SYSTEMATICS, BIONOMICS AND SEED PRODUCTION OF *Macrobrachium* spp. OF THE VEMBANAD LAKE

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S.SURESH KUMAR

SCHOOL OF INDUSTRIAL FISHERIES
COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY
COCHIN - 682 016

1998

Dedicated To
My Parents

DECLARATION

I, Suresh Kumar S, do hereby declare that the thesis entitled "**Systematics, Bionomics and Seed Production of *Macrobrachium* spp. of the Vembanad Lake**" is a genuine record of research work done by me under the supervision of **Dr.B.Madhusoodana Kurup**, Reader, School of Industrial Fisheries, Cochin University of Science and Technology and has not been previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of any university or institution.

Cochin 682 016
March 1998

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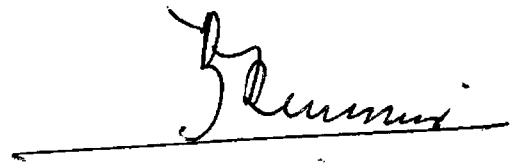
Suresh Kumar, S.

CERTIFICATE

This is to certify that this thesis is an authentic record of research work carried out by Sri. **Suresh Kumar, S.** under my supervision and guidance in the **School of Industrial Fisheries, Cochin University of Science and Technology** in partial fulfilment of the requirements for the degree of **Doctor of Philosophy** and no part thereof has been submitted for any other degree.



Dr.B.Madhusoodana Kurup
(Supervising Teacher)

Dr.B.Madhusoodana Kurup
Reader
School of Industrial Fisheries
Cochin University of Science and Technology
Cochin - 682 016

Cochin -16
March 1998

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Suresh Kumar, S.

CONTENTS

Section 1

General Introduction

General Introduction

1. Background of the study

Freshwater prawns of the genus *Macrobrachium* Bate 1868 gained considerable attention in recent years both as a protein rich delicacy and foreign exchange earner. Aquaculture of freshwater prawns of the genus *Macrobrachium* has been emerging as a major industry on a global basis ever since the attainment of scientific techniques of seed production and innovative farming. Moreover, this group also supports a lucrative fishery in the inland water bodies of India, especially in Vembanad lake and adjoining rivers. *Macrobrachium rosenbergii* is most popular among them because of its larger size, high demand in external as well as internal markets, great culture potential and also by virtue of its contribution to commercial fishery. In recent years, the fishery of *Macrobrachium rosenbergii* of inland waters in general and Vembanad lake in particular are being dwindled alarmingly due to changes brought about in the aquatic ecosystem due to human interventions. Reasons attributed behind the depletion of natural stock of this species in the Vembanad lake are mainly the reduction brought about in the extent of its natural habitat owing to the intensification of agriculture, physical obstruction imposed on the migratory path of berried females and juveniles, over fishing and pollution hazards (Kurup *et al.*, 1992; Harikrishnan and Kurup, 1997b).

Among various species of the genus *Macrobrachium, M.rosenbergii* is the most preferred for commercial aquaculture. Commercial level prawn farming of this species is now getting widely spread, especially in south-east

Asian countries. With the availability of seed becoming a reality, there has been a renewed interest in the raising of this species by resorting to scientific farming in Kerala in general and polders adjacent to Vembanad lake in particular. Major constraints met within the commercial farming of *M. rosenbergii* are the non-availability of seed in required numbers at right time and the highly skewed size disparity problems inherent in males of this species due to the differential growth associated with the developmental profile of male morphotypes and dynamics of their interaction. The mature male population of *M. rosenbergii* can be differentiated into three morphotypes based on the morphological characteristics, relative growth, reproductive potential and territorial habits, besides four transitional stages have also been described. Though the biology and fishery of *M.rosenbergii* was subjected to detailed studies in different parts of the country, however, no concerted attempts have so far been made to explicate the pattern of distribution of *Macrobrachium* spp. in Vembanad lake or to investigate the biological and biochemical variations if any, among various male morphotypes of the natural population of *M. rosenbergii*. Interestingly, *M. striatus* has been conferred with a distinctive taxonomic status very recently from the Vembanad lake though earlier workers considered this only as a striped variety of *M. equidens*, and therefore, the biology of this species remained unravelled. Although the seed production of *M. rosenbergii* became a reality, none of the hatcheries could so far been attained the designated production capacity due to non availability of mother prawns round the year and high mortality rates and failures encountered in production cycles. Brood stock rearing techniques have not been developed so far by giving adequate importance to variations in reproductive capability of different male

morphotypes. Aspects on seed production were studied only in *M.rosenbergii* as *M.striatus* do not have any aquaculture importance. Against this background, a detailed investigation on the systematics, bionomics and seed production of *Macrobrachium* spp. of Vembanad lake was attempted with the following objectives.

1. to identify different *Macrobrachium* spp. of the Vembanad lake and to establish the allometric relationship between various morphometric characters among them and also among the morphotypes of *M.rosenbergii*
2. to prepare a key for the easy identification of *Macrobrachium* spp. of the Vembanad lake
3. to explicate the distribution of *Macrobrachium* spp. in different regions of the Vembanad lake and correlate their occurrence with prevailing physico-chemical characteristics of the lake
4. to study the aspects of bionomics viz. food and feeding habits, reproductive biology and breeding migration of various morphotypes of *M.rosenbergii* and males and females of *M.striatus*
5. to characterise different male morphotypes of *M.rosenbergii* biochemically and to provide a biochemical explanation for the size heterogeneity problem seen among them
6. to examine the reproductive capability of different male morphotypes of *M.rosenbergii* and also to assess their performance in broodstock rearing

7. to elucidate the safe duration for transportation of broodstock and early larvae of *M.rosenbergii*
8. to develop an improvised larval rearing system for *M.rosenbergii* and to assess its suitability in the commercial level larval rearing
9. to assess the effect of container colouration on the larval culture of *M.rosenbergii.*

The results of the present study are presented in ten chapters which are organised under four sections. A general introduction to the topic is provided in the first section, besides a brief review of relevant literature and a brief description of the study area.

The second section consists of two chapters, the former deals with the systematics and results of morphometric analysis while in the latter, the distribution of *Macrobrachium* spp. in the Vembanad lake is presented. A detailed morphometric description of male and female morphotypes of *M.rosenbergii* is also provided in chapter 1. Temporal and spatial variations in the occurrence and availability of different species of *Macrobrachium* are delineated and correlated with the prevailing physico-chemical parameters viz. temperature, pH, salinity and dissolved oxygen and the results are presented in the second chapter.

Third section deals with bionomics of *M.rosenbergii* and *M.striatus* and consists of 4 chapters. Chapter 3 deals with seasonal, maturity stage wise and morphotype wise variations in food and feeding habits, while in chapter 4 reproductive biology of different morphotypes of *M.rosenbergii* and males and females of *M.striatus* are presented. Breeding migration and variations in sex

ratio of *M.rosenbergii* and *M.striatus* are presented in chapter 5. In chapter 6 biochemical characterisation of different male morphotypes of *M.rosenbergii* is attempted.

Section four consists of four chapters (Chapters 7 to 10) embarking various aspects of seed production of *M.rosenbergii*. A comparative evaluation of reproductive potential of male morphotypes of *M.rosenbergii* in broodstock rearing is provided in Chapter 7. Methods of packing for transportation of brood stock and early larvae of *M.rosenbergii* are discussed in chapter 8. While, result of two phase clear water system developed for the larval rearing of *M.rosenbergii* and effect of various container colouration on larval metamorphosis are presented in chapters 9 and 10 respectively. This is followed by summary and references.

2. Review of literature

Family Palaemonidae accommodates a wide array of species which inhabit different types of water bodies such as freshwater, brackish water and sea. Holthuis (1950, 1952a and b , 1956, 1966, 1969) recorded variation within and between species and made a detailed study on the distribution and taxonomy and also exhaustively reviewed the subfamily Palaemonidae. Literature regarding the taxonomy and distribution of palaemonid prawns in general and *Macrobrachium* in particular are those of Lanchester (1901,1906), Nobili (1903), De Man (1904), Calman (1913), Roux (1935, 1936), Kubo (1940), Holthuis (1949, 1950, 1952a & b, 1956, 1980), Yaldwyn (1954, 1957), Johnson (1962, 1966, 1973) and Kensley and Walker (1982). Patwardhan (1937) studied biology, morphology, fishery and distribution of *M.rosenbergii*.

Studies on the taxonomy and distribution of *Macrobrachium* spp. in Indian waters are limited to Henderson and Matthai (1910), Natraj (1942), Chopra and Tiwari (1947), Tiwari (1947a&b, 1952, 1955 a&b, 1961), Jones (1969), Tiwari and Pillai (1973), Kurian (1954), John (1958), Jayachandran (1984, 1987, 1991, 1992), Jayachandran and Joseph (1989a, 1992) and Raman *et al.* (1986). Descriptive accounts of new species of freshwater prawns of Indian waters are those of Tiwari (1949), Jayachandran (1987, 1989,) Jayachandran and Joseph (1988, 1992), Jalihal *et al.* (1988) and Pillai (1990a). Fishery of different *Macrobrachium* species were reported by Ibrahim (1962), Rajyalakshmi (1961, 1980), Rajyalakshmi and Ranadhir (1969), Rao (1967), Raman (1967) and Kurup *et al.* (1992a).

Morphometric studies on the palaemonid prawns were carried out notably by Yaldwyn (1957), Cole (1958), Misra (1958, 1959), Tiwari (1963), Rao (1967), Koshy (1969, 1971, 1972), Jayachandran and Joseph (1985b, 1986, 1988) and Jayachandran and Balasubramanian (1987) with a view to establish the relationship between the pattern of growth of body parts for bringing out sexual dimorphism if any, and also for delineating the species level differentiation. Length-weight relationship of various freshwater prawns were investigated by Rao (1967), Kadir *et al.* (1982), Natarajan *et al.* (1988) and Singh and Srivastava (1991).

The growth rate of males of *M.rosenbergii* in culture systems were found to be not only highly differential but also exhibit variations in morphological features (Fujimura and Okamoto, 1972; Smith *et al.*, 1978; Brody *et al.*, 1980; Malecha *et al.*, 1984). This variability was found to be

associated with morphotypic differentiation (Cohen, *et al.*,1981). Adult male population of *M.rosenbergii* can be differentiated into three morphologically distinguishable morphotypes viz. small males (SM), orange clawed males (OC) and blue clawed males (BC) representing three phases in the developmental pathway (Brody *et al.*, 1980; Cohen *et al.*, 1981; Kuris *et al.*, 1987). The above male morphotypes differ from each other morphologically, anatomically, physiologically and the hierarchy among them are closely associated with social roles and reproductive behaviour (Telecky, 1984; Sagi, 1984; Sagi and Ra'anan, 1988; Barki *et al.*, 1991; Karplus *et al.*, 1990a, 1992 a&b). Two transitional stages of OC viz. weak orange clawed males (WOC) and pre-transforming strong orange clawed males (t-SOC) are also distinguishable and therefore, the fully differentiated OC are known as strong orange clawed males (SOC) (Sagi and Ra'anan, 1988). Harikrishnan and Kurup (1997a) brought out the heterogeneous nature of BC population consisting of weak blue clawed males (WBC) as well as strong blue clawed males (SBC). BC with relatively smaller body size in terms of carapace length and body weight disproportionate with claw length is differentiated as old blue clawed males (OBC) (Sagi and Ra'anan, 1988). Sureshkumar and Kurup (1996) and Kurup *et al.* (1997a) studied the length-weight relationships of different male morphotypes of *M.rosenbergii.* Female population in culture system was known to be rather homogeneous (Cohen *et al.*, 1981; Karplus *et al.*, 1987) and does not have perceptible size variation. However, Harikrishnan (1997), Harikrishnan and Kurup (1997a) and Harikrishnan *et al.* (1998) distinguished the female morphotypes in the natural population and characterised them allometrically.

Though morphotypic differentiation could be established in the grow out and natural population of *M.rosenbergii* (Cohen *et al.*, 1981; Ra'anan and Cohen, 1985; Sagi and Ra'anan, 1988; Harikrishnan and Kurup, 1997a) however, no concerted attempts have so far been made to characterise them biochemically. Sherief *et al.* (1992) studied the biochemical composition of pond reared *M.rosenbergii* giving due emphasis to fast growing bulls and stunted runts. A comparative study on the nutrient composition of hepatopancreas of *M.rosenbergii* and *Penaeus indicus* was attempted by Sherief and Xavier (1994). Maugle *et al.* (1980) studied the variation in carotenoid composition in juvenile *M.rosenbergii* during eye stalk ablation. Rubbi *et al.* (1985), while examining quality changes during short-term preservation, observed that the proximate composition of *M.rosenbergii* vary with sex, maturity, different anatomical proportions and also with different seasons. An increase in the protein, glycogen and lipid content was observed in the testes and ovary of *M.kistnensis* during breeding season (Sarojini, *et al.*, 1982; Mirajkar *et al.*, 1983). Sarojini *et al.* (1985) conducted an in depth study on the variation of protein, glycogen, lipid, DNA and RNA during the reproductive cycle of *M.kristnensis*. An increase in protein and RNA contents in muscle of *M.rosenbergii* after three consecutive injections of estradiol-17 beta was reported by Ghosh and Ray (1992). Joseph *et al.* (1991) studied the variation in the proximate composition of *M.idella* from three different biotopes of Kerala and observed that there exists no significant variation in protein and fat content among them.

John (1958) classified *M.rosenbergii* as an omnivore in its feeding habits and similar observations were made by Raman (1967), Rao (1967) and

Ling (1969a). Ling (1969a) identified aquatic worms, insects, insect larvae, small molluscs, crustaceans, fish remains, materials of plant origin, algae etc. from the stomach of *M. rosenbergii*. Lee *et al.* (1980), by studying the digestive enzymes, opined that *M.rosenbergii* is showing carnivorous feeding habits. Costa and Wanninayake (1986) reported that food of *M.rosenbergii* of all size groups consists of detritus, plant and animals matter. Munshi *et al.* (1991) reported that *M.rosenbergii* is a filter feeder predator. Panikkar and Menon (1955) observed mud, sand and detritus in the food of prawns while John (1957) reported that preference to food changes with its environment. Rao (1965) observed that *M.rosenbergii* eats their exuvia after moulting and similar observation was made by Natraj (1947) in *M.idella*. Feeding habits of *M.americanum* (Smitherman *et al.*, 1974), *M.idella* (Jayachandran and Joseph, 1989b), *M.lanchesteri* (Johnson, 1968), *M.Choprai* (Prakash and Agarwal, 1989) and *M.equidens* (Muthy and Rajagopal 1990) were also studied in detail.

Cannibalistic nature of *M.rosenbergii* was reported by Rao (1969), Ling (1969a), Wickins (1972) and Peebles (1977). *M.idella* also showed similar tendency (Natraj, 1947). New (1990) opined that cannibalism in grow-outs is one of the major limiting factors of freshwater prawn in aquaculture. Langdon *et al.* (1985) stated that much of the failure in the development of artificial diets for larvae is due to the lack of understanding on the feeding behaviour and mechanism as well as digestive capabilities and processes.

Deru (1990) studied the morphological and ontogenic changes in the gut during larval development of *M.rosenebrgii*. Stephenson and Knight (1980) observed high food assimilation during larval stages when compared to adults in *M.rosenbergii*. Several digestive enzymes have been measured in

adult *M.rosenbergii* (Lee *et al.*, 1980; Tsai *et al.*,1986), *M.dayanum* (Tyagi and Prakash, 1967) and *M.lamerrei* (Murthy, 1977). Moller (1978) reported that capture of food by larvae is a matter of chance encounter, ingestion depended on sensory cues, whereas post larvae utilise visual, chemical and rheotactic sense for the location and capture of food particles.

Kamaruddin *et al.* (1994) reported that variation in ontogenic digestive enzyme activities in developing prawn larvae seems to be coincided with development of hepatopancreas. Harpaz *et al.* (1987) provided a quantitative information regarding the changes in feeding behaviour that occur during moult cycle. The sequence of food intake and food rejection behaviour of *M.rosenbergii* when administered with Quinine (Bitter food) and Betaine-HCl (Chemo-attractant) pellets was also demonstrated (Steiner and Harpaz, 1987; Harpaz and Steiner, 1987). Ponnuchamy *et al.* (1984) observed that increased population densities affect the physiological process of food conversion of *M.lanchesteri* and *Caridina weberi* and brought out the intergeneric variation in the regulation of food intake and growth.

Breeding habits of *M.rosenbergii* were studied by Rao (1965), Raman (1967) and Ling (1969a). Ling (1969a) and Ang *et al.* (1990) reported this species as a multiple brooder. The appearance and their gradual increase in low saline area of the estuaries indicate the commencement of breeding season in prawns (Rajyalakshmi, 1961; Raman, 1967; Jinadasa, 1985; Kurup *et al.*, 1992a). *M.rosenbergii* is reported to have a restricted breeding period in natural waters (Rajyalakshmi, 1961; Rao, 1967) whereas, Raman (1967) expressed the possibility of more than one spawning in a breeding season. Breeding season of *M.rosenbergii* in the Hooghly estuary is reported to be

during December to July (Rajyalakshmi, 1961; Rao, 1967), on the contrary, in Kerala waters the breeding season is from July to December (Raman, 1967; Kurup *et al.*, 1992a). Jinadasa (1985) reported an year round spawning of *M.rosenbergii* in Bolgoda lake, Sri Lanka with two distinct peaks corresponding to the monsoonal showers. Ibrahim (1962) reported that *M.malcomsonii* of Godavari river is characterised by a prolonged breeding season extending from April to November with two peaks, whereas Rajyalakshmi (1974) observed that this species breeds from May to October with a single peak in July to September. A prolonged breeding was also reported in *Palaemon idae* in southern Kerala (Natraj, 1947; Jayachandran, 1984). *M.tenellum* (Arroya *et al.*, 1982), *M.amazonicum* (Romero, 1982) *M.acanthurus* (Pinheiro, 1983) and *M.feicinum* (Inyang, 1984) were also reported to have breeding periods coinciding with the rainy season and consequent decrease in water temperature. Truesdale and Mermilliod (1979) studied the reproduction of *M.ohione* in relation to the aquatic environmental conditions. Raman (1967) opined that temperature is an additional factor which induces the breeding movements, besides salinity.

Rajyalakshmi (1961) reported that *M.rosenbergii* attained sexual maturity at the age of two years in West Bengal waters, whereas it attained sexual maturity within one year in Kerala waters (Raman, 1967). Rao (1967) reported that the species attained a mean size of 155 mm at first maturity in Hooghly rivers while Goorah and Parameswaran (1983) estimated 118 mm as the size at first maturity in captivity. *M.tenellum* attained sexual maturity at a length of 74 mm (Arroya *et al.*, 1982). Medium sized prawns such as *M.idella*,

M.felicinum and *M.acanthurus* attained sexual maturity at a length of 41, 30 and 40 mm. respectively (Jayachandran, 1984; Inyang, 1984; Berber, 1984).

Ling (1962), Rao (1965) and Chow *et al.* (1982) studied the mating and courting behaviour of *M.rosenbergii* under laboratory conditions. Rao (1965) furnished a detailed account of the mating behaviour and mating postures of *M.rosenbergii.* Females of *M.rosenbergii* and *M.kistensis* are known to release a male attracting pheromones after pre-mating moult (Ling, 1969a; Sarojini *et al.*, 1984) and a similar possibility in *M.idella* was also reported (Shyama, 1987). Rao (1965) is of the view that in *M.rosenbergii* females are inactive before mating and males are active participant in mating, on the contrary, Nagamine and Knight (1980) reported that females are active after premating moult and actively search a suitable male. Generally extrusion of eggs takes place within 24 hours after pre-mating moult (Ling, 1969a; Sandifer and Smith, 1975). Shedding of unfertilised eggs in *M.rosenbergii* (Ling, 1969a), *M. idella* (Shyama, 1987), *M.equidens* and *M.striatus* (Pillai, 1990a,b) were observed within two or three days.

Many of the *Macrobrachium* spp. need estuarine condition for the successful completion of the larval metamorphosis. (Raman, 1967; Ling, 1969a; Rao, 1967; Lee and Fielder, 1979; Read, 1983; Pandian, 1987; Gamba, 1987). *M.rosenbergii* undertakes a spawning migration from freshwater habitat to estuarine regions and spawns in areas of salinity between 5 to 20 ppt (John, 1957) Raman (1967) observed downward movement of the stock of *M.rosenbergii* during monsoon for the purpose of breeding. Similar observation was also made by Rao (1967) in the Hooghly estuary. After metamorphosis the post larvae remain in brackish water areas for a few weeks and migrate to

freshwater habitat (Ling, and Merican, 1961; Ling, 1969a; Natividad. 1982). Upstream and downstream migration of a species would be an adaptive advantage for getting specific salinity for the reproduction and subsequent development (Hughes and Richard, 1973). Lee and Fielder (1979) observed a large scale upstream migration of the population of *M.australiense* in South-east Queensland and postulated that they acquire a positively rheotactic response to prevent themselves being washed into the sea. Females of *M.rosenbergii* moved more distance at night than males and exhibited a weaker tendency to return to home site (Peebles, 1979). Read (1983) observed that adults of *M.petersi* migrate to the estuary under flood conditions and upstream in response to elevated salinity. Breeding migration of *Palaemon carcinus* and *P.mirabilis* were studied by Rajyalakshmi (1961). Jinadasa (1985) reported two peak in fishery commensurate with the breeding migration of *M.rosenbergii* in Bolgoda lake, Sri Lanka. In *M.olfersi* and *M.acanthurus*, a bimodal endogenous rhythm of a 12 hr. period with high activity at dawn and dusk were reported by Gamba and Rodriguez (1987). *M.malcomsonii* was categorised as a larval migrant and performs no migration for breeding in Godavari estuary but the larvae are brought to the estuarine zone by the water currents (Ibrahim. 1962; Rajyalakshmi, 1980).

Generally brood stock for the hatchery operation is collected from grow-out ponds (New 1995) or from wild population (Harikrishnan and Kurup, 1997b). As the occurrence of berry in the wild is highly seasonal (Harikrishnan and Kurup, 1996a and b) brood stock rearing in the hatchery premises itself is necessary for an year round operation of the hatchery. Varghese *et al.* (1992) attempted brood stock rearing of *M.rosenbergii* and asserted that 1:3.75 and

1:4.75 male: female ratio are superior in terms of berry production, least time for incubation and larval survival. Daniels *et al.* (1992) obtained optimal results in berry production when keeping a ratio 2 BC males with 20 females, whereas Malecha (1983) opined that 1:4 to 1:5 sex ratio is optimal for the brood stock rearing of *M.rosenbergii*.

Daniels *et al.* (1992) suggested a temperature of 27-32^{0}C at 15 ppt is ideal for optimal brood stock rearing. Lower temperature may reduce number of eggs, increase incubation periods and render the eggs prone to fungal infection. Lewis *et al.* (1991) correlated nutrient composition of eggs to viability of eggs and opined that it will reflect the nutrient demand of the developing embryo and larvae. Lewis *et al.* (1991) also brought out and compared the variation in (n-3) HUFA content of eggs of wild and pond reared brood stock. Marian and Murugadas (1991) assessed the effect of eyestalk ablation on the reproductive growth of *M.malcomsonii*. Murugadas and Pandian (1991) studied the effect of dietary protein on the reproductive growth and egg production of *M.nobilii* in captivity whereas Ang *et al.* (1992) delineated the protein requirement of brood stock of *M.rosenbergii*. Gomez-Diaz and Ohno (1986) assessed the effect of rearing condition of ovigerous females on the morphological development, survival rate and adaptation to temperature.

Gomez-Diaz (1987a and b) studied the variation in the effect of temperature and salinity on the larvae of intraspecific strains of three different parental stock and on their hybrids. Malecha (1987) commented on the selective breeding and interspecific and intraspecific hybridisation of crustaceans especially *Macrobrachium* spp. Sankolli *et al.* (1982) attempted

cross breeding of *M.rosenbergii* and *M.malcomsonii* and succeeded in the production of a hybrid, whereas, a recent attempt by Sundarapandian *et al.* (1995) on similar lines failed in the production of hybrid between above two species. Larval development of interspecific hybrid of *M.asperulum* and *M.shokitai* was studied by Shokita (1978). Mashiko (1984) attempted intraspecific hybridisation of estuarine population and upper freshwater population of *M.nipponense.*

As there is a distinct localisation of berry collection centre, hatchery and grow-out, transportation of berried prawns and earlier larval stages are inevitable for year round seed production in commercial hatcheries (Harikrishnan and Kurup, 1996a; New and Singholka, 1985). Singholka (1982a) devised a simple cool truck for the transportation of live animals especially post larvae of *M.rosenbergii.* Alias and Siraj (1988) assessed the effect of packing density and habitat material on the survival of post-larvae of *M.rosenbergii.* Vadhyar *et al.* (1992) proved that introduction of plastic straws as a habitat material will improve the survival time as well as rate. Smith and Wannamaker (1983) studied the transportation of juvenile and adults of *M.rosenbergii.* Transportation of brood stock of *M.malcomsonii* under oxygen packing in hypo thermal conditions could help in increasing the survival (Venketaswamy *et al.*, 1992). Joshi and Raje (1993) attempted packing trials to standardise packing density, means of packing, mode of transportation and size of post larvae of *M.rosenbergii* on the seed survival. New (1995) suggested optimum packing density and corresponding safe duration for post larval transportation using inflated oxygen filled plastic bags. Schmitt and Uglow (1993) reported that sudden changes in temperature causes stress in *M.rosenbergii.* Venugopalan and

Thampi (1992) observed no mortality on abrupt transfer of post larvae of *M.rosenbergii* from freshwater to different salinity. Armstrong *et al.* (1978) studied the interaction of ionised and unionised ammonia on the short time survival of *M.rosenbergii* post larvae.

Two conventional systems being used for the larval rearing of *M.rosenbergii* are the classical green water system (Ling, 1969b; Fujimura and Okamoto, 1972; Kok and Sin, 1982; Lee, 1982; Aniello and Singh, 1982; Hudon *et al.*,1989) and improvised clear water system (Aquacop, 1977, 1983; Malecha, 1983; Chineah,1982). Suharto *et al.* (1982) described a method of rearing larvae of *M.rosenbergii* in conical fibre glass tanks. Menasveta and Piyatiratitivokul (1980) compared various systems of larval rearing and reported that production fluctuated more in static system than in closed recirculating system. Cook and De-Baissac (1994) reported that although phytoplankton cells have been observed in the gut of larvae, the ability of larvae to digest and assimilate algal cells have not been demonstrated. Cook and De-Baissac (1994) concluded that phytoplankton contributed little to larval energy metabolism. In inland hatcheries, sea water supply will be limited and recirculating system can be adopted for effective utilisation of the limited supply of sea water (Singholka and Sukapunt, 1982; Manasveta, 1982; Chavez and Ramirez, 1983; Ong, 1983; Vu *et al.*, 1989; Cohen and Ra'anan, 1991, Angell, 1992, 1994; Daniels and D'Abramo, 1992; Daniels *et al.*, 1992; Choudhury *et al.*, 1993). For getting good results biological filter shall be 6% of the total volume of larval rearing medium (Griessinger *et al.*, 1989). Hummel *et al.* (1987) and Hudon *et al.* (1989) compared various factors affecting the mortality in different larval rearing systems. In recirculating systems, two partial (20%) water exchange on

10^{th} and 20^{th} day of 35 day culture were found to be beneficial (Angell, 1992). Chineah and Chooramun (1987) described larval rearing in a recirculating system without the use of antibiotics, water exchange and phytoplanktons. Inland hatcheries were using trucked sea water to meet their requirement both in India (Prakash, 1988) and Thailand (Manasveta 1991). Larval rearing using artificial sea water was attempted by Reddy *et al.* (1991) and Nair and Hameed (1992) whereas, Yambot and Cruz (1986) and Prakash (1988) successfully reared larvae of *M.rosenbergii* in a medium prepared using common salt and salt pan residue. Menasveta (1991) reviewed the use of salt pan brine for prawn larviculture in static water, closed recirculating system and open water culture system. Qureshi *et al.* (1993) attempted seed production of *M.malconsonii* in synthetic sea water. Menasveta (1980) observed an improvement in survival of larvae when ozone treated water was used for larval rearing.

Simple methods for the separation of post larvae from the mixed culture system were devised by Smith and Hopkins (1977a) and Martinez-palacios *et al.* (1985) which were found to be advantageous over dip-net harvesting. However, Daniels *et al.* (1992) found dip-net is more simple and effective. Howlader and Kiortsis (1978) observed more percentage representation of males in the post larvae collected during the early days from the initial period of metamorphosis and larval development and also suggested a method for the selection of fast growing male seeds. Smith and Hopkins (1977b) devised a clear acrylic tank to facilitate hatching and collection of larvae of *M.rosenbergii.* Singh and Philip (1995) explained a photo-flow devise for the separation of weak larvae of *M.rosenbergii* based on the photopositive nature of healthy larvae.

Commercial level larval rearing as well as laboratory culture was attempted in *M.equidens* (Pillai, 1980), *M. lamarrei lammarei* (Jalihal *et al.*, 1982) *M.jelskii, M.amazonicum* (Gamba, 1984), *M.americanum* (Holtschmit and Pfeiler, 1984) *M.holthuisi* (Moreira *et al.*, 1979), *M.australiense* (Lee and Fielder, 1981), *M.lar* (Atkinson, 1977), *M.iheringi* (Brueno and Rodreguez, 1995), *M.choprai* (Prakash *et al.*, 1987) and *M.vollenhovenii* (Willfuehr *et al.*, 1993). Abbreviated larval development of freshwater prawns, *M.niphane* from Thailand, *M.hainannense* from China and *M.pilimanus* from Singapore were described and illustrated in detail (Shokita *et al.*,1991; Wong, 1989; Chong and Khoo, 1987). In vitro incubation of eggs of *M.rosenbergii* and *M.nobilii* were attempted by Stolpe (1976) and Balasund and Pandian (1981) respectively. Pillai (1993) extensively studied the larval development and morphology of 11 caridean prawns including *M.idella, M.equidens* and *M.striatus* of Southwest coast of India

Colorni (1985) studied the bacterial flora associated with the larvae of *M.rosenbergii. Alcaligenes* sp. and *Vibrio* sp. were found to be the most frequently encountered genera of aerobic heterotrophic bacteria in freshwater prawn hatcheries (Anderson *et al.*, 1989). Singh and Philip (1993) found prawn infusion agar is most suitable for the primary isolation of heterotrophic bacteria. Roegge *et al.* (1977) assessed 10 chemicals to control Zoothamnium in the larval rearing system of *M.rosenbergii* and found that 50 ppm formalin was effective in completely controlling the parasite.

Stephenson and Knight (1980) studied oxygen consumption, growth, caloric content and ash content in the larvae of *M.rosenbergii.* Silverthone and Reese (1978) concluded that post larvae stocked in cool ponds

from warm hatcheries might benefit from pre-acclimation to lower temperature. Yaakob (1992) found that the sources of breeders were one of the factors affecting the growth of *M.rosenbergii* larvae in the hatchery. *M.nipponense* was found to have 20% higher survival and faster rate of metamorphosis than *M.rosenbergii* (MacLean and Brown, 1991). The euryhalinity of *M.petersi* larvae was compared with other *Macrobrachium* spp. and different levels of larval survival were discussed in relation to salinity (Read, 1986).

Meyers and Hagwood (1984) conducted studies with a view to evaluate the acceptance of flake feeds by the larvae of *M.rosenbergii.* Lavina and Figueroa (1978), Manzi *et al.* (1980) and Sorgeloos (1980) suggested Artemia as a principal diet of larval stages of *M.rosenbergii.* Better results in terms of growth, metamorphosis rate, survival and stress resistance were observed in larvae of *M.rosenbergii* fed with Artemia enriched with Omega-3 HUFA. Lovett and Felder (1988) reported that larvae of *M.rosenbergii* fed on a diet restricted to *Brachionus plicatilis* had a significantly lower survival and rate of metamorphosis than the larvae fed on a diet that include Artemia. Tuna flesh as a feed for the larviculture of *M.rosenbergii* is being used in hatcheries in Fiji (Kwong, 1984). Studies on the replacement of Artemia with Moina were conducted by Aniello and Singh (1982) and Alam *et al.* (1995). Significantly higher production was obtained when larvae fed with egg custard augmented with cod liver oil during day and overnight with Moina (Alam *et al.*, 1995). Kumlu and Jones (1995) evaluated feeding and digestion of larvae of *M.rosenbergii* fed with Artemia and microgranulated diets. Alam *et al.*(1993b) attempted to wean *M.rosenbergii* larvae from Artemia to Moina and observed a

faster development in larvae fed with weaned food when compared to those fed with Artemia.

Published information are enormous on the status and methods of larval rearing of *M.rosenbergii* from different regions of the world. In Fiji (Kwong, 1984); Singapore (Tay and Ng, 1980) Indonesia (Adisukresno, 1982; Ismail and Cholik, 1982), Malaysia (Ong, 1982) and Thailand (Singholka, 1982a) larval culture of *M.rosenbergii* is being carried out most successfully. Adisukresno *et al.* (1980) reviewed the progress made in the larval rearing of *M.rosenbergii* in Brackish water Aquaculture Development Centre, Japara, Indonesia. Samarasinghe (1983) pointed out the difficulties encountered during the breeding trials on *M.rosenbergii* in Sri Lanka.

An average production of 50 PL/l was reported from high intensity culture of *M.rosenbergii* with the usage of antibiotics (Aquacop, 1977). Alikunhi *et al.* (1980) attained 90% survival of larvae when fed with Moina and 'thelly' meat. Adisukresno *et al.* (1980) observed 72% survival when initial stocking density was maintained at 15L/l while, Malecha (1983) and New (1988, 1990) reported a production of 30L/l and 30-50L/l in Hawaiian and Thai hatcheries respectively. In India a survival of 20% could be achieved in successful runs which is worked out to be 12 PL/l (Sebastian and Nair, 1995), however, higher survival up to 75% could also be obtained in exceptional cases (Sebastian *et al.*, 1993). A post larval production of 6.6 to 40.6/l was achieved when synthetic sea water was used in closed recirculating system for larval rearing (Sandifer and Smith, 1975). Prakash (1988) obtained 74-80% larval survival with a production of 14-15 PL/l when larval rearing was carried out using artificial sea water. Yambot and Cruz (1986) reported a low survival

(6.71%) when a combination of sea salt and deionised water was used for the larval rearing of *M.rosenbergii.* A survival rate of 80% was achieved at metamorphosis in recirculating system when larvae were stocked at a density of 50/l (Daniels *et al.*, 1992).

Nghia (1991) reported improvements in output and cost effectiveness of *M. rosenbergii* larviculture adopting improved management and feeding strategies. Fuller *et al.* (1992) analysed the economics of commercial production of *M.rosenbergii* and opined that minor variations in survival resulted in substantial variability in net returns. Wang and Williamson (1977) described a pilot hatchery capable of producing a continuous output of post larvae of *M.rosenbergii.* Subrahmanyam (1986)presented a design of freshwater prawn hatchery for the successful conduct of larval rearing. Rao (1986) highlighted the important factors affecting hatchery operation of freshwater prawns such as environmental conditions, mechanical failure, power breakdown and human negligence.

As already mentioned, in *M.rosenbergii,* 11 larval stages were reported by Uno and Kwon (1969) representing 11 successive moulting. Under controlled conditions the transition from a free swimming larva to crawling adult like post larva takes place over a period of 15 days (Ling, 1969a) and it may extend up to 36 to 42 days (Suharto *et al.*, 1982; Adisukresno *et al.*, 1980). Moreover, New (1995) pointed out that the spectral quality required for the optimal development of larvae is quite unknown. In Thailand, larval rearing tanks of backyard hatcheries were covered with black tarpaulin to prevent sun-cancer and spread of disease, while, Indian hatcheries preferred semi-transparent roofings (Raju and Nair, 1992; New, 1995). Transparent roof tiles

and special lamps are being used in Taiwan to illuminate the larval rearing tank. (Hsieh *et al.*, 1989). Lin and Omori (1993) reported reduced feeding due to excitation in lighter coloured containers and suggested dull or non-bright coloured environment for the successful larval rearing.

Post larvae showed a rapid increase in size variation following metamorphosis due to large difference in growth rate among individuals within a population (Sandifer and Smith, 1975; Malecha, 1977; Ra'anan and Cohen, 1984). Two distinct types of juveniles have been described viz. jumpers and laggards based on their relative growth rates (Willis and Berrigan, 1977; Karplus and Hulata, 1995). Determination of growth pattern of juvenile prawns was found to occur sometimes between metamorphosis and the early juvenile stage (Karplus *et al.*, 1990b). Howlader and Kiortsis (1978) observed a variation in sex composition in adult population with age at metamorphosis, whereas, Sandifer and Smith (1979) and Karplus *et al.* (1990b) could find out no significant difference in growth of early and late metamorphosing juveniles when raised under laboratory conditions.

3. Vembanad lake

The Vembanad lake, extending to a stretch of 60 km from Cochin bar mouth in the north to Alleppey in south, is the largest estuarine system in the South-west coast of India. It is located between $9^0 28'$ and $10^0 10'$ N latitude and $76^0 13'$ and $76^0 31'$ E longitude with an estimated area of 21,050 ha. The present investigation was undertaken giving due emphasis to the extend of water body designated as "Vembanad lake" whereas, the confluent brackish

water area lying north of Cochin bar mouth and extending up to Azhikode in the north was excluded from this study.

The northern part of the Vembanad lake, near bar mouth is comparatively deeper than its southern region owing to the presence of navigational channel where depth varies from 8-12 m. The other parts of the lake is comparatively shallow with depth ranging from 0.75 to 5 m. Width of the lake varies from about 100m at a few places to about 9 km at Kumarakom. The lake is connected to Arabian Sea at Cochin through a 425m wide channel which is the only source for tidal incursion in to the lake. Tides are of semidiurnal type, showing substantial range and time. Average tidal amplitude near the mouth of the estuary is 0.9m. Until two decades ago, tidal effects were reaching up to Pulinkizhu, approximately 80 km south of the Cochin and the deltaic region of the lower Kuttanad used to become brackish gradually from December onwards, attaining salinity up to 28 ppt in the interior waters (Josanto, 1971).

The lake receives inflow of freshwater through a network of rivers such as Pampa, Manimala, Achencoil, Meenachil and Muvattupuzha. Pampa, and Manimala rivers join together before meeting the Achencoil river at Veeyapuram and all these rivers influx at the southern most part of the lake. River Meenachil opens at the middle of the lake, whereas, River Muvattupuzha opens at northern part in the downstream region. The lake and adjoining canals and rivers have been supporting a lucrative fishery. Fishing had been an important traditional occupation for the inhabitants of the various villages situated adjacent to this lake.

A salinity barrier of 1402 m length was commissioned at Thanneermukkom in 1976 for preventing salt water incursion in to the Kuttanad during December to March and thereby protecting *Punja* crop. The barrier was originally envisaged to be closed for a period of three months from 15th of December to 15th of March every year while shutters remained open during monsoon months so as to facilitate the evacuation of flood water. However, alterations in the operation schedule such as prolonged closure period up to April-May has brought in some adverse effects besides causing serious conflicts between fishermen and agriculturists. Furthermore, a shifting of salinity gradient zone towards the north of the lake has also been resulted. There is practically no tidal exchange in the areas south of the barrier through out the year. Thus, the lake is separated into two entirely different ecosystems, retaining estuarine conditions in the regions from Cochin to Thanneermukkom and transforming the region from Thanneermukkom to Alleppey into almost a freshwater habitat. In the present study the part of lake extending from Cochin to Thanneermukkom is regarded as "downstream region" while the region lying between Thanneermukkom and Alleppey was taken as the "upstream region". The 5 km stretch of the confluent portion of the five major rivers emptying into the lake are designated as "riverine region".

4. Fishery Survey Cruises

The entire stretch of lake extending from bar mouth at Cochin to Alleppey was apportioned to 10 zones (Fig. 1), besides each 5 km stretch of the adjoining rivers Pampa, Manimala, Achencoil, Meenachil and

Muvatttupuzha were taken as three zones (Fig. 1). Boundaries and approximate area of each zones are presented in Table 1 . Cruises were carried out in Vembanad lake and adjoining rivers on a monthly basis from March 1994 to February 1996 with the help of a 25 feet fibre glass boat, M.B. King Fisher of the School of Industrial Fisheries. 29 stations representing the 13 zones of the lake were also selected for sampling to delineate the pattern distribution of different *Macrobrachim* spp. in the lake (Fig. 1). The availability of different species in various zones of the lake was assessed by examining the exploited catch and also by conducting local enquiry and experimental fishing. Surface and bottom water samples from one station representing each zone were also collected for recording physico-chemical parameters viz. temperature, salinity, dissolved oxygen and pH. Samples of *M.rosenbergii* for bionomics were collected during the fishery survey cruises from the upper regions of the lake in order to assure an year round availability of specimens. Whereas, samples of *M.striatus* were collected from Kumbalam (Fig. 1) situated in the downstream region of the lake as there was regular operation of the indigenous gear ('padal') for the exploitation of this species. Different male morphotypes and berried females for the experiments on broodstock rearing, broodstock transportation and larval rearing was collected from the lake during the fishery survey cruises and transported to the laboratory as per standard procedures.

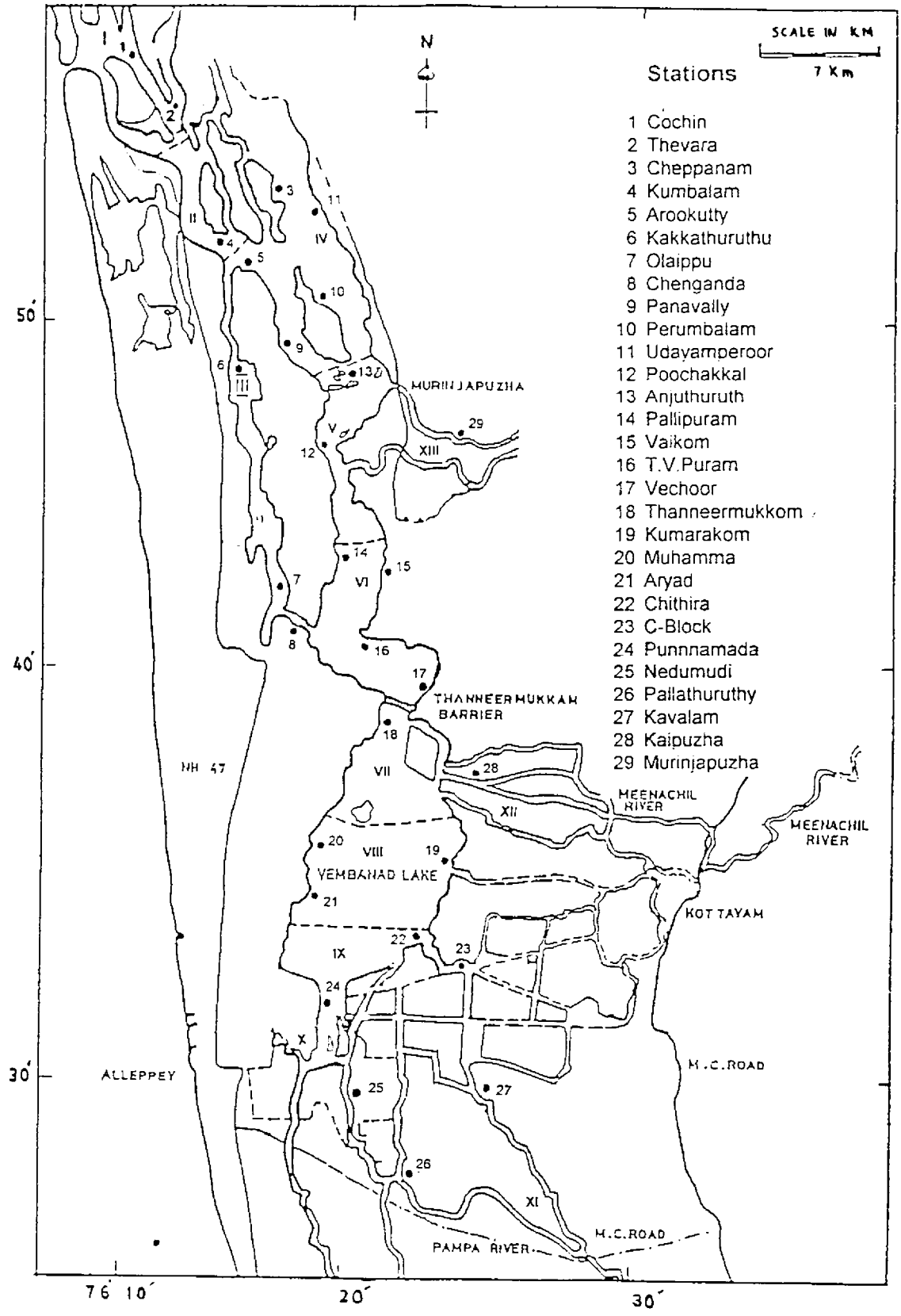


Fig. 1. Vembanad lake showing cruise zones and stations of sampling

Table 1. Boundaries and area of cruise zones in the Vembanad lake selected for the observation of physico-chemical parameters of water and sampling.

Zones	Boundaries	Area (ha)
1	Cochin bar mouth - Thevara	1745.0
2	Thevara - Arookutty	2497.0
3	Arookutty - Chenganda	1237.0
4	Arookutty - South Paravoor	3076.0
5	South Paravoor - Manpuram	1085.0
6	Neriakadavu - Thanneermukkom	2803.0
7	Thanneermukkom - Pathiramanal	2000.0
8	Pathiramanal - North of Marthandam kayal	3689.0
9	Rani kayal - Punnamada	2196.0
10	Punnamada - Nedumudi - Kainakari	725.0
11	Kainakari - Kavalam - C-block	1087.1
12	Kaipuzha river	395.7
13	Muvattupuzha river	150.0

Section 2

Systematics and Distribution

Chapter 1 Systematics of *Macrobrachium* spp.

Chapter 2 Ecology and Distribution of *Macrobrachium* spp.

Chapter 1

Systematics of *Macrobrachium* spp.

Introduction

Palaemonid prawns support a lucrative fishery in inland water bodies on a global basis and the genus *Macrobrachium* Bate, 1868 accommodates a number of species having commercial importance. The freshwater prawn fishery of Vembanad lake is mainly constituted by the genus *Macrobrachium* with six species in the exploited stock. The morphological variations shown by the species are basically used as taxonomic tool in the crustacean systematics and the characters often given due importance are nature of rostrum and its spines, carapace, carinae and sulcii, carination of abdomen, telson and appendages (George, 1969). Johnson (1973) expressed the view that changes in the shape and armature of 2nd cheliped due to simple allometric growth process may serve as a useful character in differentiating closely related species. De Man (1904), Calman (1913) and Kubo (1940) provided detailed taxonomic descriptions of the genus *Palaemon* collected from Tahiti Islands, Madagascar and Japan respectively. Holthuis (1950, 1952a and b, 1956, 1966, 1969) recorded variations within and between species, made a detailed study on the distribution and taxonomy and also exhaustively reviewed the subfamily Palaemonidae. Lanchester (1901, 1906) studied taxonomy of crustaceans including *Macrobrachium* spp. while Roux (1935, 1936) revised the geographical distinction of Decapod Crustaceans collected from Malay peninsula. Studies on the taxonomy and distribution of *Macrobrachium* spp. of Indian waters are limited to Henderson and Matthai (1910), Patwardhan (1937) Natraj (1942), Kurian (1954) and John (1958). A detailed survey on the

palaemonid resources of south-west coast of India was carried out by Jayachandran (1984, 1987) and Jayachandran and Joseph (1989a) and reported 17 species belong to genera *Palaemon* and *Macrobrachium*. Description of new species of freshwater prawns of the Indian waters are those of Tiwari (1949), Jayachandran and Joseph (1985a, 1986, 1992), Jalihal *et al.* (1988) and Pillai (1990a). Fishery and biology of *M. rosenbergii* have been reported from Bengal (Chopra, 1943; Rajyalakshmi, 1961) and Kerala (Panikkar and Menon, 1955; Raman, 1967; Kurup *et al.*, 1992a).

Sokel and Sneath (1963) appraised the importance of numerical methods for evaluating the extent of affinity or similarity between taxonomic groups. Whereas, Huxley (1932) tried to put a quantitative expression to the differential growth between body as a whole and an organ whose proportion changes during growth. Morphometric studies on palaemonid prawns were carried out notably by Tiwari (1963), Rao (1967), Koshy (1969,1971,1972) and Jayachandran and Joseph (1985b, 1988) with a view to establish the relationship between the pattern of growth of body parts, to bring out sexual dimorphism and also for species level differentiation. Tazelaar (1930) established a bimodality in claw length of *M. rosenbergii* (=*P.carcinus*) from natural habitat. Yaldwyn (1957) studied the morphometric characteristics of *Palaemon affinis* while Jayachandran and Joseph (1985b & 1988) and Jayachandran and Balasubramanian (1987) established the morphometric relationships of body parts of *M. idella* and *M.scabriculum*. However, very few number of morphometric characters were used in the above studies. Misra (1958) coined a new equation for studying the growth gradient in the podomeres of second cheliped of Palaemonids based on the data of *Palaemon hendersonii*. Misra

(1959) also studied the growth of podomeres of the second cheliped of four species of *Macrobrachium.* Cole (1958) reported the morphometry of *Palaemon serratus* while Koshy (1969) examined morphometry of *M.lamerrei.* Sex specific variations in the growth of *M.dayanus* (Koshy, 1971), *M.lamerrei* (Koshy, 1972) and *M. malcomsonii* (Rajyalakshmi, 1980) have already been established. Weight, the usual measurement of overall growth does not provide a most useful reference dimension for studying the relative growth of body parts of *M.rosenbergii* because the changes in body parts will also contribute to the changes in weight (Kuris *et al.*, 1987).

In grow-out systems, males of *M. rosenbergii* are characterised by the heterogeneous individual growth (HIG) (Smith *et al.*, 1978; Brody *et al.*, 1980). In the adult male population of *M. rosenbergii,* morphologically distinguishable individuals were differentiated viz. small males (SM), orange clawed males (OC) and blue clawed males(BC) based on colouration, relative body size, cheliped characteristics, growth pattern and hierarchical dominance (Cohen *et al.*, 1981; Ra'anan, 1982; Sagi, 1984; Teleckey, 1984; Ra'anan and Cohen, 1985; Ra'anan and Sagi, 1985; Kuris *et al.*, 1987; Karplus *et al.*, 1992a and b). The above three morphotypes differ each other morphologically, anatomically and physiologically and the hierarchy among them are closely associated with social roles and reproductive behaviour (Sagi and Ra'anan, 1988). These three morphotypes represent the developmental stages in the maturation process of males of *M. rosenbergii* and are known to undergo transformation from SM→OC→BC in an irreversible order (Cohen *et al.*, 1981). Besides, two transitional stages of OC viz. weak orange clawed males (WOC) and pre-transforming orange clawed males (t-SOC) were also

distinguishable of which the former being an intermediate stage between SM and OC and the latter between OC and BC and, therefore, fully differentiated OC are known as strong orange clawed males (SOC). Small males occupy the initial stage of developmental pathway and they are subordinates, not territorial, reproductively competent and sexually active (Ra'anan, 1982; Sagi, 1984; Teleckey, 1984; Ra'anan and Cohen, 1985). In contrast, OC are subdominant, not territorial and reproductively submissive and this is a stage of faster somatic growth (Ra'anan, 1982; Sagi, 1984; Ra'anan and Cohen, 1985). BC represents the final stage of morphogenesis which are large, reproductively active, territorial, dominant and is characterised by slow growth rate (Ra'anan, 1982; Sagi, 1984; Ra'anan and Cohen, 1985). Harikrishnan and Kurup (1997a) identified morphotypic differentiation in natural population of *M.rosenbergii* similar to that in the culture system and brought out the heterogeneous nature of the BC morphotype comprising of weak blue clawed (WBC) and strong blue clawed males (SBC). BC with relatively small body size with disproportionate second cheliped is differentiated as old blue clawed males (OBC) (Sagi and Ra'anan, 1988). The above morphotypes are phenotypically distinct and their morphometric variations were studied in detail with a view to differentiate and distinguish them morphologically (Kuris *et al.*, 1987; Kurup *et al.*, 1997a; Harikrishnan, 1997). Colour and spination generally provide a reliable basis for the easy separation of these morphotypes (Kuris *et al.*, 1987).

The female population is rather homogeneous with regard to size and weight and hitherto no morphotypic differentiation was reported in earlier studies based on grow-out systems (Cohen *et al.*, 1981; Ra'anan and Cohen, 1985; Kuris *et al.*, 1987). However, three morphotypes among females were

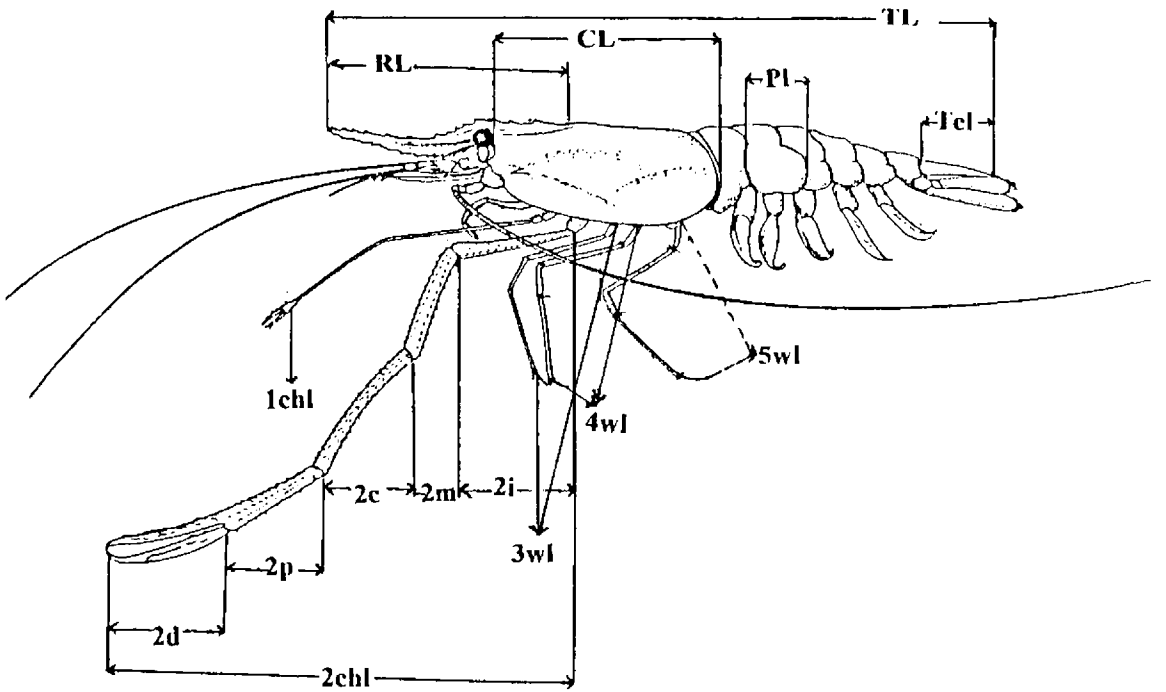
reported on the basis of their stage of maturity viz., virgin females (VG or VF), berried females (BE or BF) and open brood females (OP or OF) (D'Abramo *et al.*, 1991; Daniels and D'Abramo, 1994). Recently, Harikrishnan and Kurup (1997a) and Harikrishnan *et al.* (1998) established the morphotypic differentiation in the female population also identical to their male counterparts. Though the size and morphological difference were not found so conspicuous in females as in the case of males, it can easily be differentiated by noting the claw colouration, claw characteristics and also on the basis of morphometry (Harikrishnan, 1997; Harikrishnan *et al.*, 1998). The female morphotypes so identified are small females (SF), orange clawed females (OF) and blue clawed females (BF). Small females morphologically resemble SM but for the absence of appendix masculina and the genital pore is situated at the base of 3rd pereopod. The transitional stages of orange clawed females viz. weak orange clawed females (WOF) and transforming orange clawed females (TOF) are also distinguishable from the fully differentiated strong orange clawed female (SOF) similar to their male counterparts. Similarly, weak blue clawed females (WBF) and strong blue clawed females (SBF) could also be differentiated. On the contrary, female counterpart of OBC males could not be encountered in the population (Harikrishnan and Kurup, 1997a).

Against this background an attempt was made to study the allometric relationships in different species of *Macrobrachium* as well as various morphotypes of *M.rosenbergii* collected from the exploited stock of Vembanad lake.

Materials and Methods

Specimens for the present study were collected from various fishing gears operated at 29 different stations representing 13 zones of the Vembanad lake (Fig. 1). Species level identification of the genus *Macrobrachium* was done following George (1969) and Jayachandran and Joseph (1992). Detailed descriptions of various species were made on the basis of present observations and also in due consultation with George (1969), Holthuis (1980), Jayachandran and Joseph (1992) and Pillai (1990a). Male and female morphotypic forms of *M. rosenbergii* were also identified on the basis of Harikrishnan and Kurup (1997a).

Morphometric analysis was carried out in six species so identified from the lake, based on 15 different body parameters with a view to establish the variations, if any, in the relative proportion of various morphometric measurements. The parameters so considered are total length, carapace length, rostral length, length of telson, pleural width, length of first cheliped, lengths of each podomeres in the second cheliped viz. ischium, merus, carpus, propodus and dactylus, total length of 2nd cheliped and length of 3rd, 4th and 5th walking legs (Fig. 1.1) All the measurements were taken in millimetres. Total length was taken as the length between tip of the rostrum to tip of the telson with the help of a ruler whereas carapace length and rostral length were measured using Vernier-Caliper, from posterior margin of right orbit to the posterior most margin of the carapace and tip of the rostrum to the base of the last rostral spine respectively. Telson was measured from its proximal margin to the distal tip and the pleural width was measured at the widest part of the pleural flap of the second abdominal segment. Total length of the chelipeds and walking legs were



TL - Total Length	2i - Length of Ischism of 2nd Cheliped	1chl - Length of 1st Cheliped
CL - Carapace Length	2m - Length of Merus of 2nd Cheliped	2chl - Length of 2nd Cheliped
RL - Rostral Length	2c - Length of Carpus of 2nd Cheliped	3wl - Length of 3rd Walking Leg
Tel - Length of Telson	2p - Length of Propodus of 2nd Cheliped	4wl - Length of 4th Walking Leg
Pl - Width of 2nd Pleura	2d - Length of Dactylus of 2nd Cheliped	5wl - Length of 5th Walking Leg

Fig. 1.1 Schematic diagram showing various morphometric measurements recorded in *Macrobrachium rosenbergii* and *M.striatus*

taken along their extended length with a ruler from the proximal base of the ischium to the distal end of dactylus. Measurement of each podomeres were recorded following Kuris *et al.* (1987). Morphometric characters used for the differentiation of male and female morphotypes were total length, carapace length, rostral length, length of telson, width of second abdominal pleura and length of each podomere and total length of second cheliped. In *M.scabriculum,* the chelipeds are unequal and therefore the measurements of the larger cheliped was recorded.

435 males and 189 females of *M. rosenbergii* belonging to various morphotypic forms were analysed for elucidating the morphotype wise difference, while an assorted group comprising 106 males and 117 females were used for the species level analysis. 132 males and 106 females of *M. idella*, 98 males and 107 females of *M. equidens*, 112 males and 103 females of *M. striatus*, 40 males and 30 females of *M.scabriculum* and 15 males of *M. rude* were also used for morphometric studies. The data so obtained were subjected to statistical analysis (Snedecor and Cochran, 1967). For the morphometric analysis males of *M.rude* could only be collected during the present study as the presence of this species could be found sparsely only from one station.

Ratios of above morphometric measurements with the respect to total length, carapace length and lengths of carpus and merus of second cheliped were worked out. These ratios were tabulated and compared in order to delineate the species level and morphotype wise differences.

Allometric growth technique (Kuris *et al.*, 1987) was employed by applying the equation $Y=a-bX$, where a and b are regression parameters. Rate of growth of independent variable relative to reference character was

considered negatively allometric if b<1, positively allometric if b>1 and isometric if b=1 following Kuris *et al.* (1987). Comparative variations in rostral length and lengths of merus, carpus and propodus with respect to total length and carapace length were usually considered as basic criteria for the differentiation of species of the genus *Macrobrachium* (George, 1969; Jayachandran and Joseph, 1992) and therefore these characters were selected for detailed statistical analysis. Regression coefficients (b) of different species estimated for rostral length, lengths of merus, carpus and propodus of second cheliped and total length of second cheliped by treating total length and carapace length as independent variables were compared using analysis of covariance (ANACOVA) and the difference between the individual species were tested using *t*-test (Snedecor and Cochran, 1967). Coefficient of determination (d) which is an index of relationship between two variables was also calculated for each species.

D^2-Analysis (Rao, 1957) was carried out with the above fifteen morphometric characters to quantify the extent of sexual dimorphism seen in individual species and also to bring out the morphological variation among the species. Preliminary studies showed that there exist clear sexual dimorphism and therefore, sex wise analysis was done in all the species studied. In both *M.scabriculum* and *M.rude*, many of the relationships were found to be non-linear and therefore, for D^2 analysis only those characters showing linearity viz. Total length, Carapace length, Rostral length, Length of 1st cheliped, Lengths of 3rd and 4th walking leg were only considered.

In order to differentiate *M.equidens* and *M.striatus* morphologically, 105 different ratios were worked out with the selected 15 morphometric

measurements as given above to nullify the variation in the size of samples. 15 ratios which showed linearity to each other were selected for further analysis using D^2 statistics for differentiating the variation in morphology between *M. equidens* and *M. striatus*..

D^2 analysis and analysis of covariance were not performed in male and female morphotypes of *M. rosenbergii* because detailed analysis in these lines have already been carried out (Harikrishnan, 1997).

Results

6 species of the genus *Macrobrachium* Bate, 1968 viz. *M. rosenbergii*, *M. idella*, *M. equidens*, *M. striatus*, *M.scabriculum* and *M. rude* were identified from the Vembanad lake.. Male morphotypic forms of *M. rosenbergii* viz. small males (SM), orange clawed males (OC) and blue clawed males (BC) could be collected and identified during the present study. Transitional stages of orange clawed males such as weak orange clawed (WOC), strong orange clawed (SOC) and pre-transforming strong orange clawed males (t-SOC) as well as the transitional stages of blue clawed males such as weak blue clawed (WBC), strong blue clawed (SBC) and old blue clawed males (OBC) could also be collected and identified. Detailed description of the above six species together with complete synonymy and pattern of regional distribution are presented. Besides, various morphotypes and their transitional stages of *M. rosenbergii* are also described.

1. Description of Species

Taxonomic position

Sub order : Natantia Boas, 1880

Infra order : Caridea Dana, 1852

Super family : Palaemonoidea Rafinesque, 1815

family : Palaemonidae Rafinesque, 1815

Genus : Macrobrachium Bate, 1868

1.1 Macrobrachium Bate, 1868

Characters of taxonomic value:

Pleura of second abdominal somite overlapping those of first and third segments. Carapace cylindrical with a prominent laterally compressed rostrum with teeth on dorsal and ventral sides. Gills phillobranchiate, upper antennular flagellum bifid. No epipodites on legs. Carpus of 2nd pair of pereopods entire, not segmented. No chela on third pereopod. Branchiostegal spine absent, anterior margin of carapace below antennal spine unarmed. Hepatic spine present dactylus of last 3 legs normal, not bifid. Males having appendix musculina and an appendix interna on the endopodes of second pleopod.

General distribution:

Members of the genus *Macrobrachium* are distributed through out the tropical and sub-tropical zones of the world. Holthuis (1980) detailed useful information on distribution, local names and habitat of commercial species coming under this genus. Many *Macrobrachium* spp. have been transplanted from their natural habitat to other parts of the world both for research and farming (New and Singholka, 1985).

1.2 Key to the Species of the Genus *Macrobrachium* Bate, 1868 of the Vembanad lake

1. Rostrum long and upturned 2
   Rostrum short and dorsally convex 5

2. Propodus (chela) longer than carpus.....3
   Propodus shorter than carpus.....*M. idella*

3. Rostrum very long with a prominent basal crest, serration not uniform .....*M. rosenbergii*
   Rostrum moderately long , uniformly serrated 4

4. Rostrum straight and extending barely up to anterior margin of antennal scale. 5-6 longitudinal stripes on the body ....*M. striatus*

   Rostrum slightly upturned and reaching beyond antennal scale. Greyish spots on the body with larger spots on carapace ..... *M. equidens*

5. Carpus distinctly longer than merus, 4-5 ventral spines on rostrum..... .... *M. rude*

   Carpus equal to or slightly longer than merus, 2-3 ventral spines on rostrum.....*M.scabriculum*

1.3.1 *Macrobrachium rosenbergii* (De Man, 1879) (Plate 1.1 A&B)

Palaemon rosenbergii De Man, 1879

Synonymy:

Palaemon carcinus rosenbergii Ortman, 1891

Palaemon whitei Sharp, 1893

Palaemon (Eupalaemon) rosenbergii Nobili, 1899

Palaemon spinipes Schenkel, 1902

Palaemon decqueti Sunier, 1925

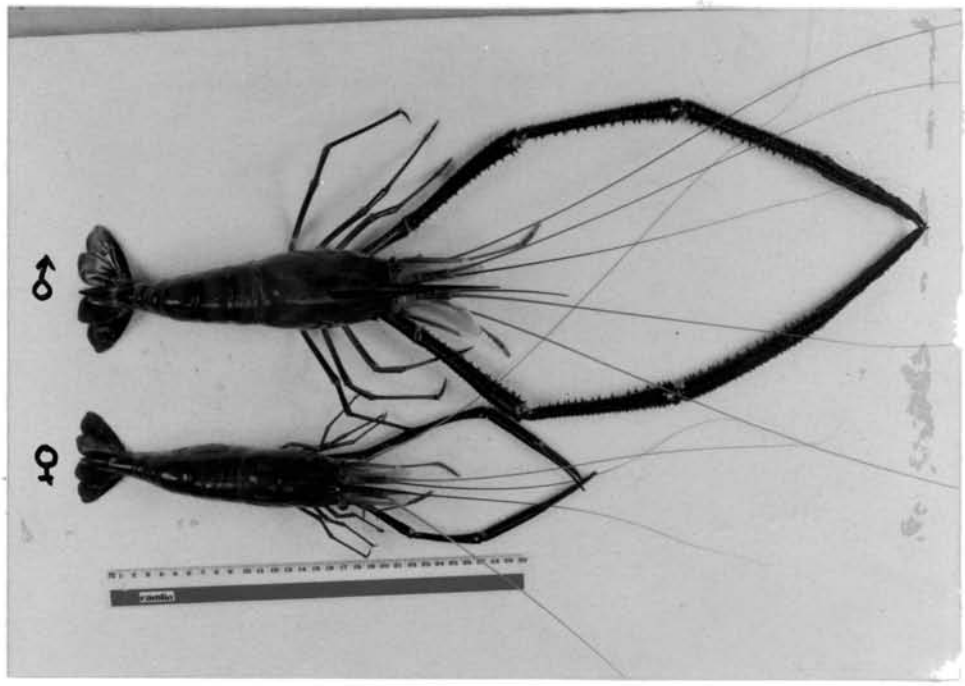
Cryphiops (Macrobrachium) rosenbergii Johnson, 1966

Distinguishing characters

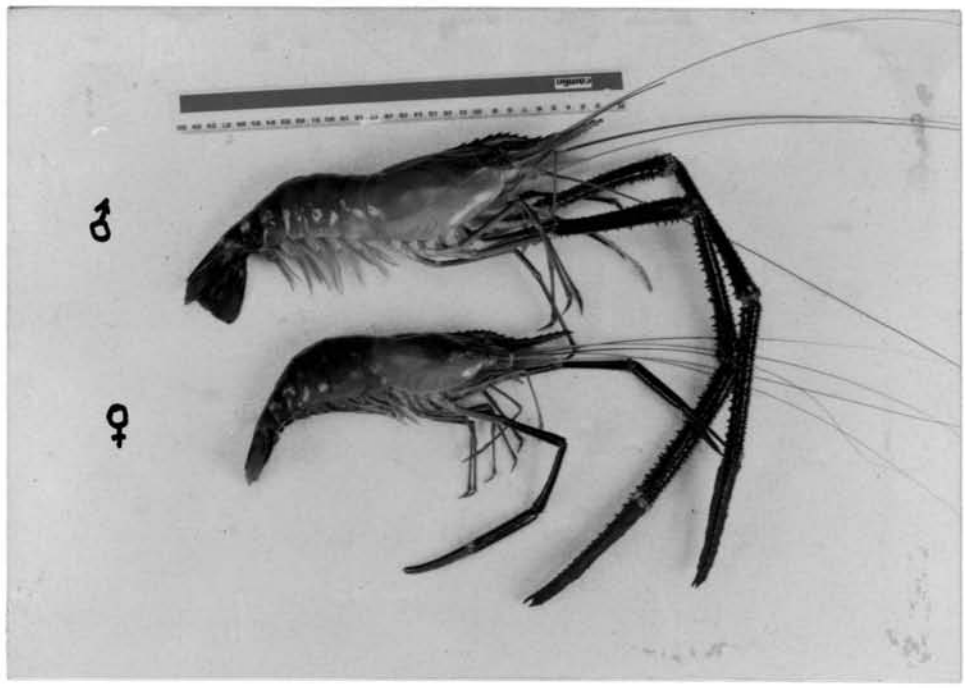
Rostrum slender, long and upturned which extending beyond the antennal scale, with a prominent basal crest. Both the margin of rostrum are armed with normally 11-14 dorsal and 8-14 ventral teeth. The second chelipeds are strong and equal or sub equal, more than body length and with strong spines in adult males whereas more than half the body length with feeble spination in sub-adults of males and females. The joints in second chelipeds are beset with broad based spines which are less strongly developed in ischium and movable finger. Carpus of the 2nd pereopod in adult male slightly longer than half as long as chela. Fingers of 2nd cheliped is of same length as the palm. Tip of the telson is acutely pointed and the sub-terminal spinules do not reach the tip of telson.

Colouration: Body dark grey or yellowish grey with 5 to 7 horizontal stripes in carapace of juveniles. Often orange patches at the articulations of the

Plate 1.1



A. *Macrobrachium rosenbergii* (De Man) -- Dorsal view



B. *Macrobrachium rosenbergii* (De Man) -- Lateral view

abdominal segment. 2nd pereopods deep blue or orange or bluish orange and the pubescence grey. Rest of the pereopods and pleopodes dull white with yellowish or bluish hue.

