

## **Life history and Population Dynamics of an Estuarine Amphipod –*Eriopisa chilensis***

**Chilton (Gammaridae)**

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### **Abstract**

The life cycle of the gammarid amphipod *Eriopisa chilensis* Chilton from the Cochin estuary, south west coast of India was studied for the first time under laboratory conditions. Amphipods especially gammarids are known as potential live feed in fish culture and this forms the base of our study. *E. chilensis* can withstand wide variations in salinity (5-35) and temperature (27.5-34 °C) of the medium. It was cultured in unaerated finger bowls using dried algal matter (*Chara* sp.) as food. Life span of females was found to be higher (maximum: 220 days) than males (maximum: 175 days). Females were iteroparous and attained sexual maturity within  $39.3 \pm 6$  days (mean  $\pm$  SD), whereas males matured within  $26.5 \pm 5.6$  days. Number of broods in a life span ranged from 4 to 7. The maximum number of juveniles produced in a single brood was 29 and the maximum number of juveniles produced by a single female over a lifetime was 139. The duration of embryonic development was  $12 \pm 2.45$  days. Population dynamics of *E. chilensis* was studied based on monthly sampling over one year from the mangrove swamps of Pudukkottai. It occurred in varying densities in the epifaunal community (21-1583 ind. m<sup>-2</sup>). Extrapolation of laboratory data to the field suggests that *E. chilensis* in Cochin estuary has a multivoltine life cycle.

**Key words:** - *Eriopisa chilensis*, Amphipoda, life cycle, population dynamics, Cochin estuary, India

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## 1. Introduction

Life-history traits of 214 amphipod species were reviewed by Sainte-Marie (1991) and stated that life-history patterns of gammarid amphipods are influenced by latitude, depth and salinity. Nelson (1980) reviewed the reproductive pattern in 65 species of gammaridean amphipods. Morino (1978) classified breeding activity and life history of amphipods into four categories and concluded that low latitude species tend to breed throughout the year and have short life spans. According to Cunha et al. (2000) low-latitude, warm – water amphipods show iteroparous, multivoltine life history patterns. Multivoltinism and continuous reproduction have been reported in many other species occurring in tropical Indian Ocean (Chandani and Alan 2004). Steele and Steele (1991) pointed out that tropical species are characterized by small size, low fecundity, short brood intervals and multivoltine life cycle. On the other hand low-latitude species are characterized by semi-annual or annual life histories, small body size and high reproductive potentials (Sainte-Marie 1991). Krishnan and John (1974) have observed that the brackish-water amphipod *Melita zeylanica* breeds throughout the year in India. Asari (1983) has studied the biology of *Eriopisa chilensis* and *Idunella chilensis* from mangroves of Pitchavaram, India.

The Cochin estuary (Lat. 9° 5' to 10° N and Long. 76° 15' to 76° 25' E) is a bar-built tidal estuary, which is the northern extension of the Vembanad Lake along the Kerala coast of India. The mangrove swamps of Pudukkottai are considered to be of great economic importance and act as good nursery grounds for shrimps and juvenile marine fishes (Rajagopalan et. al. 1986). Fodder organisms like amphipods and tanaidaceans, support the growth, and production of estuarine fishes and prawns.

*E. chilkenis* was first recorded from Chilka Lake by Chilton (1921) and Asari (1983) studied the biology of *E. chilkenis* and reported that they are filter feeders feeding on organic-rich detritus. Work done on the gammarid amphipods of Cochin backwaters by Nair et al. (1983) gave an account of the ecology and population dynamics of this group. *E. chilkenis* occur in large numbers in the organically enriched sediments of the Cochin estuary and it can be regarded as a tolerant species of organic pollution (Nisha, unpublished). *E. chilkenis* was encountered in varying densities in the benthic epifaunal communities in the mangrove swamps of Pudukkottai in the present study. It also has an important trophic role in these areas in shredding leaf litter. In spite of its ecological importance, no work on this species has been carried out in the Cochin estuary. In this paper, an attempt has been made to study the different traits of its life cycle in the laboratory, such as age at maturity, life-span, number of broods per female, duration of embryonic development, life time fecundity (based on number of juveniles released), growth rate and biochemical components. Along with this, the population dynamics was also studied in the Cochin estuary. This investigation was designed to find out whether this species could be cultured in large numbers economically to be used as a feed for fish culture.

## **2. Materials and Methods**

### **2.1 Amphipod collection and maintenance for laboratory culture**

Live epibenthic samples were collected from Pudukkottai, Cochin estuary (Figure 1) using a van Veen grab (0.048 m<sup>2</sup> mouth area) and transported to the laboratory along with the sediments. In the laboratory, individuals of *E. chilkenis* were sorted out and kept in tanks of the recirculating system for one month, to acclimatize to experimental conditions. Pairs (males

and females) of this species were later isolated and transferred to separate finger bowls, each containing 125 ml of unaerated brackish water. Temperature was maintained at  $26 \pm 1$  °C, salinity  $19 \pm 1$  and pH 7.4-8.6. A few strands of dried algal matter were added to each bowl as food for the animals. These bowls were labelled for later identification. Individuals of 3 categories were studied: - juveniles, males and females. The set of individuals released from a brood was reared together in finger bowls for further experiments.

## 2.2 Feeding rates

These were tested with different types of feeds like decaying mangrove leaves, natural detritus available at the sampling site, flesh of young mussel (*Villorita cyprinoids*), alga (*Chara* sp.) and blue-green alga scraped from the sides of the culture tanks. For further experiments *Chara* sp. (muskgrass) was selected as feed based on its abundance and local availability, and also for the reason that the farmers in the field can culture these amphipods without much expense.

Feeding experiments were conducted in 125 ml finger bowls with unfiltered brackish water. *Chara* sp. was soaked in water, dried using blotting paper and weighed before introducing into the culture bowls. The quantity of feed used in each bowl ranged from 0.2 to 0.5 g w/wt (wet weight). Trials were run using 10 amphipods each for 2 sets of culture bowls (adults and ovigerous females). In treatment trials, they were allowed to feed for 24 hr. Bowls containing alga without amphipods were used as controls. On termination of the experiment, the excess feed was netted (mesh size 10  $\mu$ m) and re-weighed as before. Feeding rate was calculated as amount of feed consumed per day per individual.

