MINOR RESEARCH PROJECT

FINAL REPORT

BIOLOGY AND DISTRIBUTION OF ATYID SHRIMPS IN THE KUTTANAD REGION OF PAMBA RIVER

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1. INTRODUCTION

Kuttanad known for its vast paddy fields and river systems has the unique distinction of being one of the few regions in the world where paddy farming is practiced below the sea level. It is spread across three districts of Kerala namely, Alappuzha, Pathanamthitta and Kottayam and drained by Meenachil, Pamba, Manimala and Achankovil Rivers. The extensive river systems and adjoining paddy fields provide immense opportunities for aquaculture. But defective farming practices like indiscriminate use of chemical fertilizers, pesticides and the construction of Thannirmukkam bund to prevent the intrusion of sea water into the paddy fields upset the ecobiology of Kuttanad. In this context a study has been conducted on the biology and distribution of atyid shrimps in the Kuttanad region of Pamba River.

Family Atyidae De Haan, 1849 belongs to the order Decapoda Latreille, 1802, Infraorder Caridea Dana, 1852 and Super family Atyoidea De Haan, 1849. Atyidae is the only family reported under the Super family Atyoidea. Family Atyidae De Haan, 1849 is characterized by: inflexible rostrum; carapace without longitudinal lateral ridges and without cardiac notch in posterior margin; eyes well developed or reduced without pigments; antennule with 2 flagella, neither with accessory branch; mandible without palp, with molar process not distinctly separated from incisor process; two anterior pairs of pereiopods similar, with fingers of chela usually terminating in tufts of setae; 2nd pereiopod with carpus usually not articulated; pereiopods with or without exopods.

According to the classification by Holthuis (1986) there are 4 subfamilies under the family Atyidae, namely **Atyinae** De Haan, 1849; **Caridellinae** Holthuis, 1986; **Paratyinae** Holthuis, 1986 and **Typhlatyinae** Holthuis, 1986. However, studies by Sket & Zakšek (2009)

synonymized the subfamily Typhlatyinae Holthuis, 1986 with Paratyinae Holthuis, 1986 that resulted in three valid subfamilies which are: **Atyinae** De Haan, 1849; **Paratyinae** Holthuis, 1986 and **Caridellinae** Holthuis, 1986.

Atyid shrimps are one of the abundant macro-invertebrates in the natural inland water bodies. Out of the 43 genera reported worldwide, only one genus has been reported from India which is *Caridina* H.M. Edwards, 1837. It is regarded as one of the confusing and neglected genera because of its phenotypic plasticity and species richness.

Atid shrimps are diverse and variable and they play an important role in the aquatic ecology because of their omnivorous habit and their role as food source for predators. These organisms are generally small and slender. Because of their small size the rarely form human food. But they are commercially cultured and used as live food in aquaculture. Some of the atyid shrimps are beautifully coloured (*Caridina babaulti* Bouvier, 1918) and are one of the best sold items in the ornamental aquaculture industry. They feed on attached algae and hence provide additional advantage in aquaria. They are regarded as bioindicators because of their absence in polluted waters. *Caridina* is described as a crustacean material for experimental biology because of their short generation time, perennial breeding habit, high survival rates, hardiness related to concentration of dissolved oxygen, salinity and temperature.

Caridina belongs to the subfamily Atyinae. According to the report by De Grave *et al* (2009) *Caridina* is species rich and the number reported may go beyond 279. Majority of the species are found in freshwater habitats but a few prefers brackish water (*Caridina gracilirostris* De Man, 1892). A survey on the atyid shrimps of Kerala reported 15 species of *Caridina* from different freshwater and brackish water habitats (Tessa Thomas, 2012).

Considering the ecological significance of Kuttanad, the present work made an attempt to study the atyid shrimps in the Kuttanad region of Pamba River with the following objectives.

- Morphology of the genus *Caridina*.
- *Caridina natarajani*: Diagnostic features, General biology, Population fluctuations and Length-Weight relationship
- Relationship of fecundity with total length and body weight

2. REVIEW OF LITERATURE

Family Atyidae De Haan, 1849 comes under the order Decapoda Latreille, 1802, Infraorder Caridea Dana, 1852 and Super family Atyoidea De Haan, 1849. Atyidae is a group of shrimps characterized by spoon-like fingers of chela terminating in tufts of setae. So far 43 genera have been reported under the family Atyidae. Among them genus *Caridina* contains the maximum number of species and it has wide distributional range. Genera like *Antecaridina*, *Atyidina*, *Micratia*, *Australatya*, *Caridinides*, *Gallocaris*, *Jonga*, *Caridinopsis*, *Archaeatya*, *Pycneus* and *Jolyvetya* are monotypic. Kemp, De Man and Holthuis were the pioneers to study on atyids. In India a few detailed studies had been carried out on the taxonomy and population ecology of atyids (Pillai, 1958; Babu, 1963; Tiwari & Pillai, 1968; Thomas *et al*., 1973; Jalihal *et al*., 1984; Richard & Chandran, 1994; Mariappan & Richard, 2006; Jayachandran *et al*., 2008; Valarmathi, 2009 and Tessa Thomas, 2012). According to the report by De Grave *et al* (2009) *Caridina* is species rich and the number reported may go beyond 279.

Atyids are commonly found in freshwater ecosystems where they form an important component of the food web. Henderson (1893) reported *C. wyckki* from Madras that formed the first report of an atyid shrimp in India. Kemp (1913) made a study on the decapod crustaceans of Brahmaputra valley and reported two new species of *Caridina* namely, *Caridina excavata* and *C. hodgarti*. Two new species of *Caridina* namely, *C. rajadhari* and *C. babaulti* had been reported from central India (Bouvier, 1918). Roux (1931) reported *Caridina carli* as new species and *C. cavaleriei industana* as new subspecies from Tamil Nadu. Natarajan (1942) commented on the occurrence of *Caridina* in Travancore and reported *C. gracilirostris*, *C. laevis*, *C. nilotica* var. *gracilipes* and *C. weberi* var. *sumatrensis*. Pillai (1958) made a detailed study on the biology of *Caridina laevis*.

While describing the *Caridina* of Travancore Pillai (1964) described a new variety namely, *C. nilotica* (Roux) var. *veliensis*. Tiwari & Pillai (1968) described a new species from Museum Tank in Trivandrum, *Caridina natarajani*, which shows close affinity with *Caridina laevis*. Tiwari & Pillai (1971) reported 5 species of *Caridina* from the Andaman Islands including one new species, *C. prashadi*. Thomas *et al*. (1973) described a new species namely, *C. pseudogracilirostris* from the Cochin backwaters. Dutt & Ravindranath (1975) recorded *Caridina brachydactyla peninsularis* for the first time from India.

Smith & Williams (1980) assessed the intraspecific variations within a population of *Paratya australiensis*. De Silva (1982) while studying the Atyidae of Sri Lanka reported *C. costai* and *C. pristis cruszi* as new species and subspecies respectively and they also recorded *C. typus* and *C. propinqua* for the first time from the Island nation. Almelkar (1983) studied atyids from Lonavala near Mumbai and reported a new subspecies, *C. gurneyi lonavalensis*. De Silva (1983) gave a brief report on the distribution of atyid shrimps in Sri Lanka. Richard (1983) studied the genus *Caridina* in and around Madras city and reported the occurrence of *Caridina gurneyi lonavalensis*. Jalihal *et al*. (1984) described *C. williamsoni*, *C. shenoyi*, *C. kempi*, *C. gurneyi* and *C. panikkari* as new taxa from Dharwar in Karnataka. Raman *et al*. (1986) in their study on the distribution and abundance of prawn fauna in the freshwater habitats of South India reported *M. lanchesteri* and three species of *Caridina* namely, *C. rajadhari*, *C. nilotica* var. *bengalensis* and *C. weberi* var. *sumatrensis*.

Jalihal *et al*. (1994) described *Caridina* as a potential crustacean material for experimental biology. Richard & Chandran (1994) while describing the Atyidae of Madras identified a new species, *Caridina kunnathurensis*. Ebenezer & Richard (1999) reported the

occurrence of *Caridina typus* from Kanyakumari district of Tamil Nadu, for the first time from the Indian mainland.

Dutta (2001) studied the systematics and distribution of prawns in Assam and reported the occurrence of *Caridina weberi*. Fossati *et al*. (2002) studied the distribution of *Atyoida pilipes* and *Caridina weberi* in rivers of Nuku-Hiva Island, French Polynesia. Jayachandran *et al.* (2005) during a biodiversity survey gave an overall report on the palaemonid and atyid prawns in Kerala. Mariappan & Richard (2006) while studying the Atyidae and Palaemonidae of Tamil Nadu described *Caridina jalihali* as new species. Cai & Ng (2007) while revising *Caridina gracilirostris* gave descriptions for two new species, *C. neglecta* and *C. longifrons*. Thomas & Jayachandran (2007) reported *Caridina jalihali* for the first time from Kerala. Jayachandran *et al*. (2008) studied the caridinian shrimp resources of Kerala and reported eleven species of *Caridina.* Sket & Zakšek (2009) revised the European cave shrimp species and brought to science one new genus and four new species, namely, *Gallocaris* gen. nov., *Troglocaris bosnica*, *T. prasence*, *T. kapelana* and *T. neglecta*. Valarmathi (2009) made a survey on the diversity of *Macrobrachium* spp. and *Caridina* spp. in southern India.

Distribution of shrimps

De Silva (1987) after studying the salinity tolerances of three species of atyids commented that the synergetic action of temperature and salinity must be taken into consideration while studying the geographic distribution of atyids. Shrimps may undertake dial vertical migration to escape from variations in temperature (Hart, 1983; Lehman, 1996). The limitations in physiological tolerance, human interference in habitat and the introduction of carnivorous culture fishes may have contributed significantly to the present day isolation of some

atyids (De Silva & De Silva, 1988; Benzie & De Silva, 1988). De Silva (1989) studied the temperature tolerance of *C. fernandoi*, *C. simoni* and *C. pristis*. Fossati *et al*. (2002) while studying the distribution and habitat utilization of atyid shrimps observed that *Atyoida pilipes* was abundant in lotic habitats whereas *C. weberi* was found among plants in lentic habitats.

Population ecology

Atyid shrimps are components of the littoral fauna and they play an important role in the ecology of freshwater habitats in the tropics (De Silva, 1988b). They are important in the stream food web because of their omnivorous habit and their role as a food source for predators (March & Pringle, 2003). Atyid shrimps play an important role in stream recovery after heavy discharges of sediments over benthic substrata (Pringle *et al*., 1993). Atyids can influence algal production, detritus processing and benthic community structure in streams but, their effects vary and depend on the presence of other biota (March *et al*., 2002). But Williams (2002) opined that atyid shrimps had no role in leaf litter decomposition.

Environmental factors like temperature and rainfall influence the population size and reproductive pattern of atyids (De Silva 1982; Dudgeon, 1985; De Silva 1988a). Tropical and subtropical atyids are perennial breeders (Hart, 1981) whereas temperate atyids breed only during summer (Williams, 1977; Shokita, 1979). Richardson *et al*. (2004) while studying the distribution of caridean shrimps in southern Australia commented on the possibility of dams and weirs influencing shrimp abundance and timing of breeding. The timing and extend of the breeding season may vary with respect to geographic location and this may be due to variations in temperature.

Hart (1981) studied the seasonal changes in the population structure of *C. nilotica* and reported that higher birth rates during summer did not make corresponding increase in the population density due to high mortality. De Silva & De Silva (1989) reported enhanced breeding during the rainy season in *Caridina fernandoi*. Negative correlation between population density and rainfall was observed in *C. kunnathurensis* (Valarmathi, 2009).

Chromatophores

Shrimps are gaining popularity in the pet market as ornamental species. Jayachandran *et al*. (2005) listed a few species of *Macrobrachium* and *Caridina* are species having potentials in the ornamental pet market. Vasantha (1973) studied the effect of temperature on red and white chromatophores of *C. weberi*. The red chromatophores aggregated and white chromatophores dispersed at high temperature. The chromatophores of *C. weberi* underwent small but significant cyclic changes in degree of expansion during various stages of the moult cycle (Nagabhushanam & Vasantha, 1971).