Distribution and economic importance

Macrobrachium rosenbergii is the most commercially important species of the genus *Macrobrachium* and is indigenous in the whole south and south west Asian areas as well as northern Oceania and in the western Pacific islands (Holthuis, 1980). Quereshi (1956) reported the occurrence and fishery of this species from Pakistan. Occurrence of *M. rosenbergii* and its exploitation have reported from Bangladesh (Ahmad, 1957), Malaysia and Indonesia (Johnson, 1968), Thailand (Longhurst, 1970) and Sri Lanka (Jinadasa 1985). *M.rosenbergii* has been transplanted to more countries especially to Hawaii, Mauritius, Central and South America, Tahiti etc. (New and Singholka, 1985).

Jones (1967) reported a regular fishery of this species from different parts including Bombay coast, Kerala and Northern half of the coast of Bay of Bengal and Raman (1967) dealt extensively with the fishery and biology from the Vembanad lake, South India. Longhurst (1970) stated that in S.W. India *M. rosenbergii* caught in very limited quantities in certain areas only. Kurian and Sebastian (1976), Raman (1967) and Kurup *et al.* (1992a) delineated monsoon and post-monsoon as the peak fishing seasons, however, the catch started dwindling owing to indiscriminate fishing and man-made ecological transformations.

Morphotypes of *Macrobrachium rosenbergii* (De Man)

1) Male morphotypes

Three male morphotypes viz. (1) small male (SM), (2) fully differentiated orange clawed male, strong orange clawed males (SOC) and (3) fully differentiated blue clawed male, strong blue clawed males (SBC) could be collected from the Vembanad lake. Two transitional stages of OC viz. weak orange clawed (WOC) and pretransforming orange clawed male (t-SOC) and that of BC viz. weak blue clawed male (WBC) and old blue clawed male (OBC) could also be differentiated from this water body.

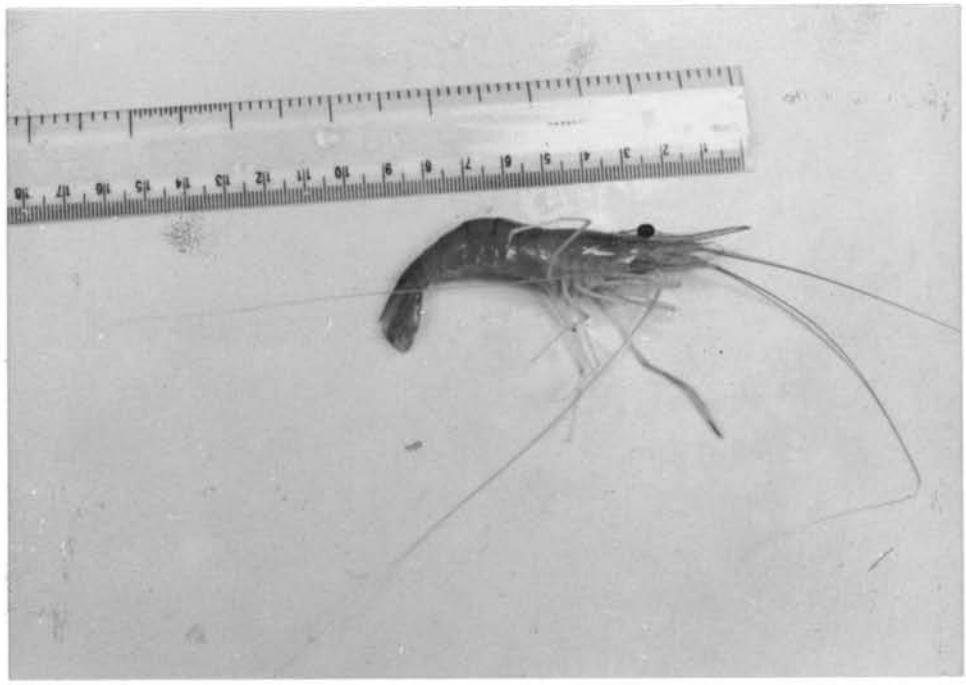
i) Small Male (SM) (Plate 1.2A)

SM is the first stage of male morphogenesis. Body very small ranging from 75 to 139 mm in total length and the colour pattern is quite variable. Body translucent with light greyish colouration. 2nd cheliped also translucent with bluish hue on the sides of the propodus and fixed finger blue. Carpus may have a red band on the distal end. A red spot on propodus at the point of articulation with dactylus. Dactylus is slightly yellowish. Chelipeds devoid of spination and the surface is more or less smooth.

ii) Weak Orange Clawed Males (WOC) (Plate 1.2B)

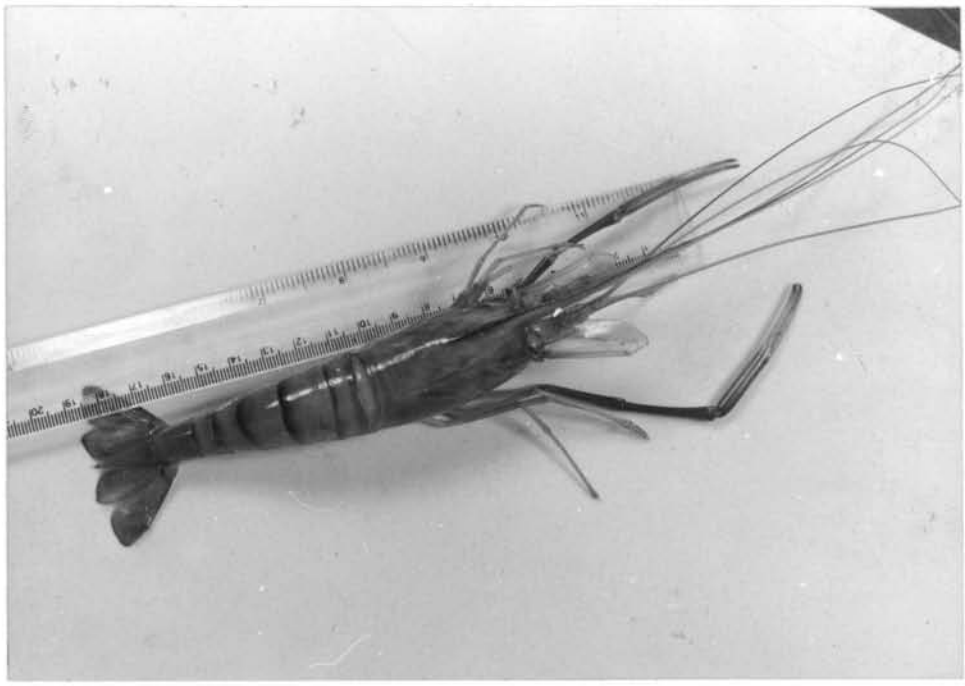
WOC is the transitional stage between SM and SOC. Characterised by weak 2nd cheliped which is orange in colour. Spination of 2nd cheliped feeble that imparts its surface a rough appearance. Most of the portion of propodus is orange in colour. Inner median sides of the ischium, merus and

Plate 1.2



A. *Macrobrachium rosenbergii* (De Man)

Small Male (SM)



B. *Macrobrachium rosenbergii* (De Man)

Weak Orange Clawed Male (WOC)

carpus with orange chromatophore, whereas, outer proximal area suffused with blue pigments. Dactylus yellowish orange and naked.

iii) Strong Orange Clawed Males (SOC) (Plate 1.3A)

Representing second stage of male morphogenesis. Large animals ranging in total length from 155 to 284 mm, characterised with strong chelipeds with orange colouration. Ischium, merus and carpus possess stout spines and the colouration is similar to that of WOC. Propodus orange in colour with whitish medial face. Spines on propodus fragile and orange in colour with a black horny tip. Spines on the cheliped form an acute angle (30-45°) with the surface of the chelipeds. Dactylus fully covered with greyish brown hairs.

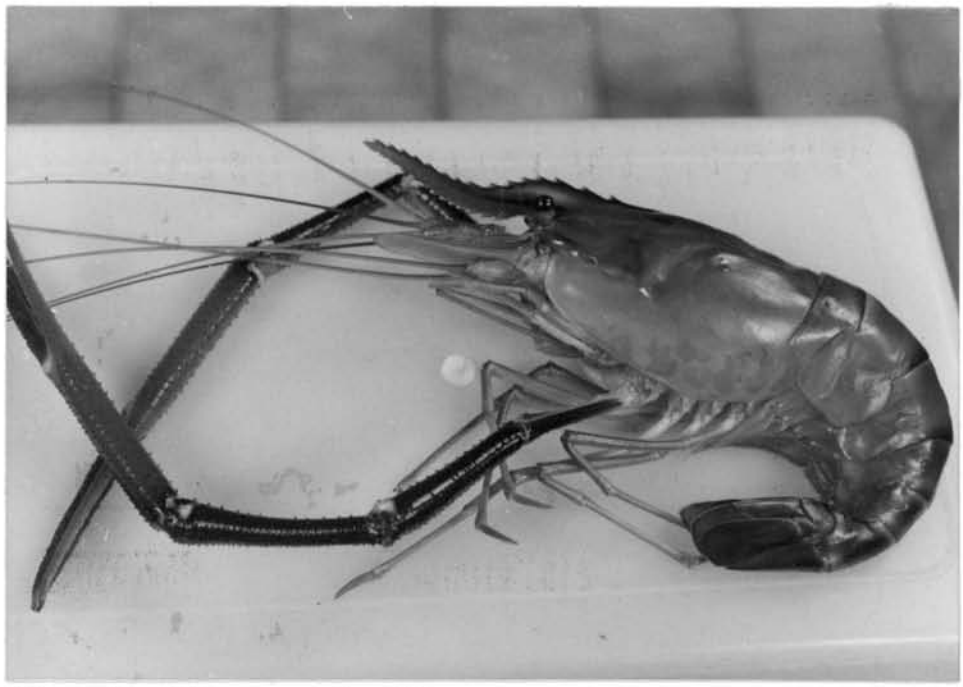
iv) Pre-transforming Strong Orange Clawed Males (t-SOC) (Plate 1.3B)

This is the transitional stage between OC and BC. This group is found to be more heterogeneous in nature as the perceptible variation could be observed in total length from 106 to 293 mm. Body size and colouration resemble WOC and SOC, but can easily be distinguished by the presence of bluish colouration which may be replacing orange colouration which can be taken as the first sign of transformation to BC.

v) Weak Blue Clawed Males (WBC) (Plate 1.4A)

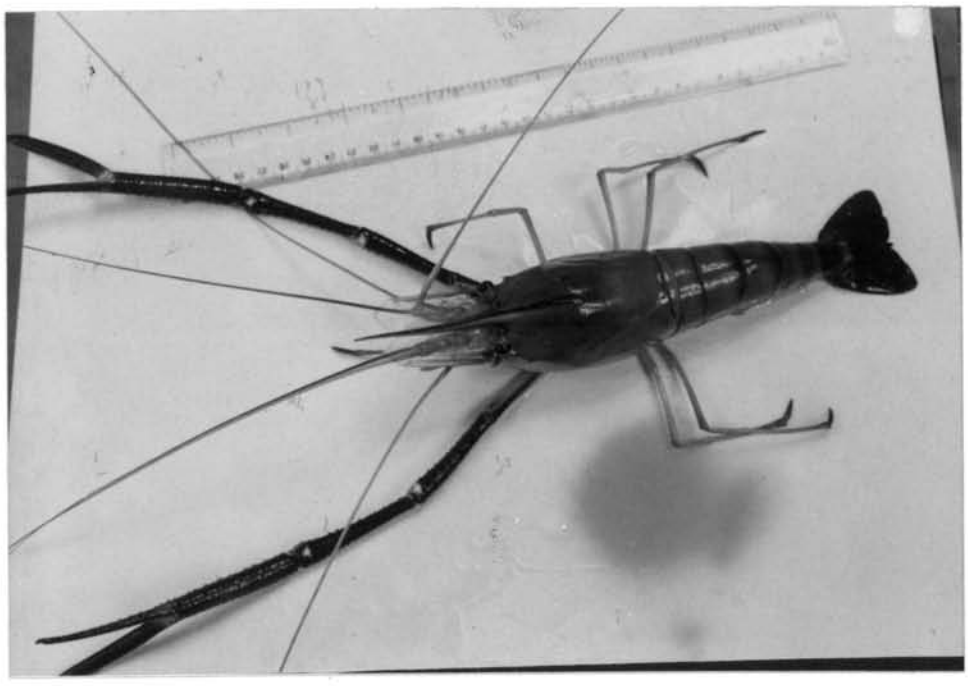
Body size of this group rather heterogeneous with total length ranged from 108 to 258 mm. Chelipeds characterised by deep blue colouration

Plate 1.3



A. *Macrobrachium rosenbergii* (De Man)

Strong Orange Clawed Males (SOC)



B. *Macrobrachium rosenbergii* (De Man)

Pre-Transforming Strong Orange Clawed Male (t-SOC)

with feeble spination and naked dactylus. Inner surface of ischium, merus and carpus are light bluish.

vi) Strong Blue Clawed Males (SBC) (Plate 1.4B)

Representing 3rd morphotypic stage of male morphogenesis. Large animals with total length ranging from 178 to 289 mm. Characterised by the presence of a deep blue or peacock blue, large and strong cheliped. Stout spination on ischium, merus and carpus and the spines are deep blue in colour and forms an angle 60-75° with the surface of cheliped. Dactylus have a thick covering of greyish brown plumes.

vii) Old Blue Clawed Males (OBC) (Plate 1.5A)

Largest individuals ranging from 248 to 354 mm in total length, representing the terminal position of male morphotypic transformation pathway. Presence of exceptionally large cheliped longer than total length which are disproportionate with body length. Colouration and spination similar to that of SBC.

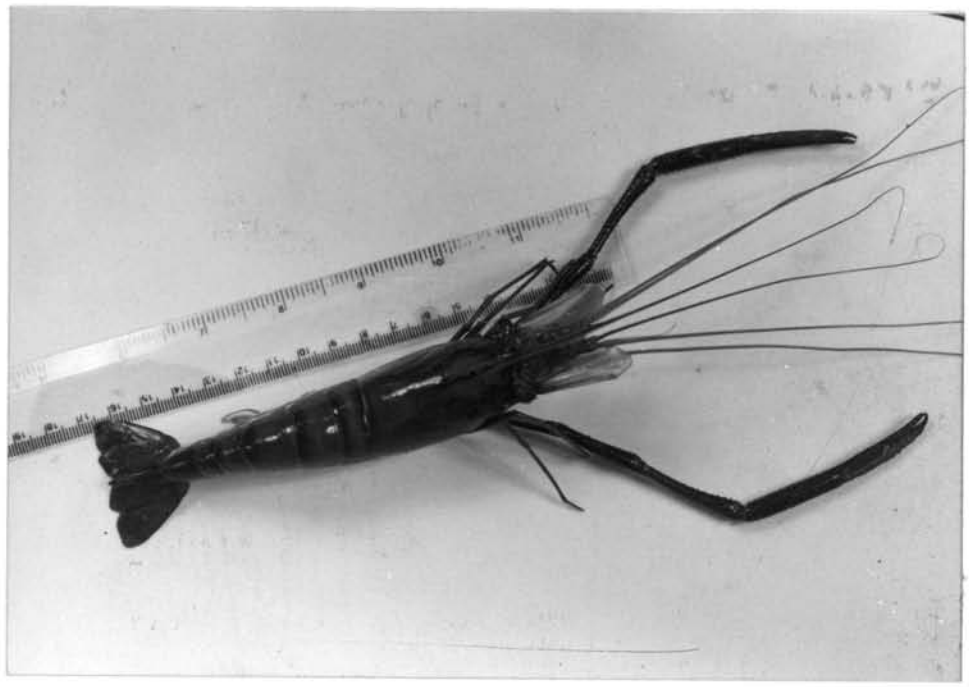
2) Female Morphotypes

Three morphologically distinguishable forms could be identified among female population, identical to that of male population. Eventhough there is no perceptible variation in their size and morphology similar to that of their male counterparts, however, their easy differentiation is possible based on colour pattern and pattern of spination on the podomeres of 2nd cheliped. Three

Plate 1.4

A. *Macrobrachium rosenbergii* (De Man) –

Weak Blue Clawed Male (WBC)



B. *Macrobrachium rosenbergii* (De Man)

Strong Blue Clawed Male (SBC)

female morphotypes such as small females (SF), strong orange clawed females (SOF) and strong blue clawed female (SBF) could be distinguished in the female population. Two transitional stages of SOF viz, weak orange clawed females (WOF) and transforming orange clawed females (TOF) and one transitional stage of SOF viz. weak blue clawed female (WBF) could also be differentiated in the exploited stock. Only a very few SF could be collected during the present investigation.

i) Small Female (SF) (Plate 1.5B)

Females having very small translucent body (≈98 mm). Podomeres of the 2nd cheliped are also translucent, suffused with light blue pigments. Resembles small males but distinguishable by the lack of appendix masculina and position of opening of genital pore at the base of 3rd pereopod.

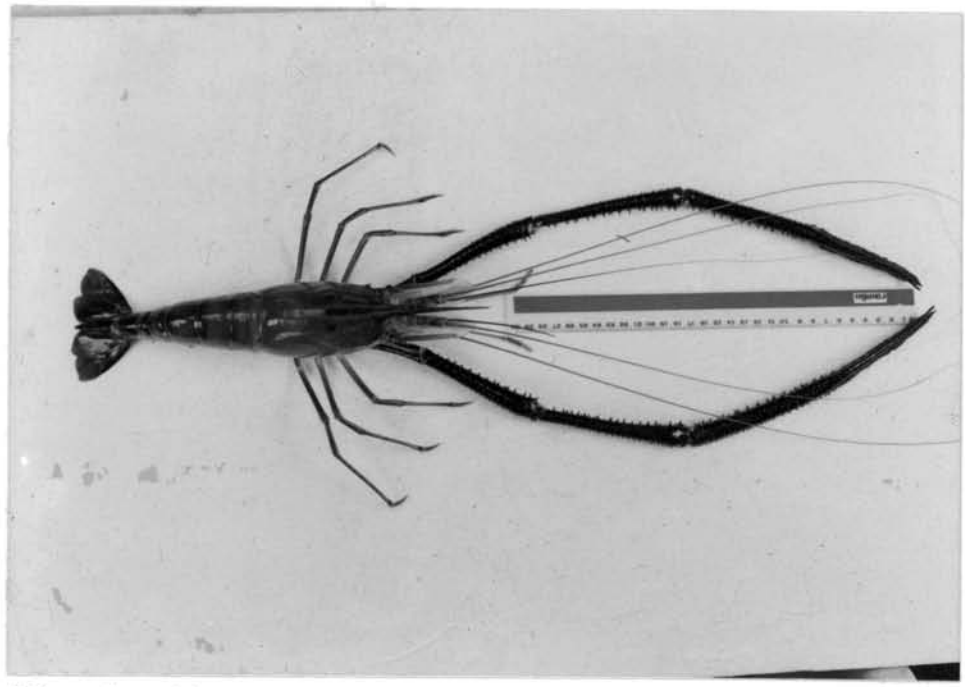
ii) Weak Orange Clawed Female (WOF) (Plate 1.6A)

Representing transitional stage between SF and SOF. Total length ranges from 159 to 210 mm. Characterised by a weak 2nd cheliped with light yellowish or orange colouration and feeble colouration. Outer face of ischium, merus and carpus suffused with light blue pigments. Lateral and dorsal surfaces of propodus orange in colour while tip of the fingers ending in bluish spine.

iii) Strong Orange Clawed Female (SOF) (Plate 1.6B)

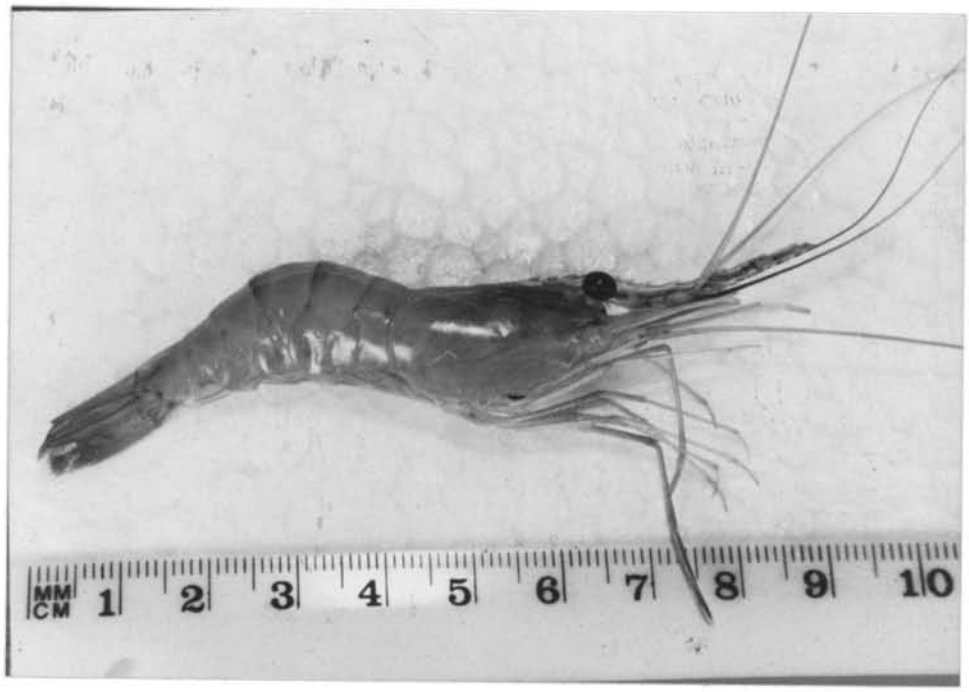
Representing second female morphotypic stage. 2nd cheliped is large with distinct spines on propodus when compared to that of WOF. Inner

Plate 1.5



A. *Macrobrachium rosenbergii* (De Man) –

Old Blue Clawed Male (OBC)



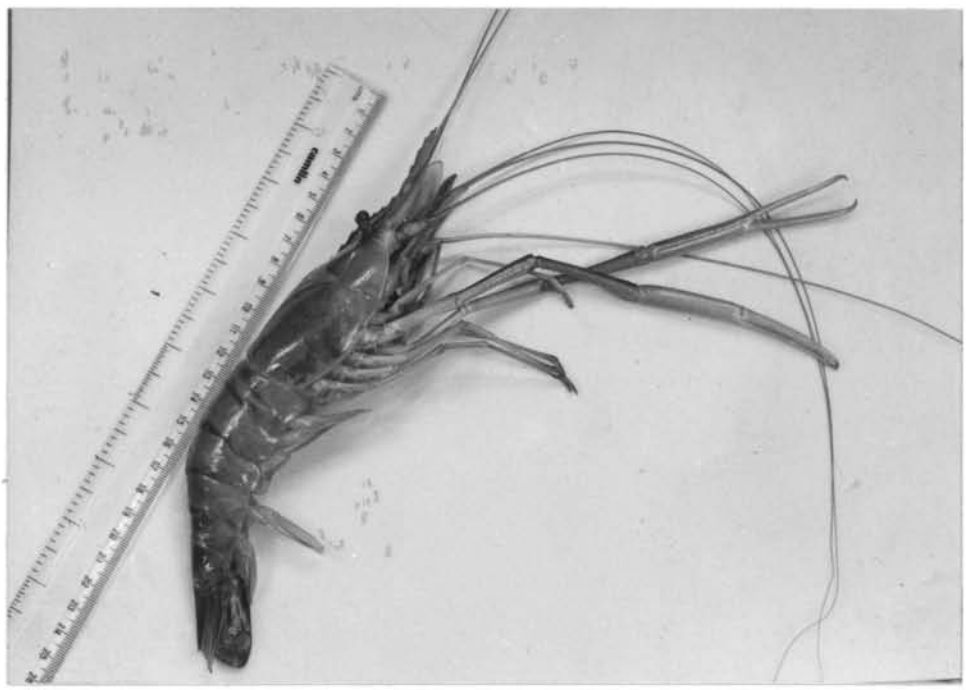
B. *Macrobrachium rosenbergii* (De Man)

Small Female (SF)

Plate 1.6

A. *Macrobrachium rosenbergii* (De Man) –

Weak Orange Clawed Female (WOF)



B. *Macrobrachium rosenbergii* (De Man)

Strong Orange Clawed Female (SOF)

and medial face of ischium, merus and carpus orange in colour while outer face slightly bluish. Propodus deep orange in colour with prominent spination. Dactylus naked and yellowish grey with blue tips.

Transforming Orange Clawed Female (TOF) (Plate 1.7.1)

Representing the transitional stage between SOF and WBF. Total length varies between 142 to 258 mm. Ischium, merus and carpus slightly bluish with orange hue. Propodus blue at the sides and dorsally, inner ventral side suffused with orange pigments. Dactylus naked and bluish black in colour. Prominent spines seen in larger animals.

v) Weak Blue Clawed Female (WBF) (Plate 1.7.2)

Characterised by the presence of a weak, deep blue coloured 2nd cheliped. Ischium, merus and carpus having deep blue or bluish black pigmentation with whitish or light bluish inner face. Propodus bluish black with a faint orange ring at the point of articulation of the dactylus. Fixed claw with dull white colouration while movable finger is naked and deep blue in colouration. Both the fingers end in a reddish spine.

iii) Strong Blue Clawed Female (SBF) (Plate 1.7.3)

SBF represents the 3rd female morphotypic stage of *M. rosenbergii*. Ischium, merus and carpus deep blue coloured with small whitish spines. Propodus deep blue with prominent bluish black spines. A prominent orange

Plate 1.7

A. *Macrobrachium rosenbergii* (De Man)

1. **Transforming Orange Clawed Females (TOF)**
2. **Weak Blue Clawed Females (WBF)**
3. **Strong Blue Clawed Females (SBF)**

patch at the site of articulation of propodus and dactylus. Dactylus with thick grey hairs and terminal position is naked.

1.3.2 *Macrobrachium idella* (Hilgendorf, 1898) (Plate 1.8 A&B)

Palaemon (Eupalaemon) idae idella Hilgendorf, 1898

Synonymy:

Palaemon (Eupalaemon) multidens Coutière, 1900

Distinguishing characters

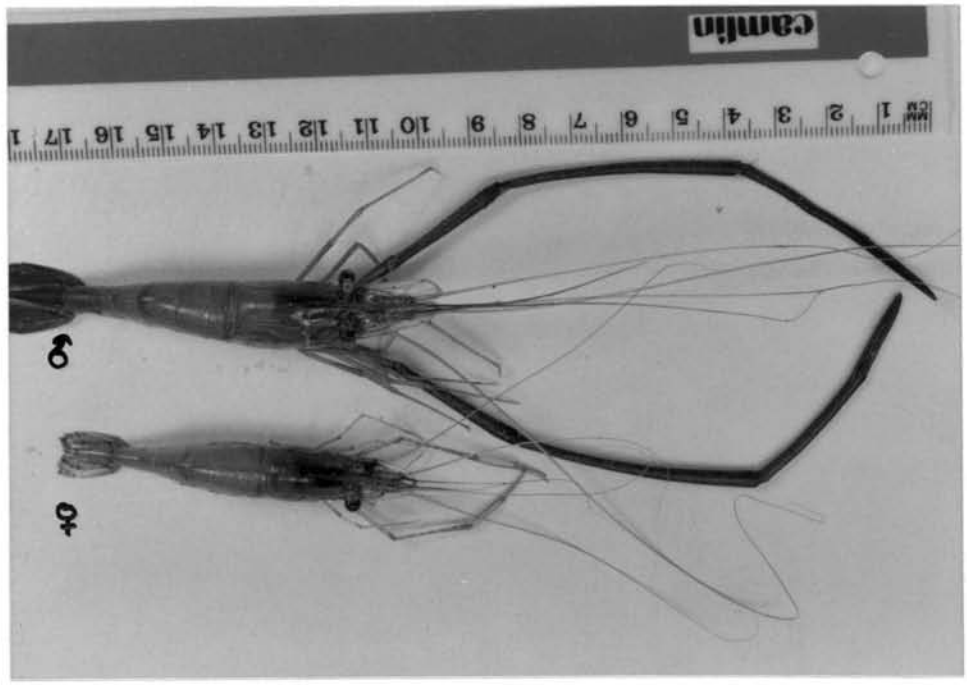
Body slightly compressed and robust. Rostrum extending up to the tip of antennal scale, uniformly toothed on upper margin with 12-14 dorsal and 4-7 ventral teeth, without an elevated basal crest. Second chelate leg tuberculated. Carpus of second cheliped slightly longer than propodus whereas merus distinctly shorter than carpus.

Colouration: Body light green with two elongated dark greyish blotches. Body normally translucent, large and old animals often opaque and darker coloured. Second pereopod of males and females rather translucent and gain dull green coloration with age.

Distribution and economic importance

Macrobrachium idella is distributed in Indo-west Pacific region, East Africa, Madagascar and India (Holthuis, 1980). Baily and Chrichton (1971) reported this species as being exploited for food in Tanzania. however, it forms only of lesser economic importance. It is also distributed in Malayan archipelago (Henderson and Matthai, 1910)

Plate 1.8



A. *Macrobrachium idella* (Hilgendorf) -- Dorsal view

B. *Macrobrachium idella* (Hilgendorf) -- Lateral view

Kurian and Sebastian (1976) reported only a sustenance fishery of this species in the south-western and eastern regions of India. Jayachandran (1984, 1987) delineated its regional distribution in various water bodies of south west coast of India, giving special emphasis to Kerala waters.

1.3.3 *Macrobrachium equidens* (Dana, 1852) (Plate 1.9 A&B)

Palaemon equidens Dana, 1852

Synonymy:

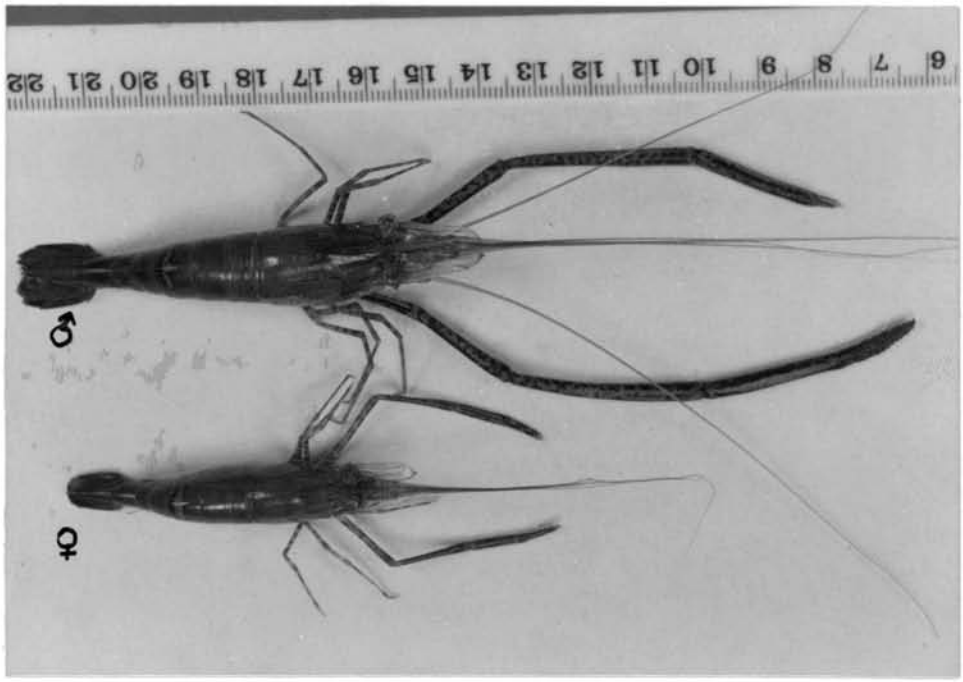
Palaemon sundaicus batavina De Man, 1897
Palaemon (Eupalaemon) sundaicus brachydactyla Nobil i, 1899
Palaemon (Eupalaemon) acanthosoma Nobili,1899
Palaemon (Eupalaemon) sundaicus baramensis De Man, 1902
Palaemon (Eupalaemon) nasutus Nobili, 1903
Palaemon sulcatus Henderson & Matthai, 1910

Distinguishing characters

Body slightly compressed and robust.. Rostrum slightly upturned, without a basal crest and serrated with 9-13 dorsal and 4-6 ventral teeth extending up to the distal margin of antennal scale. Hepatic and antennal spines are well developed and are in one line.

Colouration: Body more or less translucent with greyish spots, those on carapace being larger and prominent. Second pereopod dull green with a characteristic dark brown or greyish and yellowish mottling on inner side. Mottling is prominent in fingers and both fingers are velvety in adult male. Pereopods transversely banded with yellowish orange alternating with greenish or greyish band which is very prominent in juveniles.

Plate 1.9



A. *Macrobrachium equidens* (Dana) -- Dorsal view

B. *Macrobrachium equidens* (Dana) -- Lateral view

Distribution and economic importance

M. equidens is widely distributed in Indo-west Pacific including south east Africa, coast of India, Andaman and Nicobar islands, South China and Malay archipelago (Holthuis, 1980). Commercial exploitation of this species has been reported from Indonesia (Djajadiredja and Sachlan, 1956), Philippines (Domantay, 1956) and Malaya (Johnson, 1966).

In India this species is widely distributed in Malabar coast (Panikkar, 1937), Andaman and Nocobar islands (Tiwari and Pillai, 1973) Karwar (Jagadisha, 1977), Netravathy- Gurpur estuaries (Natarajan *et al.*, 1979) Vembanad lake (Nair, 1993), Krishna estuary (Ravindranath, 1982) and back waters of Kerala (Jayachandran, 1987) but do not have any commercial importance (Kurian and Sebastian, 1976)

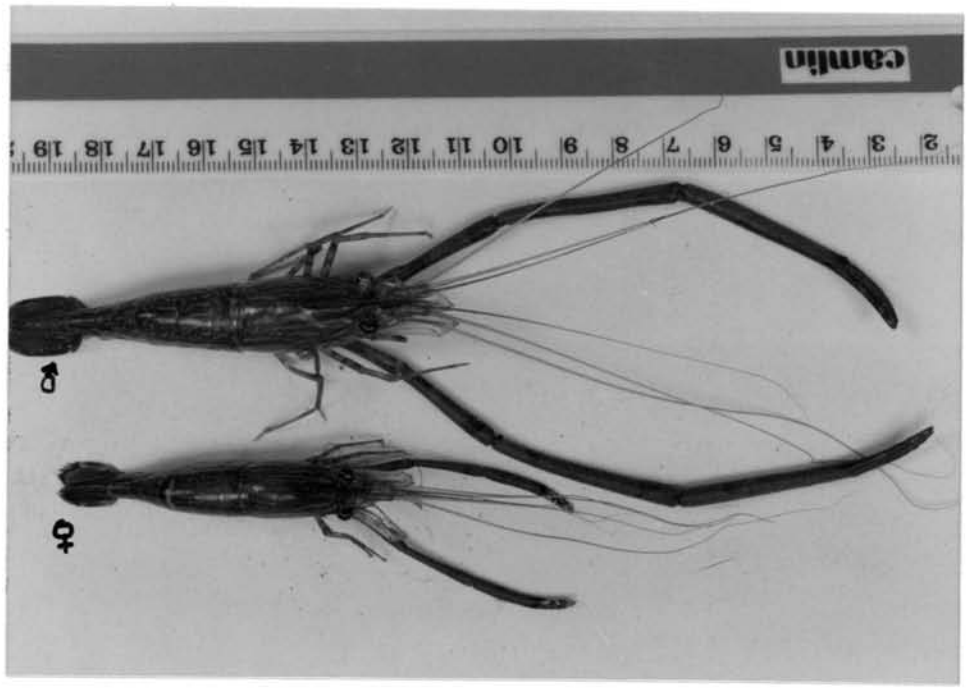
1.3.4 *Macrobrachium striatus* Pillai, 1990 (Plate. 1.10 A&B)

Distinguishing characters

Closely resembles *M. equidens*. Rostrum well developed, straight and do not reaching the anterior margin of antennal scale, serrated and compressed. Antennal and hepatic spines are well developed and are in one line, the former has a strong carina which continues posteriorly some distance towards hepatic spine.

Colouration: Body robust with 5-6 greenish or greyish brown longitudinal wavy stripes running along the sides of the abdomen of which dorsal one or two are discontinuous. All the pereopods, pleopodes and uropod also striped in sub adult while stripes disappeared from the second pereopods in larger animals.

Plate 1.10



A. *Macrobrachium striatus* Pillai -- Dorsal view

B. *Macrobrachium striatus* Pillai -- Lateral view

Second pereopods of adult never showed mottled appearance on carpus and palm, only fingers are mottled.

Distribution and economic importance

This species was considered as a sub-species/ variety of *M. equidens*, and therefore, a detailed account on the distribution is lacking. Fishery is reported from Karwar (Jagadisha, 1977) and Vembanad lake (Nair, 1993) as a striped variety of *M. equidens*.

1.3.5 *Macrobrachium scabriculum* (Heller, 1862) (Plate. 1.11 A&B)

Palaemon scabriculus Heller, 1862

Synonymy

Palaemon dolichodactylus Hilgendorf, 1879
Palaemon (Parapalaemon) scabriculus De Man, 1987
Palaemon (Parapalaemon) dolichodactylus Hilgendorf, 1898
Palaemon dubius Henderson & Matthai, 1910
Palaemon (Macrobrachium) dolichodactylus, J.Roux, 1934

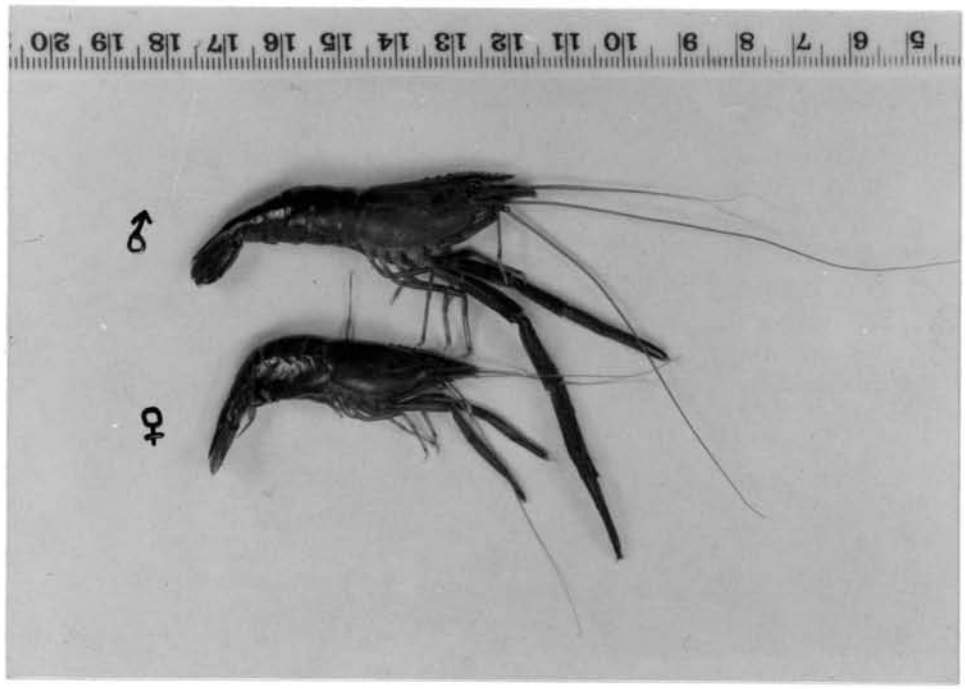
Distinguishing characters

Body cylindrical and robust. Rostrum short, do not reaching the anterior margin of antennal scale, dorsally convex and uniformly toothed. 12-15 dorsal and 2-3 ventral rostral spines. Second chelate leg unequal, propodus and basal part of the fingers covered with velvety hairs. Fingers longer than palm. Carpus shorter than merus.

Colouration: deep brown or greyish brown in colour with a yellowish patch running along the entire length on dorsal side of abdomen.

Plate 1.11

A. *Macrobrachium scabriculum* (Heller) -- Dorsal view



B. *Macrobrachium scabriculum* (Heller) -- Lateral view

Distribution and economic importance

Distributed in Indo-West Pacific including East Africa and Madagascar to India, Sri Lanka, Bangladesh and Sumatra (Holthuis, 1980). Fishery was reported from Bangladesh (Ahmad, 1957), Kenya and Tanzania (Baily and Crichton, 1971) and it is of only minor economic importance in India (Jones, 1967; Kurian and Sebastian, 1976).

1.3.6 *Macrobrachium rude* (Heller, 1862) (Plate 1.12 A&B)

Palaemon rudis, Heller, 1862

Synonymy:

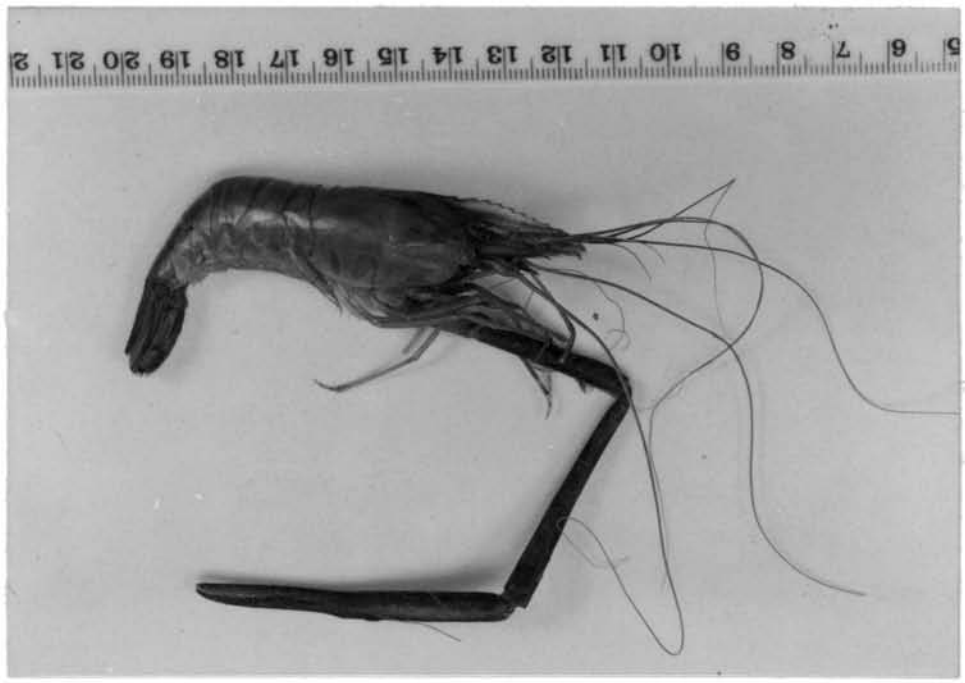
Palaemon mossambicus Hilgendorf, 1879
Palaemon (Eupalaemon) rudis Coutière, 1900
Palaemon (Eupalaemon) alcocki Nobili, 1903
Palaemon delagoae Stebbing, 1915
Urocaridella borradailei stebbing, 1923

Distinguishing characters

Body slightly compressed and robust. Rostrum short, dorsally convex, without basal crest. Rostrum uniformly toothed with 12-13 dorsal and 4-5 ventral spines. Hepatic spine situated at lower level than antennal spine. All the segments of second cheliped with velvety pubescence. Carpus is distinctly longer than merus and shorter than propodus (Chela). In live specimen 2nd chelipeds hold in the shape of 'W' while moving.

Colouration: light greenish or reddish brown without any spots and striations, entire 2nd cheliped of the adult males greyish in colour.

Plate 1.12



Macrobrachium rude **(Heller) Lateral view**

Distribution and economic importance

Distributed in Indo-West Pacific including East Africa, Madagascar, India and Bangladesh (Holthuis, 1980). Baily and Crichton (1971) mentioned about minor fishery of this species in Kenya and Tanzania, while Qureshi (1956) and Ahmad (1957) reported its fishery from Bangladesh.

Sakuntala (1976) suggested this species to be a brackish water prawn. Jones (1967) reported a stray fishery in south-west and a regular fishery in north-east coasts of India. It is reported to be common in Bengal (Chopra, 1943; George, 1969) and Chilka lake, Orissa (Kurian and Sebastian, 1976), Pulikat lake (Raman and Kadir, 1979), Kakkinada Bay (Rajyalakshmi, 1975) and Hooghly river (David, 1954; Rao, 1969).

1.4.1 Morphometric analysis

Details of various morphometric measurements recorded from three male morphotypes and their transitional stages are presented in Table 1.1.1 to 1.1.3. Small males of *M.rosenbergii* fall in a lower size range with a mean of 104.19 mm. A gradual increase could be observed in the total length commensurate with the path way of male morphogenesis and exceptions to this situation were t-SOC and WBC. Size distribution of t-SOC and WBC showed rather heterogeneous assemblage as evidenced from higher standard deviation. Lowest size observed in t-SOC was 106 mm which was well below when compared to its preceding morphotypes viz. WOC and SOC. In WBC also a similar condition in size range lower than that of SOC could be observed. In SM, OC and its transitional stages and WBC, second cheliped was found to be

smaller than total length, whereas SBC and OBC possess a long second cheliped which was higher than total body length.

Pattern of size distribution observed among female morphotypes of *M. rosenbergii* collected from the Vembanad lake was similar to that of their male counterparts (Table 1.1.4 to 1.1.7). TOF and WBF showed a wider size range when compared to the other morphotypes. Smallest size of TOF and WBF were found to be smaller than the lowest size recorded in their preceding morphotypes. Invariably, in all the female morphotypes, mean cheliped length was found to be lower than total length. Width of second pleura recorded from SBF was found to be larger when compared to other morphotypes.

Merus was distinctly longer than or as long as ischium in SBC and OBC as evident by ratio lower than 1.00 whereas, in other morphotypes shorter merus was also encountered (Table 1.2.1). In OBC, the ratio of rostral length to carpus of second cheliped ranged from 0.919 to1.623, whereas, in SM, WOC, and SOC still higher ranges could be seen. Similar observation was noticed in respect of merus length also (Table 1.2.1).

The variation in the morphometric characters of female morphotypes were not that much perceptible as in the case of males. The ratio of telson length to total length was found to be uniform in all female morphotypes. Ratio of pleural width to total length showed a gradual increase from WOF to SBF commensurate with the developmental pathway (Table 1.2.2). Average length of second cheliped was found to be 0.651 to 0.710 of the total length which indicate that 2^{nd} cheliped was shorter than total length. The ratio of propodus of 2^{nd} cheliped to other body dimensions of female

M.rosenbergii showed no perceptible variation as in the case of their male counterparts (Table 1.2.2).

The result of regression analysis showed that in all male morphotypes except OBC, the body dimensions showed linear relationship. In OBC most of the relationships was found to be non-linear (Table. 1.3.1 to 1.3.4). Coefficient of determination (d) calculated for various relationships showed that many of the morphometric measurements in SM, WOC, SOC, t-SOC, WBC and SBC were found to be closely related (Table. 1.3.1 to 1.3.4). Regression coefficient (b) between total length and 2nd cheliped was found to be positively allometric from SOC onwards, whereas, this relationship showed negative allometry in SM and WOC. Regression of total length to propodus of the 2nd cheliped showed a higher b value in the larger morphotypes viz. SOC, SBC and OBC, whereas, the same in respect of smaller morphotypes viz. SM, WOC and WBC were found to be lower. The relationship showed negative allometry in SM and WOC, on the contrary, in other advanced morphotypes it showed positive allometry, however, in OBC also a negative allometric relationship could be found out.

In TOF and SBF all the body dimensions showed linear relationships, whereas many of the relationships in WOF, SOF and WBF were found to be non-linear (Table. 1.3.5 to 1.3.7)

The relationship between total length and 2nd cheliped length showed negative allometry in all the female morphotypes and this would indicate the small size of 2nd cheliped when compared to total length. On the contrary, the relationship between ischium and merus of 2nd cheliped showed

positive allometry in WOF and TOF whereas, in other morphotypes this relationship was found to be negatively allometric.

Details of various morphometric measurements recorded from assorted specimens of *M. rosenbergii* is presented in Table 1.4.1. Male belonging to length group of 121 to 278 mm (M=188.10 ± 29.84) and female of 107 to 253 mm (M=190.50 ± 28.05) were used for morphometric analysis. Similar measurements in respect of *M.idella, M. equidens, M. striatus, M.scabriculum* and *M. rude* are also presented in Table 1.4.2 to 1.4.6 respectively.

Range and mean of various ratios worked out from male and female of different *Macrobrachium* spp. are presented in Table 1.5.1 and 1.5.2 respectively. In *M. rosenbergii,* carpus was found to be longer than half as long as propodus and the ratios obtained with total length were 0.161 for carpus and 0.300 for propodus. In *M. idella,* propodus to carpus ratio was found to be 0.896 and 0.980 in males and females respectively which indicate that the length of carpus was longer than propodus and only in smaller animals this ratio was found to be reversed. In all other species propodus was found to be longer than carpus (Table 1.5.1 and 1.5.2). In *M.scabriculum* merus to carpus ratio was found to be greater than one and in all other species this ratio was found to be less than one which would suggests that length of carpus was shorter than merus in *M.scabriculum.* In *M.scabriculum* and *M.rude* the ratio of carpus and merus to total length were 0.220 and 0.197 respectively in former and 0.289 and 0.469 in the latter and this can reliably be used as a distinguishing character between these two species. In *M. idella* the ratio of carpus and merus was

recorded as 0.228 and 0.415 which show that carpus is distinctly longer than merus.

Various morphometric characters recorded from the six species were regressed each other and regression parameters so obtained are presented in Table 1.6.1 to 1.6.6. In *M. rosenbergii* all the relationships were found to be linear by obtaining significant 'r' values (Table 1.6.1). Regression coefficient revealed that length of 2nd cheliped showed positive allometry with the total length, on the contrary, all other morphometric characters showed negative allometry with total length in *M.rosenbergii*. Relationship of rostral length with respect to carapace length showed almost isometry, whereas length of propodus, 1st and 2nd chelipeds and walking legs showed positive allometry, however, all and other characters showed negative allometry.

In *M. idella* and *M. equidens* also all the relationships were found to be linear (Table 1.6.2 & 1.6.3). In *M. striatus* the correlation of dactylus of 2nd cheliped with other morphometric parameters showed lower 'r' values (ranging from 0.239 to 0.368) which would suggests that the relationship is non-linear in males, whereas, in females of *M. striatus* such disparity could not be seen (Table .1.6.4).

In *M.scabriculum* the relationship between the podomeres of 2nd cheliped and total length of 2nd cheliped with other morphometric parameters showed a non-linear relationship as evident by very low 'r' values (Table 1.6.5). On the contrary, the length of 1st cheliped and length of other walking legs showed a linear relationship with total length, carapace length and rostral length. The relationship between the podomeres viz. carpus and propodus to merus, propodus and dactylus to carpus and propodus to dactylus in

M.scabriculum were found to be linear (Table 1.6.5) In females of *M.scabriculum*, the relationship between pleural width to all other parameters were also found to be non-linear (Table 1.6.5). Length of podomeres of females of *M.scabriculum* showed linear relationship with many of the morphometric characters studied.

During the present study, adults male of *M. rude* could only be collected as this species was very rare and have restricted distribution in Vembanad lake. *M. rude* also showed non-linear relationships between many of the morphometric characters studied similar to that of *M.scabriculum* (Table. 1.6.6). In *M.rude* also podomeres as well as the total length of 2nd cheliped showed non linear relationship with total length, carapace length and rostral length.

Results of the comparison of regression coefficient of total length-rostral length relationship of male *M. rosenbergii* showed a significant differences ($P<0.01$) among various species studied (Table 1.7.1). Results of t-test showed that significant variation in the above relationship exist between *M. rosenbergii* and *M.idella* ($P<0.001$) and also *M.equidens* ($P<0.01$) *and M. striatus* ($P<0.001$). The regression coefficient of the total length- rostral length relationship between *M.idella* and *M.equidens* ($P<0.05$) and *M.equidens* and *M.striatus* ($P<0.01$) were also found to vary significantly.

Relationships between total length and length of merus ($F=29.76$, $P<0.001$), Carpus ($F=53.62$, $P<0.001$) and propodus ($F=12.82$, $P<0.001$) of 2nd cheliped and the total length of 2nd cheliped ($F=29.67$, $P<0.01$) were also found to vary significantly among the *Macrobrachium* species of Vembanad lake (Table 1.7.2 to 1.7.5). Result of the t-test showed that the growth of the

podomeres as well as the total length of cheliped varied between most of the species studied (Table 1.7.1 to 1.7.6).

Comparison of regression coefficients of the relationship between carapace length with merus ($F=36.28$, $P<0.01$), carpus ($F=66.14$, $P<0.01$) and propodus ($F=14.92$, $P<0.01$) of 2nd cheliped and total length of 2nd cheliped ($F=36.38$, $P<0.01$) showed significant variation in different species (Table 1.7.6 to 1.7.10). On the contrary, carapace length and rostral length ($F=1.89$, $P<0.1$) relationship showed no significant variation among different *Macrobrachium* spp. (Table 1.7.6). The results of the t-test revealed that there exists species specific variations in the regression coefficient of lengths of merus, carpus, propodus and total length of cheliped to carapace length.(Table 1.7.6 to 1.7.10)

On the contrary, among females, regression coefficients of total length- rostral length relationships ($F=1.11$, $P>0.05$) and carapace length- rostral length relationships ($F=1.39$, $P>0.05$) were found to be insignificant (Table. 1.7.11 and 1.7.12) . Results of comparison of regression coefficients of merus, carpus, propodus and total length of 2nd cheliped with total length and carapace length of females of different *Macrobrachium* spp. are presented in Tables 1.7.11 to 1.7.20.

1.4.2 D^2 Analysis

Distance function analysis was carried out based on 15 morphometric characters in 6 species of *Macrobrachium* collected from the Vembanad lake. Morphometric measurements of males and females of different species were analysed and the results are presented in Table 1.8.1. D^2 value revealed sexual dimorphism at significant level in all the *Macrobrachium* spp. studied and among them *M.scabriculum* ($D=3.285$, $P<0.01$) showed

maximum D-value, in contrast, in *M. equidens* (D=1.94, P<0.01) and *M. striatus* (D=1.58, P<0.01) showed least values which would manifest the existence of lower degree of sexual dimorphism in the latter two species.

Result of the D^2 analysis revealed that morphometry of males of the *Macrobrachium* spp. are significantly different among each other and the maximum D-value could be observed in *M. rosenbergii* with other species (Table 1.8.2). In females also, similar trends could be seen (Table. 1.8.3).

Morphometric variables of both males and females of *M. equidens* vary significantly from *M. striatus* as evident from the significant difference in D-values. These finding would not only be useful in differentiating these two species but also helpful in supporting the validity of their separate taxonomic identity.

Using the above 15 morphometric characters, 105 different morphometric ratios were worked out of which 15 ratios showing linear relationship were selected for D^2 analysis. The 15 ratios taken into consideration for further differentiation of *M. equidens* and *M. striatus* were the lengths of ischium, merus, carpus, propodus and total length of second cheliped to total body length, length of ischium, propodus and length of second cheliped to carapace length, carapace length, rostral length, length of 1st cheliped and ischium of 2nd cheliped to the length of 3rd walking leg to the length of carpus of second cheliped and rostral length and length of ischium of second cheliped to the merus of 2nd cheliped. Correlation matrix of r values showing the linear relationship of selected ratios in males and female of *M.equidens* and *M.striatus* were presented in Table 1.9.1 and 1.9.2. Results of the D^2 analysis ratios was useful in bringing out the extent of sexual dimorphism as well

as the morphological differences inherent in *M.equidens* and *M.striatus* (Table 1.10.1 and 1.10.2).

Discussion

Prawns collected from the exploited stock of Vembanad lake were identified and classified on the basis of available keys and they show very much agreement with the earlier descriptions (George, 1969; Holthuis, 1980; FAO, 1983; Pillai, 1990a & b; Jayachandran and Joseph, 1992). All the species in their early juvenile stage are translucent and often with dark lines and spots on the body and this is posing much difficulty in their proper identification. Available keys are primarily based on the adult characteristics and therefore may not be suitable for the identification of juveniles or sub-adults up to species level. Therefore, the key developed in the present study based on easily measurable characters will be having much utility for the easy identification of the species inhabiting the Vembanad lake.

All the six species described were previously reported from the Vembanad lake (Jayachandran, 1987). In contrast, *M. canarae* and *M. sankollii* recorded from the upper stretches of Meenachil river (Jayachandran, 1991) could not be encountered now in the catches examined up to 5 km stretch in this river adjoining the Vembanad lake.

Single aged adult population of *M. rosenbergii* especially the males are characterised with a highly skewed size structure associated with different morphotypes having varying growth rates and reproductive potential (Cohen *et al.*, 1981; Kuris *et al.*, 1987; Sagi and Ra'anan, 1988; Harikrishnan and Kurup,

1997a). In the present study, similar morphological difference as reported in the grow-out population could be observed from the natural population also. The size range of various male morphotypes observed during the present study are on a higher side when compared to grow-out populations (Cohen *et al.*, 1981; Kuris *et al.*, 1987; Sagi and Ra'anan, 1988) and are very much comparable to the size structure as reported by Harikrishnan (1997). The difference in size structure between the grow-out and natural populations may be due to the presence of multi-aged specimens in the latter.

Kuris *et al.* (1987) opined that BC males are readily distinguishable from other male morphotypes having dramatically greater propodus and carpus length in relation to carapace length. In the present study it could be seen that the ratio of carpus and propodus to the carapace length gradually increased from SM to OBC except WBC and this fully complies with the observation of Kuris *et al.* (1987). The disparity observed in the WBC may be due to its wider size range and smaller mean size when compared to fully differentiated blue clawed males, the SBC. Carpus length is reported to be the best discriminator between OC and BC males, the former possess a carpus 61% larger that that of OC males (Kuris *et al.*, 1987). Definite and uniform morphological criteria could not be delineated for the differentiation of morphotypes from various ratios arrived at as they have showed considerable overlapping. This may also be due to multi-aged nature of the population in the lake in contrast to the single aged cultured population, the latter is only so far used for similar studies.

The ratio of total length of 2nd cheliped to the total body length showed a value less than 1 in SM to WBC whereas, the growth was found to be

positively allometric except in SM and WOC. On the contrary, in females the above relationship showed a negative allometry. This may be due to the presence of larger cheliped in males of *M.rosenberii* especially in higher morphotypes when compared to their females counterparts.

Relationships of propodus with respect to carapace length was found to be positively allometric in various morphotypes showing highest value in BC (b=2.134). On the contrary, OBC showed a negative allometry and this would further support the fact that the growth rate of OBC is stunted as reported by Sagi and Ra'anan (1988) and Kurup *et al.* (1997a). However, carpus with respect to carapace length showed a negative allometry and an exception to this is in SBC and this finding showed strong agreement with that of Kuris *et al.* (1987) who reported that there exist a positive allometric growth of propodus and carpus with respect to carapace length in SBC.

According to Harikrishnan (1997) there is considerable variation in the growth of various body parts with respect of total length and carapace length. In the present study also a clear variation could be observed in the regression coefficients of various morphometric relationships in different morphotypes (Table 1.3.1 to 1.3.7) and this fully supports the findings of Harikrishnan (1997). Harikrishnan (1997) also delineated significant differences in the morphology of various male morphotypes of *M.rosenbergii* and in their transitional stages with the help of D^2 analysis using 9 morphometric parameters.

M. rosenbergii showed morphotypic differentiation and therefore, an assorted group of all morphotypes belonging to various length groups were taken as a unit entity for the species level taxonomic studies. It is worth

noticing that all the morphometric relationship of this group have shown linearity (Table 1.6.1). In *M. idella,* two types of males with two different claw characteristics were reported, however, they are not allometrically different (Harikrishnan, 1997). Morphotypic differentiation could not be observed in other species of *Macrobrachium* collected from the Vembanad lake during the present study as reported earlier (Harikrishnan, 1997).

Taxonomic positions of *M.equidens* and *M.striatus* were under dispute (Pillai, 1990b) as these two species were considered to be spotted and striped varieties of *M.equidens* (Jagadisha, 1977; Nair, 1993). However, *M.equidens* and *M.striatus* can easily be differentiated by noticing the colour pattern (Plate. 1.3 and 1.4) Nevertheless, this character cannot be considered as an important taxonomic tool for the species level identity in view of the fact that the characteristic colour pattern appear clearly in juveniles above 20-25 mm of both the species and vanishes on preservation (Pillai, 1990a). Pillai (1990b) reported that the colour pattern of striped and non-striped forms were distinct and no mixing in was observed between these two species. The distinct colour pattern characteristic of each of these species appeared only when the post larvae grew to a size of 20-25 mm. Jagadisha (1977) brought out some distinct differences between these two species such as nature of the rostrum, relative size of carpus and chela and pubescence in the dactylus of 2nd cheliped. The results of the present study fully agree with earlier observation (Jagadisha, 1977) as the variation in the shape of rostrum can very well be distinguishable from the photographs (Plates 1.9 and 1.10). Pillai (1990a) described the striped variety as a new species and separated from *M.equidens* on the basis of difference in colouration, structural difference of zoeal stages

and by also confirming that the two species showed inability to interbreed (Pillai, 1990b). Jayachandran and Joseph (1992) provided a species identification key along with a short review of bionomics of these two species, however, *M.equidens* and *M.striatus* were treated as *M.equidens equidens* and *M.equidens pillaii* respectively. In the present study it was found that *M.striatus* have a more or less straight rostrum which barely reaches the anterior margin of antennal scale, whereas the rostrum is more upturned in the case of females and sub-adults, on the contrary, rostrum of *M.equidens* is upturned and reaching up to the anterior margin of antennal scale. Koshy (1969) reported that in female *M. lamarrei* rostrum is correspondingly longer than in males. In *M.equidens* and *M.striatus* the ratio of rostral length to carapace length was found to be 1.165 and 1.074 respectively, whereas in females the same ratios were 1.178 and 1.103. This fully confirms the fact that the female possesses a comparatively longer rostrum which is at variance with the sex specific differential growth in *M. lamarrei* as reported by Koshy (1969).

In systematics where body proportions play an important role in delineation of species, investigation on relative growth of parts in relation to the rest of body or in relation to each other can throw much light for arriving at true taxonomic status (Misra, 1959). Ratios worked out between various morphometric measurements fully conform to the morphologic criteria usually taken for the differentiation of *Macrobrachium* spp. (George, 1969; Jayachandran and Joseph, 1992). The results of the present study show that *M.scabriculum* and *M.rude* can easily be distinguished from other species of *Macrobrachium* by observing the shorter length of the rostrum in relation to carapace length. It could also be seen that the ratio of rostrum to carapace is

less than 1 in *M.scabriculum* and *M.rude* however, in others this ratio is greater than 1 denoting the presence of a larger rostrum when compared to carapace. *M. rosenbergii* can also be differentiated from the other species by noticing the presence of longer rostrum and therefore, the mean of rostrum to carapace ratio is distinctly greater in *M. rosenbergii* when compared to *M. idella, M. equidens* and *M. striatus.*

M. idella can easily be differentiated by noticing the propodus which is shorter than carpus (Jayachandran and Joseph, 1992). Present findings fully confirm this observation and also quantified the extent of difference in the ratios of propodus and carpus to total length in various *Macrobrachium* spp. of Vembanad lake (Table 1.5.1 and 1.5.2). Ischium to carpus ratio can be taken as a criteria for the differentiation of *M. rosenbergii* and *M.rude* in which ratio was greater than 0.5 in the former and less than 0.5 in the latter (Table 1.5.1). Merus is as long as or shorter than carpus in *M.scabriculum* ,whereas other species possess a distinctly longer merus when compared to carpus (Jayachandran and Joseph, 1992). Merus to carpus ratio was found to be greater than 1 in *M.scabriculum* and lesser than 1 in other species and this lend to support the finding of Jayachandran and Joseph (1992). Jagadisha (1977) brought out variation in the relative size of carpus and chela in *M. equidens* and *M. striatus* whereas, in the present study a difference could be observed in the means of ratio of chela (propodus) to carpus of the above two species (1.253 and 1.408 respectively), however, the ranges showed overlapping.

Growth of various body parts in *M. rosenbergii* with respect to total length and carapace length was found to be higher in males when compared to

females and this can very well be correlated to the faster growth and larger size of males. On the contrary, pleural width and length of telson showed higher regression coefficient in females of *M. rosenbergii* when compared to males (Table 1.6.1) and can be explained on the basis of large second pleura seen in berried females, which is required for the formation of brood pouch. In other *Macrobrachium* spp. also pleural width showed higher growth rate when compared to that of their male counterparts (Table. 1.6.2 to 1.6.5).

In males of *M. rosenbergii*, a positive allometry could be observed between total length and length of second cheliped and this can very well be explained by the larger size of the cheliped in males which is often longer than total length. Whereas in females, the length of cheliped is only more than half the body length and correspondingly it shows a negative allometric relationship.

Similar results could be observed in the case of *M. idella* but the difference in growth of 2nd cheliped showed a highly positive allometry in males (2.2017) and negatively allometry in females. This may be due to the occurrence of males with exceptionally large cheliped in the sample as described as 'M2' Males (Harikrishnan, 1997). The relationship between the podomeres of 2nd cheliped of males of *M. rosenbergii* and *M. idella* showed a very high correlation by showing higher r values ($r>0.9$), on the contrary, *M.scabriculum* and *M.rude* showed very low r values showing no significant relationship between the lengths of different podomeres and other morphometric characters and also among lengths of different podomeres. This may be due to significantly large and broad cheliped seen in *M.scabriculum* when compared to other species. Only adults of *M.rude* in the size range of 85-

109 mm was collected during the present study (Table 1.4.6) and this in comparison with other species is distinctly higher. Smaller size range and low degree of freedom may be attributed as the reasons for the smaller r values arrived at in most of the relationships.

In *M. idella* there is no significant difference in rostrum length with respect to carapace length and total length between the two sexes (Jayachandran and Balasubramanian, 1987) and the results of the present study fully support the above findings. Regression coefficients of rostral length of males and females of *M.idella* with total length were worked out as 0.301 and 0.310 respectively and no significant variation was noticed between them (Table 1.6.2), and are therefore comparable with Jayachandran and Joseph (1988). Koshy (1971) reported sex specific variation in the regression coefficients of rostral length and length of second cheliped to the length of cephalothorax.

Comparison of regression coefficients of various relationships showed that among the *Macrobrachium* spp. there exist significant variations in the morphometric relationships. Regression coefficient of total length-rostral length relationships of *Macrobrachium* spp. showed significant variation among males, on the contrary, females showed no significant variation in the above relationships. These finding are similar to the allometric relationships of rostrum with reference to carapace length as reported in *M.lamerrei* (Koshy, 1969) and *M.scabriculum* (Jayachandran and Balasubramanian, 1987).

The comparison of regression coefficients of various body parts with respect to total length and carapace length showed species specificity (Table 1.7.1. to 1.7.20). This can be explained on the basis of variation noticed

in the size and structure of podomeres of 2nd cheliped in various *Macrobrachium* spp. (Plate 1.1 and 1.8 ; Table 1.4.1 to 1.4.6). Jayachandran and Balasubramanian (1987) opined that each of the *Macrobrachium* spp. is characterised by its own species specific pattern of growth. Rajyalakshmi (1980) brought out difference in growth rate of male and female of *M.malcomsonii.*

The results of the present study show that the ratio of length of rostrum to length of carapace can be taken as a tool for the easy differentiation of various species of *Macrobrachium.* Comparison of regression coefficients of rostral length-carapace length relationship using analysis of covariance showed that the variation is insignificant among different species, both in males and females. This may be due to the similarity of regression coefficients arrived at in different species which ranged from 0.716 to 1.005 in males and 0.719 to 0.997 in females. It may, therefore, sensibly be asserted that even though the variation in the growth of rostrum of *Macrobrachium* spp. with respect to carapace length do not vary considerably, the ratio of the rostral length to carapace length can be taken as a criterion for the species level differentiation. The insignificant difference recorded in regression coefficients of rostral length-carapace length relationship may be due to the considerable overlapping in the ratio of rostral length to carapace length in different *Macrobrachium* spp.

Using D^2 analysis the extent of sexual dimorphism is quantified in different species of *Macrobrachium* inhabiting Vembanad lake and the results showed that *M. scabriculum* ($D=3.285, P<0.01$) showed greatest difference. This may be attributed to the difference noticed in claw characteristics. 2nd cheliped

of *M.scabriculum* is heavy and strongly unequal in males (Plate 1.11). Relatively higher values (D=2.3, P<0.01) arrived at in *M. idella* in the present study may be due to the presence of large clawed males. In *M. rosenbergii* also comparatively high D^2 value could be observed which can also be explained on the basis of variations noticed in size structure of the male population when compared to their females counterparts (Kuris *et al.*, 1987). Since D^2 analysis confirmed the existence of sexual dimorphism, further analysis on the species level differentiation was carried out separately for males and females.

Results of the D^2 analysis revealed that there exist significant difference in the morphology among males of *Macrobrachium* spp. of the Vembanad lake showing highest between *M. rosenbergii* and other species and this may be due to the large size of males of *M. rosenbergii* when compared to other species studied. Similar trend could also be observed in females.

The regression coefficients of various relationships of *M. equidens* and *M. striatus* were found to vary significantly and therefore can be used for their easy differentiation. However, Jagadisha (1977) and Pillai (1990a &b) are of the view that there exist only minute morphological difference between these two species and therefore the species differentiation could be possible on the basis of colour, variation in larval morphology and inability to interbreed (Pillai, 1990a). In the present study, a distinct morphological variation could be established between males (D= 2.118, P<0.01; Table. 1.8.2) as well as females (D= 2.085, P<0.01; Table. 1.8.3) of *M. equidens* and *M. striatus* and therefore the results will be immensely useful in strengthening the validity of existence of two separate species as reported by Pillai (1990a).

Some of the ratios worked out on the morphometric measurements of *M.equidens* and *M.striatus* did not show linearity and this may be due to the disproportionality in growth rate of different body parts. The results D^2 analysis using different morphometric ratios were comparable with that of the D^2 values arrived at from original morphometric data. Sexual dimorphism is found to be higher in *M. equidens* when compared to *M.striatus* and the species level difference is higher in males. Results of D^2 analysis using ratios showed almost similarity with that of value obtained when direct measurement were used, however, the values obtained from the former were found to be much more useful in the establishment of sexual dimorphism and species differentiation. The distinct taxonomic identity of *M.equidens* and *M.striatus* can also be established on the basis of the results obtained from D^2 analysis.