### 2.3 Life span and mortality

Total life span was measured by rearing all the individuals released from a single brood together in unarearated finger bowls until all of them died. Water was changed every day and fresh feed was added every alternate day. The time of birth and death was recorded to measure the total life span. Trials were run using five culture sets. Mortality in juveniles, females with brood and males after copulation were also assessed during this process.

### 2.4 Moulting and Growth rates

Individuals released from a single brood were reared together in a finger bowl and the moulting rate was assessed separately for males and females. Growth rates were assessed as the average length increment in body size. Live animals were removed from the culture bowls soon after their release from the brood pouch and measured for total length at regular intervals. An ocular micrometer was used for the body length measurements. Body size (length) was measured as distance from tip of the cephalon to the tip of the telson. Growth rate measurements were not carried out separately for males and females.

### 2.5 Sexual maturity and sex ratio

Newly born juveniles from a single brood was separated into finger bowls and reared together. A mature female was added to assess the time required for male maturity. Adults were added only after 10 days when the juveniles have grown sufficiently, as they were found to consume newly born juveniles. The day at which the female was found to be ovigerous was recorded. Trials were run using 5 sets of culture bowls. This was the time for male maturity, similarly a fully matured male was added to the newly born juvenile set after 10 days and the

time for female maturity was calculated. Number of males and females from a single brood was counted to find out the sex ratio. Males were identified based on the presence of an enlarged second gnathopod and females based on the presence of brood pouch / lamellae.

## 2.6 Fecundity, embryonic development

After one month of acclimation in the laboratory, pairs of amphipods (males and females) were removed from the initial tank and placed in separate finger bowls. They were observed daily until the female was found to be ovigerous. The fecundity of *E. chilensis* was estimated as the total number of juveniles released by a female. The embryonic development time was recorded as the period from oviposition to release of juveniles from the brood pouch. The developmental stages were identified based on the description of Dick et al. 2002.

## 2.7 Biochemical analysis

Live samples maintained during the culture were sorted out into three groups viz. juveniles, adults and ovigerous females for biochemical analysis. The specimens were rinsed with distilled water to remove salt, lyophilized and stored in a desiccator. Before analysis, the samples were thoroughly homogenized using a pestle and mortar. The determination of protein and carbohydrate were followed as per the standard methods described by Raymont et al. (1964). Energy equivalents were calculated using the conversion factors given by Winberg (1971) and the values were corrected for biologically unavailable nitrogen oxidation energy according to Kersting (1972). Energy equivalents are expressed in K cal g<sup>-1</sup>.

## 2.8 Sampling methodology to study the population dynamics in field

Population density and dynamics of *E. chilkenis* was studied from monthly samples collected over a period of one year (October 2003-September 2004) at low tide from the sampling site (Puduvypin - 9° 59' N and 76° 13' E), adjacent to mangrove vegetation (Figure 1) in the Cochin estuary. The selected area has a depth of 3-4 m and is influenced by tides. The mud samples were collected in duplicate using van Veen grab (mouth area 0.048 m<sup>2</sup>), sieved using 500 µm screen and preserved in 4% formalin coloured with Rose Bengal. From these samples *E. chilkenis* specimens were, separated and counted in the laboratory as juveniles (<5 mm) and adults (>5 mm). Sediment grain size was analysed using the pipette method of Krumbein and Pettijohn (1966) and organic carbon was estimated by the wet oxidation method (El. Wakeel and Riley 1957). Organic matter was calculated as 1.724 times the carbon value (Trask 1955).

Qualitative sampling consisted of recording the abundance of *E. chilkenis* from two sites separated by a distance of 3.5 km in the estuary. One was along the organically enriched central estuarine region (>3% sediment TOC) to estimate its presence in a polluted environment and the other along the mangrove of Puduvypin to study its population dynamics (site selected as *E. chilkenis* was abundant in this environment).

### **3. Results**

#### **3.1 Food and feeding**

Experimentation with different feeds showed that the amphipods fed on a variety of feeds like decaying mangrove leaves, natural detritus available at the sampling site, flesh of young mussel (*Villorita cyprinoids*), alga (*Chara* sp.) and blue-green alga scraped from the sides of the culture tanks. Juveniles were found to survive only on the blue-green alga and

natural detritus. Based on the observation made during the study, *E. chilensis* can be categorized as an omnivore showing a preference for natural detritus and decaying mangrove litter. At times they showed cannibalistic behaviour by feeding on their own juveniles and also fed on moulted exoskeleton.

Feeding rates of adults on dried algal matter (*Chara* sp.) were calculated, after subjecting them to 24 hr starvation. Average feeding rate was  $615 \mu\text{g day}^{-1} \text{ individual}^{-1}$ . Adults showed an average feeding rate of  $1095 \mu\text{g day}^{-1} \text{ individual}^{-1}$  whereas females with broods showed lower rate of  $205 \mu\text{g day}^{-1} \text{ individual}^{-1}$ .

### 3.2 Life span and mortality

Females lived on average 1.4 times longer than males (average for females: 189 days and for males 132 days) (Table 1). Mortality was high towards the last weeks of the life span in both sexes. However in juveniles, mortality was relatively less (8-33%). In females, mortality was observed during the reproductive phase also, usually towards the end of embryonic development (7<sup>th</sup> to 9<sup>th</sup> day). Mortality in males was found to be related to copulatory behaviour as 10-20% of males died after copulation.

### 3.3 Moulting and growth rate

Moulting rate was found to be higher in females, as the females always moulted after the release of juveniles from the brood pouch. Total number of moults in females ranged between 6 and 9 as against 5 and 7 in males (Table 1). A higher size increment per moult was observed in males compared to females as the males attained larger size in a shorter duration.