Food and Feeding

Stomach content analysis may be helpful in assessing the trophic position of a species within the ecosystem and in framing sustainable management strategies (Richardson *et al*., 2000). The family Atyidae is unique among the Malacostraca in having representatives that filter passively by means of the chelipeds (Fryer, 1977). Jalihal *et al*. (1982) suggested *C. kempi* as a prospective species for culture both in inland and coastal low saline waters because of its hardiness, tolerance to fluctuations in temperature and salinity.

Moulting

Moulting is a periodic phenomenon associated with growth in Crustaceans. Temperature, quality and quantity of food, sex, physiological condition and developmental stage influence the frequency of moulting. Nagabhushanam & Chinnayya (1972) studied the moulting behaviour of *C. weberi* and observed that the animals moult throughout the year with two moulting peaks which coincided with high temperatures. Ponnuchamy *et al*. (1984) observed that population density stress affects moult production and growth in *Macrobrachium lanchesteri* and *C. weberi*.

Sexual dimorphism

Sexual dimorphism is not prominent in *Caridina* except differences in the morphology of 1st and 2nd pereiopods. Shenoy *et al*., 1993 reported that *Caridina* exhibits sexual dimorphism with regard to the number of aesthetasc bearing segments in the outer flagellum of antennular peduncle.

Morphometrics

Growth and reproduction are important aspects in the life history of a species. Growth may be quantified as an increase in total length (TL), carapace length (CL), telson length (TL), rostral length (RL) and body weight (W). De Silva (1988a, b) reported positive relationship between length and weight in males and non-ovigerous females of *C. simoni* and *C. pristis*. Enin (1994) while studying the length-weight parameters of West African prawns reported isometric growth in *Nematopalaemon hastatus* and allometric growth in *Macrobrachium macrobrachion*.

Fecundity

Reproductive performance and abundance of a species is estimated in terms of fecundity. Fecundity has different aspects such as, potential fecundity, realized fecundity and actual

fecundity (Anger & Moreira, 1998). The parameters such as total body length, length and volume of the abdomen, length of pleopods and mortality rate of eggs influence fecundity. Caridean females carry eggs in a brood pouch formed by the growth of the abdominal pleura and the bristles of the pleopods. The strategy of carrying eggs enhances the survival of the embryos, optimising the reproductive success of the species (Shakuntala, 1977; Nazari, *et al*., 2003). Hancock *et al*. (1998) suggested that egg size is under strong genetic control while clutch size is influenced by environment.

Weerakkody (1984) established a linear relationship between the logarithmic values of fecundity and body length in *C. simoni*. Nazari *et al*. (2003) compared the fecundity, egg size and egg mass volume of *Macrobrachium potiuna* and *Macrobrachium olfersi*. Bello-Olusoji (2004) analyzed the weight-fecundity and length-fecundity relationship of *Caridina* spp. and showed that the relationship between fecundity and weight is weak ($R^2 = 0.382$) and that between fecundity and length is relatively strong ($R^2 = 0.64$). Bhuiyan *et al*. (2007) reported positive correlation between the number of eggs and the length of female body in *Macrobrachium dayanum*.

3. RESULTS

3.1 General morphology of the genus *Caridina* H. Milne Edwards, 1837

Carapace

Carapace covers cephalothorax and with an anterior extension, the rostrum. In *Caridina* it is thin and the grooves on the carapace are not noticeable due to its very little calcification. Carapace with a sharp antennal spine that is either fused with or a little below the inferior orbital margin. The pterygostomian region, situated anterolaterally carries a sharp spine in some species.

Rostrum

Rostrum is an anterior immovable prolongation of the carapace. Its shape, length and rostral formula are characters having taxonomic significance and it varies between species. Sometimes even members of the same species collected from different regions or at different times show differences in rostral characteristics.

The members of the genus *Caridina* exhibit wide range of variations in the shape, length, number and arrangement of teeth on the rostrum. It may be slightly convex (*C. natarajani* Tiwari & Pillai, 1968), upturned (*C. williamsoni* Jalihal *et al*., 1984), straight or slightly slanting (*C. gurneyi* Jalihal *et al*., 1984). Intra and interspecific variations are frequent in the length of the rostrum, it may be short, hardly reaching the end of 1st antennular segment (*Caridina vithuraensis*), moderately long, extending up to the middle of 3rd antennular segment (*C. natarajani* Tiwari & Pillai, 1968) or very long, extending beyond the end of scaphocerite (*C. gracilirostris* De Man, 1892). With regard to serration there are differences: teeth on both

margins (*C. laevis*, *C. natarajani* and vast majority of other species), edentulous on both margins (*C. zebra* Short, 1993) and teeth only on upper margin (*C. mengaeoides* Guo & Suzuki, 1996). There are differences in the number and arrangement of teeth on the upper margin of rostrum; teeth may be numerous and equidistantly placed up to the tip (*C. williamsoni*) or a few, widely spaced teeth on proximal part of rostrum (*C. gracilirostris*) or numerous closely set teeth at the proximal half and the distal edentulous part sometimes carries 1-3 intermediate teeth (*C. gracilipes* De Man, 1892). Ventral margin also shows wide variations in the number of teeth, a few (*C. natarajani*) or a large number of equidistant teeth arranged up to the tip (*C. gracilirostris*).

Abdomen

The abdomen consists of six segments, all movably articulated with one another. In the normal position, there is a characteristic dorsal hump in the 3rd segment. The 1st abdominal segment is narrow and its tergum comes into close contact with the posterior margin of the carapace when the abdomen is straightened. The posterolateral margins of the carapace are overlapped by the pleura of the 1st abdominal segment. The pleurae of the 2nd abdominal segment overlap the pleurae of the 1st and 3rd abdominal segments. All the abdominal terga are arranged in such a way that the anterior end of one tergum is being overlapped by the posterior end of the tergum in front. The tergum of the 6th abdominal segment covers the anterior margin of the telson. On the ventral side, the median posterior margin of the last abdominal sternum bears a small triangular prolongation just in front of the anus, the preanal carina, its apex directed backwards and carries either a spine or a few setae.

Telson

The 6th abdominal segment bears a triangular plate, the telson, the dorsal surface of the telson bears a number of short spines on either side. The posterior margin also bears spines, which are plumose or spine-like. The armature of the telson is considered as a character having taxonomic value.

Appendages

All the appendages are biramous and are variously modified for feeding, respiration and locomotion.

a. Cephalic appendages

Antennule (Fig.1: A)

The antennule consists of a basal protopod of three podomeres; precoxa, coxa and basis. From the tip of the distal podomere arises too many jointed setose flagella. The outer of these is longer; its proximal part is dilated and bears chemo-mechano-receptors called aesthetascs. The elongated basal segment has a depression on its dorsal side, for the accommodation of the eye; towards the proximal side of the depression is the opening of the statocyst. The basal segment on its lateral side bears a large spine, the stylocerite, which extends up to 3/4th of its length, but in members of *Caridina serrata* species group it extends beyond the basal segment. The outer margin of the stylocerite is sparsely setose. The anterolateral margin of the basal segment bears a short spine, which extends to 1/4th of the middle segment. The middle segment is narrow and long. The distal segment is the shortest having two surfaces distally for the articulation of the flagella.

Antenna (Fig.1: B)

Each appendage has a protopod of two segments and two rami. The outer flattened scale, the scaphocerite, is considered as the exopod and the inner filamentous multisegmented flagellum, the endopod. The exopod is with an outer straight nonsetose margin which anteriorly ends in a spine. The anterior and inner margins bear a row of long and jointed feathery setae. The endopod consists of a basal segment, followed by an elongated cylindrical segment and a many jointed flagellum. The large basal segment of the protopod lodges the major portion of the antennary gland. The renal aperture is situated at the base of the endopod towards its median side.

Mandible (Fig.1: C)

The mandibles are small and stout articulated obliquely with the sternum and directed towards the oral aperture. It is divisible into a basal portion, the apophysis, and a head made up of two lobes. The apophysis represents the coxa of a typical decapodan appendage. It is concave posteriorly; anteriorly the apophysis carries the head, which is divisible into an upper molar process and a lower incisor process. The incisor process of the right and left mandibles shows asymmetry, the number and the shape of the teeth are not the same on the two sides. Below the region of the teeth, the rim of the mandible bears a variable number of stout setae and a tuft of closely set bristles. The molar process is separated from the incisor process by a shallow notch, the entire grinding area is raised into transverse ridges and corresponding grooves.

Maxilla I (Fig.1: D)

These are small, distinguishable into three regions. The proximal coxal segment is thin and depressed, expanding mesially to form an endite, fringed with setae. The basis is flattened

with an endite which expands to form a cutting edge bearing a row of teeth-like setae. The endopod small, situated on the outer side of the basis, is provided with a few bristles and a hook-like projection at the tip.

Maxilla II (Fig.1: E)

The coxa bears a fleshy endite with long, arched setae. The basis has an elongated endite divided into two by a notch in the middle and bears at its inner margin a double row of long setae. The scaphognathite which represents the flattened exopod, tapers posteriorly, bearing long bristles. The anterior and outer margin of the scaphognathite is fringed with plumose setae. The endopod is small, unsegmented, placed between the basis and the anterior part of the scaphognathite.

b. Thoracic appendages

First maxilliped (Fig.1: F)

The coxa forms a distinct basal lobe. The basis is elongated and its concave inner margin has a double row of setae. Attached to the protopod on its outer side is an expanded exopod which is produced into a narrow anterior part corresponding to the flagellum of posterior appendages. The endopod is small, triangular and lies between the exopod and the basis, with a few setae. A small epipod is present on the outer aspect of the coxa.

Second maxilliped (Fig.1: G)

It is a more or less pediform appendage and plays a major role in feeding. The coxa on its outer side bears a well developed podobranch in most species but in a few it is rudimentary (*C. thomasi*). The basis is coalesced with the ischium, bearing small setae on its inner margin.

The merus and the carpus are separate; the propodus bears a few long and feathery setae on its inner margin. The flattened dactylus is concave on its topographically inner margin (morphologically outer margin) and heavily chitinised, bearing three rows of strong setae, with which the food comes into contact during mastication. The exopod is unsegmented with a number of feathery setae, creating currents of water towards the anterior side.

Third maxilliped

It is completely pediform. The protopod consists of a large coxa and a small basis. The coxa bears a well developed epipod on its outer lower side. The endopod consists of three long segments; the proximal segment is formed by the fusion of ischium and merus. The carpus is long and has on its outer side several transverse rows of short setae. The distal podomere represents the coalesced propodus and dactylus and is flattened in a vertical plane. Its broad basal part is concave on the inner side and is armed with several rows of closely set brush-like setae. The narrow distal portion of the propodus and dactylus has a large apical spine and a few smaller spines. The exopod is similar to those of the 2^{nd} maxilliped. Attached to the coxa of the third maxilliped is pair of arthrobranchiae.

Pereiopods

A typical pereiopod consists of an endopod of seven podomeres; coxa, basis, ischium, merus, carpus, propodus and dactylus. The exopod is absent. Epipods are present on 1- 4 pairs of pereiopods and 2-3 setobranchs present on the coxa of all pereiopods. The 1^{st} and 2^{nd} pereiopods are chelate and the remaining three pairs non-chelate.

The basis of the 1st cheliped is small and the succeeding podomeres are flattened in a vertical plane. Carpus with or without an anterior excavation, the distal portion of the chela bears tufts of setae. The coxa of the 1st cheliped bears an arthrobranch.

The 2nd pereiopod is longer than the 1st. The carpus, without an anterior excavation, is almost double the length of the carpus of the 1st cheliped. The chela is slender than the first.