Table 1.1.1 Minimum, maximum and standard deviation of various morphometric measurements recorded in small males of Macrobrachium rosenbergii

Sl.No.	Measurements	Small Males n= 15			
		Minimum (mm)	Maximum (mm)	Mean (mm)	SD
1	Total length	75.0	139	104.19	16.31
2	Carapace length	19.2	37	27.18	4.45
3	Rostral length	27.9	54	39.08	6.81
4	Length of telson	10.2	19	13.48	2.27
5	2nd abdominal pleural width	7.1	13	9.30	1.49
6	Length of ischium of 2nd cheliped	8.5	17	11.91	2.49
7	Length of merus of 2nd cheliped	9.1	18	12.21	2.19
8	Length of carpus of 2nd cheliped	10.3	21	14.69	3.00
9	Length of propodus of 2nd cheliped	12.1	37	21.23	6.54
10	Length of dactylus of 2nd cheliped	5.1	17	10.03	3.26
11	Total length of 2nd cheliped	40.9	93	60.04	13.51

Table 1.1.2 Minimum, maximum and standard deviation of various morphometric measurements recorded in orange clawed males of Macrobrachium rosenbergii

Sl.No.	Measurements	Weak Orange Clawed Male (WOC) n=107				Strong Orange Clawed Males (SOC) n= 22				Pretransforming Strong Orange Clawed Males (t-SOC) n= 107			
		Minimum (mm)	Maximum (mm)	Mean (mm)	SD	Minimum (mm)	Maximum (mm)	Mean (mm)	SD	Minimum (mm)	Maximum (mm)	Mean (mm)	SD
1	Total length	108	258	184.03	25.50	155	284	213.09	21.29	106	293	204.09	51.12
2	Carapace length	37	73	50.92	7.56	41	27	61.82	15.36	34	96	57.55	10.81
3	Rostral length	54	94	69.19	8.77	55	110	29.55	16.49	47	115	76.42	12.54
4	Length of telson	11	29	21.58	2.72	18	32	24.55	4.53	17	38	23.99	3.64
5	2nd abdominal pleural width	11	24	16.39	2.37	14	32	10.50	4.57	12	27	18.10	3.05
6	Length of ischium of 2nd cheliped	17	41	24.50	4.82	18	45	29.86	7.72	13	58	28.79	7.29
7	Length of merus of 2nd cheliped	17	41	25.42	4.65	19	52	32.45	10.01	15	92	30.99	10.21
8	Length of carpus of 2nd cheliped	21	47	30.14	5.19	21	63	38.18	12.18	16	115	36.77	12.95
9	Length of propodus of 2nd cheliped	30	98	53.25	12.78	42	127	25.14	27.75	26	198	62.61	25.71
10	Length of dactylus of 2nd cheliped	14	50	25.76	6.57	20	72	37.23	16.43	11	75	33.77	12.43
11	Total length of 2nd cheliped	88	225	133.32	24.95	100	287	125.64	56.93	70	463	159.16	51.99

Table 1.1.3 Minimum, maximum and standard deviation of various morphometric measurements recorded in blue clawed males of Macrobrachium rosenbergii

Sl.No.	Measurements	Weak Blue Clawed Male (WBC) n= 102				Strong Blue Clawed Males (SBC) n= 51				Old Blue Clawed Males (OBC) n= 31			
		Minimum (mm)	Maximum (mm)	Mean (mm)	SD	Minimum (mm)	Maximum (mm)	Mean (mm)	SD	Minimum (mm)	Maximum (mm)	Mean (mm)	SD
1	Total length	122	286	195.28	35.25	178	289	252.39	23.68	248	354	286.00	19.49
2	Carapace length	31	39	54.71	10.18	50	92	76.29	9.88	70	104	59.87	7.99
3	Rostral length	48	105	73.17	11.73	63	109	94.25	10.21	96	123	106.19	8.43
4	Length of telson	15	33	22.76	3.59	21	36	28.86	3.50	13	38	31.48	4.19
5	2nd abdominal pleural width	11	27	17.64	3.32	11	26	22.24	3.11	19	31	25.23	2.57
6	Length of ischium of 2nd cheliped	11	47	27.40	7.42	15	55	39.39	8.07	35	83	51.90	8.40
7	Length of merus of 2nd cheliped	15	69	29.46	9.24	18	85	49.37	14.66	51	96	76.68	13.11
8	Length of carpus of 2nd cheliped	18	87	34.36	10.94	22	105	59.35	19.51	61	125	97.39	15.30
9	Length of propodus of 2nd cheliped	24	140	62.64	22.43	44	190	115.29	34.13	130	225	179.94	22.93
10	Length of dactylus of 2nd cheliped	15	67	32.23	11.69	20	93	57.80	16.00	66	103	87.55	9.90
11	Total length of 2nd cheliped	82	134	153.86	47.27	99	432	263.40	22.93	285	504	405.90	52.26

Table 1.1.4. Minimum, maximum and standard deviation of various morphometric measurements recorded in orange clawed females of Macrobrachium rosenbergii

Sl.No.	Measurement	Weak Orange Clawed Female (WOF) n= 8				Strong Orange Clawed Females (SOF) n= 10				Transforming Orange Clawed Females (TOF) n= 49			
		Minimum (mm)	Maximum (mm)	Mean (mm)	SD	Minimum (mm)	Maximum (mm)	Mean (mm)	SD	Minimum (mm)	Maximum (mm)	Mean (mm)	SD
1	Total length	159	210	180.88	14.73	169	224	191.20	14.57	142	258	186.24	26.53
2	Carapace length	42	54	47.38	4.27	47	63	57.80	9.46	38	76	50.96	8.87
3	Rostral length	60	74	68.00	4.95	62	96	75.30	9.41	51	96	70.02	10.37
4	Length of telson	18	24	21.13	1.69	19	26	22.40	1.85	16	33	22.02	3.50
5	2nd abdominal pleural width	14	22	16.88	2.37	16	22	19.20	1.94	14	32	19.76	4.46
6	Length of ischium of 2nd cheliped	20	24	22.25	1.39	21	27	23.70	2.10	18	36	23.55	4.24
7	Length of merus of 2nd cheliped	20	25	22.13	1.96	21	28	24.20	2.04	11	51	24.33	6.42
8	Length of carpus of 2nd cheliped	22	30	27.13	2.47	27	36	30.80	2.60	20	49	30.04	5.89
9	Length of propodus of 2nd cheliped	35	58	46.25	8.88	40	53	47.20	4.71	20	91	43.92	13.18
10	Length of dactylus of 2nd cheliped	16	26	21.38	3.81	17	25	21.60	2.58	12	43	20.94	6.74
11	Total length of 2nd cheliped	97	137	117.75	13.28	112	138	125.90	8.69	75	216	121.84	26.89

Table 1.1.5. Minimum, maximum and standard deviation of various morphometric measurements recorded in blue clawed females of Macrobrachium rosenbergii

Sl.No.	Measurements	Weak Blue Clawed Female (WBF) n= 60				Strong Blue Clawed Females (SBF) n= 62			
		Maximum (mm)	Minimum (mm)	Mean (mm)	SD	Maximum (mm)	Minimum (mm)	Mean (mm)	SD
1	Total length	115	242	195.55	24.42	152	266	209.45	23.65
2	Carapace length	29	72	53.57	8.36	40	77	59.19	8.02
3	Rostral length	34	89	70.78	10.86	56	94	75.89	8.52
4	Length of telson	14	28	22.90	2.72	17	31	24.39	2.60
5	2nd abdominal pleural width	11	29	21.77	4.39	16	32	25.13	3.63
6	Length of ischium of 2nd cheliped	14	33	24.83	4.04	18	41	27.23	4.76
7	Length of merus of 2nd cheliped	16	35	25.72	4.26	19	42	28.63	4.57
8	Length of carpus of 2nd cheliped	17	43	32.15	5.29	23	51	36.05	5.59
9	Length of propodus of 2nd cheliped	30	71	50.58	10.02	41	87	57.21	9.68
10	Length of dactylus of 2nd cheliped	13	39	23.55	5.60	18	44	27.27	5.86
11	Total length of 2nd cheliped	82	180	133.28	21.85	105	221	149.11	23.01

Table 1.2.1 Minimum, maximum and mean of different ratios worked out with various morphometric measurements of male morphotypes of Macrobrachium rosenbergii

	Small Males (SM)			Weak Orange Clawed Males (WOC)			Strong Orange Clawed Males (SOC)			Pretransforming Orange Clawed Males (t-SOC)			Weak Blue Clawed Males (WBC)			Strong Blue Clawed Males (SBC)			Old Blue Clawed Males (OBC)		
Ratios	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
CL/TL	0.241	0.277	0.261	0.205	0.593	0.278	0.257	0.318	0.287	0.235	0.415	0.281	0.189	0.349	0.250	0.251	0.357	0.302	0.264	0.339	0.314
RL/TL	0.359	0.404	0.374	0.283	0.722	0.379	0.344	0.419	0.373	0.242	0.575	0.375	0.283	0.511	0.376	0.317	0.413	0.373	0.333	0.426	0.371
TEL/TL	0.115	0.165	0.130	0.051	0.222	0.118	0.108	0.125	0.115	0.093	0.179	0.118	0.085	0.133	0.117	0.093	0.142	0.114	0.045	0.133	0.110
PL/TL	0.078	0.095	0.089	0.010	0.167	0.090	0.077	0.126	0.091	0.063	0.142	0.089	0.065	0.111	0.090	0.055	0.102	0.088	0.070	0.097	0.088
2i/TL	0.940	0.125	0.114	0.101	0.241	0.133	0.116	0.181	0.139	0.080	0.252	0.140	0.082	0.221	0.139	0.750	0.210	0.155	0.141	0.285	0.181
2m/TL	0.088	0.129	0.117	0.113	0.250	0.138	0.123	0.190	0.149	0.092	0.400	0.150	0.104	0.294	0.149	0.090	0.321	0.194	0.189	0.319	0.268
2c/TL	0.102	0.154	0.141	0.132	0.278	0.164	0.135	0.23	0.175	0.118	0.200	0.178	0.120	0.370	0.173	0.111	0.400	0.233	0.226	0.426	0.314
2p/TL	0.152	0.266	0.200	0.146	0.430	0.289	0.251	0.464	0.342	0.134	0.861	0.302	0.113	0.596	0.318	0.210	0.699	0.452	0.488	0.731	0.629
2d/TL	0.068	0.122	0.094	0.085	0.315	0.145	0.116	0.263	0.170	0.074	0.413	0.163	0.085	0.313	0.162	0.101	0.337	0.227	0.248	0.357	0.306
2CH/TL	0.463	0.669	0.571	0.582	1.398	0.728	0.845	1.047	0.806	0.429	2.013	0.770	0.476	1.460	0.777	0.497	1.599	1.035	1.059	1.639	1.419
RL/CL	0.317	1.643	1.438	1.069	1.905	1.369	1.146	1.585	1.304	1.048	1.732	1.340	1.052	1.854	1.349	1.090	1.580	1.244	1.000	1.369	1.188
TEL/CL	0.432	0.655	0.498	0.193	0.619	0.428	0.348	0.469	0.405	0.324	0.538	0.421	0.333	0.538	0.420	0.304	0.474	0.381	0.141	0.423	0.352
PL/CL	0.310	0.370	0.343	0.264	0.429	0.324	0.269	0.421	0.319	0.231	0.473	0.318	0.250	0.426	0.324	0.220	0.358	0.292	0.224	0.394	0.281
2i/CL	0.356	0.486	0.437	0.328	0.667	0.482	0.402	0.674	0.486	0.289	0.892	0.499	0.244	0.793	0.495	0.300	0.698	0.515	0.429	0.933	0.678
2m/CL	0.343	0.500	0.450	0.379	0.833	0.500	0.455	0.634	0.520	0.333	1.415	0.533	0.375	1.015	0.531	0.360	1.113	0.644	0.568	1.082	0.856
2c/CL	0.374	0.600	0.541	0.414	0.952	0.595	0.512	0.768	0.611	0.356	1.769	0.633	0.383	1.279	0.622	0.440	1.333	0.772	0.670	1.369	1.087
2p/CL	0.573	1.000	0.765	0.609	1.342	1.041	0.945	1.548	1.184	0.469	3.046	1.072	0.528	2.059	1.126	0.744	2.408	1.498	1.463	2.440	2.006
2d/CL	0.266	0.459	0.361	0.345	0.687	0.522	0.418	0.878	0.568	0.267	1.154	0.573	0.327	1.121	0.578	0.372	1.078	0.749	0.736	1.133	0.976
2CH/CL	1.745	2.514	2.193	1.845	3.191	2.618	2.429	3.500	2.802	1.566	7.123	2.737	1.875	5.044	2.778	1.980	5.465	3.428	3.143	5.320	4.527
RL/2cL	2.377	3.667	2.695	1.718	3.520	2.325	1.667	3.095	2.167	0.913	3.938	2.187	1.023	3.423	2.236	0.924	3.591	1.731	0.919	1.623	1.118
TEL/2cL	0.762	1.333	0.935	0.306	1.083	0.727	0.492	0.857	0.671	0.294	1.188	0.687	0.333	1.043	0.696	0.280	1.000	0.527	0.127	0.508	0.332
PL/2cL	0.563	0.917	0.644	0.375	0.783	0.551	0.581	0.714	0.529	0.178	0.875	0.521	0.218	0.826	0.536	0.207	0.561	0.402	0.165	0.428	0.268
2i/2cL	0.724	1.167	0.816	0.564	1.000	0.813	0.667	1.035	0.799	0.448	1.130	0.801	0.478	1.111	0.808	0.468	0.953	0.691	0.372	0.788	0.541
2m/2cL	0.571	1.250	0.844	0.538	1.053	0.844	0.694	0.917	0.854	0.522	1.217	0.849	0.722	1.743	0.865	0.515	1.023	0.842	0.536	0.915	0.791
2p/2cL	1.300	2.250	1.432	0.750	2.267	1.768	1.444	2.417	1.950	0.478	2.826	1.723	0.800	2.957	1.827	0.967	2.500	1.977	1.496	2.296	1.868
2d/2cL	0.481	1.167	0.877	0.438	1.211	0.883	0.639	1.195	0.963	0.343	1.435	0.916	0.571	1.913	0.937	0.483	1.286	1.001	0.852	1.268	0.914
2CH/2cL	3.545	5.667	4.092	3.325	5.237	4.425	3.806	5.073	4.603	2.448	6.174	4.373	3.367	6.217	4.500	3.533	5.405	4.509	3.577	4.915	4.200
RL/2mL	2.888	4.500	3.227	2.050	3.667	2.759	2.019	3.421	2.534	1.141	4.200	2.575	1.290	3.870	2.594	1.141	4.389	2.057	1.089	1.963	1.424
TEL/2mL	0.889	1.417	1.114	0.367	1.182	0.862	0.596	0.947	0.766	0.373	1.267	0.810	0.420	1.111	0.807	0.333	1.222	0.826	0.171	0.611	0.422
PL/2mL	0.643	1.000	0.769	0.429	0.947	0.654	0.482	0.800	0.620	0.224	0.944	0.615	0.275	0.864	0.662	0.262	0.649	0.478	0.229	0.500	0.341
2i/2mL	0.899	1.417	0.977	0.688	1.160	0.965	0.814	1.261	0.936	0.630	1.540	0.945	0.440	1.200	0.944	0.557	1.000	0.824	0.443	1.000	0.691
2c/2mL	0.800	1.750	1.210	0.950	1.857	1.191	1.091	1.440	1.175	0.821	1.914	1.186	0.574	1.385	1.170	0.927	1.943	1.198	1.093	1.857	1.283
2p/2mL	1.302	2.667	1.712	0.857	2.519	2.098	1.926	2.698	2.279	0.914	2.780	2.026	1.037	2.649	2.125	0.184	3.245	2.359	1.924	3.429	2.384
2d/2mL	0.560	1.333	0.808	0.700	1.421	1.046	0.920	1.413	1.125	0.657	1.552	1.078	0.636	1.760	1.085	0.592	1.476	1.191	0.937	1.625	1.188
2CH/2mL	4.481	6.833	4.899	3.800	6.238	5.238	5.045	5.783	5.390	3.938	6.122	5.157	3.164	5.892	5.239	4.321	7.113	5.378	4.608	7.143	5.358

TL- Total length
CL- Carapace length
RL- Rostral length
TEL- Length of telson
PL- Pleural width

2i- Ischium of 2nd cheliped
2m- Merus of 2nd cheliped
2c- Carpus of 2nd cheliped
2p- Propodus of 2nd cheliped
2d- Dactylus of 2nd cheliped

2CH- Length of 2nd cheliped

Table 1.2.2. Minimum, maximum and mean of different ratios worked out with various morphometric measurements of female morphotypes of Macrobrachium rosenbergii

	Weak Orange Clawed Females (WOF)			Strong Orange Clawed Females (SOF)			Transforming Orange Clawed Females (TOF)			Weak Blue Clawed Females (WBF)			Strong Blue Clawed Females (SBF)		
Ratios	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
CL/TL	0.249	0.290	0.262	0.277	0.456	0.303	0.240	0.312	0.273	0.240	0.298	0.273	0.249	0.341	0.282
RL/TL	0.348	0.394	0.374	0.354	0.429	0.383	0.327	0.402	0.376	0.301	0.400	0.370	0.286	0.421	0.364
TEL/TL	0.112	0.122	0.117	0.111	0.126	0.117	0.097	0.167	0.118	0.106	0.129	0.117	0.105	0.135	0.117
PL/TL	0.086	0.105	0.093	0.090	0.110	0.100	0.079	0.134	0.105	0.820	0.144	0.111	0.101	0.138	0.120
2i/TL	0.100	0.133	0.124	0.094	0.144	0.125	0.100	0.153	0.126	0.820	0.150	0.127	0.095	0.165	0.129
2m/TL	0.950	0.134	0.123	0.100	0.139	0.127	0.065	0.244	0.129	0.920	0.182	0.131	0.106	0.159	0.136
2c/TL	0.119	0.170	0.151	0.153	0.176	0.161	0.100	0.194	0.161	0.100	0.203	0.164	0.142	0.200	0.172
2p/TL	0.211	0.312	0.254	0.222	0.278	0.247	0.113	0.360	0.233	0.174	0.359	0.258	0.205	0.366	0.273
2d/TL	0.094	0.140	0.118	0.100	0.132	0.113	0.071	0.170	0.110	0.083	0.255	0.200	0.091	0.200	0.130
2CH/TL	0.571	0.737	0.651	0.616	0.738	0.660	0.446	0.854	0.649	0.478	0.837	0.680	0.591	0.859	0.710
RL/CL	1.315	1.511	1.439	1.036	1.548	1.315	1.132	1.674	1.383	1.082	1.560	1.359	1.027	1.488	1.293
TEL/CL	0.407	0.489	0.447	0.265	0.434	0.394	0.372	0.589	0.435	0.379	0.512	0.431	0.349	0.483	0.414
PL/CL	0.296	0.415	0.356	0.217	0.370	0.338	0.318	0.488	0.387	0.310	0.538	0.406	0.360	0.490	0.425
2i/CL	0.386	0.523	0.472	0.269	0.509	0.419	0.355	0.578	0.464	0.298	0.545	0.465	0.305	0.540	0.460
2m/CL	0.377	0.510	0.469	0.289	0.491	0.427	0.250	0.895	0.475	0.340	0.660	0.481	0.037	0.563	0.484
2c/CL	0.472	0.643	0.575	0.349	0.623	0.543	0.368	0.688	0.590	0.362	0.771	0.604	0.524	0.729	0.610
2p/CL	0.796	1.184	0.971	0.554	0.981	0.831	0.455	1.197	0.851	0.640	1.349	0.945	0.730	1.316	0.969
2d/CL	0.347	0.531	0.450	0.253	0.472	0.380	0.273	0.569	0.403	0.308	0.886	0.440	0.328	0.719	0.460
2CH/CL	2.256	2.796	2.487	1.482	2.604	2.220	1.702	2.842	2.380	1.760	3.186	2.495	2.017	3.088	2.522
RL/2cL	2.259	2.920	2.519	2.219	2.966	2.444	1.959	3.619	2.361	1.810	3.647	2.276	1.590	2.600	2.135
TEL/2cL	0.667	0.960	0.785	0.656	0.800	0.728	0.592	1.190	0.744	0.566	1.059	0.722	0.550	0.800	0.683
PL/2cL	0.159	0.880	0.628	0.531	0.700	0.624	0.483	1.238	0.682	0.486	1.045	0.680	0.600	0.857	0.700
2i/2cL	0.778	0.909	0.823	0.583	0.900	0.775	0.600	1.524	0.794	0.595	0.929	0.777	0.583	0.933	0.756
2m/2cL	0.741	0.909	0.817	0.636	0.867	0.788	0.550	2.429	0.817	0.568	1.624	0.809	0.667	0.966	0.795
2p/2cL	1.333	2.160	1.702	1.429	1.625	1.531	0.690	2.000	1.451	1.192	2.176	1.579	1.200	2.000	1.593
2d/2cL	0.593	1.000	0.790	0.630	0.781	0.700	0.483	1.190	0.688	0.533	1.444	0.735	0.467	1.025	0.756
2CH/2cL	3.852	4.800	4.342	3.833	0.430	4.094	3.276	6.952	4.062	3.378	5.824	4.165	3.622	4.828	4.145
RL/2mL	2.840	3.650	3.085	2.769	3.714	3.116	1.490	5.000	2.965	2.000	4.059	2.841	2.129	3.550	2.690
TEL/2mL	0.840	1.200	0.961	0.864	1.143	0.929	0.490	1.818	0.934	0.581	1.294	0.902	0.710	1.080	0.861
PL/2mL	0.640	1.100	0.761	0.708	1.048	0.797	0.510	1.455	0.828	0.548	1.353	0.849	0.750	1.200	0.882
2i/2mL	0.957	1.050	1.008	0.750	1.048	0.983	0.627	1.636	0.992	0.452	1.150	0.972	0.750	1.067	0.950
2c/2mL	1.100	1.350	1.227	1.154	1.517	1.277	0.412	1.818	1.265	0.548	1.762	1.260	1.038	1.500	1.263
2p/2mL	1.696	2.700	2.085	1.769	2.524	1.958	0.824	2.364	1.818	1.194	2.417	1.968	1.459	2.750	2.007
2d/2mL	0.739	1.250	0.965	0.773	1.143	0.895	0.490	1.108	0.858	0.484	1.696	0.916	0.583	1.323	0.952
2CH/2mL	4.850	6.000	5.320	4.929	6.143	5.219	2.863	6.818	5.075	3.194	6.050	5.199	4.613	6.200	5.220

TL- Total length
CL- Carapace length
RL- Rostral length
TEL- Length of telson
PL- Pleural width
2i- Ischium of 2nd cheliped
2m- Merus of 2nd cheliped
2c- Carpus of 2nd cheliped
2p- Propodus of 2nd cheliped
2d- Dactylus of 2nd cheliped
2CH- Length of 2nd cheliped

Table 1.3.1 Values of intercept (a), slope (regression coefficient (b) and correlation coefficient (r) of different morphometric characters of male morphotypes of Macrobrachium rosenbergii

Relationships	Small Males df = 15			Weak Orange Clawed Males df = 107		
	Regression Constant a	Regression Coefficient b	Correlation Coefficient r	Regression Constant a	Regression Coefficient b	Correlation Coefficient r
TL x CL	0.596	0.267	0.977	10.825	0.218	0.735
TL x RL	-3.715	0.411	0.984	20.875	0.263	0.763
TL x Tel	1.268	0.117	0.944	8.937	0.069	0.644
TL x Pl	0.400	0.085	0.937	4.317	0.066	0.706
TL x 2i	-3.181	0.145	0.960	-3.249	0.151	0.797
TL x 2m	0.729	0.110	0.821	-3.066	0.155	0.849
TL x 2c	-1.409	0.154	0.841	-1.108	0.170	0.835
TL x 2p	-18.824	0.384	0.958	-6.226	0.323	0.645
TL x 2d	-9.670	0.189	0.946	-9.838	0.119	0.772
TL x 2chl	-22.686	0.794	0.958	13.649	0.799	0.816
CL x RL	-0.252	1.447	0.946	24.290	0.882	0.760
CL x Tel	2.360	0.409	0.803	9.682	0.234	0.649
CL x Pl	3.440	0.326	0.976	4.734	0.229	0.730
CL x 2i	-2.280	0.520	0.939	1.351	0.456	0.713
CL x 2m	1.112	0.408	0.830	1.223	0.475	0.773
CL x 2c	-0.191	0.548	0.813	5.797	0.478	0.697
CL x 2p	-17.451	1.423	0.968	-12.275	1.287	0.761
CL x 2d	-9.103	0.704	0.961	-9.819	0.718	0.827
CL x 2chl	-18.739	2.899	0.955	-3.904	2.695	0.816
RL x Tel	2.97	0.269	0.808	8.060	0.195	0.630
RL x Pl	1.573	0.198	0.906	5.110	0.163	0.603
RL x 2i	-1.395	0.314	0.942	-2.048	0.384	0.698
RL x 2m	2.595	0.246	0.765	-3.507	0.418	0.789
RL x 2c	0.276	0.369	0.838	0.094	0.437	0.739
RL x 2p	-13.585	0.891	0.927	-1.954	0.798	0.548
RL x 2d	-7.113	0.439	0.916	-9.077	0.518	0.692
RL x 2chl	12.109	1.846	0.930	-7.602	2.037	0.716
Tel x Pl	3.184	0.453	0.692	8.719	0.356	0.408
Tel x 2i	-0.542	0.924	0.850	-0.498	1.159	0.654
Tel x 2m	2.948	0.687	0.711	-0.432	1.198	0.702
Tel x 2c	3.400	0.838	0.633	3.106	1.253	0.657
Tel x 2p	-9.188	2.257	0.781	5.756	2.201	0.468
Tel x 2d	-5.156	1.127	0.783	-4.412	1.444	0.599
Tel x 2chl	-3.382	4.706	0.799	7.932	5.810	0.633
Pl x 2i	-2.061	1.503	0.907	4.125	1.243	0.611
Pl x 2m	1.398	1.162	0.789	4.073	1.302	0.665
Pl x 2c	-0.165	1.597	0.792	6.428	1.447	0.661
Pl x 2p	-17.429	4.162	0.945	-7.613	3.713	0.689
Pl x 2d	-9.182	2.063	0.941	-5.052	1.940	0.701
Pl x 2chl	-18.307	8.424	0.927	-7.014	7.705	0.732
2i x 2m	3.510	0.730	0.821	4.130	0.869	0.902
2i x 2c	2.117	1.055	0.867	7.086	0.941	0.875
2i x 2p	-9.369	2.569	0.967	7.277	1.876	0.708
2i x 2d	-4.998	1.262	0.953	-0.242	1.102	0.809
2i x 2chl	-3.742	5.334	0.976	18.493	4.686	0.906
2m x 2c	3.496	0.917	0.669	4.361	1.014	0.909
2m x 2p	-10.620	2.609	0.873	4.673	1.911	0.695
2m x 2d	-5.121	1.214	0.833	-5.166	1.256	0.889
2m x 2chl	-6.491	5.450	0.883	9.744	4.861	0.905
2c x 2p	-6.023	1.856	0.850	2.910	1.670	0.677
2c x 2d	-2.768	0.870	0.801	-4.627	1.041	0.822
2c x 2chl	0.460	4.056	0.900	3.761	4.298	0.893
2p x 2d	-0.411	0.492	0.987	4.497	0.418	0.814
2p x 2chl	16.620	2.045	0.990	37.767	1.794	0.919
2d x 2chl	19.929	3.998	0.965	40.786	3.458	0.910

TL- Total length
CL- Carapace length
RL-Rostral length
Tel- Length of telson
Pl- Pleural width
2i -length of ischium of 2nd cheliped
2m -length of merus of 2nd cheliped
2c -length of carpus of 2nd cheliped
2p -length of propodus of 2nd cheliped
2d -length of dactylus of 2nd cheliped
2chl- Length of 2nd cheliped

Table 1.3.2 Values of intercept (a), slope (regression coefficient, b) and correlation coefficient (r) of different morphometric characters of male morphotypes of Macrobrachium rosenbergii

Relationship	Strong Orange Clawed Males df = 22			Pre-transforming Strong Orange Clawed Males df = 107		
	Regression Constant a	Regression Coefficient b	Correlation Coefficient r	Regression Constant a	Regression Coefficient b	Correlation Coefficient r
TL x CL	-16.154	0.366	0.983	-8.336	0.323	0.930
TL x RL	-4.016	0.392	0.982	2.475	0.362	0.899
TL x Tel	1.709	0.107	0.927	3.053	0.103	0.878
TL x Pl	-1.234	0.097	0.979	2.949	0.074	0.758
TL x 2i	-6.332	0.170	0.908	-11.077	0.195	0.843
TL x 2m	-17.424	0.234	0.966	-18.721	0.244	0.742
TL x 2c	-21.240	0.279	0.946	-21.401	0.285	0.682
TL x 2p	-63.257	0.649	0.934	-45.523	0.530	0.641
TL x 2d	-41.502	0.372	0.935	-35.765	0.342	0.807
TL x 2chl	-108.242	1.332	0.966	-96.721	1.254	0.750
CL x RL	15.883	1.030	0.960	17.986	1.015	0.875
CL x Tel	7.426	0.277	0.939	7.560	0.285	0.848
CL x Pl	3.847	0.253	0.851	6.019	0.210	0.744
CL x 2i	2.790	0.438	0.822	-1.400	0.525	0.778
CL x 2m	-5.385	0.612	0.940	-8.926	0.694	0.734
CL x 2c	-6.025	0.715	0.902	-9.348	0.801	0.669
CL x 2p	31.823	1.730	0.958	-29.964	1.609	0.676
CL x 2d	-23.099	0.984	0.920	-23.650	1.001	0.821
CL x 2chl	-40.443	3.495	0.943	-49.637	3.628	0.754
RL x Tel	3.461	0.265	0.965	-5.574	0.241	0.831
RL x Pl	0.137	0.243	0.878	5.483	0.165	0.679
RL x 2i	-2.886	0.412	0.880	-7.023	0.469	0.806
RL x 2m	-13.300	0.525	0.978	-17.128	0.630	0.773
RL x 2c	-16.101	0.682	0.924	-19.865	0.741	0.718
RL x 2p	-51.685	1.594	0.947	-35.028	1.278	0.623
RL x 2d	-35.472	0.920	0.924	-31.593	0.858	0.816
RL x 2chl	-83.972	3.252	0.945	-79.045	3.117	0.752
Tel x Pl	-2.520	0.897	0.889	3.300	0.617	0.736
Tel x 2i	-8.991	1.583	0.829	-10.553	1.640	0.818
Tel x 2m	-19.389	2.112	0.956	-22.840	2.244	0.799
Tel x 2c	-24.225	2.542	0.946	-28.573	2.724	0.765
Tel x 2p	-65.755	5.740	0.937	-59.476	5.089	0.720
Tel x 2d	-43.407	3.305	0.912	-38.374	3.015	0.832
Tel x 2chl	-118.360	11.978	0.530	-12.443	11.696	0.818
Pl x 2i	3.531	1.350	0.800	2.652	1.444	0.604
Pl x 2m	-2.883	1.811	0.827	-2.070	1.826	0.545
Pl x 2c	-5.529	2.242	0.841	-2.933	2.193	0.516
Pl x 2p	-18.597	4.806	0.791	-45.374	5.965	0.707
Pl x 2d	-15.150	2.712	0.754	-15.636	2.739	0.633
Pl x 2chl	-23.438	10.209	0.820	-47.726	11.428	0.670
2i x 2m	-5.220	1.262	0.973	-6.202	1.292	0.922
2i x 2c	-7.631	1.534	0.972	-8.576	1.575	0.887
2i x 2p	-25.839	3.381	0.942	-7.366	2.430	0.689
2i x 2d	-22.205	2.007	0.943	-13.476	1.647	0.911
2i x 2chl	-38.690	7.177	0.973	-22.147	6.296	0.883
2m x 2c	-0.720	1.199	0.985	-1.030	1.220	0.962
2m x 2p	-13.070	2.718	0.980	1.377	1.976	0.785
2m x 2d	-14.262	1.602	0.976	-3.283	1.202	0.931
2m x 2chl	-8.279	5.667	0.996	8.757	4.853	0.954
2c x 2p	-7.560	2.166	0.950	9.189	1.453	0.732
2c x 2d	-11.259	1.283	0.951	1.409	0.885	0.870
2c x 2chl	0.297	4.592	0.982	22.702	3.711	0.924
2p x 2d	-6.131	0.584	0.986	6.698	0.435	0.849
2p x 2chl	22.974	2.032	0.991	41.712	1.876	0.928
2d x 2chl	47.038	3.409	0.984	32.307	3.736	0.947

TL- Total length
CL- Carapace length
RL-Rostral length
Tel- Length of telson
Pl- Pleural width
2i -length of ischium of 2nd cheliped
2m -length of merus of 2nd cheliped
2c -length of carpus of 2nd cheliped
2p -length of propodus of 2nd cheliped
2d -length of dactylus of 2nd cheliped
2chl- Length of 2nd cheliped

Table 1.3.3 Values of intercept (a), slope (regression coefficient, b) and correlation coefficient (r) of different morphometric characters of male morphotypes of Macrobrachium rosenbergii

Relationship	Weak Blue Clawed Males df = 102			Strong Blue Clawed Males df = 51		
	Regression Constant a	Regression Coefficient b	Correlation Coefficient r	Regression Constant a	Regression Coefficient b	Correlation Coefficient r
TL x CL	-1.246	0.287	0.907	-15.397	0.363	0.871
TL x RL	7.512	0.336	0.924	-0.450	0.375	0.870
TL x Tel	2.553	0.103	0.930	-2.686	0.125	0.846
TL x Pl	0.125	0.091	0.884	-4.007	0.104	0.792
TL x 2i	-11.279	0.119	0.860	-22.344	0.245	0.718
TL x 2m	-17.718	0.242	0.844	-39.445	0.382	0.569
TL x 2c	-17.397	0.565	0.782	-55.954	0.457	0.554
TL x 2p	-33.379	0.492	0.707	-111.308	0.898	0.623
TL x 2d	-23.559	0.286	0.788	-60.521	0.469	0.693
TL x 2chl	-79.720	1.196	0.816	-229.051	1.551	0.634
CL x RL	18.270	1.003	0.871	32.945	0.804	0.777
CL x Tel	5.645	0.313	0.888	8.503	0.267	0.754
CL x Pl	2.514	0.276	0.849	3.080	0.251	0.798
CL x 2i	-3.315	0.561	0.770	-1.190	0.532	0.651
CL x 2m	-12.536	0.768	0.846	-9.212	0.768	0.518
CL x 2c	-8.363	0.781	0.727	-18.997	1.027	0.520
CL x 2p	-28.733	1.670	0.758	-47.511	2.134	0.618
CL x 2d	-17.803	0.914	0.796	-29.825	1.149	0.708
CL x 2chl	-52.947	3.780	0.814	-76.910	4.461	0.604
RL x Tel	2.559	0.276	0.902	5.169	0.251	0.734
RL x Pl	0.951	0.228	0.807	4.689	0.186	0.611
RL x 2i	-9.297	0.502	0.792	-10.023	0.524	0.663
RL x 2m	-16.918	0.634	0.805	-24.720	0.784	0.548
RL x 2c	-15.003	0.675	0.724	-37.184	1.624	0.536
RL x 2p	-30.485	0.273	0.665	-52.598	1.781	0.533
RL x 2d	-21.268	0.738	0.740	-25.424	0.883	0.563
RL x 2chl	-71.702	3.083	0.765	-127.525	4.116	0.576
Tel x Pl	0.208	0.766	0.829	6.017	0.562	0.632
Tel x 2i	-10.367	0.659	0.802	-6.570	1.592	0.690
Tel x 2m	-19.729	2.161	0.840	-19.154	2.374	0.567
Tel x 2c	-17.506	2.278	0.748	-37.936	3.371	0.604
Tel x 2p	-36.920	4.337	0.694	-54.035	5.867	0.601
Tel x 2d	-24.401	2.487	0.764	-28.577	2.993	0.654
Tel x 2chl	-83.694	10.435	0.792	-117.695	13.204	0.633
Pl x 2i	-3.654	1.761	0.786	3.445	1.617	0.623
Pl x 2m	-6.787	2.055	0.738	-1.508	2.288	0.486
Pl x 2c	-5.272	2.247	0.681	-5.786	2.930	0.467
Pl x 2p	-24.318	4.930	0.729	-33.510	6.692	0.610
Pl x 2d	-11.937	2.504	0.710	-23.953	3.677	0.714
Pl x 2chl	-40.030	10.993	0.771	-37.359	13.527	0.577
2i x 2m	0.599	1.053	0.847	-10.647	1.524	0.839
2i x 2c	-2.609	1.349	0.916	-19.059	1.991	0.823
2i x 2p	-2.430	2.375	0.786	-12.326	3.241	0.776
2i x 2d	-2.001	1.249	0.793	-0.415	1.554	0.783
2i x 2chl	-4.440	5.777	0.907	-42.080	7.755	0.858
2m x 2c	2.441	1.085	0.916	-2.705	1.287	0.944
2m x 2p	3.491	2.008	0.826	14.248	2.047	0.819
2m x 2d	-0.415	1.108	0.875	15.748	2.852	0.780
2m x 2chl	13.248	4.773	0.932	28.121	4.766	0.958
2c x 2p	2.723	1.774	0.850	22.300	1.567	0.896
2c x 2d	0.471	0.924	0.864	20.552	0.628	0.765
2c x 2chl	11.634	4.139	0.958	48.780	3.616	0.968
2p x 2d	3.306	0.462	0.886	10.925	0.407	0.867
2p x 2chl	27.678	2.015	0.956	24.660	2.071	0.967
2d x 2chl	34.596	3.703	0.916	38.697	3.888	0.854

TL- Total length
CL- Carapace length
RL-Rostral length
Tel- Length of telson
Pl- Pleural width
2i -length of ischium of 2nd cheliped
2m -length of merus of 2nd cheliped
2c -length of carpus of 2nd cheliped
2p -length of propodus of 2nd cheliped
2d -length of dactylus of 2nd cheliped
2chl- Length of 2nd cheliped

Table 1.3.4 Values of intercept (a), slope (regression coefficient (b) and correlation coefficient (r) of different morphometric characters of male morphotypes of Macrobrachium rosenbergii

Relationships	Old Blue Clawed Males df = 31 Regression Constant a	Regression Coefficient b	Correlation Coefficient r
TL x CL	-3.422	0.326	0.795
TL x RL	12.439	0.328	0.757
TL x Tel	5.558	0.091	0.421
TL x Pl	-0.867	0.091	0.691
TL x 2i	-8.202	0.21	0.488
TL x 2m	8.919	0.237	0.352
TL x 2c	20.178	0.27	0.344
TL x 2p	-31.042	0.738	0.627
TL x 2d	-11.269	0.347	0.684
TL x 2chl	-10.148	1.455	0.542
CL x RL	47.741	0.65	0.617
CL x Tel	13.345	0.202	0.385
CL x Pl	7.678	0.195	0.606
CL x 2i	11.101	0.454	0.423
CL x 2m	22.173	0.606	0.370
CL x 2c	36.854	0.624	0.352
CL x 2p	35.037	0.612	0.562
CL x 2d	18.509	0.764	0.621
CL x 2chl	105.169	3.346	0.512
RL x Tel	6.916	0.231	0.446
RL x Pl	17.213	0.104	0.340
RL x 2i	13.531	0.616	0.619
RL x 2m	1.738	0.706	0.454
RL x 2c	12.393	0.8	0.441
RL x 2p	19.501	1.515	0.557
RL x 2d	23.649	0.602	0.513
RL x 2chl	19.601	3.638	0.581
Tel x Pl	20.500	0.15	0.244
Tel x 2i	31.380	0.652	0.325
Tel x 2m	47.157	0.938	0.300
Tel x 2c	72.825	0.78	0.214
Tel x 2p	144.828	0.956	0.125
Tel x 2d	79.485	0.257	0.109
Tel x 2chl	301.190	0.326	0.267
Pl x 2i	36.347	0.617	0.189
Pl x 2m	87.207	-0.417	0.082
Pl x 2c	110.500	-0.5	0.084
Pl x 2p	133.707	1.833	0.206
Pl x 2d	49.706	1.5	0.390
Pl x 2chl	367.260	1.532	0.075
2i x 2m	41.097	0.686	0.439
2i x 2c	47.918	0.983	0.523
2i x 2p	108.757	1.371	0.502
2i x 2d	63.228	0.469	0.398
2i x 2chl	197.770	4.01	0.645
2m x 2c	30.263	0.875	0.709
2m x 2p	83.177	1.262	0.722
2m x 2d	54.086	0.436	0.578
2m x 2chl	143.773	3.419	0.858
2c x 2p	61.668	1.214	0.810
2c x 2d	48.128	0.405	0.626
2c x 2chl	99.708	3.144	0.921
2p x 2d	16.809	0.393	0.911
2p x 2chl	21.315	2.137	0.938
2d x 2chl	39.834	4.182	0.792

TL- Total length
CL- Carapace length
RL-Rostral length
Tel- Length of telson
Pl- Pleural width
2i -length of ischium of 2nd cheliped
2m -length of merus of 2nd cheliped
2c -length of carpus of 2nd cheliped
2p -length of propodus of 2nd cheliped
2d -length of dactylus of 2nd cheliped
2chl- Length of 2nd cheliped

Table 1.3.5. Values of intercept (a), slope (regression coefficient, b) and correlation coefficient (r) of different morphometric characters of female morphotypes of Macrobrachium rosenbergii

Relationships	Weak Orange Clawed Females df = 8			Strong Orange Clawed Females df = 10		
	Regression Constant a	Regression Coefficient b	Correlation Coefficient r	Regression Constant a	Regression Coefficient b	Correlation Coefficient r
TL x CL	2.609	0.247	0.854	28.862	0.151	0.933
TL x RL	14.620	0.295	0.878	-34.813	0.566	0.927
TL x Tel	1.720	0.107	0.934	0.593	0.114	0.896
TL x Pl	-10.011	0.149	0.924	-1.922	0.110	0.830
TL x 2i	17.949	0.024	0.252	32.199	-0.044	0.308
TL x 2m	16.065	0.034	0.251	11.901	-0.064	0.460
TL x 2c	20.648	0.036	0.213	0.692	0.157	0.883
TL x 2p	-33.846	0.443	0.734	2.398	0.234	0.725
TL x 2d	-10.984	0.179	0.692	-1.341	0.120	0.679
TL x 2chl	20.816	0.536	0.594	47.191	0.412	0.690
CL x RL	21.883	0.973	0.840	64.271	0.160	0.170
CL x Tel	5.983	0.320	0.807	18.282	0.071	0.363
CL x Pl	-0.135	0.359	0.647	16.464	0.047	0.231
CL x 2i	15.998	0.132	0.405	24.194	0.008	0.038
CL x 2m	10.880	0.237	0.516	22.625	0.027	0.126
CL x 2c	15.880	0.237	0.410	28.696	0.036	0.132
CL x 2p	-32.424	1.661	0.798	40.656	0.113	0.228
CL x 2d	-9.112	0.644	0.722	17.973	0.063	0.230
CL x 2chl	10.334	2.267	0.729	116.168	0.168	0.183
RL x Tel	3.084	0.265	0.777	9.416	0.177	0.848
RL x Pl	-6.023	0.337	0.704	6.772	0.169	0.776
RL x 2i	10.454	0.173	0.617	26.436	-0.037	0.158
RL x 2m	4.778	0.225	0.643	13.534	0.145	0.633
RL x 2c	6.309	0.306	0.613	11.324	0.265	0.907
RL x 2p	-54.709	1.485	0.827	21.046	0.356	0.673
RL x 2d	-16.788	0.561	0.730	8.338	0.180	0.623
RL x 2chl	-33.168	2.219	0.827	72.340	0.729	0.747
Tel x Pl	-10.022	1.273	0.909	-1.767	0.936	0.895
Tel x 2i	18.787	0.164	0.199	23.570	0.006	0.005
Tel x 2m	16.699	0.257	0.221	9.093	0.674	0.613
Tel x 2c	23.546	0.169	0.116	5.535	1.128	0.805
Tel x 2p	-21.858	3.224	0.614	9.302	1.692	0.667
Tel x 2d	-5.984	1.295	0.575	1.023	0.919	0.661
Tel x 2chl	37.175	3.814	0.486	47.500	3.500	0.747
Pl x 2i	22.532	-0.017	0.028	23.394	0.016	0.015
Pl x 2m	22.830	-0.042	0.050	17.255	0.362	0.344
Pl x 2c	27.454	-0.019	0.019	13.745	0.888	0.662
Pl x 2p	16.072	1.788	0.477	24.936	1.160	0.478
Pl x 2d	9.953	0.677	0.421	9.447	0.633	0.476
Pl x 2chl	88.889	1.710	0.305	79.330	2.426	0.544
2i x 2m	-6.226	1.274	0.903	16.354	0.331	0.341
2i x 2c	-8.403	1.597	0.899	32.735	-0.820	0.066
2i x 2p	-53.516	4.484	0.702	47.415	-0.009	0.004
2i x 2d	-17.742	1.758	0.643	17.946	0.154	0.126
2i x 2chl	-68.145	8.355	0.876	96.503	1.240	0.300
2m x 2c	3.567	1.065	0.846	13.115	0.731	0.573
2m x 2p	-18.781	2.939	0.650	25.327	0.904	0.392
2m x 2d	-2.721	1.089	0.562	7.755	0.572	0.453
2m x 2chl	-7.117	5.644	0.835	53.649	2.986	0.701
2c x 2p	-11.885	2.143	0.596	-3.556	1.648	0.910
2c x 2d	3.269	0.668	0.434	-4.917	0.861	0.869
2c x 2chl	0.509	4.322	0.804	32.133	0.044	0.911
2p x 2d	2.388	0.411	0.958	-3.278	0.527	0.963
2p x 2chl	52.092	1.420	0.950	47.049	1.671	0.905
2d x 2chl	52.680	3.044	0.892	59.018	3.096	0.918

TL- Total length
CL- Carapace length
RL-Rostral length
Tel- Length of telson
Pl- Pleural width
2i -length of ischium of 2nd cheliped
2m -length of merus of 2nd cheliped
2c -length of carpus of 2nd cheliped
2p -length of propodus of 2nd cheliped
2d -length of dactylus of 2nd cheliped
2chl- Length of 2nd cheliped

Table 1.3.6 Values of intercept (a), slope (regression coefficient, b) and correlation coefficient (r) of different morphometric characters of female morphotypes of Macrobrachium rosenbergii

Relationships	Transforming Orange Clawed Females df = 49			Weak Blue Clawed Females df = 60		
	Regression Constant a	Regression Coefficient b	Correlation Coefficient r	Regression Constant a	Regression Coefficient b	Correlation Coefficient r
TL x CL	-8.499	0.319	0.955	-10.994	0.330	0.964
TL x RL	0.193	0.375	0.959	21.910	0.250	0.562
TL x Tel	1.102	0.112	0.851	2.151	0.106	0.951
TL x Pl	-7.472	0.146	0.870	-8.642	0.156	0.864
TL x 2i	-2.004	0.137	0.858	-3.038	0.143	0.861
TL x 2m	-12.335	0.197	0.813	-3.411	0.149	0.853
TL x 2c	-6.364	0.197	0.880	-2.081	0.175	0.808
TL x 2p	-31.905	0.407	0.820	-11.285	0.316	0.771
TL x 2d	-22.504	0.233	0.918	-4.291	0.142	0.621
TL x 2chl	-52.608	0.937	0.924	-19.815	0.783	0.875
CL x RL	15.992	1.060	0.906	33.227	0.701	0.540
CL x Tel	5.253	0.329	0.833	6.953	0.298	0.914
CL x Pl	-1.818	0.423	0.842	-0.850	0.422	0.804
CL x 2i	3.279	0.398	0.831	2.667	0.414	0.856
CL x 2m	-4.917	0.574	0.793	2.019	0.442	0.868
CL x 2c	0.342	0.583	0.877	6.445	0.480	0.759
CL x 2p	-22.127	1.296	0.872	0.011	0.944	0.788
CL x 2d	-15.329	0.712	0.936	0.252	0.435	0.650
CL x 2chl	-23.423	2.851	0.940	11.141	2.280	0.873
RL x Tel	3.457	0.265	0.785	14.884	0.113	0.451
RL x Pl	-4.443	0.346	0.804	7.430	0.203	0.500
RL x 2i	0.944	0.323	0.789	13.252	0.164	0.439
RL x 2m	-9.358	0.481	0.777	14.751	0.155	0.395
RL x 2c	-4.006	0.486	0.856	16.102	0.227	0.465
RL x 2p	-25.652	0.994	0.782	31.295	0.272	0.295
RL x 2d	-17.970	0.556	0.855	18.192	0.076	0.147
RL x 2chl	-38.072	2.284	0.881	75.400	0.818	0.406
Tel x Pl	-0.846	0.936	0.735	-9.267	1.355	0.840
Tel x 2i	4.481	0.866	0.715	-3.856	1.253	0.844
Tel x 2m	-4.278	1.299	0.708	-2.988	1.253	0.801
Tel x 2c	2.085	1.270	0.754	-3.938	1.576	0.812
Tel x 2p	-14.124	2.636	0.700	-13.608	2.803	0.763
Tel x 2d	-11.747	1.484	0.771	-6.389	1.307	0.637
Tel x 2chl	-11.835	6.070	0.791	-24.389	6.885	0.859
Pl x 2i	7.784	0.798	0.838	10.939	0.638	0.694
Pl x 2m	2.077	1.126	0.782	10.294	0.709	0.730
Pl x 2c	9.627	1.033	0.781	12.894	0.885	0.735
Pl x 2p	-2.756	2.363	0.799	21.332	1.344	0.590
Pl x 2d	-5.155	1.321	0.873	10.951	0.579	0.455
Pl x 2chl	16.732	5.320	0.882	55.458	3.575	0.719
2i x 2m	-5.367	1.261	0.833	5.067	0.832	0.783
2i x 2c	4.787	1.072	0.772	5.742	1.063	0.813
2i x 2p	-7.721	2.193	0.706	-3.115	2.162	0.873
2i x 2d	-10.262	1.325	0.833	-2.529	1.050	0.759
2i x 2chl	-8.301	5.526	0.872	7.694	5.057	0.936
2m x 2c	16.181	0.570	0.621	9.114	0.896	0.722
2m x 2p	9.822	1.402	0.683	1.236	1.919	0.817
2m x 2d	0.378	0.845	0.805	0.448	0.898	0.684
2m x 2chl	36.165	3.522	0.841	15.954	4.562	0.890
2c x 2p	-12.303	1.872	0.837	4.768	1.425	0.752
2c x 2d	-9.865	1.025	0.896	2.067	0.668	0.631
2c x 2chl	-1.445	4.104	0.899	16.625	3.629	0.878
2p x 2d	0.734	0.460	0.899	-1.939	0.504	0.902
2p x 2chl	36.889	1.934	0.948	27.209	2.097	0.961
2d x 2chl	41.630	3.831	0.961	56.039	3.280	0.840

TL- Total length
CL- Carapace length
RL-Rostral length
Tel- Length of telson
Pl- Pleural width
2i -length of ischium of 2nd cheliped
2m -length of merus of 2nd cheliped
2c -length of carpus of 2nd cheliped
2p -length of propodus of 2nd cheliped
2d -length of dactylus of 2nd cheliped
2chl- Length of 2nd cheliped

Table 1.3.7 Values of intercept (a), slope (regression coefficient, b) and correlation coefficient (r) of different morphometric characters of female morphotypes of Macrobrachium rosenbergii

Relationships	Strong Blue Clawed Females df = 62 Regression Constant a	Regression Coefficient b	Correlation Coefficient r
TL x CL	-5.867	0.311	0.916
TL x RL	12.551	0.302	0.839
TL x Tel	3.445	0.100	0.908
TL x Pl	-4.735	0.143	0.929
TL x 2i	-8.777	0.172	0.854
TL x 2m	-7.009	0.170	0.881
TL x 2c	-6.785	0.205	0.865
TL x 2p	-4.907	0.297	0.725
TL x 2d	-9.644	0.176	0.711
TL x 2chl	-27.478	0.843	0.867
CL x RL	26.149	0.840	0.790
CL x Tel	7.829	0.280	0.681
CL x Pl	1.496	0.399	0.882
CL x 2i	-2.036	0.494	0.832
CL x 2m	0.702	0.472	0.828
CL x 2c	1.287	0.587	0.842
CL x 2p	6.504	0.857	0.710
CL x 2d	-4.654	0.539	0.737
CL x 2chl	6.457	2.410	0.840
RL x Tel	8.244	0.213	0.696
RL x Pl	-0.675	0.340	0.798
RL x 2i	-4.321	0.416	0.744
RL x 2m	-0.959	0.390	0.727
RL x 2c	1.236	0.459	0.699
RL x 2p	3.820	0.704	0.620
RL x 2d	-4.430	0.418	0.607
RL x 2chl	-0.223	1.968	0.729
Tel x Pl	-5.182	1.243	0.892
Tel x 2i	-7.878	1.439	0.788
Tel x 2m	-7.363	1.476	0.841
Tel x 2c	-7.765	1.797	0.837
Tel x 2p	-3.769	2.500	0.673
Tel x 2d	-7.530	1.427	0.634
Tel x 2chl	26.774	7.212	0.817
Pl x 2i	-0.617	1.108	0.845
Pl x 2m	1.101	1.095	0.870
Pl x 2c	2.595	1.331	0.865
Pl x 2p	8.816	1.926	0.722
Pl x 2d	-1.018	1.126	0.697
Pl x 2chl	11.894	5.461	0.862
2i x 2m	4.129	0.900	0.937
2i x 2c	8.697	1.005	0.856
2i x 2p	14.417	1.572	0.773
2i x 2d	0.875	0.970	0.787
2i x 2chl	27.243	4.476	0.926
2m x 2c	3.866	1.124	0.919
2m x 2p	8.159	1.713	0.809
2m x 2d	-2.523	1.041	0.811
2m x 2chl	11.292	4.814	0.956
2c x 2p	8.272	1.358	0.784
2c x 2d	-1.633	0.802	0.764
2c x 2chl	10.778	3.837	0.932
2p x 2d	0.220	0.481	0.793
2p x 2chl	22.387	2.215	0.932
2d x 2chl	58.899	3.308	0.843

TL- Total length
CL- Carapace length
RL-Rostral length
Tel- Length of telson
Pl- Pleural width
2i -length of ischium of 2nd cheliped
2m -length of merus of 2nd cheliped
2c -length of carpus of 2nd cheliped
2p -length of propodus of 2nd cheliped
2d -length of dactylus of 2nd cheliped
2chl- Length of 2nd cheliped

Table 1.4.1 Minimum, maximum, mean and standard deviation of various morphometric measurements recorded in males and females of Macrobrachium rosenbergii

Sl.No.	Measurements	Males n=106				Females n=117			
		Minimum (mm)	Maximum (mm)	Mean (mm)	SD	Minimum (mm)	Maximum (mm)	Mean (mm)	SD
1	Total length	121	278	188.10	29.84	107	253	190.50	28.05
2	Carapace length	37	88	53.99	10.88	26	76	52.39	9.63
3	Rostral length	41	106	71.41	11.68	40	96	70.56	10.25
4	Length of telson	14	33	21.48	3.27	13	31	22.26	3.37
5	II abdominal pleural width	11	25	16.86	3.05	11	32	20.88	4.83
6	Length of I cheliped	46	127	71.86	13.91	31	97	71.38	11.64
7	Length of ischium of II cheliped	14	51	23.79	5.71	12	38	24.00	4.57
8	Length of merus of II cheliped	15	80	24.87	8.14	13	40	24.82	4.78
9	Length of carpus of II cheliped	17	99	30.73	10.26	16	49	31.61	6.08
10	Length of propodus of II cheliped	24	185	57.49	21.37	18	91	49.03	11.80
11	Length of dactylus of II cheliped	13	93	27.83	10.92	8	43	22.88	6.33
12	Total length of II cheliped	75	415	137.90	44.61	60	216	129.50	25.93
13	Length of III walking leg	47	121	73.38	13.46	38	111	73.44	12.10
14	Length of IV walking leg	47	128	75.72	14.06	41	114	77.09	12.39
15	Length of V walking leg	48	134	78.04	14.74	46	114	79.35	13.81

Table1.4.2 Minimum, maximum, mean and standard deviation of various morphometric measurements recorded in males and females of Macrobrachium idella

Sl.No.	Measurements	Males n=132				Females n=106			
		Minimum (mm)	Maximum (mm)	Mean (mm)	SD	Minimum (mm)	Maximum (mm)	Mean (mm)	SD
1	Total length	34	116	72.97	20.51	39	88	66.35	11.55
2	Carapace length	8	35	20.24	7.00	8.7	26.6	17.35	4.03
3	Rostral length	9	39	22.75	6.50	10.5	29	20.30	4.02
4	Length of telson	4	20	10.72	3.34	4.8	13	9.39	1.80
5	II abdominal pleural width	3	14	7.37	2.51	3.7	16	8.65	2.27
6	Length of I cheliped	10	57	29.92	11.36	11	36	23.23	5.20
7	Length of ischium of II cheliped	4	28	12.87	6.15	3.7	15	8.03	2.70
8	Length of merus of II cheliped	4	38	18.05	10.31	4.2	28	8.57	2.86
9	Length of carpus of II cheliped	6	75	33.35	21.27	5	52	13.86	5.64
10	Length of propodus of II cheliped	5	70	31.64	19.69	5	51	13.46	5.71
11	Length of dactylus of II cheliped	3	28	11.87	6.41	2	19	5.61	2.24
12	Total length of II cheliped	20	205	95.90	56.80	19.8	146	43.95	15.60
13	Length of III walking leg	14	66	37.96	14.50	14	48	27.30	6.21
14	Length of IV walking leg	15	70	40.14	14.99	14	51	30.05	5.97
15	Length of V walking leg	16	71	42.06	14.75	15	53	32.46	7.05

Table 1.4.3 Minimum, maximum, mean and standard deviation of various morphometric measurements recorded in males and females of Macrobrachium equidens

Sl.No.	Measurement	Males n=98				Females n=107			
		Minimum (mm)	Maximum (mm)	Mean (mm)	SD	Minimum (mm)	Maximum (mm)	Mean (mm)	SD
1	Total length	31	111	64.30	17.09	38	80	56.44	7.88
2	Carapace length	8	35	17.97	5.56	9	23.8	15.23	2.82
3	Rostral length	9	36	20.75	5.79	9.5	24	16.76	3.17
4	Length of telson	5	17	9.02	2.80	4.6	12	7.62	1.32
5	II abdominal pleural width	3	13	6.66	1.79	3.6	12	7.33	1.76
6	Length of I cheliped	12	49	24.47	8.56	11	31	20.02	3.53
7	Length of ischium of II cheliped	4.8	19	8.85	3.47	3.9	11	7.01	1.49
8	Length of merus of II cheliped	5	31	11.60	5.72	4.8	12	7.90	1.47
9	Length of carpus of II cheliped	7	50	18.11	10.72	5.8	20	11.36	2.44
10	Length of propodus of II cheliped	7	51	20.04	11.06	7.7	22	14.18	2.93
11	Length of dactylus of II cheliped	3	18	8.42	3.86	3.7	9	6.24	1.28
12	Total length of II cheliped	26	151	58.60	30.45	22.2	63	40.45	7.88
13	Length of III walking leg	13	65	30.23	10.62	14	37	23.53	3.85
14	Length of IV walking leg	15	68	31.72	11.01	14	38	24.66	3.96
15	Length of V walking leg	15	65	32.91	10.86	15	35	26.14	3.90

Table 1.4.4 Minimum, maximum, mean and standard deviation of various morphometric measurements recorded in males and females of Macrobrachium striatus

Sl.No.	Measurements	Males n= 112				Females n= 103			
		Minimum (mm)	Maximum (mm)	Mean (mm)	SD	Minimum (mm)	Maximum (mm)	Mean (mm)	SD
1	Total length	42.0	96	69.61	17.87	40.0	86.0	62.53	9.15
2	Carapace length	11.2	30	20.69	5.37	11.5	27.0	17.96	3.26
3	Rostral length	13.0	31	22.01	5.66	14.0	29.0	19.93	3.17
4	Length of telson	4.5	14	9.58	2.54	5.9	12.0	8.49	1.32
5	II abdominal pleural width	5.0	14	7.87	2.11	4.0	13.0	8.07	1.90
6	Length of I cheliped	14.0	40	27.82	7.57	13.0	37.0	23.72	4.49
7	Length of ischium of II cheliped	5.0	21	10.37	3.90	3.5	12.4	7.83	1.90
8	Length of merus of II cheliped	5.0	29	14.38	5.91	5.0	19.0	9.99	2.71
9	Length of carpus of II cheliped	7.0	49	23.18	11.34	8.0	26.0	13.79	3.91
10	Length of propodus of II cheliped	8.0	69	30.38	14.24	9.0	34.0	19.30	5.25
11	Length of dactylus of II cheliped	3.0	24	10.63	4.45	3.0	17.0	7.25	2.23
12	Total length of II cheliped	25.0	161	78.31	34.66	28.0	88.0	50.93	13.24
13	Length of III walking leg	17.0	48	32.65	9.13	17.0	40.0	26.86	4.80
14	Length of IV walking leg	19.0	49	33.42	9.03	18.0	43.0	28.03	4.83
15	Length of V walking leg	21.0	49	34.31	8.89	19.0	46.0	29.24	4.99

Table 1.4.5 Minimum, maximum, mean and standard deviation of various morphometric measurements recorded in males and females of Macrobrachium scabriculum

Sl.No.	Measurements	Males n= 40				Females n= 30			
		Minimum (mm)	Maximum (mm)	Mean (mm)	SD	Minimum (mm)	Maximum (mm)	Mean (mm)	SD
1	Total length	42.8	73	55.97	6.66	39.0	62.0	52.90	6.34
2	Carapace length	14.0	5	18.66	2.74	11.0	20.0	15.99	2.72
3	Rostral length	12.3	21	16.44	2.26	11.0	18.0	14.37	2.24
4	Length of telson	6.0	10	7.73	1.10	5.0	11.9	7.49	1.57
5	II abdominal pleural width	4.0	9	5.91	1.17	5.0	11.9	7.85	1.82
6	Length of I cheliped	15.0	27	22.30	2.94	13.0	24.0	19.63	3.17
7	Length of ischium of II cheliped	4.0	15	6.13	2.65	4.0	6.0	5.07	0.60
8	Length of merus of II cheliped	4.3	17	12.04	2.85	5.0	9.0	7.02	1.06
9	Length of carpus of II cheliped	4.5	15	10.86	2.37	4.9	8.0	6.60	1.07
10	Length of propodus of II cheliped	13.2	44	27.20	7.33	8.0	14.0	11.38	2.31
11	Length of dactylus of II cheliped	7.8	25	16.40	4.99	4.0	7.2	6.11	1.11
12	Total length of II cheliped	33.2	82	56.22	11.79	22.0	36.0	30.07	4.56
13	Length of III walking leg	18.0	31	24.10	3.01	11.0	24.0	19.67	3.93
14	Length of IV walking leg	18.0	32	24.08	3.09	12.0	25.0	20.40	4.18
15	Length of V walking leg	19.0	34	25.08	3.10	15.0	26.0	22.13	3.39

Table 1.4.6 Minimum, maximum, mean and standard deviation of various morphometric measurements recorded in males of Macrobrachium rude

Sl.No.	Measurements	Males n=15			
		Minimum (mm)	Maximum (mm)	Mean (mm)	SD
1	Total length	85	109	92.87	7.12
2	Carapace length	27	36	30.33	2.76
3	Rostral length	24	35	28.12	2.78
4	Length of telson	9	16	12.59	1.88
5	II abdominal pleural width	8	11	9.42	1.03
6	Length of I cheliped	32	48	39.51	3.78
7	Length of ischium of II cheliped	9	24	15.81	4.78
8	Length of merus of II cheliped	21	33	26.75	4.11
9	Length of carpus of II cheliped	24	71	44.75	11.40
10	Length of propodus of II cheliped	43	71.6	52.67	9.18
11	Length of dactylus of II cheliped	15	34.3	20.48	5.01
12	Total length of II cheliped	101	195	140.00	25.70
13	Length of III walking leg	34	64	47.93	6.77
14	Length of IV walking leg	35	65	48.67	7.23
15	Length of V walking leg	38	66	51.09	6.84

Table1.5.1 Minimum, maximum, and mean of different ratios worked out using various morphometric measurements in males of Macrobrachium spp. of the Vembanad lake.

	M. rosenbergii			*M.idella*			*M. equidens*			*M.striatus*			*M.scabriculum*			*M.rude*		
Ratios	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
CL/TL	0.238	0.333	0.286	0.200	0.400	0.272	0.225	0.420	0.277	0.220	0.388	0.296	0.289	0.362	0.332	0.287	0.353	0.327
RL/TL	0.316	0.420	0.380	0.252	0.462	0.312	0.285	0.553	0.322	0.301	0.469	0.317	0.260	0.330	0.290	0.275	0.343	0.303
TEL/TL	0.085	0.128	0.115	0.089	0.222	0.147	0.082	0.198	0.140	0.083	0.184	0.138	0.119	0.172	0.138	0.096	0.151	0.136
PL/TL	0.055	0.121	0.090	0.073	0.325	0.100	0.075	0.146	0.105	0.088	0.326	0.114	0.083	0.155	0.106	0.093	0.109	0.101
1CH/TL	0.289	0.479	0.381	0.256	0.615	0.398	0.071	0.461	0.370	0.321	0.531	0.398	0.346	0.500	0.399	0.368	0.466	0.426
2i/TL	0.080	0.185	0.126	0.077	0.263	0.167	0.093	0.263	0.136	0.038	0.269	0.145	0.069	0.272	0.134	0.098	0.255	0.171
2m/TL	0.090	0.290	0.136	0.085	0.446	0.228	0.096	0.421	0.175	0.111	0.306	0.200	0.080	0.290	0.220	0.206	0.353	0.289
2c/TL	0.110	0.359	0.161	0.115	0.846	0.415	0.154	0.711	0.269	0.132	0.577	0.319	0.080	0.339	0.197	0.276	0.671	0.469
2p/TL	0.121	0.670	0.300	0.114	0.462	0.394	0.195	0.711	0.299	0.062	0.775	0.419	0.240	0.670	0.492	0.267	0.754	0.559
2d/TL	0.089	0.337	0.145	0.058	0.315	0.152	0.072	0.413	0.131	0.029	1.571	0.147	0.142	0.431	0.297	0.059	0.361	0.216
2CH/TL	0.402	1.504	0.724	0.404	2.369	1.205	0.519	2.105	0.880	0.348	1.809	1.084	0.600	2.160	1.040	1.100	1.941	1.488
3CH/TL	0.314	0.451	0.390	0.327	0.738	0.504	0.294	0.921	0.464	0.368	0.653	0.466	0.380	0.480	0.430	0.391	0.587	0.515
4CH/TL	0.314	0.483	0.402	0.367	0.738	0.534	0.294	1.000	0.487	0.351	0.674	0.478	0.380	0.470	0.430	0.402	0.606	0.523
5CH/TL	0.333	0.506	0.414	0.388	0.783	0.564	0.294	1.053	0.507	0.364	0.691	0.488	0.393	0.537	0.449	0.437	0.659	0.550
TL/CL	3.000	4.195	3.514	2.500	5.000	3.727	2.375	4.455	3.634	2.579	4.464	3.391	2.760	3.459	3.014	2.800	3.500	3.100
RL/CL	1.077	1.732	1.335	1.017	1.500	1.159	1.000	1.389	1.165	1.000	1.375	1.074	0.760	1.000	0.880	0.828	1.000	0.928
TEL/CL	0.304	0.488	0.403	0.320	0.833	0.545	0.273	0.727	0.508	0.300	0.600	0.465	0.348	0.476	0.417	0.333	0.485	0.414
PL/CL	0.220	0.476	0.315	0.267	1.625	0.374	0.273	0.600	0.380	0.286	1.062	0.386	0.260	0.428	0.316	0.267	0.333	0.311
1CH/CL	1.079	1.659	0.337	0.933	2.083	1.464	0.169	1.636	1.343	1.064	1.974	1.346	1.305	1.548	1.201	1.067	1.556	1.310
2i/CL	0.318	0.580	0.441	0.321	1.000	0.610	0.296	1.000	0.494	0.142	0.840	0.489	0.190	0.833	0.331	0.278	0.888	0.534
2m/CL	0.360	0.909	0.475	0.333	1.400	0.822	0.333	1.625	0.630	0.381	1.100	0.675	0.230	0.910	0.650	0.580	1.111	0.887
2c/CL	0.377	1.125	0.565	0.500	2.944	1.487	0.533	2.750	0.961	0.497	1.885	1.075	0.245	1.000	0.595	0.800	2.111	1.454
2p/CL	0.480	2.102	1.046	0.500	1.855	1.416	0.635	2.750	1.074	0.232	2.464	1.411	0.750	1.929	1.481	0.771	2.288	1.720
2d/CL	0.309	1.057	0.506	0.243	1.074	0.554	0.250	1.434	0.471	0.110	5.500	0.496	0.458	1.335	0.893	0.172	1.096	0.664
2CH/CL	1.600	4.716	2.527	1.750	7.611	4.335	1.800	8.125	3.158	1.310	6.000	3.651	1.800	6.480	3.130	3.171	6.111	4.594
3CH/CL	1.108	1.683	1.367	1.067	2.556	1.851	1.071	2.192	1.673	1.222	2.054	1.576	1.140	1.480	1.300	1.133	2.037	1.591
4CH/CL	1.188	1.780	1.410	1.200	2.368	1.964	1.071	2.375	1.759	1.177	2.232	1.618	1.160	1.430	1.300	1.167	2.111	1.614
5CH/CL	1.169	1.732	1.453	1.267	2.600	2.082	1.071	2.500	1.828	1.241	2.235	1.652	1.125	1.586	1.352	1.266	2.074	1.696

Table 1.5.1 Continued....

