REVIEW OF LITERATURE

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Chapter 2

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A General review of Cladocera

The early description of the cladocerans was associated with the invention of microscope. The Dutch microscopist Swammerdam (1669) described these creatures as 'water fleas' in his book "Insects" on creatures with branching arms. Subsequently Schaeffer (1775) gave a better description for the first time. These authors used different names and did not separate the cladocerans taxonomically from other microcrustaceans.

A scientific study of cladocerans was made by O.F. Müller (1785) who included them under Entomostraca and gave scientific binomial names. It was Milne-Edwards (1840) who divided Branchiopoda into two independent orders Phillopoda and Cladocera. The Order Cladocera included the genera *Macrothrix* Baird 1843, *Diaphanosoma* Fischer 1850, *Moina* Baird 1850, *Ceriodaphnia* Dana 1853, *Simocephalus* and *Scapholeberis* Schoedler 1858, *Ilyocryptus* Sars 1862, *Pseudosida* Herrick 1884, *Latonopsis* Sars 1888 and *Oxyurella* Dybowski and Grochowski 1894.

Monographs by Fischer (1850), Lilljeborg (1853) and Leydig (1860) represented descriptions of many European species. Sars (1862) showed that Cladocera constituted the largest group of freshwater crustaceans in number of species, and a most diversified group in structure and habits. He later classified them into two divisions called Calyptomera and Gymnomera (Sars, 1865) and further grouped them into four well marked 'tribes' namely

Anomopoda, Ctenopoda, Onychopoda and Haplopoda which comprised eight families. Subsequently Kurz (1875), Claus (1876) and Schoedler (1877) published their works on the European species.

In the latter half of nineteenth century several workers started active cladoceran studies outside Europe as well, particularly in North America (Birge, 1879; Herrick, 1879, 1884) in Australia (King, 1853; Sars, 1885; 1888) and in tropical Asia (Richard, 1894; Daday, 1898). Sampling populations and studies of environmental features became a regular part of limnological investigations during this period (Birge, 1895).

Calman (1909) grouped the branchiopod crustaceans into four orders Anostraca, Notostraca, Conchostraca and Cladocera as a significant step in their earlier classification. By the beginning of 20th century the interest on general cladoceran morphology had declined and researchers paid more attention to study aspects pertaining to the ecology of *Daphnia*.

The central position of *Daphnia* in the food web of the freshwaters has directed the interest of numerous investigators to its food uptake and utilization. Naumann (1921) already recognized that daphniids provided an important link between plankton and fish production. There were several studies on seasonal changes, population dynamics, and cyclomorphosis during this period. Many contradictory observations were made and various explanations were offered for these seasonal changes by Wesenberg-Lund (1926) and Berg (1931). Subsequently the work on filter feeding mechanisms of *Daphnia* by Cannon (1933); growth and reproduction by Wood and Banta (1936), Anderson *et al.* (1937) and Ingle *et al.* (1937) were also published. Techniques for the maintenance of cladoceran culture were also devised by

Lutz *et al.* (1937) and Banta (1937). Later these techniques helped the study of population growth and dynamics by Brooks (1946) and Edmondson (1955).

In the second half of 20th century a number of workers were actively engaged in the studies of these crustaceans from different parts of the world. A review on egg development was done by Green (1956). Revisionary studies have already been undertaken in a number of genera and species complexes around the world during this period. Contributions on the 'Systematics and Evolution of Moinidae' Goulden (1968); 'Evolution and Adaptive radiation in the Chydoridae' Fryer (1968); 'World Chydoridae' Smirnov (1974); 'Evolution and Adaptive radiation in Macrothricidae' Fryer (1974); 'Revision of Australian Cladocera' Smirnov and Timms (1975) were important in this regard.

Arnold (1971) evaluated the effect of different species of algae on the assimilation, survival and reproduction in *Daphnia pulex*. Vijverberg (1976) studied the effect of food quality and quantity on the growth, birth rate and longevity of *Daphnia hyalina*. The general life history characteristics of cladocerans were reviewed by Lynch (1980). The influence of biotic factors on cladoceran morphology was presented by Kruger and Dodson (1981).