Newly-born juveniles were in the size range of 1.63-1.92 mm and the number of antennal segments were 6. Initially growth was exponential for about 20 days after hatching with a growth rate of  $0.12 \text{ mm day}^{-1}$  (Figure 2). Individuals from the same brood exhibited different growth rates, even the number of antennal segments varied from one to another, as some 15-day old individuals had 9 segments while others had 11 segments. Hence, size of individual or number of antennal segments cannot be taken as reliable measure of age. Growth rate was generally higher in early developmental stages than at later stages. The maximum length observed during the laboratory experiment was 15.20 mm for males and 14 mm for females, whereas in the natural population males attained up to 17.76 mm.

#### 3.4 Attainment of sexual maturity and sex ratio

Females of *E. chilkenis* attained sexual maturity within 30-49 days ( $39.25 \pm 5.99$ ) at sizes ranging from 5.48 to 5.76 mm. Males attained sexual maturity much earlier than females, within  $26.5 \pm 5.55$  days and a size range of 5.08 to 5.81 mm. According to this observation, females attained a size of 5 mm within 39 days whereas males attained the same size within 27 days. This clearly indicates that the length increment per moult was higher in males compared to females and males grew faster than females. The sex ratio tended towards unity at the time of maturity attainment. The number of males decreased as they died at an earlier age and as a result, the number of males was relatively low in number than females towards the end of life span. This might be a reason for relatively low number of males in the natural benthic populations than females (Nair and Anger 1979; Kemp et al. 1985; Moore and Francis 1986). Age of the female at the time of brooding significantly affected the time

required for the attainment of maturity in the next generation. Increased age of the female delayed the attainment of maturity of the offspring (Fig. 3).

### 3.5 Mating behaviour

Sexually mature, males were observed to grasp mature females and mount them. Precopulatory riding behaviour, a condition known as amplexus was not observed in this case. A mature female amphipod was available for fertilization only for a short time immediately after moulting when the cuticle was sufficiently flexible to allow release of the eggs into the brood pouch through the genital pores. The copulation process continued several times even after the release of eggs to ensure complete fertilization. The presence of a male was a prerequisite for the release of eggs into the brood pouch. It was observed that isolated culture bowls containing only females did not release eggs into the brood pouch in the absence of a male.

### 3.6 Embryonic development and hatching

The brood pouch, which was initially yellowish in colour (due to the presence of under developed eggs), turned to white as the embryo developed. The embryonic development time was recorded as the period from oviposition to release of juveniles from the brood pouch. Time between oviposition and hatching of juveniles (incubation period) varied from 8 to 14 days. There was no significant relationship between the state of the brood (early or late) and incubation period. Mature eggs hatched directly into juveniles that resembled adults. Different stages of embryonic development identified were as follows: 1<sup>st</sup> and 2<sup>nd</sup> day: Formation of morulla and blastula; 4<sup>th</sup> day: Eggs were black, homogeneous ovals with a clear zone beneath

the egg membrane (chorion); 5<sup>th</sup> day: Movement of the early embryo towards the periphery of the membrane; 8<sup>th</sup> day: Curled very early embryos, eyespots and appendages were not visible and the embryo was tightly expanded within the egg membrane; 10<sup>th</sup> day: Eggs were slightly elongated at the head region of the embryo and appendages were well developed. The juveniles were released one at a time by the female and the whole process took several hours, depending upon the number of juveniles released.

### 3.7 Fecundity

The fecundity of *E. chilensis* was estimated as the number of juveniles released by a female. Newly released juveniles were transferred immediately to new finger bowls so as to avoid cannibalisation. The number of eggs/juveniles produced from a single brood increased with the age of the female. The number of broods produced during the life cycle ranged from 4 to 7 (Figure 4). Females were able to carry eggs at a size of 5-6 mm. During the study, only one set was observed to produce 7 broods. Total number of juveniles produced in a brood ranged from 4 to 29 and the total number of juveniles over the lifespan of a single female varied from 35 to 139. In most cases a significant positive correlation was obtained between age of the female and fecundity.

### 3.8 Biochemical composition

Protein, carbohydrate and energy equivalents are given in Table 2. Carbohydrate content was higher in all the three categories studied as against the protein content. The highest carbohydrate content was in ovigerous females (87.95 mg g<sup>-1</sup>) and the lowest in

juveniles ( $51.04 \text{ mg g}^{-1}$ ). Protein showed a decreasing trend during the growth, i.e. higher in juveniles ( $27.12 \text{ mg g}^{-1}$ ) and lower in adults ( $20.74 \text{ mg g}^{-1}$ ).

### 3.9 Distribution and population dynamics in field

The distribution and population dynamics of *E. chilkenis* are concordant with previous records of the amphipods in the Cochin estuary (Nair et al. 1983). *E. chilkenis* was encountered in varying densities in the epifaunal community in the mangrove rich regions of Pudukkottai ( $21-1583 \text{ ind. m}^{-2}$ ). Changes observed in the proportion of adults and juveniles over a period of 12 months are shown as individuals per  $\text{m}^2$  (Table 3). These data were compared with the total gammarid population, comprised of *Eriopisa chilkenis*, *Corophium triaenonyx*, *Melita zeylanica*, *Quadrivisio bengalensis*, *Grandidierella gilesi* and *G. bonneri*. High densities of *E. chilkenis* have been attributed to its short life-span (4-8 months) and continuous gonad maturation. It attained large standing stock in these areas due to high fecundity and survival. *E. chilkenis* population underwent considerable fluctuation during the annual cycle. Laboratory culture of *E. chilkenis* showed that it breeds throughout the year, but in the field they were absent during February. The maximum population density of  $1583 \text{ ind. m}^{-2}$  was observed during November. Total gammarid amphipod population ( $20,416 \text{ ind. m}^{-2}$ ) also peaked during the same month.

Temperature, salinity, pH, dissolved oxygen and ammonia, measured during different months are given in Figures 5 and 7. All the environmental parameters measured were subjected to considerable variations throughout the period of observation. Salinity values ranged from 5.11 (June 04) to 33.61 (February 04). High population density coincided with a salinity of 16.68 (November 03). Sediment texture was characterized by high sand and clay

fraction (mean: 43% and 38% respectively). The organic matter (Figure 6) in the sediment was generally high ranging from 16.6 (October 03) to 72.74 mg g<sup>-1</sup> (February 04). High population density coincided with moderate (35.34 mg g<sup>-1</sup>) organic enrichment, (November 03).