	M. rosenbergii			*M.idella*			*M. equidens*			*M.striatus*			*M.scabriculum*			*M.rude*		
Ratios	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
TL/2cL	2.788	9.045	6.377	1.180	8.670	3.246	1.404	6.500	4.251	1.734	7.514	3.491	3.404	13.023	4.981	1.500	3.600	2.200
CL/2cL	0.889	2.652	1.816	0.340	2.000	0.844	0.363	1.875	1.163	0.531	2.013	1.026	1.099	4.279	1.654	0.474	1.250	0.742
RL/2cL	1.071	3.591	2.424	0.391	2.667	1.007	0.409	2.250	1.360	0.544	2.390	1.109	0.990	3.670	1.470	0.456	1.125	0.685
TEL/2cL	0.333	1.087	0.732	0.138	1.667	0.473	0.203	0.888	0.595	0.179	0.974	0.477	0.438	1.674	0.692	0.173	0.500	0.308
PL/2cL	0.253	0.826	0.571	0.123	2.167	0.322	0.136	0.875	0.449	0.186	1.957	0.402	0.340	1.419	0.527	0.151	0.375	0.229
1CH/2cL	1.202	3.565	2.418	0.491	2.750	1.210	0.100	2.375	1.550	0.714	3.974	1.377	1.438	4.884	1.970	0.667	1.333	0.944
2i/2cL	0.515	1.130	0.790	0.255	0.875	0.437	0.300	0.888	0.551	0.243	0.920	0.481	0.313	1.250	0.533	0.250	0.462	0.363
2m/2cL	0.679	1.217	0.849	0.343	1.091	0.585	0.467	0.857	0.681	0.419	1.100	0.650	0.964	1.954	1.330	0.442	0.958	0.636
2p/2cL	1.091	2.957	1.868	0.325	1.174	0.898	0.986	1.364	1.136	0.954	2.060	1.322	1.750	3.349	2.293	0.814	1.875	1.233
2d/2cL	0.593	1.435	0.904	0.123	0.750	0.413	0.294	1.545	0.511	0.221	5.500	0.475	0.917	2.837	1.372	0.136	0.833	0.478
2CH/2cL	3.636	6.217	4.507	2.175	4.818	3.032	2.600	4.000	3.368	2.636	5.080	3.453	4.000	8.400	4.850	2.523	4.208	3.231
3CH/2cL	1.220	3.696	2.473	0.681	3.333	1.516	0.591	2.875	1.928	0.846	3.273	1.603	1.630	4.880	2.130	0.813	1.417	1.134
4CH/2cL	1.152	3.957	2.554	0.604	3.833	1.622	0.682	3.125	2.027	0.878	3.390	1.650	1.460	5.120	2.140	0.807	1.471	1.152
5CH/2cL	1.192	4.043	2.630	0.642	4.500	1.742	0.682	3.071	2.108	0.882	3.546	1.693	1.547	5.581	2.220	0.925	1.583	1.210
TL/2mL	3.450	11.060	7.518	2.240	11.800	5.317	2.375	10.400	6.154	3.269	9.000	5.283	2.952	12.444	5.468	2.800	4.900	3.500
CL/2mL	1.100	2.778	2.138	0.714	3.000	1.395	0.615	3.000	1.693	0.909	2.625	1.557	1.000	4.089	1.818	0.900	1.714	1.160
RL/2mL	1.325	4.389	2.858	0.771	3.750	1.650	0.692	3.400	1.973	0.931	3.000	1.680	0.990	3.510	1.610	0.800	1.667	1.075
TEL/2mL	0.413	1.220	0.862	0.257	2.000	0.773	0.333	1.417	0.862	0.310	1.200	0.722	0.455	1.600	0.752	0.333	0.667	0.478
PL/2mL	0.313	1.000	0.673	0.241	3.250	0.529	0.231	1.167	0.645	0.333	2.740	0.609	0.344	1.356	0.574	0.267	0.524	0.359
1CH/2mL	1.488	3.842	2.849	1.000	4.024	2.005	0.169	3.800	2.263	1.296	4.500	2.088	1.035	4.660	2.170	1.267	1.952	1.502
2i/2mL	0.638	1.158	0.932	0.619	1.400	0.787	0.438	1.143	0.802	0.324	1.304	0.739	0.310	1.364	0.586	0.379	1.044	0.600
2c/2mL	0.821	1.474	1.188	0.984	2.913	1.754	1.167	2.143	1.506	0.909	2.385	1.572	0.500	1.259	0.831	1.044	2.261	1.630
2p/2mL	1.333	2.737	2.199	0.650	1.852	1.693	1.140	2.200	1.684	0.529	3.132	2.069	1.671	3.111	2.569	0.931	2.952	1.953
2d/2mL	0.696	1.421	1.063	0.241	1.000	0.702	0.483	2.125	0.756	0.250	8.462	0.736	0.917	3.125	1.560	0.207	1.055	0.747
2CH/2mL	4.444	6.368	5.318	4.200	7.217	5.234	4.141	5.739	4.993	2.985	7.857	5.380	3.810	10.000	5.400	3.828	6.391	5.183
3CH/2mL	1.513	4.000	2.915	1.382	5.000	2.516	1.241	4.273	2.805	1.435	4.500	2.436	1.310	4.670	2.340	1.478	2.391	1.820
4CH/2mL	1.425	4.158	3.008	1.280	5.250	2.685	1.154	4.182	2.947	1.654	4.625	2.505	1.380	4.890	2.340	1.522	2.478	1.848
5CH/2mL	1.475	4.167	3.098	1.360	5.750	2.876	1.154	4.800	3.070	1.534	5.426	2.573	1.586	5.333	2.429	1.500	2.435	1.936

TL- Total length
CL- Carapace length
RL- Rostral length
TEL- Length of telson
PL- Pleural width

2i- Ischium of 2nd cheliped
2m- Merus of 2nd cheliped
2c- Carpus of 2nd cheliped
2p- Propodus of 2nd cheliped
2d- Dactylus of 2nd cheliped

1CH- Length of 1st cheliped
2CH- Length of 2nd cheliped
3CH- Length of 3rd walking leg
4CH- Length of 4th walking leg
5CH- Length of 5th walking leg

Table 1.5.2 Minimum, maximum and mean of different ratios worked out using various morphometric measurements in females of Macrobrachium spp. of the Vembanad lake.

	M. rosenbergii			*M.idella*			*M. equidens*			*M.striatus*			*M.scabriculum*		
Ratios	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
CL/TL	0.211	0.326	0.274	0.172	0.386	0.259	0.179	3.298	0.269	0.228	0.328	0.287	0.265	0.327	0.301
RL/TL	0.294	0.424	0.371	0.211	0.360	0.306	0.241	0.440	0.329	0.214	0.364	0.297	0.240	0.330	0.270
TEL/TL	0.091	0.134	0.117	0.104	0.250	0.142	0.106	0.222	0.135	0.114	0.178	0.136	0.125	0.238	0.142
PL/TL	0.067	0.144	0.109	0.080	0.208	0.129	0.089	0.222	0.129	0.086	0.164	0.128	0.091	0.238	0.149
1CH/TL	0.290	0.473	0.374	0.218	0.575	0.349	0.229	0.443	0.354	0.265	0.455	0.378	0.333	0.404	0.369
2i/TL	0.090	0.165	0.126	0.078	0.188	0.120	0.085	0.167	0.124	0.068	0.182	0.124	0.080	0.109	0.096
2m/TL	0.098	0.158	0.130	0.091	0.318	0.128	0.106	0.167	0.139	0.109	0.232	0.158	0.120	0.150	0.130
2c/TL	0.128	0.209	0.165	0.125	0.591	0.225	0.128	0.305	0.201	0.153	0.317	0.217	0.107	0.140	0.125
2p/TL	0.163	0.360	0.225	0.078	0.580	0.200	0.170	0.340	0.250	0.164	0.439	0.305	0.158	0.255	0.214
2d/TL	0.067	0.255	0.119	0.031	0.222	0.084	0.069	0.150	0.110	0.068	0.200	0.115	0.091	0.127	0.115
2CH/TL	0.496	0.854	0.676	0.492	1.659	0.653	0.489	0.939	0.714	0.600	1.073	0.805	0.500	0.620	0.570
3CH/TL	0.316	0.541	0.386	0.039	0.569	0.405	0.367	0.475	0.416	0.309	0.523	0.428	0.240	0.410	0.370
4CH/TL	0.339	0.556	0.405	0.327	0.597	0.450	0.356	0.493	0.437	0.333	0.600	0.447	0.260	0.440	0.380
5CH/TL	0.344	0.522	0.416	0.347	0.602	0.487	0.376	0.607	0.464	0.382	0.625	0.467	0.380	0.455	0.417
TL/CL	3.067	4.750	3.669	2.590	5.820	3.895	3.032	5.600	3.756	3.042	4.375	3.509	3.056	3.777	3.344
RL/CL	1.124	1.645	1.362	1.011	1.727	1.194	1.000	1.571	1.128	1.000	1.428	1.103	0.800	1.000	0.910
TEL/CL	0.304	0.556	0.429	0.368	1.000	0.551	0.389	0.857	0.508	0.373	0.615	0.475	0.389	0.832	0.475
PL/CL	0.255	0.537	0.397	0.316	0.800	0.498	0.333	0.857	0.484	0.313	0.588	0.447	0.278	0.832	0.499
1CH/CL	1.089	1.710	1.372	0.789	2.340	1.352	0.917	2.100	1.327	1.000	1.666	1.322	1.105	1.333	1.232
2i/CL	0.305	0.578	0.460	0.293	0.628	0.466	0.308	0.666	0.465	0.219	0.632	0.435	0.250	0.400	0.323
2m/CL	0.373	0.563	0.475	0.297	1.167	0.496	0.385	0.791	0.522	0.412	0.731	0.552	0.380	0.510	0.440
2c/CL	0.483	0.771	0.606	0.500	2.167	0.829	0.462	1.341	0.753	0.519	1.048	0.760	0.344	0.466	0.416
2p/CL	0.647	1.349	0.932	0.294	2.125	0.770	0.615	1.500	0.938	0.643	1.429	1.065	0.497	0.933	0.718
2d/CL	0.265	0.886	0.433	0.118	0.792	0.323	0.267	0.600	0.414	0.250	0.775	0.401	0.344	0.420	0.382
2CH/CL	2.017	3.186	2.472	1.703	6.083	2.524	1.769	3.989	2.678	2.059	3.781	2.811	1.580	2.270	1.900
3CH/CL	1.109	1.850	1.415	0.150	2.300	1.575	1.250	2.300	1.561	1.000	1.750	1.499	0.900	1.360	1.230
4CH/CL	1.147	1.900	1.486	0.940	2.545	1.746	1.235	2.500	1.638	1.235	2.000	1.566	0.980	1.400	1.270
5CH/CL	1.200	1.968	1.524	1.053	2.818	1.890	1.345	2.700	1.739	1.235	2.083	1.635	1.267	1.557	1.390

Table 1.5.2 Continued.....

	M. rosenbergii			*M.idella*			*M. equidens*			*M.striatus*			*M.scabriculum*		
Ratios	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
TL/2cL	4.789	7.824	6.104	1.690	8.000	5.094	3.279	7.833	5.070	3.154	6.556	4.726	6.888	8.666	7.581
CL/2cL	1.297	2.071	1.668	0.462	2.000	1.312	0.745	0.167	1.363	0.955	1.925	1.349	1.968	2.666	2.278
RL/2cL	1.436	3.040	2.267	0.519	2.800	1.563	0.819	2.500	1.502	0.977	2.750	1.512	1.710	2.570	2.030
TEL/2cL	0.488	0.870	0.713	0.212	1.500	0.721	0.450	1.200	0.685	0.423	0.888	0.640	0.947	1.700	1.071
PL/2cL	0.444	0.829	0.659	0.173	1.067	0.651	0.375	1.200	0.651	0.389	0.800	0.598	0.714	1.700	1.123
1CH/2cL	1.789	2.853	2.281	0.692	2.925	1.762	0.984	2.833	1.792	1.269	2.667	1.722	2.428	3.500	2.802
2i/2cL	0.526	0.933	0.765	0.288	1.200	0.606	0.369	0.833	0.624	0.346	0.800	0.580	0.555	0.857	0.731
2m/2cL	0.568	0.929	0.789	0.417	1.200	0.637	0.458	0.900	0.702	0.545	0.889	0.730	1.000	1.270	1.070
2p/2cL	1.125	2.037	1.546	0.417	1.234	0.980	1.000	1.400	1.252	0.818	1.933	1.408	1.200	2.000	1.622
2d/2cL	0.474	1.444	0.719	0.167	0.667	0.411	0.303	0.757	0.555	0.333	0.968	0.530	0.677	1.000	0.870
2CH/2cL	3.342	4.767	4.100	2.500	4.600	3.223	2.975	4.043	3.577	3.000	4.600	3.718	3.810	4.860	4.290
3CH/2cL	1.837	3.265	2.351	0.250	2.818	2.038	1.230	3.167	2.106	1.269	3.000	2.018	1.770	3.500	2.810
4CH/2cL	1.865	3.353	2.469	0.981	3.110	2.265	1.311	3.666	2.211	1.462	3.125	2.107	1.940	3.670	2.900
5CH/2cL	1.919	3.350	2.535	1.019	3.600	2.460	1.311	3.833	2.348	1.614	3.333	2.202	2.714	3.666	3.161
TL/2mL	6.325	10.230	7.756	3.140	11.000	8.031	6.000	9.400	7.223	4.316	9.167	6.488	7.142	9.388	8.087
CL/2mL	1.778	2.682	2.118	0.857	3.367	2.074	1.263	2.600	1.940	1.368	2.429	1.852	2.143	2.903	2.427
RL/2mL	1.806	3.619	2.881	0.964	3.600	2.462	1.368	3.000	2.139	1.230	3.143	2.072	1.710	2.900	2.200
TEL/2mL	0.636	1.071	0.906	0.393	2.400	1.138	0.750	1.714	0.977	0.579	1.333	0.880	0.986	1.983	1.147
PL/2mL	0.545	1.160	0.838	0.321	1.778	1.033	0.625	1.714	0.929	0.538	1.667	0.824	0.806	1.983	1.199
1CH/2mL	2.214	3.450	2.898	1.286	4.200	2.781	1.617	3.400	2.551	1.737	3.429	2.434	2.428	3.500	2.988
2i/2mL	0.690	1.300	0.970	0.500	1.250	0.956	0.625	1.250	0.891	0.443	1.167	0.797	0.625	0.918	0.778
2c/2mL	1.077	1.762	1.277	0.833	2.400	1.603	1.110	2.182	1.439	1.125	1.833	1.380	0.790	1.000	0.942
2p/2mL	1.286	2.750	1.964	0.417	2.600	1.560	1.471	2.436	1.795	1.500	2.273	1.935	1.250	2.097	1.729
2d/2mL	0.529	1.696	0.912	0.167	1.400	0.657	0.571	1.125	0.793	0.500	1.250	0.729	0.800	1.129	0.926
2CH/2mL	4.286	6.200	5.211	2.833	7.000	5.119	4.492	6.527	5.125	4.430	5.727	5.112	3.970	5.030	4.580
3CH/2mL	2.250	3.828	2.986	0.333	4.222	3.234	2.500	3.800	3.002	1.737	4.000	2.774	2.240	3.550	2.970
4CH/2mL	2.389	3.931	3.137	1.821	4.880	3.586	2.333	4.400	3.150	2.000	4.800	2.897	2.450	3.870	3.080
5CH/2mL	2.621	3.941	3.219	1.893	5.200	3.888	2.667	4.600	3.345	2.211	5.000	3.026	2.714	4.032	3.374

TL- Total length
CL- Carapace length
RL- Rostral length
TEL- Length of telson
PL- Pleural width

2i- Ischium of 2nd cheliped
2m- Merus of 2nd cheliped
2c- Carpus of 2nd cheliped
2p- Propodus of 2nd cheliped
2d- Dactylus of 2nd cheliped

1CH- Length of 1st cheliped
2CH- Length of 2nd cheliped
3CH- Length of 3rd walking leg
4CH- Length of 4th walking leg
5CH- Length of 5th walking leg

Table 1.6.1 Values of intercept (a), slope (regression coefficient, b) and correlation coefficient (r) of different morphometric characters of Macrobrachium rosenbergii

Relationships	Males		df = 104	Females		df = 115
	Regression Constant a	Regression Coefficient b	Correlation Coefficient r	Regression Constant a	Regression Coefficient b	Correlation Coefficient r
TL x CL	-11.585	0.349	0.956	-10.577	0.331	0.962
TL x RL	0.242	0.378	0.966	7.461	0.331	0.906
TL x Tel	2.843	0.099	0.903	0.633	0.114	0.945
TL x Pl	1.420	0.082	0.801	-9.041	0.157	0.912
TL x Ichl	-8.519	0.427	0.917	-1.744	0.384	0.924
TL x 2i	-6.441	0.161	0.840	-3.892	0.146	0.899
TL x 2m	-15.201	0.218	0.801	-5.407	0.159	0.930
TL x 2c	-18.978	0.264	0.769	-4.834	0.191	0.881
TL x 2p	-50.773	0.576	0.804	-18.666	0.355	0.844
TL x 2d	-27.275	0.294	0.804	-10.901	0.177	0.785
TL x 2chl	-91.393	1.219	0.665	-32.800	0.852	0.921
TL x 3wl	-5.625	0.420	0.931	1.782	0.376	0.871
TL x 4wl	-5.609	0.432	0.918	3.567	0.386	0.873
TL x 5wl	-7.390	0.454	0.920	-5.060	0.443	0.899
CL x RL	19.155	0.968	0.901	21.570	0.935	0.879
CL x Tel	7.101	0.266	0.885	5.511	0.320	0.914
CL x Pl	4.666	0.266	0.804	-1.962	0.436	0.869
CL x Ichl	8.475	1.174	0.919	13.464	1.105	0.914
CL x 2i	-0.839	0.456	0.870	1.599	0.428	0.901
CL x 2m	-7.671	0.621	0.831	0.868	0.457	0.920
CL x 2c	-8.850	0.733	0.778	3.188	0.542	0.859
CL x 2p	-32.867	1.674	0.852	-5.110	1.033	0.843
CL x 2d	-17.850	0.846	0.846	-5.207	0.536	0.815
CL x 2chl	-50.227	3.484	0.850	0.546	2.461	0.914
CL x 3wl	11.131	1.153	0.930	16.866	1.080	0.859
CL x 4wl	11.921	1.183	0.915	19.621	1.097	0.852
CL x 5wl	10.873	1.244	0.919	10.811	1.308	0.912
RL x Tel	4.131	0.243	0.867	2.575	0.279	0.849
RL x Pl	2.688	0.198	0.758	-5.483	0.374	0.793
RL x Ichl	-3.340	1.053	0.883	2.894	0.971	0.855
RL x 2i	3.688	0.385	0.788	-1.376	0.360	0.807
RL x 2m	-11.680	0.526	0.755	-2.444	0.386	0.828
RL x 2c	-14.759	0.637	0.725	-1.319	0.467	0.786
RL x 2p	-39.547	1.359	0.743	-13.061	0.880	0.764
RL x 2d	-21.991	0.698	0.747	-7.743	0.434	0.703
RL x 2chl	-69.675	2.907	0.761	-18.200	2.093	0.827
RL x 3wl	-0.537	1.035	0.899	7.382	0.936	0.793
RL x 4wl	-0.158	1.063	0.883	9.423	0.959	0.793
RL x 5wl	-1.886	1.119	0.887	2.631	1.087	0.807
Tel x Pl	3.075	0.642	0.687	-7.187	1.261	0.879
Tel x Ichl	-3.412	3.504	0.825	3.415	3.054	0.883
Tel x 2i	-5.271	1.353	0.776	-2.010	1.169	0.862
Tel x 2m	-13.915	1.852	0.745	-3.730	1.283	0.903
Tel x 2c	-16.357	2.192	0.700	-2.253	1.521	0.842
Tel x 2p	-46.091	4.822	0.739	-14.615	2.860	0.816
Tel x 2d	-27.659	2.583	0.775	-9.147	1.439	0.765
Tel x 2chl	-81.634	10.219	0.750	-22.608	6.833	0.887
Tel x 3wl	-1.601	3.490	0.849	8.207	2.931	0.815
Tel x 4wl	-0.371	3.542	0.825	8.642	3.076	0.836
Tel x 5wl	-1.257	3.691	0.820	1.782	3.485	0.849
Pl x Ichl	14.099	3.426	0.753	28.019	2.077	0.861
Pl x 2i	0.043	1.409	0.755	7.416	0.794	0.840
Pl x 2m	-5.778	1.877	0.705	6.281	0.888	0.896
Pl x 2c	-8.114	2.304	0.687	8.911	1.087	0.863
Pl x 2p	-25.576	4.927	0.705	9.923	1.873	0.766

....Continued table 1.6.1

Relationships	Regression Constant a	Regression Coefficient b	Correlation Coefficient r	Regression Constant a	Regression Coefficient b	Correlation Coefficient r
Pl x 2d	-12.636	2.400	0.672	3.492	0.929	0.708
Pl x 2chl	-39.425	10.517	0.721	32.531	4.642	0.865
Pl x 3wl	16.251	3.389	0.770	30.424	2.060	0.822
Pl x 4wl	18.062	3.420	0.744	32.504	2.135	0.832
Pl x 5wl	16.217	3.667	0.761	28.986	2.412	0.843
1chl x 2i	-2.637	0.368	0.896	-1.186	0.353	0.899
1chl x 2m	-10.459	0.506	0.864	-2.014	0.376	0.915
1chl x 2c	-13.213	0.611	0.829	-0.943	0.456	0.873
1chl x 2p	-37.231	1.318	0.858	-11.185	0.844	0.832
1chl x 2d	-20.397	0.671	0.855	-8.421	0.438	0.806
1chl x 2chl	-63.541	2.803	0.874	-15.328	2.028	0.911
1chl x 3wl	6.458	0.930	0.962	2.396	0.995	0.957
1chl x 4wl	6.014	0.970	0.960	6.654	0.987	0.927
1chl x 5wl	4.712	1.020	0.963	0.338	1.107	0.933
2i x 2m	-6.201	1.348	0.945	1.519	0.971	0.927
2i x 2c	-8.739	1.659	0.923	4.863	1.114	0.837
2i x 2p	-25.478	3.487	0.931	-2.241	2.136	0.827
2i x 2d	-13.112	1.721	0.900	-4.090	1.124	0.811
2i x 2chl	-40.418	7.494	0.959	4.140	5.222	0.920
2i x 3wl	23.804	2.084	0.883	18.825	2.276	0.859
2i x 4wl	25.093	2.128	0.864	22.986	2.255	0.831
2i x 5wl	24.449	2.252	0.872	16.183	2.632	0.870
2m x 2c	-0.803	1.219	0.967	3.314	1.140	0.896
2m x 2p	-8.217	2.540	0.967	-6.663	2.244	0.909
2m x 2d	-5.282	1.280	0.954	-5.642	1.149	0.868
2m x 2chl	-2.374	5.422	0.989	-1.312	5.269	0.972
2m x 3wl	36.849	1.412	0.854	18.696	2.206	0.872
2m x 4wl	39.179	1.412	0.817	21.496	2.240	0.865
2m x 5wl	39.342	1.496	0.826	14.423	2.616	0.906
2c x 2p	-2.189	1.942	0.932	-2.746	1.638	0.844
2c x 2d	-1.927	0.968	0.910	-3.271	0.827	0.795
2c x 2chl	8.140	4.222	0.971	3.950	3.971	0.932
2c x 3wl	40.467	1.071	0.816	22.001	1.628	0.818
2c x 4wl	42.857	1.069	0.780	24.330	1.699	0.820
2c x 5wl	43.411	1.127	0.785	18.244	1.933	0.851
2p x 2d	0.644	0.496	0.970	-1.816	0.504	0.939
2p x 2chl	19.208	2.064	0.989	25.326	2.124	0.967
2p x 3wl	42.476	0.538	0.854	34.879	0.786	0.767
2p x 4wl	44.505	0.543	0.825	38.440	0.788	0.751
2p x 5wl	44.907	0.576	0.830	33.085	0.944	0.806
2d x 2chl	28.352	3.935	0.963	43.522	3.456	0.917
2d x 3wl	44.195	1.049	0.850	41.029	1.417	0.741
2d x 4wl	46.276	1.058	0.821	45.624	1.375	0.703
2d x 5wl	46.996	1.115	0.826	40.270	1.708	0.783
2chl x 3wl	37.382	0.261	0.865	21.886	0.398	0.853
2chl x 4wl	39.461	0.263	0.834	25.124	0.401	0.840
2chl x 5wl	39.634	0.278	0.843	18.163	0.473	0.887
3wl x 4wl	1.188	1.016	0.972	6.876	0.956	0.934
3wl x 5wl	-0.256	1.067	0.975	1.685	1.057	0.926
4wl x 5wl	-0.030	1.031	0.984	1.479	1.010	0.906

TL- Total length
CL- Carapace length
RL- Rostral length
Tel- Length of telson
Pl- Pleural width
1chl- Length of 1st cheliped
2i- Ischium of 2nd cheliped
2m- Merus of 2nd cheliped
2c- Carpus of 2nd cheliped
2p- Propodus of 2nd cheliped
2d- Dactylus of 2nd cheliped
2chl- Length of 2nd cheliped
3wl- Length of 3rd walking leg
4wl- Length of 4th walking leg
5wl- Length of 5th walking leg

Table 1.6.2 Values of intercept (a), slope (regression coefficient, b) and correlation coefficient (r) of different morphometric characters of Macrobrachium idella

Relationships	Males		df = 130	Females		df = 104
	Regression Constant a	Regression Coefficient b	Correlation Coefficient r	Regression Constant a	Regression Coefficient b	Correlation Coefficient r
TL x CL	-3.995	0.332	0.973	-3.888	0.320	0.918
TL x RL	0.769	0.301	0.950	-0.290	0.310	0.893
TL x Tel	-0.309	0.151	0.929	-0.328	0.137	0.875
TL x Pl	-0.651	0.110	0.897	-2.865	0.173	0.889
TL x Ichl	-8.656	0.529	0.955	-2.643	0.390	0.866
TL x 2i	-6.746	0.269	0.897	-1.715	0.147	0.819
TL x 2m	-14.762	0.450	0.895	-2.149	0.162	0.653
TL x 2c	-32.375	0.901	0.869	-7.673	0.325	0.664
TL x 2p	-30.490	0.851	0.887	-7.099	0.310	0.626
TL x 2d	-8.180	0.275	0.879	-1.946	0.114	0.586
TL x 2chl	-77.630	2.202	0.889	-16.921	0.796	0.661
TL x 3wl	-11.473	0.677	0.958	-3.786	0.464	0.810
TL x 4wl	-11.647	0.710	0.971	-6.682	0.554	0.918
TL x 5wl	-8.626	0.695	0.966	-5.011	0.565	0.926
CL x RL	4.692	0.892	0.962	6.136	0.817	0.819
CL x Tel	1.823	0.440	0.922	2.969	0.370	0.826
CL x Pl	0.970	0.316	0.880	0.662	0.460	0.818
CL x Ichl	-1.679	1.561	0.962	4.642	1.071	0.829
CL x 2i	-3.251	0.796	0.907	0.939	0.409	0.795
CL x 2m	-8.876	1.330	0.903	0.558	0.462	0.651
CL x 2c	-20.857	2.678	0.881	-1.948	0.911	0.650
CL x 2p	-19.103	2.506	0.891	-2.209	0.903	0.636
CL x 2d	-4.377	0.803	0.876	-0.270	0.339	0.608
CL x 2chl	-48.836	6.514	0.897	-3.599	2.276	0.659
CL x 3wl	-2.410	1.994	0.963	5.163	1.260	0.766
CL x 4wl	-2.161	2.090	0.976	4.529	1.471	0.850
CL x 5wl	0.819	2.037	0.967	6.368	1.505	0.860
RL x Tel	-0.327	0.457	0.890	2.390	0.345	0.768
RL x Pl	-0.274	0.336	0.869	0.008	0.425	0.754
RL x Ichl	-7.203	1.632	0.934	4.011	0.947	0.371
RL x 2i	-5.615	0.812	0.860	0.495	0.371	0.720
RL x 2m	-13.424	1.383	0.873	0.317	0.406	0.571
RL x 2c	-30.109	2.789	0.853	-2.908	0.826	0.588
RL x 2p	-26.999	2.577	0.851	-3.096	0.815	0.573
RL x 2d	-7.223	0.839	0.851	-0.281	0.290	0.519
RL x 2chl	-76.145	7.562	0.866	-5.193	2.419	0.623
RL x 3wl	-9.622	2.091	0.938	2.406	1.212	0.736
RL x 4wl	-9.904	2.200	0.954	0.973	1.432	0.826
RL x 5wl	-6.629	2.153	0.949	3.081	1.448	0.826
Tel x Pl	0.750	0.617	0.820	-0.838	1.010	0.804
Tel x Ichl	-3.398	3.108	0.913	1.520	2.312	0.801
Tel x 2i	-3.931	1.567	0.851	-0.001	0.855	0.745
Tel x 2m	-9.848	2.601	0.843	0.235	0.888	0.560
Tel x 2c	-22.392	5.198	0.816	-3.057	1.802	0.576
Tel x 2p	-20.115	4.873	0.826	-2.817	1.733	0.547
Tel x 2d	-4.743	1.550	0.807	-0.173	0.615	0.495
Tel x 2chl	-56.786	14.240	0.837	-5.640	5.278	0.610
Tel x 3wl	-4.198	3.931	0.905	1.919	2.674	0.728
Tel x 4wl	-4.389	4.153	0.925	0.381	3.160	0.818
Tel x 5wl	-1.439	4.056	0.918	2.007	3.245	0.831
Pl x Ichl	0.939	3.933	0.870	7.389	1.832	0.798
Pl x 2i	-1.712	1.979	0.809	2.871	6.597	0.693
Pl x 2m	-6.828	3.375	0.823	3.563	0.579	0.759
Pl x 2c	-16.786	6.803	0.804	3.469	1.202	0.483
Pl x 2p	-15.190	6.355	0.811	3.902	1.105	0.438

....Continued table 1.6.2

Relationships	Regression Constant a	Regression Coefficient b	Correlation Coefficient r	Regression Constant a	Regression Coefficient b	Correlation Coefficient r
Pl x 2d	-3.115	2.034	0.797	2.089	0.407	0.411
Pl x 2chl	-40.515	18.512	0.816	13.805	3.483	0.505
Pl x 3wl	0.256	5.116	0.887	9.382	2.040	0.699
Pl x 4wl	1.350	5.264	0.883	9.257	2.405	0.783
Pl x 5wl	4.168	5.142	0.876	10.701	2.518	0.810
1chl x 2i	-1.488	0.480	0.887	1.223	0.293	0.736
1chl x 2m	-6.385	0.816	0.900	-0.194	0.377	0.687
1chl x 2c	-15.778	1.642	0.877	-3.112	0.731	0.674
1chl x 2p	-14.229	1.533	0.884	-2.895	0.704	0.641
1chl x 2d	-2.710	0.487	0.863	-0.385	0.258	0.598
1chl x 2chl	-37.880	4.471	0.894	-4.978	2.105	0.702
1chl x 3wl	1.536	1.217	0.954	-3.611	1.008	0.792
1chl x 4wl	1.900	1.278	0.968	3.971	1.123	0.839
1chl x 5wl	4.685	1.249	0.962	5.426	1.164	0.860
2i x 2m	-2.751	1.616	0.963	0.093	1.056	0.765
2i x 2c	-9.292	3.313	0.957	-3.276	2.135	0.783
2i x 2p	-7.906	3.073	0.959	-3.761	2.145	0.777
2i x 2d	-0.534	0.964	0.924	-0.692	0.785	0.724
2i x 2chl	-19.948	9.002	0.974	-6.944	6.335	0.841
2i x 3wl	-9.940	2.177	0.923	7.841	2.389	0.747
2i x 4wl	11.232	2.246	0.921	6.947	2.878	0.855
2i x 5wl	13.879	2.189	0.912	9.664	2.841	0.835
2m x 2c	-3.214	2.026	0.982	-2.077	1.860	0.942
2m x 2p	-2.104	1.870	0.979	-2.149	1.821	0.911
2m x 2d	1.325	0.585	0.940	-0.077	0.663	0.845
2m x 2chl	-2.813	5.470	0.993	0.945	5.236	0.959
2m x 3wl	14.569	1.296	0.921	12.918	1.646	0.711
2m x 4wl	15.868	1.345	0.925	14.265	1.842	0.756
2m x 5wl	18.505	1.305	0.912	17.017	1.804	0.732
2c x 2p	1.806	0.895	0.966	0.273	0.951	0.939
2c x 2d	2.507	0.281	0.931	0.701	0.354	0.890
2c x 2chl	7.619	2.647	0.991	6.270	2.715	0.882
2c x 3wl	17.510	0.613	0.899	14.651	0.892	0.761
2c x 4wl	18.952	0.635	0.901	16.808	0.955	0.774
2c x 5wl	21.556	0.615	0.886	19.661	0.924	0.740
2p x 2d	1.991	0.312	0.959	0.611	0.371	0.946
2p x 2chl	5.574	2.855	0.990	8.048	2.666	0.976
2p x 3wl	16.915	0.665	0.923	16.350	0.793	0.685
2p x 4wl	18.312	0.690	0.906	18.073	0.890	0.730
2p x 5wl	20.827	0.671	0.896	21.107	0.845	0.685
2d x 2chl	-4.167	8.428	0.952	8.062	6.395	0.919
2d x 3wl	14.488	1.976	0.874	16.413	1.892	0.641
2d x 4wl	15.632	2.064	0.883	18.179	2.118	0.682
2d x 5wl	18.203	2.089	0.874	21.085	2.031	0.647
2chl x 3wl	15.506	0.237	0.917	12.950	0.320	0.755
2chl x 4wl	16.871	0.243	0.919	14.381	0.357	0.799
2chl x 5wl	19.473	0.235	0.907	17.333	345.000	0.764
3wl x 4wl	1.777	1.011	0.977	6.215	0.882	0.838
3wl x 5wl	4.639	0.986	0.969	8.879	0.873	0.821
4wl x 5wl	3.022	0.972	0.988	3.429	0.967	0.956

TL- Total length
CL- Carapace length
RL- Rostral length
Tel- Length of telson
Pl- Pleural width

1chl- Length of 1st cheliped
2i- Ischium of 2nd cheliped
2m- Merus of 2nd cheliped
2c- Carpus of 2nd cheliped
2p- Propodus of 2nd cheliped

2d- Dactylus of 2nd cheliped
2chl- Length of 2nd cheliped
3wl- Length of 3rd walking leg
4wl- Length of 4th walking leg
5wl- Length of 5th walking leg

Table 1.6.3 Values of intercept (a), slope (regression coefficient, b) and correlation coefficient (r) of different morphometric characters of Macrobrachium equidens

Relationships	Males		df = 96	Females		df = 105
	Regression Constant a	Regression Coefficient b	Correlation Coefficient r	Regression Constant a	Regression Coefficient b	Correlation Coefficient r
TL x CL	-2.268	0.315	0.966	-1.850	0.303	0.846
TL x RL	-0.383	0.328	0.969	-1.061	0.316	0.785
TL x Tel	-0.551	0.149	0.908	0.878	0.119	0.720
TL x Pl	0.727	0.092	0.879	-2.578	0.176	0.785
TL x Ichl	-7.813	0.500	0.976	-2.476	0.399	0.889
TL x 2i	-1.662	0.163	0.805	-0.906	0.140	0.741
TL x 2m	-5.993	0.273	0.817	-1.633	0.169	0.906
TL x 2c	-13.988	0.499	0.795	-2.444	0.245	0.788
TL x 2p	-12.869	0.511	0.790	-3.927	0.321	0.862
TL x 2d	-2.992	0.181	0.677	-0.815	0.125	0.766
TL x 2chl	-32.849	1.284	0.805	-8.910	0.875	0.875
TL x 3wl	-7.474	0.586	0.943	-8.004	0.734	0.869
TL x 4wl	-7.189	0.605	0.939	-1.278	0.460	0.914
TL x 5wl	-5.849	0.602	0.948	2.575	0.418	0.844
CL x RL	2.683	1.005	0.965	1.565	0.997	0.888
CL x Tel	0.795	0.458	0.910	3.126	0.636	0.636
CL x Pl	1.496	0.287	0.891	0.991	0.416	0.666
CL x Ichl	-2.446	0.149	0.948	4.843	0.997	0.795
CL x 2i	-0.005	0.493	0.790	1.754	0.345	0.692
CL x 2m	-3.672	0.850	0.826	1.276	0.435	0.834
CL x 2c	-10.010	1.564	0.812	1.793	0.628	0.724
CL x 2p	-8.107	1.566	0.788	1.784	0.814	0.782
CL x 2d	-1.220	0.548	0.668	1.557	0.307	0.674
CL x 2chl	-21.788	3.980	0.812	4.852	1.877	0.794
CL x 3wl	-2.558	1.824	0.956	5.937	1.155	0.846
CL x 4wl	-2.163	1.885	0.953	6.924	1.165	0.829
CL x 5wl	-0.765	1.874	0.960	9.837	1.070	0.774
RL x Tel	0.049	0.433	0.895	3.544	0.243	0.589
RL x Pl	1.171	0.264	0.854	2.358	0.296	0.533
RL x Ichl	-4.894	1.411	0.933	6.506	0.807	0.723
RL x 2i	-0.874	0.469	0.782	2.229	0.285	0.606
RL x 2m	-4.639	0.783	0.792	2.055	0.349	0.752
RL x 2c	-11.479	1.426	0.771	2.750	0.514	0.666
RL x 2p	-10.392	1.467	0.768	3.656	0.628	0.679
RL x 2d	-2.593	0.541	0.687	1.510	0.282	0.695
RL x 2chl	-27.385	4.144	0.788	10.689	1.776	0.714
RL x 3wl	-5.587	1.726	0.941	7.318	0.967	0.796
RL x 4wl	-5.357	1.787	0.940	7.948	0.997	0.798
RL x 5wl	-4.098	1.784	0.951	10.499	0.933	0.759
Tel x Pl	1.955	0.521	0.814	0.063	0.954	0.708
Tel x Ichl	-1.554	2.873	0.918	6.010	1.839	0.680
Tel x 2i	1.136	0.855	0.690	1.280	0.753	0.659
Tel x 2m	-1.539	1.456	0.713	2.152	0.754	0.671
Tel x 2c	-6.551	2.732	0.714	2.871	1.115	0.596
Tel x 2p	-3.417	2.599	0.658	3.956	1.342	0.598
Tel x 2d	0.443	0.906	0.557	1.613	0.607	0.617
Tel x 2chl	-10.370	7.642	0.703	10.258	3.963	0.658
Tel x 3wl	-0.305	3.384	0.892	8.875	1.923	0.653
Tel x 4wl	0.032	3.511	0.893	9.178	2.033	0.671
Tel x 5wl	1.374	3.494	0.901	12.341	1.811	0.608
Pl x Ichl	-3.826	4.237	0.867	8.132	1.623	0.809
Pl x 2i	-0.713	1.438	0.742	3.633	0.461	0.545
Pl x 2m	-5.075	2.506	0.785	3.549	0.593	0.711
Pl x 2c	-12.450	4.592	0.768	4.706	0.909	0.654
Pl x 2p	-10.740	4.624	0.749	4.819	1.278	0.768

....Continued table 1.6.3

Relationships	Regression Constant a	Regression Coefficient b	Correlation Coefficient r	Regression Constant a	Regression Coefficient b	Correlation Coefficient r
Pl x 2d	-1.192	1.475	0.580	3.232	0.410	0.562
Pl x 2chl	-28.978	13.159	0.774	16.707	3.241	0.725
Pl x 3wl	-4.741	5.255	0.887	11.798	1.601	0.733
Pl x 4wl	-4.312	5.414	0.881	12.870	1.610	0.716
Pl x 5wl	-2.395	5.304	0.875	14.559	1.580	0.714
1chl x 2i	1.334	0.309	0.779	1.243	0.288	0.682
1chl x 2m	-1.079	0.520	0.796	0.702	0.359	0.864
1chl x 2c	-5.238	0.958	0.783	1.038	0.516	0.745
1chl x 2p	-3.540	0.967	0.766	0.526	0.682	0.822
1chl x 2d	0.676	0.326	0.626	0.929	0.265	0.729
1chl x 2chl	-8.523	2.754	0.792	3.509	1.845	0.828
1chl x 3wl	-2.866	1.123	0.926	4.375	0.956	0.878
1chl x 4wl	-3.285	1.167	0.928	5.147	0.975	0.870
1chl x 5wl	-4.915	1.149	0.926	7.257	0.943	0.855
2i x 2m	-1.757	1.509	0.915	2.341	0.792	0.805
2i x 2c	-6.371	2.765	0.895	2.418	1.275	0.778
2i x 2p	-5.235	2.854	0.896	4.279	1.412	0.719
2i x 2d	0.278	0.942	0.718	1.398	0.690	0.801
2i x 2chl	-13.364	8.128	0.926	9.038	4.474	0.849
2i x 3wl	7.764	2.537	0.829	9.743	1.965	0.762
2i x 4wl	8.600	2.611	0.823	10.450	2.027	0.764
2i x 5wl	10.149	2.570	0.821	13.463	1.807	0.692
2m x 2c	-3.136	1.831	0.978	-0.221	1.467	0.881
2m x 2p	-1.922	1.893	0.980	0.242	1.826	0.915
2m x 2d	1.522	0.612	0.768	0.661	0.706	0.807
2m x 2chl	-2.643	5.279	0.992	0.092	5.111	0.953
2m x 3wl	11.753	1.593	0.858	5.161	2.326	0.888
2m x 4wl	12.549	1.652	0.859	5.927	2.373	0.880
2m x 5wl	14.205	1.612	0.849	8.744	2.203	0.830
2c x 2p	1.939	0.999	0.969	1.461	1.112	0.934
2c x 2d	2.670	0.329	0.773	1.529	0.414	0.789
2c x 2chl	7.692	0.281	0.990	4.959	3.124	0.970
2c x 3wl	15.049	0.838	0.846	9.112	1.269	0.806
2c x 4wl	15.948	0.871	0.848	10.208	1.272	0.786
2c x 5wl	17.470	0.852	0.841	12.822	1.172	0.736
2p x 2d	1.827	0.339	0.822	1.454	0.337	0.769
2p x 2chl	3.952	2.727	0.990	3.537	2.603	0.969
2p x 3wl	14.638	0.778	0.810	7.770	1.111	0.847
2p x 4wl	15.500	0.809	0.813	8.629	1.131	0.837
2p x 5wl	16.992	0.794	0.809	11.369	1.041	0.784
2d x 2chl	12.708	5.322	0.797	8.583	5.110	0.833
2d x 3wl	17.452	1.482	0.636	8.568	2.398	0.801
2d x 4wl	18.418	1.543	0.639	9.293	2.465	0.800
2d x 5wl	19.429	1.563	0.656	11.616	2.328	0.768
2chl x 3wl	12.902	0.296	0.848	6.232	0.428	0.875
2chl x 4wl	13.733	0.307	0.849	7.090	0.434	0.864
2chl x 5wl	15.287	0.301	0.843	10.013	0.399	0.806
3wl x 4wl	0.659	1.027	0.991	2.377	0.947	0.920
3wl x 5wl	2.365	1.010	0.988	4.666	0.913	0.901
4wl x 5wl	1.943	0.976	0.989	5.011	0.857	0.871

TL- Total length
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1chl- Length of 1st cheliped
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2m- Merus of 2nd cheliped
2c- Carpus of 2nd cheliped
2p- Propodus of 2nd cheliped

2d- Dactylus of 2nd cheliped
2chl- Length of 2nd cheliped
3wl- Length of 3rd walking leg
4wl- Length of 4th walking leg
5wl- Length of 5th walking leg

Table 1.6.4 Values of intercept (a), slope (regression coefficient, b) and correlation coefficient (r) of different morphometric characters of Macrobrachium striatus

Relationships	Males		df = 110	Females		df = 101
	Regression Constant a	Regression Coefficient b	Correlation Coefficient r	Regression Constant a	Regression Coefficient b	Correlation Coefficient r
TL x CL	-1.796	0.322	0.948	-2.355	0.325	0.911
TL x RL	1.871	0.290	0.915	2.973	0.271	0.782
TL x Tel	-0.131	0.139	0.855	0.585	0.126	0.874
TL x Pl	1.742	0.089	0.650	-3.195	0.180	0.866
TL x Ichl	-3.828	0.453	0.919	-4.414	0.450	0.917
TL x 2i	-6.711	0.242	0.825	-1.805	0.154	0.741
TL x 2m	-13.904	0.401	0.908	-5.338	0.245	0.828
TL x 2c	-30.520	0.760	0.872	-9.422	0.371	0.867
TL x 2p	-36.551	0.947	0.865	-11.366	0.490	0.853
TL x 2d	-8.796	0.287	0.349	-3.817	0.177	0.725
TL x 2chl	-80.975	2.109	0.885	-26.126	1.106	0.865
TL x 3wl	-6.950	0.566	0.939	-2.321	0.466	0.888
TL x 4wl	-5.117	0.552	0.942	-1.603	0.473	0.896
TL x 5wl	-1.395	0.508	0.836	-1.348	0.489	0.896
CL x RL	4.725	0.842	0.903	5.455	0.805	0.828
CL x Tel	1.141	0.409	0.853	1.990	0.361	0.892
CL x Pl	2.438	0.266	0.662	0.556	0.476	0.823
CL x Ichl	0.760	1.309	0.906	1.702	1.225	0.891
CL x 2i	-4.595	0.713	0.828	0.055	0.433	0.742
CL x 2m	-9.851	1.159	0.892	-2.394	0.689	0.831
CL x 2c	-23.024	2.204	0.860	-4.452	1.015	0.846
CL x 2p	-27.454	2.759	0.857	-4.920	1.347	0.837
CL x 2d	-4.739	0.778	0.322	-1.095	0.464	0.679
CL x 2chl	-60.329	6.122	0.874	-11.766	3.051	0.851
CL x 3wl	-1.168	1.633	0.921	3.690	1.288	0.875
CL x 4wl	0.974	1.569	0.911	4.173	1.327	0.895
CL x 5wl	3.334	1.487	0.832	4.631	1.369	0.895
RL x Tel	0.355	0.420	0.815	2.121	0.319	0.766
RL x Pl	2.091	0.265	0.615	-0.943	0.452	0.754
RL x Ichl	-2.407	1.370	0.881	1.913	1.095	0.773
RL x 2i	-4.496	0.666	0.721	1.527	0.317	0.528
RL x 2m	-11.680	1.170	0.840	-2.319	0.618	0.724
RL x 2c	-26.984	2.247	0.818	-4.119	0.899	0.728
RL x 2p	-31.847	2.787	0.807	-4.548	1.197	0.722
RL x 2d	-5.371	0.760	0.293	-0.193	0.374	0.531
RL x 2chl	-75.006	6.870	0.824	-9.459	3.030	0.725
RL x 3wl	-5.809	1.740	0.915	4.039	1.145	0.756
RL x 4wl	-3.394	1.668	0.903	3.882	1.212	0.794
RL x 5wl	-0.414	1.563	0.816	3.829	1.275	0.810
Tel x Pl	4.055	0.409	0.489	-1.491	1.126	0.783
Tel x Ichl	4.667	2.429	0.804	-0.319	2.833	0.834
Tel x 2i	-2.413	1.318	0.735	-0.856	1.024	0.712
Tel x 2m	-6.900	2.202	0.814	-3.472	1.587	0.775
Tel x 2c	-16.129	4.059	0.760	-6.957	2.446	0.825
Tel x 2p	-17.617	4.957	0.739	-7.968	3.214	0.808
Tel x 2d	-1.642	1.366	0.272	-1.938	1.083	0.642
Tel x 2chl	-43.059	12.536	0.774	-19.253	8.271	0.825
Tel x 3wl	2.743	3.129	0.846	1.688	2.965	0.816
Tel x 4wl	5.043	2.975	0.829	2.217	3.041	0.831
Tel x 5wl	7.725	2.765	0.743	2.454	3.157	0.836
Pl x Ichl	9.298	2.384	0.660	7.907	1.961	0.830
Pl x 2i	0.472	1.248	0.582	2.357	0.679	0.679
Pl x 2m	-0.976	1.947	0.602	1.414	1.064	0.747
Pl x 2c	-6.908	3.800	0.596	0.207	1.685	0.818
Pl x 2p	-7.458	4.777	0.596	1.803	2.170	0.785

....Continued table 1.6.4

Relationships	Regression Constant a	Regression Coefficient b	Correlation Coefficient r	Regression Constant a	Regression Coefficient b	Correlation Coefficient r
Pl x 2d	0.193	1.436	0.239	1.340	0.733	0.624
Pl x 2chl	-14.871	11.772	0.608	5.781	5.598	0.803
Pl x 3wl	9.766	2.940	0.666	10.218	2.062	0.816
Pl x 4wl	11.689	2.799	0.653	10.664	2.153	0.846
Pl x 5wl	14.196	2.565	0.577	11.490	2.201	0.838
1chl x 2i	-2.877	0.470	0.792	0.009	0.330	0.778
1chl x 2m	-7.119	0.766	0.856	-2.461	0.525	0.871
1chl x 2c	-18.106	1.467	0.830	-4.915	0.789	0.904
1chl x 2p	-20.699	1.815	0.818	-5.414	1.042	0.890
1chl x 2d	-4.758	0.580	0.348	-1.770	0.380	0.765
1chl x 2chl	-48.800	4.518	0.843	-12.781	2.685	0.910
1chl x 3wl	0.561	1.154	0.944	4.659	0.935	0.873
1chl x 4wl	2.329	1.120	0.943	4.360	0.998	0.926
1chl x 5wl	5.074	1.045	0.848	5.172	1.015	0.912
2i x 2m	0.875	1.316	0.872	1.242	1.117	0.785
2i x 2c	-3.546	2.591	0.871	1.320	1.592	0.773
2i x 2p	-2.901	3.226	0.863	2.596	2.133	0.772
2i x 2d	3.542	0.782	0.279	0.741	0.831	0.708
2i x 2chl	-5.572	8.134	0.901	5.159	5.842	0.839
2i x 3wl	15.547	1.703	0.827	13.266	1.733	0.686
2i x 4wl	16.871	1.653	0.826	14.039	1.785	0.702
2i x 5wl	18.990	1.510	0.728	15.084	1.807	0.689
2m x 2c	-4.323	1.905	0.966	0.112	1.369	0.946
2m x 2p	-3.820	2.369	0.955	0.934	1.838	0.947
2m x 2d	2.216	0.649	0.349	0.918	0.634	0.769
2m x 2chl	-6.128	5.852	0.978	3.367	4.758	0.972
2m x 3wl	15.649	1.211	0.886	14.049	1.280	0.722
2m x 4wl	16.843	1.183	0.896	13.760	1.427	0.799
2m x 5wl	18.696	1.094	0.799	14.531	1.472	0.798
2c x 2p	2.017	1.224	0.974	1.504	1.290	0.901
2c x 2d	3.993	0.328	0.348	0.996	0.454	0.796
2c x 2chl	8.720	3.006	0.991	5.132	3.320	0.981
2c x 3wl	19.339	0.596	0.861	13.854	0.942	0.768
2c x 4wl	20.362	0.586	0.872	13.444	1.057	0.856
2c x 5wl	21.694	0.556	0.797	14.362	1.079	0.847
2p x 2d	3.197	0.279	0.368	0.565	0.346	0.816
2p x 2chl	5.778	2.391	0.990	0.299	2.483	0.895
2p x 3wl	18.958	0.468	0.849	13.107	0.712	0.779
2p x 4wl	19.886	0.463	0.866	12.955	0.781	0.848
2p x 5wl	21.562	0.429	0.773	13.970	0.791	0.833
2d x 2chl	66.737	1.147	0.356	15.718	4.854	0.818
2d x 3wl	30.952	0.218	0.297	16.507	1.425	0.662
2d x 4wl	31.476	0.241	0.337	16.884	1.536	0.709
2d x 5wl	32.394	0.215	0.290	18.262	1.514	0.677
2chl x 3wl	17.497	0.200	0.875	12.408	0.283	0.782
2chl x 4wl	18.544	0.196	0.887	12.155	0.312	0.853
2chl x 5wl	20.219	0.183	0.797	13.074	0.317	0.843
3wl x 4wl	2.665	0.994	0.972	3.195	0.925	0.918
3wl x 5wl	5.186	0.887	0.881	3.815	0.947	0.911
4wl x 5wl	3.577	0.914	0.881	1.532	0.989	0.958

TL- Total length
CL- Carapace length
RL- Rostral length
Tel- Length of telson
Pl- Pleural width

1chl- Length of 1st cheliped
2i- Ischium of 2nd cheliped
2m- Merus of 2nd cheliped
2c- Carpus of 2nd cheliped
2p- Propodus of 2nd cheliped

2d- Dactylus of 2nd cheliped
2chl- Length of 2nd cheliped
3wl- Length of 3rd walking leg
4wl- Length of 4th walking leg
5wl- Length of 5th walking leg

Table 1.6.5 Values of intercept (a), slope (regression coefficient, b) and correlation coefficient (r) of different morphometric characters of Macrobrachium scabriculum

Relationships	Males df = 38			Females df = 28		
	Regression Constant a	Regression Coefficient b	Correlation Coefficient r	Regression Constant a	Regression Coefficient b	Correlation Coefficient r
TL x CL	-3.545	0.397	0.963	-5.686	0.410	0.953
TL x RL	-0.040	0.301	0.885	-0.948	0.290	0.820
TL x Tel	0.793	0.124	0.751	0.710	0.128	0.519
TL x PI	-0.405	0.113	0.644	0.629	0.137	0.474
TL x Ichl	1.050	0.380	0.860	-5.480	0.475	0.950
TL x 2i	9.860	0.044	0.036	1.684	0.064	0.681
TL x 2m	11.516	-0.012	0.033	-1.358	0.151	0.888
TL x 2c	6.149	0.105	0.246	-1.141	0.154	0.920
TL x 2p	21.873	0.095	0.086	-2.204	0.257	0.704
TL x 2d	14.346	0.037	0.049	-2.420	0.161	0.919
TL x 2chl	39.539	0.189	0.110	-4.703	0.562	0.873
TL x 3wl	0.715	0.418	0.926	-7.997	0.523	0.844
TL x 4wl	-0.090	0.432	0.930	-10.786	0.590	0.895
TL x 5wl	3.033	0.394	0.846	-4.890	0.511	0.954
CL x RL	3.088	0.716	0.867	2.884	0.719	0.874
CL x Tel	2.109	0.301	0.752	3.725	0.236	0.410
CL x PI	-0.021	0.318	0.747	3.953	0.244	0.364
CL x Ichl	4.898	0.933	0.870	2.562	1.068	0.919
CL x 2i	2.615	0.188	0.195	3.284	0.112	0.511
CL x 2m	9.819	0.056	0.064	1.288	0.333	0.844
CL x 2c	6.000	0.323	0.312	1.613	0.338	0.867
CL x 2p	-17.848	0.501	0.188	3.267	0.507	0.598
CL x 2d	11.533	0.261	0.143	-0.106	0.389	0.953
CL x 2chl	33.667	0.880	0.212	6.168	1.178	0.788
CL x 3wl	5.189	1.014	0.925	-1.038	1.295	0.899
CL x 4wl	5.099	1.017	0.902	-2.464	1.430	0.933
CL x 5wl	6.501	0.996	0.881	3.789	1.147	0.921
RL x Tel	2.314	0.329	0.678	4.964	0.174	0.251
RL x PI	1.035	0.296	0.575	6.484	0.095	0.117
RL x Ichl	6.047	0.988	0.761	2.370	1.201	0.849
RL x 2i	3.359	0.168	0.144	2.862	0.154	0.578
RL x 2m	11.788	-0.057	0.054	1.951	0.324	0.675
RL x 2c	9.229	0.171	0.136	2.334	0.326	0.687
RL x 2p	30.850	-0.222	0.069	1.439	0.692	0.670
RL x 2d	18.039	-0.100	0.045	0.056	0.421	0.849
RL x 2chl	55.226	0.060	0.012	8.585	1.495	0.733
RL x 3wl	5.247	1.147	0.864	-1.707	1.487	0.848
RL x 4wl	3.680	1.240	0.908	-3.246	1.645	0.882
RL x 5wl	8.936	0.982	0.717	1.909	1.407	0.929
Tel x PI	0.467	0.704	0.663	0.511	0.979	0.841
Tel x Ichl	7.851	1.869	0.699	11.169	1.130	0.559
Tel x 2i	1.570	0.589	0.245	3.735	0.178	0.469
Tel x 2m	10.584	0.034	0.016	4.245	0.315	0.459
Tel x 2c	13.154	-0.145	0.056	3.987	0.405	0.597
Tel x 2p	35.588	-1.085	0.163	4.703	0.891	0.604
Tel x 2d	27.373	-1.420	0.313	3.558	0.341	0.481
Tel x 2chl	60.896	-0.606	0.056	16.669	1.789	0.614
Tel x 3wl	8.622	2.002	0.732	13.368	0.841	0.335
Tel x 4wl	7.426	2.156	0.766	11.320	1.212	0.455
Tel x 5wl	10.503	1.885	0.340	14.910	0.964	0.445
PI x Ichl	13.839	1.432	0.568	12.593	0.897	0.517
PI x 2i	5.106	0.172	0.076	4.092	0.125	0.382
PI x 2m	9.045	0.306	0.151	4.300	0.293	0.499
PI x 2c	9.717	0.392	0.161	4.482	0.323	0.555
PI x 2p	22.204	0.845	0.135	7.684	0.471	0.372

....Continued table 1.6.5

Relationships	Regression Constant a	Regression Coefficient b	Correlation Coefficient r	Regression Constant a	Regression Coefficient b	Correlation Coefficient r
Pl x 2d	15.311	0.183	0.043	4.301	0.231	0.379
Pl x 2chl	46.073	1.716	0.170	20.557	1.212	0.485
Pl x 3wl	15.294	1.490	0.579	14.006	0.721	0.335
Pl x 4wl	15.203	1.501	0.567	13.608	0.865	0.378
Pl x 5wl	15.856	1.560	0.587	16.890	0.668	0.359
1chl x 2i	1.857	0.191	0.213	2.476	0.132	0.703
1chl x 2m	9.803	0.047	0.059	1.160	0.277	0.818
1chl x 2c	3.429	0.389	0.399	1.487	0.282	0.840
1chl x 2p	15.342	0.532	0.213	0.513	0.558	0.759
1chl x 2d	9.303	0.318	0.188	0.122	0.305	0.869
1chl x 2chl	30.431	1.156	0.288	5.636	1.245	0.864
1chl x 3wl	3.319	0.932	0.912	-1.230	1.064	0.858
1chl x 4wl	3.790	0.910	0.865	-3.502	1.217	0.923
1chl x 5wl	6.593	0.829	0.786	1.815	1.035	0.966
2i x 2m	10.384	0.077	0.086	-0.020	1.306	0.725
2i x 2c	11.265	0.126	0.117	1.800	1.030	5.770
2i x 2p	27.210	-0.002	0.001	-4.848	3.129	0.807
2i x 2d	18.293	-0.310	0.164	0.405	1.126	0.603
2i x 2chl	48.860	1.201	0.270	-2.704	6.466	0.844
2i x 3wl	23.342	0.124	0.109	-1.484	4.172	0.633
2i x 4wl	22.178	0.310	0.265	-2.161	4.450	0.635
2i x 5wl	24.054	0.167	0.142	1.259	4.117	0.723
2m x 2c	5.489	0.603	0.502	1.163	0.887	0.896
2m x 2p	8.629	1.711	0.553	1.456	1.502	0.698
2m x 2d	8.405	0.736	0.350	0.339	0.875	0.844
2m x 2chl	19.146	3.346	0.692	5.036	3.792	0.892
2m x 3wl	23.400	0.065	0.051	-0.862	3.109	0.850
2m x 4wl	23.154	0.085	0.065	-0.630	3.185	0.819
2m x 5wl	20.924	0.382	0.292	5.317	2.547	0.806
2c x 2p	0.573	2.212	0.859	0.604	1.535	0.706
2c x 2d	-1.681	1.502	0.857	0.181	0.845	0.808
2c x 2chl	11.170	3.680	0.914	3.657	3.763	0.876
2c x 3wl	19.436	0.388	0.367	1.696	2.560	0.693
2c x 4wl	20.595	0.289	0.266	-0.088	2.918	0.743
2c x 5wl	20.254	0.401	0.368	3.269	2.687	0.842
2p x 2d	-0.521	0.521	0.914	2.846	0.287	0.597
2p x 2chl	14.272	1.514	0.969	8.937	1.857	0.940
2p x 3wl	22.167	0.071	0.173	7.575	1.063	0.625
2p x 4wl	23.268	0.030	0.070	5.890	1.275	0.705
2p x 5wl	20.934	0.152	0.360	9.326	1.125	0.766
2d x 2chl	22.775	1.994	0.868	10.813	3.151	0.768
2d x 3wl	22.113	0.121	0.201	-0.165	3.244	0.919
2d x 4wl	23.782	0.018	0.029	-1.097	3.516	0.936
2d x 5wl	22.500	0.157	0.253	5.728	2.684	0.879
2chl x 3wl	20.611	0.063	0.240	-0.008	0.654	0.760
2chl x 4wl	21.799	0.041	0.152	-1.766	0.737	0.806
2chl x 5wl	19.038	0.109	0.402	2.730	0.645	0.868
3wl x 4wl	1.035	0.956	0.929	0.039	1.035	0.974
3wl x 5wl	3.768	0.884	0.857	7.794	0.729	0.844
4wl x 5wl	4.208	0.867	0.865	7.184	0.733	0.902

TL- Total length
CL- Carapace length
RL- Rostral length
Tel- Length of telson
Pl- Pleural width

1chl- Length of 1st cheliped
2i- Ischium of 2nd cheliped
2m- Merus of 2nd cheliped
2c- Carpus of 2nd cheliped
2p- Propodus of 2nd cheliped

2d- Dactylus of 2nd cheliped
2chl- Length of 2nd cheliped
3wl- Length of 3rd walking leg
4wl- Length of 4th walking leg
5wl- Length of 5th walking leg

Table 1.6.6 Values of intercept (a), slope (regression coefficient, b) and correlation coefficient (r) of different morphometric characters of Macrobrachium rude

Males df = 13

Relationships	Regression Constant a	Regression Coefficient b	Correlation Coefficient r	Relationships	Regression Constant a	Regression Coefficient b	Correlation Coefficient r
TL x CL	-5.304	0.270	0.695	Pl x 2d	28.946	-0.969	0.164
TL x RL	0.526	0.297	0.759	Pl x 2chl	119.785	1.931	0.075
TL x Tel	0.379	0.131	0.498	Pl x 3wl	19.152	3.055	0.467
TL x Pl	-2.723	0.131	0.900	Pl x 4wl	14.789	3.596	0.515
TL x 1chl	2.211	0.402	0.756	Pl x 5wl	26.049	2.658	0.402
TL x 2i	9.009	0.073	0.109				
TL x 2m	12.446	0.154	0.267	1chl x 2i	-12.385	0.714	0.564
TL x 2c	-11.366	0.604	0.376	1chl x 2m	4.443	0.565	0.520
TL x 2p	11.4725	0.43928	0.345	1chl x 2c	-48.330	2.356	0.779
TL x 2d	27.914	-0.087	0.102	1chl x 2p	-12.272	1.593	0.543
TL x 2chl	12.5524	1.1976	0.378	1chl x 2d	0.260	0.495	0.306
TL x 3wl	-12.313	0.649	0.682	1chl x 2ch	-68.552	5.228	0.740
TL x 4wl	-22.515	0.766	0.755	1chl x 3wl	-18.783	1.689	0.945
TL x 5wl	0.521	0.544	0.566	1chl x 4wl	-23.405	1.824	0.954
				1chl x 5wl	-14.029	1.648	0.910
CL x RL	2.418	0.847	0.840				
CL x Tel	-2.827	0.508	0.747	2i x 2m	24.339	0.152	0.177
CL x Pl	0.210	0.304	0.810	2i x 2c	15.988	1.820	0.761
CL x 1chl	27.230	0.405	0.296	2i x 2p	34.411	1.028	0.443
CL x 2i	45.437	-0.997	0.565	2i x 2d	15.885	0.248	0.194
CL x 2m	20.960	0.191	0.128	2i x 2chl	74.738	4.001	0.716
CL x 2c	67.116	-0.737	0.178	2i x 3wl	32.253	0.992	0.700
CL x 2p	41.009	0.377	0.113	2i x 4wl	33.022	0.990	0.654
CL x 2d	28.795	-0.269	0.134	2i x 5wl	35.992	0.955	0.667
CL x 2chl	129.085	-0.175	0.021				
CL x 3wl	39.115	0.291	0.119	2m x 2c	-4.048	1.825	0.655
CL x 4wl	34.453	0.469	0.179	2m x 2p	3.029	1.781	0.659
CL x 5wl	43.026	0.266	0.107	2m x 2d	-1.060	0.780	0.525
				2m x 2ch	9.271	4.812	0.740
RL x Tel	1.079	0.409	0.607	2m x 3wl	29.560	0.687	0.417
RL x Pl	0.540	0.316	0.850	2m x 4wl	30.189	0.691	0.392
RL x 1chl	23.569	0.567	0.418	2m x 5wl	27.148	0.895	0.537
RL x 2i	28.793	-0.492	0.269				
RL x 2m	22.319	0.157	0.107	2c x 2p	23.049	0.617	0.636
RL x 2c	50.146	-0.192	0.047	2c x 2d	13.174	0.148	0.278
RL x 2p	55.472	-0.171	0.043	2c x 2chl	40.842	2.170	0.929
RL x 2d	26.834	-0.250	0.114	2c x 3wl	25.589	0.499	0.843
RL x 2chl	156.730	-0.667	0.070	2c x 4wl	25.957	0.507	0.803
RL x 3wl	32.651	0.543	0.224	2c x 5wl	27.924	0.518	0.864
RL x 4wl	26.983	0.771	0.297				
RL x 5wl	36.260	0.527	0.215	2p x 2d	-4.682	0.483	0.878
				2p x 2chl	32.056	2.090	0.868
Tel x Pl	5.708	0.295	0.536	2p x 3wl	32.840	0.298	0.488
Tel x 1chl	34.518	0.396	0.197	2p x 4wl	34.763	0.274	0.421
Tel x 2i	31.316	-1.232	0.485	2p x 5wl	33.763	0.342	0.554
Tel x 2m	17.481	0.736	0.337				
Tel x 2c	48.510	-0.298	0.049	2d x 2chl	86.111	2.618	0.599
Tel x 2p	41.681	0.476	0.081	2d x 3wl	43.716	0.213	0.192
Tel x 2d	16.222	0.285	0.088	2d x 4wl	45.573	0.156	0.132
Tel x 2chl	141.988	-0.319	0.220	2d x 5wl	44.624	0.326	0.291
Tel x 3wl	47.104	0.066	0.018				
Tel x 4wl	46.566	0.167	0.043	2chl x 3w	21.602	0.191	0.753
Tel x 5wl	50.005	0.860	0.024	2chl x 4w	22.685	0.188	0.696
				2chl x 5w	22.730	0.206	0.802
Pl x 1chl	21.072	1.957	0.536				
Pl x 2i	21.503	-0.605	0.131	3wl x 4wl	-1.411	1.045	0.978
Pl x 2m	18.230	0.904	0.228	3wl x 5wl	6.031	0.940	0.929
Pl x 2c	27.812	1.798	0.163				
Pl x 2p	52.240	-0.167	0.016	4wl x 5wl	10.515	0.834	0.880

TL- Total length
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2c- Carpus of 2nd cheliped
2p- Propodus of 2nd cheliped
2d- Dactylus of 2nd cheliped
2chl- Length of 2nd cheliped
3wl- Length of 3rd walking leg
4wl- Length of 4th walking leg
5wl- Length of 5th walking leg

Table 1.7.1. Comparison of regression coefficients of TOTAL LENGTH X ROSTRAL LENGTH in males of various Macrobrachium spp. and results of t-test

Species	df	ΣX^2	ΣXY	ΣY^2	RC	DEVIATIONS FROM REGRESSION df	SS {d y.x2	MSS	
M.rosenbergii	105	94390.642	35708.132	14467.557	0.3783	104	959.113	9.222	
M.idella	131	55549.879	16734.203	5584.730	0.3012	130	543.611	4.182	
M.equidens	97	28607.444	9396.574	3287.144	0.3285	96	200.689	2.091	
M.striatus	111	17295.309	5017.031	1738.819	0.2901	110	283.476	2.577	
M.scabriculum	39	1776.204	534.371	205.158	0.3009	38	44.392	1.168	
M.rude	14	759.733	225.740	116.324	0.2971	13	49.250	3.788	
WITHIN						491	2080.530	4.237	
Reg.Coeff.						5	272.782	54.556	
COMMON	497	198379.210	67616.051	25399.731	0.3408	496	2353.312	4.745	12.8752
Adj.Means						5	1303.531	260.706	54.9482
TOTAL	503	1396513.936	566509.171	233466.681	0.4057	501	3656.843		
Comparison of slopes F=			54.556	(5, 496)	12.8752	P<0.001			
Comparison of elevation F=			260.706	(5, 501)	54.9482	P<0.001			

	df	t	Probability
M.rosenbergii X M.idella	234	5.69	P<0.001
M.rosenbergii X M.equidens	200	3.07	P<0.01
M.rosenbergii X M.striatus	214	4.43	P<0.001
M.rosenbergii X M.scabriculum	142	1.22	
M.rosenbergii X M.rude	117	0.76	
M.idella X M.equidens	226	2.06	P<0.05
M.idella X M.striatus	240	0.69	
M.idella X M.scabriculum	168	0.01	
M.idella X M.rude	143	0.06	
M.equidens X M.striatus	206	2.60	P<0.01
M.equidens X M.scabriculum	134	0.84	
M.equidens X M.rude	109	0.56	
M.striatus X M.scabriculum	148	0.29	
M.striatus X M.rude	123	0.12	
M.scabriculum X M.rude	51	0.06	

Table 1.7.2. Comparison of regression coefficients of TOTAL LENGTH X LENGTH OF MERUS OF SECOND CHELIPED in males of various Macrobrachium spp. and results of t-test