The coxa of the 3rd pereiopod of the female carries the genital aperture. The podomeres are arranged linearly, dactylus is small and flattened vertically, the lower edge bearing a large terminal spine and a row of small spines. The fourth pereiopod is similar to 3rd.

In the male the genital aperture is situated on the inner aspect of the coxa of the 5th pereiopod. The dactylus is flattened and bears a series of comb-like spinules on its posterior margin. The proportions of the various podomeres of the pereiopods and the number of spines and spinules present on it are regarded as taxonomically relevant characters. A pair of pleurobranchiae is present on the pleural wall of the last five thoracic somites.

c. Abdominal appendages

Pleopods

The abdominal appendages are five pairs of pleopods and a pair of uropods. In the male, the 1st and 2nd pleopods exhibit sexual dimorphism. The other three conform to the structural pattern of the typical pleopod. The basis is flattened and much elongated than coxa. The basis bears the flattened and unjointed endopod and exopod. The endopod on its inner aspect bears a small appendix interna bearing a few retinacula at the tip. The margins of the exopods and the endopods are indentated with feathery, jointed, natatory setae.

The uropod consists of a sympod of one segment, an outer, larger exopod and an inner, smaller endopod. The endopod and the inner margin of the exopod are provided with long natatory setae. The outer margin of the exopod is straight, ends in a sharp spine. The blade of exopod is divided partially; the division originates at the outer lateral spine. Along the border of the suture are a row of backwardly directed spines, the diaeresis, which is species specific. The uropods along with the telson form a powerful tail-fan, which plays an important role in sudden darting movements.

Materials and Methods

Specimens of *Caridina* were collected from 2 different sites in a tributary of Pamba River. They were found hidden among aquatic plants, collected by dragging rectangular mosquito net (1 mm mesh size) along the banks of the river. Specimens were preserved in 8% formaldehyde and identified by referring relevant literature.

3.2 *Caridina natarajani* Tiwari & Pillai, 1968

Caridina natarajani Tiwari, K.K. & Pillai, R.S., 1968. *Proc. Zool. Soc. Calcutta* 21: 163

Caridina natarajani is abundantly present in the rivers and freshwater ponds of southern and central Kerala. They are reported from nine major rivers namely, Karamana river, Kallada River, Meenachil River, Neyyar River, Muvattupuzha River, Manimala River, Pampa River, Achankovil River and Vamanapuram River.

Characters: Rostrum moderately long, slightly convex usually extending up to the middle of 3rd antennular segment; in males, it is shorter hardly reaching the middle of 2nd antennular segment. Tip of rostrum slender, slightly upturned and devoid of teeth. Rostral formula: 11-23/1-7 (3-5 post-orbital). Antennal spine sharp, distinct, lower than the inferior orbital angle; pterygostomian angle rounded. (Fig.2: A)

Telson with 3-5 pairs of dorsal spines, posterior end convex, without median projection, bearing 6-8 distal spines, those at the centre are longer and strongly plumose. (Fig.4: A)

Carpus of 1st pereiopod shorter with a slight anterior excavation (Fig.3: A), whereas that of 2nd pereiopod slender, elongated and without anterior excavation (Fig.3: B).

Dactylus of 3rd pereiopod ending in a sharp spine, with 8-10 accessory spines on its posterior margin; carpus with a big sub-terminal spine and an inner row of 4-5 spinules; ischium and merus bear 0-1 and 2-3 spines respectively on the posterior margin (Fig.3: C, D). 4th pereiopod similar to 3rd.

Dactylus of 5th pereiopod ending in a sharp claw, its posterior margin is armed with 45-75 comb-like spinules; carpus with a big sub-terminal spine and an inner row of 4-5 spinules; ischium and merus bear 0 and 1-3 spines respectively on the posterior margin (Fig.4: B, C) .

Endopod of the male 1st pleopod without appendix interna (Fig.2: B); preanal carina triangular with a few distal setae.

Uropodal diaeresis with 12-14 spines (Fig.4: D, E)

Eggs large, green in colour measuring 0.42-0.58 x 0.65-0.76 mm. Fecundity 50-90 eggs (size: 15.0-20.0 mm).

Colouration: Body translucent with orange and red chromatophores all over the body.

Distribution: Kerala and Tamil Nadu.

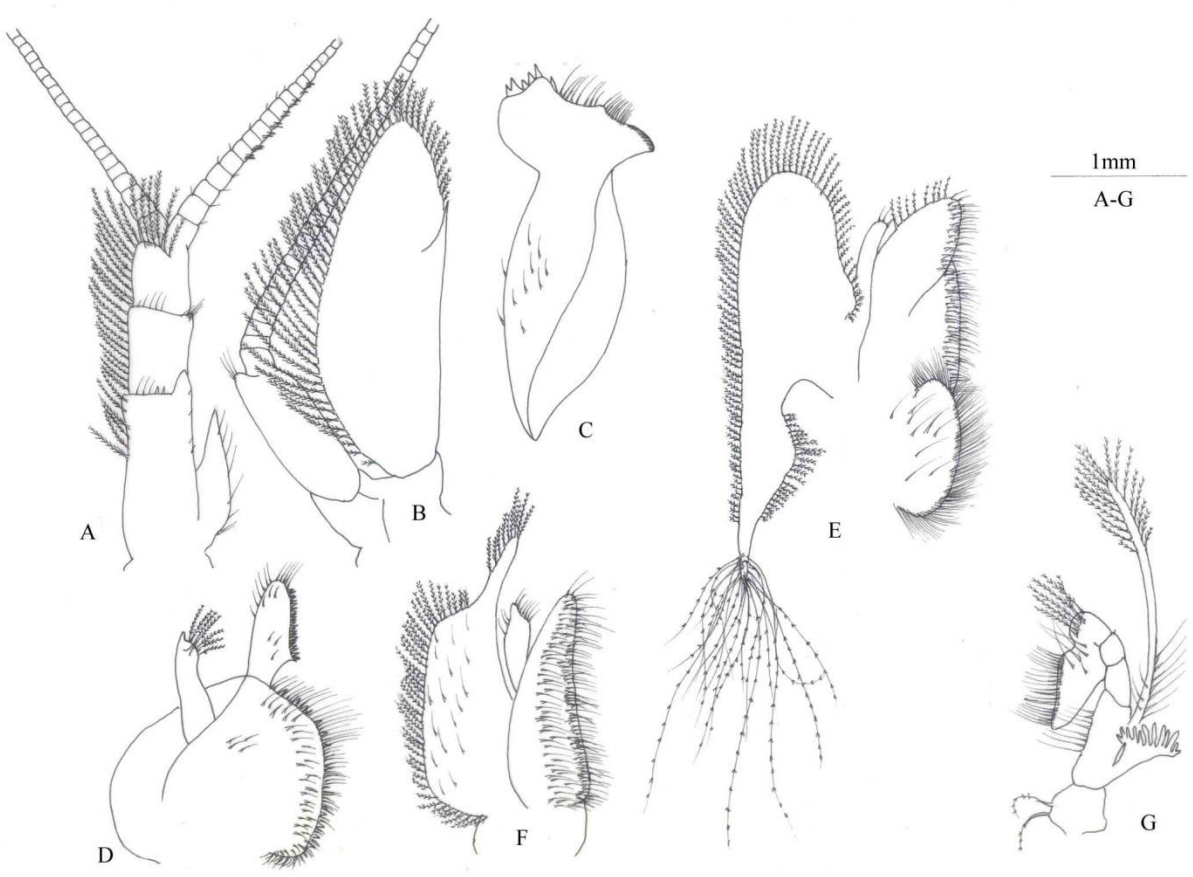

Fig. 1 : *Caridina natarajani* ; **A- Antennule, B- Antenna, C- Mandible, D- Maxillula E- Maxilla, F- Maxilliped I, G- Maxilliped II**