*E. chilkenis* tolerated a wide range of salinity (5.22-35.35) and temperature (27.5-34 °C) conditions. Gravid females were observed in high numbers during November and December (250 m<sup>-2</sup>; 229 m<sup>-2</sup>, respectively) when the salinity was around 16.68 and 28.85 respectively indicating a preference for medium saline conditions during the breeding period, but they were absent during February, March and June (Table 3). It may be also possible that ovigerous females were under recorded due to egg spillages during fixation. Females with broods accounted for 13% of the total *E. chilkenis* population. A maximum of 46 eggs were recorded during the study and the highest number of juveniles was also recorded during the same period (November-December). Juveniles were absent during February and March, but were present during the low saline period (May-October), indicating their ability to tolerate low to moderate saline conditions.

*E. chilkenis* was tolerating wide fluctuations in salinity whereas other gammarid amphipods were absent during March-May period (Figure 7 and Table 3). In the laboratory, *E. chilkenis* maintained in the finger bowls were subjected to natural evaporation and the experiments confirmed that they could survive in a wide range of salinity, from 18.39 (initial) to 35.35 (final) over four days without any mortality. This implies that *E. chilkenis* could tolerate short duration salinity fluctuations in nature while other gammarid amphipods moved out to locations of preferred salinity. The percentage contribution of *E. chilkenis* to the total number of amphipods was 45.91% (Table 3). Population dynamics in the organic-rich

environment of Cochin estuary followed a similar trend with the maximum abundance in November but at low densities (42-667 ind. m<sup>2</sup>).

#### **4. Discussion**

*E. chilkenis* can be cultured on different types of feeds like dead and decaying animals, algal matter and detritus. They also exhibited cannibalistic behaviour in the laboratory, by feeding on their own young ones. They even ingested moulted exoskeletons, which indicates that this species requires a high nitrogen food source at times (Agnew and Moore 1986). According to our observation, the average feeding rate of brooding females on dried algal matter was relatively low compared to other adults. Body distension caused by crammed stomach or swollen ovaries might constrict the gut and mechanically impair feeding (Thruston 1979).

Mortality was low in juveniles, but increased with age. Death of males after copulation was observed, which might be due to excess expenditure of energy during the behavioural activities associated with copulation. Mortality occurred even in females during brooding, which might be due to the energy expenditure during incubation and usually occurred towards the end of the developmental stages (7<sup>th</sup> to 9<sup>th</sup> day) of the embryo. The energy allocated for reproduction is divided between the reproductive output (brood size and egg volume) and behavioural activities associated with breeding (mating amplexus, fighting and brooding of embryos and juveniles). The costs of such activities can be substantial in amphipods and may vary with prevailing environmental conditions (Clarke 1987).

There was a shift from an equal number of males and females in the population at the time of attainment of sexual maturity to a female domination towards the end of the life cycle.

According to Moore (1981), sex ratios in populations may either be 1:1, skewed towards females or males, or show seasonal variations. Female-biased sex ratio towards the end of life cycle indicates an increased female longevity.

The number of offspring produced from a single brood varied with the age of the female. Significant positive correlation was found between the number of juveniles released and the age of the female. The number of eggs carried by a female amphipod generally increased at each successive moult (Fincham 1974). Brood size in gammarideans has often been found to be proportional to body length of females (Beare and Moore 1996; Costa and Costa 1999; Persson 1999; Cunha et al. 2000). Age of the female at the time of breeding influenced life-cycle characteristics of its offspring, namely attainment of sexual maturity in the next generation. In *E. chilkenis*, individuals from early broods attained sexual maturity earlier than those from late broods, but in *Corophium insidiosum*, Nair and Anger (1979), have observed that the individuals from late broods attained sexual maturity earlier. In *E. chilkenis*, there was no significant relationship between age of the female and incubation period and again, this observation ran counter to the observation of Nair and Anger (1979), in *C. insidiosum* wherein early brood females were found to incubate their offspring for longer periods. Such contradictory observations may be due to phylogenetic and physiological constraints (Sainte-Marie 1991).

*E. chilkenis* males and females attained different sizes at the same age, the males being larger. Based on our observations, females of *E. chilkenis* took an average of 39 days to attain a size of 5 mm whereas males attained this size within 27 days. According to Sainte-Marie (1991), about 97% of gammarids have larger males compared to females. Growth rates in the early stages were higher, and it is generally accepted that the growth is exponential

(Welton and Clark 1980). The maximum body size attained by individuals under laboratory conditions was smaller (15.2 mm) than the size normally attained in natural environment (17.76 mm). Growth variations could also be associated with poor food quality. In addition to the quality of the food supplied, the small body size attained under laboratory conditions could also be due to stress. For example, Chen et al (1990) observed lower growth rates of penaeid shrimps under culture conditions due to deterioration of water quality caused by ammonia build-up. A similar situation may also be applicable in the present case since the excess food supplied was removed only once every week, leading to contamination with ammonia.

The average protein content was less compared to other species of amphipods, whereas the carbohydrate content compared favourably (Nair and Anger 1980). This might be due to the difference in the feeds used during the experimental set-up.

*E. chilkenis* was encountered in varying densities in the epifaunal community in the Cochin estuary. Although it tolerated a wide range of salinity (5.22-32.64) and temperature (27.5-34°C), the preferred range of salinity appears to be 16 to 28. *E. chilkenis* could survive in water with DO levels ranging from 2.43 to 6.34 ml l<sup>-1</sup> and ammonium concentration ranging from 4.9 to 35.32 µM l<sup>-1</sup>. Maximum density of *E. chilkenis* including the gravid females and juveniles were obtained during November and December, when the salinity ranged between 16 and 28, organic matter ranged between 35-37 mg g<sup>-1</sup> and the sediment was a mixture of sand and clay in almost equal proportion. Experimental studies that have been carried out with *Corophium multisetosum* have also established that temperature, salinity and sediment type affect survival, sexual maturation and production of offspring (Cunha et. al. 2000). Nair et al., 1983 also reported the abundance of amphipods in the Cochin estuary

during late monsoon and post-monsoon seasons (August-December) when low to medium levels of salinity were recorded.