Subsequently the 'Revision of Scapholeberinae' was done by Dumont and Pensaert (1983) while Idris (1983) published the 'Freshwater Cladocera of Malaysia'. Consequently there was an increase in the cladoceran researchers especially in the field of systematics. Fryer (1987) in his publication, 'A New Classification of the branchiopod Crustacea' considered Cladocera as an artificial group comprising representatives of rather different

phylogenetic origin and classified them into four orders such as Anomopoda, Ctenopoda, Onychopoda and Haplopoda. A significant contribution to cladoceran taxonomy was made by Frey (1987) and his followers. They used a population approach especially the study of large groups of specimens, their morphological variability, ontogenetic changes, experimental crosses and electron-microscopic examinations.

Vijverberg (1989) made an excellent review of culture techniques of cladocerans under laboratory and *in situ* conditions. Subsequently, demographic and population growth approaches were published by Gliwicz (1990) and Stearns (1992). Chemical communication in predator-prey relationships received much attention in aquatic ecology (Larsson and Dodson, 1993). Several studies have demonstrated that the presence of info-chemicals released by predators into water especially the 'fish kairomones' may lead to behavioural as well as morphological changes (Machacek, 1993). This ultimately leads to changes in their life history characteristics (Weider and Pijanowska, 1993). Contributions of Ringleberg (1993), Boersma and Vijverberg (1994) and Spaak and Hoekstra (1995) were also of major importance in ecology.

Aquatic toxicology, has received increasing attention over the last few decades as problems of water pollution are faced in both industrialized and developing countries. *Daphnia magna* has been used for ecotoxicological studies all over the world (Koivisto, 1995). Alberdi *et al.* (1996) assessed the potential of *Daphnia* species as biological indicators for pesticides. Barry (1996) evaluated the effects of endosulphan on the growth, reproduction and population dynamics of *Daphnia carinata* when fed at low and high food levels.

Besides the traditional domains, the new trends emerged in cladoceran studies was the widespread application of molecular techniques in taxonomy and ecological studies. Molecular evidences suggested Cladocera as a monophyletic group (Crease and Taylor, 1998). A reclassification of Anomopod families was made by Dumont and Silva Briano (1998). In this system Suborder 'Radopoda' was divided into seven anomopod families that gave a new status for some previous subfamilies: the Superfamily Eurycercoidea included three families (Eurycercidae, Sayciidae and Chydoridae) and Superfamily Macrothricoidea included four families (Ophryoxidae, Acantholeberidae, Macrothricidae, and Neothricidae).

Later Negrea *et al.* (1999) proposed a scheme of classification of Branchiopoda in which the Class Branchiopoda was divided into five superorders and eleven orders. Cladocera has been reinstated as Superorder Cladocera and included 3 orders viz. Ctenopoda, Anomopoda and Onychopoda. The Order Haplopoda was placed under a new Superorder Leptodorida.

Influence of environmental factors to cladoceran resting eggs was studied by Rojas *et al.* (2001). Crispim and Watanabe (2001) analysed the resting egg banks. Ovie and Egbore (2002) evaluated the effect of different algal densities of *Scenedesmus acuminatus* on the population growth of *Moina micrura* Kurz; and found an inhibition of population growth at higher algal densities. The percentage of egg-bearing females and the number of eggs per egg-bearing females followed a similar pattern.

Mooij *et al.* (2003) evaluated the influence of temperature and food on the population dynamics and demographic characteristics of temperate Genus

Daphnia. Tatarazako *et al.* (2003) studied the mechanisms associated with the switch from parthenogenetic to gamogenetic reproduction and suggested the role of juvenile hormone in the chemical signaling responsible for inducing the production of male offspring.

The Sixth International Symposium on Cladocera at Poland in August 2002, threw some light on the present trends in cladoceran research. The important papers presented for the symposium included that of Arbaciauskas (2004), who demonstrated that although ex-ephippial daphniids and those of parthenogenetic origin differ in life histories, there is no ex-diapause effect on fitness of successive parthenogenetic generations. Mikulski *et al.* (2004) showed that short term exposure of various instars of *Daphnia* to simulated predation threat induces different defensive responses. Alekseev and Lampert (2004) demonstrated that photoperiod and maternal effects are important factors influencing life history and population dynamics in *Daphnia.* Slusarezyk and Rygielska (2004) looking for potential sources of environmental clues inducing the formation of resting eggs in *Daphnia*, concluded that kairomone extracted from fish faeces was the most active agent for induction. Vandekerkhove *et al.* (2004) demonstrated that isolation of resting eggs from sediments enhances overall hatching success, reduces hatching time, inter and intraspecific variability. Nandini *et al.* (2004) using standard life table approach quantified the life history parameters of *Moina macrocopa* subjected to different environmental stress.