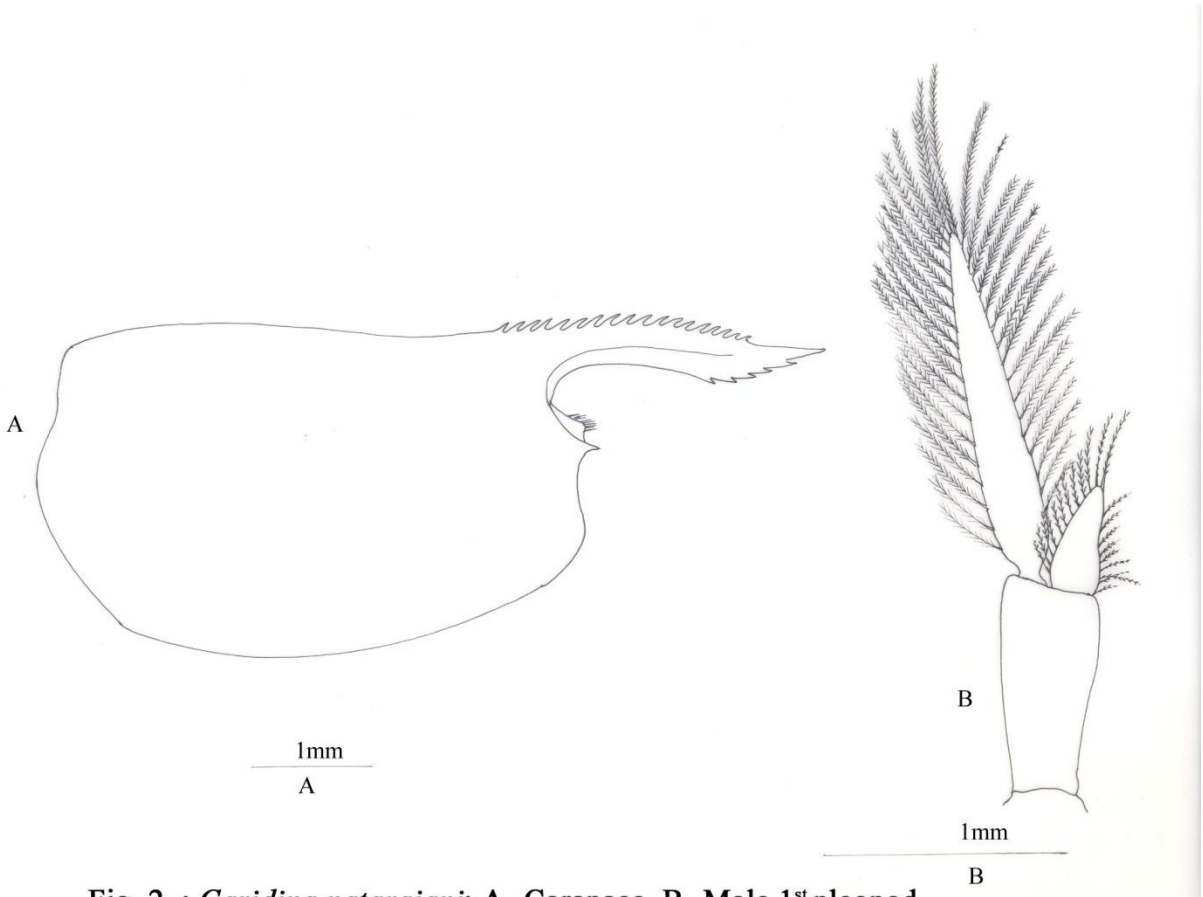

Fig. 2 : *Caridina natarajani*; A- Carapace, B- Male 1st pleopod

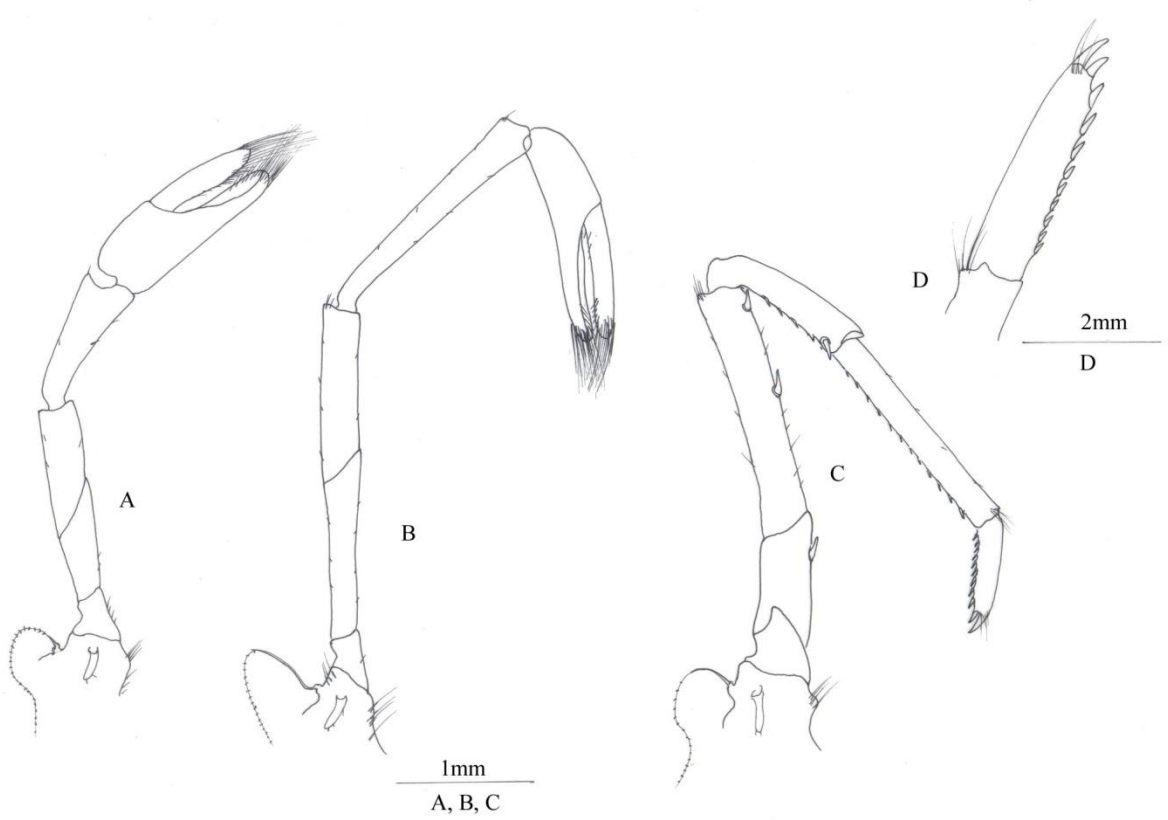

Fig. 3: *Caridina natarajani;* A- 1st pereiopod, B- 2nd pereiopod, C- 3rd pereiopod D- Dactylus of 3rd pereiopod enlarged

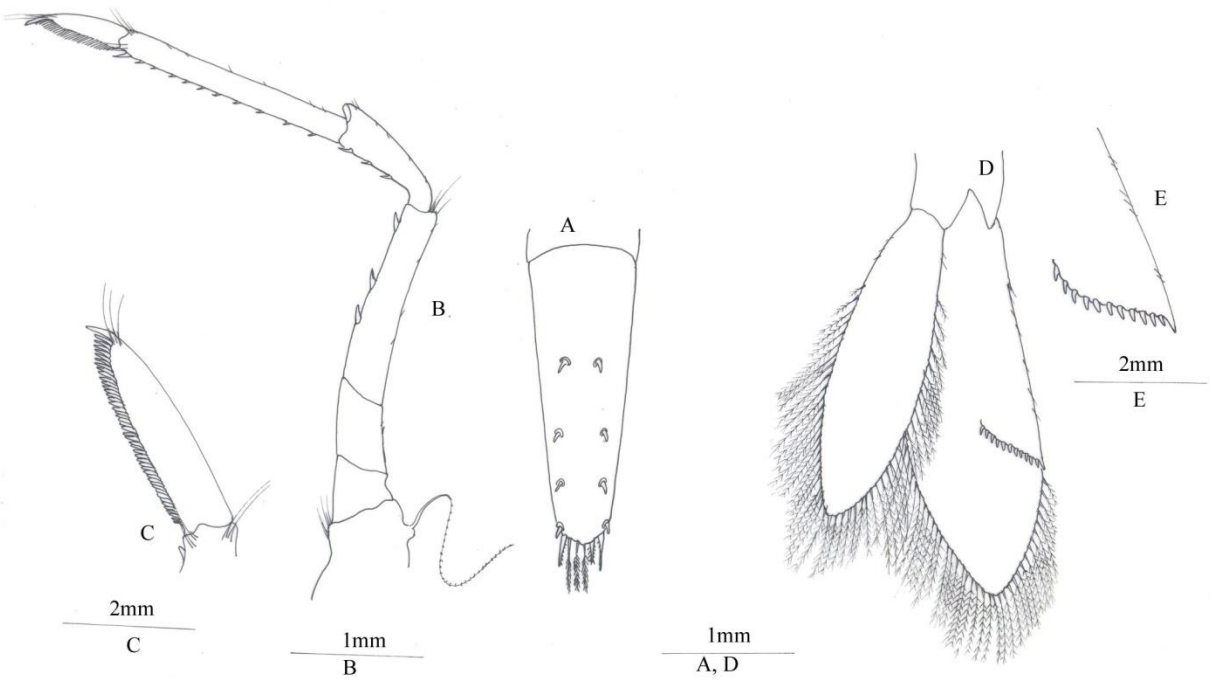

Fig. 4: *Caridina natarajani*; A- Telson, B- 5th pereiopod, C- Dactylus of 5th pereiopod enlarged D- Uropod, E- Diaeresis

3.3 General Biology

Materials and methods

Specimens collected from a tributary of Pamba River at Kuttanad region has been reared in rectangular glass tanks for observing the behaviour, moulting periodicity, incubation period and larval development. They are hardy and can survive without aeration but needs to remove excreta and leftover food daily. It was removed by siphoning and water was replaced once in a week for maintaining oxygen concentration and removing metabolic wastes.

Results

Bionomics

Caridina H. Milne Edwards, 1837 is an abundant macroinvertebrate in the freshwater ecosystems of Kerala. They are usually found hidden among aquatic plants where the velocity of current is not so intense. In natural conditions, the body is translucent with a few scattered orange-red chromatophores, but when brought to the laboratory they lose the colour within a few days. When kept in rectangular glass tanks they usually hide themselves among the aquatic plants and come down for feeding.

Food and Feeding

Shrimps are omnivorous in habit feeding on a variety of substances. Analysis of the gut contents of the specimens collected from the natural habitat showed detritus that may be associated with the benthic habit of the animal. In the laboratory they have been found feeding on the algae on the walls of the container. Besides algae they were found to feed on moult and the commercially available pellet feed.

Moulting

Moulting is a periodic phenomenon associated with growth in Crustacea. Age, physiological state, food and temperature can influence moulting. Males exhibit periodic non-reproductive moults that is associated with somatic growth. In females moulting takes place after the complete development of the ovary which is followed by the extrusion of eggs into the brood chamber. In *C. natarajani* the interval between successive moults in males was 8-9 days and in females 7-8 days.

Sexual dimorphism

Except differences in size and morphology of 1st and 2nd pleopods, sexual dimorphism is not much pronounced in *Caridina*. Generally males are shorter and slender than females. In males the 1st pleopod is shorter, subrectangular and completely fringed with setae. In females it is longer, slender posteriorly, with a few setae on the anterior border. In females the 2nd pleopod is similar to those behind, but in males, a rod-like appendix masculina armed with rows of stout spines is present in between the endopod and appendix interna. The coxa of the 3rd pereiopod carries the genital aperture in females whereas in males it is situated on the inner aspect of the coxa of the 5th pereiopod. *Caridina natarajani* exhibit sexual dimorphism with regard to the length of rostrum. In females it is longer usually extending up to the middle of 3rd antennular segment or more whereas in males it is short, hardly reaching the middle of 2nd antennular segment.

Breeding dress

During the breeding season, after the premating moult, the pleopods of the female develop large number of ovigerous setae called the breeding dress, for holding the fertilized

eggs. In ovigerous females long setae appear on both the inner and outer margins of basis, the setae of the inner margin carry the eggs while those of the outer margin close the brood pouch and support the egg mass. The last pair of pleopods does not carry eggs. The breeding dress was shed about 1-2 days after the hatching of the eggs.

Incubation period and larval development

In *Caridina natarajani* the incubation period varies between 13 and 15 days. The larvae exhibit abbreviated development with 3 zoeal stages and a post larval stage.

3.4 Population studies

Specimens of *Caridina* were collected from a tributary of Pamba River for a period of one year from November 2015 to October 2016. It is a perennial shallow stream with muddy bottom and plenty of marginal vegetation. The shrimps were collected by using a rectangular mosquito net and preserved in 8% formaldehyde for further analysis.

Results

A total of 638 specimens were collected during the period of study. Among them were 210 males, 93 ovigerous females, 180 non ovigerous females and 155 juveniles. Figures show the fluctuations in the populations of males, non ovigerous females, ovigerous females and juveniles respectively.

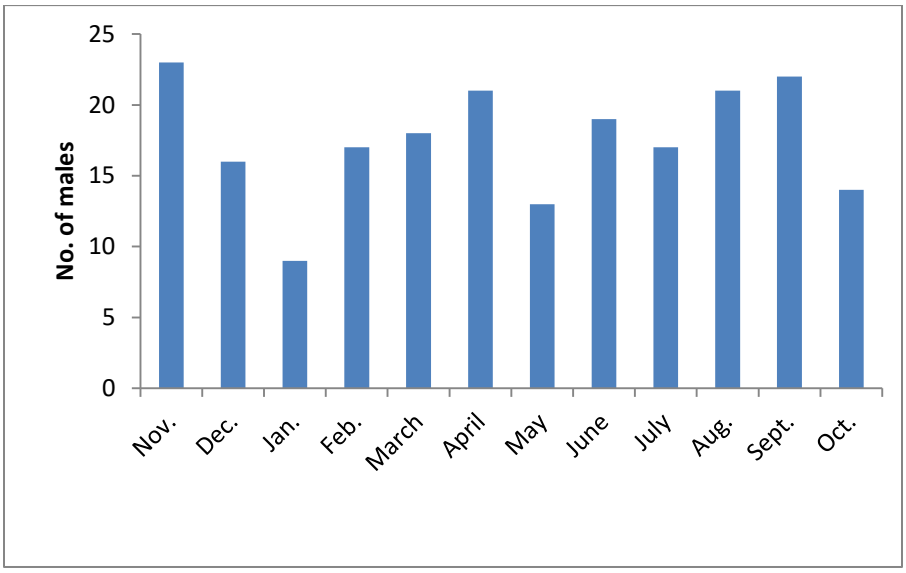

Fig. 5: Fluctuations in the population of *Caridina natarajani* (Male)

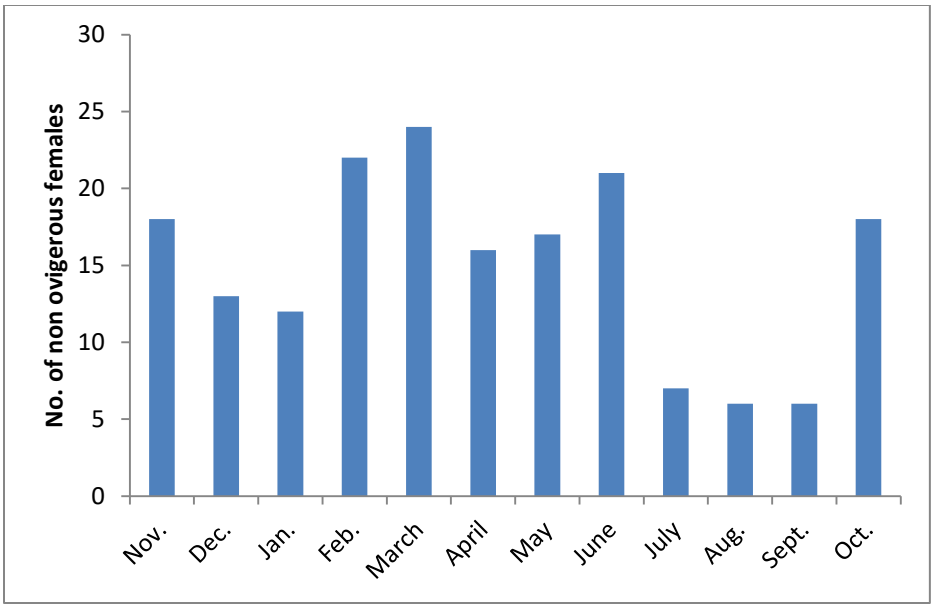

Fig. 6: Fluctuations in the population of *Caridina natarajani* (Non ovigerous female)