*E. chilkenis* tolerated a wide range of salinity compared to other amphipod species. Although salinity is often considered to be less important for reproductive activities, some studies have shown its influence on amphipods' brood size. Vlasblom and Bolier (1971) stated that although embryos of *Echinogammarus marinus* could develop in salinities ranging between 4 and 7, the number of emergent juveniles was reduced. Cunha et al. (2000) also reported the significance of salinity on the brood size in field populations of *C. multisetosum*. When salinity does not vary significantly, other factors may determine the distribution of estuarine amphipod such as algal cover, shelter or interspecific relationships (Nicolaidou and Karakiri 1989). Tanks presently used for mass culture contained *Corophium triaenonyx* and *E. chilkenis* and it was observed that in the presence of *C. triaenonyx*, the number of *E. chilkenis* decreased drastically, possibly be due to competition for food and space. According to the observations made during the present study, *E. chilkenis* seeks shelter under algal cover, leaves and detritus that were added to the culture tanks. Our study indicates the possibility of *E. chilkenis* producing several generations in one year.

Laboratory culture of *E. chilkenis* showed that it breeds throughout the year but in the natural population it was absent during February. Nair et al. (1983) stated that salinity was the predominant factor controlling the abundance of the gammarid amphipods in the Cochin estuary. The absence of this species in February might be due to the high salinity (33.61) and/or the high organic matter ( $72.74 \text{ mg g}^{-1}$ ) present during this month. According to the classic model of Pearson and Rosenberg (1978), an increase in organic matter above a critical level causes hypoxia, smothering and change in physiochemical properties of the sediment,

leading to decrease in faunal density. The total benthic macrofauna was also less during this month. A distinct density peak, both of *E. chilkenis* and total gammarid amphipods was observed in November. During this month the salinity was 16 and organic matter was 35.34 mg g<sup>-1</sup>. Steele and Steele (1975) observed a correlation between the quantity of organic matter in the sediment and the seasonal release of young in gammarids of the North-western Atlantic. They suggested that the release of young ones coincided with optimum conditions for their survival.

*E. chilkenis* reproduces almost year-round. Females produced broods consecutively (iteroparity) under laboratory conditions. Based on other observations (duration of embryonic development, maturation and life span), one could expect six or seven generations annually, thereby exhibiting a multivoltine life cycle. Fenwick (1984) emphasized the importance of phylogenetic constraints and concluded that there is no simple optimum life-history strategy, but a combination of different life-history traits may be equally successful in a given environment. That opinion was confirmed by Sainte-Marie (1991) who suggested that phylogenetic and physiological constraints should be best considered for the interpretation of gammaridean life-history patterns.

Analysis of the gut contents of the fish, *Daysciaena albida* (Bengal corvine) collected from the Cochin backwaters showed that amphipods and isopods formed the major part of their diet (Kurup and Samuel 1988). Gammarids like *Anisogammarus pugettensis*, *Gammarus lacustris* and *Gammarus tigrinis* have already been examined for their potential in fish culture (Chang and Parsons 1975; Mathias et al. 1982 and Reish and Barnard 1979). Similarly *E. chilkenis* also can be used as an alternative fish feed, as this gammaridean can tolerate wide ranges of temperature and salinity and consumes a wide variety of plant and animal material,

in addition to scavenging dead and decaying organisms. The added advantage of this species is its resistance to handling stress. It therefore can easily be mass cultured in the laboratory for supplying as natural live feed. Our study provides a basic knowledge about the life history and ecological affinity for evaluating the potential role of this amphipod species as a test organism in estuarine areas.

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Table 1 Life cycle criteria of *Eriopisa chilensis* (Temperature  $26 \pm 1$  °C, Salinity  $19 \pm 1$ , M- Male, F- Female)