						DEVIATIONS FROM REGRESSION			
Species	df	ΣX^2	ΣXY	ΣY^2	RC	df	SS {d y.x2	MSS	
M.rosenbergii	105	94390.642	20607.585	7018.151	0.2183	104	2519.055	24.222	
M.idella	131	55549.879	24975.785	14029.608	0.4496	130	2800.244	21.540	
M.equidens	97	28607.444	7823.987	3208.990	0.2735	96	1069.170	11.137	
M.striatus	111	17295.309	6937.486	3373.977	0.4011	110	591.216	5.375	
M.scabriculum	39	1776.204	-20.974	224.459	-0.0118	38	224.211	5.900	
M.rude	14	759.733	116.993	252.777	0.1540	13	234.761	18.059	
WITHIN						491	7438.658	15.150	
Reg.Coeff.						5	2254.584	450.917	
COMMON	497	198379.210	60440.862	28107.962	0.3047	496	9693.242	19.543	29.7635
Adj Means						5	10877.805	2175.561	111.3227
TOTAL	503	1396513.936	176433.490	42861.390	0.1263	501	20571.046		
Comparison of slopes F=			450.917 (5, 496)		29.7635	P<0.001			
Comparison of elevation F=			2175.561 (5, 501)		111.3227	P<0.001			

	df	t	Probability
M.rosenbergii X M.idella	234	9.07	P<0.001
M.rosenbergii X M.equidens	200	1.93	P<0.05
M.rosenbergii X M.striatus	214	5.80	P<0.001
M.rosenbergii X M.scabriculum	142	2.19	P<0.05
M.rosenbergii X M.rude	117	0.36	
M.idella X M.equidens	226	5.85	P<0.001
M.idella X M.striatus	240	1.48	
M.idella X M.scabriculum	168	4.51	P<0.001
M.idella X M.rude	143	1.76	
M.equidens X M.striatus	206	4.67	P<0.001
M.equidens X M.scabriculum	134	3.76	P<0.001
M.equidens X M.rude	109	0.94	
M.striatus X M.scabriculum	148	7.06	P<0.001
M.striatus X M.rude	123	2.57	P<0.01
M.scabriculum X M.rude	51	1.27	

Table 1.7.3 Comparison of regression coefficients of TOTAL LENGTH X LENGTH OF CARPUS OF SECOND CHELIPED in males of various Macrobrachium spp. and results of t-test

						DEVIATIONS FROM REGRESSION			
Species	df	ΣX^2	ΣXY	ΣY^2	RC	df	SS {d y.x2	MSS	
M.rosenbergii	105	94390.642	24940.283	11155.066	0.2642	104	4565.242	43.897	
M.idella	131	55549.879	50032.691	59705.969	0.9007	130	14642.502	112.635	
M.equidens	97	28607.444	14273.006	11257.693	0.4989	96	4136.515	43.089	
M.striatus	111	17295.309	13145.611	13132.059	0.7601	110	3140.499	28.550	
M.scabriculum	39	1776.204	186.782	324.011	0.1052	38	304.369	8.010	
M.rude	14	759.733	459.107	1959.377	0.6043	13	1681.939	129.380	
WITHIN						491	28471.067	57.986	
Reg.Coeff.						5	15545.795	3109.159	
COMMON	497	198379.210	103037.480	97534.176	0.5194	496	44016.862	88.744	53.6192
Adj.Means						5	59695.942	11939.188	134.5357
TOTAL	503	1.397E+06	1.791E+05	1.267E+05	0.1283	501	103712.804		
Comparison of slopes F=			3109.159 (5, 496)		53.6192	P<0.001			
Comparison of elevation F=			11939.188 (5, 501)		134.5357	P<0.001			

	df	t	Probability
M.rosenbergii X M.idella	234	13.14	P<0.001
M.rosenbergii X M.equidens	200	5.27	P<0.001
M.rosenbergii X M.striatus	214	9.99	P<0.001
M.rosenbergii X M.scabriculum	142	1.13	
M.rosenbergii X M.rude	117	1.28	
M.idella X M.equidens	226	6.06	P<0.001
M.idella X M.striatus	240	1.88	
M.idella X M.scabriculum	168	3.50	P<0.001
M.idella X M.rude	143	0.76	
M.equidens X M.striatus	206	4.56	P<0.001
M.equidens X M.scabriculum	134	2.80	P<0.01
M.equidens X M.rude	109	0.39	
M.striatus X M.scabriculum	148	5.45	P<0.001
M.striatus X M.rude	123	0.67	
M.scabriculum X M.rude	51	1.84	

Table 1.7.4 Comparison of regression coefficients of TOTAL LENGTH X LENGTH OF PROPODUS OF SECOND CHELIPED in males of various Macrobrachium spp. and results of t-test

						DEVIATIONS FROM REGRESSION			
Species	df	ΣX^2	ΣXY	ΣY^2	RC	df	SS {d y.x2	MSS	
M.rosenbergii	105	94390.642	54324.113	48352.491	0.5755	104	17087.640	164.304	
M.idella	131	55549.879	47295.948	51189.488	0.8514	130	10921.052	84.008	
M.equidens	97	28607.444	14632.546	11979.065	0.5115	96	4494.600	46.819	
M.striatus	111	17295.309	16383.306	20734.200	0.9473	110	5214.806	47.407	
M.scabriculum	39	1776.204	169.040	2150.600	0.0952	38	2134.513	56.171	
M.rude	14	759.733	333.733	1230.053	0.4393	13	1083.452	83.342	
WITHIN						491	40936.063	83.373	
Reg.Coeff.						5	5346.166	1069.233	
COMMON	497	1.984E+05	1.331E+05	1.356E+05	0.6711	496	46282.229	93.311	12.8247
Adj.Means						5	41561.373	8312.275	89.0815
TOTAL	503	1.397E+06	4.316E+05	2.213E+05	0.3091	501	87843.602		
Comparison of slopes F=			1069.233	(5, 496)	12.8247	P<0.001			
Comparison of elevation F=			8312.275	(5, 501)	89.0815	P<0.001			

	df	t	Probability
M.rosenbergii X M.idella	234	4.72	P<0.001
M.rosenbergii X M.equidens	200	0.91	
M.rosenbergii X M.striatus	214	4.40	P<0.001
M.rosenbergii X M.scabriculum	142	1.72	
M.rosenbergii X M.rude	117	0.30	
M.idella X M.equidens	226	5.66	P<0.001
M.idella X M.striatus	240	1.34	
M.idella X M.scabriculum	168	3.56	P<0.001
M.idella X M.rude	143	1.23	
M.equidens X M.striatus	206	6.59	P<0.001
M.equidens X M.scabriculum	134	2.42	P<0.05
M.equidens X M.rude	109	0.27	
M.striatus X M.scabriculum	148	4.85	P<0.001
M.striatus X M.rude	123	1.92	
M.scabriculum X M.rude	51	1.00	

Table1.7.5. Comparison of regression coefficients of TOTAL LENGTH X LENGTH OF SECOND CHELIPED in males of various Macrobrachium spp. and results of t-test

						DEVIATIONS FROM REGRESSION			
Species	df	ΣX^2	ΣXY	ΣY^2	RC	df	SS {d y x2	MSS	
M.rosenbergii	105	94390.642	99871.981	162690.236	1.0581	104	57018.609	548.256	
M.idella	131	55549.879	1.223E+05	3.411E+05	2.2017	130	71776.958	552.130	
M.equidens	97	28607.444	3.673E+04	7.285E+04	1.2839	96	25689.899	267.603	
M.striatus	111	17295.309	36466.403	98223.477	2.1085	110	21335.659	193.961	
M.scabriculum	39	1776.204	334.848	5171.536	0.1885	38	5108.411	134.432	
M.rude	14	759.733	909.833	7611.353	1.1976	13	6521.765	501.674	
WITHIN						491	187451.300	381.775	
Reg.Coeff.						5	56645.566	11329.113	
COMMON	497	1.984E+05	2.966E+05	6.876E+05	1.4952	496	244096.866	492.131	29.6749
Adj.Means						5	289369.702	57873.940	117.5987
TOTAL	503	1.397E+06	7.872E+05	9.772E+05	0.5637	501	533466.568		
Comparison of slopes F=			11329.113	(5, 496)	29.6749	P<0.001			
Comparison of elevation F=			57873.940	(5, 501)	117.5987	P<0.001			

	df	t	Probability
M.rosenbergii X M.idella	234	9.12	P<0.001
M.rosenbergii X M.equidens	200	1.65	
M.rosenbergii X M.striatus	214	6.64	P<0.001
M.rosenbergii X M.scabriculum	142	1.74	
M.rosenbergii X M.rude	117	0.16	
M.idella X M.equidens	226	6.07	P<0.001
M.idella X M.striatus	240	0.54	
M.idella X M.scabriculum	168	3.90	P<0.001
M.idella X M.rude	143	1.17	
M.equidens X M.striatus	206	5.67	P<0.001
M.equidens X M.scabriculum	134	2.95	P<0.05
M.equidens X M.rude	109	0.14	
M.striatus X M.scabriculum	148	5.76	P<0.001
M.striatus X M.rude	123	1.63	
M.scabriculum X M.rude	51	1.54	

Table 1.7.6. Comparison of regression coefficients of CARAPACE LENGTH X ROSTRAL LENGTH in males of various Macrobrachium spp. and results of t-test

						DEVIATIONS FROM REGRESSION			
Species	df	ΣX^2	ΣXY	ΣY^2	RC	df	SS {d y.x2	MSS	
M.rosenbergii	105	12552.991	12148.406	14467.557	0.9678	104	2710.696	26.064	
M.idella	131	6468.386	5769.991	5584.730	0.8920	130	437.729	3.367	
M.equidens	97	3033.156	3048.637	3287.144	1.0051	96	222.947	2.322	
M.striatus	111	2000.877	1683.832	1738.819	0.8415	110	321.794	2.925	
M.scabriculum	39	301.278	215.652	205.158	0.7158	38	50.796	1.337	
M.rude	14	114.313	96.860	116.324	0.8473	13	34.253	2.635	
WITHIN						491	3778.215	7.695	
Reg.Coeff.						5	72.879	14.576	
COMMON	497	24471.000	22963.377	25399.731	0.9384	496	3851.094	7.764	1.8942
Adj.Means						5	7238.665	1447.733	186.4601
TOTAL	503	122313.282	164923.167	233466.681	1.3484	501	11089.759		
Comparison of slopes F=			14.576	(5,496)	1.8942	P>0.05			
Comparison of elevation F=			1447.733	(5,501)	186.4601	P<0.001			

	df	t	Probability
M.rosenbergii X M.idella	234	1.35	
M.rosenbergii X M.equidens	200	0.48	
M.rosenbergii X M.striatus	214	1.39	
M.rosenbergii X M.scabriculum	142	0.98	
M.rosenbergii X M.rude	117	0.26	
M.idella X M.equidens	226	3.01	P<0.01
M.idella X M.striatus	240	1.11	
M.idella X M.scabriculum	168	1.75	
M.idella X M.rude	143	0.26	
M.equidens X M.striatus	206	3.49	P<0.01
M.equidens X M.scabriculum	134	3.35	P<0.01
M.equidens X M.rude	109	1.08	
M.striatus X M.scabriculum	148	1.28	
M.striatus X M.rude	123	0.04	
M.scabriculum X M.rude	51	0.93	

Table 1.7.7. Comparison of regression coefficients of CARAPACE LENGTH X LENGTH OF MERUS OF SECOND CHELIPED in males of various Macrobrachium spp. and results of t-test

						DEVIATIONS FROM REGRESSION			
Species	df	{x2	ΣX^2	ΣXY	ΣY^2	df	SS {d y.x2	MSS	
M.rosenbergii	105	12552.991	7797.868	7018.151	0.6212	104	2174.146	20.905	
M.idella	131	6468.386	8601.807	14029.608	1.3298	130	2590.729	19.929	
M.equidens	97	3033.156	2577.523	3208.990	0.8498	96	1018.656	10.611	
M.striatus	111	2000.877	2318.299	3373.977	1.1586	110	687.901	6.254	
M.scabriculum	39	301.278	16.724	224.459	0.0555	38	223.531	5.882	
M.rude	14	114.313	21.807	252.777	0.1908	13	248.617	19.124	
WITHIN						491	6943.580	14.142	
Reg.Coeff.						5	2565.196	513.039	
COMMON	497	24471.000	21334.027	28107.962	0.8718	496	9508.776	19.171	36.2784
Adj.Means						5	9098.992	1819.798	94.9249
TOTAL	503	122313.282	54465.954	42861.390	0.4453	501	18607.768	-	
Comparison of slopes F=			513.039	(5, 496)	36.2784	P<0.001			
Comparison of elevation F=			1819.798	(5, 501)	94.9249	P<0.001			

	df	t	Probability
M.rosenbergii X M.idella	234	10.26	P<0.001
M.rosenbergii X M.equidens	200	2.83	P<0.01
M.rosenbergii X M.striatus	214	6.11	P<0.001
M.rosenbergii X M.scabriculum	142	2.36	P<0.05
M.rosenbergii X M.rude	117	1.01	
M.idella X M.equidens	226	5.46	P<0.001
M.idella X M.striatus	240	1.81	
M.idella X M.scabriculum	168	5.28	P<0.001
M.idella X M.rude	143	2.71	P<0.01
M.equidens X M.striatus	206	3.73	P<0.001
M.equidens X M.scabriculum	134	4.32	P<0.001
M.equidens X M.rude	109	2.03	P<0.05
M.striatus X M.scabriculum	148	7.19	P<0.001
M.striatus X M.rude	123	3.65	P<0.001
M.scabriculum X M.rude	51	0.40	

Table 1.7.8. Comparison of regression coefficients of CARAPACE LENGTH X LENGTH OF CARPUS OF SECOND CHELIPED in males of various Macrobrachium spp. and results of t-test

						DEVIATIONS FROM REGRESSION			
Species	df	ΣX^2	ΣXY	ΣY^2	RC	df	SS {d y.x2	MSS	
M.rosenbergii	105	12552.991	9201.726	11155.066	0.7330	104	4409.919	42.403	
M.idella	131	6468.386	17319.068	59705.969	2.6775	130	13334.260	102.571	
M.equidens	97	3033.156	4745.342	11257.693	1.5645	96	3833.653	39.934	
M.striatus	111	2000.877	4410.352	13132.059	2.2042	110	3410.717	31.007	
M.scabriculum	39	301.278	97.450	324.011	0.3235	38	292.491	7.697	
M.rude	14	114.313	-84.277	1959.377	-0.7372	13	1897.245	145.942	
WITHIN						491	27178.284	55.353	
Reg.Coeff.						5	18304.404	3660.881	
COMMON	497	24471.000	35689.662	97534.176	1.4584	496	45482.688	91.699	66.1371
Adj.Means						5	55013.001	11002.600	119.9861
TOTAL	503	122313.282	56601.350	126688.371	0.4628	501	100495.689		
Comparison of slopes F=			3660.881 (5,496)		66.1371	P<0.001			
Comparison of elevation F=			11002.600 (5, 501)		119.9861	P<0.001			

	df	t	Probability
M.rosenbergii X M.idella	234	14.59	P<0.001
M.rosenbergii X M.equidens	200	6.40	P<0.001
M.rosenbergii X M.striatus	214	10.11	P<0.001
M.rosenbergii X M.scabriculum	142	1.22	
M.rosenbergii X M.rude	117	2.13	P<0.05
M.idella X M.equidens	226	5.80	P<0.001
M.idella X M.striatus	240	2.21	P<0.05
M.idella X M.scabriculum	168	4.43	P<0.001
M.idella X M.rude	143	3.51	P<0.001
M.equidens X M.striatus	206	3.75	P<0.001
M.equidens X M.scabriculum	134	3.70	P<0.001
M.equidens X M.rude	109	3.33	P<0.005
M.striatus X M.scabriculum	148	6.08	P<0.001
M.striatus X M.rude	123	4.66	P<0.001
M.scabriculum X M.rude	51	1.47	

Table 1.7.9 Comparison of regression coefficients of CARAPACE LENGTH X LENGTH OF PROPODUS OF SECOND CHELIPED in males of various Macrobrachium spp. and the results of t-test

						DEVIATIONS FROM REGRESSION		
Species	df	ΣX^2	ΣXY	ΣY^2	RC	df	SS {d y x2	MSS	
M.rosenbergii	105	12552.991	21008.491	48352.491	1.6736	104	13193.006	126.856	
M.idella	131	6468.386	16211.971	51189.488	2.5063	130	10556.788	81.206	
M.equidens	97	3033.156	4749.496	11979.065	1.5659	96	4542.019	47.313	
M.striatus	111	2000.877	5519.651	20734.200	2.7586	110	5507.601	50.069	
M.scabriculum	39	301.278	151.020	2150.600	0.5013	38	2074.899	54.603	
M.rude	14	114.313	42.427	1230.053	0.3711	13	1214.307	93.408	
WITHIN						491	37088.620	75.537	
Reg.Coeff.						5	5634.287	1126.857	
COMMON	497	24471.000	47683.056	135635.897	1.9486	496	42722.907	86.135	14.9180
Adj.Means						5	31255.138	6251.028	72.5725
TOTAL	503	122313.282	134216.132	221255.345	1.0973	501	73978.044		
Comparison of slopes F=			1126.857	(5, 496)	14.9180	P<0.001			
Comparison of elevation F=			6251.028	(5, 501)	72.5725	P<0.001			

	df	t	Probability
M.rosenbergii X M.idella	234	5.40	P<0.001
M.rosenbergii X M.equidens	200	0.57	
M.rosenbergii X M.striatus	214	4.82	P<0.001
M.rosenbergii X M.scabriculum	142	1.94	
M.rosenbergii X M.rude	117	1.25	
M.idella X M.equidens	226	5.23	P<0.001
M.idella X M.striatus	240	1.21	
M.idella X M.scabriculum	168	3.92	P<0.001
M.idella X M.rude	143	2.49	P<0.05
M.equidens X M.striatus	206	5.93	P<0.001
M.equidens X M.scabriculum	134	2.51	P<0.05
M.equidens X M.rude	109	1.73	
M.striatus X M.scabriculum	148	5.10	P<0.001
M.striatus X M.rude	123	3.36	P<0.005
M.scabriculum X M.rude	51	0.15	

Table 1.7.10. Comparison of regression coefficients of CARAPACE LENGTH X LENGTH OF SECOND CHELIPED in males of various Macrobrachium spp. and the results of t-test

Species	df	{x2	{xy	{y2	RC	DEVIATIONS FROM REGRESSION df	SS {d y.x2	MSS	
M.rosenbergii	105	12552.991	38008.085	162690.236	3.0278	104	47608.932	457.778	
M.idella	131	6468.386	42132.847	341055.173	6.5137	130	66616.279	512.433	
M.equidens	97	3033.156	12072.361	72847.522	3.9801	96	24797.925	258.312	
M.striatus	111	2000.877	12248.302	98223.477	6.1215	110	23245.898	211.326	
M.scabriculum	39	301.278	265.193	5171.536	0.8802	38	4938.106	129.950	
M.rude	14	114.313	-20.043	7611.353	-0.1753	13	7607.839	585.218	
WITHIN						491	174814.980	356.039	
Reg.Coeff.						5	64764.124	12952.825	
COMMON	497	24471.000	104706.744	687599.297	4.2788	496	239579.103	483.022	36.3804
Adj.Means						5	245735.389	49147.078	101.7491
TOTAL	503	122313.282	245283.435	977198.632	2.0054	501	485314.492		
Comparison of slopes F=			12952.825	(5, 496)	36.3804	P<0.001			
Comparison of elevation F=			49147.078	(5, 501)	101.7491	P<0.001			

	df	t	Probability
M.rosenbergii X M.idella	234	10.31	P<0.001
M.rosenbergii X M.equidens	200	2.47	P<0.05
M.rosenbergii X M.striatus	214	7.06	P<0.001
M.rosenbergii X M.scabriculum	142	1.91	
M.rosenbergii X M.rude	117	1.57	
M.idella X M.equidens	226	5.72	P<0.001
M.idella X M.striatus	240	0.79	
M.idella X M.scabriculum	168	4.63	P<0.001
M.idella X M.rude	143	3.11	P<0.005
M.equidens X M.striatus	206	4.87	P<0.001
M.equidens X M.scabriculum	134	3.44	P<0.001
M.equidens X M.rude	109	2.53	P<0.05
M.striatus X M.scabriculum	148	6.15	P<0.001
M.striatus X M.rude	123	4.13	P<0.001
M.scabriculum X M.rude	51	0.61	

Table 1.7.11 Comparison of regression cofficients of TOTAL LENGTH X ROSTRAL LENGTH in females of various Macrobrachium spp. and results of t-test

Species	df	ΣX^2	ΣXY	ΣY^2	RC	DEVIATIONS FROM REGRESSION df	SS {d y.x2	MSS	
M.rosenbergii	116	91893.248	30440.282	12290.769	0.3313	115	2207.213	19.193	
M.idella	105	14147.145	4390.980	1710.678	0.3104	104	347.809	3.344	
M.equidens	106	6637.088	2095.727	1073.097	0.3158	105	411.351	3.918	
M.striatus	102	8616.065	2333.658	1034.539	0.2708	101	402.469	3.985	
M.scabriculum	29	1204.700	348.920	150.459	0.2896	28	49.400	1.764	
WITHIN						453	3418.241	7.546	
Reg.Coeff.						4	33.626	8.406	
COMMON	458	1.225E+05	3.961E+04	1.626E+04	0.3233	457	3451.867	7.553	1.1141
Adj.Means						4	788.511	197.128	26.0982
TOTAL	463	1.596E+06	6.313E+05	2.539E+05	0.3955	461	4240.378		

Comparison of slopes F=	8.406	(4, 457)	1.1141 P>0.05
Comparison of elevation F=	197.128	(4, 461)	26.0982 P<0.001

	df	t	Probability
M.rosenbergii X M.idella	219	0.68	P>0.05
M.rosenbergii X M.equidens	220	0.35	P>0.05
M.rosenbergii X M.striatus	216	1.54	P>0.05
M.rosenbergii X M.scabriculum	143	0.36	P>0.05
M.idella X M.equidens	209	0.19	P>0.05
M.idella X M.striatus	205	1.51	P>0.05
M.idella X M.scabriculum	132	0.40	P>0.05
M.equidens X M.striatus	206	1.38	P>0.05
M.equidens X M.scabriculum	133	0.45	P>0.05
M.striatus X M.scabriculum	129	0.33	P>0.05

Table 1.7.12 Comparison of regression coefficients of TOTAL LENGTH X MERUS OF SECOND CHELIPED in females of various Macrobrachium spp. and results of t-test

						DEVIATIONS FROM REGRESSION			
Species	df	{x2	{xy	{y2	RC	df	SS {d y.x2	MSS	
M.rosenbergii	116	91893.248	14581.410	2677.231	0.1587	115	363.486	3.161	
M.idella	105	14147.145	2285.305	866.127	0.1615	104	496.963	4.778	
M.equidens	106	6637.088	1120.665	230.739	0.1688	105	41.516	0.395	
M.striatus	102	8616.065	2110.737	753.838	0.2450	101	236.756	2.344	
M.scabriculum	29	1204.700	181.310	34.590	0.1505	28	7.302	0.261	
WITHIN						453	1146.023	2.530	
Reg.Coeff.						4	59.268	14.817	
COMMON	458	122498.246	20279.427	4562.525	0.1655	457	1205.292	2.637	5.8569
Adj.Means						4	414.366	103.591	39.2779
TOTAL	463	1596192.268	204800.928	27896.830	0.1283	461	1619.657		
Comparison of slopes F=			14.817	(4, 457)		5.8569	P<0.01		
Comparison of elevation F=			103.591	(4, 461)		39.2779	P<0.001		

	df	t	Probability
M.rosenbergii X M.idella	219	0.16	
M.rosenbergii X M.equidens	220	0.59	
M.rosenbergii X M.striatus	216	4.59	P<0.001
M.rosenbergii X M.scabriculum	143	0.18	
M.idella X M.equidens	209	0.31	
M.idella X M.striatus	205	3.23	P<0.005
M.idella X M.scabriculum	132	0.19	
M.equidens X M.striatus	206	4.01	P<0.001
M.equidens X M.scabriculum	133	0.97	
M.striatus X M.scabriculum	129	2.23	P<0.05

Table 1.7.13 Comparison of regression coefficients of TOTAL LENGTH X LENGTH OF CARPUS OF SECOND CHELIPED in females of various Macrobrachium spp. and results of t-test

Species	df	ΣX^2	ΣXY	ΣY^2	RC	DEVIATIONS FROM REGRESSION df	SS {d y.x2	MSS	
M.rosenbergii	116	91893.248	17578.803	4329.915	0.1913	115	967.161	8.410	
M.idella	105	14147.145	4592.050	3376.964	0.3246	104	1886.421	18.139	
M.equidens	106	6637.088	1623.736	639.490	0.2446	105	242.250	2.307	
M.striatus	102	8616.065	3195.796	1577.557	0.3709	101	392.200	3.883	
M.scabriculum	29	1204.700	185.860	33.908	0.1543	28	5.234	0.187	
WITHIN						453	3493.266	7.711	
Reg.Coeff.						4	435.515	108.879	
COMMON	458	122498.246	27176.245	9957.833	0.2219	457	3928.781	8.597	14.1192
Adj.Means						4	1322.828	330.707	38.4682
TOTAL	463	1596192.268	246652.286	43365.658	0.1545	461	5251.609		
Comparison of slopes F=			108.879	(4, 457)	14.1192	P<0.001			
Comparison of elevation F=			330.707	(4, 461)	38.4682	P<0.001			

	df	t	Probability
M.rosenbergii X M.idella	219	4.09	P<0.001
M.rosenbergii X M.equidens	220	1.79	
M.rosenbergii X M.striatus	216	6.35	P<0.001
M.rosenbergii X M.scabriculum	143	0.49	
M.idella X M.equidens	209	1.68	
M.idella X M.striatus	205	1.02	
M.idella X M.scabriculum	132	1.50	
M.equidens X M.striatus	206	4.41	P<0.001
M.equidens X M.scabriculum	133	2.12	P<0.05
M.striatus X M.scabriculum	129	4.01	P<0.001

Table 1.7.14 Comparison of regression coefficients of TOTAL LENGTH X LENGTH OF PROPODUS OF SECOND CHELIPED in females of various Macrobrachium spp. and results of t-test

Species	df	ΣX^2	ΣXY	ΣY^2	RC	DEVIATIONS FROM REGRESSION df	SS {d y.x2	MSS	
M rosenbergii	116	91893.248	32658.017	16297.863	0.3554	115	4691.504	40.796	
M.idella	105	14147.145	4382.820	3460.280	0.3098	104	2102.472	20.216	
M equidens	106	6637.088	2129.477	919.109	0.3208	105	235.877	2.246	
M.striatus	102	8616.065	4221.592	2841.189	0.4900	101	772.746	7.651	
M.scabriculum	29	1204.700	309.340	160.188	0.2568	28	80.756	2.884	
WITHIN						453	7883.355	17.403	
Reg.Coeff.						4	204.856	51.214	
COMMON	458	122498.246	43701.246	23678.630	0.3567	457	8088.211	17.698	2.9429
Adj.Means						4	3584.690	896.172	50.6355
TOTAL	463	1596192.268	427433.822	126132.591	0.2678	461	11672.901		
Comparison of slopes F=			51.214	(4, 457)	2.9429	P<0.05			
Comparison of elevation F=			896.172	(4, 461)	50.6355	P<0.001			

	df	t	Probability
M.rosenbergii X M.idella	219	0.91	
M.rosenbergii X M.equidens	220	0.57	
M.rosenbergii X M.striatus	216	2.37	P<0.05
M.rosenbergii X M.scabriculum	143	0.59	
M.idella X M.equidens	209	0.22	
M.idella X M.striatus	205	3.52	P<0.001
M.idella X M.scabriculum	132	0.43	
M.equidens X M.striatus	206	4.68	P<0.001
M.equidens X M.scabriculum	133	1.33	
M.striatus X M.scabriculum	129	2.95	P<0.005

Table 1.7.15 Comparison of regression coefficients of TOTAL LENGTH X LENGTH OF SECOND CHELIPED in females of various Macrobrachium spp. and results of t-test

Species	df	{x2	{xy	{y2	RC	DEVIATIONS FROM REGRESSION df	SS {d y.x2	MSS	
M.rosenbergii	116	91893.248	64818.231	55611.077	0.7054	115	9890.601	86.005	
M.idella	105	14147.145	11260.265	20503.339	0.7959	104	11540.854	110.970	
M equidens	106	6637.088	4873.877	4740.875	0.7343	105	1161.794	11.065	
M striatus	102	8616.065	9528.125	14077.945	1.1059	101	3541.213	35.062	
M.scabriculum	29	1204.700	676.510	498.110	0.5616	28	118.209	4.222	
WITHIN						453	26252.672	57.953	
Reg.Coeff.						4	1344.233	336.058	
COMMON	458	122498.246	91157.008	95431.346	0.7441	457	27596.904	60.387	5.7988
Adj.Means						4	11214.834	2803.709	46.4289
TOTAL	463	1596192.268	878887.126	522740.019	0.5506	461	38811.738		
Comparison of slopes F=			336.058	(4, 457)	5.7988	P<0.01			
Comparison of elevation F=			2803.709	(4, 461)	46.4289	P<0.001			

	df	t	Probability
M.rosenbergii X M.idella	219	1.01	
M.rosenbergii X M.equidens	220	0.32	
M.rosenbergii X M.striatus	216	4.51	P<0.001
M.rosenbergii X M.scabriculum	143	0.59	
M.idella X M.equidens	209	0.53	
M.idella X M.striatus	205	2.64	P<0.005
M.idella X M.scabriculum	132	0.83	
M.equidens X M.striatus	206	4.76	P<0.001
M.equidens X M.scabriculum	133	1.78	
M.striatus X M.scabriculum	129	3.32	P<0.001

Table 1.7.16 Comparison of regression coefficients of CARAPACE LENGTH X ROSTRAL LENGTH in females of various Macrobrachium spp. and results of t-test

					DEVIATIONS FROM REGRESSION				
Species	df	ΣX^2	ΣXY	ΣY^2	RC	df	SS {d y.x2	MSS	
M.rosenbergii	116	10847.915	10144.051	12290.769	0.9351	115	2804.911	24.391	
M.idella	105	1719.325	1404.020	1710.678	0.8166	104	564.140	5.424	
M.equidens	106	849.596	847.471	1073.097	0.9975	105	227.746	2.169	
M.striatus	102	1095.593	881.868	1034.539	0.8049	101	324.704	3.215	
M.scabriculum	29	222.735	159.769	150.459	0.7173	28	35.855	1.281	
WITHIN						453	3957.356	8.736	
Reg.Coeff.						4	48.655	12.164	
COMMON	458	14735.163	13437.179	16259.543	0.9119	457	4006.011	8.766	1.3924
Adj.Means						4	4296.182	1074.045	122.5256
TOTAL	463	126183.674	176045.609	253912.862	1.3952	461	8302.193		
Comparison of slopes F=			12.164	(4, 457)	1.3924	P>0.05			
Comparison of elevation F=			1074.045	(4, 461)	122.5256	P<0.01			

	df	t	Probability
M.rosenbergii X M.idella	219	1.16	P>0.05
M.rosenbergii X M.equidens	220	0.47	P>0.05
M.rosenbergii X M.striatus	216	1.08	P>0.05
M.rosenbergii X M.scabriculum	143	0.72	P>0.05
M.idella X M.equidens	209	1.22	P>0.05
M.idella X M.striatus	205	0.15	P>0.05
M.idella X M.scabriculum	132	0.65	P>0.05
M.equidens X M.striatus	206	1.57	P>0.05
M.equidens X M.scabriculum	133	1.64	P>0.05
M.striatus X M.scabriculum	129	0.71	P>0.05

Table 1.7.17 Comparison of regression coefficients of CARAPACE LENGTH X LENGTH OF MERUS OF SECOND CHELIPED in females of various Macrobrachium spp. and results of t-test

Species	df	ΣX^2	ΣXY	ΣY^2	RC	DEVIATIONS FROM REGRESSION df	SS {d y.x2	MSS	
M.rosenbergii	116	10847.915	4959.256	2677.231	0.4572	115	410.046	3.566	
M.idella	105	1719.325	793.855	866.127	0.4617	104	499.585	4.804	
M.equidens	106	849.596	369.183	230.739	0.4345	105	70.314	0.670	
M.striatus	102	1095.593	755.041	753.838	0.6892	101	233.492	2.312	
M.scabriculum	29	222.735	74.061	34.590	0.3325	28	9.964	0.356	
WITHIN						453	1223.401	2.701	
Reg.Coeff.						4	59.763	14.941	
COMMON	458	14735.163	6951.397	4562.525	0.4718	457	1283.163	2.808	5.5322
Adj.Means						4	166.723	41.681	14.8447
TOTAL	463	126183.674	57768.266	27896.830	0.4578	461	1449.887		
Comparison of slopes F=			14.941	(4, 457)	5.5322	P<0.01			
Comparison of elevation F=			41.681	(4, 461)	14.8447	P<0.01			

	df	t	Probability
M.rosenbergii X M.idella	219	0.09	
M.rosenbergii X M.equidens	220	0.43	
M.rosenbergii X M.striatus	216	4.24	P<0.001
M.rosenbergii X M.scabriculum	143	1.07	
M.idella X M.equidens	209	0.39	
M.idella X M.striatus	205	3.11	P<0.005
M.idella X M.scabriculum	132	0.92	
M.equidens X M.striatus	206	4.59	P<0.001
M.equidens X M.scabriculum	133	1.74	
M.striatus X M.scabriculum	129	3.53	P<0.001

Table 1.7.18 Comparison of regression coefficients of CARAPACE LENGTH X LENGTH OF CARPUS OF SECOND CHELIPED in females of various Macrobrachium spp. and results of t-test

					DEVIATIONS FROM REGRESSION				
Species	df	ΣX^2	ΣXY	ΣY^2	RC	df	SS {d y.x2	MSS	
M.rosenbergii	116	10847.915	5884.085	4329.915	0.5424	115	1138.291	9.898	
M.idella	105	1719.325	1566.960	3376.964	0.9114	104	1948.866	18.739	
M.equidens	106	849.596	533.761	639.490	0.6283	105	304.154	2.897	
M.striatus	102	1095.593	1111.897	1577.557	1.0149	101	449.113	4.447	
M.scabriculum	29	222.735	75.328	33.908	0.3382	28	8.432	0.301	
WITHIN						453	3848.856	8.496	
Reg.Coeff.						4	399.766	99.942	
COMMON	458	14735.163	9172.031	9957.833	0.6225	457	4248.622	9.297	11.7628
Adj.Means						4	1026.647	256.662	27.6076
TOTAL	463	126183.674	69328.099	43365.658	0.5494	461	5275.269		
Comparison of slopes F=			99.942	(6,320)	11.7628	P<0.01			
Comparison of elevation F=			256.662	(6,326)	27.6076	P<0.01			

	df	t	Probability
M.rosenbergii X M.idella	219	3.79	P<0.001
M.rosenbergii X M.equidens	220	0.94	
M.rosenbergii X M.striatus	216	5.50	P<0.001
M.rosenbergii X M.scabriculum	143	1.07	
M.idella X M.equidens	209	2.06	P<0.005
M.idella X M.striatus	205	0.78	
M.idella X M.scabriculum	132	2.09	P<0.05
M.equidens X M.striatus	206	4.42	P<0.001
M.equidens X M.scabriculum	133	2.51	P<0.05
M.striatus X M.scabriculum	129	4.89	P<0.001

Table 1.7.19 Comparison of regression coefficients of CARAPACE LENGTH X LENGTH OF PROPODUS OF SECOND CHELIPED relationships in females of various Macrobrachium spp. and results of t-test

Species	df	ΣX^2	ΣXY	ΣY^2	RC	DEVIATIONS FROM REGRESSION df	SS {d y.x2	MSS	
M.rosenbergii	116	10847.915	11210.427	16297.863	1.0334	115	4712.809	40.981	
M.idella	105	1719.325	1552.360	3460.280	0.9029	104	2058.671	19.795	
M.equidens	106	849.596	691.419	919.109	0.8138	105	356.418	3.394	
M.striatus	102	1095.593	1476.086	2841.189	1.3473	101	852.466	8.440	
M.scabriculum	29	222.735	113.032	160.188	0.5075	28	102.827	3.672	
WITHIN						453	8083.191	17.844	
Reg.Coeff.						4	237.508	59.377	
COMMON	458	14735.163	15043.324	23678.630	1.0209	457	8320.699	18.207	3.3276
Adj.Means						4	1825.814	456.454	25.0699
TOTAL	463	126183.674	120977.475	126132.591	0.9587	461	10146.513		
Comparison of slopes F=			59.377	(4, 457)	3.3276	P<0.01			
Comparison of elevation F=			456.454	(4, 461)	25.0699	P<0.01			

	df	t	Probability
M.rosenbergii X M.idella	219	0.90	
M.rosenbergii X M.equidens	220	1.28	
M.rosenbergii X M.striatus	216	1.95	
M.rosenbergii X M.scabriculum	143	1.34	
M.idella X M.equidens	209	0.62	
M.idella X M.striatus	205	3.05	P<0.005
M.idella X M.scabriculum	132	1.37	
M.equidens X M.striatus	206	4.82	P<0.001
M.equidens X M.scabriculum	133	2.19	P<0.05
M.striatus X M.scabriculum	129	4.20	P<0.001

Table 1.7.20 Comparison of regression coefficients of CARAPACE LENGTH X LENGTH OF SECOND CHELIPED in females of various Macrobrachium spp. and results of t-test

Species	df	ΣX^2	ΣXY	ΣY^2	RC	DEVIATIONS FROM REGRESSION df	SS {d y.x2	MSS	
M.rosenbergii	116	10847.915	22053.769	55611.077	2.0330	115	10775.847	93.703	
M.idella	105	1719.325	3913.175	20503.339	2.2760	104	11596.972	111.509	
M.equidens	106	849.596	1594.423	4740.875	1.8767	105	1748.647	16.654	
M.striatus	102	1095.593	3343.025	14077.945	3.0513	101	3877.244	38.389	
M.scabriculum	29	222.735	262.421	498.110	1.1782	28	188.930	6.748	
WITHIN						453	28187.641	62.224	
Reg.Coeff.						4	1321.782	330.446	
COMMON	458	14735.163	31166.813	95431.346	2.1151	457	29509.424	64.572	5.3105
Adj.Means						4	5523.608	1380.902	21.3854
TOTAL	463	126183.674	248073.899	522740.019	1.9660	461	35033.031		
Comparison of slopes F=			330.446 (4, 457)		5.3105	P<0.01			
Comparison of elevation F=			1380.902 (4, 461)		21.3854	P<0.01			

	df	t	Probability
M.rosenbergii X M.idella	219	0.93	
M.rosenbergii X M.equidens	220	0.58	
M.rosenbergii X M.striatus	216	3.90	P<0.001
M.rosenbergii X M.scabriculum	143	1.44	
M.idella X M.equidens	209	1.19	
M.idella X M.striatus	205	2.31	P<0.05
M.idella X M.scabriculum	132	1.63	
M.equidens X M.striatus	206	4.92	P<0.001
M.equidens X M.scabriculum	133	2.43	P<0.05
M.striatus X M.scabriculum	129	4.54	P<0.001

Table 1.8.1 D-square analysis between males and females of different Macrobrachium spp.

Species	df1	df2	D	F	Prob.
M.rosenbergii	209	15	2.207	16.92	P<0.01
M.idella	224	15	2.300	19.50	P<0.01
M.equidens	190	15	1.938	11.92	P<0.01
M.striatus	201	15	1.581	8.35	P<0.01
M.scabriculum	56	6	3.285	28.52	P<0.01

Table 1.8.2 D-square analysis between males of different Macrobrachium spp.

Species combination	df1	df2	D	F	Prob.
M.rosenbergii X M.idella	224	15	8.094	241.50	P<0.01
M.rosenbergii X M.equidens	190	15	7.251	166.10	P<0.01
M.rosenbergii X M.striatus	204	15	7.812	207.20	P<0.01
M.rosenbergii X M.scabriculum	132	6	6.412	192.09	P<0.01
M.rosenbergii X M.rude	107	6	9.309	181.81	P<0.01
M.idella X M.equidens	216	15	1.641	9.48	P<0.01
M.idella X M.striatus	230	15	2.984	33.89	P<0.01
M.idella X M.scabriculum	158	6	4.695	109.46	P<0.01
M.idella X M.rude	133	6	5.044	55.15	P<0.01
M.equidens X M.striatus	196	15	2.118	14.58	P<0.01
M.equidens X M.scabriculum	124	6	3.817	66.44	P<0.01
M.equidens X M.rude	99	6	5.652	66.14	P<0.01
M.striatus X M.scabriculum	138	6	3.202	48.69	P<0.01
M.striatus X M.rude	113	6	5.065	54.30	P<0.01
M.scabriculum X M.rude	41	6	2.145	7.58	P<0.01

Table 1.8.3 D-square analysis between females of different Macrobrachium spp.

Species combination	df1	df2	D	F	Prob.
M.rosenbergii X M.idella	209	15	8.472	249.20	P<0.01
M.rosenbergii X M.equidens	210	15	9.239	297.98	P<0.01
M.rosenbergii X M.striatus	206	15	9.350	298.75	P<0.01
M.rosenbergii X M.scabriculum	133	6	7.372	208.82	P<0.01
M.idella X M.equidens	199	15	2.836	26.66	P<0.01
M.idella X M.striatus	195	15	3.541	40.71	P<0.01
M.idella X M.scabriculum	122	6	2.757	28.52	P<0.01
M.equidens X M.striatus	196	15	2.085	14.19	P<0.01
M.equidens X M.scabriculum	123	6	3.330	41.70	P<0.01
M.striatus X M.scabriculum	119	6	3.162	37.24	P<0.01

Table 1.9.1 Correlation matrix showing correlation coefficients of various ratios of morphometric measurements in males of *Macrobrachium equidens*

	2i/TL	2m/TL	2c/TL	2p/TL	2chl/TL	2i/CL	2p/CL	2chl/CL	CL/2c	RL/2c	1chl/2c	2i/2c	3chl/2c	RL/2m	2i/2m
2i/TL	1.000														
2m/TL	0.798	1.000													
2c/TL	0.731	0.946	1.000												
2p/TL	0.755	0.958	0.945	1.000											
2chl/TL	0.809	0.981	0.979	0.983	1.000										
2i/CL	0.904	0.614	0.535	0.593	0.631	1.000									
2p/CL	0.731	0.895	0.880	0.958	0.930	0.689	1.000								
2chl/CL	0.794	0.921	0.915	0.943	0.949	0.749	0.982	1.000							
CL/2c	-0.668	-0.816	-0.900	-0.868	-0.882	-0.575	-0.870	-0.890	1.000						
RL/2c	-0.633	-0.810	-0.900	-0.848	-0.870	-0.495	-0.823	-0.849	0.968	1.000					
1chl/2c	-0.685	-0.852	-0.916	-0.864	-0.895	-0.510	-0.808	-0.840	0.926	0.941	1.000				
2i/2c	-0.619	-0.572	-0.735	-0.631	-0.628	0.609	-0.556	-0.546	0.725	0.761	0.702	1.000			
3chl/2c	-0.598	-0.768	-0.867	-0.828	-0.838	-0.473	-0.814	-0.828	0.942	0.944	0.921	0.756	1.000		
RL/2m	-0.718	-0.876	-0.814	-0.855	-0.862	-0.633	-0.857	-0.873	0.843	0.869	0.847	0.501	0.784	1.000	
2i/2m	0.503	-0.561	-0.572	-0.550	-0.520	0.408	-0.480	-0.442	0.492	0.534	0.521	0.826	0.507	0.526	1.000

Table 1.9.2 Correlation matrix showing correlation coefficients of various ratios of morphometric measurements in males of *Macrobrachium striatus*

	2i/TL	2m/TL	2c/TL	2p/TL	2chl/TL	2i/CL	2p/CL	2chl/CL	CL/2c	RL/2c	1chl/2c	2i/2c	3chl/2c	RL/2m	2i/2m
2i/TL	1.000														
2m/TL	0.683	1.000													
2c/TL	0.690	0.931	1.000												
2p/TL	0.663	0.909	0.947	1.000											
2chl/TL	0.754	0.951	0.981	0.982	1.000										
2i/CL	0.947	0.618	0.626	0.618	0.687	1.000									
2p/CL	0.635	0.873	0.913	0.971	0.946	0.646	1.000								
2chl/CL	0.705	0.915	0.948	0.950	0.963	0.724	0.979	1.000							
CL/2c	-0.658	-0.855	-0.920	-0.891	-0.914	-0.657	-0.905	-0.933	1.000						
RL/2c	-0.714	-0.864	-0.909	-0.890	-0.917	-0.680	-0.878	-0.907	0.967	1.000					
1chl/2c	-0.659	-0.791	-0.852	-0.845	-0.860	-0.626	-0.834	-0.849	0.929	0.933	1.000				
2i/2c	0.502	-0.571	-0.660	-0.598	-0.577	0.066	-0.594	-0.574	0.663	0.589	0.533	1.000			
3chl/2c	-0.650	-0.826	-0.896	-0.871	-0.891	-0.612	-0.858	-0.879	0.961	0.958	0.955	0.629	1.000		
RL/2m	-0.674	-0.907	-0.809	-0.811	-0.850	-0.654	-0.807	-0.849	0.831	0.898	0.781	0.456	0.812	1.000	
2i/2m	0.361	-0.404	-0.686	-0.571	-0.441	0.579	-0.386	-0.457	0.555	0.704	0.640	0.753	0.621	0.447	1.000

TL- Total length
CL- Carapace length
RL- Rostral length

2i- Ischium of 2nd cheliped
2m- Merus of 2nd cheliped
2c- Carpus of 2nd cheliped
2p- Propodus of 2nd cheliped

1CH- Length of 1st cheliped
2CH- Length of 2nd cheliped
3CH- Length of 3rd walking leg

Table 1.9.3 Correlation matrix showing correlation coefficients of various ratios of morphometric measurements in females of *Macrobrachium equidens*

	2m/TL	2c/TL	2chl/TL	2m/CL	2c/CL	2p/CL	2chl/CL	RL/2c	1chl/2c	3wll/2c	4wl/2c	RL/2m	1chl/2m	3wl/2m	4chl/2m
2m/TL	1.000														
2c/TL	0.615	1.000													
2chl/TL	0.774	0.937	1.000												
2m/CL	0.411	0.355	0.394	1.000											
2c/CL	0.676	0.747	0.643	0.764	1.000										
2p/CL	0.447	0.586	0.562	0.794	0.912	1.000									
2chl/CL	0.695	0.610	0.589	0.881	0.956	0.944	1.000								
RL/2c	-0.413	-0.688	-0.700	-0.666	-0.810	-0.824	-0.824	1.000							
1chl/2c	-0.410	-0.798	-0.730	-0.499	-0.643	-0.492	-0.536	0.594	1.000						
3wll/2c	-0.535	-0.875	-0.828	-0.685	-0.710	-0.614	-0.608	0.701	0.784	1.000					
4wl/2c	-0.515	-0.845	-0.792	-0.769	-0.676	-0.569	-0.575	0.729	0.807	0.886	1.000				
RL/2m	-0.475	-0.383	-0.446	-0.741	-0.542	-0.661	-0.665	0.837	0.824	0.638	0.400	1.000			
1chl/2m	-0.574	-0.429	-0.488	-0.709	-0.568	-0.889	-0.563	0.730	0.751	0.465	0.476	0.830	1.000		
3wl/2m	-0.728	-0.411	-0.522	-0.412	-0.626	-0.680	-0.786	0.536	0.734	0.650	0.468	0.492	0.577	1.000	
4chl/2m	-0.717	-0.452	-0.539	-0.595	-0.729	-0.564	-0.583	0.461	0.442	0.563	0.719	0.522	0.602	0.743	1.000

Table 1.9.4 Correlation matrix showing correlation coefficients of various ratios of morphometric measurements in females of *Macrobrachium striatus*

	2m/TL	2c/TL	2chl/TL	2m/CL	2c/CL	2p/CL	2chl/CL	RL/2c	1chl/2c	3wll/2c	4wl/2c	RL/2m	1chl/2m	3wl/2m	4chl/2m
2m/TL	1.000														
2c/TL	0.846	1.000													
2chl/TL	0.928	0.940	1.000												
2m/CL	0.896	0.750	0.818	1.000											
2c/CL	0.719	0.902	0.819	0.823	1.000										
2p/CL	0.733	0.776	0.841	0.830	0.856	1.000									
2chl/CL	0.796	0.832	0.874	0.915	0.933	0.947	1.000								
RL/2c	-0.628	-0.810	-0.742	-0.642	-0.826	-0.677	-0.758	1.000							
1chl/2c	-0.649	-0.828	-0.754	-0.633	-0.813	-0.681	-0.739	0.627	1.000						
3wll/2c	-0.745	-0.866	-0.805	-0.732	-0.848	-0.701	-0.788	0.788	0.856	1.000					
4wl/2c	-0.725	-0.842	-0.790	-0.728	-0.839	-0.698	-0.790	0.852	0.879	0.900	1.000				
RL/2m	-0.800	-0.740	-0.787	-0.820	-0.742	-0.712	-0.797	0.888	0.714	0.747	0.805	1.000			
1chl/2m	-0.829	-0.654	-0.746	-0.816	-0.612	-0.666	-0.715	0.579	0.779	0.721	0.739	0.772	1.000		
3wl/2m	-0.853	-0.680	-0.759	-0.845	-0.643	-0.658	-0.732	0.549	0.628	0.846	0.742	0.761	0.860	1.000	
4chl/2m	-0.832	-0.649	-0.741	-0.840	-0.628	-0.654	-0.731	0.597	0.642	0.740	0.836	0.810	0.880	0.899	1.000

TL- Total length
CL- Carapace length
RL- Rostral length

2i- Ischium of 2nd cheliped
2m- Merus of 2nd cheliped
2c- Carpus of 2nd cheliped
2p- Propodus of 2nd cheliped

1CH- Length of 1st cheliped
2CH- Length of 2nd cheliped
3CH- Length of 3rd walking leg

Table 1.10.1 D-square analysis using different ratios of morphometric measurements of Macrobrachium equidens and M.striatus

	df1	df2	D	F	Prob.
Males	196	15	57.94	10910	P<0.01
Females	196	15	8.832	254.5	P<0.01

Table 1.10.2 D-square analysis using different ratios in males and females of Macrobrachium equidens and M.striatus

	df1	df2	D	F	Prob.
M.equidens	191	15	162.5	83.87	P<0.01
M.striatus	201	15	54.97	10089	P<0.01

Chapter 2

Ecology and Distribution of *Macrobrachium* Spp.

Introduction

The Vembanad lake, extending between the lat. 9°28′ and 10°10′ N and long. 76°13′ and 76°31′ E is the largest estuarine system in the south west coast, of India, showed all the characteristics of a typical tropical positive estuary (Pritchard, 1967; Qasim, *et al.*, 1969; Madhuprathap, *et al.*, 1977 Lekshmanan, *et al.*, 1982). Alterations brought about in the ecology of this lake with a view to intensify paddy cultivation in Kuttanad coupled with the adverse effects from agriculture wastes and other human interventions to the aquatic ecosystem have imparted severe ecological imbalance (Balchand, 1983; Kurup *et al.*, 1992a). With the commissioning of salinity barrier at Thanneermukkom across Vembanad lake, the estuarine characteristics were more or less retained from Cochin to Thanneermukkom. On the contrary, upstream part has fully been transformed into a freshwater habitat (Kurup *et al.*, 1992a). Genus *Macrobrachium* is represented by 6 species (Jayachandran and Joseph, 1992) which are widely distributed in the Vembanad lake, of which 4 contribute to the fishery either subsistence or at commercial level. Pattern of distribution of *Macrobrachium* spp. in a water body where ecology has transformed due to man-made alterations, deserves special attention in the context of the dwindling nature of the fishery resources (Kurup *et al.*, 1992a). Studies on the spatial and temporal distribution pattern of *Macrobrachium* spp. are limited to some

species of commercial importance (Ibrahim, 1962; Raman, 1967; Rajyalakshmi, 1980; Jinadasa, 1985; Kurup *et al.*, 1992a; Prakash, 1994) and no attempt has hitherto made to delineate the pattern of distribution of freshwater prawns in estuaries. Therefore, an attempt is made to study the seasonal and spatial distribution patterns of *Macrobrachium* spp. in the Vembanad lake and also to understand the bearing of various physico-chemical parameters on the pattern of distribution.

Physico-chemical parameters of the Vembanad lake, especially around Cochin area was studied by Balakrishnan (1957), Ramamritham and Jayaraman (1963), George and Kartha (1963), Cherian (1967), Qasim and Gopinath (1969) and Sankaranarayanan and Qasim (1969). Josanto (1971) studied the bottom salinity characteristics of Vembanad lake with reference to the salt water penetration to the lake prior to the commissioning of the salinity barrier. Balakrishnan and Shynamma (1976), Leskshmanan *et al.* (1982) and KWBSP (1989) studied the physico-chemical parameters since the commissioning of the salinity barrier. Kurup and Samuel (1987) studied the fish distribution pattern in this lake with reference to the variations in physico-chemical characteristics.

Distribution of freshwater prawns of the Indian waters are limited to the studies of Henderson and Matthai (1910), Natraj (1942), Chopra and Tiwari (1947), Tiwari (1955b, 1961), Tiwari and Pillai (1973), Kurian (1954), John (1958), Jayachandran (1984, 1992), Jayachandran and Joseph (1986, 1989a), Jones (1967) and Raman *et al.* (1986). Natraj (1942) and Kurian (1954) reported the occurrence of *M. rosenbergii, M. idella, M. equidens* and *M. daynus* from the erstwhile Travancore. Jayachandran (1987) surveyed 23

different water bodies of south west coast of India and presented a detailed account on the distribution of 13 species belonging to the genus *Macrobrachium*. Investigations on the distribution and abundance of *M. rosenbergii* from Hooghly estuary (Rao, 1967), Vembanad lake (Raman, 1967; Kurup *et al* ., 1992a; Harikrishnan and Kurup, 1997b) and Bolgoda lake, Sri Lanka (Jinadasa, 1985) were carried out. Similar information regarding *M.malcomsonii* was reported by Ibrahim (1962), Rajyalekshmi (1961, 1980) and Rajyaleshmi and Ranadhir (1969).

Materials and Methods

Water quality parameters from 13 zones were observed by collecting samples on a monthly basis from March 1995 to February 1996 during the fishery survey cruises in M.B. King Fisher. Temperature was recorded to the nearest 0.1^{0}C with the help of a mercury thermometer and pH, using a portable pH pen. Salinity and dissolved oxygen were estimated using argentometric titration (Strickland and Parson, 1972) and azide- modification of Winkler method (Greenberg *et al.*, 1992) respectively. Rainfall data was procured from Mankombu Agricultural Station, situated in the Alleppey district, which is proximal to the upper reaches of the lake.

Data on distribution and abundance of various species of *Macrobrachium* collected from 29 stations representing 13 stations of the lake on a monthly basis from March 1995 to February 1996. Direct observations of the exploited catch were made during the fishery survey cruise from various fishing gears, besides conducting experimental fishing. Nature of occurrence of

different species was expressed following the scheme of classification adopted by Jayachandran (1987) such as present, common and abundant.

Indepth study on the numerical abundance of various species was made from a sample station viz. Kumbalam, situated in the down stream part of the lake (Fig. 1 station 4), which showed wide fluctuation in salinity and is also characterised with a combination of muddy, sandy and stony bottom. 10 bush traps (*Padal*) were immersed in water and the catches were observed on a weekly basis in fishing season while, fortnightly observations were made during lean period. Specimens were brought to the laboratory, segregated, enumerated and average number of individuals belonging to each species per day was worked out and presented. Cast net catches in the vicinity of this station was also observed as *M. rosenbergii* adults were rarely represented in *'Padal'* catches in the selected station. Numerical occurrence of various *Macrobrachium* spp. arrived at from the selected stations was correlated with different water quality parameters recorded following standard procedures (Snedecor and Cochran, 1967). Richness index (R2) was calculated by the formula $R2 = S/\sqrt{n}$, where S is the total number of species in the community and n is the number of individual observed (Ludwig and Reynolds, 1988). Shannon index was calculated by the formula $H' = -\sum (P_i \times \ln(P_i))$, where P_i is the portion of individuals belongs to i^{th} species (Ludwig and Reynolds, 1988). Evenness index (E1) was calculated from the Shannon index using the formula $E1 = e^{H'}/\ln(s)$ (Ludwig and Reynolds, 1988).

Results

Annual rainfall pattern showed a sharp increase from May to June 1995 and thenceforth decreased up to December. Lowest rain fall was recorded in the months of December to February (Fig. 2.1). Annual rainfall recorded was 2940 mm in 1995-'96 and monsoon accounted for major discharge of rainfall, registering 67.35% while post-monsoon registered only 14.10% and the pre-monsoon showers was relatively higher (18.54%) when compared to that of post-monsoon.

Monthly variation in the water temperature in 13 zones of the Vembanad lake are depicted in Fig. 2.2.1. A clear pattern in the variation of temperature could be seen in different zones with a major peak in April-May and a minor peak in September-October. Highest surface temperature of 32^0C was recorded in April in station 6, whereas lowest (24^0C) was in July in station 13. Bottom temperature was found to be lower than surface temperature and varied between 24.5^0C in June to 31.5^0C in March. In the months from June to August, commensurate with the monsoon showers, water temperature showed lower values. Fluctuations of temperatures were more pronounced in the down stream region when compared to that of upstream and riverine regions.

High fluctuations in the surface and bottom salinity of different zones of the lake could be seen in the present study. Salinity was found in a range of 20.0 to 28.6 ppt in the months of March and April respectively in the high saline zones (zone 1 and 2) of the lake and decreased to less than 2 ppt during the onset of monsoon (Fig. 2.2.2). Limited intrusion of salinity to the upstream area due to the operation of salinity barrier was discernible and the

highest salinity observed was 8 ppt in zone 7 just south of the salinity barrier. A reduction in higher values (Maximum <15 ppt) of salinity was also discernible in the southernmost parts of downstream area (zone 5 and 6) in contrast to 5 ppt salinity recorded in Kaipuzha which emptying just south of bund as a result of salinity intrusion through the barrier.

In the present study pH showed variations between 4.8 in zone 12 to 9.5 in zone 6 and 7. (Fig. 2.2.3). A slightly acidic pH was observed in upstream area in many of the months, on the contrary, lower stretches showed alkaline nature. A prominent fluctuation in the dissolved oxygen content in the range 2.2 to 9.5 ml/l could be observed in the present study (Fig 2.2.4).

M. rosenbergii has been recorded from all the stations of the lake with a definite peak of occurrence in monsoon and post-monsoon seasons. In the down stream region *M. rosenbergii* was abundant from August to December, however, it become sparse and sporadic during March to May (Table 2.1.1). Whereas in upstream area the presence of *M. rosenbergii* could be observed round the year with maximum abundance during March to December. In Kumarakom, Chithira and C-block, the presence of *M. rosenbergii* was noticed almost year round. In stations 25 to 27 in the Pampa river system *M. rosenbergii* was predominantly abundant during the months of April to December, whereas, it became rare during July to February in Kaipuzha. In Murinjapuzha (station 29) also regular occurrence of *M. rosenbergii* could be registered in all the months except in April.

Presence of *M. idella* was found only during June to December in lower and upper regions of the Vembanad lake (Table 2.1.2). The catches were

mainly noticed from various types of '*padal*' (Bush traps) and cast nets. In Pampa (Stations 25 to 27) this spices was found to be very rare, on the contrary, it was predominantly seen in cast net catches of Kaipuzha and Murinjapuzha (Station 28 and 29). *M. idella* constituted a good fishery in the upper reaches of the lake (Stations 19 to 23) during August to November whereas it was found abundant in lower stretch during July to November. At Kumbalam (Station 4) and adjacent stations an almost year round availability of *M.idella* could be discernible.

M. equidens showed regular occurrence in high numbers during October to May when the salinity was high (Table 2.1.3). In lower stretches (Stations 1 to 8) its regular availability could be discernible in the months from November to June whereas it was recorded only in trace numbers in the '*padal*' catches in other months. In the southern areas of the lower stretch of Vembanad lake (Stations 10 to 13), the occurrence of *M. equidens* was recorded during October-November to April.

The presence of *M. striatus* could be seen in stray numbers in the '*padal*' and cast net catches in the lower stretch of the Vembanad lake during June to April with a peak from August to January (Table 2.1.4). *M. striatus* was not commercially exploited from the Vembanad lake and it was found along with *M. idella* and *M. equidens*. *M. striatus* was found to be very rare in the upper stretches as well as in the Pampa river system, on the contrary, it was found represented in moderate numbers at Kaipuzha and Murinjapuzha (Stations 28 and 29) during June to November.

No commercial exploitation of *M.scabriculum* could be seen in the Vembanad lake as it was found only in stray numbers in '*Padal*' and cast net

from almost all regions of the lake (Table 2.1.5). In lower stretch of the Vembanad lake *M.scabriculum* was observed during June to January whereas, in the upper stretches and in Pampa river system an year round availability was observed. From Kaipuzha and Murinjapuzha the occurrence of *M.scabriculum* was recorded from April to September and August to January respectively.

In the present study, *M.rude* could only be collected from Kumbalam (Station 4) and sample composed of 15 male specimens. In all other stations studied, their absence was quite noteworthy.

Number of male and female specimens of different *Macrobrachium* spp. collected from Kumbalam (Station 4) is presented in Table. 2.2. Among them *M. idella* was the most dominant species having an year round availability, showing a peak during August to February. Females dominated in the catches in all the months except May. The occurrence of *M.rosenbergii* was noticed only during June to February in the cast net catches while juveniles appeared in stray numbers in the *'padal'* catches. Presence of *M. equidens* was recorded from September to June with a dominance of females in the catches except in January.

In Kumbalam, *M. striatus* was recorded from June to March and it showed a mutually repellent behaviour with that of *M. equidens*. The occurrence of *M.scabriculum* in sparse number was registered during June to January with a peak during October to December. *M.rude* was very rare and its presence was irregularly noticed from July to March. Highest number of 818 individuals belonging to all the six species of *Macrobrachium* could be recorded during October (Table. 2.3). During May to October the number of individuals showed a gradual increase, thereafter a decrease could be registered

up to May (Table 2.3; Fig. 2.2.2). During October to January all the six species of *Macrobrachium* were found in the catches except in the month of November.

Richness of *Macrobrachium* spp. is highest in the months of December and January as evident from the highest richness index arrived at (R2= 0.293 and 0.295 respectively). In April and May, only *M.idella* and *M.equidens* could be encountered in the exploited stock (Table 2.3). Shannon index showed highest value in December (0.847) and March (0.831) whereas, lowest was in June and July (0.258 and 0.291 respectively) (Table 2.3). Evenness index (E1) showed highest values during November (1.282) and December (1.302), showing high degree of evenness in the occurrence of all the 6 species.

The result of correlation analysis between various species and different physico-chemical parameters are presented in Table 2.4. Occurrence of all the species except *M. equidens* showed a negative correlation with salinity. However, *M. equidens* showed significant positive relationship with temperature. Interestingly, all the *Macrobrachium* spp. studied showed a positive correlation with pH and dissolved oxygen, however, the correlation was not found significant in all these cases.

Discussion

Pattern of fluctuation of water temperature can very well be correlated to the fluctuation noticed in the rainfall. Monthly fluctuation pattern of water temperature as well as the highest and lowest temperatures recorded during the study period fully agrees with earlier reports (Haridas *et al.*, 1973; Pillai *et al.*, 1975; Silas and Pillai, 1975; Lekshmanan *et al.*, 1982; Kurup and Samuel, 1987; KWBSP, 1989). It is pertinent to mention that the major share

(>60%) of the total annual rainfall is contributed during the monsoon months and a resultant reduction in water temperature could also be observed in the lake. Freshwater prawns are reported to be migrating to the estuarine regions of the lake for facilitating the successful development of the larvae (John, 1957; Raman, 1967; Ling, 1969a). The reproductive cycle and other biological cycles may be viewed as an integrated response of the individuals of a population to the environment, both in a functional and temporal sense (Sastry, 1983). As the salinity intrusion to the rivers seldom occurred ever since the commissioning of the salinity barrier, temperature may play a major role in the timely downward movements of individuals to a preferred area for breeding. Raman (1967) reported that mature bull males of *M. rosenbergii* probably occurred and preferred deep and cool area of river Pampa, confirming its preference to low temperature habitats.

Salinity appeared as the most fluctuating water quality parameter in the lake and the operation of the salinity barrier at Thanneermukkom plays a major role in the distribution of salinity in the Vembanad lake. Salinity in downstream area showed high fluctuation when compared to upstream area where the highest salinity recorded was only 8 ppt. The present salinity values recorded from the lake when compared against Josanto (1971) revealed that a total change in the pattern of salinity distribution in the lake has taken place since the commissioning of the barrier. An increase in salinity during the dry months when the freshwater discharges got reduced and a corresponding decrease in salinity during monsoon when freshwater pushes salt water down the lake were usually seen(Josanto, 1971). Pronounced variation could be observed in the surface and bottom salinity in stations 1 and 2, which may be

due to the formation of salinity tongue as a result of the intrusion of saline water through the bottom (Wellershaus, 1973). Josanto (1971) reported a salinity fluctuation between 23 and 31 ppt in March prior to the commissioning of the salinity barrier, whereas, in the present study the fluctuation was in a range of 12 to 28 ppt which is on a lower side. Similarly in the upstream area, bottom salinity fluctuated between 18 and 22 ppt prior to the commissioning of the salinity barrier (Josanto, 1971), on the contrary, variation in the range of 0 to 8 ppt could only be recorded during the present study and this is found higher when compared to Kurup and Samuel (1987) who recorded a salinity fluctuation of 0 to 3 ppt only in upstream area. An increasing trend observed in the highest salinity recorded from upstream area can be attributed to the changes in the operation schedule of salinity barrier (Kurup *et al.*, 1992a). A decrease in the highest salinity previously recorded from the southern parts of downstream area is also worth mentioning and this may be due to the commissioning of Idukki hydro-electric project and subsequent diversion of part of water to Muvattupuzha river whereby a perennial flow in Muvatttupuzha, is being maintained. The seasonal variations in salinity have a profound influence on the distribution of estuarine animals as salinity act as the master factor controlling the life of estuarine animals (Kinne, 1966).

Lowest values of pH were recorded in the zone 8 and 12 whereas, highest were from zone 6 and 7 and these observation fully agree with KWBSP (1989). Harikrishnan (1997) reported a high levels of hardness and alkalinity coincided with the higher pH in Punnamada area. A slightly acidic pH was observed in upstream area in many of the months, on the contrary, lower stretches showed an alkaline nature. This may be due to the lowered intrusion

of saline water which have a buffering action as well as minimised free flushing action of floods due to salinity barrier which imparts numerous environmental problems and also results in upsetting the ecological balance (Balchand, 1983). The wide fluctuation of pH (4.8 to 9.5) and dissolved oxygen could also be discernible in the present study, on the contrary, fluctuation was still narrower in earlier reports (Silas and Pillai, 1975; Kurup and Samuel, 1987; KWBSP, 1989). Fluctuation in the pH and dissolved oxygen in northern areas of upper stretch (Zone 7 to 9) may also be attributed to the high degree of bottom churning due to the dredging of clam shell deposits. Odum (1970) opined that most estuarine sediment contain high concentration of oxygen demanding materials and when they discharged to the water, a high oxygen demand is exerted. Windom (1976) pointed out a wide fluctuation in the oxygen demand and pH in the areas of dredging and also dredging will directly affect the animals by habitat disruption, inhibition and stimulation due to water quality changes and interference with migration.

More than 40 species coming under the genus *Macrobrachium* were identified from Indian waters and about 14 of the moderate sized prawns contribute to the commercial fishery and *M. rosenbergii* being the largest species (Jayachandran and Joseph, 1989a). In Vembanad lake *M. rosenbergii* and *M.idella* are commercially exploited with a peak fishing season during monsoon and post-monsoon (Raman, 1967; Jayachandran and Joseph, 1989a; Kurup, *et al.*, 1992b). *M.equidens* and *M.striatus* were also seen in considerable numbers in the cast net catches and bush trap catches (Pillai, 1990 a&b; Kurup *et al.*, 1992a). *M.scabriculum* often caught as stray catches and has no commercial value, while *M.rude* occurs only in very low numbers.

Jayachandran (1987) reported occurrence of six species belonging to the genera *Macrobrachium* from the Vembanad lake.

In lower stretches of the lake, a good fishery of *M. rosenbergii* was recorded in the monsoon and post-monsoon seasons (Harikrishnan and Kurup, 1997b) which were delineated as the breeding period of this species (Raman, 1967; Kurup *et al.*, 1992a.). Kurup *et al.* (1992a) observed a shift in the breeding ground of *M.rosenbergii* from Kumarakom (Zone 8 of present study) to Thevara-Perumbalam (Zone 2 and 4 of present study) and after breeding the adults may prone to fishing mortality or returned to freshwater habitat (Ling, 1969a; Raman, 1967; Kurup *et al.*, 1992a, Harikrishnan and Kurup, 1997b). This may be the reason for the limited occurrence of *M. rosenbergii* in the low saline areas in downstream region after pre-monsoon period. Rajyalakshmi (1980) observed a positive correlation between the magnitude of occurrence and the amount of rainfall. Rao (1967) reported good fishery of *M. rosenbergii* in freshwater and gradient zones of Hooghly and Matlah estuary during the spawning period and only stray catches were recorded from the marine zone which is well in agreement with the present observation. Present findings also showed similarity with the pattern of distribution of *M.malcomsonii* in Hooghly and Godavari river systems (Rajyalekshmi, 1980) and *M.choprai* from Ganga river system (Prakash, 1994). Jinadasa (1985) showed two peaks in the occurrence of *M. rosenbergii* in Bolgoda lake Sri Lanka commensurate with the two monsoonal rains which lowered salinity as well as temperature in the lake. Highest occurrence of *M. rosenbergii* in Kolleru lake was also reported in winter and monsoon period (Rao, 1992) and from September to January in Irrawadi river in Burma (Taw, 1982) and present findings showed a strong

agreement with these findings.. Kadir *et al.*(1982) noticed that the density of this species in Pulikat lake is depended up on the influx of water.