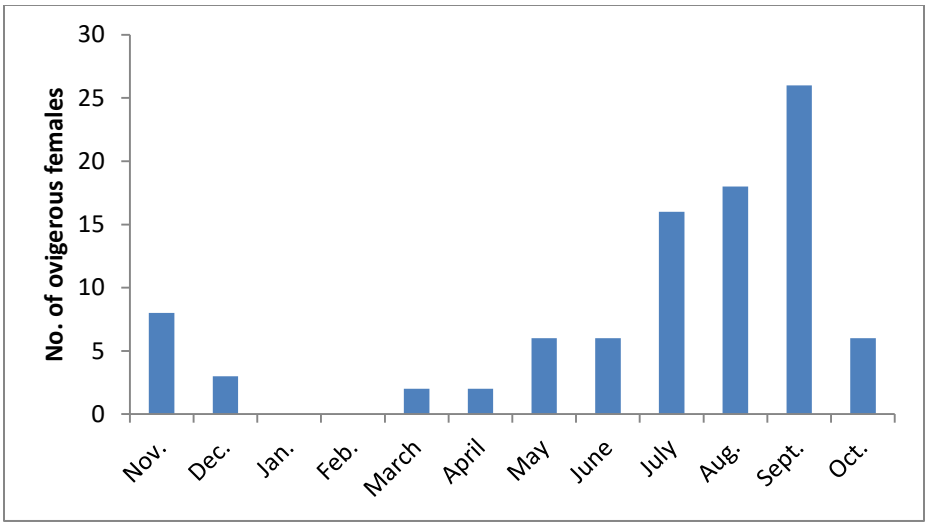

Fig.7: Fluctuations in the population of *Caridina natarajani* (Ovigerous female)

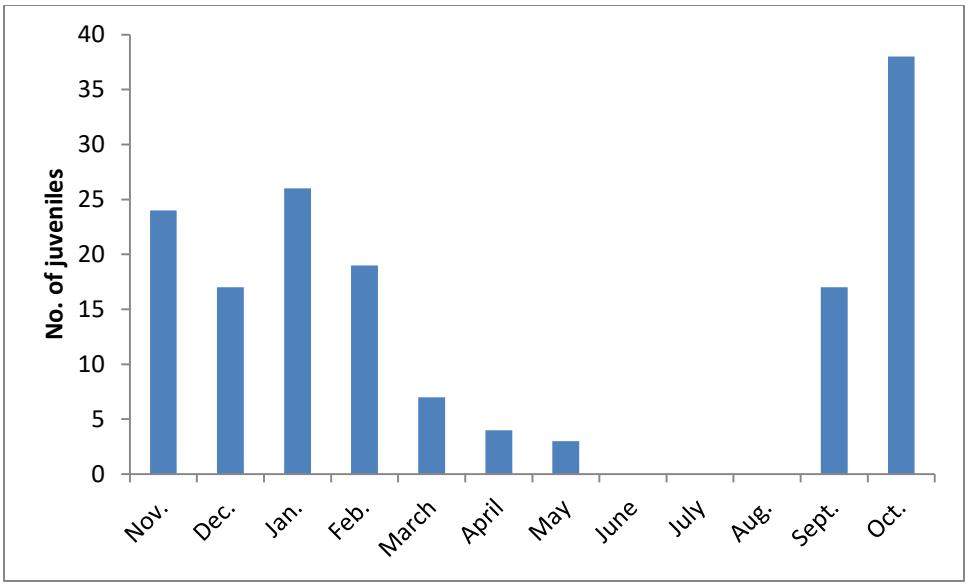

Fig. 8: Fluctuations in the population of *Caridina natarajani* (Juveniles)

The following observations were made on the population structure of *Caridina natarajani*

1. Maximum number of individuals was collected during the months of September, October and November.
2. Ovigerous females were abundant in the months of July, August and September that coincides with south west monsoon.
3. Though atyids are reported as perennial breeders their number was negligible in the summer months.
4. Juveniles dominated the collections of October to February.

3.5 Morphometrics and length-weight relationship

Introduction

Growth and reproduction are important aspects of the life history of a species. Growth is measured as an increase in total length (TL), carapace length (CL), cephalothoracic length (CTL), telson length (TL), rostral length (RL) and body weight (WT). Analysis of growth, fecundity and mortality are essential for stock assessment and management.

Materials and Methods

Caridina natarajani collected from a tributary of Pamba River were preserved in 8% formaldehyde. Males and females were sorted out and a total of 80 specimens of *C. natarajani* were measured for total length (TL), carapace length (CL), cephalothoracic length (CTL), rostral length (RL) and telson length (LT). Total length (TL) was measured from the tip of the rostrum to the end of the telson; carapace length (CL) from the tip of the rostrum to the posterior mid-dorsal edge of the carapace; cephalothoracic length (CTL) from the posterior orbital margin to the posterior mid-dorsal edge of the carapace; rostral length (RL) from the tip of the rostrum to the posterior orbital margin and telson length (LT) from the base of the 6^{th} segment to the tip of telson.

Linear relationship of the form $y = a + b\,x$ ('y' is dependent variable, 'x' is independent variable and 'a', 'b' are constants) is established for the two sexes separately. Then the linear relationship between TL-CL, TL-CTL, TL-RL, TL-LT, TL-WT (Body weight) was fitted for each sex. Since the relationship between TL-WT was not linear log values were taken for the fitting of the equation.

Results

The results relating to the morphometrics and length-weight relationships of *C. natarajani* are given in table: 1.

Table 1: Regression equations showing the relationship of different characters of C. *natarajani*

Characters	Male	Female
TL-CL	y = 0.317 x +0.17X ** R^2 =0.614	y = 0.383 x -0.105X ** R^2 =0.664
TL-CTL	y = 0.158 x +0.762X ** R^2 =0.461	y = 0.221 x +0.042X ** R^2 =0.0.570
TL-RL	y = 0.084 x +0.427X ** R^2 =0.154	y = 0.227 x -1.187X ** R^2 =0.619
TL-LT	y = 0.130 x -0.117X ** R^2 =0.567	y = 0.130 x -0.117X ** R^2 =0.567
TL-WT	y* = 2.444 x -4.382**X * R^2 =0.757	y* = 3.542 x -5.707**X * R^2 =0.72

** Significant at 1 % probability

y = CL, CTL, RL, LT; y* = log WT; X* = log TL; X = TL

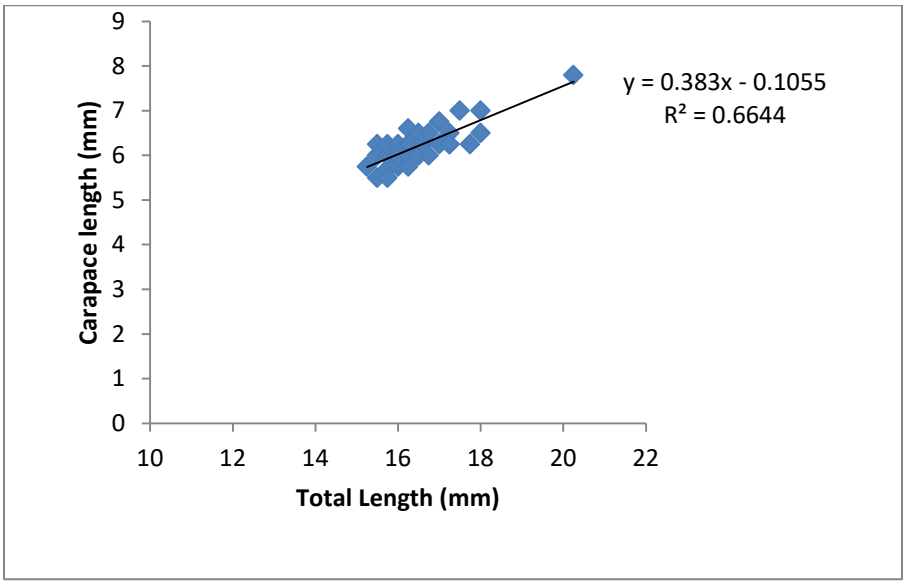

Fig. 9: Relationship between Total length and Carapace Length of *C. natarajani* (Female)

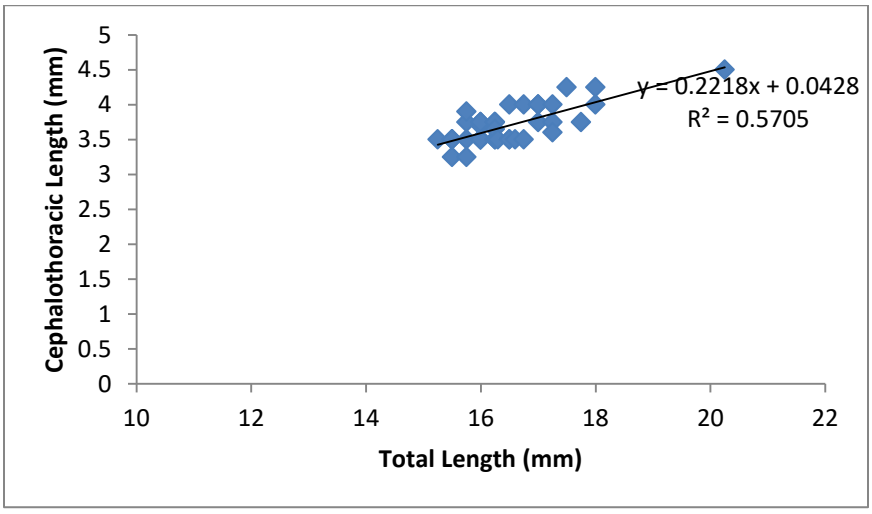

Fig. 10: Relationship between Total length and Cephalothoracic Length of *C. natarajani* (Female)

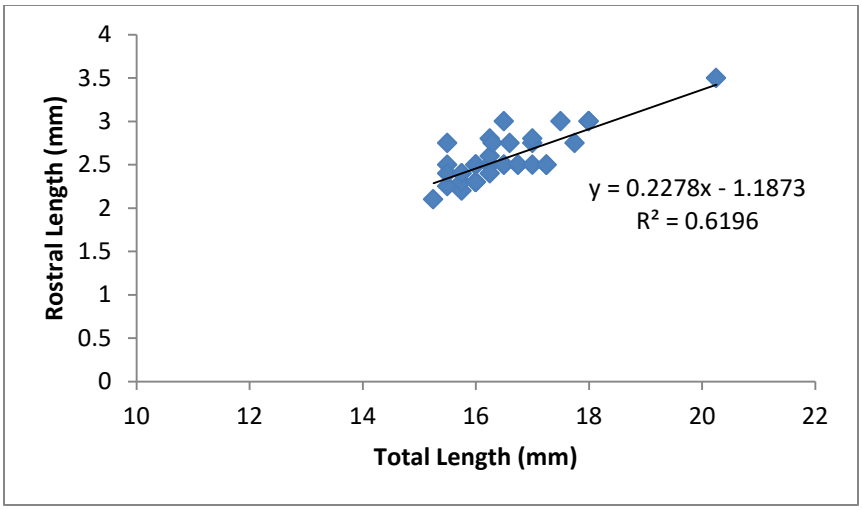

Fig. 11: Relationship between Total length and Rostral Length of *C. natarajani* (Female)