Kawasaki *et al.* (2004a) studied the chemical composition of *Daphnia* resting eggs. The study demonstrated that the resting eggs have shells that are made up of crystalline calcium phosphate. This property of the resting eggs may ensure *Daphnia* survival in harsh environments. Kawasaki *et al.* (2004b)

studied the chemical composition, microanatomy and physical properties of the resting eggs using X-ray analytical microscope. The analysis demonstrated that phosphorus, sulphur, potassium and calcium are present in the resting eggs. Sarma *et al.* (2004) have made an elaborate review of recent works on different life history variables of cladoceran taxa in tropical and temperate freshwater bodies. Their study concluded that tropical and temperate species differ in several life history characteristics and environmental factors contribute to these differences.

Effect of temperature and photoperiod in hatching of ephippium was recently studied by Vandekerkhove *et al.* (2005a). Decaestecker *et al.* (2005) investigated the effect of eight endoparasites in natural *Daphnia magna* populations. Chadwick and Little (2005) studied the impact of microsporidian parasite in the life history of *Daphnia magna* and showed that the parasite causes shift in life history strategy towards early reproduction.

Review of Indian Cladocera

Although systematic studies on Cladocera was initiated in different parts of the world from 17th century, the earliest records of studies on Indian Cladocera dates back to the report of a new species of genus *Daphnia* from Nagpur by Baird (1860). Further studies in this direction were made during the first half of the 20th century by Gurney (1906, 1907). This was followed by the isolated reports from different parts of the country which included that of Daday (1911) from Tibet and Arora (1931) from Punjab. Subsequently Sewell (1935) and Brehm (1936, 1950) reported a few more species. Biswas (1964, 1966 and 1971) and Nayar (1971) published a series of reports from Rajasthan.

One of the important contributions from South India during this period was that of Michael (1973) who made studies on Cladocera from Madurai. Further, Patil (1976) reported Cladocera from Shillong and Nasar (1977) from Bihar. Quadri and Yousuf (1978) reported for the first time from Kashmir followed by Sharma (1978) from Calcutta and nearby areas. Michael and Hann (1979) also made some contributions to the studies on Chydoridae. A good number of studies on freshwater cladocerans of Tamil Nadu were made by Raghunathan (1986), Venkataraman and Krishnaswamy (1984a, 1984b, 1985, 1986) and Hudec (1987). Another important contribution during this period was that of Rane (1985a, 1985b) from Madhya Pradesh. All studies up to this period have been neatly compiled by Michael and Sharma (1988) in their monograph on 'Indian Cladocera' wherein he has listed 90 species from Indian subcontinent, of which 19 species are from Kerala.

Later important contributions in this aspect were by Raghunathan (1989a, 1989b); Sharma (1991), Rane (1992), Battish (1992), Venkataraman (1992, 1993, 1994, 1995) and Murugan *et al.* (1998). Venkataraman (1999) made an extensive study and added 34 species to the cladoceran fauna of Tamil Nadu. Subsequently Raghunathan and Sureshkumar (2002) published a check list of the cladoceran fauna of Tamil Nadu. Further, Durga Prasad and Padmavathy (2003a, 2003b) made cladoceran studies in Lake Kolleru of Andhra Pradesh. Chandrasekhar (2004) studied cladocerans from Adra Lake in West Bengal. Babu and Nayar (2004) studied the Cladocera of Periyar Lake, and added 15 species to the fauna of Kerala. Recently, Raghunathan (2006) indicated that the total number of cladoceran species of Tamil Nadu is 77, of which Chydoridae represented the most dominant group.

Review of Biological studies

Studies on the biology of Cladocera were initiated in India by Michael (1962). All the subsequent studies were done in the last four decades. A detailed review of important contributions on these aspects from Indian subcontinent is given below.

Michael (1962) made studies on the seasonal variations of *Ceriodaphnia cornuta* Sars collected from a natural pond at Barrackpore, West Bengal. He reported that *C. cornuta* passes through 1-2 pre-adult instars followed by 9 adult instars producing a total number of 42.0 eggs in a life span of 12.0 days.