Due to the operation of salinity barrier the region south of Thanneermukkom become transformed to an almost freshwater habitat (Kurup *et al.*, 1992a) and this may be the reason for the regular availability of *M. rosenbergii* in the upper stretches of the lake. Highest salinity recorded from the upstream area was 8 ppt in the month of April and due to the lower salinity conditions prevailing in this part in most of the months, *M. rosenbergii* may prefer to inhabit this part of the lake (zones 7 to 9). The results of the present study also indicate the possibility of a resident stock of *M. rosenbergii* in these areas especially in Kumarakom (Zone 8) and Chithira (zone 9). Raman (1967) reported an year round availability of *M. rosenbergii* in the river Pampa (Pulinkizh and Ranni) where salinity seldom intrudes. Low salinity observed in the zone 8 and 9 due to the operation of salinity barrier might be reason for the presence of a resident stock as this species can tolerate a salinity even up to 18 ppt without much stress (Venugopalan and Thampi, 1992)

Distribution of *M. idella* was found to be more prominent in the lower stretches of the lake when compared to other species. The year round occurrence of *M. idella* in the stations 3 and 4 showed its higher tolerance to the salinity stress as these stations are characterised by marked fluctuation in salinity. It is worth mentioning about the stray occurrence of *M. idella* in the Pampa river system in contrast to the good fishery prevailed in the southern parts of the upstream region in the month of August to November. Occurrence of *M.idella* was noticed in Kaipuzha and Murinjapuzha in most of the months.

However, a specific pattern in the migration of *M.idella* could not be arrived at in the present study.

Distribution patterns of *M. equidens* and *M. striatus* were found to be almost similar to that of *M.idella.* These species were well restricted to lower stretches of the lake and also in Kaipuzha and Murinjapuzha region whereas, their occurrence were very sparse in upper stretches and Pampa river. Johnson (1966) categorised this type of prawns as essentially inhabitants of low saline brackish waters and only penetrate marginally into fully freshwater regions. Positive correlation observed in the relationship between the occurrence *M.equidens* and salinity (Table 2.4) fully support the suggestion of Johnson (1966). Pillai (1990a & b) differentiated *M.equidens* and *M.striatus* on the basis of phenotypic difference, variation in the larval morphology and on the basis of inability to interbreed. In the present study it could be seen that these two species showed a differential availability in the lower stretches of the Vembanad lake (Table 2.2). Besides, the occurrence of *M.equidens* showed a direct correlation with salinity while, *M. striatus* showed an inverse relationship and this can also be taken as an ecological tool for differentiation of these two species.

M.scabriculum showed a restricted distribution in the lower stretches of the lake whereas, in the upper stretches it was found in almost all the months. Johnson (1966) categorised this species as a inhabitant of freshwater regions often living far from the sea, but its larvae were found in saline waters. *M.rude* could be recorded only from Kumbalam in very few quantities whereas, in all other stations its total absence is noteworthy.

Individuals belonging to various species of *Macrobrachium* was found high in the months of July to November (Table. 2.3) and this is well in agreement with the report of Ibrahim (1962), Raman (1967), Rajyaleshmi (1980), Jinadasa (1985), Kurup *et al.* (1992a) and Prakash (1994) who have reported that maximum occurrence of prawn takes place in the monsoon and post monsoon periods. Evenness index was appeared to be maximum in April and May which may be due to the low species number and also due to the more or less even occurrence of *M. idella* and *M. equidens*.. Evenness index was found to be minimum in the months of June to August which may be due to the occurrence of only five species and among them *M. idella* showed an obvious dominance in the exploited stock.

Table 2.1.1. Pattern of distribution of Macrobrachium rosenbergii in Vembanad lake

No.	Zone	Stations	MAR 95	APR 95	MAY 95	JUN 95	JUL 95	AUG 95	SEP 95	OCT 95	NOV 95	DEC 95	JAN 96	FEB 96
1	1	Cochin	-	-	-	-	-	++	+	++	+	++	+	+
2	1	Thevara	-	-	-	-	-	++	++	+++	++	+	+	
3	2	Cheppanam	-	-	-	+	-	++		++	++	++	+	+
4	2	Kumbalam	-	-	-	+	+	+++	++	+++	+++	+	+	+
5	2	Arookutty	-	-	-	+	+	++	+	++	++	+	+	-
6	3	Kakkathuruthu	-	-		-	-	+	++	+++	++	+	+	
7	3	Olaippu		-	-	+	+	+++	++	++		+	+	
8	3	Chenganda	-	-	-		+	+++	+++	+++	++	+	+	-
9	4	Panavally		-	-	+	+	++	+	++	-	++	- -	
10	4	Perumbalam	-	-	-		+	++	++	+	+		+	-
11	4	Udayamperoor			-	-	+	++	++	++	++	+	+	-
12	5	Poochakkal	-	-		-	+	++	++	+	+	++	+	-
13	5	Anjuthuruth	-		+	++	++	++		++	++	+	- -	-
14	6	Pallipuram	-	-	-		+	+	+	++	++	++	+	-
15	6	Vaikom	-	-	-	+	+	++	++	++	++	+	+	-
16	6	T.V.Puram	-	-		+	++	+	+				+	-
17	6	Vechoor	-	-	-	+	+	++	++	+++	+++	++	- -	-
18	7	Thannermukkom				+	-	++	+	++	++	+	- -	-
19	8	Kumarakom	+	+	++	++	+++	+++	+++	++	+++	++	++	+
20	8	Muhamma	-		-		++	++			+	+	++	-
21	8	Aryad	-		+	++	+	++	+	++	++	++	+	+
22	9	Chithira	+	+	+	+++	+++	+++	+++	+++	++	++	++	+
23	9	C-Block	-	+	+	++	+++	+++	+++	+++	++	++	+	++
24	10	Punnnamada	+	+	-	+	++	++	+++	++	+	+		+
25	11	Nedumudi	+	+	++	+++	++	+++	+++	++	++	+++	-	-
26	11	Pallathuruthy	+			+++	+	+	+++	+	++	+++	-	+
27	11	Kavalam	-	-	-	+++			+++	+	++	+++		-
28	12	Kaipuzha	-	-	-		+	++	++	++	-	-	+	+
29	13	Murinjapuzha	+	-	+	++	+++	+++	++	++	++	++	++	++

+ = Present
++ = Common
+++ = Abundant
- = Absent
Blank = Data not available

Table 2.1.2 Pattern of distribution of Macrobrachium idella in Vembanad lake

		Stations	MAR 95	APR 95	MAY 95	JUN 95	JUL 95	AUG 95	SEP 95	OCT 95	NOV 95	DEC 95	JAN 96	FEB 96
1	1	Cochin				++		++	++	++	-	+		-
2	1	Thevara	-	+	+	++	++	++		++	+	+	+	-
3	2	Cheppanam		+	++	+	++	+	++	++	++	+	-	++
4	2	Kumbalam	++	+	+	+	++	+++	+++	+++	+++	+++	++	++
5	2	Arookutty	+		+	++	+++	++	+++	+++		++	+	-
6	3	Kakkathuruthu	-	+	-	-	+++	+	+++	+	++	+	++	+
7	3	Olaippu	-	-	+	-	+++	+	++	+++	++	+++	++	+
8	3	Chenganda		-		+	-	+++	+++	+++	+++	+++	+	+
9	4	Panavally	-		-	+	+	++	+++	++	++		++	-
10	4	Perumbalam	-	-		+++	+++	+++	+++	+++	+++	+++	+	-
11	4	Udayamperoor		-	-	+++	+++	+++	++	+++	++	+		+
12	5	Poochakkal	-	-	+	+		+++	+++	+++	+++	+	-	++
13	5	Anjuthuruth	-	-	-	+	+++	+	+++	+++	++	++	-	++
14	6	Pallipuram			-	+++	+++	-	++	+	+	-	-	-
15	6	Vaikom	-	-		+	++	+++	++	+	++	+		-
16	6	T.V.Puram	-	-	+	-		+	+++	++	+++	+	-	
17	6	Vechoor	-			-	++	+++	++	+++	++	++	-	+
18	7	Thannermukkom	-	-	-	-	+	+	+	++	+	++		
19	8	Kumarakom	-		-	-	-	++	+++	++	++	++	-	-
20	8	Muhamma		-		+++	++	+++	++	+++	+++	+++	++	-
21	8	Aryad	-	-	-	+	-	++	+++	+++	+	-	-	-
22	9	Chithira	-	-	-	+++	+++	++	+++	++	++		-	
23	9	C-Block	-			-	+	+	+	+++	+	-		-
24	10	Punnnamada		-	-		+	-	+	-	++			
25	11	Nedumudi				-	-	-	-	+	-		-	-
26	11	Pallathuruthy	-	-		-		+		-	-	-	+	-
27	11	Kavalam			-		-		-	-		-	-	-
28	12	Kaipuzha		-		+	+	++	++	+++	++	++	+	++
29	13	Murinjapuzha		+	+	+	++	+++	+++	++	+	++		-

\+ = Present
++ = Common
+++ = Abundant
\- = Absent
Blank = Data not available

Table 2.1.3 Pattern of distribution of Macrobrachium equidens in Vembanad lake

	Zone	Stations	MAR 95	APR 95	MAY 95	JUN 95	JUL 95	AUG 95	SEP 95	OCT 95	NOV 95	DEC 95	JAN 96	FEB 96
1	1	Cochin	-	-	-	-	+	+	-	+	++	-	+	+
2	1	Thevara	+	+	+	+	+	+	+	+	+		++	+
3	2	Cheppanam	+	+		-	+	+	+		+	+	++	++
4	2	Kumbalam	+	++	+	+	-	-	+	+	+	++	++	++
5	2	Arookutty	++	+	+	+						+	+	+
6	3	Kakkathuruthu	+	+	+		-	+	-	+	+	-	-	+
7	3	Olaippu	-	+	+	-	+		+		+	-	-	++
8	3	Chenganda	++		-	-	+	+	++	-	++	++	+	+
9	4	Panavally	+	+	++	+	+		+	++		++		++
10	4	Perumbalam	+	++	+	+	+	++	+		+	++	+	+
11	4	Udayamperoor		+	+	-	+	++	+	+	+	++	+	+
12	5	Poochakkal		+	-	+	-	-	-	+	+	+	+	
13	5	Anjuthuruth	+		-			-		+		+		+
14	6	Pallipuram				-	-	-	+	-				-
15	6	Vaikom	+	-	-	-			-	-	+	-	-	-
16	6	T.V.Puram	-		-	-	-	-	-	-	-	-	-	
17	6	Vechoor			-	-		-	-	+		-	+	
18	7	Thannermukkom		-	-	-			-	-	-	-		
19	8	Kumarakom				-	-	-	-			-	-	-
20	8	Muhamma	-					-	+	-	-	+	-	-
21	8	Aryad		-	-	-	-	-		+	-			
22	9	Chithira			-	-					-	-		+
23	9	C-Block	-			-	-	-	-	-		-	-	
24	10	Punnnamada			-	-	-	-	-	+	-	-		-
25	11	Nedumudi		-	-		-			-	-		-	-
26	11	Pallathuruthy	-		-	-	-		-				-	
27	11	Kavalam	+	+	-	+		++	+		++	+		+
28	12	Kaipuzha	++		+	+	++	+	+	+	+	+	+	+
29	13	Murinjapuzha	-	+	+	-	+	+		++	+	++	++	++

\+ = Present
++ = Common
+++ = Abundant
\- = Absent
Blank = Data not available

Table 2.1.4 Pattern of distribution of Macrobrachium striatus in Vembanad lake

	Zones	Stations	MAR 95	APR 95	MAY 95	JUN 95	JUL 95	AUG 95	SEP 95	OCT 95	NOV 95	DEC 95	JAN 96	FEB 96
1	1	Cochin		-					+	+	++	+		
2	1	Thevara	-			-	+		+	+	+			-
3	2	Cheppanam		-	-		-	+	++	+	+	+	+	+
4	2	Kumbalam	-	-	-	+	+	++	+	+	+	+	+	+
5	2	Arookutty				-	+	++	+	++	+		+	+
6	3	Kakkathuruthu	-	-	-	-	+	+	+	+	-	+	+	-
7	3	Olaippu		-			+	+	-	+	+	+	-	
8	3	Chenganda	-	+	-	-	+	+	+	-	+	+	-	+
9	4	Panavally		-	-	-	-	+	++	+	++		-	
10	4	Perumbalam	-	-		+	-	++	+	+	+	++	+	+
11	4	Udayamperoor	-	-			+	+	+	-	+	+	+	+
12	5	Poochakkal	-			++	+	++	+	+		-		-
13	5	Anjuthuruth	-	-		++		+	+	+	+	+	-	-
14	6	Pallipuram	-		-	+	+	+	+	++		+	-	
15	6	Vaikom						+		+	+		+	-
16	6	T.V.Puram		-	-		-	-		+		+		+
17	6	Vechoor			-	-		-	-	-		-	-	-
18	7	Thannermukkom		-	-			-		-	-		-	
19	8	Kumarakom						+		-	-	-		-
20	8	Muhamma	-				-	-	-		-		-	-
21	8	Aryad	-			+	-	-		-	-		-	
22	9	Chithira				+				+				
23	9	C-Block												
24	10	Punnnamada												
25	11	Nedumudi	-	-	-	-					-	-	-	-
26	11	Pallathuruthy				-	-	-				-		-
27	11	Kavalam	-	-			-		-		-		-	
28	12	Kaipuzha			-	+	+	+		+	+	+	+	+
29	13	Murinjapuzha	-		-		+	+	++	++	+	+	+	+

\+ = Present
++ = Common
+++ = Abundant
\- = Absent
Blank = Data not available

Table 2.1.5 Pattern of distribution of Macrobrachium scabriculum in Vembanad lake

	Zone	Stations	MAR 95	APR 95	MAY 95	JUN 95	JUL 95	AUG 95	SEP 95	OCT 95	NOV 95	DEC 95	JAN 96	FEB 96
1	1	Cochin	-	-	-	-	+	-	-	-	-	-	-	-
2	1	Thevara		-	-	-	-	+	+	+		-	-	
3	2	Cheppanam				+			++	-	-	-		
4	2	Kumbalam	-	-	-	+	+	++	+	++	++	++	+	-
5	2	Arookutty		-	-	-	+		+	-	++			
6	3	Kakkathuruthu	-		-	-	+	+	+	+		-	-	
7	3	Olaippu		-	-	-		+	+	+	+	-		-
8	3	Chenganda			-	+	+		-	-	-	-	-	-
9	4	Panavally		-	-	+		+	-	+	+		-	
10	4	Perumbalam	-		-	+	-	-		+	+	+		-
11	4	Udayamperoor		-	-	+	-	-	-	-	+	+	-	-
12	5	Poochakkal	-	-	-	-	+	+	+	+	-	-		-
13	5	Anjuthuruth			-	-	-		-	-	+	-	-	
14	6	Pallipuram	-	-			-	-	-	+	+	-		-
15	6	Vaikom	-	-	-	-		-	+		-	-		
16	6	T.V.Puram		-	-	+	+	+		+	-			-
17	6	Vechoor	-	-	-	-		+	+	+		+	-	
18	7	Thannermukkom	-	-	-		-	+	+	-	-	-	-	-
19	8	Kumarakom	-		-	-	+	-		+	-	-	-	
20	8	Muhamma			+	+		+	+			+	+	-
21	8	Aryad		+	++		+		+	++		+		+
22	9	Chithira	-		+	++		+		-	+	+	-	
23	9	C-Block		+	-	-	++		++	+	-		+	-
24	10	Punnnamada	+		+	+	+	+	++		+		+	+
25	11	Nedumudi		+	+	+		+	-	-	+		+	
26	11	Pallathuruthy	+	+	+	+	+	+	+		-	+	+	
27	11	Kavalam	+	+		+		+	-	-	+	+	+	
28	12	Kaipuzha		+	-	+	+	+	+	-	+			
29	13	Murinjapuzha				+	+	+	+	+		-	+	+

\+ = Present
++ = Common
+++ = Abundant
\- = Absent
Blank = Data not available

Table 2.2 Monthly occurrence of Macrobrachium spp. at Kumbalam

	M.rosen-bergii	*M.idella*	*M.equi-dens*	*M.Stria-tus*	*M.Scab-riculum*	*M.rude*
MALES						
MAR 95	0	47	24	1	0	1
APR	0	38	32	0	0	0
MAY	0	42	13	0	0	0
JUN	4	54	1	1	1	0
JUL	14	39	0	7	5	2
AUG	19	124	0	9	8	4
SEP	8	118	8	11	4	3
OCT	16	87	12	18	20	2
NOV	5	96	5	20	8	0
DEC 95	1	158	8	15	16	5
JAN 96	2	113	19	9	4	1
FEB	0	137	14	11	0	0
FEMALES						
MAR 95	0	89	38	11	0	0
APR	0	48	41	0	0	0
MAY	0	29	22	0	0	0
JUN	1	274	4	5	0	0
JUL	2	684	0	13	2	0
AUG	5	481	0	12	14	0
SEP	14	354	4	24	9	0
OCT	20	598	9	18	18	0
NOV	13	328	15	18	12	0
DEC 95	8	168	21	9	9	0
JAN 96	1	238	14	10	2	0
FEB	3	195	28	4	0	0

Table 2.3 Diversity indices caculated for Macrobrachium spp. at Kumbalam

Month	No. of species (S)	No. of Individuals (n)	Richness Index (R2)	Diversity Index (Shannon-Index)	Evenness Index (E1)
Mar 95	4	211	0.275	0.831	1.657
Apr	2	159	0.159	0.690	2.876
May	2	106	0.194	0.634	2.721
Jun	5	354	0.266	0.258	0.804
Jul	5	768	0.180	0.291	0.831
Aug	5	676	0.192	0.467	0.992
Sep	6	557	0.254	0.640	1.059
Oct	6	818	0.210	0.675	1.096
Nov	5	520	0.219	0.725	1.282
Dec 95	6	418	0.293	0.847	1.302
Jan 96	6	413	0.295	0.594	1.010
Feb	4	392	0.202	0.542	1.241

Table 2.4 Correlation coefficients with respect to occurrence of Macrobrachium spp.and different water quality parameters

Species	Salinity	Temp.	DO	pH
M.rosenbergii	-0.519	-0.123	0.283	0.175
M.idella	-0.685 *	-0.491	0.239	0.088
M.equidens	0.892 *	0.698 *	0.224	0.292
M.striatus	-0.286	-0.22	0.293	0.549
M.scabriculum	-0.149	0.076	0.409	0.469
M.rude	-0.228	-0.328	0.128	0.324

*Sigificant at 5% level (P<0.05)

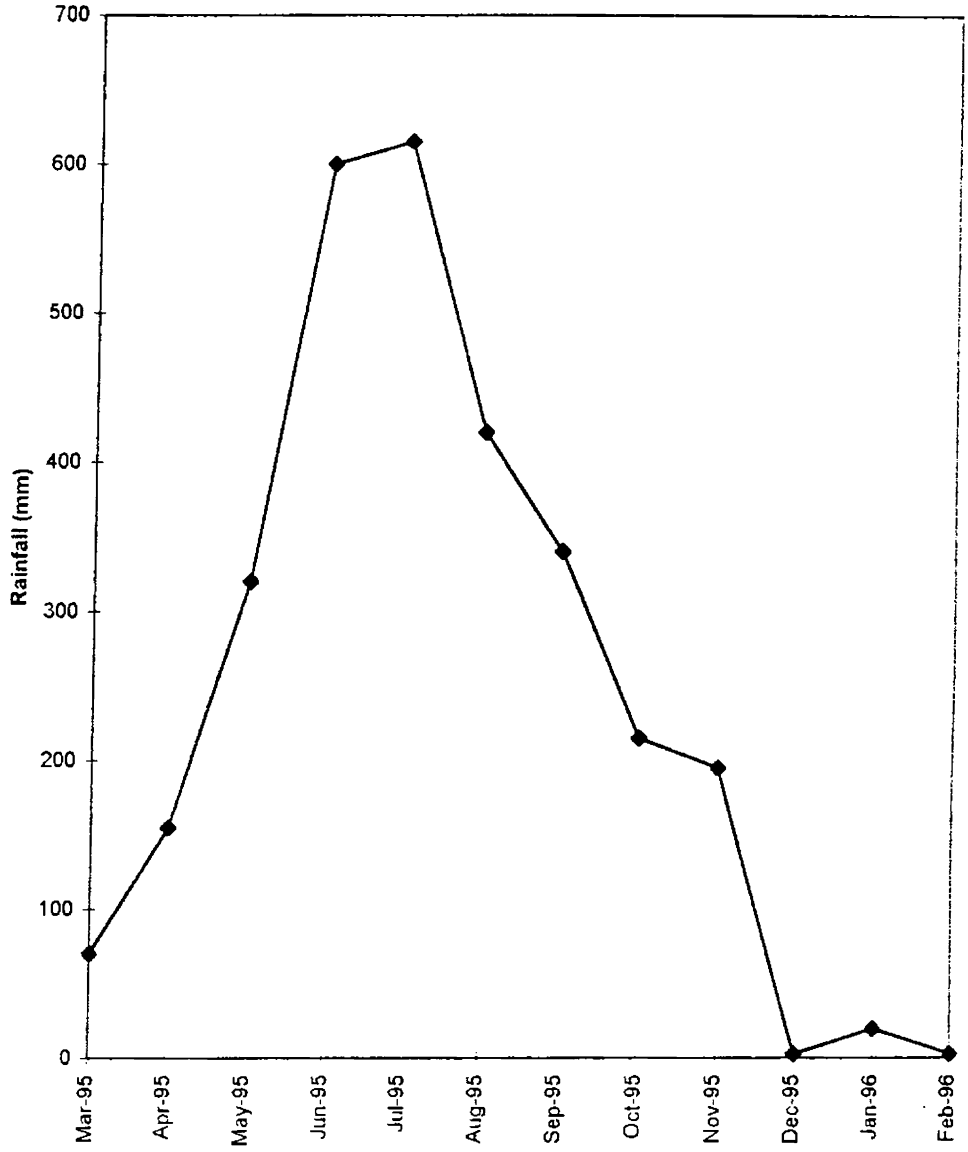


Fig. 2.1 Pattern of rainfall distribution during 1995-96 in the study area

Fig. 2.2.1

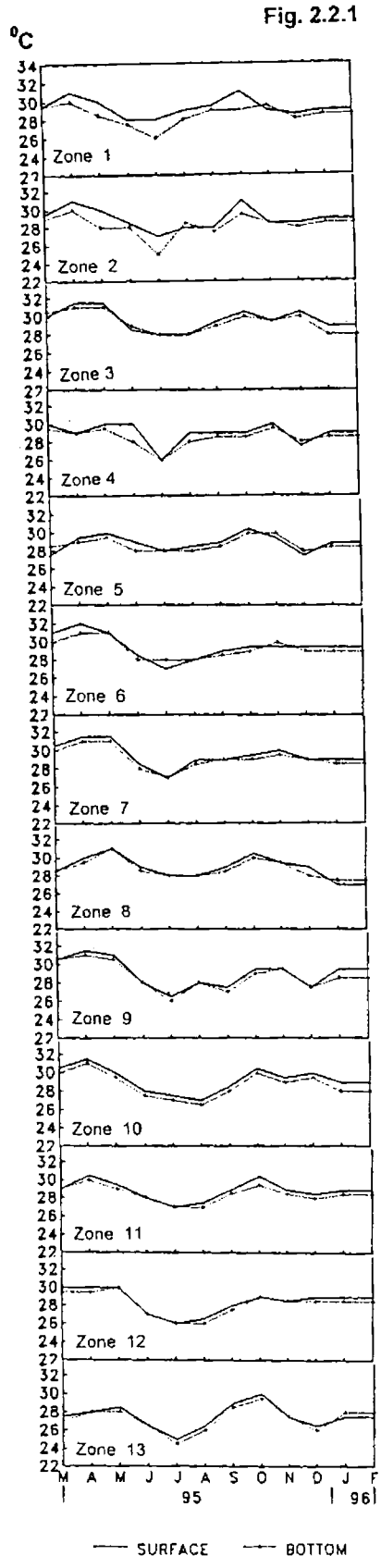


Fig. 2.2.2

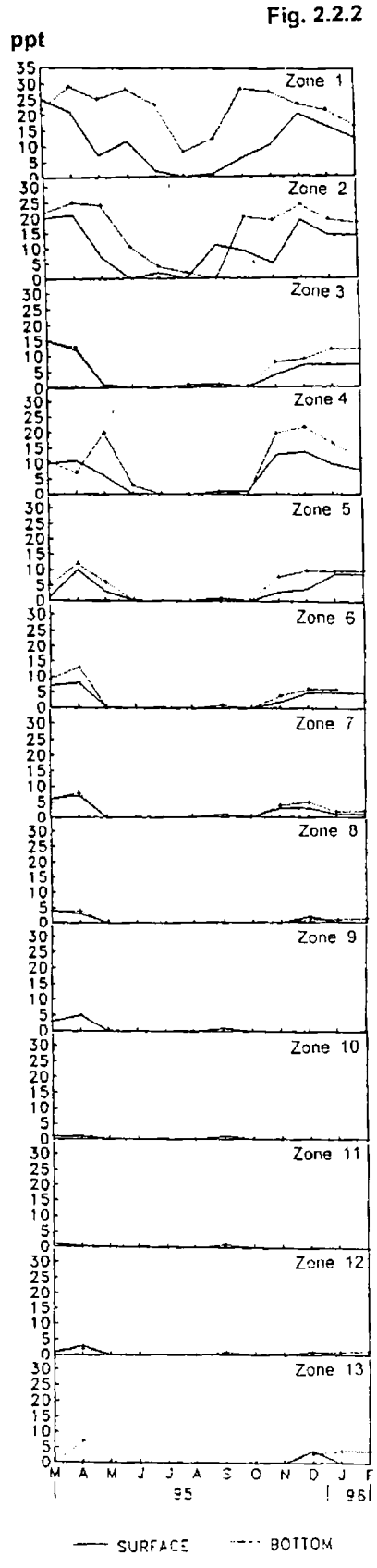


Fig. 2.2.1 Monthly variation in water temperature in different zones of Vembanad lake

Fig. 2.2.2 Monthly variation in salinity in different zones of Vembanad lake

Fig. 2.2.3

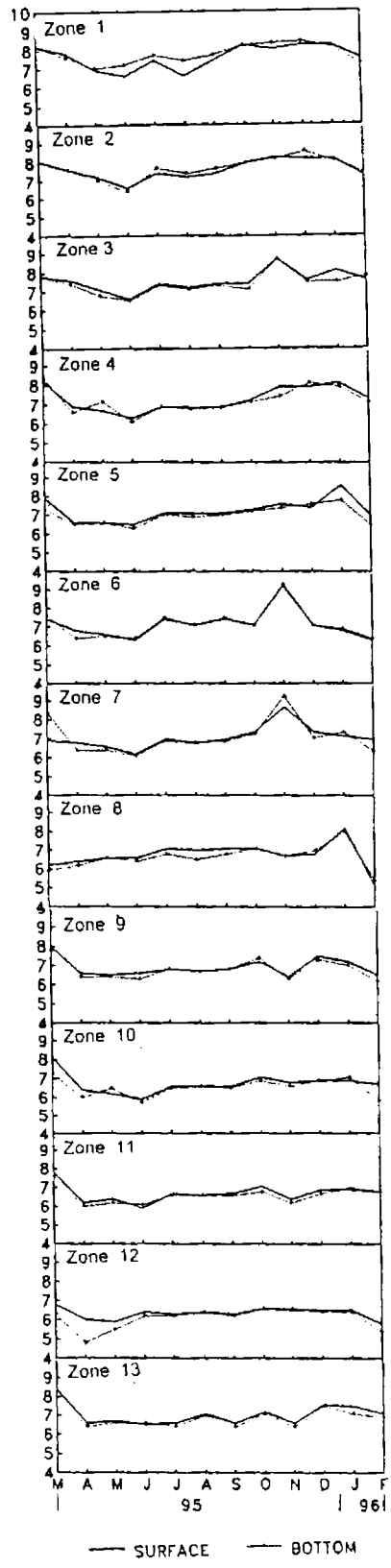


Fig. 2.2.4

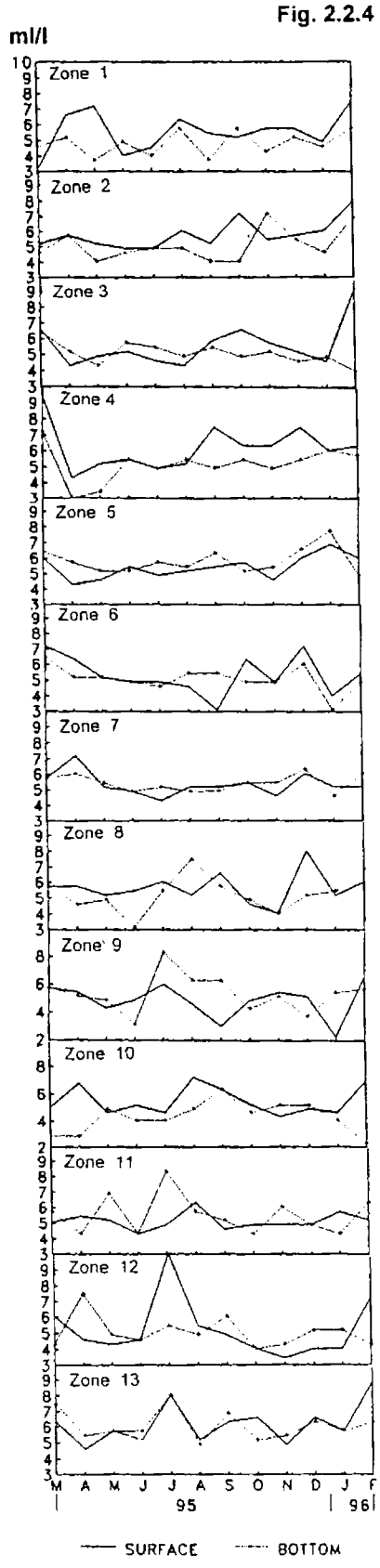


Fig. 2.2.3 Monthly variation in water pH in different zones of Vembanad lake

Fig. 2.2.4 Monthly variation in dissolved oxygen in different zones of Vembanad lake

Section 3

Bionomics of *Macrobrachium rosenbergii* (de Man) and *M.striatus* Pillai

Chapter 3 Food and Feeding Habits of *Macrobrachium rosenbergii* and *M.striatus*

Chapter 4 Reproductive Biology of *Macrobrachium rosenbergii* and *M.striatus*

Chapter 5 Breeding Migration and Sex Ratio of *Macrobrachium rosenbergii* and *M.striatus*

Chapter 6 Biochemical Characterisation of Male Morphotypes of *Macrobrachium rosenbergii*

Chapter 3

Food and feeding habits of *Macrobrachium rosenbergii* and *M.striatus*

Introduction

Studies on food and feeding of animals are of great importance in understanding growth, migration, reproduction, seasonal variation in body condition, etc. Basic knowledge on the food preference and feeding habits of a species are of primary necessity for ascertaining its suitability for aquaculture. Members of the genus *Macrobrachium* are adapted themselves to a wide range of feed of both animal and plant origin and are reported to be omnivorous in their feeding habits. In the absence of proper feeding these species often become cannibalistic and this acts as the most commercial disadvantage from the view point of farming (Wickins, 1972; Peebles, 1977). Feeding mechanism, food contents, behaviour and process of feeding are studied with respect to domesticated and natural populations of *M.rosenbergii* (John, 1957; Raman, 1967; Rao, 1967; Ling, 1969a; Lee *et al.*, 1980; Munshi *et al.*,1991). Feeding habits of *M.americanum* (Smitherman *et al.*, 1974), *M.idella* (Jayachandran and Joseph, 1989), *M.lanchesteri* (Johnson, 1968), *M.Choprai* (Prakash and Agarwal, 1989) and *M.equidens* (Murthy and Rajagopal, 1990) are also known. Deru (1990) and Kamaruddin *et al.* (1994) studied the morphological variation in gut and digestive enzyme activity during larval development of *M.rosenbergii.* Harpaz *et al.* (1987), Steiner and Harpaz (1987) and Harpaz and Steiner (1987) studied the feeding behaviour of *M.rosenbergii* in captivity.

Eventhough the food preference and feeding intensity of *M.rosenbergii* were studied from natural waters, however, the food preference and feeding habit of morphotypes of *M.rosenbergii* either from grow-out or natural populations are totally unknown. Moreover, *M.striatus* has been conferred with distinct taxonomic status quite recently and therefore, its food and feeding habits were also not yet unravelled. Therefore, the present study is aimed to delineate the seasonal, maturity stage wise, morphotype wise variation if any, in the food preference and intensity of feeding of *M.rosenbergii* and males and females of *M.striatus*.

Materials and methods

A preliminary qualitative study of the gut content revealed that *M.rosenbergii* and *M.striatus* are omnivores and detritus feeders and therefore, volumetric points method recommended by Swynnerton and Worthington (1940) is found to be suitable for the estimation of volume and percentage of different food items encountered from the gut of these species.

Random samples of 10-20 live specimens of each sex of both *M.rosenbergii* and *M.striatus* were collected on a monthly basis from the landing centres located at the upstream region of the lake and Kumbalam in the downstream region respectively and preserved in 5% formalin, after making some perforations on the carapace for better preservation of gut, gonads and hepatopancreas. A total of 676 specimens of *M.rosenbergii* and 463 specimens of *M.striatus* belonging to the size group of 72-297 mm and 38-96 mm respectively were used for gut content analysis during March 1994 to February 1996. The specimens so collected were segregated based on sex, stage of

maturity and morphotype wise. After weighing the specimens, stomach was dissected out and weighed. The food items in general showed a high degree of mutilation as it was in masticated condition. Therefore, the gut contents could only be identified up to higher taxonomic groups. Index of preponderance of each food item was worked out by applying the formula recommended by Natarajan and Jhingran (1962). Monthly variation in feeding intensity was studied by deriving gastrosomatic index, the percentage weight of stomach to the total body weight. Feeding intensity was also assessed by classifying the stomachs as 'nil', 'trace', '1/4 full', '1/2 full', '3/4 full' and 'full' depending on the state of distension and amount of food in the stomach. The contents of intestine was excluded from the analysis as these were found to be in partially or fully digested state.

Results

Following materials were identified from the stomach contents of both *M.rosenbergii* and *M.striatus*.

1. Detritus:- Contributed significantly to the diet and was identified by black, dark brown or dark green colour.
2. Mud:- Presence of mud was noticed in many guts and was difficult to separate from detritus.
3. Sand:- Sand was encountered occasionally and was separated by continuous washing.
4. Fish remains :-This category include fish bones and scales

5. Animal matter:- Includes semi-digested and mutilated flesh of different animals

6. Plant matter:- Represented by the broken roots, leaves and stem. Some times decayed barks of plants with attached algal mass could also be encountered. In *M.rosenbergii* a sizeable quantity of coconut kernel was also encountered from the stomach contents as the same is being used as the bait in different types of fishing operations. Coconut kernel was included under plant matter. A high percentage of algal mass was encountered from the stomach content of *M.striatus* which was found difficult to separate and identify as the same were in mutilated form along with detritus and plant materials. Therefore, these algal masses are included under plant matter.

7. Filamentous algae:- Their presence is noticed in *M.rosenbergii* in very small quantity. *Spirogyra* sp. contributed the major portion of this group. In *M.striatus* it was not well represented and if present it was in highly mutilated form, therefore included under plant matter.

8. Diatoms :- Benthic diatoms were found in fairly large numbers, however their relative volume was small in *M.rosenbergii*. They were predominantly represented by *Navicula, Nitzschia,* and *Coscinodiscus.* In *M.striatus* diatoms were very difficult to differentiate from plant matter and detritus therefore, included under plant matter.

9. Crustacean remains:- Comprises of mainly crustacean appendages, broken shells, etc. The regular occurrence of this item could be noticed in mutilated from majority of samples.

10. Miscellaneous matter:- Semi-digested and unidentifiable items were grouped under this category.

Preference to food items

Index of preponderance of various food items worked out in males and females of *M.rosenbergii* and *M.striatus* are presented in Table 3.1 and 3.2. Detritus showed a regular occurrence in moderate quantity in males and females of *M.rosenbergii* whereas, both sexes of *M.striatus* showed preference to plant matter. Semi-digested and unidentifiable food items occurred in considerable quantities in the gut contents of both males and females of *M.striatus.*

Monthly variation in the index of preponderance worked out for various food items encountered from the gut of both sexes of *M.rosenbergii* and *M.striatus* are presented in Table 3.3 and 3.4 respectively. In *M.rosenbergii,* detritus showed a regular occurrence during most of the months whereas in *M.striatus,* plant matter and unidentifiable materials predominated in the stomach contents.

In *M.rosenbergii,* maturing females showed higher preference towards plant matter while, orange berried prawns preferred crustacean remains. Besides, detritus and plant matter also showed a regular occurrence in all the maturity stages (Table 3.5).

In *M.striatus* miscellaneous matter, plant matter and detritus showed highest occurrences in immature, maturing and matured stages of males respectively (Table 3.6). Index of preponderance worked out in females of *M.striatus* are presented in Table 3.7.

Among various male morphotypes t-SOC, SBC and OBC showed strong preference towards detritus whereas, SOC showed preference towards

crustacean appendages (Table 3.8). The food of SM and WBC consisted of higher percentage of plant matter, while that of WOC consumed almost equal proportions of detritus, sand, animal matter, plant matter and miscellaneous items. Gut contents of the female morphotypes invariably comprised of plant matter, detritus and sand (Table 3.9).

Gastrosomatic index

Variation in the gastrosomatic index recorded from males and females of *M.rosenbergii* during March 1994 to February 1996 are depicted in Fig. 3.1 and 3.2. In male *M.rosenbergii,* a prominent peak of gastrosomatic index was observed in June 1994 (5.679) and May 1995 (3.893) and thereafter it showed a decreasing trend up to February in both the years studied. Whereas in females, gastrosomatic index showed higher values during June 1994 (3.745) and May 1995 (5.023) indicating its higher feeding intensity.

In males of *M.striatus,* gastrosomatic index was relatively high during July 1994 (3.928) and August 1995 (3.646), thereafter in both the years of study, a gradual decline in gastrosomatic index was quite discernible in December (Fig. 3.3). In contrast, a specific pattern in seasonal variation of gastrosomatic index could not be delineated in females of *M.striatus*(Fig 3.4).

A distinct variation in feeding intensity could be observed in *M.rosenbergii* commensurate with the ovarian maturation process (Fig. 3.5). Feeding intensity was high in immature females as evidenced by higher gastrosomatic index, whereas, it was lowest in matured females.

Gastrosomatic indices estimated in different maturity stages of *M.striatus* are depicted in Fig. 3.6 and 3.7. Among various maturity stages of *M.striatus,* highest gastrosomatic index was registered in matured males and immature females while, lowest was in maturing males and matured females. In general, variation in gastrosomatic index in different maturity stages of female of *M.striatus* showed almost similar pattern of female *M.rosenbergii.*

Gastrosomatic indices of various male and female morphotypes are presented in Fig. 3.8 and 3.9 and it appears to be higher in SOC and WBC which would manifest their voracious feeding habit. A decreasing trend from WOF to SBF could be observed coinciding with the transformation pathway of female morphotypes of *M.rosenbergii* (Fig. 3.9).

Stomach conditions

Percentage occurrence of various stomach conditions in males and females of *M.rosenbergii* and *M.striatus* during March 1994 to February 1996 is presented in the Fig. 3.10 to 3.13. In *M.rosenbergii,* females showed a higher percentage of 'full' stomachs during the initial months of the breeding period (August-September). On the contrary, an increase in the percentage of empty stomach could be discernible towards the end of breeding season (December-January).

In *M.rosenbergii,* a decrease in the percentage of full stomach was observed commensurate with the progression of female maturity stages (Fig. 3.14). In yellow berried females 50% of the stomach observed were in 'full' conditions which shows its voracious feeding habit. Thereafter, a gradual

decrease in 'full' stomach was noticed in conjunction with the re-maturation of the gonad.

Variation in the stomach conditions during the changing maturation phases of males and females of *M.striatus* are depicted in Fig. 3.15 and 3.16. Percentage occurrence of 'full' stomach in male *M.striatus* showed an increasing trend from 4.5% in immature to 18% in matured animals. Whereas, empty stomach showed a more or less uniform occurrence (10%) irrespective of the maturity stages in males.

Percentage occurrence of various stomach conditions in male and female morphotypes of *M.rosenbergii* are presented in Fig. 3.17 and 3.18. In SOC 'full' and '3/4 full' stomach could be seen in more than 60% of the individuals which would manifest its voracious feeding habits. Higher percentage of empty stomachs were observed in SM, t-SOC and OBC. Among various female morphotypes, an increase in the percentage of 'full' stomachs could be discernible coinciding with developmental pathway from SOF onwards. Interestingly, the occurrence of empty stomachs also showed an increasing trend from SOF to SBF.

Discussion

Variety of organisms encountered from the gut revealed that both *M.rosenbergii* and *M.striatus* are bottom feeders. Diets of these species were found to be almost similar however, *M.rosenbergii* showed preference towards detritus, in contrast, *M.striatus* relished plant matter. Gut contents of both the species consisted of detritus, small worms, small arthropods and fish remains which represents different trophic levels. Natarajan *et al.* (1979) reported the dominance of crustacean remains in both juvenile and adult prawns.

Qualitative estimation of gut contents of *M.rosenbergii* fully agrees with Raman (1967), Rao (1967), Ling (1969a) and Costa and Wanninayake (1986) who have reported that aquatic worms, insects, insect larvae, small molluscs, crustaceans, fish remains, materials of plant origin, algae and detritus are the items of food often encountered. Panikkar and Menon (1955) observed mud, sand and detritus in the gut contents of prawns. Ibrahim (1962) reported that major portion of the food of *M.malcomsonii* was constituted by detritus, sand and mud while, Jayachandran and Joseph (1989b) and Kadir *et al.* (1982) observed a significant quantity of detritus and crustacean remains in the stomach of *M.idella* and *M.rude.*

In the gut content of *M.striatus,* fairly good quantity of decaying bark of twigs used for making 'padal' with algae on them were observed. It may, therefore, be inferred that *M.striatus* preferred food which is abundant in their dwelling habitat. This observation agrees with the report of Jayachandran and Joseph (1989b) that abundance of detritus and insect remains in the gut of *M.idella* corresponds to the increased availability of these food items in the habitat. John (1957) also reported that *M.rosenbergii* shows a change in food preference with the environmental changes. *M.lanchestri* prefers to algae (Johnson, 1968) while, Murthy and Rajagopal (1990) observed that in smaller size groups of *M.equidens,* diatom showed a predominance, in contrast, diatoms were negligible or absent in adults. In the present study a higher occurrence of diatoms was observed in the gut having a considerable amount of detritus. This may be due to the possible ingestion of diatoms along with detritus. Similar possibility was reported in *M.idella* (Jayachandran and Joseph, 1989b).

Presence of fish scales by accidental entry along with detritus was observed in the gut content of *M.rosenbergii* (Raman, 1967) and *M.equidens* (Murthy and Rajagopal, 1990). Whereas, in the present study a considerable quantity of fish bones, fish scales and animal tissue were encountered in the gut content of *M.rosenbergii* pointing towards its predatory habit. Munshi *et al.*(1991) reported that *M.rosenbergii* is a filter feeder predator. Lee *et al.* (1980) after studying the digestive enzymes of *M.rosenbergii* suggested that it is carnivorous. Rao (1965) reported that *M.rosenbergii* will eat their exuvia after moulting and similar observations were made by Natraj (1947) in *M.idella.* Murthy and Rajagopal (1990) reported that crustacean appendages formed the most important food item of *M.equidens* other than decayed organic matter, sand and mud.

The variation in food preference of different maturity stages was not perceptible. SOC, OBC and SBF were found to be more carnivorous in their feeding habits as evidenced by the occurrence of relatively high percentage of animal matter in their gut contents. The gut content of SOC showed a higher percentage of crustacean body parts and animal matter regularly and therefore, the faster growth rate shown by this morphotype (Sagi and Ra'anan, 1988; Kurup *et al.*, 1997) can be explained on the basis of ingestion of high protein food and their voracious feeding habits. The fast growing nature of SOC can further be explained by its higher gastrosomatic index among various male morphotypes of *M.rosenbergii*, which also manifests its voracious feeding habit. Carnivorous feeding habits of large size group of *M.idella* was reported by Jayachandran and Joseph (1989b) whereas, detritus, sand and crustacean remains constituted major portion of gut content of *M.equidens* (Kadir *et al.*,

1982). In *M.rosenbergii* and *M.striatus* a perceptible variation in food preference could not be brought out with respect to different maturity stages.

The percentage of empty stomachs showed an increase in both *M.rosenbergii* and *M.striatus* towards the end of breeding season and this is very well comparable with Ibrahim (1962) that a reduction in feeding in matured females of *M.malcomsonii* was noticed due to the enlargement of gonads and after the oviposition females become voracious feeder as evidenced by the occurrence of gorged stomachs. Variation in feeding intensity of *M.rosenbergii* can further be confirmed by noticing a lower gastrosomatic index in matured females against higher gastrosomatic index seen in yellow berried females. Percentage of empty stomachs were more in females and this may be due to the reduced feeding as a result of enlargement of gonads which occupy major portion of the cephalothorax. Similar pattern of variation in gastrosomatic index could also be noticed in different female maturity stages of *M.striatus*. Murthy *et al.* (1997) reported a decline in feeding intensity in females of *M.equidens* with the advancement of maturity and also during moulting.

Table 3.1 Index of preponderance of various food items in *Macrobrachium rosenbergii*

		MALES	FEMALES
	Number of samples	356	320
1	Detritus	24.07	27.52
2	Sand	12.85	14.66
3	Crustacean remains	10.85	10.23
4	Fish remains	4.43	5.40
5	Animal tissue	8.13	4.21
6	Mud	6.25	3.05
7	Plant matter	19.22	23.77
8	Filamentous algae	0.19	0.25
9	Diatoms	0.22	0.07
10	Miscellaneous matter	13.78	10.83

Table 3.2 Index of preponderance of various food items in *Macrobrachium striatus*

		MALES	FEMALES
	Number of samples	398	476
1	Detritus	22.95	16.80
2	Sand	2.14	4.52
3	Crustacean remains	12.50	8.70
4	Fish remains	4.25	2.84
5	Animal tissue	7.38	13.84
6	Mud	4.73	6.99
7	Plant matter	25.48	23.47
8	Miscellaneous matter	20.57	22.84

Table 3.3 Index of preponderance of various food items in males and females of Macrobrachium rosenbergii during March 1994 to February 1996

	Food Items	Mar 1994	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec 1994	Jan 1995	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec 1995	Jan 1996	Feb 1996
Males	Number of samples	18	18	10	15	23	9	10	8	5	5	21	31	19	17	16	18	12	15	11	8	9	22	18	22
	1 Detritus	32 50	28 90	34 80	26 40	23 80	31 50	28 50	22 80	25 30	12 80	21 90	32 80	41 80	32 20	29 50	22 80	24 10	25 80	21 26	4 88	23 56	28 58	29 58	25 88
	2 Sand	5 93	8 54	3 58	8 22	12 56	15 28	3 20	12 47	13 56	12 45	6 24	5 55	18 24	15 46	6 54	12 56	2 07	12 56	6 25	4 25	12 68	1 83	12 45	2 46
	3 Crustacean remains	12 41	2 59	4 86	5 85	6 32	2 54	8 77	2 68	6 59	4 59	8 56	1 66	8 25	4 85	3 68	3 58	4 86	0 48	20 00	6 89	3 58	9 21	10 80	12 57
	4 Fish remains	2 88	9 82	8 00	6 15	9 84	6 85	2 48	18 24	12 56	4 98	13 33	16 58	2 23	19 14	22 46	14 23	9 68	0 58	12 68	22 58	4 15	3 54	12 56	12 89
	5 Animal tissue	8 83	5 93	12 54	9 84	2 86	3 22	8 26	4 12	3 58	22 65	0 00	2 58	2 55	8 24	6 41	4 56	5 89	8 25	2 68	29 58	6 85	6 25	1 45	6 25
	6 Mud	6 99	14 56	4 69	0 95	4 58	1 65	12 99	2 24	12 09	12 45	0 89	2 52	0 64	4 76	6 02	12 33	14 89	0 68	5 61	0 94	12 45	5 88	1 45	1 76
	7 Plant matter	15 48	15 68	18 45	22 58	18 85	18 00	14 25	13 56	8 67	18 69	32 68	21 48	18 46	11 48	18 59	18 15	13 85	18 46	11 89	14 36	15 86	18 00	12 14	21 56
	8 Filamentous algae	0 49	0 25	0 25	0 23	0 14	0 14	0 12	0 00	0 00	0 13	0 25	0 00	0 12	0 12	0 14	0 08	0 00	0 21	0 11	0 08	0 07	0 22	0 40	0 10
	9 Diatoms	0 24	0 17	0 00	0 00	0 40	0 20	0 14	0 23	0 11	0 80	0 00	0 10	0 18	0 09	0 10	0 00	0 01	0 40	0 80	0 80	0 40	0 10	0 40	0 20
	10 Miscellaneous matter	16.25	13 56	12 85	19 68	20 55	19 55	21 34	25 64	17.56	12 56	18 45	16 85	7 54	3 58	8 56	11 91	24 85	32 58	18 94	15 88	20 40	26 58	18 79	16 45
Females	Number of samples				15	15	14	27	24	8	17	6				16	18	13	24	20	17	29	28	30	
	1 Detritus				32 80	27 10	21 54	21 94	23 92	24 58	29 58	21 54				33 60	12 56	14 95	29 86	28 58	37 58	9 65	15 18	23 42	
	2 Sand				9 85	14 22	4 88	6 48	10 42	10 88	18 28	7 66				5 24	5 24	13 04	6 58	6 38	0 24	8 25	14 58	4 22	
	3 Crustacean remains				8 53	12 30	14 56	15 88	19 26	7 46	2 68	14 58				11 47	14 11	18 26	12 88	8 65	4 89	11 35	7 22	8 54	
	4 Fish remains				2 47	14 75	8 52	9 58	5 24	6 15	8 45	8 00				4 88	8 22	0 26	2 45	0 58	0 00	9 88	2 56	8 58	
	5 Animal tissue				4 56	8 58	5 64	4 84	19 56	4 58	8 24	7 58				6 58	8 48	2 26	4 67	12 58	14 44	18 84	2 58	4 98	
	6 Mud				0 00	0 00	14 28	4 98	8 58	8 58	8 28	4 25				3 25	8 58	14 22	8 45	5 30	0 00	5 54	12 68	14 62	
	7 Plant matter				18 18	10 00	10 40	22 58	0 36	25 09	10 73	24 99				20 04	32 06	15 48	18 55	21 48	20 00	22 43	32 25	22 16	
	8 Filamentous algae				0 21	0 08	0 00	0 00	0 09	0 22	0 00	0 16				0 24	0 16	0 00	0 00	0 34	0 41	0 00	0 24	0 12	
	9 Diatoms				0 00	0 21	0 11	0 00	0 00	0 21	0 26	0 11				0 14	0 00	0 22	0 14	0 19	0 00	0 20	0 18	0 14	
	10 Miscellaneous matter				23 80	12 80	20 27	14 58	12 47	14 25	15 68	11 25				14 58	14 57	21 33	18 82	15 98	22 44	14 28	12 56	15 24	

Table 3.4 Index of preponderance of various food items in males and females of Macrobrachium striatus during March 1994 to February 1996

	Food Items	Mar 1994	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec 1994	Jan 1995	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec 1995	Jan 1996	Feb 1996
Males	Number of samples	24				18	26	17	21	24	19	18	22	23			18	24	24	26	19	24	22	12	17
	1 Detritus	13 20				16 60	15 24	13 58	19 30	18 58	26 99	29 33	31 58	24 20			12 80	24 91	21 55	14 67	22 50	13 86	15 22	22 66	14 78
	2 Sand	14 56				6 52	2 46	0 89	3 50	2 64	1 60	3 62	3 40	0 89			0 46	4 50	2 50	0 46	6 50	0 86	7 30	3 66	2 60
	3 Crustacean remains	5 00				11 30	4 58	8 24	7 58	1 21	9 70	8 52	3 41	0 75			12 56	14 28	18 45	2 84	3 46	18 45	6 98	11 65	21 39
	4 Fish remains	4 00				8 24	3 41	2 40	3 50	10 50	1 40	0 86	2 30	1 80			3 59	4 10	6 00	0 00	3 58	6 10	1 80	3 39	0 80
	5 Animal tissue	17 69				6 54	8 36	9 40	10 56	12 50	5 33	4 38	12 54	8 80			12 34	0 68	0 34	2 40	6 90	8 00	9 20	8 80	0 87
	6 Mud	7 28				5 24	8 45	6 85	0 86	2 94	3 56	0 80	8 46	8 27			3 47	3 56	0 86	9 46	1 86	4 90	8 30	5 34	3 40
	7 Plant matter	14 69				32 47	29 56	34 15	28 84	32 15	26 84	35 07	15 18	26 82			31 40	25 01	26 40	43 55	26 86	17 86	24 03	31 48	32 56
	8 Miscellaneous matter	23 38				11 09	27 94	24 51	25 88	18 50	24 58	19 22	23 15	32 47			23 58	22 98	23 90	26 62	26 54	29 95	29 17	14 80	23 58
Females	Number of samples	22	15		18	23	32	26	18	34	22	48	24	12			16	13	24	25	21	19	22	24	18
	1 Detritus	18 56	24 86		19 54	18 84	22 60	23 58	16 56	8 47	26 52	19 84	23 58	25 47			26 54	18 24	6 45	24 51	18 20	12 66	14 99	23 40	9 74
	2 Sand	1 56	3 58		2 46	0 88	2 40	1 30	4 59	0 00	4 26	2 11	0 84	4 58			3 46	0 48	0 80	3 46	1 46	0 94	0 88	3 20	0 80
	3 Crustacean remains	8 52	3 54		0 51	2 45	18 46	8 47	3 22	8 41	2 47	3 58	9 84	8 76			14 78	15 40	12 56	5 48	0 00	7 99	18 54	4 71	5 88
	4 Fish remains	3 54	8 47		0 58	4 15	4 17	0 80	0 80	1 40	0 20	3 40	0 80	0 60			1 50	0 60	1 90	2 40	0 90	0 40	2 40	3 60	2 40
	5 Animal tissue	9 65	0 86		4 50	8 64	6 33	8 67	6 88	14 38	18 34	15 69	0 00	18 24			5 47	14 25	15 43	8 91	3 55	6 78	9 84	10 58	8 99
	6 Mud	2 80	8 99		8 48	8 99	8 92	0 40	2 68	0 80	3 91	2 68	0 80	0 60			4 33	2 80	0 90	0 80	0 50	3 58	3 71	2 44	2 37
	7 Plant matter	34 86	25 84		36 86	42 17	26 85	29 88	36 52	43 82	19 54	36 54	36 45	19 58			32 66	36 50	45 28	23 71	48 73	28 40	25 80	18 60	48 24
	8 Miscellaneous matter	20 51	27 86		29 10	17 90	10 27	28 90	28 93	24 72	24 78	18 18	27 91	24 17			11 28	13 73	16 88	30 93	28 66	38 25	25 84	33 17	23 58

Table 3.5 Index of preponderance of various food items in different maturity stages of female Macrobrachium rosenbergii

	Immature	Maturing	Matured	Yellow Berry	Orange Berry	Grey Berry	black Berry	Spent
Number of samples	50	103	10	8	29	49	27	44
1 Detritus	32.06	22.67	28.09	20.79	27.85	23.37	33.46	38.04
2 Sand	15.69	15.43	24.58	15.42	7.27	17.21	8.95	12.42
3 Crustacean remains	5.55	7.32	7.17	22.99	19.80	13.83	13.24	11.82
4 Fish remains	5.41	4.30	14.04	7.18	8.38	4.32	2.74	1.25
5 Animal tissue	1.68	4.11	6.32	16.09	7.39	2.66	3.97	6.26
6 Mud	4.94	1.62	0.42	1.92	3.30	6.31	1.76	1.27
7 Plant matter	25.81	32.69	16.02	12.64	12.53	19.12	23.92	16.24
8 Filamentous algae	0.08	0.34	0.00	0.29	0.00	0.70	0.37	0.08
9 Diatoms	0.08	0.11	0.00	0.00	0.00	0.10	0.07	0.08
10 Miscellaneous matter	8.71	11.42	3.37	2.68	13.48	12.39	11.53	12.53

Table 3.6 Index of preponderance of various food items in different maturity stages of male Macrobrachium striatus

	Immature	Maturing	Matured
Number of samples	112	241	123
1 Detritus	17.50	23.55	29.81
2 Sand	0.94	0.28	2.96
3 Crustacean remains	11.50	5.91	12.80
4 Fish remains	10.80	1.38	4.20
5 Animal tissue	7.50	11.90	6.79
6 Mud	3.40	6.80	4.00
7 Plant matter	20.81	28.70	22.60
8 Miscellaneous matter	27.55	21.48	16.84

Table 3.7 Index of preponderance of various food items in different maturity stages of female Macrobrachium striatus

	Immature	Maturing	Matured	Berry	Spent
Number of samples	85	92	67	70	84
1 Detritus	23.30	21.60	8.55	18.90	18.40
2 Sand	5.80	9.85	0.74	1.83	3.80
3 Crustacean remains	4.20	0.00	24.64	10.66	4.00
4 Fish remains	5.44	2.31	0.00	9.20	0.00
5 Animal tissue	4.56	6.00	24.64	8.00	28.55
6 Mud	2.00	8.00	9.60	2.00	15.80
7 Plant matter	32.99	30.64	10.83	22.60	13.65
8 Miscellaneous matter	21.71	21.60	21.00	26.81	15.80

Table 3.8 Index of preponderance of various food items in different male morphotypes of Macrobrachium rosenbergii

	SM	WOC	SOC	t-SOC	WBC	SBC	OBC
Number of samples	43	66	26	77	77	41	26
1 Detritus	21.63	18.42	17.93	29.78	21.60	27.94	25.19
2 Sand	12.45	11.35	9.70	14.39	9.82	19.96	11.66
3 Crustacean remains	16.90	9.20	32.37	10.60	7.59	7.40	23.24
4 Fish remains	2.01	5.89	2.07	4.30	0.98	9.86	16.86
5 Animal tissue	5.25	10.51	19.72	9.28	5.55	5.30	6.78
6 Mud	6.23	9.16	3.88	5.53	8.68	2.36	2.50
7 Plant matter	24.22	17.33	0.49	15.16	24.19	18.20	6.39
8 Filamentous algae	0.14	0.15	0.07	0.18	0.25	0.20	0.26
9 Diatoms	0.11	0.15	0.07	0.29	0.16	0.25	0.34
10 Miscellaneous matter	11.07	17.84	13.71	10.49	21.17	8.53	6.78

SM= Small Males
WOC = Weak orange clawed males
SOC = Strong orange clawed males
t-SOC = Pre-transforming strong orange clawed males
WBC = Weak blue clawed males
SBC= Strong blue clawed males
OBC = Old blue clawed males

Table 3.9. Index of preponderance of various food items estimated from different female morphotypes of Macrobrachium rosenbergii

	WOF	SOF	TOF	WBF	SBF
Number of samples	46	34	66	84	90
1 Detritus	26.41	27.11	30.57	24.78	26.22
2 Sand	15.81	15.25	13.51	14.77	13.61
3 Crustacean remains	12.27	5.01	5.09	11.69	17.20
4 Fish remains	4.20	6.02	6.48	2.75	8.67
5 Animal tissue	3.83	5.05	3.81	3.39	4.81
6 Mud	3.16	1.33	1.93	3.95	4.46
7 Plant matter	27.11	22.03	25.07	28.43	15.07
8 Filamentous algae	0.09	0.44	0.19	0.04	0.59
9 Diatoms	0.10	0.25	0.09	0.02	0.04
10 Miscellaneous matter	7.01	17.50	13.25	10.16	9.34

WOF = Weak orange clawed female
SOF = Strong orange clawed female
TOF = Transforming orange clawed female
WBF = Weak blue clawed female
SBF = Strong blue clawed female

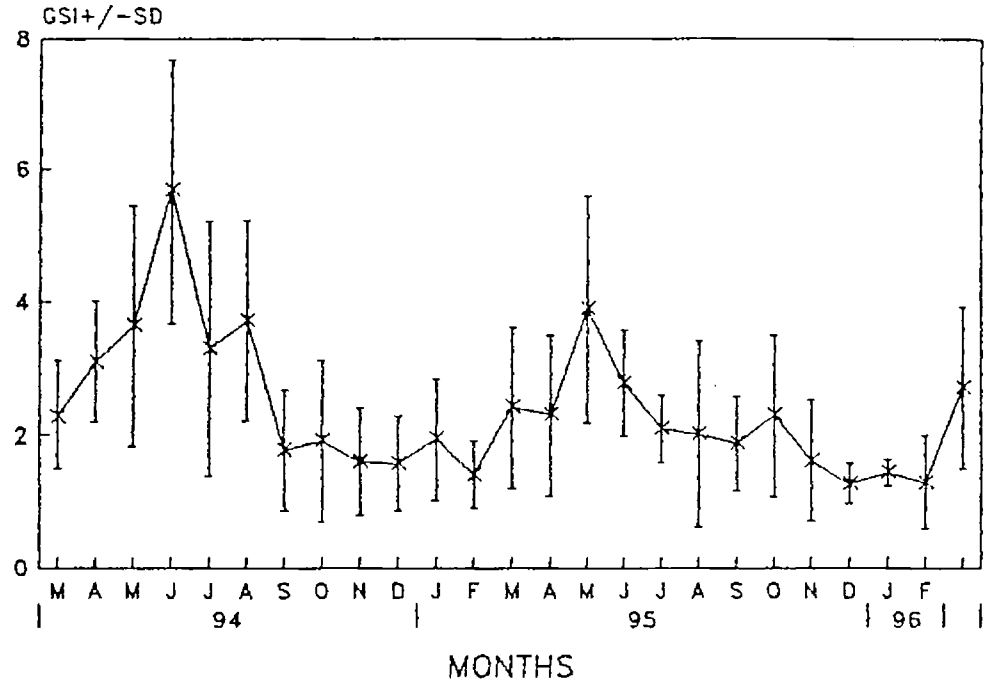


Fig. 3.1 Monthly variation of Gastrosomatic Index in males of *Macrobrachium rosenbergii*

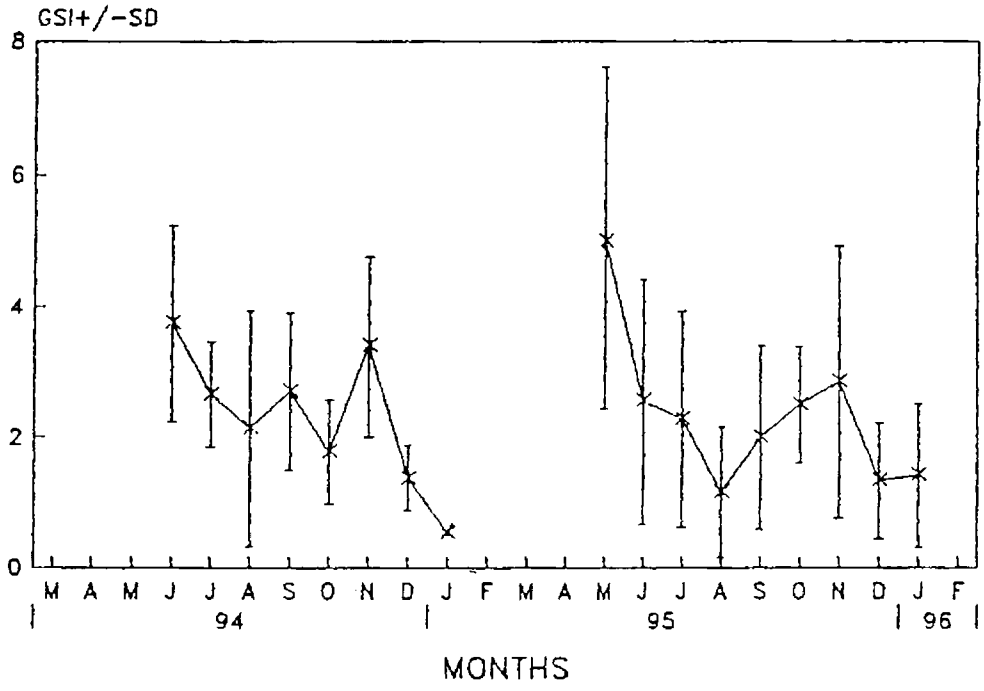


Fig. 3.2 Monthly variation of Gastrosomatic Index in females of *Macrobrachium rosenbergii*

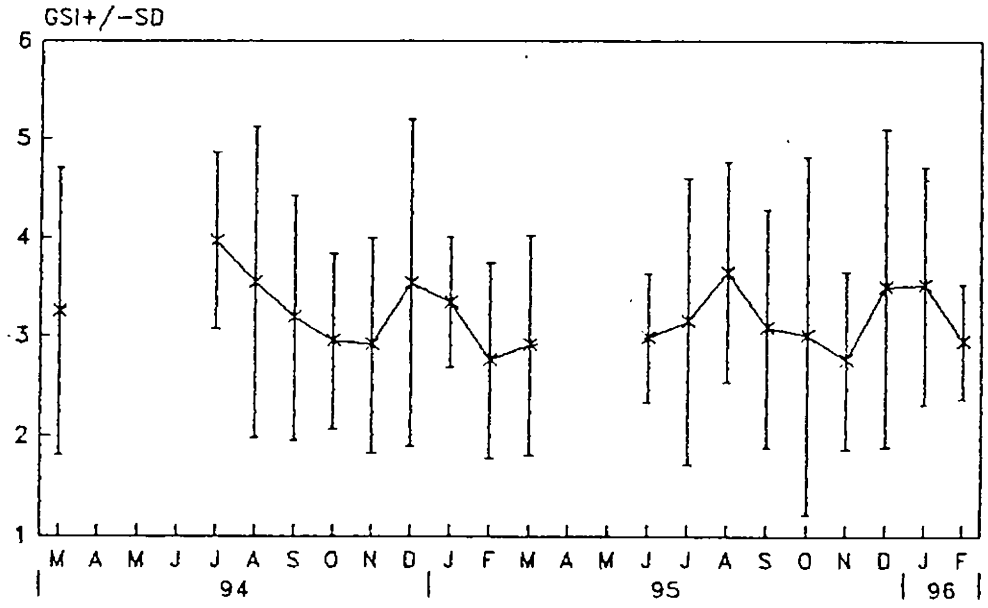


Fig. 3.3 Monthly variation of Gastrosomatic Index in males of *Macrobrachium striatus*

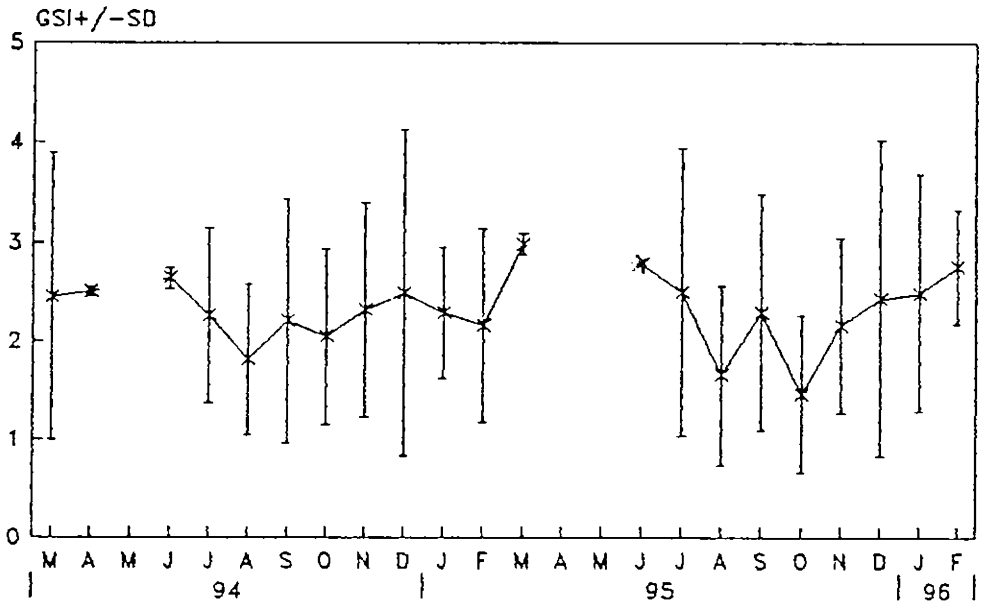


Fig. 3.4 Monthly variation of Gastrosomatic Index in females of *Macrobrachium striatus*

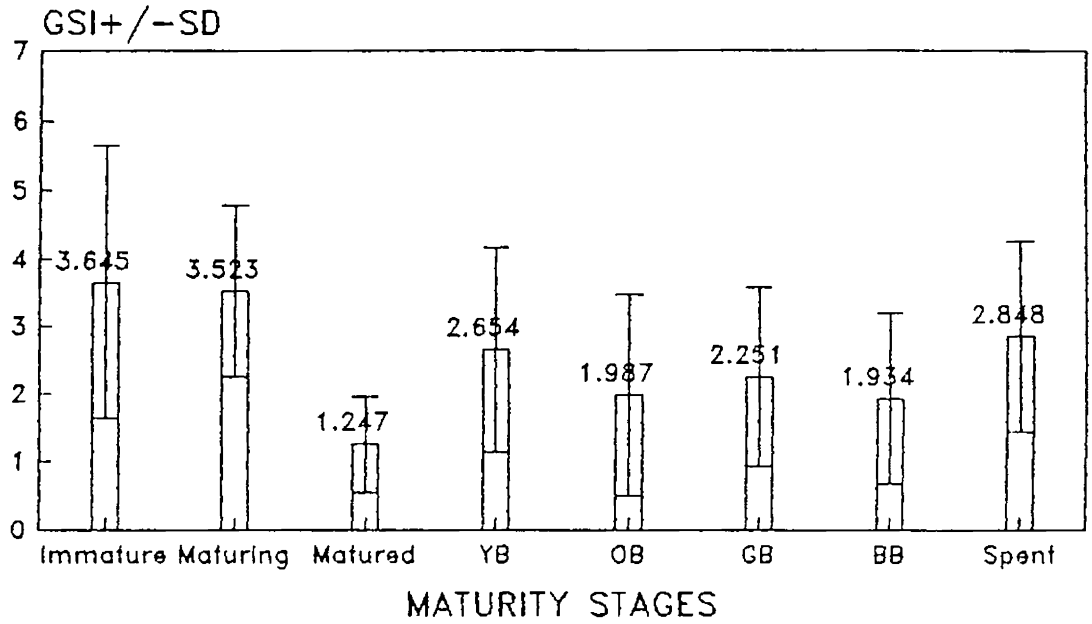


Fig. 3.5 Variation of Gastrosomatic index in female maturity stages of *Macrobrachium rosenbergii*