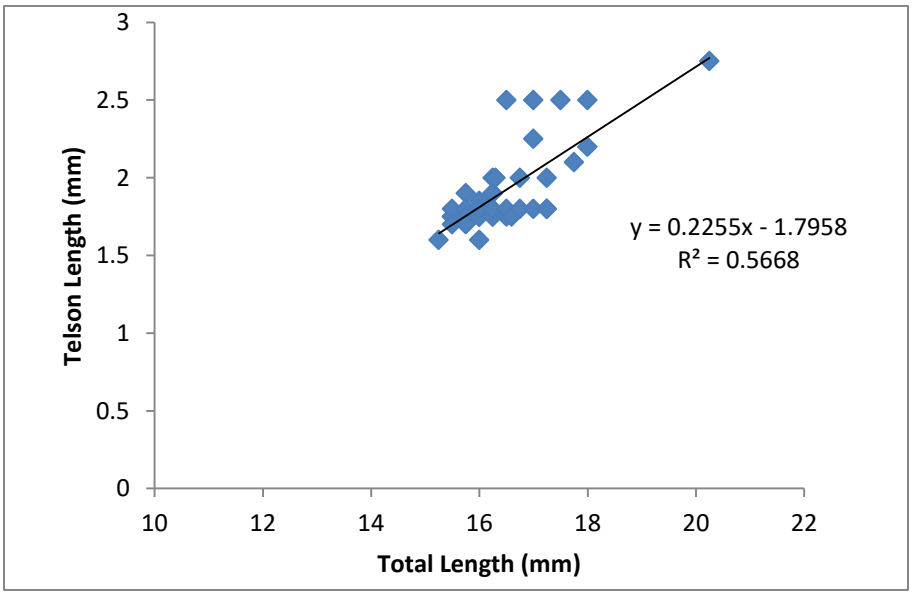

Fig. 12: Relationship between Total length and Telson Length of *C. natarajani* (Female)

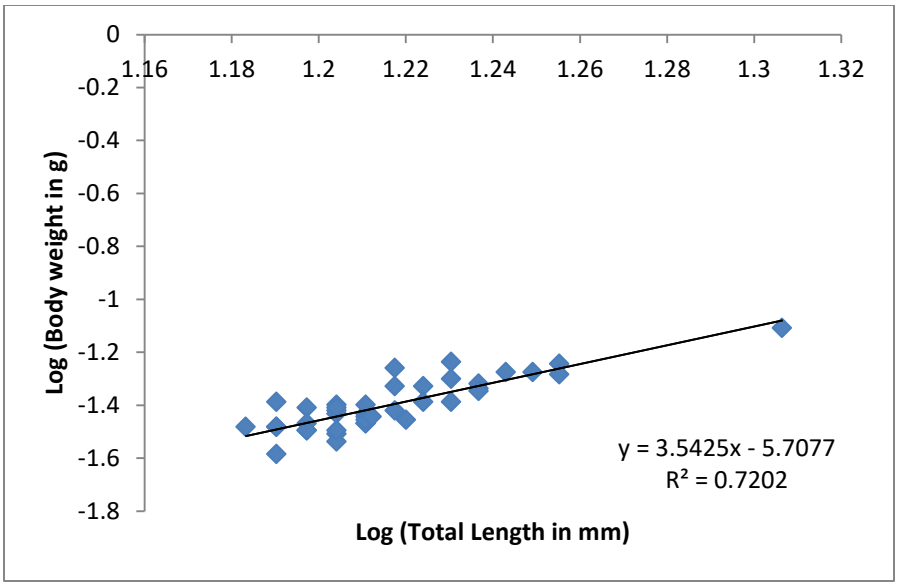

Fig. 13: Relationship between Log Total length and Log Body weight of *C. natarajani* (Female)

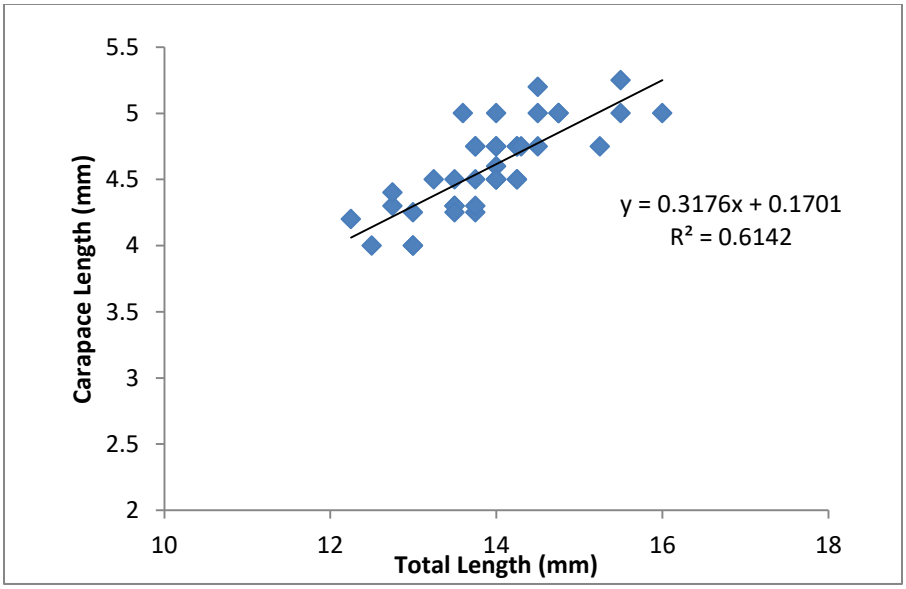

Fig. 14: Relationship between Total length and Carapace Length of *C. natarajani* (Male)

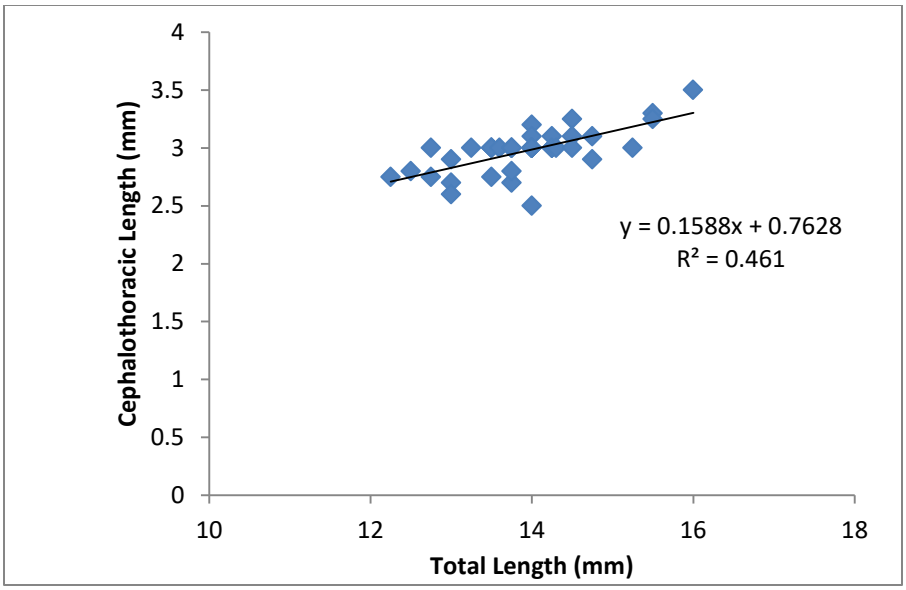

Fig. 15: Relationship between Total length and Cephalothoracic Length of *C. natarajani* (Male)

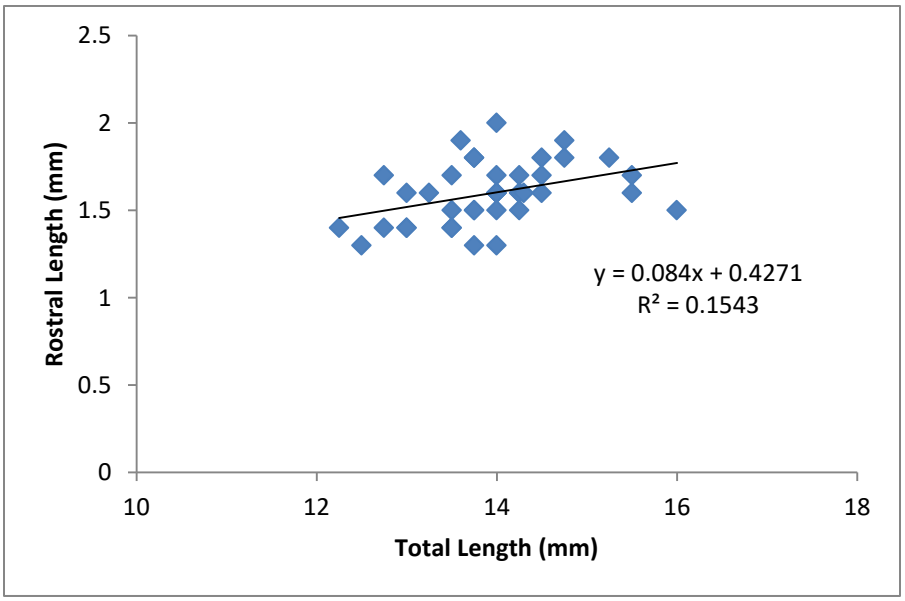

Fig. 16: Relationship between Total length and Rostral Length of *C. natarajani* (Male)

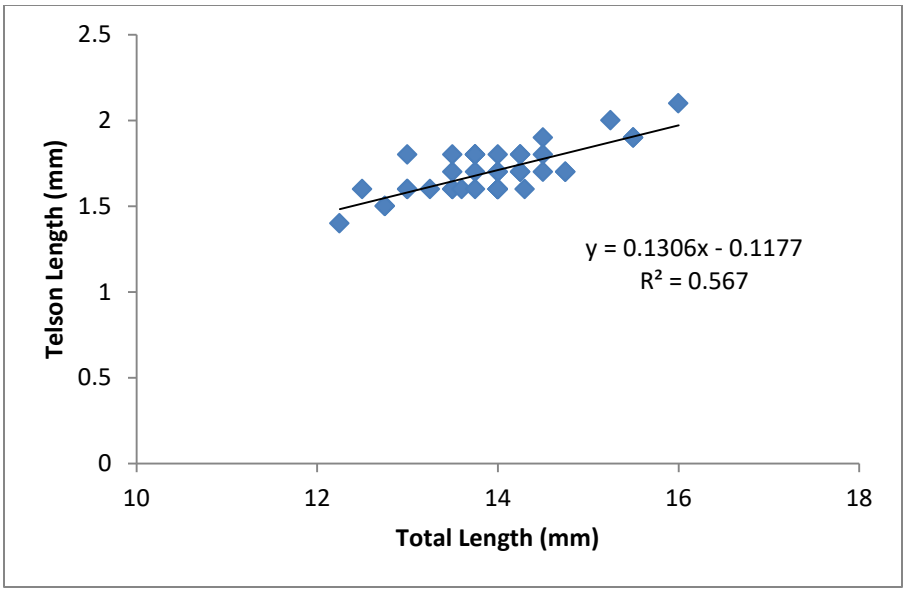

Fig. 17: Relationship between Total length and Telson Length of *C. natarajani* (Male)