The other subsequent contributions during this period was that of Parabrhmam *et al.* (1967), who made studies on the occurrence, growth and feeding habits of *Moina dubia* Gurney and Richard in sewage stabilization ponds. The culturing methods and its phytoplankton relationships were discussed in detail. Their study indicated that 28°- 30°C and pH 7.5 to 8.2 are favourable for the growth of *Moina dubia.*

Navaneethakrishnan and Michael (1971), while studying the egg production and growth in *Daphnia carinata* King under the laboratory conditions observed that the number of eggs produced gradually increased from the first to the last instar. They reported that *D. carinata* passes through 5 pre-adult and 8 adult instars at a temperature range of 29-31°C in a life span of 24.0 days, producing 42.4 eggs.

Murugan and Sivaramakrishnan (1973) studied the biology of *Simocephalus acutirostratus* King under laboratory conditions. They studied

the life span, instar duration, egg production, growth and stages in embryonic development. They reported that *S. acutirostratus* passes through 4 pre-adult instars and 18 adult instars at a temperature range of 28 -30°C in a life span of 44.0 days. A total number of 248.0 eggs were produced with a bimodal pattern of egg production.

Murugan (1975a) conducted studies on egg production, development and growth in *Moina micrura* Kurz from Madurai and showed the presence of 2 pre-adult and 11 adult instars producing about 61.2 eggs in a life span of 13.0 days at 28 -30°C. One of the interesting observations in that study was the uniform instar duration (24 hrs) of both the pre-adult and adult instars. There was only a single peak of egg production at 4th adult instar followed by a very gradual decline until the last instar.

Murugan (1975b) studied the biology of *Ceriodaphnia cornuta* Sars from Tamil Nadu. The study revealed that the species had 2 pre-adult instars followed by 18 adult instars. In a mean life span of 21.21 days it produced 123.60 eggs at 28-30°C.

Murugan and Sivaramakrishnan (1976) conducted studies on longevity, instar duration, growth, reproduction and embryonic development of *Scapholeberis kingi* (Sars) from Tamil Nadu. They found that *S. kingi* produced 239.4 eggs during a life span of 20.56 days at 28-30°C and in the meanwhile the animal passed through 2 pre-adult instars followed by 17 adult instars. There was a gradual increase in the number of eggs from the first adult instar till the 6th and showed uniform high rate of egg production in the succeeding eight instars with minor fluctuations. There was a sharp decline after 14th adult instar and absence of eggs towards the last instar.

Murugan (1977) studied the effects of different artificial media on the development of parthenogenetic egg of *Simocephalus acutirostratus* Sars collected from a seasonal pond at Madurai. The hatchability of the different stages of the embryo was tested in an artificial medium which contained varied proportions of sodium chloride, potassium chloride and calcium chloride. The hatchablity was found to be 100% in 0.001 to 0.1 M of sodium chloride. Also 100% hatchablity was noted from 0.001 to 0.05 M of calcium chloride. High percentage of hatchablity was recorded when isotonic solutions sodium and calcium were mixed. The results were discussed and compared with an allied temperate species *Simocephalus vetulus* (O.F.Müller).

Murugan and Venkataraman (1977) studied the *in vitro* development of the parthenogenetic egg of *Daphnia carinata* King and described eight stages during the process. They observed that the basic pattern of development was similar to that of other daphniids. But duration of the total period of development and the individual stages in *D. carinata* differed from those of other tropical and temperate forms. The total duration of embryonic development was found to be 28-30 hrs.

O' Brien and Vinyard (1978) studied the polymorphism and predation of *D. carinata* in South Indian ponds. They found that the crested forms of *D. carinata* evaded the waterbug *Anisops* more easily than normal forms. In experiments with *D. carinata* they also found a higher feeding rate and population growth rate in uncrested forms.

Venkataraman and Job (1980) made studies on the effect of temperature on the growth, development and egg production in *D. carinata.*

Sharma *et al.* (1981) conducted the laboratory studies on the life cycle of a male cladoceran *Daphnia lumholtzi* Sars from a lake at Shillong for the first time in India. The study indicated that the average life span of male *D. lumholtzi* was 36.33 days. *D. lumholtzi* passed through 13 instars at 12-18°C with a gradual increase in the duration of the different instars throughout the life span.

Venkataraman (1981) studied the seasonal variation in egg production of *Daphnia carinata* King with reference to physicochemical as well as biological factors in a temporary pond at Madurai. Based on laboratory observation on the life history of *D. carinata* he concluded that the animal had undergone 3 pre-adult instars followed by 15 adult instars in a life span of 26 days and produced a total number of 57.8 eggs at 29±1°C.