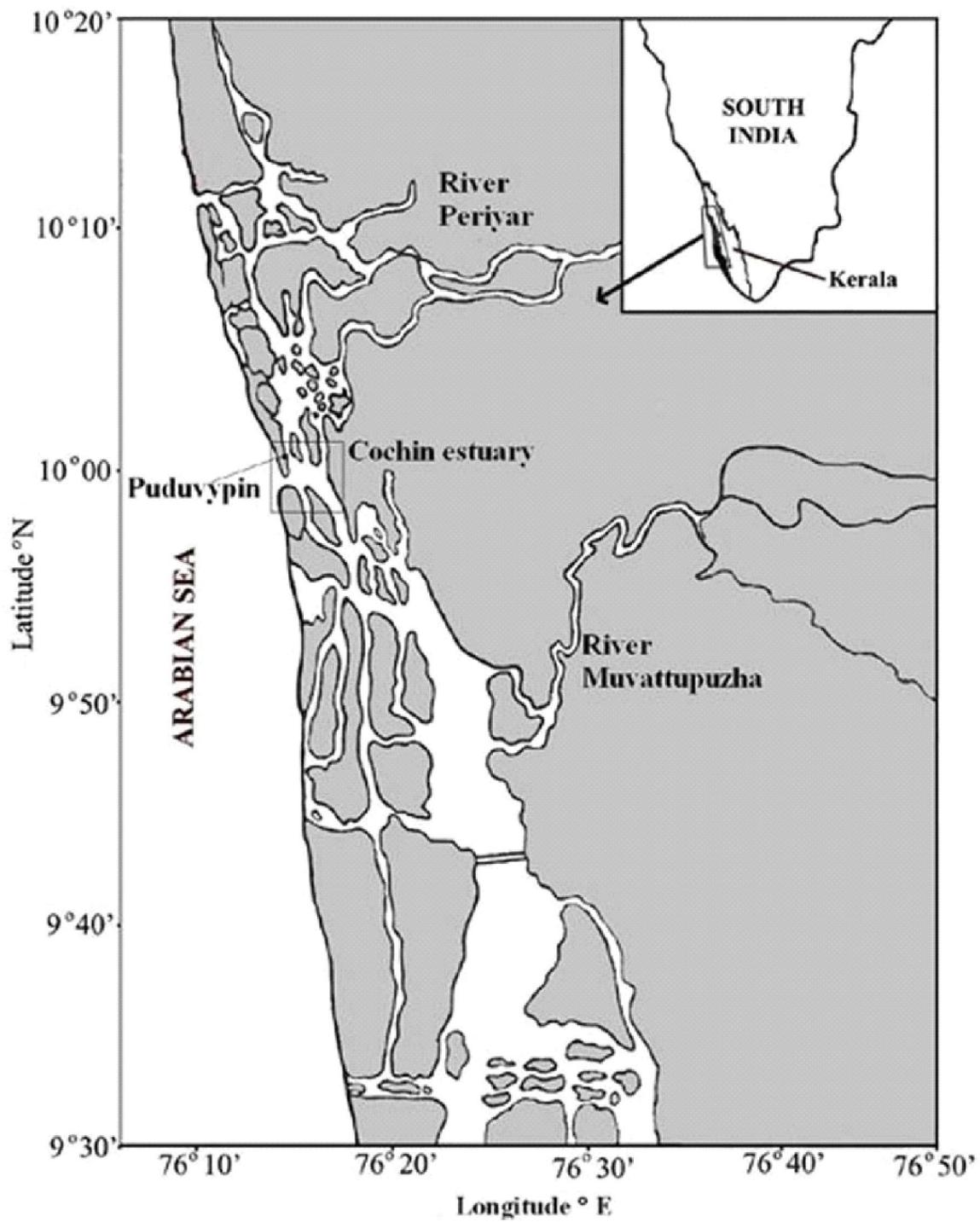
Life-cycle criteria	M/F	Range	Mean ( $\pm$ )SD	n
Life span (days)	M	124 -175	132 22.88	8
	F	170 - 220	189 20.84	8
Number of moults	M	5 - 7	6.38 0.74	8
	F	6 - 9	7.63 0.92	8
Body length (mm)	M	11.44 -15.2	13.4 1.45	6
	F	8.56 -14	10.38 1.79	8
Average growth rate from 0 – 20 days (mm per day)	M/F	-	0.12 -	6
Broods per female	F	4 - 7	5.14 1.07	7
No. of juveniles per brood	F	4 - 29	13.72 7.39	33
Juveniles per female (sum)	F	35-139	72.16 39.74	6
Incubation time (days)	F	8 - 14	12 2.45	8
Sexual maturity of female (days)	F	30 - 49	39.25 5.99	16
Size (mm)		5.48 - 5.76	5.5 0.21	5
Sexual maturity of male (days)	M	20 - 38	26.5 5.55	8
Size (mm)		5.08 - 5.81	5.05 0.31	5

Table 2 *E. chilensis* biochemical composition and energy contents in adults, juveniles and ovigerous females

	Juveniles	Adults	Ovigerous females
Carbohydrate (mg g <sup>-1</sup> )	51.04	71.57	87.95
Protein (mg g <sup>-1</sup> )	27.12	20.736	21.378
Energy equivalent (K Cal g <sup>-1</sup> )	0.336	0.39	0.4

Table 3 Population density (ind.m<sup>-2</sup>) of total gammarid amphipods and *E. chilensis* in field

Date	Total No. of gammarid amphipods (ind. m <sup>-2</sup> )	Total No. of <i>E. chilensis</i> (ind. m <sup>-2</sup> )	Gravid Females of <i>E. chilensis</i> (ind. m <sup>-2</sup> )	Juveniles of <i>E. chilensis</i> (ind. m <sup>-2</sup> )	Contribution (%) of <i>E. chilensis</i> towards other gammarids
Oct - 03	3250	250	83	42	8
Nov - 03	20416	1583	250	250	8
Dec - 03	1646	1063	229	333	65
Jan - 04	3605	667	63	83	19
Feb - 04	21	0	0	0	0
Mar - 04	21	21	0	0	100
Apr - 04	271	271	21	42	100
May - 04	271	271	42	42	100
Jun - 04	605	292	0	42	48
Jul - 04	459	271	63	125	59
Aug - 04	1666	458	125	104	28
Sep - 04	3459	563	104	42	16