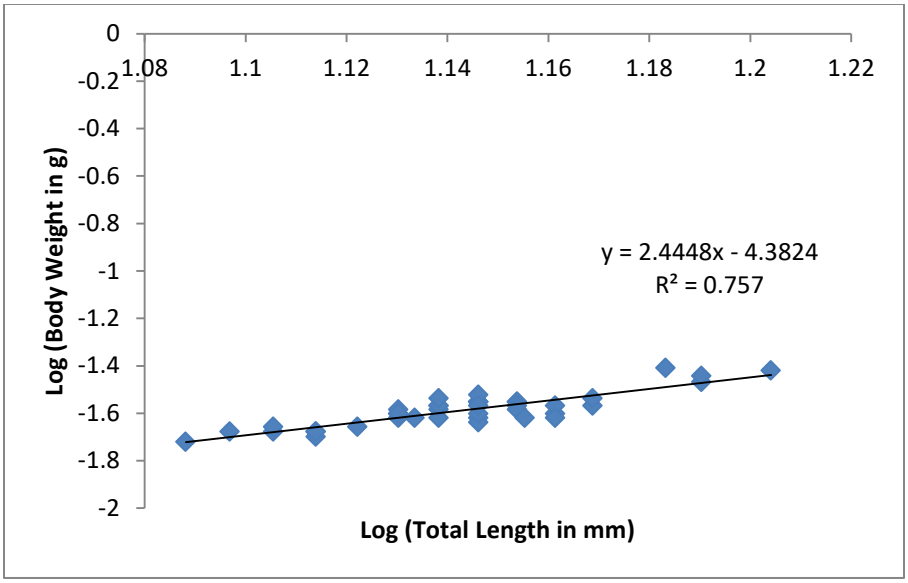

Fig. 18: Relationship between Log Total length and Log Body weight of *C. natarajani* (Male)

3.6 Fecundity of *Caridina natarajani*

Sl. No.	Variant X	Equation Log F = Log a + b Log X	R^2
1	Total length (mm)	Log F = 0.705 + 0.918 Log TL	0.325**
2	Body weight (g)	Log F = 2.192 + 0.303 Log WT	0.142**

Table 2: Relationship between Fecundity (F) with Total length (TL) and Body weight (WT) of *C. natarajani* Tiwari & Pillai, 1968

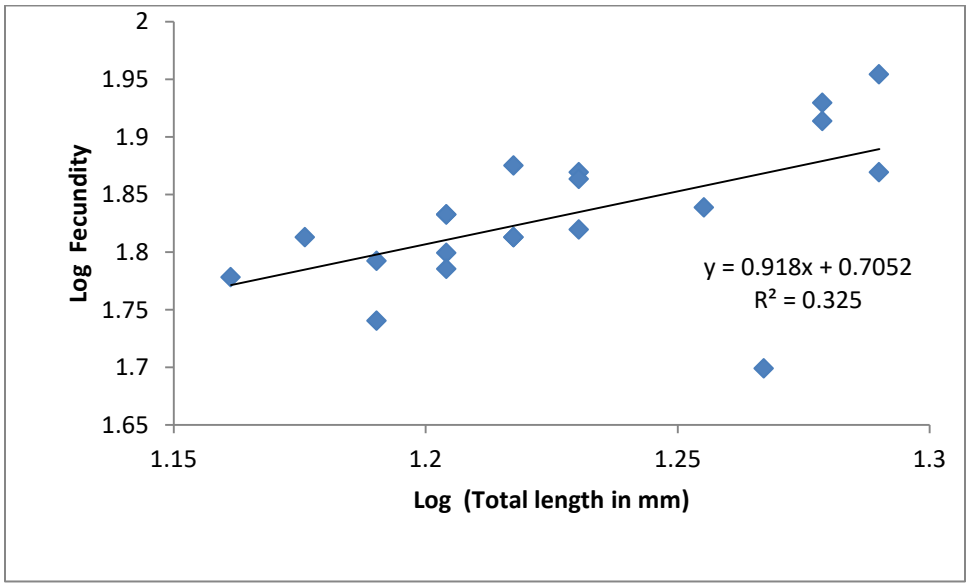

Fig. 19: Relationship between Log Total length and Log Fecundity of *Caridina natarajani*

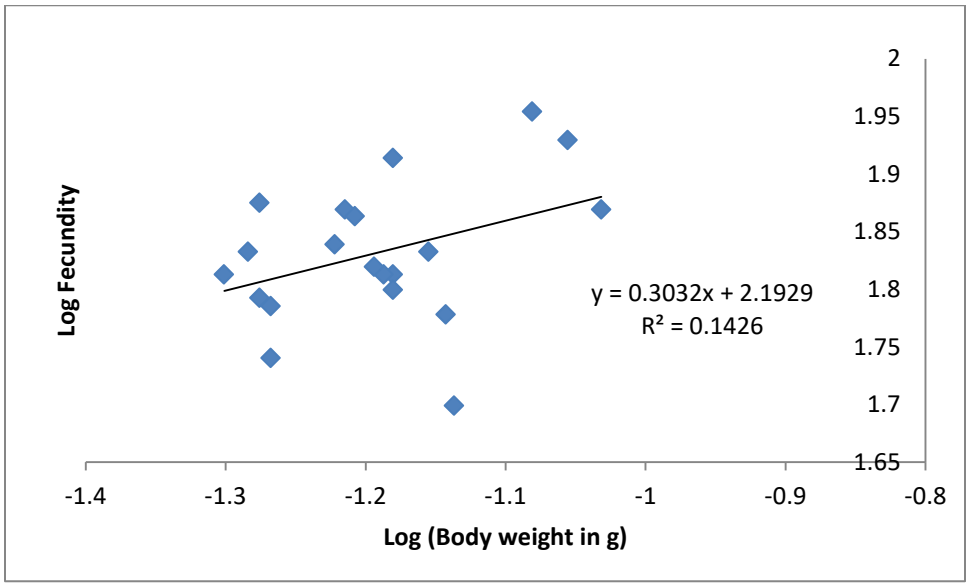

Fig. 20: Relationship between Log Body Weight and Log Fecundity of *Caridina natarajani*

The relationship between fecundity with total length and body weight of *C. natarajani* is given in table 1. The number of eggs carried by females of *C. natarajani* (14.5-19.5 mm TL) ranged from 50-90. The logarithmic values of fecundity have been found to be positively correlated to the logarithmic values of length and weight of the animal. But the increase in fecundity with regard to length and weight is not consistent because individuals of the same length and weight class carried varying number of eggs and some of the larger females carried fewer eggs than the smaller females.

4. Discussion

Atyid shrimps are one of the best represented macroinvertebrates in the natural inland water bodies. Globally, 43 genera have been reported under the family Atyidae. So far only one genus has been reported from India which is *Caridina* H.M. Edwards, 1837. Atyidae is the only family reported under the Super family Atyoidea.

Caridina belongs to the subfamily Atyinae. Majority of the species are found in freshwater habitats but a few prefers brackish water (*Caridina gracilirostris* De Man, 1892). According to the report by De Grave *et al*. (2009) *Caridina* is species rich and the number reported may go beyond 279. A survey on the atyid shrimps of Kerala reported 15 species of *Caridina* from different freshwater and brackish water habitats (Tessa Thomas, 2012).

Tiwari *et al*. (1968) described *Caridina natarajani* from Museum Tank in Trivandrum. It is abundantly present in the rivers and freshwater ponds of southern and central Kerala. They are reported from nine major rivers namely, Karamana river, Kallada River, Meenachil River, Neyyar River, Muvattupuzha River, Manimala River, Pampa River, Achankovil River and Vamanapuram River.

Sexual dimorphism is not distinct in *Caridina* and the major differences lie in the nature of 1st and 2nd pleopods (Pillai, 1958). It exhibits dimorphism in the number of aesthetasc bearing segments in the outer flagellum of antennular peduncle (Shenoy *et al*., 1993).

The atyids in the tropics are perennial breeders (Babu, 1963). Knowledge of fecundity is essential to assess the abundance and reproductive potential of the population. In *Caridina natarajani* the fecundity ranges between 50 and 90 and the incubation period is 13 to 15 days. Babu (1963) reported 11-14 days of incubation in *Caridina propinqua* and he reported variations

in incubation period with respect to temperature. The females moult within 24 hours after the hatching of the eggs. Pillai (1958) and Babu (1963) reported moulting after the release of eggs.

In *Caridina natarajani* fecundity has been positively correlated to the length and weight of the animal. Similar observations were made by Babu (1963) in *Caridina propinqua* and De Silva (1988a, b) in *Caridina simoni* and *Caridina pristis*. Bello- Olusoji (2004) studied the relationship of fecundity with weight and length in *Caridina* spp. He reported weak relationship between fecundity and weight ($R^2 = 0.382$) and relatively strong relationship between fecundity and length ($R^2 = 0.64$).

Tropical atyids breed throughout the year whereas those in the temperate region breed predominantly during summer. Environmental factors like rainfall and temperature influence the population size and reproduction of atyids (De Silva, 1988a). The present study showed low population density during the south west monsoon season. Valarmathi (2009) reported negative correlation between population density and rainfall in *Caridina kunnathurensis*. The present study reported maximum number of ovigerous females during the rainy season and their occurrence in the dry period is scanty.

5. BIBLIOGRAPHY

Almelkar, G.B., 1983. Studies on the freshwater prawns of the Bombay area (Crustacea, Decapoda, Caridea). *Ph.D Thesis, Konkan Agricultural University*, Dapoli.

Anger, K. & Moreira, G.S., 1998. Morphometric and reproductive traits of tropical Caridean shrimps. *Journal of Crustacean Biology* 18(4):823-838.

Babu, N., 1963. Observations on the biology of *Caridina propinqua* De Man. *Indian Journal of Fisheries* 107-117.

Bello-Olusoji, A.O., Omolayo, A.T. & Arinola, A., 2004. Taxonomical studies on rocky freshwater prawns at Erin-Ijesha waterfalls. *Food, Agriculture & Environment* 2(3&4):280-283.

Benzie, J.A.H. & De Silva, P.K., 1988. The distribution and ecology of the freshwater prawn *Caridina singhalensis* (Decapoda, Atyidae) endemic to Sri Lanka. *J. Trop. Ecol.*, 4(4):347-359.

Bhuiyan, A.S., Arzu, G. & Bhuiyan, S.S., 2007. The correlation between fecundity with length and weight of *Macrobrachium dayanum* (Hall) from the River Padma, Rajshahi, Bangladesh. *J. Bio-sci.*, 15:173-175.

Bouvier, E.L., 1918. Sur quelques Crustaces decapodes recueillis par M. Guy Babault dans les eaux douces de l'Inde anglaise. *Bull. Mus. Nat. Hist. Paris* 24:386-393.

Cai, Y. & Ng, P.K.L., 2007. A revision of the *Caridina gracilirostris* De Man, 1892, species group, with descriptions of two new taxa (Decapoda: Caridea: Atyidae). *Journal of Natural History* 41(25-28):1585-1602.

De Grave, S., Pentcheff, N.D., Ahyong, S.T., Chan, T.Y., Crandall, K.A., Dworschak, P.C., Felder, D.L., Feldmann, R.M., Fransen, C.H.J.M., Goulding, L.Y.D., Lemaitre, R., Low, M.E.Y., Martin, J.W., Ng, P.K.L., Schweitzer, C.E., Tan, S.H., Tshudy, D. & Wetzer, R., 2009. A classification of living and fossil genera of Decapod crustaceans. *The Raffles Bulletin of Zoology* Suppl. No.21:1-109.

De Silva, K.H.G.M., 1982. Aspects of the ecology and conservation of Sri Lanka's endemic freshwater shrimp *Caridina singhalensis*. *Biological conservation* 24(3):219-231.

De Silva, K.H.G.M., 1983. Studies on Atyidae (Decapoda, Caridea) of Sri Lanka. II. Distribution of atyid shrimps in Sri Lanka. *Crustaceana* 44(2):205-215.

De Silva, K.H.G.M., 1987. Salinity tolerances of three species of freshwater atyid shrimps (Decapoda: Caridea) of SriLanka. *J. Natn. Sci. Coun. Sri Lanka* 15(2):161-174.

De Silva, K.H.G.M., 1988a. Studies on Atyidae (Decapoda, Caridea) of Sri Lanka III. Aspects of the population ecology of *Caridina simoni* Bouvier, 1904. *Crustaceana*. 54(1):85-103.

De Silva, K.H.G.M., 1988b. Studies on Atyidae (Decapoda, Caridea) of Sri Lanka. Some aspects of the population ecology of the endemic freshwater shrimp *Caridina pristis* Roux, 1931. *Crustaceana* 54(3):225-243.