Murugan and Job (1982) studied the life cycle of *L. acanthocercoides* based on collections obtained from a pond at Madurai College campus, Tamil Nadu. They observed *L. acanthocercoides* had undergone 3 pre-adult instars and 13 adult instars in a life span of 23 days at temperature of 28-30°C under laboratory conditions. The pre-adult instar duration was found to be uniform with 24 hrs while the adult instar duration varied from 19-60 hrs. One of the notable observations in their study was that *L. acanthocercoides* produced a constant number of 2 eggs per brood in all adult instars unlike many other cladocerans.

Kanaujia (1982) studied the life cycle of *Ceriodaphnia cornuta* Sars collected from a pond in Cuttack under laboratory conditions at two different temperature ranges 16-25°C and 28-31°C. Based on the observations he

concluded that the instar duration, number of instars, egg production and longevity of *C. cornuta* showed a direct relationship with temperature.

Khan (1983) studied the effect of food on growth, life span and reproduction of *Ceriodaphnia cornuta*. It was noted that moulting, instar duration, growth and reproduction rates were lowered and life span was shortened in diluted culture medium. The growth and reproduction rates were high in the medium containing moderate quantity of food.

Kanaujia (1984) studied the life history, ephippia development and cyclomorphosis of *Daphnia lumholtzi* Sars under laboratory and field conditions. He observed that *D. lumholtzi* had undergone 3 to 4 pre-adult instars followed by 20 adult instars and produced 301.0 eggs during a life span of 54 days at a temperature range of 18-26°C. Moreover, he reported that seasonal water temperature exerted an important influence in the life cycle of *D. lumholtzi.*

Sharma *et al,* (1984) studied the in *vitro* development of *Daphnia lumholtzi.* The embryonic duration was 72 hrs at 10°C and 60 hrs at 20°C. When the temperature increased further to 28°C, there was a reduction in embryonic duration to 40 hrs.

Sharma and Dattagupta (1984) studied the process of cyclomorphosis leading to morphological changes in *Daphnia lumholtzi* under the influence of environmental factors. They observed that head and tail lengths of *D. lumholtzi* showed variations with the rise and fall of water temperature.

Venkataraman and Krishnaswamy (1985) during the laboratory studies on growth and reproduction of *Diaphanosoma senegal* Gauthier collected

from a seasonal pond at Madurai showed that this species had a life span of 18.7 days. Based on the observations he concluded that *D. senegal* has passed through 3 pre-adult and 16 adult instars at 28°-30°C. His study showed that *D. senegal* attained the maximum body size at the end of its life cycle and the growth increment was more during pre-adult instars.

Jana and Pal (1985a) made studies on *Moina micrura* in different culture media. Jana and Pal (1985b) also studied the relative growth and egg production of *Daphnia carinata* in different culture media.

Further, Sharma and Pant (1985) studied the oxygen consumption in *Simocephalus vetulus* in relation to size, density and temperature.

Venkataraman and Krishnaswamy (1986) conducted experimental studies with the notonectid water bug *Anisops bouvieri* as a predator to study the benefits of helmet development in cyclomorphic form of *Daphnia cephalata*. The observations were compared with another non-helmeted form of *Daphnia similis*. It was observed that the development of crest is a predation avoidance mechanism.

Manimegalai *et al.* (1986) further studied the helmet development in *D. cephalata* in relation to predation under laboratory conditions.

Kanaujia (1987) studied the biology and ephippia development in *Simocephalus vetulus* (O. F. Müller) collected from a fish pond at Cuttack, Orissa. The study revealed that this species had undergone 3-4 pre-adult instars followed by 20 adult instars during the life span of 41 days and produced a total number of 496.7 eggs at 21-31°C.

Kanaujia (1988a) made some observations on the life cycle of *C. cornuta* under laboratory conditions, for which collections were made from a pond at Cuttack, Orissa. In that study he observed 2 pre-adult and 25 adult instars for this species which produced 155 eggs during a life span of 31 days at 28-31°C. Moreover, the influence of different culture medium on the life cycle was also studied and discussed.

Kanaujia (1988 b) studied the annual life cycle of *Simocephalus vetulus* (O. F. Müller) under laboratory conditions. From the study he concluded that temperature and food influenced the life cycle of *S. vetulus*. Body size increased with suitable food in the medium and there was reduction in the duration of instar and total life span.

Murugan and Moorthy (1988) studied the longevity, instar duration, growth and fecundity of *Daphnia cephalata* King under laboratory conditions. The study revealed that during the life span of 52 days, *D. cephalata* produced 200 eggs at 27±2°C.