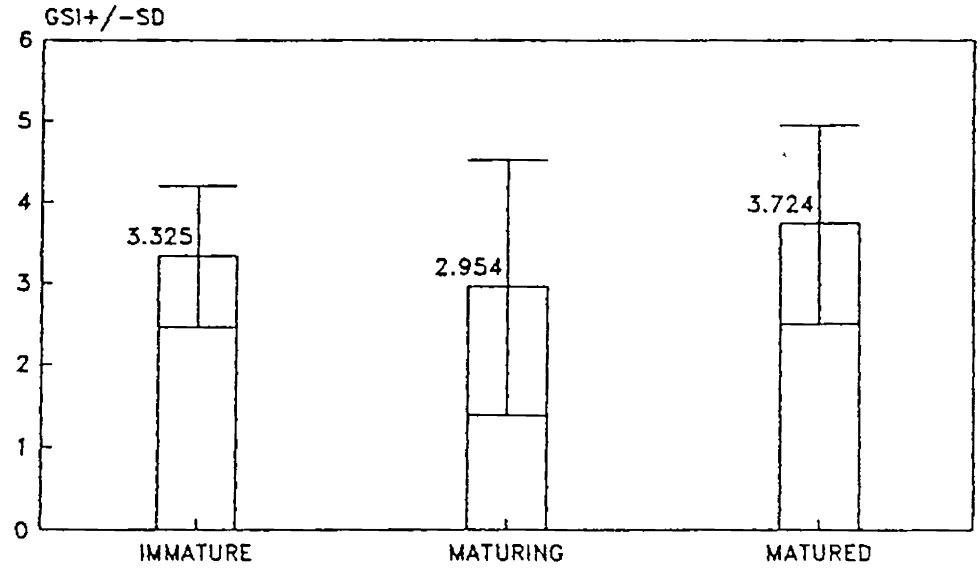


Fig. 3.6 Variation of Gastrosomatic index in male maturity stages of *Macrobrachium striatus*

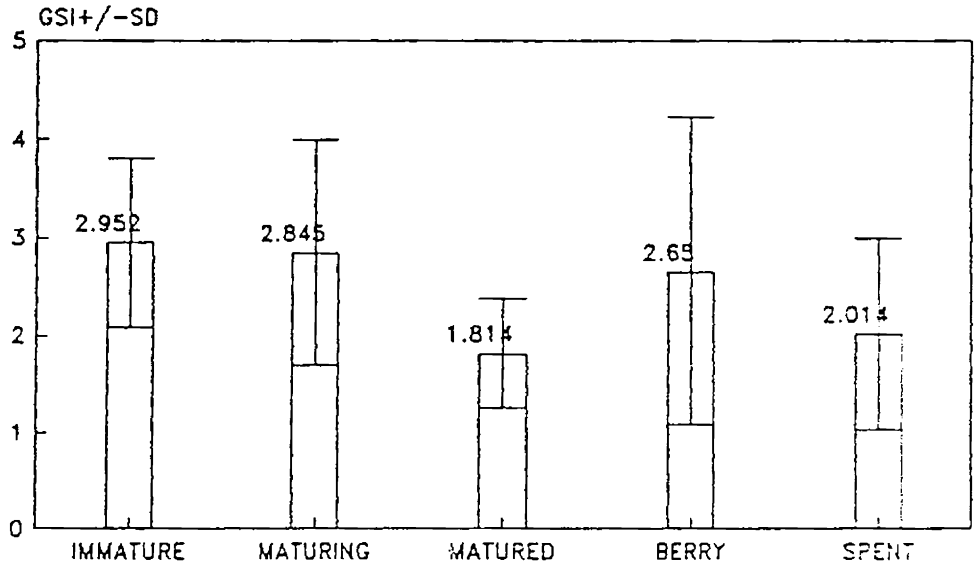


Fig. 3.7 Variation of Gastrosomatic index in female maturity stages of *Macrobrachium striatus*

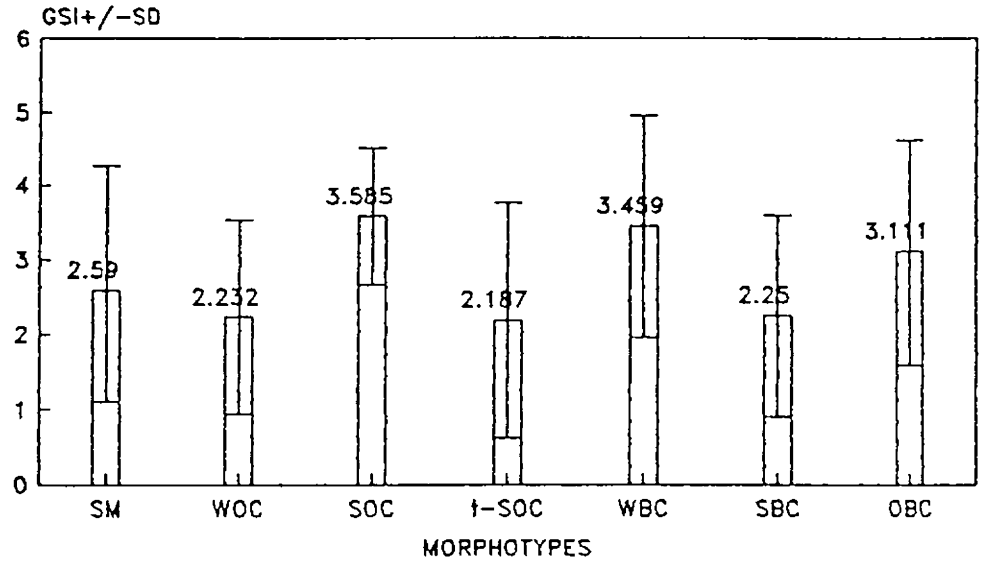


Fig. 3.8 Variation of Gastrosomatic index in male morphotypes of *Macrobrachium rosenbergii*

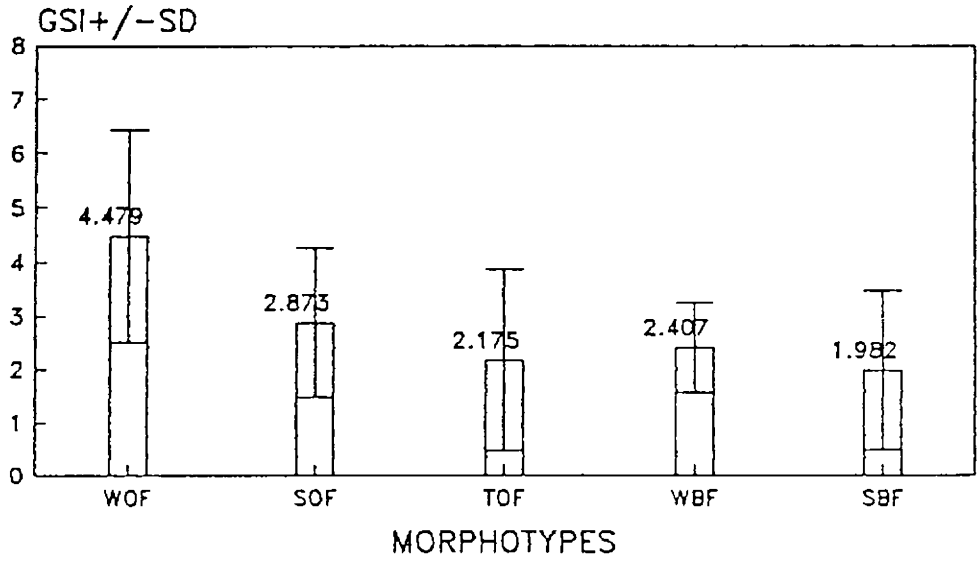


Fig. 3.9 Variation of Gastrosomatic index in female morphotypes of *Macrobrachium rosenbergii*

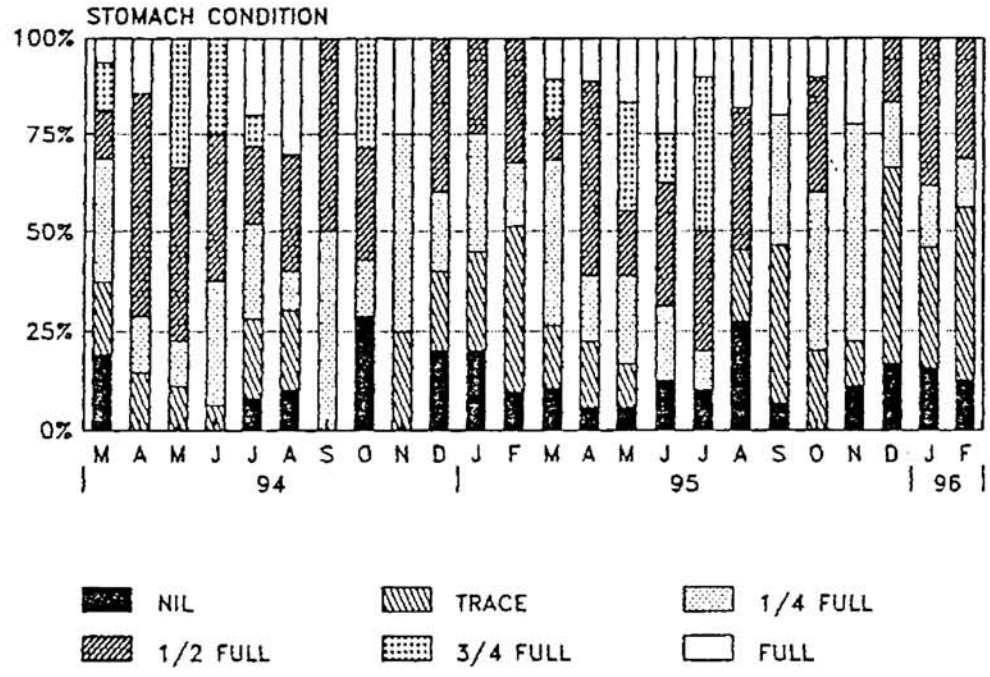


Fig. 3.10 Variations of stomach condition in males of *Macrobrachium rosenbergii*

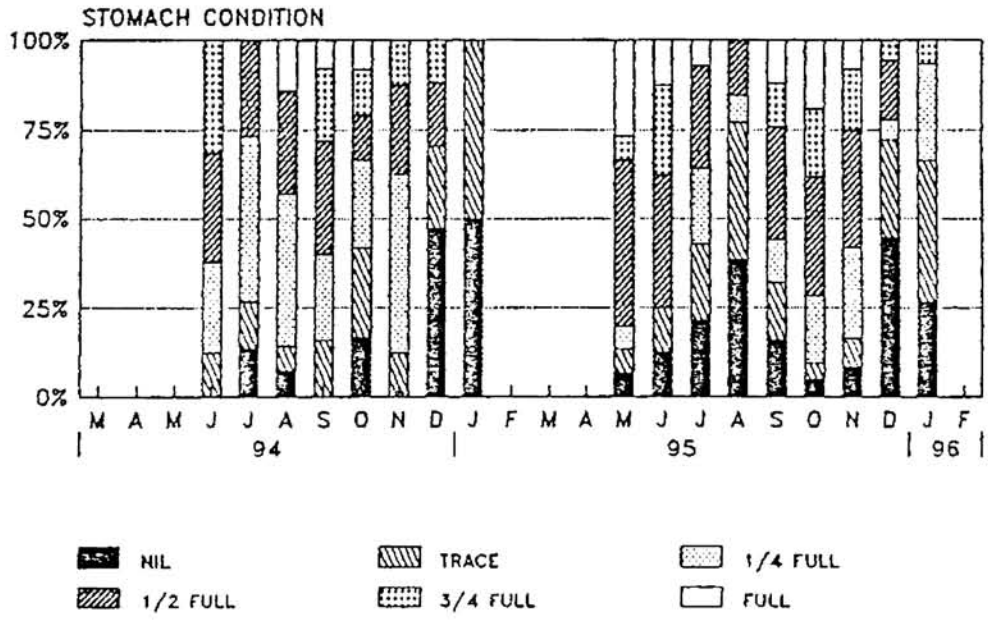


Fig. 3.11 Variations of stomach condition in females of *Macrobrachium rosenbergii*

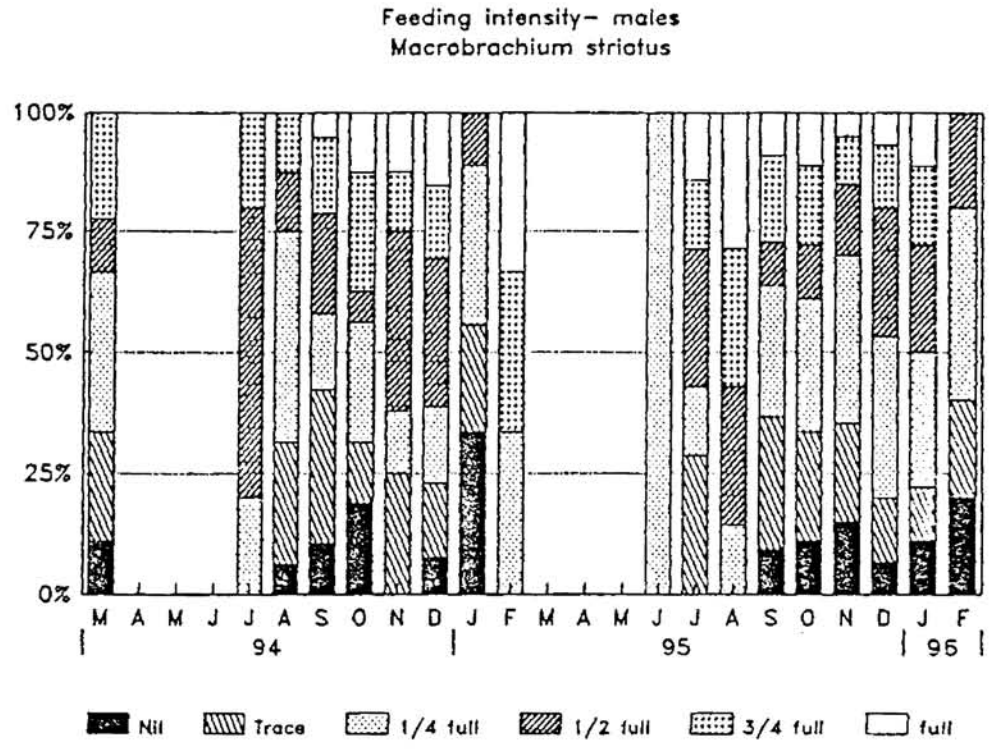


Fig. 3.12 Variations of stomach condition in males of *Macrobrachium striatus*

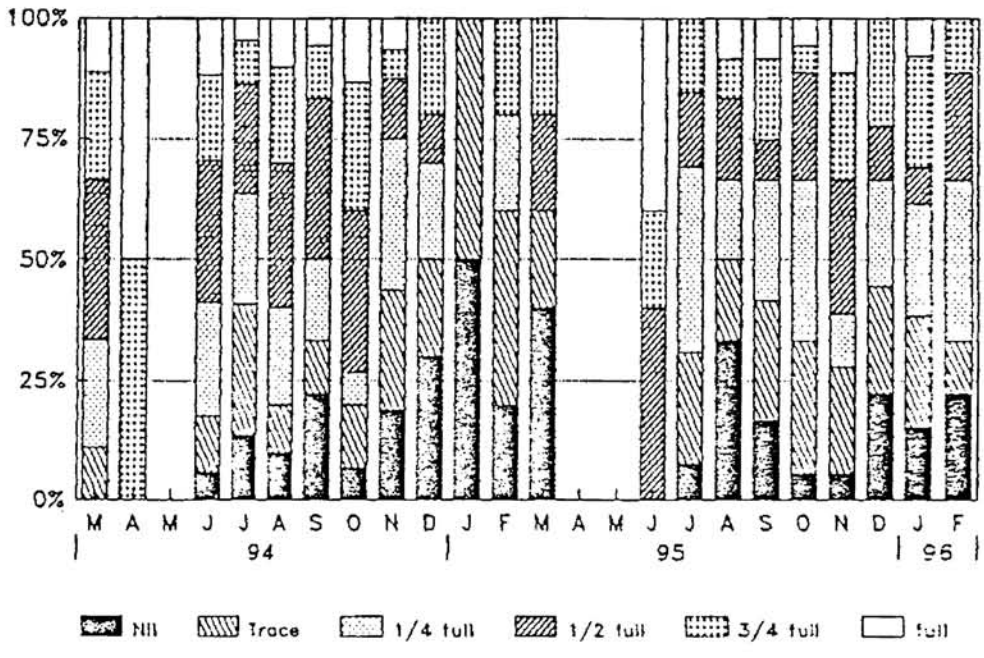


Fig. 3.13 Variations of stomach condition in females of *Macrobrachium striatus*

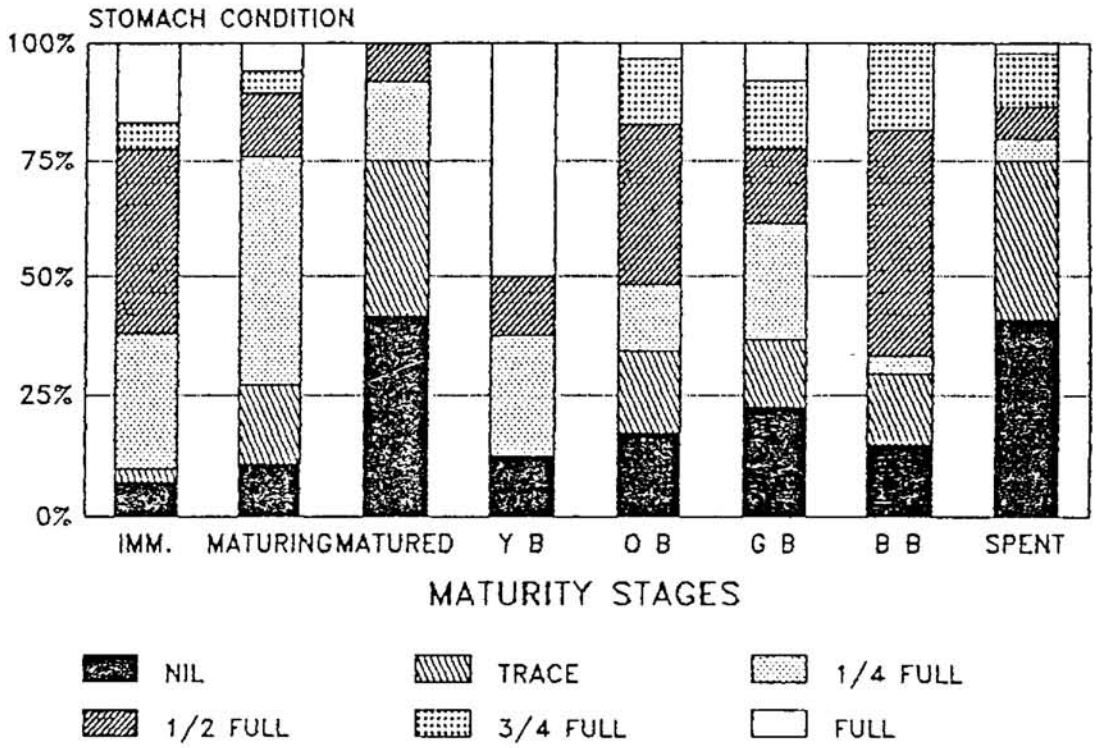


Fig. 3.14 Variations of stomach condition in female maturity stages of *Macrobrachium rosenbergii*

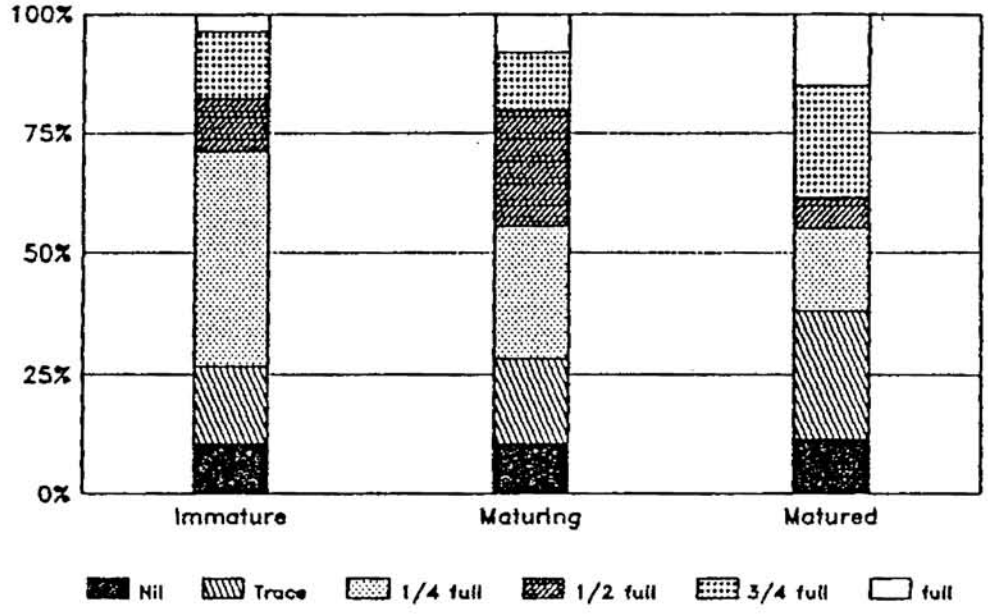


Fig. 3.15 Variations of stomach condition in male maturity stages of *Macrobrachium striatus*

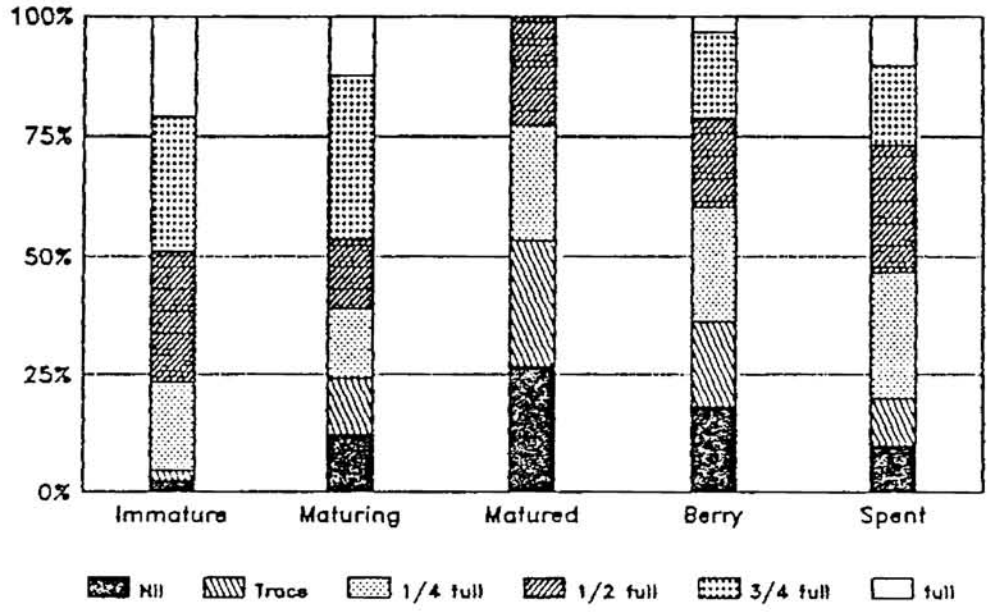


Fig. 3.16 Variations of stomach condition in female maturity stages of *Macrobrachium striatus*

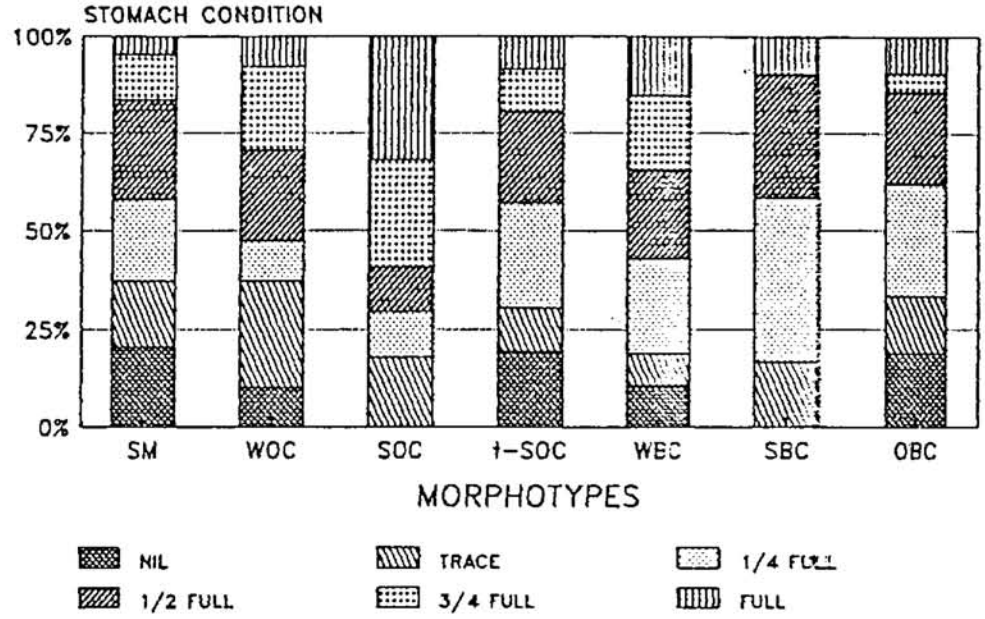


Fig. 3.17 Variations of stomach condition in male morphotypes of *Macrobrachium rosenbergii*

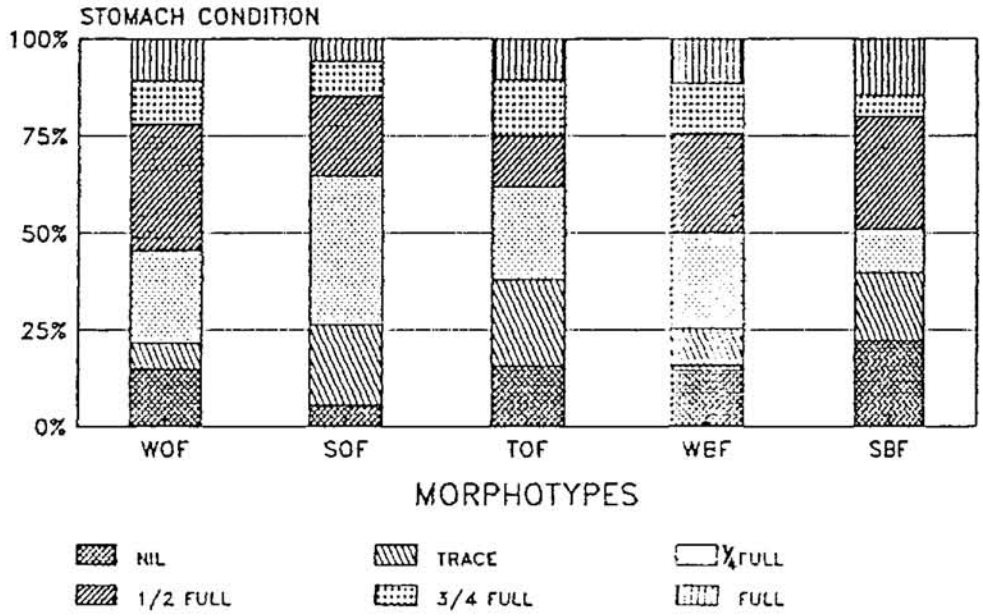


Fig. 3.18 Variations of stomach condition in female morphotypes of *Macrobrachium rosenbergii*

Chapter 4

Reproductive Biology of *Macrobrachium rosenbergii* and *M.striatus*

Introduction

Most of the species of *Macrobrachium* undertake breeding migration as brackish water conditions are essentially required for the successful completion of larval metamorphosis (Ling, 1969a; Raman, 1967; Kurup *et al.*, 1992a). Man made alterations brought about in the ecosystem and consequent transformations which eventually hampered spawning migration and recruitment have resulted in the dwindling of the stock of Macrobrachium spp. during the last few decades (Carlander, 1980; Frusher, 1983; Kurup, *et al.*, 1992a). Reproductive biology of *Macrobrachium* spp. have been subjected to detailed investigation and the most notable works among them are those of John (1957), Ling and Merican, (1961), Ibrahim (1962), Ling (1964, 1969a), Lewis *et al.* (1966), Raman (1967), Rao (1967), Koshy and Tiwari (1975), Rajayleshmi (1961, 1975, 1980), Robertson (1983), Berber (1984), Jayachandran (1984), Jinadasa (1985), Murthy *et al.* (1987) and Prakash (1994). The age at first maturity of *M.rosenbergii* were studied by Rajyalakshmi (1961); Raman (1967), Rao (1967) and Goorah and Parameswaran (1983). While similar information of lesser palaemonids are those of Arroya *et al.* (1982), Jayachandran (1984), Inyang (1984) and Berber (1984). Descriptive accounts on courtship of *M.rosenbergii* are provided by Ling (1962), Rao (1965) and Chow *et al.* (1982). Reproductive biology of the morphotypes of *M.rosenbergii* from grow-out as well as natural habitat are not yet fully understood, while similar information

with regard to *M.striatus* is totally unknown. Therefore, in the present study an attempt was made to explicate the reproductive biology of various morphotypes of *M.rosenbergii* as well as little known *M.striatus* of the Vembanad lake.

Materials and Methods

Monthly sample of *M.rosenbergii* were collected during the fishery survey cruises while that of *M.striatus* were procured from the catches of 'padal' operated at Kumbalam. The specimens collected in live condition were preserved in 5% formalin, after making some perforations on the carapace for better preservation of gut, gonads and hepatopancreas and brought to the laboratory for detailed examination.

Animals were segregated morphotype wise and maturity stage wise following Kuris *et al.* (1987), Ang *et al.* (1990) and Harikrishnan and Kurup (1997a) and the specimens were dissected out to remove gonads and hepatopancreas (=mid gut gland), after recording total weight to the nearest 0.1g with the help of a electronic balance. Weight of gonad and hepatopancreas were also recorded to nearest 0.1 mg after removing excess moisture using filter paper. Gonadosomatic and hepatosomatic indices were calculated as the percentage weight of gonad and hepatopancreas respectively to the total body weight. Monthly average of GSI was sequentially arranged in time series in order to delineate spawning season (King, 1995).

In order to calculate the size at first maturity, percentage occurrence of individuals with maturity stage 3 and above were plotted against length groups. Length at first maturity was ascertained from the length at which 50% of the individuals showed maturity.

80 berried females of *M.rosenbergii* and 58 of *M.striatus* were sorted based on length, embryonic development and morphotype wise. Eggs were carefully removed from the brood pouch, weighed and absolute fecundity was estimated following standard procedures (Kurup and Kuriakose, 1994). Absolute fecundity so arrived at was regressed to 25 and 16 morphometric measurements in *M.rosenbergii* and *M.striatus* respectively to establish the relationship of various body dimensions to fecundity. Relationship of fecundity to total weight, total length and carapace length of prawns of different length groups and having different stages of maturity and morphotypic stage were compared statistically using analysis of covariance (Snedecor and Cochran, 1967). The relative fecundity derived with respect to total weight, total length and carapace length were compared using analysis of variance to assess variation, if any, between embryonic developmental stages, morphotypes and length groups.

Results

1. Description of Maturity Stages

A. *Macrobrachium rosenbergii*

I. Males

In males, size of the animals can not be used as a criterion in assessing the reproductive stage in view of the fact that male morphotypes show differences in the reproductive activity (Cohen *et al.*, 1981; Kuris *et al.*, 1987; Harikrishnan and Kurup, 1997a).

II. Females

Females of *M.rosenbergii* were classified into 5 stages based on the development of ovaries and furthermore, the fourth stage (Berried female) was

further classified into 4 stages based on the extent of embryonic development. Both maturity and embryonic stages were considered in a sequential manner in the present study.

1. Immature females

Ovaries ill developed and appear like flabby, off white mass of tissue. Immature females can easily be identified by the presence of five to eight bluish black striation on the carapace. Ovary not visible through carapace. Immature females are invariably below 90 mm total length.

2. Maturing females

Ovaries started developing, show slight orange colouration, not visible through the carapace. No striations on the carapace. Second cheliped with bluish and/or yellowish colour. Maturing females are found to be having 90 mm and above in total length.

3. Matured females

Ovaries well developed and occupy about $2/3^{rd}$ of the cephalothorax, orange in colour, visible through the carapace. In larger animals with thick carapace, ovaries not visible through carapace however, an orange colouration of the ovaries visible through the base of rostrum.

4. Berried females with yellow eggs (Yellow berry)

Females just after oviposition. Colour of the eggs yellowish or bright orange. This stage lasts for about 3-5 days.

5. Berried females with orange eggs (Orange berry)

Eggs incubated for about a week. Colour of the egg mass changed from yellowish to orange.

6. Berried females with grey eggs (Grey Berry)

Eggs incubated for more than two weeks. Egg mass greyish in colour. Eyes of embryo show pigmentation.

7. Berried females with slate grey or Black eggs (Black Berry)

Egg mass slate grey or black in colour. Eggs almost completed incubation and are ready to hatch within 2-3 days. Eye of the embryo clearly visible.

8. Spent females

Females already released the larvae, brood pouch broad and devoid of eggs. Pleopods with ovigerous setae.

B. *Macrobrachium striatus*

I. Males

Among males, three stages could be identified based on the structure of testis, total length and external morphological features.

1. Immature males

Small males with more or less translucent body. Testis appeared as a translucent mass. Individuals having less than 30mm belongs to this group.

2. Maturing males

Animals having more than 30 mm total length. 2nd cheliped moderate with greyish colour having yellowish striations and/or patches. Testis gained white colour and seminal vesicle developed. Coiled portion

of vas-deferens not well developed, embedded in a gelatinous mass of connective tissues.

3. Matured males

Large males with opaque body. 2nd chelipeds very large with brownish- grey colouration. Testis well developed.

II. Females

Five maturity stages were identified in *M.striatus* based on the development of ovaries. A distinct variation in colour of the egg mass of *M.striatus* could not be observed with the progression of incubation.

1. Immature females

Ovaries not developed and appeared like a translucent flabby, off white mass of tissue. Internal organs of cephalothorax easily visible through the carapace. Yellow striations on 2nd cheliped prominent.

2. Maturing females

Ovaries started development, slight greenish colour on the dorsal side, with off white ventral side. Ovary may be visible through the carapace in advance maturing stage. Feeble yellow striations on the 2nd cheliped.

3. Matured females

Ovaries reddish brown in colour, well developed and occupies major portion of the cephalothorax. Ovaries visible through the carapace.

4. Berried females

Females bearing eggs on the ventral side of the abdomen.

5. Spent females

Females already released the larvae. Brood pouch broad and devoid of eggs.

2. Description of Morphotypes of *M.rosenbergii* with Reference to Reproductive Activity.

I. Male

Reproductive activity of male morphotypes of *M.rosenbergii* are well established and documented (Telekey, 1984; Ra'anan and Sagi, 1985; Kuris *et al.*, 1987; Sureshkumar and Kurup, 1998).

1. Small males

Small males are reproductively active. Though they are not dominant in the hierarchy, however, they can successfully mate using sneak mating strategy.

2. Weak Orange Clawed Males

Reproductively submissive morphotype and does not show hierarchial dominance. WOC shows very low success in mating.

3. Strong Orange Clawed Males

SOC are reproductively submissive, shows very low mating success and subdominant in their hierarchy.

4. Pre-transforming Strong Orange Clawed Males

t-SOC are reproductively submissive morphotypes showing moderate mating success. They are subdominant in their hierarchy.

5. Weak Blue Clawed Males

Reproductive potential of this morphotype is not known and so also the hierarchial dominance.

6. Strong Blue Clawed Males

Reproductively very active morphotype having high mating success. SBC showing a tendency to sequester moulted females. SBC Showed hierarchial dominance.

7. Old Blue Clawed Males

Reproductively active morphotypes showing hierarchial dominance.

II. Females

Female morphotypes were distinguished and categorised recently (Harikrishnan and Kurup, 1997a, Harikrishnan *et al.*, 1998) and the variations, if any, in their reproductive activity have not yet been studied. Berried females were encountered from all the female morphotypes except small females, which showed that all the morphotypes except SF are sexually active.

Similar morphotypic differentiation could not be observed in *M.striatus.*

3. Seasonal Occurrence of Various Maturity Stage of *Macrobrachium rosenbergii* and *M.striatus*

Occurrence of various maturity stages in female population of *M.rosenbergii* during March 1994 to February 1996 is depicted in Fig 4.1. Non-berried females viz. immature, maturing and matured females dominated in the

exploited population during July to September while berried females showed its predominance during October to January.

Matured and berried females of *M. striatus* were encountered in most of the months during 1994-96 except in May 1994, April 1995 and May 1995. Highest number of matured and berried females could be registered during November -December (Fig. 4.3). During January, towards the end of breeding season, a higher percentage of immature females could also be registered.

4. Seasonal Occurrence of Morphotypes of *M.rosenbergii*

Reproductively submissive male morphotypes viz. WOC, SOC and t-SOC were predominant from March to June and thenceforth a dominance of reproductively active morphotypes could be discernible (Fig. 4.4). In November to December 1995 OBC showed predominance, in contrast, SBC was found to be abundant during October to December 1994. Small males were encountered in very few numbers in the exploited stock with a negligible contribution of only 0.13% in August 1994 (Fig. 4.4).

Monthly variations in the occurrence of female morphotypes and their transitional stages in female population of *M.rosenbergii* are presented in Fig. 4.5. Females were totally absent in the exploited stock during March and April during both the years. Appearance of SF could only be observed in August and December 1994. Orange clawed females (WOF, SOF and TOF) showed a distinct predominance during May to August. In contrast, the percentage occurrence of blue clawed females showed an increasing trend from September to January in both the years.

Percentage occurrence of various maturity stages among different female morphotypes of *M.rosenbergii* is depicted in Fig. 4.6. Small females were fully comprised of by immature individuals. The occurrence of immature and maturing individuals among the female morphotypes showed a gradual decrease from SF to SBF however, an exception to this situation was WBF.

5. Seasonal Variation in GSI

Monthly variation of GSI in males of *M.rosenbergii* is depicted in Fig. 4.7. The GSI showed a gradual increase during April to October and thereafter a sudden decrease could be noticed during November and December. Almost similar pattern was seen in both the years of study.

GSI of females of *M.rosenbergii* showed very pronounced variation when compared to that of males (Fig. 4.8). A gradual increase in GSI of males from 0.13 to 0.62 could be noticed during June to October 1994. GSI decreased to 0.10 in November 1994 and subsequently, showed an increase to 0.22 in January 1995. At variance with this, a gradual ascent from 0.08 to 0.36 was observed in August -October period and thenceforth a remarkable decline up to February could be recorded in 1995-1996.

In male *M.striatus*, GSI showed lowest value (0.18) in the month of August and increased to 0.38 in October 1994. Similar trend could also be seen in the second year (Fig. 4.9).

In *M.striatus* also, variation of GSI was very much prominent in females when compared to males (Fig. 4.10). Among females, GSI showed an

upward trend from June to September 1994 and then it decreased during November 1994 to March 1995.

6. Variation of GSI Among different Morphotypes and Maturity Stages

In females of *M.rosenbergii*, an increase in GSI could be noticed during development from immature to matured stage, in constrast, in yellow berries, a decline in GSI could be discernible. A progression in GSI commensurate with the embryonic development was seen in *M.rosenbergii* as ripe ovaries were encountered in black berried females (Fig. 4.11).

Variation of GSI in male and female morphotypes of *M.rosenbergii* are shown in Fig. 4.12 and 4.13 respectively. Among male morphotypes, SOC showed lowest GSI of 0.105 and thenceforth an increase was observed from SOC to SBC coinciding with the developmental pathway. Interestingly, in SM the GSI was 0.350 which was apparently higher than its successive four morphotypes. Among female morphotypes, GSI showed a higher value in TOF whereas, the same in respect of its preceding and succeeding morphotypes were very low (Fig. 4.13).

Among males of *M.striatus*, an increase in GSI was observed with the development from immature to mature stages (Fig. 4.14). The pattern of variation of GSI in different female maturity stages of *M.striatus* were found to be almost similar to that of *M.rosenbergii* (Fig. 4.15).

7. Seasonal Variation in HSI

In males of *M.rosenbergii*, HSI showed a gradual increase during April - August 1994 and thereafter a decline during November 1994 to April

1995 (Fig. 4.16) could be discernible. Two distinct peaks of GSI was noticed during June 1995 and October 1995. Whereas, seasonal variation of HSI in females of *M.rosenbergii* did not show any specific pattern (Fig. 4.17).

In *M.striatus*, the fluctuation of HSI among females was higher when compared to males (Fig. 4.18 and 4.19). HSI of males of *M.striatus* was lowest (2.53) in August 1994, and gradually increased, showing highest (3.85) value in October 1994, however it started plummeting in the subsequent months (Fig. 4.18). Whereas, in 1995, no such specific pattern of variation in HSI could be observed. HSI of females plummeted from 3.58 to 2.00 during March - September period in 1994 and thenceforth increased to 3.02 in March 1995. The pattern of variation of HSI of females during 1995-1996 was more or less comparable with that of 1994-95.

8. Variation in HSI among Morphotypes and maturity stages

Among female morphotypes of *M.rosenbergii* an increasing pattern in HSI could be noticed from immature to maturing stage (Fig. 4.20). Both matured and spent females showed lowest HSI value of 2.526 and 2.469 respectively.

Variation of HSI amongst male morphotypes of *M.rosenbergii* showed an inverse relationship with GSI (Fig. 4.21). Highest HSI was encountered in SOC (6.351) and thereafter a decreasing trend could be discernible commensurate with morphogenesis. Highest HSI was observed in SOF (5.605) while the lowest was in WBF (3.64) (Fig. 4.22).

In males of *M.striatus*, an increase in HSI from 2.670 to 3.471 was registered coinciding with the gonadal maturation (Fig. 4.23). A decrease of HSI from immature to matured females of *M.striatus* was recorded and matured females showed lowest HSI values (1.374) (Fig. 4.24). HSI of berried females (2.471) were on a higher side when compared to matured (1.374) and spent females (1.955).

9. Size at first maturity

Percentage occurrence of matured females of *M.rosenbergii* and *M.striatus* in various length group are shown in Fig. 4.25 and 4.26. The size at first maturity of females of *M.rosenbergii* was estimated to be 145 mm (Fig. 4.25) and that of *M.striatus* were 47 and 43 mm for males and females respectively (Fig. 4.26).

10. Fecundity

Minimum, maximum, mean and standard deviation of fecundity and various morphometric characters studied in *M.rosenbergii* are presented in Table 4.1. Highest absolute fecundity enumerated was 2,27,161 for a grey berried female having total length of 258 mm (208g) while lowest (30,666) was in a orange berry of 158 mm total length (33.7g). Fecundity per unit measurements of the body dimension was estimated directly from the mean of observations as well as from the logarithmic equation derived and presented in Table 4.1. Number of eggs per unit dimension of total length, carapace length

and total weight recorded from *M.rosenbergii* was found to be 447, 1623 and 896 respectively.

Results of regression analysis of fecundity with various morphometric characters are also presented in Table 4.1. Relative fecundity of yellow, orange, grey and black berried females of *M.rosenbergii* showed a gradual decrease commensurate with the embryonic development (Table 4.2) though the variation was not found to be significant ($P>0.05$) (Table 4.5). Nevertheless, an increasing trend was noticed in black berried females. The relationship of fecundity with total length, carapace length and total weight of berried females during various embryonic developmental stages showed no significant variation($P<0.05$) (Table 4.6).

Differences noticed in relative fecundity in different length classes of *M.rosenbergii* are presented in Table 4.3. The relationship between fecundity to total length, carapace length and total weight in different length groups showed no significant variation (Table 4.5), whereas, relative fecundity in various length group showed significant variation (Table 4.6). Absolute and relative fecundities recorded from various female morphotypes are presented in Table 4.4. The relationship of fecundity to total length, carapace length and total weight showed no significant variation among various female morphotypes (Table 4.5).

Details of fecundity and morphometric measurements of *M.striatus* and results of regression analysis are presented in Table 4.7. Highest fecundity enumerated in *M.striatus* was 9,625 eggs (total length 80 mm, weight 7.4063g) while lowest was 1,175 eggs (total length 53 mm, weight 2.0853g). Average

absolute fecundity was worked out to be 4,352 eggs. In *M.striatus*, number of eggs per unit dimension of total length, carapace length and total weight were recorded to be 66, 229 and 1033 respectively (Table 4.7).

Variation in fecundity in different length groups of *M.striatus* is presented in Table 4.8. The relationship between fecundity and total length ($F=4.366$; $P<0.01$) and carapace length ($F=3.8202$; $P<0.01$) showed significant variation, whereas, relationship of fecundity to total weight ($F=2.0066$; $P>0.05$) showed insignificant variation in different length groups. Relative fecundity with respect to total length ($F=44.07$; $P<0.001$), Carapace length ($F=51.13$; $P<0.001$) and total weight ($F=19.17$; $P<0.001$) differed significantly in various length groups.

Discussion

Males of *M.rosenbergii* showed a regular occurrence in Vembanad lake from April-May onwards and subsequently, berried females also started appearing in August with peak availability during September-November periods (Fig. 4.1). By examining the pattern of availability of male and female in the lake it appears that April-May to December-January is the breeding season of *M.rosenbergii*. Downward migration of *M.rosenbergii* from rivers to estuaries for the purpose of breeding has been reported earlier by Ling and Merican (1961), Johnson (1966), Raman (1967), Rao (1967) and Jinadasa (1985). Breeding season of *M.rosenbergii* was found to be highly related to the prevailing climatic conditions of the region. The breeding season of *M.rosenbergii* coincided with the south-west monsoon showers in Vembanad lake (Raman, 1967) while, in Hooghly river, it coincided with the North-west

Monsoon (Rao, 1967) . In Bolgoda lake, Sri Lanka, *M.rosenbergii* shows two peaks in breeding corresponding to monsoon showers (Jinadasa, 1985). Similarly in *M.striatus* also, the occurrence of relatively higher number of matured and berried females during September to January indicates the possibility of breeding of this species in the above periods (Fig 4.2 and 4.3).

Male morphotypes of *M.rosenbergii* represent stages of morphogenesis and these morphotypes undergo transformation in an irreversible pattern from small males to orange clawed and subsequently to blue clawed males (Cohen *et al.*, 1981; Kuris *et al.*, (1987). Numerical abundance of reproductively inactive morphotypes in the population in the beginning of breeding season and subsequent increase of reproductively active male morphotypes in the peak breeding season (Fig. 4.4) clearly manifest the transformation process undergone by the males in the natural population inhabiting Vembanad lake.

At the end of breeding season, an unusual increase in the immature females of *M.rosenbergii* and their subsequent absence in the lake would suggest that the newly recruited individuals might have ascended to the riverine region for further development. (Fig 4.1). Similar pattern of distribution of *M.striatus* could also be discernible. Presence of immature individuals and their subsequent disappearance may manifest the possibility of return migration of juveniles of *M.striatus* to the freshwater habitat. Presence of matured specimens of *M.striatus* through out the breeding season at Kumbalam can be attributed to the relatively high salinity prevailed in the station. This observation

is well in agreement with Pillai (1993) that berried females of *M.striatus* were encountered from higher salinity gradient zones of Vembanad lake.

Small females of *M.rosenbergii* encountered from the lake were very small as well as immature and therefore, can be designated as juvenile female prior to attainment of sexual maturity, which are morphologically similar to that of small males without appendix masculina. As the developmental pathway of female morphogenesis (Harikrishnan *et al.*, 1998) are progressing from SF to SBF, a corresponding increase in the occurrence of matured and berried stages could also be observed except in case of WBF (Fig. 5.6). It would thus appear that the transformation from WOF→ SOF →TOF →SBF may be an expression of age and WBF may represents a stage in the postulated bypass transformation as suggested by Harikrishnan (1997). In contrast, 3% of total SBF encountered from the lake were immature which indicate that the terminal morphotypic stage also comprises of immature individuals. It may, therefore, be inferred that variation in colour pattern in different female morphotypes are the manifestation of age rather than the expression of reproductive activity in contrast to male morphotypes wherein the difference in colour pattern of 2nd cheliped is the real expression of their dominance and reproductive potential (Sagi and Ra'anan, 1985; Sureshkumar and Kurup, 1998).

Homogenous nature of size-structure of females in grow-out population was reported earlier (Cohen, *et al.*, 1981; Kuris *et al.*, 1987) and recently Harikrishnan *et al.* (1997) established a more or less homogenous nature of female morphotypes in natural system. From the present observation

on reproductive capacity of female morphotypes, it may be inferred that the homogeneity in size distribution of females might have been created as a result of uniformity in reproductive activity. Among male morphotypes, suppression of growth of SM due to the presence of BC in their vicinity has already been reported and therefore, the removal of BC consequently stimulates SM to grow at an enhanced rate (Ra'anan and Cohen, 1985; Karplus *et al.*, 1992b).

In fishes, gonadosomatic index can be taken as a useful criterion for determining the duration and intensity of spawning (June 1953; Erdman, 1968). In consonance with this, the specific peak of GSI of males and females recorded in September to November can be considered as the period of higher breeding activity in *M.rosenbergii*. Large sized males were encountered in the catches during October 1994 and correspondingly a higher value of GSI could also be observed during that time. Similarly, higher GSI was observed in females of *M.striatus* during August-September to December-January and therefore, this period could be delineated as its breeding season in the Vembanad lake. The magnitude of variation of GSI in males was relatively low in *M.striatus* when compared to *M.rosenbergii* and this may be due to the regular occurrence of matured males in moderate number in the exploited stock.

Variation in gonadosomatic index in different maturity stages of females showed similar patterns in *M.rosenbergii* and *M.striatus*. Increase of GSI could be noticed when yellow berry turns to black berry and this would manifests the simultaneous development of ovary along with embryonic development. This observation would lend to support the possibility of more than one spawning of an individual in a breeding season. This is well in

agreement with the findings of Cole (1958) and Geurao *et al.* (1994) that *Palaemon serratus* had up to 3 spawning on French coast and *P.xiphias* spawn 5-6 times in Spain in a breeding season. Raman (1967) also reported the possibility of more than one spawning in *M.rosenbergii* of Vembanad lake.

Gonadosomatic index in male morphotypes of *M.rosenbergii* can be taken as a reliable index of their reproductive activity. From SM to SOC there is a steady decrease in GSI and it progresses afterwards commensurate with the transformation pathway. This fully agrees with the earlier reports on reproductive activity of various male morphotypes by Cohen *et al.* (1981) and Ra'anan and Sagi (1985). GSI recorded from SM is higher than that or four of its succeeding morphotypes and therefore indicates its higher reproductive activity. GSI of TOF showed highest values during the present study and this may be due to the occurrence of a high percentage of matured individuals in this category.

Hepatopancreas plays a major role in the food assimilation (Dhall and Moriarty, 1984) and its relative weight probably manifests the provision for energy utilisation for growth and metaboloism. A specific peak in HSI of males of *M.rosenbergii* and *M.striatus* with the progress of breeding season during June to November could be observed. These higher values of HSI may be due to the increased activity of males either for somatic growth or reproduction. On the contrary, in females of *M.rosenbergii* and *M.striatus* a declining trend could be observed in HSI during breeding season as the developing ovaries may occupy a major portion of the cephalothorax.

Sagi and Ra'anan (1988) opined that the relative size of hepatopancreas is highly correlated with the morphotypic stage and its relative energy expenditure in growth and sexual activity. In the present investigation, relatively higher HSI could be observed in SOC which manifests the possibility of higher rate of food assimilation and growth. This observation corroborates with the earlier reports (Kuris *et al.*, 1987; Kurup *et al.*, 1997a) that SOC has a relatively high somatic growth rate. A gradual decrease in HSI could be noticed in SOC to OBC coinciding the developmental pathway of morphotypes and this observation is in full agreement with Ra'anan and Sagi (1985) who reported that growth is reduced and moulting is infrequent in the latter stage of male morphogenesis. Similarly, lowest HSI was recorded in SM in the present study which also conforms to its retarded growth as suggested by Cohen *et al.*(1981) and Sagi and Ra'anan (1988). In contrast, an increase in HSI could be noticed from SM to SOC which also conforms to the established fact that the former is characterised with a reduced growth rate in contrast to rapidly growing phase of the latter.

Average fecundity in *M.rosenbergii* is computed at 95,687 eggs and is comparable with the report of Jinadasa (1985) and Goorah and Parameswaran (1983). According to Ling (1969a) fecundity ranges from 60,000 to 1,00,000 in *M.rosenbergii,* however, Rao reported that it varies from 40,000 to 1,50,000 eggs depending on the size of the prawn. The result of the present study showed that the absolute fecundity varied from 30,666 to 2,27,161 for females of total length 158 mm (33.7g) and 258 mm (202.0g) and this is well comparable with the report of Rao (1986).

Jinadasa (1985) observed a linear relationship between carapace length and fecundity in *M.rosenbergii* collected from Bolgoda Lake, Sri Lanka. However, similar relationship was obtained in respect of total weight, total length and carapace length in *M.rosenbergii* and *M.striatus* collected from Vembanad lake only when log transformed values were used for the analysis (Table.4.1 and 4.7) and this would suggest existence of a curvilinear relationship (Beganal, 1978) between fecundity and other morphometric characters. The exponential value (regression coefficient) between total length and fecundity was found to be lower than the cube in *M.rosenbergii* (Table 4.1) and higher than the cube in *M.striatus* (Table 4.7) and this is well in agreement with the generally accepted view that fecundity is related to the length of the fish by a factor closer to the cube (Beganal, 1978). The exponential values between fecundity and total body weight (0.7547) was found to be slightly deviated from 1 in *M.rosenbergii*, however, this is comparable with that of Kurup and Kuriakose (1994). Sakunthala (1976) reported the direct relationship of fecundity to total length in *M.idae* and *M.rude* respectively. Similar relationship was reported in *M.lamerrei, M.dayanum* (Kozhy and Tiwari, 1975), *M.novaehollanidae* (Greenwood *et al.*, 1976), *M.amazonicum* (Rojas and Silva, 1979) and *M.acanthurus* (Berber, 1984).

Fecundity of *M.malcomsonii* (Rajyalekshmi, 1961; Ibrahim, 1962; Sankolli and Shenoy, 1980) and *M.idella* (Natraj, 1947; Jayachandran, 1984) when compared to *M.rosenbergii* is found to be on a lower side. Cabrera *et al.* (1979) classified the prawns of the genus *Macrobrachium* based on the fecundity and placed *M.rosenbergii* as a species with medium fecundity. *M.americanum* (9,00,000 eggs per year) and *M.carcinus* (10,50,000 eggs per

year) are showing higher fecundity when compared to *M.rosenbergii*. Fecundity of *M.striatus* is found to be on a lower side when compared to its related species, *M.idella*.

The relative fecundity of orange, yellow, grey and black berries showed a gradual decrease commensurate with the progression of maturation though the difference is not statistically significant. Nevertheless, an increasing trend could be seen when grey berry turns to black (Table 4.2). The egg loss during incubation may be the reason for the decreasing trend in the former group while the increasing trend noticed in the black berry might be due to loss in weight of the female in its advanced stage of incubation as a result of diminishing feeding activity. In *M. malcomsonii* a reduction in feeding rate is observed with the progression of maturation of the ovary as a result of increment in the gonadal volume which occupy a major portion of the cephalothorax and after the extrusion of egg it become voracious feeder as evidenced by gorged stomach (Ibrahim, 1962). In the present study also, it could be seen that the total weight of black berried females belonging to different length groups were found to be lower when compared to its counter parts in other groups (Table 4.2). Gonadosomatic index of the black berry of *M.rosenbergii* was also found to be higher when compared to other berried female which would indicate the progression of ovarian development (Fig. 4.9). The ovarian development and consequent reduction in feeding intensity may contribute considerably to the decrease in the body weight and this decrease may account for increase in relative fecundity in black berried female.

The results of ANOVA showed that there is no statistically significant difference in the absolute fecundity and relative fecundity among four maturity stages of berried prawn. It may, therefore, be inferred that under natural conditions though berry loss is taking place during the period of incubation it is statistically not significant among the four types of berried female. This observation is totally at variance with the observation of Ang *et al.* (1991) who reported that 32.3 and 34.3% berry loss during the change of first to second and second to third stage of maturation respectively. This disparity may be due to the variation in size of the berried prawn used for the studies.

An attempt was also made to derive an easily measurable index of fecundity. Among the morphometric parameters studied, total weight, total length and carapace length showed strong positive correlation to fecundity and therefore, can be taken as most reliable and convenient indices of fecundity estimation of *M.rosenbergii*. Indirect estimation of fecundity by resorting to reliable indices is immensely useful for hatchery operation of *M.rosenbergii* as it causes only least disturbance to the mother prawns. Available reports suggest that each gram of berried female can roughly produce 1,000 larvae and berried females of 10-12cm total length normally carry about 10,000- 30,000 eggs (New and Singholka, 1985). On the contrary, the results of the present study showed that eggs per gram body weight of *M.rosenbergii* varied from 378.7 to 1576.5 and the same in respect of millimetre body length ranged from 183.9 to 880.5. It would thus worked out to be an average egg per gram body as 887.75 while the same per millimetre of total length and carapace length were 452.13 and 1624.56 respectively. The average number of eggs computed based on the

equation Log F = log a + b logX, per unit gram body weight was 844.41 while. in unit millimeter of total length, carapace length were 424.07, 1526.75 respectively (Table 4.1) and these computed fecundity values were found to vary only 3.03%, 6.20% and 6.02% respectively from the estimated fecundity. In the case of *M.striatus,* the average relative fecundity observed and estimated with respect to total length, carapace length and total weight showed an error of only 0.59, 2.03 and 2.85 % respectively. It would thus appear that fecundity estimation based on the regression equation derived in the present study is comparable with the directly estimated values.

In *M.rosenbergii,* the length at first maturity of females estimated at 145 mm is very well comparable with that of Rao (1967) from Hooghly estuary. However, Goorah and Parameswaran (1983) reported size at first maturity to be as low as 118 mm from the ponds of Mauritius. First maturity size of *M.striatus* is comparable with that of *M.equidens* (Pillai, 1980; Murthy *et al.*, 1987), *M.acanthurus* (Berber, 1984) and *M.idella* (Jayachandran, 1984).

Table 4.1 Minimum, Maximum, Mean and standard deviation of various morphometric characters and fecundity and the result of regression analysis of fecundity with morphometric characteristics in Macrobrachium rosenbergii

No	Morphometric Characters	Minimum	Maximum	Mean	SD	Result of regression analysis with fecundity			Fecundity per Unit body dimension		
						Regression Constant (a)	Regression Coefficient (b)	Correlation Coefficient (r)	Observed Value	Calculated Value	% Error**
1	Total length (mm)	158	258	211.64	19.63	-0.9449	2.5361	0.6036 *	452.13	424.07	6.21
2	Carapace length (mm)	40	77	58.90	6.77	1.1076	2.1729	0.6382 *	1624.56	1526.75	6.02
3	Rostral length (mm)	60	95	78.14	7.60	0.6345	2.2815	0.5683 *	1224.60	1148.67	6.20
4	Length of Telson (mm)	20	31	24.98	2.34	1.5956	2.4023	0.5685 *	3830.53	3592.89	6.20
5	2nd Pleural Width (mm)	19	32	25.11	2.71	1.9222	2.1655	0.5899 *	3810.70	3578.67	6.09
6	1st Abdomen Diameter (mm)	60	152	95.68	18.31	2.8241	1.0764	0.4986 *	1000.12	945.00	5.51
7	5th Abdomen Diameter (mm)	39	78	58.18	8.25	2.9298	1.1466	0.4132 *	1644.67	1543.52	6.15
8	Length of ischium of 1st cheliped (mm)	10	22	14.54	2.84	3.9716	0.8458	0.4031 *	6580.93	6155.14	6.47
9	Length of merus of 1st cheliped (mm)	16	29	23.10	2.53	2.6819	1.6653	0.4699 *	4142.28	3882.50	6.27
10	Length of carpus of 1st cheliped (mm)	21	38	29.39	3.46	2.7293	1.5146	0.4611 *	3256.09	3052.21	6.26
11	Length of propodus of 1st cheliped (mm)	9	18	13.74	1.95	3.3637	1.4026	0.4918 *	6965.62	6634.61	4.75
12	Length of dactylus of 1st cheliped (mm)	5	7	5.89	0.71	3.9396	1.3154	0.4001 *	16253.90	15220.33	6.36
13	Total length of 1st cheliped (mm)	58	102	80.64	8.78	1.2155	1.9606	0.5482 *	1186.63	1114.08	6.11
14	Length of ischium of 2nd cheliped (mm)	17	38	27.25	3.71	2.7401	1.5429	0.5466 *	3511.44	3306.43	5.84
15	Length of merus of 2nd cheliped (mm)	17	37	28.15	3.72	2.6741	1.5732	0.5396 *	3399.17	3198.46	5.90
16	Length of carpus of 2nd cheliped (mm)	22	46	35.30	4.63	2.7182	1.4444	0.4932 *	2710.67	2547.01	6.04
17	Length of propodus of 2nd cheliped (mm)	31	72	54.03	8.73	3.2337	0.9931	0.4291 *	1770.99	1666.26	5.91
18	Length of dactylus of 2nd cheliped (mm)	15	44	25.79	5.62	3.4234	1.0877	0.5697 *	3710.22	3525.20	4.99
19	Length of 2nd cheliped (mm)	88	185	144.73	18.87	1.6993	1.5066	0.5254 *	661.14	622.07	5.91
20	Brood Pouch Length (mm)	42	88	71.25	8.53	1.7112	1.7505	0.5816 *	1342.97	1263.90	5.89
21	Brood Pouch Width (mm)	12	38	22.79	3.66	3.6323	0.9738	0.4338 *	4198.63	3951.18	5.89
22	Brood Pouch Depth (mm)	18	27	17.35	2.78	3.9831	0.7825	0.3265 *	5515.08	5170.73	6.24
23	Brood Pouch Area (mm)	558	2408	1645.04	394.32	2.5855	0.7382	0.5341 *	58.17	55.40	4.76
24	Brood Pouch Volume (mm)	5880	56700	29186.73	9944.83	2.7587	0.4938	0.5081 *	3.28	3.15	3.96
25	Total Weight (g)	33.7	208	109.89	36.62	3.4272	0.7547	0.6686 *	870.75	844.41	3.02
	Fecundity	30666	227161	95686.68	37015.56	--	--	--			

* Significant at 1% level (P<0.01)

**Percentage error of calculated fecundity on observed fecundity

Table 4.2 Average values of morphometric measurements and relative fecundity in different stages of embryonic development of Macrobrachium rosenbergii

No.	Berry Colour	Number of Observations	Mean Total Length (mm)	Mean Carapace Length (mm)	Mean Total Weight (g)	Mean Absolute fecundity	Relative fecundity Fec./TL *	Relative fecundity Fec./CL *	Relative fecundity Fec./TW *
1	Yellow	21	209.38	57.71	110.93	100174.1	479.41	1735.84	941.1
2	Orange	18	203.39	57.28	96.94	90076.83	429.16	1519.08	929.7
3	Grey	33	219.7	61.21	124.76	101929	458.93	1645.4	834.1
4	Black	8	202.88	56.5	74.48	70779.88	347.84	1244.61	958.6

Table 4.3 Average values of morphometric measurements and relative fecundity in different length groups of Macrobrachium rosenbergii

No.	Length Group	Number of Observations	Mean Total Length (mm)	Mean Carapace Length (mm)	Mean Total Weight (g)	Mean Absolute fecundity	Relative fecundity Fec./TL *	Relative fecundity Fec./CL *	Relative fecundity Fec./TW *
1	150-170	4	165.25	46.75	57.35	60080.5	666.18	2251.68	1047.61
2	170-190	3	182.33	49.33	55.93	49036	268.04	988.1	876.69
3	190-210	29	200.45	55.1	87.4	87268.03	434.2	1579.76	998.49
4	210-230	30	218.67	60.63	118.06	97139.73	444.18	1600.48	822.82
5	230-250	11	234.18	67.73	154.72	111924.1	478.64	1645.2	723.41
6	250-270	3	258	72.67	204	197124.7	746.05	2714.74	966.3

Table 4.4 Average values of morphometric measurements and relative fecundity in different female morphotypes of Macrobrachium rosenbergii

No.	Morphotype	Number of Observations	Mean Total Length (mm)	Mean Carapace Length (mm)	Mean Total Weight (g)	Mean Absolute fecundity	Relative fecundity Fec./TL *	Relative fecundity Fec./CL *	Relative fecundity Fec./TW *
1	WOF **	12	186.5	49.9	62.5	83247.15	445.82	1666.83	1333.22
2	TOF	8	217.3	62.57	125.6	98935.25	453.33	1584.76	786.53
3	SOF	11	210.55	58.46	104.382	96039.27	444.58	1604.8	941.25
4	WBF	33	214.47	60.19	116.98	99611.91	461.04	1638.87	880.19
5	SBF	16	203	55.13	89.71	82441.94	399.64	1470.12	918.26

* - Fec./TL = Relative fecundity with respect to total length
* - Fec./CL = Relative fecundity with respect to carapace length
* - Fec./TW = Relative fecundity with respect to total weight
** WOF - Weak Orange Clawed Female
SOF - Strong Orange Clawed Female
TOF - Trasnforming Orange Clawed Females
WBF- Weak Blue Clawed Female
SBF - Strong Blue Clawed female

Table 4.5 F-ratios obtained on the comparison of relative fecundity in various colours of berry, length groups and morphotypes in Macrobrachium rosenbergii (tested using analysis of variance)

Categories	df	Total length and Fecundity	Carapace length and Fecundity	Total weight and Fecundity
Berry colour	df1=79 df2=3	1.6563+	1.9751+	1.0565+
Length Groups	df1=79 df2=5	4.803 *	4.800 *	2.3549++
Morphotypes	df1=79 df2=4	1.0122+	0.6182+	0.3076+

* - Significant at 5% level (P<0.01)
+ - Not significant (P>0.05)

Table 4.6 F-ratios of the relationship between fecundity and different morphometric variables in different berry colours, length groups and morphotypes in Macrobrachium rosenbergii (tested using analysis of covariance)

Categories	df	Total length and Fecundity	Carapace length and Fecundity	Total weight and Fecundity
Berry colour	df1=79 df2=3	1.0618+	1.7361+	2.6470+
Length Groups	df1=79 df2=5	1.6219+	0.5350+	1.2145+
Morphotypes	df1=79 df2=4	2.0363+	0.6691+	1.7677+

+ - Not significant (P>0.05)

Table 4.7 Minimum, Maximum, Mean and standard deviation of various morphometric characters and fecundity and the result of regression analysis of fecundity with morphometric characteristics in Macrobrachium striatus

No	Morphometric Characters	Minimum	Maximum	Mean	SD	Result of regression analysis with fecundity			Fecundity per Unit body dimension		
						Regression Constant (a)	Regression Coefficient (b)	Correlation Coefficient (r)	Observed Value	Calculated Value	% Error**
1	Total length (mm)	52	80	64.31	7.22	-6.1405	5.3799	0.9183 *	66.36	65.97	0.59
2	Carapace length (mm)	14	24	18.49	2.64	-1.5473	4.0562	0.8530 *	229.42	224.77	2.03
3	Rostral length (mm)	14	25	20.10	2.74	-0.3939	3.0543	0.4780 *	214.72	195.90	8.76
4	Length of Telson (mm)	7	11	8.87	1.30	0.0198	3.7672	0.7690 *	480.24	462.89	3.61
5	2nd Pleural Width (mm)	6	12	8.22	1.40	1.6024	2.1685	0.3257	532.44	470.79	11.58
6	Total length of 1st cheliped (mm)	18	32	24.45	3.53	-1.8461	3.9164	0.8031 *	173.75	168.85	2.82
7	Length of ischium of 2nd cheliped (mm)	6	12	8.08	1.67	1.3488	2.4744	0.5880 *	529.28	493.36	6.79
8	Length of merus of 2nd cheliped (mm)	6	14	10.22	2.21	1.5394	2.0292	0.5909 *	418.11	379.00	9.35
9	Length of carpus of 2nd cheliped (mm)	9	22	14.47	3.36	0.9840	2.2537	0.6738 *	293.83	276.98	5.73
10	Length of propodus of 2nd cheliped (mm)	9	32	20.36	5.15	1.1142	1.9003	0.6411 *	209.62	195.51	6.73
11	Length of dactylus of 2nd cheliped (mm)	4	12	7.34	1.91	2.2130	1.5970	0.4054	594.78	532.65	10.45
12	Length of 2nd cheliped (mm)	33	80	53.13	11.84	-0.3873	2.3092	0.6960 *	79.88	75.13	5.95
13	Length of 3rd walking leg (mm)	21	88	28.10	4.08	-2.1537	3.9652	0.8039 *	151.22	147.44	2.50
14	Length of 4th walking leg (mm)	23	39	28.91	3.95	-2.5579	4.2077	0.8019 *	147.34	143.68	2.48
15	Length of 5th walking leg (mm)	24	39	29.89	3.90	-2.8244	4.3467	0.7794 *	142.86	138.88	2.79
16	Total Weight (g)	1.8807	8.0176	4.0656	1.3984	2.5864	1.6901	0.8455 *	1032.65	1003.26	2.85
	Fecundity	1175	9625	4352.00	1004.00	--	--	--			

* Significant at 5% level (P<0.05)

**Percentage error of observed fecundity on estimated fecundity

Table 4.8 Average value of the morphometric measurements in different length groups of berried females of Macrobrachium striatus

No.	Length Group	n	Mean Total Length (mm)	Mean Carapace Length (mm)	Mean Total Weight (g)	Avarage Fecundity	Fec./TL	Fec./CL	Fec./TW
1	50-55	10	54.29	15.00	2.32	1460.26	26.86	97.23	634.29
2	56-60	8	56.67	16.33	2.88	1995.50	35.07	121.38	687.27
3	61-65	12	61.60	17.42	3.65	3231.69	52.28	184.12	874.89
4	66-70	11	66.95	19.70	4.48	5367.76	80.08	273.18	1209.57
5	71-75	9	71.17	20.55	4.90	6882.78	96.51	332.87	1332.28
6	76-80	8	77.50	22.75	6.77	8894.55	114.65	390.43	1438.39