De Silva, K.H.G.M., 1989. Temperature tolerances and geographic distribution of three species of *Caridina* (Decapoda, Atyidae) in Sri Lanka. *Internationale Revue der gesamte Hydrobiologie* 74(1):95-107.

De Silva, P.K. & De Silva, K.H.G.M., 1988. Temperature, salinity, and pH tolerance, and the influence of other ecological factors in the geographic isolation of a freshwater atyid shrimp (Decapoda, Caridea) in Sri Lanka. *Archiv für Hydrobiologie* 111(3):435-448.

De Silva, P.K. & De Silva, K.H.G.M., 1989. Aspects of the population ecology of a tropical freshwater atyid shrimp *Caridina fernandoi* Arud. and Costa, 1962 (Crustacea: Decapoda: Caridea). *Archiv für Hydrobiologie* 117(2):237-253.

Dudgeon, D., 1985. The population dynamics of some freshwater Carideans (Crustacea: Decapoda) in Hong Kong, with special reference to *Neocaridina serrata* (Atyidae). *Hydrobiologia* 120(2):141-149.

Dutt, S. & Ravindranath, K., 1975. A new record for *Caridina brachydactyla peninsularis* Dutta, N.K., 2001. Studies on the systematics and distribution of prawns in Assam. *Journal of Bombay Natural History Society* 98(1):18-25.

Dutta, N.K., 2001. Studies on the systematics and distribution of prawns in Assam. *Journal of Bombay Natural History Society* 98(1):18-25.

Ebenezer, D. & Richard, J., 1999. *Caridina typus* H. Milne Edwards, 1837 from the Indian mainland- A report. *Journal of Bombay Natural History Society* 96(3):427-432.

Enin, U.I., 1994. Length-Weight parameters and condition factor of two West African prawns. *Rev. Hydrobiol. Trop.*, 27(2):121-127.

Fossati, O., Mosseron, M. & Keith, P., 2002. Distribution and habitat utilization in two atyid shrimps (Crustacea: Decapoda) in rivers of Nuku-Hiva Island (French Polynesia). *Hydrobiologia* 472:197-206.

Fryer, G., 1977. Studies on the morphology and ecology of the Atyid prawns of Dominica. Philosophical transactions of the Royal Society of London. Series B, *Biological Sciences*, vol. 277, No. 952:57-129.

Hancock, M.A., 1998. The relationship between egg size and embryonic and larval development in the freshwater shrimp *Paratya australiensis* Kemp (Decapoda: Atyidae). *Freshwater Biology* 39(4):715-723.

Hart, R.C., 1981. Population dynamics and production of the tropical freshwater shrimp *Caridina nilotica* (Decapoda: Atyidae) in the Littoral of Lake Sibaya. *Freshwater Biology* 11(6):531-547.

Hart, R.C., 1983. Temperature tolerances and southern African distribution of a tropical freshwater shrimp *Caridina nilotica* (Decapoda: Atyidae). *South African Journal of Zoology* 18(2):67-70.

Henderson, J.R., 1893. A contribution to Indian carcinology. *Trans. Linn. Soc. London*, 5:325-458.

Jalihal, D.R., Shenoy, S., & Sankolli, K.N., 1982. An atyid shrimp *Cardina kempi* Jalihal, Shenoy and Sankolli – a prospective species for culture. *Symp. ser. mar. biol. assoc. India*; no. 6, p. 421 (Proceedings of the symposium on coastal aquaculture, held at Cochin from January 12 to 18, 1980. part 1: prawn culture).

Jalihal, D.R., Shenoy, S. & Sankolli, K.N., 1984. Five new species of freshwater atyid shrimps of the genus *Caridina* H. Milne Edwards from Dharwar area (Karnataka State, India). *Records of zoological survey of India*, Occ. p. no., 69:1-40.

Jalihal, D.R., Almelkar, G.B. & Sankolli, K.N., 1994. Atyid shrimps of the genus *Caridina* H. Milne Edwards, 1837. Potential crustacean material for experimental biology. *Crustaceana* 66(2):178-183.

Jayachandran, K.V., Raji, A.V. & Thomas, T., 2005. Prawns and shrimps of ornamental value from Kerala. *Proceedings of the seminar on recent trends in Mariculture*: 77-80+1 colour plate.

Jayachandran, K.V., Thomas, T. & Raji, A.V., 2008. Caridinian shrimp resources of Kerala waters (Decapoda, Atyidae). *Proceedings of the Indian National Science Academy* 74(2):47-50.

Kemp, S., 1913. Crustacea Decapoda. *Rec. Ind. Mus.*, 8:289-310.

Lehman, J.T., Mbahinzireki, G.B. & Mwebaza-Ndawula, L., 1996. *Caridinia nilotica* in Lake Victoria: Abundance, biomass, and diel vertical migration. *Hydrobiologia* 317(3):177-182.

March, J.G. & Pringle, C.M., 2003. Food web structure and basal resource utilization along a tropical island stream continuum, Puerto Rico. *Biotropica* 35:84-93.

March, J.G., Pringle, C.M., Townsend, M.J. & Wilson, A.I., 2002. Effects of freshwater shrimp assemblages on benthic communities along an altitudinal gradient of a tropical island stream. *Freshwater Biology* 47:377-390.

Mariappan, N. & Richard, J., 2006. Studies on the freshwater prawns of family Atyidae and Palaemonidae from Kanchipuram and Thiruvallur Districts, Tamil Nadu, India, including one new species of the genus *Caridina* H. Milne Edwards, 1837. *Records of Zoological Survey of India*, Occ. p. No., 243:1-80.

Nagabhushanam, R. & Vasantha, N., 1971. Moulting and colour changes in the prawn, *Caridina weberi*. *Hydrobiologia* 38(1):39-47.

Nagabhushanam, R. & Chinnayya, B., 1972. The moulting behaviour of the prawn, *Caridina weberi*. *Broteria* 41(3-4):163-176.

Natarajan, S., 1942. On the occurrence of *Caridina* (Atyidae, Decapoda) in Travancore. *Current Science* 11:245.

Nazari, E.M., Costa, M.S.S., Müller, Y.M.R., Ammar, D. & Dias, M., 2003. Comparisons of fecundity, egg size, and egg mass volume of the freshwater prawns *Macrobrachium potiuna* and *Macrobrachium olfersi* (Decapoda, Palaemonidae). *Journal of Crustacean Biology* 23(4):862-868.

Pillai, R.S., 1958. Studies on *Caridina laevis* Heller (Decapoda, Arthropoda). *Ph. D Thesis*, *University of Kerala*. 348 p.

Pillai, R.S., 1964. Four species of *Caridina* from Travancore, including a new variety. *Journal of the Marine Biological Association of India* 6(1):42-47.

Ponnuchamy, R., Reddy, S.R. & Shakuntala, K., 1984. Comparative studies on the effects of population density on moult production and food conversion in two freshwater prawns. *Proc. Indian. Acad. Sci.*, (Anim. Sci.). 93(6):517-526.

Pringle, C.M., Blake, G.A., Covich, A.P., Buzby, K.M. & Finley, A., 1993. Effects of omnivorous shrimp in a montane tropical stream: sediment removal, disturbance of sessile invertebrates and enhancement of understory algal biomass. *Oecologia* 93:1-11.

Raman, K.V.A., Reddy, S.R. & Shakuntala, K., 1986. Distribution and abundance of prawns in the freshwater habitats of Bangalore, South India. *Proc. Indian. Acad. Sci.*, (Anim.Sci.) 95(1):77-87.

Richard, J., 1983. Studies on the freshwater shrimps of the genus *Caridina* in and around Madras city. *Ph. D thesis, Madras University*, pp. 179.

Richard, J. & Chandran, M.R., 1994. A systematic report on the freshwater prawns of the atyid Genus *Caridina* H. Milne-Edwards 1837, from Madras (Tamil Nadu: India). *Journal of the Bombay Natural History Society* 91(2):241-259.

Richardson, A.J., Lamberts, C., Isaacs, G., Moloney, C.L. & Gibbons, M.J., 2000. Length-weight relationships of some important forage crustaceans from South Africa. Naga 23(2):29-33.

Richardson, A.J., Growns, J.E. & Cook, R.A., 2004. Distribution and life history of caridean shrimps in regulated lowland rivers in southern Australia. *Mar. Freshwater Res.*, 55(3):295-308.

Roux, J., 1931. Crustaces Decapodes d'eau douce de 1 Inde meridionale. *Rev. Suisse. Zool. Geneve.*, 38:31-62.

Shakuntala, K., 1977. The relation between body size and number of eggs in the freshwater prawn, *Macrobrachium lamarrei* (H. Milne Edwards) (Decapoda, Caridea). *Crustaceana* 33(1):17-22.

Shenoy, S., Jalihal, D.R. & Sankolli, K.N., 1993. Ecological diversity with reference to aesthetascs in freshwater prawns. *Crustaceana* 65(3):300-308.

Shokita, 1979. The distribution and speciation of the inland water shrimps and prawns from the Ryukyu islands-II. *Bull. Coll. Sci. Univ. Ryukyus* 28:193-278.

Sket, B. & Zakšek, V., 2009. European cave shrimp species (Decapoda: Caridea: Atyidae), redefined after a phylogenetic study; redefinition of some taxa, a new genus and four new *Troglocaris* species. *Zool. J. Linn. Soc.*, 155,786-818.

Smith, M.J. & Williams, W.D., 1980. Intraspecific variation within the Atyidae: A study of morphological variation within a population of *Paratya australiensis* (Crustacea: Decapoda). *Aust. J. Mar. Freshwater Res.*, 31(3):397-407.

Tessa Thomas., 2012. Freshwater shrimps of the family Atyidae De Haan of Kerala and culture of a selected species for forage/food in aquaculture. *Ph.D Thesis, Mahatma Gandhi University*, Kottayam.

Thomas, M.M., Pillai, V.K. & Pillai, N.N., 1973. *Caridina pseudogracilirostris* sp. nov. (Atyidae: *Caridina*) from the Cochin backwater. *Journal of the Marine Biological Association of India* 15(2):871-873.

Thomas, T. & Jayachandran, K.V., 2007. New locality records of *Caridina jalihali* Mariappan & Richard (outside the type locality) with notes on diagnostic characters and sexual dimorphism. *Rec. zool. Surv. India* 107 (Part-3) : 95-99.

Tiwari, K.K. & Pillai, R.S., 1968. A new species of *Caridina* H. Milne Edwards (Crustacea: Decapoda: Atyidae) from Trivandrum, India. *Proc. Zool. Soc. Calcutta* 21:163-171.

Tiwari, K. K. & Pillai, R.S., 1971. Atyid shrimps of the genus *Caridina* H. Milne Edwards, 1837, from the Andaman Islands (Decapoda, Caridea). *Crustaceana* 21(1): 79-91.

Valarmathi, K., 2009. Studies on the freshwater prawns of the families Atyidae and Palaemonidae (Crustacea: Decapoda: Caridea) from southern India. *P.hD Thesis Zoological Survey of India, Chennai*. 154 p.

Vasantha, V., 1973. Effect of temperature on the chromatophores and chromatophorotropins in the freshwater prawn, *Caridina weberi*. *Broteria* 42(3-4):149-159.

Weerakkody, J.S., 1984. Fecundity, morphometry, post-embryonic growth and development of *Caridina simoni* Bouvier (Decapoda: Atyidae). *Journal of the National Aquatic Resources Agency* (Sri Lanka) 31:81-96.

Williams, J.L., 2002. Effects of the tropical freshwater shrimp *Caridina weberi* (Atyidae) on leaf litter decomposition. *Biotropica* 34(4):616:619.

Williams, W.D., 1977. Some aspects of the ecology of *Paratya australiensis* (Crustacea: Decapoda: Atyidae). *Aust. J. Mar. Freshwater Res*., 28:403-415.