabia*. Indian J Fish 45: 375-386.
59. Emmerson WD (1994) Seasonal breeding cycles and sex ratios of eight species of crabs from Mgazana, a mangrove estuary in Transkei, South Africa. J Crust Biol 14: 568-578.
60. Meusy J, Payen GG (1988) Female reproduction in malacostracan Crustacea. Zool Sci 5: 217-265.
61. Mouton EM, Felder DL (1995) Reproduction of the fiddler crabs *Uca* *duorarum* and *Uca* *duorarum* in a Gulf of Mexico salt marsh. Est 18:469-481.
62. Litulo C (2004) Fecundity of the pantropical fiddler crab *Uca* *duorarum* (H.Milne Edwards, 1837) (Brachyura: Ocypodidae) at costa do sol mangrove, Maputo bay southern Mozambique. Western Indian Ocean J Mar Sci 3: 87-91.
63. Lagler KF (1949) Studies of freshwater biology. Ann Arbor Michigan, USA: 119.
64. Somers KM (1991) Characterizing size – specific fecundity crustaceans. In: Wenner A, Kuris A (Eds) crustacean Issues 7. Crustacean Egg Production. A.A. Balkman, Rotterdam, pp: 357-378.
65. Haddon M (1994) Size-fecundity relationships, mating behavior, and larval release in the New Zealand paddle crab, *Uca* *teuicrura* (White 1843) (Brachyura: Portunidae), New Zeal. J Mar Fresh 28: 329-334.
66. Pinheiro MAA, Terceiro OSL (2000) Fecundity and reproductive output of the speckled swimming crab *Uca* *duorarum* (Lamarck, 1818) (Brachyura: Portunidae). Crust 73: 1121-1137.
67. Kailola PJ, Williams MJ, Stewart PC, Riechelt RE, McNee A, et al. (1993) Editors, Australian Fisheries Resources, Bureau of Resource Sciences, Canberra: 422.
68. Sastry AN (1983) Ecological aspects of reproduction. In: Vernberg FJ, Vernberg W (Eds) the Biology of Crustacea, Environmental Adaptations Academic Press, Arenaeus cribrarius Arenaeus cribrarius