**Fig. 1. Study region (Cochin estuary) showing the sampling site**

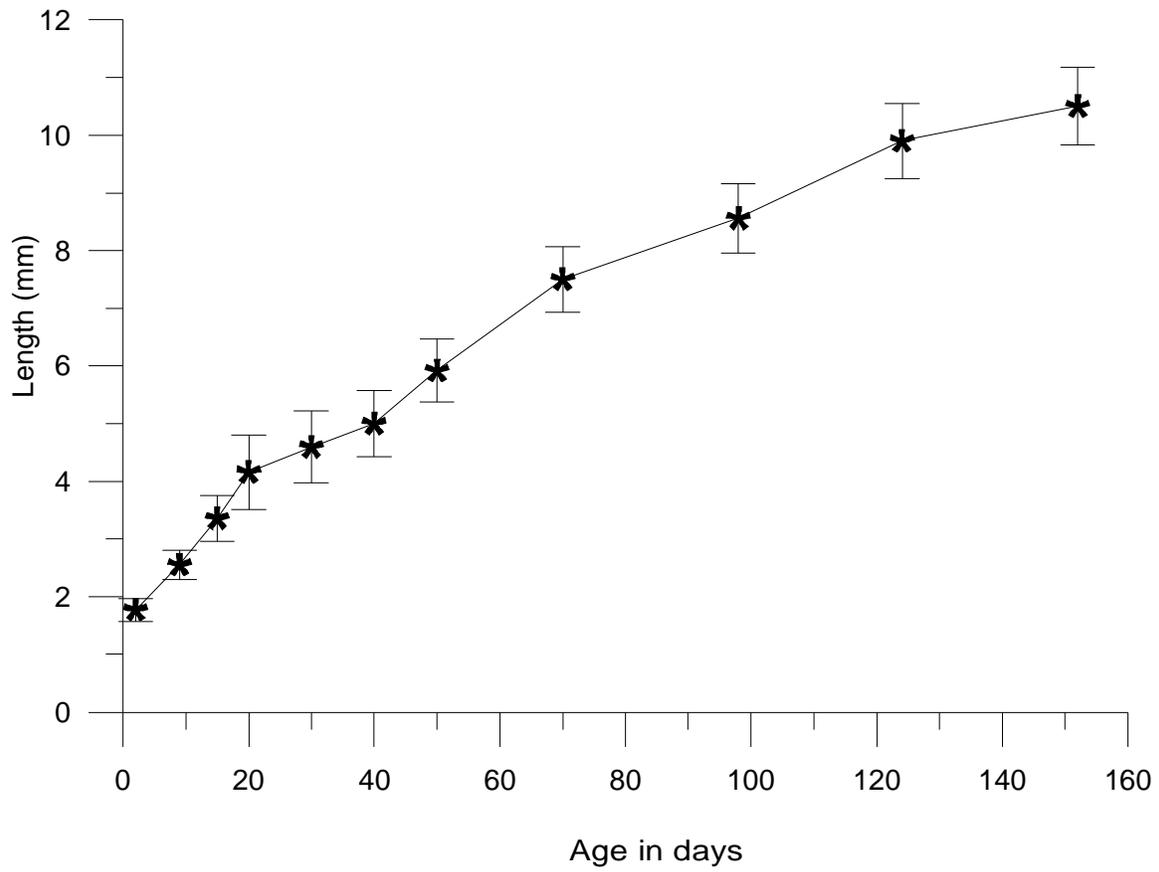


Fig. 2 *E. chilensis* growth rate ( $\text{mm day}^{-1}$ ) under Temperature  $26 \pm 1$  °C and Salinity  $19 \pm 1$

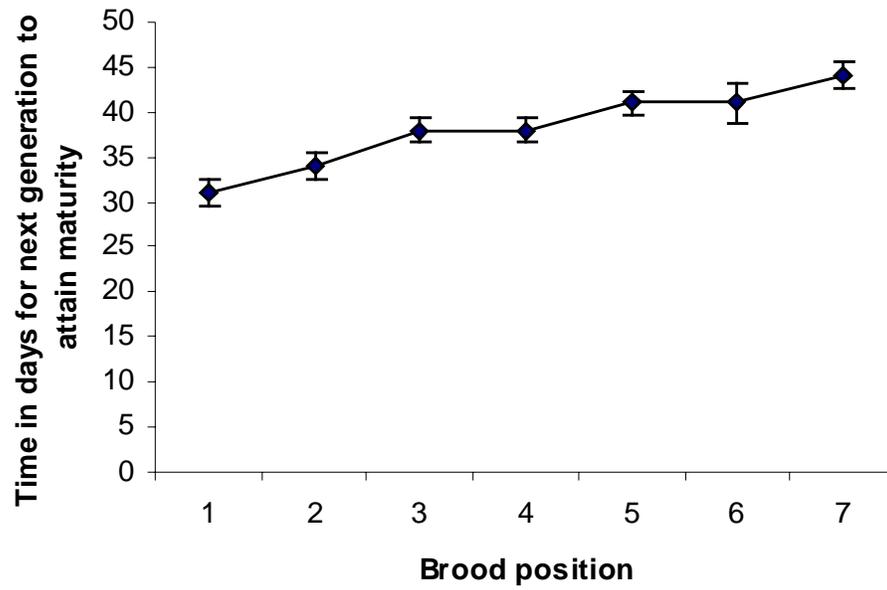


Fig. 3 *E. chilkensis* - Attainment of sexual maturity in the F1 (First) generation