Sharma and Sharma (1989) made observations on the longevity, instar duration, fecundity, growth and embryonic development of *Simocephalus exspinosus* (Koch) under laboratory conditions. During an average life span of 41.16 days *S. exspinosus* passed through 4 pre-adult instars followed by 14 adult instars and produced 265.1 eggs at 20-22°C. He reported a unimodal pattern of egg production in this species.

Malhothra and Langer (1990) studied the biological aspects of *Moina macrocopa* (Straus) under four different temperature ranges viz. 7-10°C, 13-16°C, 25-28°C and 30-32°C. They suggested that egg production and embryonic duration could be influenced by temperature.

Thresiamma *et al.* (1991) studied the influence of different culture media on the production and population density of *Moina micrura* Kurz collected from some local ponds in Kerala under laboratory conditions at 27±1°C. Experiments were conducted using different culture media, with and without addition of unicellular algae *Chlorella* sps. The population attained a peak by 9th day in the most suitable medium and sharply declined. The appearance of ephippial females were recorded subsequent to the attainment of peak production.

Chandini (1991) conducted laboratory investigations on the effects of food and cadmium stress on the reproductive value and residual reproduction value of the two cladocerans such as *Echinisca triserialis* (Brady) and *Daphnia carinata* King. Attempts were also made to test the cost of reproduction hypothesis on whether; the energy invested by organisms at particular time in reproduction could effect their future survival and reproduction.

Singh and Dutta Munshi (1991) conducted laboratory studies on the biology of two cladocerans, *Ceriodaphnia rigaudi* Richard and *Daphnia lumholtzi* Sars collected from river Ganga. The effects of different temperatures on fecundity and longevity were also discussed and results were compared with that of other Indian cladocerans.

Babu and Nayar (1993) conducted investigations on the life cycle of *Ceriodaphnia cornuta* Sars, collected from Kerala, under laboratory conditions. During this study they observed that the animal passed through 2 pre-adult instars followed by 12 adult instars and produced 67.3 eggs within a life span of 16-17 days. Absence of ephippial females and males in the

culture suggested the possibility of parthenogenetic development of unfertilized eggs.

Babu and Nayar (1997) described the life cyle of *Simocephalus serrulatus* (Koch) collected from a pond in Kerala based on laboratory culture. The study indicated that the neonates produced from the same brood pouch may be all females, all males or both male and female. The life cycle was compared with that of other related species of *Simocephalus* from India. The life cycle of the *S. serrulatus* male was also described.

Another important contribution during the period was that of Battachayarya *et al.* (1997) who studied the biology of *Daphnia lumholtzi* from Shillong.

Sureshkumar *et al.* (1999) made a preliminary laboratory observation on the development of *Pleuroxus aduncus* Jurine from a sample collected from Chennai. The study revealed that this species has six distinct developmental stages which follow a similar developmental pattern to that of other cladocerans.

Altaff and Sivakumar (2002) conducted laboratory culture of *Moina micrura* Kurz using poultry manure and mixed algae. The importance of monitoring of physicochemical characteristics and microbial population of the culture medium for a high density production of *Moina micrura* Kurz was discussed. The study revealed that mass culture of *M. micrura* can be done using chicken manure and mixed algae.

Sureshkumar and Altaff (2002) made laboratory observations on the egg production, development and growth of *Macrothrix spinosa* collected

from Chennai. The study showed that during the life span of 18.63 days it produced 97 eggs. Five pre-adult and eleven adult instars were recorded at a temperature of 29±1°C. The total life span, growth rate and the total number of eggs produced were compared with allied tropical and temperate cladocerans.

Nayar and Babu (2002) developed techniques for the mass culture of the cladoceran *Simocephalus serrulatus* (Koch) for use as live feed in aquaculture. Crowding has been found to be an important factor in inducing male production and subsequent ephippia formation. Methods for collection and storage of ephippia were also suggested for future hatching.

Sumitha and Ramanibai (2004) investigated the growth and neonate production of *Moina micrura* Kurz collected from a pond at Chennai. Specimens of *M. micrura* were exposed in the laboratory to different photoperiods (0, 8, 12, 16 and 24 hrs light and dark cycle). Body size and clutch size were gradually increased with long photoperiodic exposures. The neonate production was also very high during 24 hrs light exposure. The study concluded that light is one of the environmental factors which accelerated the neonate production in *M. micrura*.