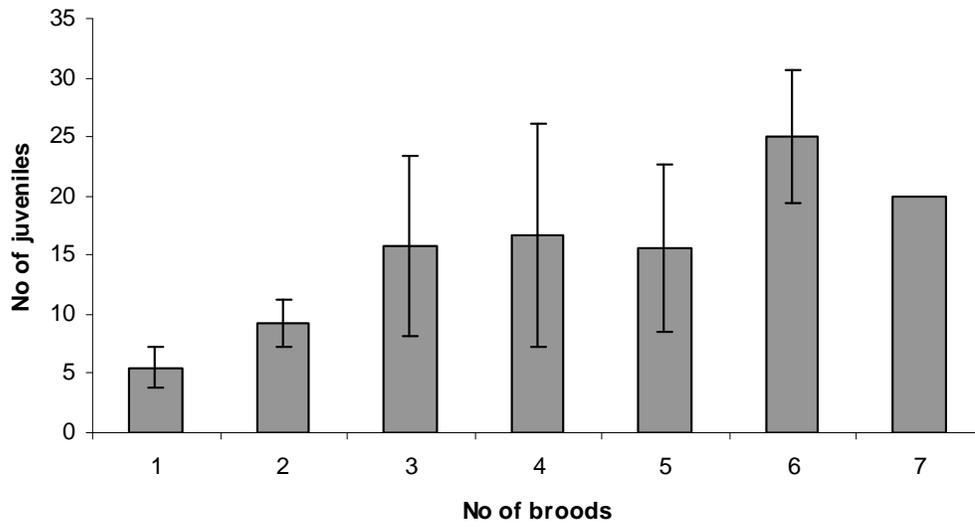


Fig. 4 *E. chilkensis* fecundity pattern mean  $\pm$  SD

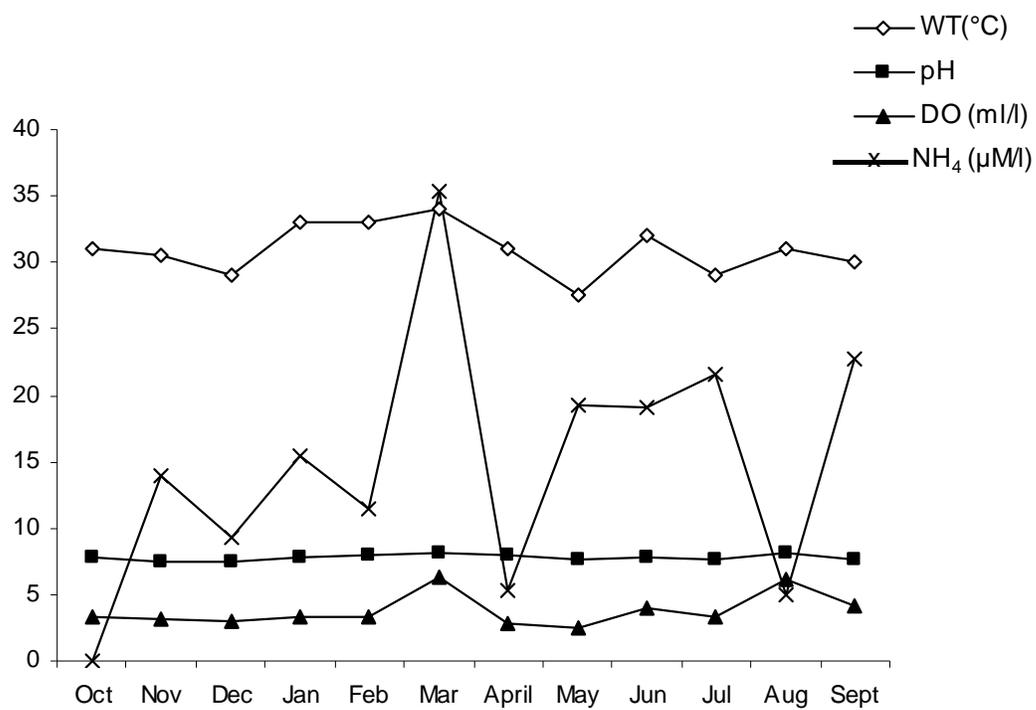


Fig. 5 Environmental conditions (Puduvypin)

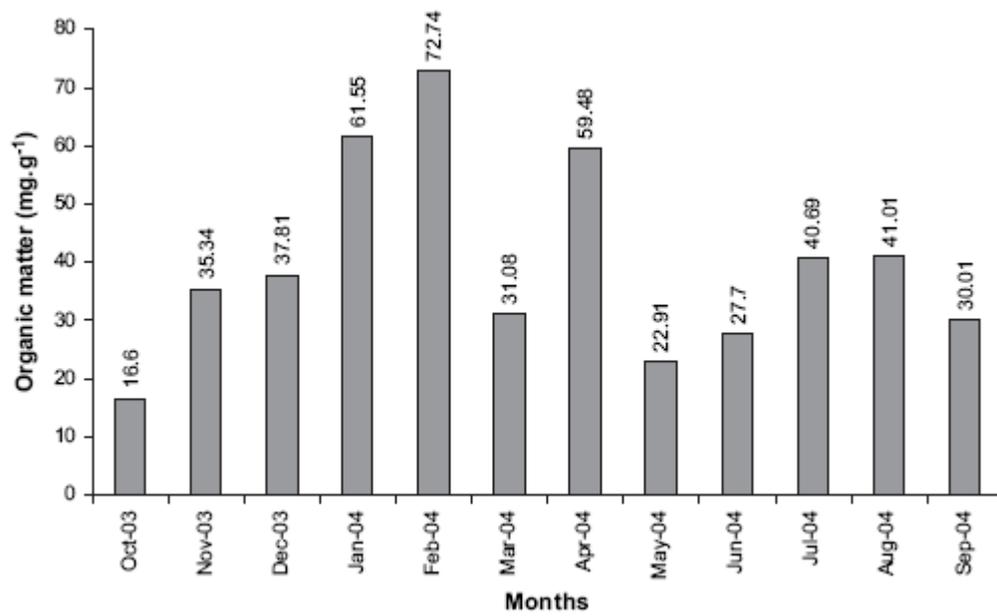


Fig. 6 Variations in organic matter in sediment

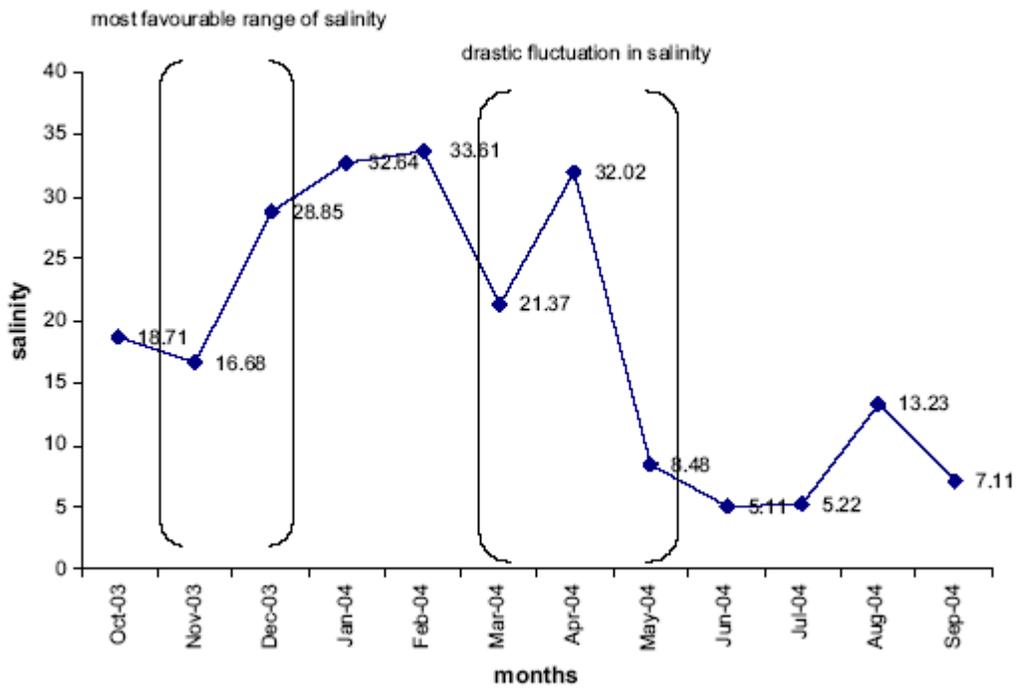


Fig. 7 Salinity variations, showing the most favourable and adverse range of salinity conditions from March-May