* - Fec./TL = Relative fecundity with respect to total length
* - Fec./CL = Relative fecundity with respect to carapace length
* - Fec./TW = Relative fecundity with respect to total weight

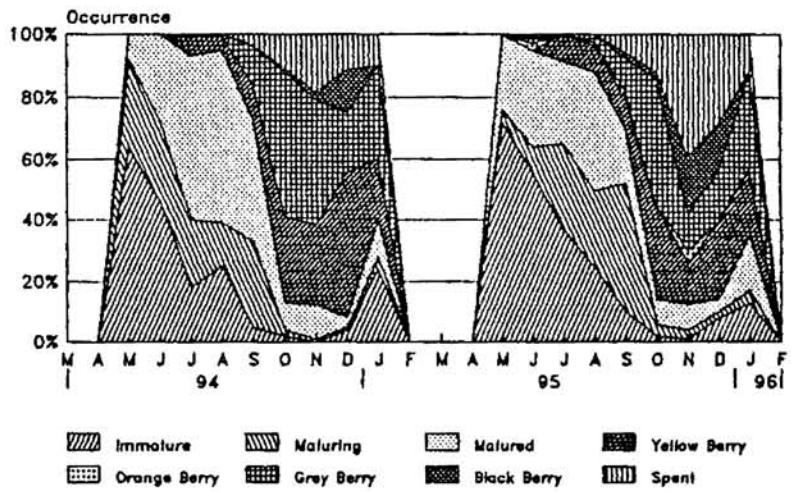


Fig. 4.1 Seasonal variation of maturity stages in *Macrobrachium rosenbergii* (Female) of Vembanad lake

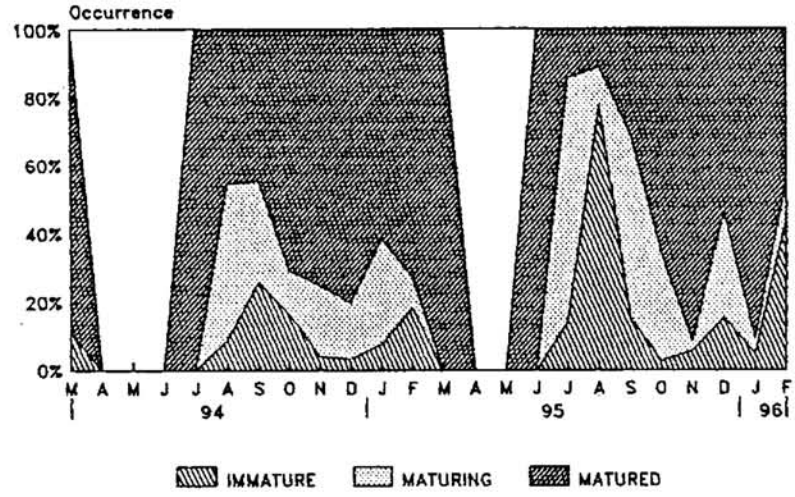


Fig. 4.2 Seasonal variation of maturity stages in *Macrobrachium striatus* (Male) of Vembanad lake

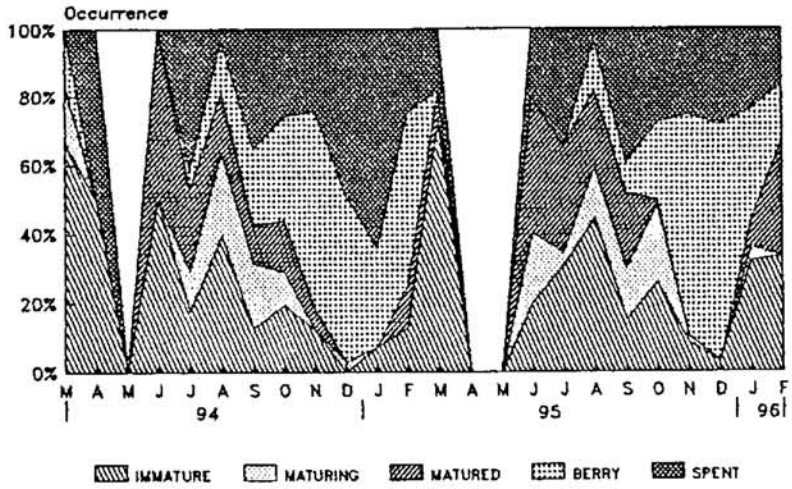


Fig. 4.3 Seasonal variation of maturity stages in *Macrobrachium striatus* (Female) of Vembanad lake

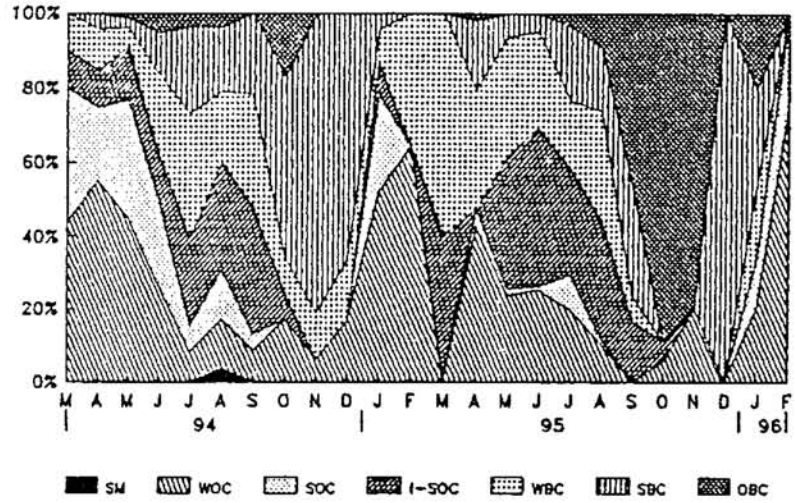


Fig. 4.4 Seasonal variation in the percentage occurrence of male morphotypes of *Macrobrachium rosenbergii* and their transitional stages in Vembanad lake

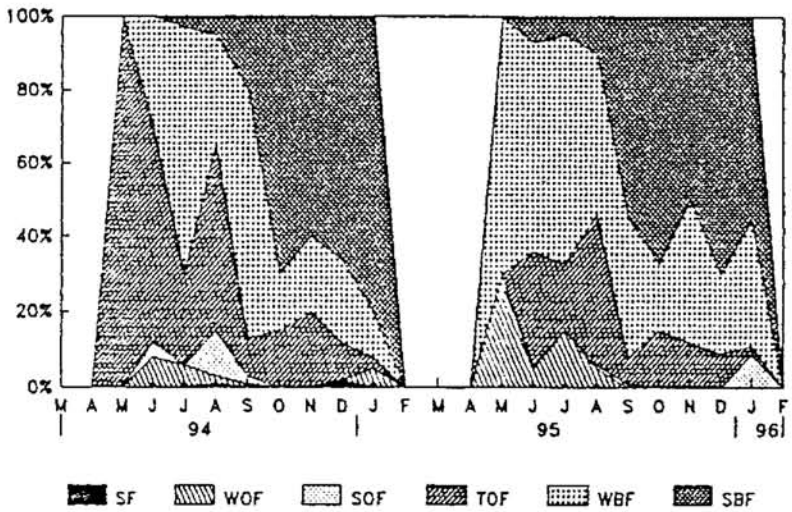


Fig. 4.5 Seasonal variation in the percentage occurrence of female morphotypes of *Macrobrachium rosenbergii* and their transitional stages in the Vembanad lake

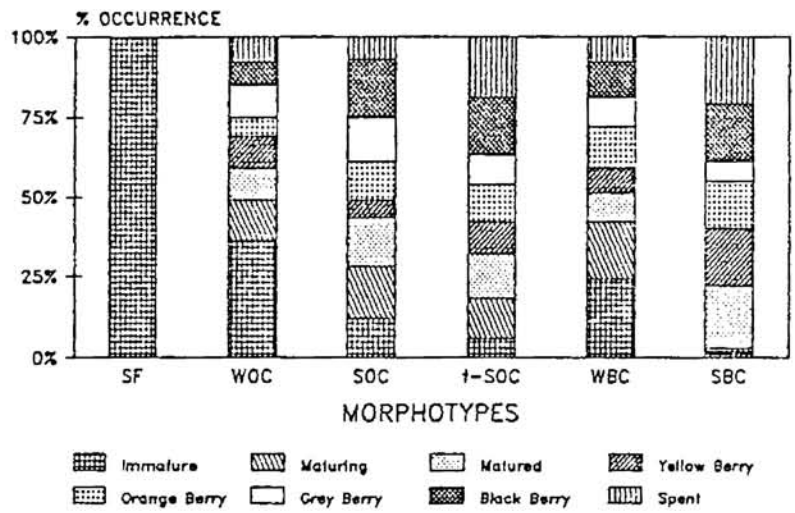


Fig. 4.6 Maturity stages in different female morphotypes of *Macrobrachium rosenbergii*

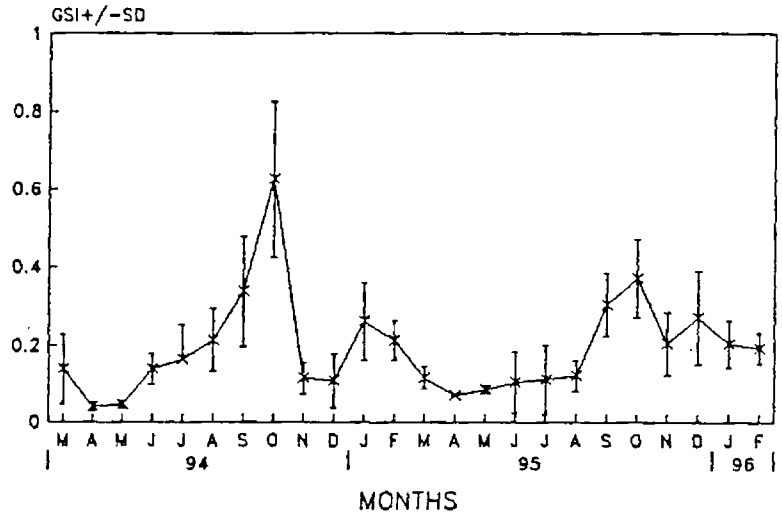


Fig. 4.7 Variation in the gonadosomatic index of *Macrobrachium rosenbergii* (Male) in Vembanad lake

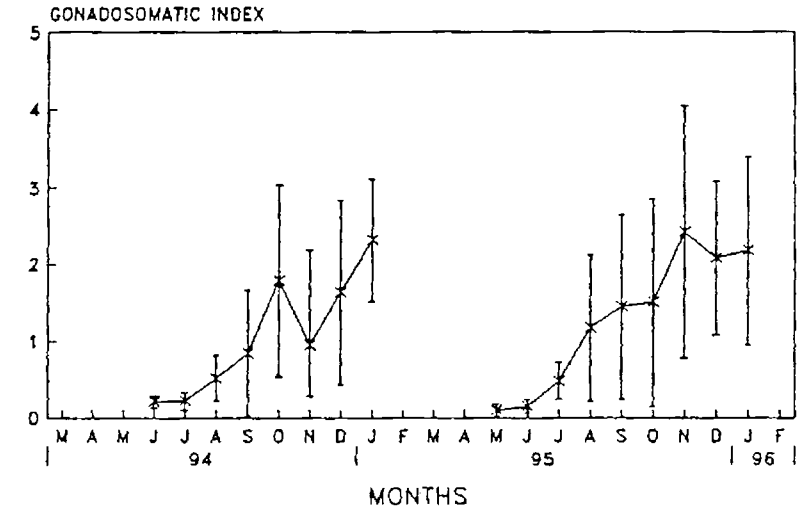


Fig. 4.8 Variation in the gonadosomatic index of *Macrobrachium rosenbergii* (Female) in Vembanad lake

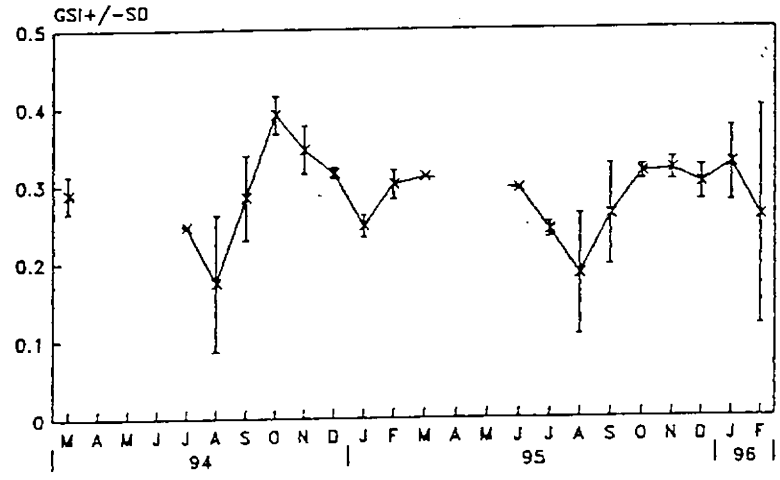


Fig. 4.9 Variation in the gonadosomatic index of *Macrobrachium striatus* (Male) in Vembanad lake

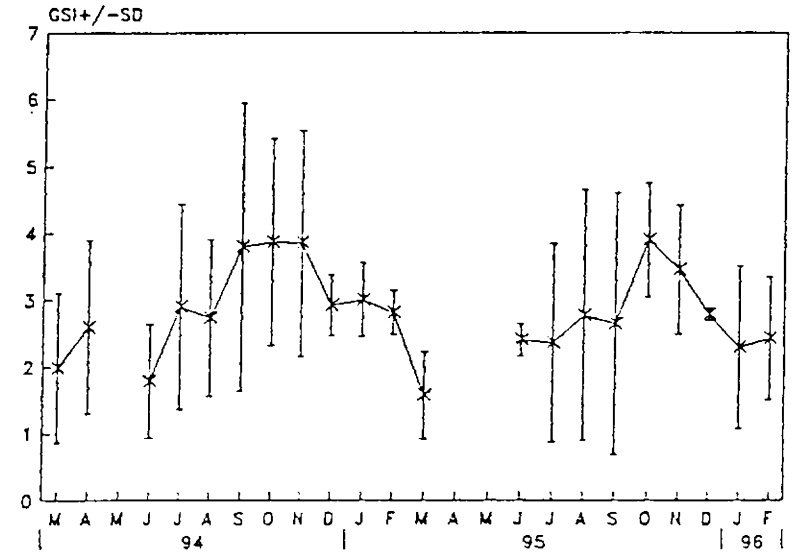


Fig. 4.10 Variation in the gonadosomatic index of *Macrobrachium striatus* (Female) in Vembanad lake

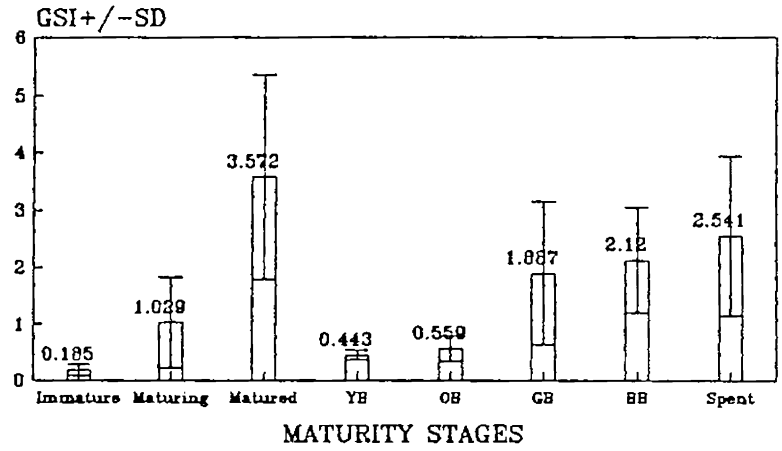


Fig. 4.11 Variation in gonadosomatic index in various maturity stages of *Macrobrachium rosenbergii* (Female)

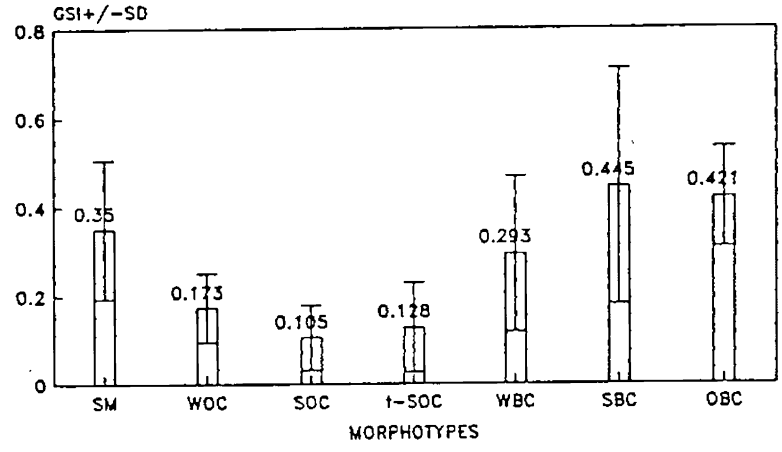


Fig. 4.12 Variation in gonadosomatic index in male morphotypes of *Macrobrachium rosenbergii*

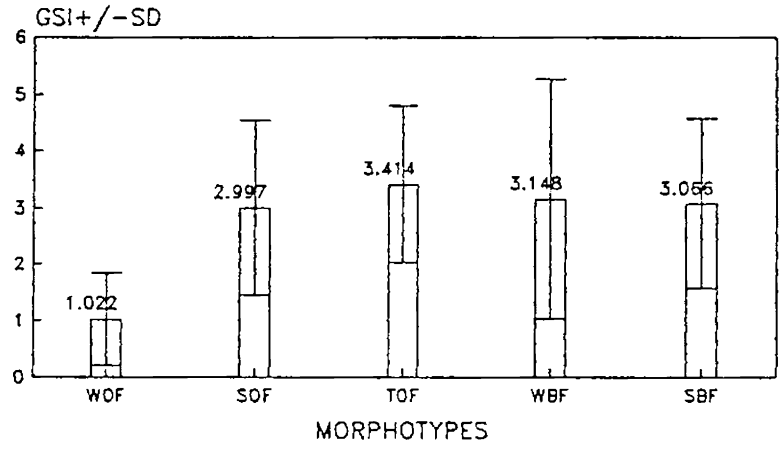


Fig. 4.13 Variation in gonadosomatic index in female morphotypes of *Macrobrachium rosenbergii*

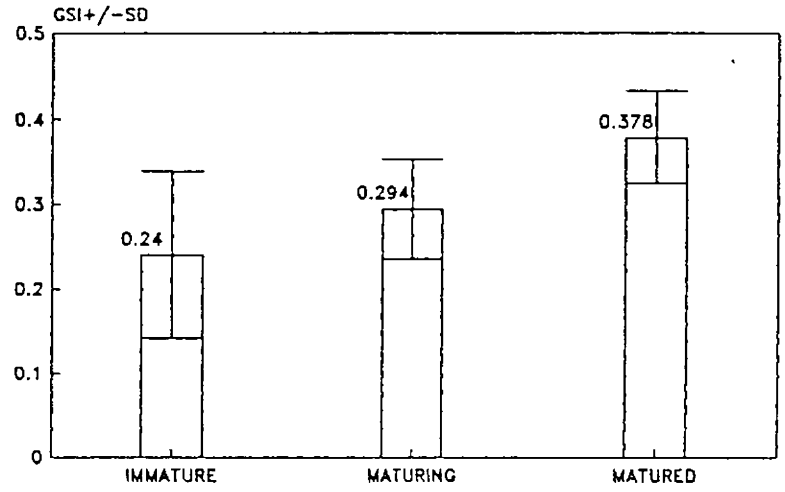


Fig. 4.14 Variation in gonadosomatic index in various maturity stages of *Macrobrachium striatus* (Male)

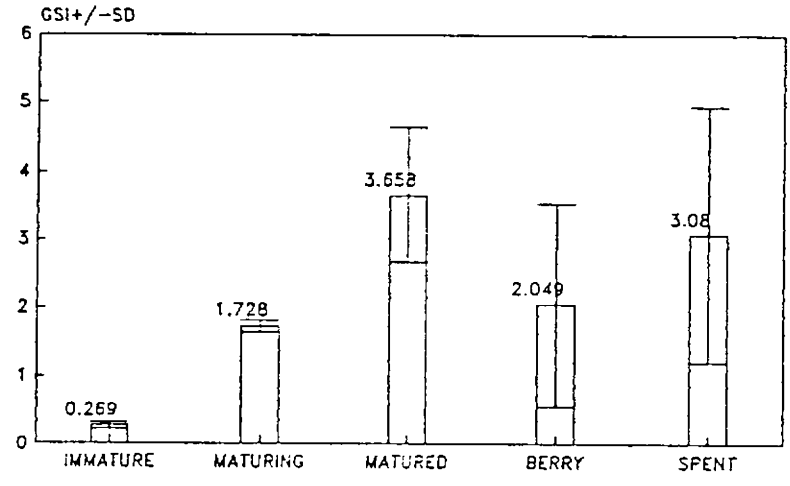


Fig. 4.15 Variation in gonadosomatic index in various maturity stages of *Macrobrachium striatus* (Female)

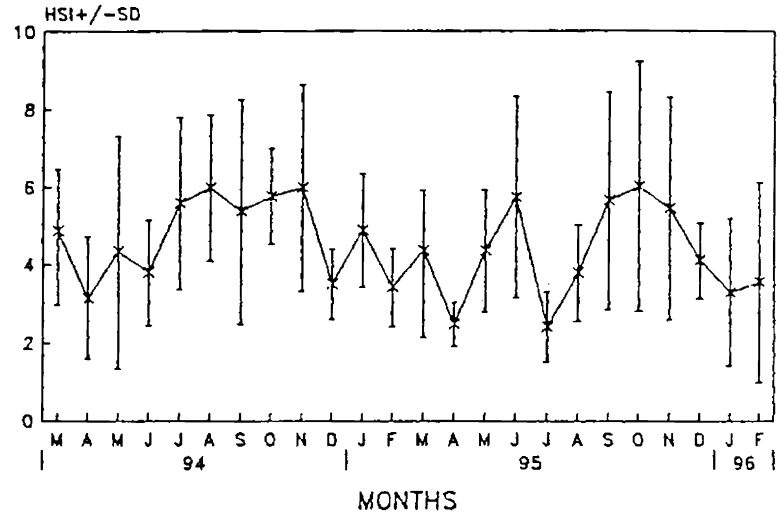


Fig. 4.16 Variation in the hepatosomatic index of *Macrobrachium rosenbergii* (Male)

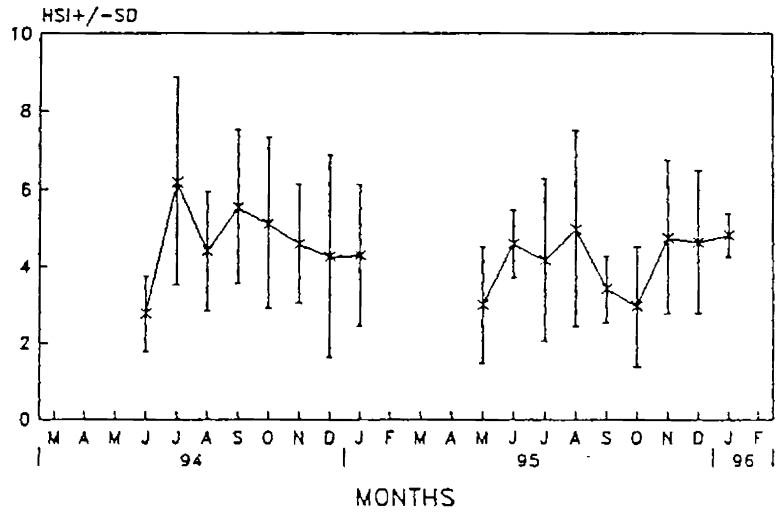


Fig. 4.17 Variation in the hepatosomatic index of *Macrobrachium rosenbergii* (Female)

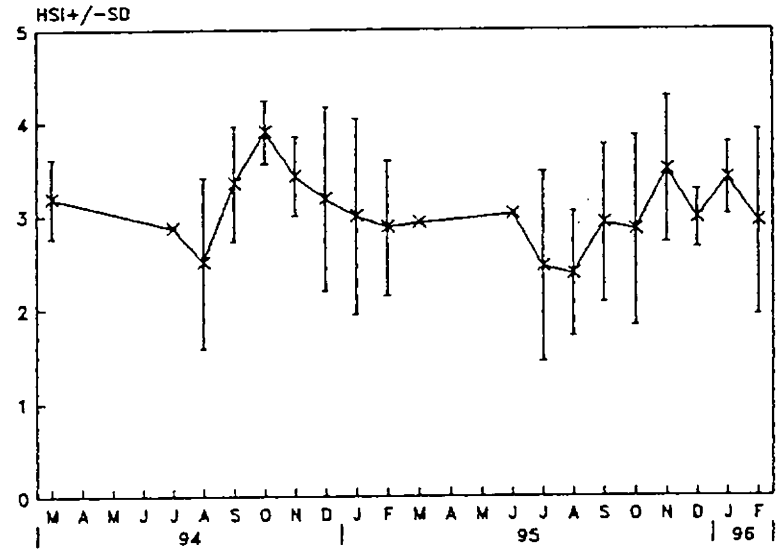


Fig. 4.18 Variation in the hepatosomatic index of *Macrobrachium striatus* (Male)

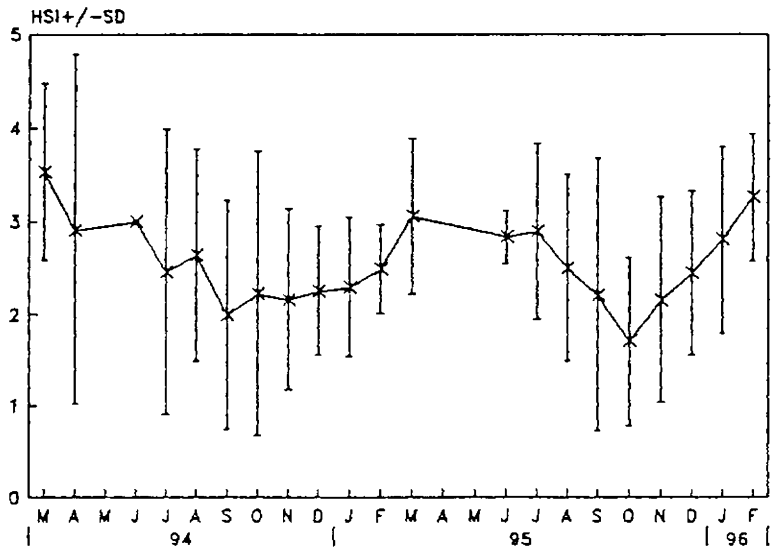


Fig. 4.19 Variation in the hepatosomatic index of *Macrobrachium striatus* (Female)

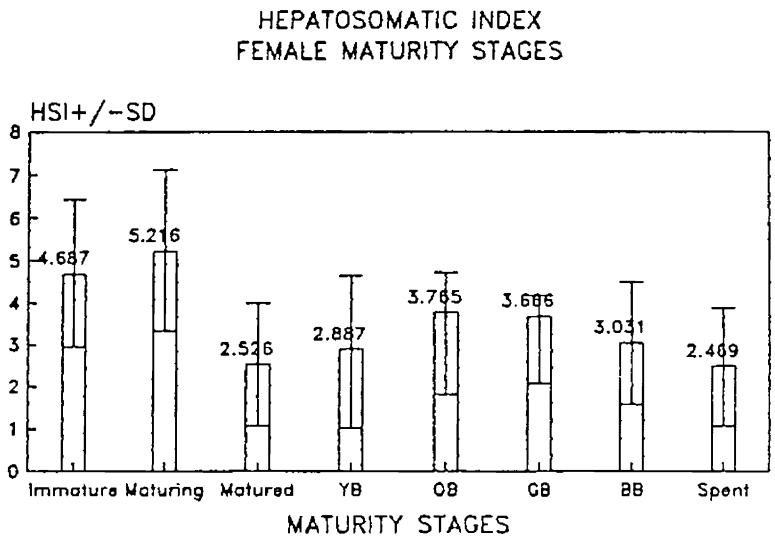


Fig. 4.20 Variation in hepatosomatic index in various maturity stages of *Macrobrachium rosenbergii* (Female)

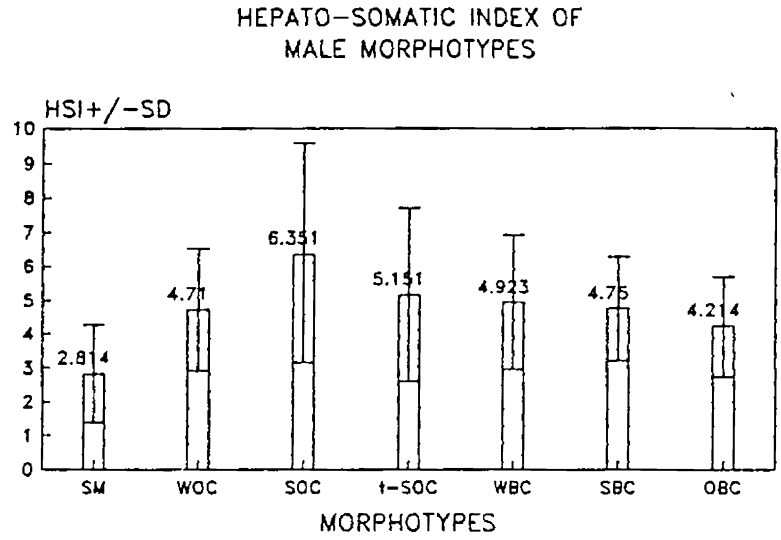


Fig. 4.21 Variation in hepatosomatic index in male morphotypes of *Macrobrachium rosenbergii*

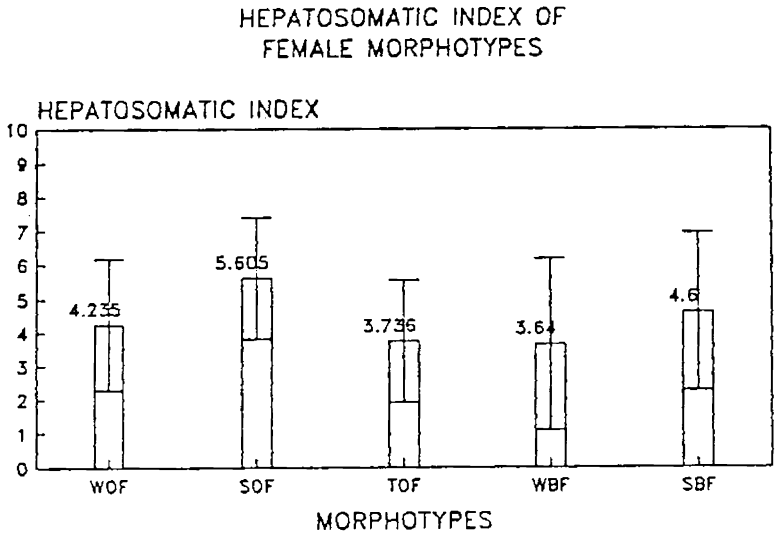


Fig. 4.22 Variation in hepatosomatic index in female morphotypes of *Macrobrachium rosenbergii*

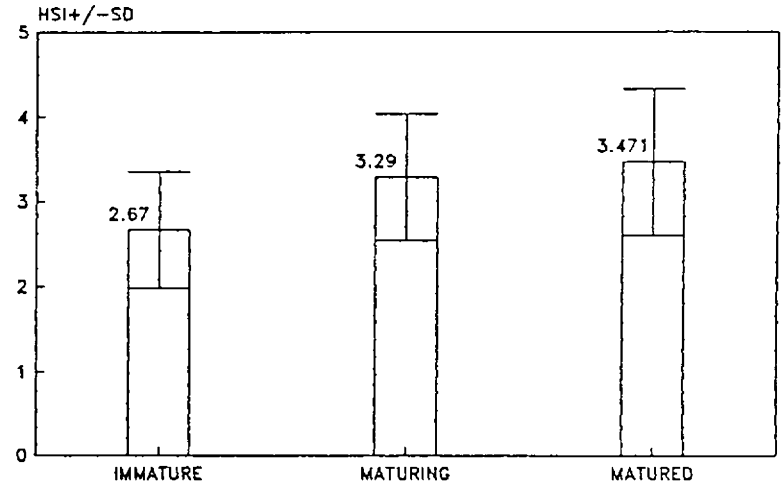


Fig. 4.23 Variation in hepatosomatic index in various maturity stages of *Macrobrachium striatus* (Male)

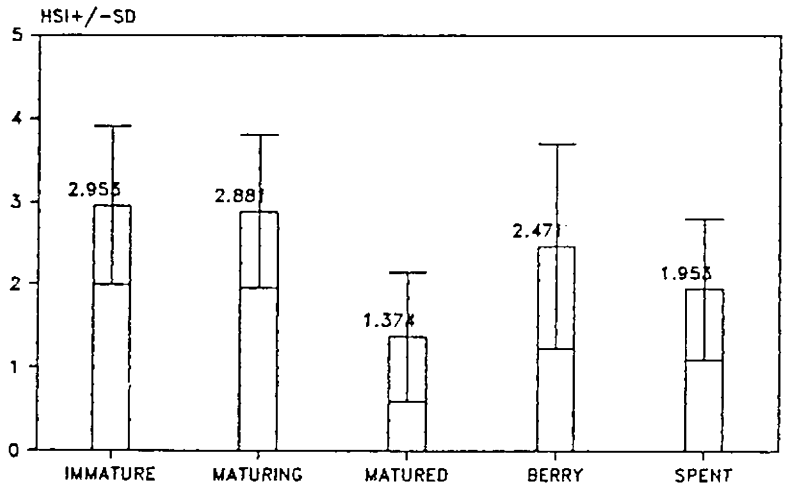


Fig. 4.24 Variation in hepatosomatic index in various maturity stages of *Macrobrachium striatus* (Female)

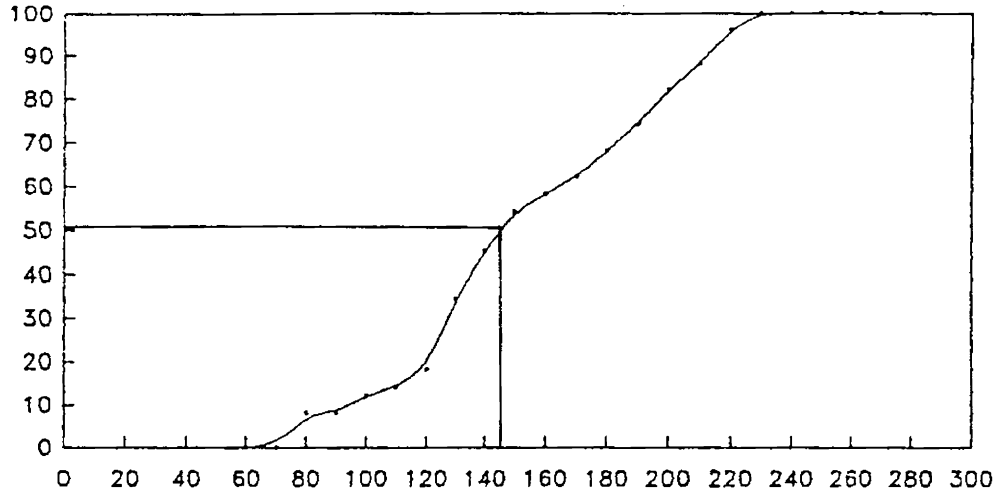


Fig. 4.25 Size at first maturity of *Macrobrachium rosenbergii* (Female)

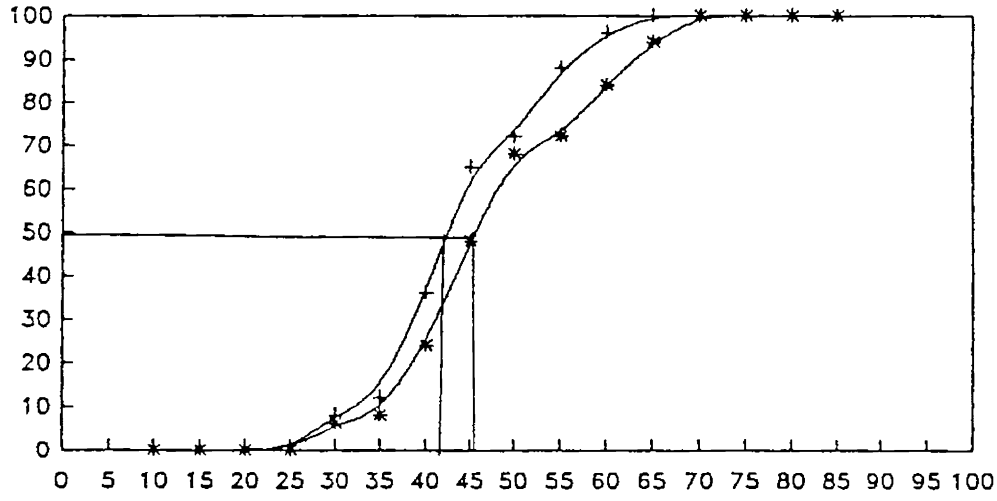
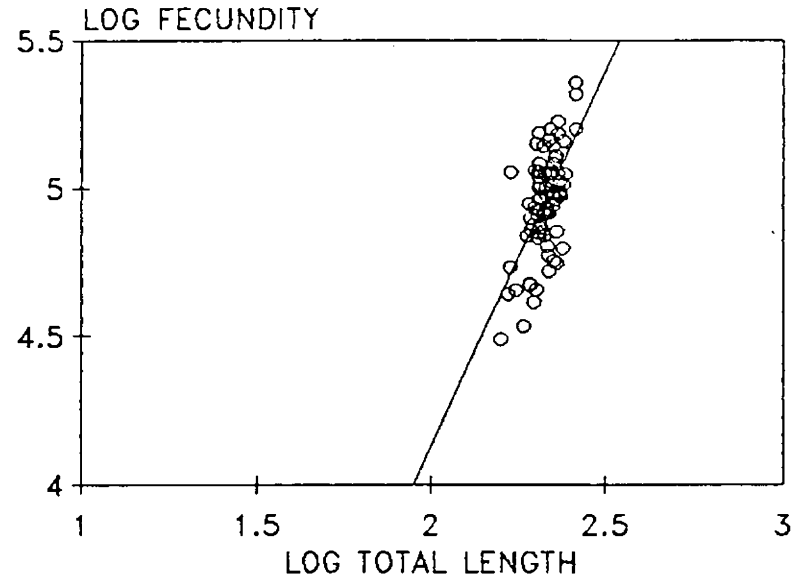
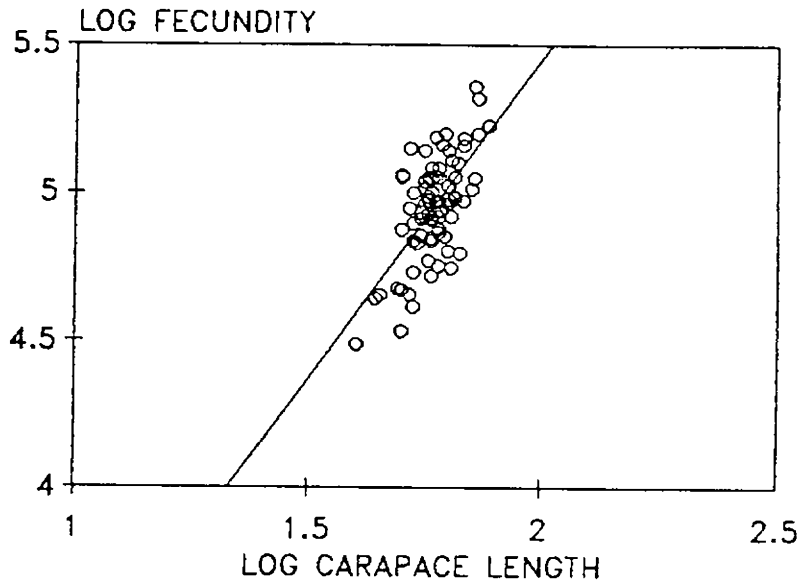


Fig. 4.26 Size at first maturity of *Macrobrachium striatus* (Male and Female)





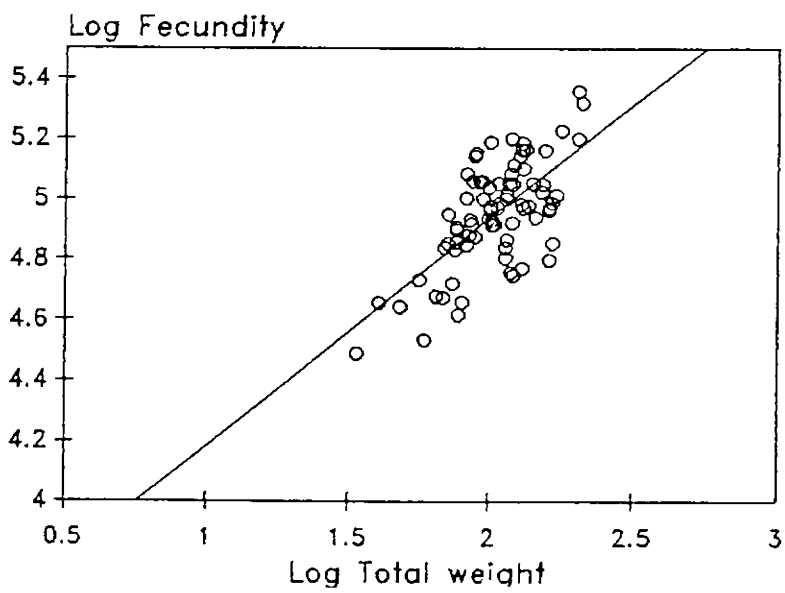
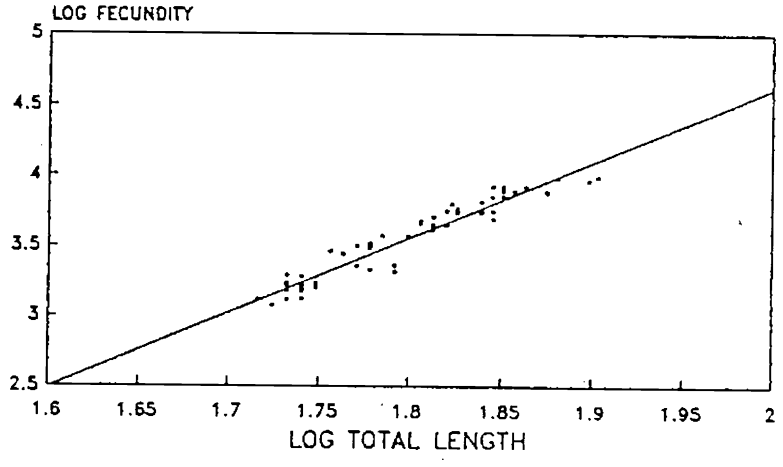
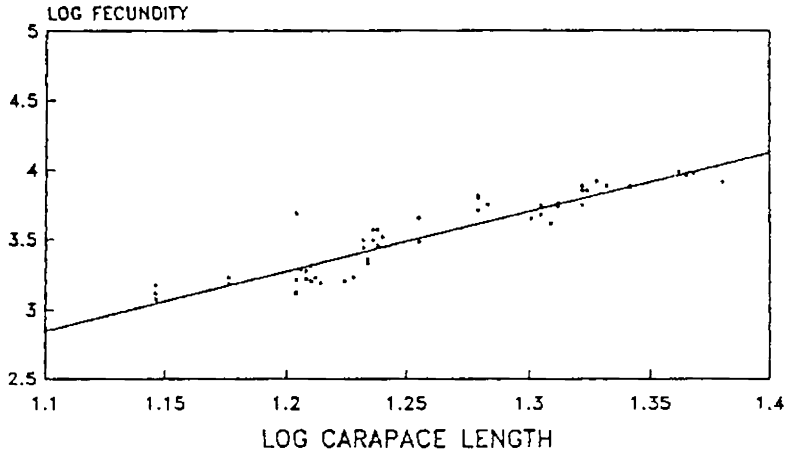


Fig. 4.27 Relationship between total length (a), carapace length (b) and total weight (c) to fecundity in *Macrobrachium rosenbergii*





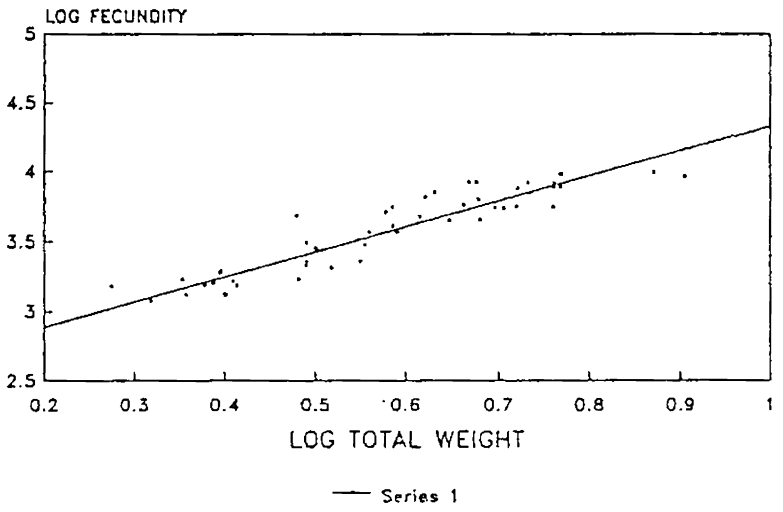


Fig. 4.28 Relationship between total length (a), carapace length (b) and total weight (c) to fecundity in *Macrobrachium striatus*

Chapter 5

Breeding migration and sex ratio of *Macrobrachium rosenbergii* and *M.striatus*

Introduction

The dwindling nature of *M.rosenbergii* in the Vembanad lake in recent years can solely be attributed to the impact of human interventions in the ecosystem which brought about severe alterations in its natural habitat (Kurup *et al.*, 1992a). Exposure to estuarine environment with salinity 12-14 ppt is essential for the completion of larval metamorphosis of *M. rosenbergii* and thereafter post larvae undertake a return migration to the riverine region (Ling and Merican, 1961). Upstream and downstream migrations of a species would be an adaptive advantage for getting specific salinity for the reproduction and subsequent development (Hughes and Richard, 1973; Sastry, 1983). Many of the *Macrobrachium* spp. needed estuarine condition for the successful development of the larvae (Raman, 1967; Ling, 1969a; Rao, 1967; Lee and Fielder, 1979; Natividad, 1982; Read, 1983; Pandian, 1987; Gamba, 1987). *M.striatus* is often present in saline regions and a specific migratory pattern has not been so far established in the earlier studies (Pillai, 1990a). Rao (1967)and Jinadasa (1985) reported breeding migration of *M.rosenbergii* in Hooghly estuary and Bolgoda lake, Sri Lanka respectively. *M.malcomsonii* on the other hand is categorised as a larval migrant and performs no migration for breeding in Godavari estuary, however, the larvae reach the estuarine zone by the water currents (Ibrahim, 1962). Upstream migration of juveniles of *M.malcomsonii* and *M.scabriculus* recorded in Godavari river (Ibrahim, 1962).

Though there is a wealth of information is available on the breeding migration of palaemonid prawns from natural waters, however, information giving

emphasis to the quantification and characterisation of breeding stock are totally lacking. In the present context of dwindling nature of the natural resources of *M.rosenbergii* due to the man-made stress imposed to the ecosystem, particularly in the obstruction caused to the downwardly migrating breeding stock and upwardly migrating juveniles. A concerted study to delineate the effect of salinity barrier on the breeding migration is highly warranted. Therefore, an attempt is made to study the pattern of migration of *M.rosenbergii* and *M.striatus* in the Vembanad lake giving due emphasis to

1. the effect of temperature and salinity on the breeding migration of *M.rosenbergii* and *M.striatus.*
2. delineate the sex specific differential migration of *M.rosenbergii* and *M.striatus*
3. study the impact of the salinity barrier on the downwardly migrating spawning stock of *M.rosenbergii.*
4. study the characteristics of the migratory stock of *M.rosenbergii* viz. length frequency and morphotypic composition etc.

Materials and Methods

The Vembanad lake was apportioned to three regions such as river proper (5 km stretch each of Pampa, Meenachil and Muvattupuzha adjoining the lake), upstream (area south of bund where saline water rarely intrude) and downstream (northern part of bund having wide salinity fluctuations) regions based on prevailing ecological characteristics (for details please refer Section 1.). The exploited stock of *M. rosenbergii* from various fishing gears were observed during March 1994 to February 1996 from three stations each from the above three regions. The fishing activity of each station was observed for a period of 24 hr. and the catches from not

less than 30% of total units were examined at fishing ground itself. As regards *M.striatus* catches were observed from 10 'padals' to enumerate the number of males and females. Specimens so collected were segregated sex wise and morphotype wise following Kuris *et al.* (1987) and Harikrishnan and Kurup (1997a) and their number was noted giving due emphasis to numerical strength of berried prawns in the catches. Total length of the specimens were also recorded to the nearest millimetre for assessing length frequency distribution. A total of 2196 males and 3055 females of *M.rosenbergii* and 202 males and 261 females of *M.striatus* were observed. The data of *M.striatus* has recorded only from a single station and therefore length frequency was not attempted. Apart form the data presented in the 2rd chapter the temperature and salinity recorded from the stations corresponding to the sampling sites were pooled and presented in this chapter. Migration of the stock was assessed on the basis of appearance of males and females in different regions of the lake. Chi-square analysis was carried out to assess the variation if any, in sex ratio from that of hypothetical value 1:1 (Snedecor and Cochran, 1967).

Results

Variations in salinity and temperature in various regions of the lake are shown in Fig. 5.1. Temperature was very high during April to May while the lowest values were recorded during June to August commensurate with monsoon showers. Maximum salinity recorded from the upstream region was only 8 ppt. In downstream region salinity varied from 20.0 to 28.6 ppt during April-May period whereas with the onset of monsoon it was reduced to less than 5 ppt in most of the stations.

A specific pattern in the seasonal availability of *M.rosenbergii* could be discernible in all the three regions (Table 5.1 to 5.3; Fig. 5.2). Males dominated in the population up to June-July periods in all the regions and thenceforth females dominated in the exploited stock (Table 5.1 to 5.3; Fig. 5.2). A regular occurrence of males of *M.rosenbergii* could be discernible in the upstream region whereas, in

riverine region the appearance was almost round the year except in March 1994 and November 1995. Presence of females was found restricted during May-June to December-January periods in riverine and upstream regions. Appearance of both males and females of *M.rosenbergii* was found restricted during May- December in downstream region. Numerical occurrence of males and females together were high in upstream region in contrast, dominance of female in downstream region during October-November periods was quite discernible.

Highest number of females were present in riverine region in August 1994 followed by September 1994 in upstream and October 1994 in downstream regions. which would suggest a gradual downward shift of stock from riverine to downstream regions (Fig.5.2). Similar trend could also be discernible in the second year. On the contrary, in males, such a specific pattern could not be delineated. Males were invariably more in the upstream region when compared to riverine and downstream regions (Table 5.1 and 5.3). A decrease in the population size of *M.rosenbergii* in upstream region during September to December could be discernible while a corresponding increase in the downstream region was quite discernible.

Chi-square analysis of sex ratio of *M.rosenbergii* did not show significant ($P>0.05$) variation from the hypothetical ratio 1:1 in the months of September 1994, November 1994, January 1995 and October 1995 to February 1996 in riverine region and this may be due to the smaller population size (Table 5.1). Whereas, in July 1994, August 1995 and October 1995 the sex ratio showed no significant variation from hypothetical value despite the population size was large. Eventhough a predominance of males could be noticed in riverine region on an annual basis, however, the sex ratio did not skewed significantly ($P>0.05$) (Table 5.1). Whereas, both in upstream and downstream regions of the lake, sex ratio showed significant difference ($P<0.001$) from the hypothetical ratio on an annual basis. The test of heterogeneity of sex ratio showed that monthly variation in sex ratio was significant in different regions of the Vembanad lake (Table 5.1 to 5.3).

The appearance of berried females could be registered from June-July to December-January periods, with a distinct peak during September to November. A specific pattern in downward movement of the berried prawns could not be delineated, however an aggregation of berried prawns in the upstream and downstream regions could be discernible (Fig. 5.3).

Length frequency distribution of males and females of *M.rosenbergii* from the three regions of the lake are shown in Fig. 5.4. Interestingly, in females the size distribution was found to be uniform in all the three regions with a distinct mode at 200-219 mm whereas, in males the 180-199 mm size group dominated in the exploited stock. However, percentage representation of larger males were relatively high in the catches from riverine and down stream regions when compared to upstream region. Among the various male morphotypes, blue clawed morphotypes dominated in upstream region in contrast to downstream region (Fig. 5.5). The presence of small males (SM) could only be encountered from downstream and upstream regions. Berries could be encountered in all the female morphotypes and therefore, it can reasonably be asserted that they are reproductively active. Weak blue clawed females (WBF) dominated in the upstream region against strong blue clawed females (SBF) in the downstream as well as riverine regions.

Very few specimens of *M.striatus* could be collected during April to June in both the years and it was virtually absent in May 1994 as well as April and May 1995. A clear predominance of females in almost all the months except October 1994, January, March, November 1995 and February 1996 was observed. Sex ratio did not skewed from the hypothetical ratio in most of the months (Table 5.4). However, overall sex ratio varied significantly with a clear predominance of females. Berried females of *M.striatus* first appeared in the month of July in 1994- 95 and August in 1995-96 and its availability showed an increase up to January in former year and December in the latter(Fig. 4.3).

Discussion

Fluctuations noticed in the temperature and salinity following a definite pattern in consonance with the prevailing climatic conditions in the present study fully agree with the earlier reports (Josanto 1971; Kurup and Samuel, 1987; KWBSP, 1989). The salinity was as high as 28 ppt was recorded in upstream region before the commissioning of the salinity barrier (Raman, 1967) and therefore the upstream region served as the breeding ground of this species. In contrast, highest salinity recorded during the present study was only 8 ppt. It would thus appear that the upstream region of the lake can no longer serve as the breeding ground of this species due to the drastic reduction seen in the salinity profile and therefore, *M.rosenbergii* is compelled to undertake a lengthy downward breeding migration to Cochin Backwaters during September- December periods. Similar observation were also made by Kurup *et al.* (1992a). Sastry (1983) opined that ecological factors have a profound influence on the breeding migration of crustaceans.

A sudden increase in the availability of males from March to May in different regions of the lake would suggest the commencement of breeding migration of *M.rosenbergii* from upper stretches of rivers to the lake which was immediately followed by females in June-July period. Predominance of females could be observed in upstream region from June and subsequently berried prawns started appearing in this region. Thereafter, a sudden increase in number of both non berried as well as berried females in the downstream regions of the lake were discernible and these findings would suggest the downward migration of females especially that of berried prawns. Pandian (1987) classified *M. rosenbergii* as an adult migrant, in which adults migrate to the brackish water region for spawning, on the contrary, adults of *M.malcomsonii* do not migrate down the estuaries and the larvae were brought to saline area by the currents. Foremost occurrence of males of *M. rosenbergii* in the breeding ground was reported by Rao (1967) from Hooghly estuary. Movement

shown by the female of *M.rosenbergii* is comparable with the movement of *M.petersi* in which the downward movement is along with the flood water and upward movement coincided with the elevation of salinity (Read, 983)

The results of the present study showed that females evinced a distinct migratory pattern on the contrary, a small proportion of the male population was only migrating far down to the breeding ground. Results of the Chi-square analysis also supports this finding. In riverine region, the sex ratio was not varying significantly, while, significant variation due to out numbering of females could be noticed in upstream and downstream regions of the lake. It may, therefore be inferred that in *M.rosenbergii* mating takes place in riverine and upstream regions of the lake and the impregnated and berried females may undertake migration down to the low saline regions of the lake.

Obstructions caused to the downward migration of breeding stock as well as the return migration of the post larvae due to human interventions are attributed as the major conjunctures for the dwindling nature of the natural resource of *M. rosenbergii* in the Vembanad lake (Kurup *et al.*, 1992a; Harikrishnan and Kurup, 1997b). Alteration in salinity due to the construction of dam in Purari in the deltaic region of Gulf of Papua was found to affect the crustacean fishery resources including *M. rosenbergii* (Frusher, 1983). Carlander (1980) suggested over fishing and water hyacinth as the major factors for the dwindling of fishery resources in Rawa Pening lake, Central Jawa. Similar reasoning can be made for the depletion of stock of *M.rosenbergii* in Vembanad lake also. Jinadasa (1985) reported that 100 and 60% of the total female landed are berried in major and minor peak of fishing respectively in the Bologoda lake, Sri Lanka.

Highest water temperature was recorded during April-May coincided with the commencement of breeding migration of males of *M.rosenbergii*, in contrast, females started downward migration with the onset of south west monsoon which corresponds with the decrease of water temperature. As there is no salinity intrusion into the river

system ever since the commissioning of the salinity barrier and therefore it can be asserted that temperature may play a key role in triggering the breeding migration rather than salinity. Raman (1967) also opined that temperature governs the breeding migration of *M.rosenbergii* in the Vembanad lake. Return migration of the adults was found to be coincided with the elevation in salinity and therefore it can reasonably asserted that the return migration was influenced by salinity. Absence of *M.rosenbergii* in estuarine region with a corresponding elevation in salinity has already been reported earlier (Raman, 1967; Rao, 1967). Read (1983) also reported the return migration of *M.petersi* from the estuaries due to the rise in salinity.

The possibility of return migration of *M.rosenbergii* from the downstream region to the Pampa river system is quite doubtful as the salinity barrier is kept closed by December. Correspondingly, in downstream region, presence of berried females could be observed up to December. Both males and females of *M. rosenbergii* was found to be virtually absent in the downstream region after December, however, its availability was noticed from the Muvattupuzha river in December-January. It is quite possible that due to the closure of the salinity barrier in December a portion of the prawns trapped in the down stream region may migrate to freshwater region through Muvattupuzha river whereas, females which had already been negotiated the barrier and reached the upstream region may further ascent to the river Pampa. Upstream region of the lake offers an ideal dwelling ground for *M.rosenbergii* as there is no high salinity intrusion due to the closure of the barrier. An year round occurrence of *M. rosenbergii* could be observed from this region and a corresponding absence in the riverine region would suggest the existence of a resident stock in the upstream region. Raman (1967) observed a resident stock in the upper reaches of the Pampa river where salinity seldom intruded before the commissioning of the salinity barrier. A similar situation might have been created now in the upstream region where the salinity seldom raises beyond 8 ppt.

The result of the present study revealed that in riverine region males and

females of *M.rosenbergii* occur in almost equal numbers without any significant variation from the hypothetical sex ratio. Whereas, in upstream and downstream regions the sex ratio varies considerably and this may be due to the combined effect of differential migration and varying fishing intensity imposed on the stock. Kurup *et al.*(1992a) reported an insignificant variation in sex ratio of *M.rosenbergii* in Vembanad lake, however, this trend could be seen only in the riverine region during the present study. On the contrary, while examining the total population females showed a clear preponderance (male : female 1:1.39) over its male counterpart and the result of Chi-square analysis also showed that the variation is significant (χ^2=139.46; P<0.005). This finding is similar to that of Rao (1967) who reported the predominance of females in the exploited stock of Hooghly estuary.

Percentage occurrence of blue clawed males of *M.rosenbergii* which is sexually active was higher in riverine and downstream regions when compared to upstream region. The overall sex ratio was around 1:1 in upstream and riverine regions, whereas the sex ratio varied considerably in downstream region with a predominance of females. Percentage occurrence of old blue clawed males (OBC) was higher at riverine region and this finding shows similarity with Raman (1967). The reproductively submissive weak orange clawed males (WOC) (Fig 4) and males belonging to smaller size group (<180 mm) (Fig. 3) were also registered in adequate numbers from the upstream region. It may be inferred that WOC might have migrated from the riverine region to upstream region, during when they have undergone morphotypic transformation to a reproductively active morphotype and thereafter they might have either migrated further down along with females or returned to riverine regions. Weak blue clawed females (WBF) and strong blue clawed females (SBF) together constitute a major portion of the female stock and their frequent presence in the downstream region couples with a higher percentage occurrence of berry among them would suggest that they may be the sexually more active female morphotype of *M.rosenbergii*.

The occurrence of males and females of *M.striatus* during June to March in lower stretches of estuaries indicate its breeding season and it is found to coincide with the monsoon and post monsoon. Occurrence of berried females of *M.striatus* was reported from Cochin backwaters from July to October (Pillai, 1990b). Whereas occurrence for a longer period extending from July to January could be noticed in the present study. Predominance of females in the Kumbalam station would suggest that females migrate downstream to facilitate the successful development of the larvae. As the animals could be collected round the year from only one station the present data base is too inadequate to delineate the migratory pattern of *M.striatus*.

Table 5.1 Sex ratio of Macrobrachium rosenbergii recorded from the riverine region of Vembanad lake.

Month	Male	Female	M : F	Chi-square	Prob.
March 94	0	0			
April	19	0	1 : 0.00	19.00	P<0.005
May	20	0	1 : 0.00	20.00	P<0.005
June	90	1	1 : 0.01	87.04	P<0.005
July	17	22	1 : 1.29	0.64	
August	18	53	1 : 2.94	17.25	P<0.005
September	5	6	1 : 1.20	0.09	
October	16	42	1 : 2.63	11.66	P<0.005
November	5	5	1 : 1.00	0.00	
December 94	6	21	1 : 3.50	8.33	P<0.005
January 95	3	5	1 : 1.67	0.50	
February	5	0	1 : 0.00	5.00	
March	10	0	1 : 0.00	10.00	P<0.005
April	69	0	1 : 0.00	69.00	P<0.005
May	75	1	1 : 0.01	72.05	P<0.005
June	139	29	1 : 0.21	72.02	P<0.005
July	94	35	1 : 0.37	26.98	P<0.005
August	33	47	1 : 1.42	2.45	
September	16	135	1 : 8.44	93.78	P<0.005
October	13	18	1 : 1.38	0.81	
November	0	0			
December 95	2	0	1 : 0.00	2.00	
January 96	2	0	1 : 0.00	2.00	
February	7	0	1 : 0.00	2.00	
Total	664	420	1 : 0.63	3.20	

Heterogeneity		df	Chi-Sqaure	
Sum of Chi-squares	=	24	522.62	
Pooled Chi- squares	=	1	3.20	
Heterogeneity		23	519.42	P<0.005

Table 5.2 Sex ratio of Macrobrachium rosenbergii recorded from the upstream region of Vembanad lake.

Month	Male	Female	M : F	Chi-square	Prob.
March 94	50	0	1 : 0.00	50.00	P<0.005
April	146	0	1 : 0.00	146.00	P<0.005
May	153	1	1 : 0.01	150.03	P<0.005
June	63	10	1 : 0.16	38.48	P<0.005
July	153	80	1 : 0.52	22.87	P<0.005
August	78	167	1 : 2.14	32.33	P<0.005
September	14	267	1 : 19.07	227.79	P<0.005
October	20	134	1 : 6.70	84.39	P<0.005
November	9	111	1 : 12.33	86.70	P<0.025
December 94	2	52	1 : 26.00	46.30	P<0.025
January 95	19	5	1 : 0.26	8.17	P<0.025
February	19	0	1 : 0.00	19.00	P<0.025
March	2	0	1 : 0.00	2.00	
April	1	0	1 : 0.00	1.00	
May	80	2	1 : 0.03	74.20	P<0.005
June	137	2	1 : 0.01	131.12	P<0.005
July	91	57	1 : 0.63	7.81	P<0.001
August	75	83	1 : 1.11	0.41	
September	16	153	1 : 9.56	111.06	P<0.005
October	13	118	1 : 9.08	84.16	P<0.005
November	1	0	1 : 0.00	1.00	
December 95	3	4	1 : 1.33	0.14	
January 96	2	3	1 : 1.50	0.20	
February	1	0	1 : 0.00	1.00	
Total	1148	1249	1 : 1.09	4.26	P<0.05

Heterogeneity		df	Chi-Sqaure	
Sum of Chi-squares	=	24	1326.14	
Pooled Chi- squares	=	1	4.26	
Heterogeneity		23	1321.88	P<0.005

Table 5.3 Sex ratio of Macrobrachium rosenbergii recorded from the downstream region of Vembanad lake.

Month	Male	Female	M : F	Chi-square	Prob.
March 94	0	0		0.00	
April	0	0		0.00	
May	23	0	1 : 0.00	23.00	P<0.005
June	37	30	1 : 0.81	0.73	
July	79	70	1 : 0.89	0.54	
August	14	65	1 : 4.64	32.92	P<0.005
September	6	40	1 : 6.67	25.13	P<0.005
October	6	274	1 : 45.67	256.51	P<0.005
November	5	227	1 : 45.40	212.43	P<0.005
December 94	0	47	0 : 47.00	47.00	P<0.005
January 95	0	0		0.00	
February	0	0		0.00	
March	0	0		0.00	
April	0	0		0.00	
May	46	2	1 : 0.04	40.33	P<0.005
June	63	74	1 : 1.17	0.88	
July	71	24	1 : 0.34	23.25	P<0.005
August	14	38	1 : 2.71	11.08	P<0.005
September	13	111	1 : 8.54	77.45	P<0.005
October	6	288	1 : 48.00	270.49	P<0.005
November	0	88	0 : 88.00	88.00	P<0.005
December 95	1	3	1 : 3.00	1.00	
January 96	0	5	0 : 5.00	5.00	P<0.05
February	0	0		0.00	
Total	384	1386	1 : 3.61	567.23	P<0.005

Heterogeneity		df	Chi-Sqaure	
Sum of Chi-squares	=	24	1115.76	
Pooled Chi- squares	=	1	567.23	
Heterogeneity		23	548.53	P<0.005

Table 5.4 Sex ratio of Macrobrachium striatus recorded from Vembanad lake.

	Males	Females	M:F	Chi-Square	Prob.
Apr 94	0	2		2.00	
May	0	0		0.00	
Jun	0	2		2.00	
Jul	1	17	1:17	14.22	P<0.01
Aug	6	22	1:3.67	9.14	P<0.01
Sep	18	20	1:1.11	0.11	
Oct	21	18	1:0.86	0.23	
Nov	12	15	1:1.25	0.33	
Dec 94	10	16	1:1.6	1.38	
Jan 95	18	13	1:0.72	0.81	
Feb	5	6	1:1.2	0.09	
Mar	9	6	1:0.67	0.60	
Apr	0	0		0.00	
May	0	0		0.00	
Jun	1	5	1:5	2.67	
Jul	7	13	1:1.86	1.80	
Aug	9	12	1:1.33	0.43	
Sep	11	24	1:2.18	4.83	P<0.05
Oct	18	18	1:1	0.00	
Nov	20	18	1:0.9	0.11	
Dec 95	15	9	1:0.6	1.50	
Jan 96	9	10	1:1.11	0.05	
Feb	11	4	1:0.36	3.27	
Mar 96	1	11	1:11	8.33	P<0.01
	202	261	1:1.29	7.52	P<0.01

Heterogeneity	df	Chi-square	
Sum of Chi-Square	24	53.90	
Pooled Chi-Square	1	7.52	
Heterogeneity	23	46.38	P<0.01

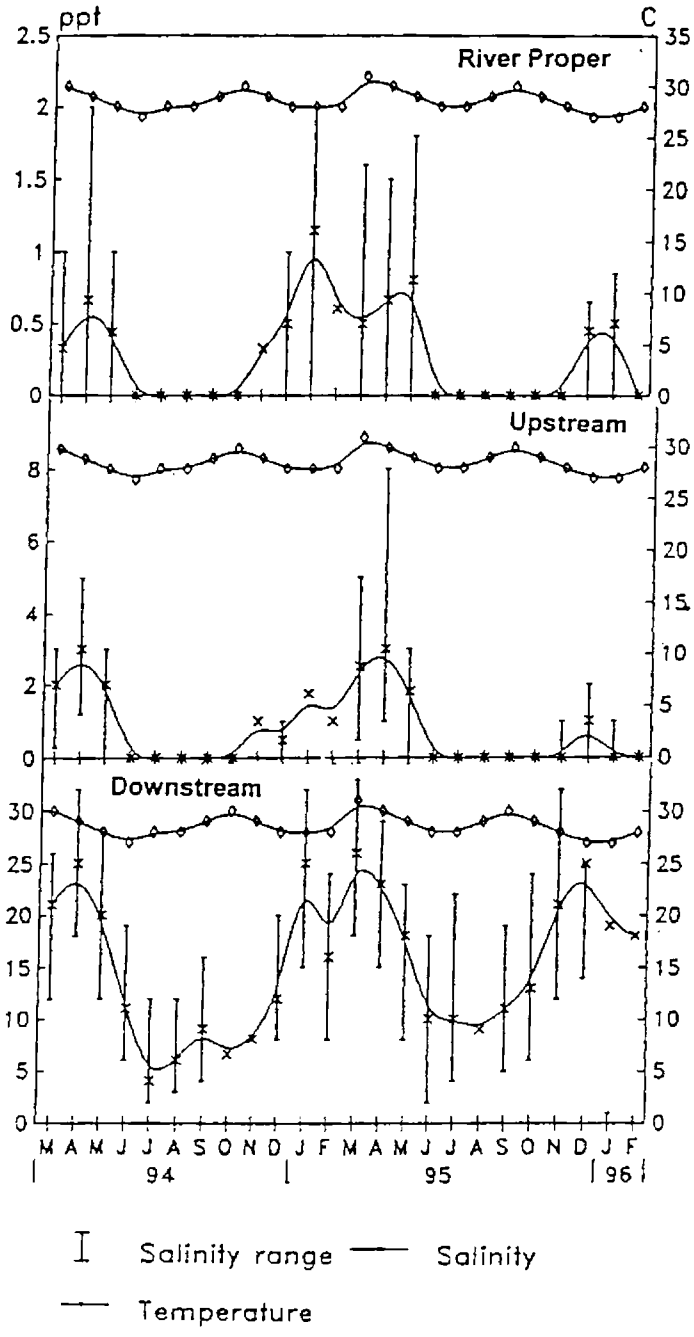


Fig. 5.1 Pattern of distribution of temperature and salinity in three regions of the lake

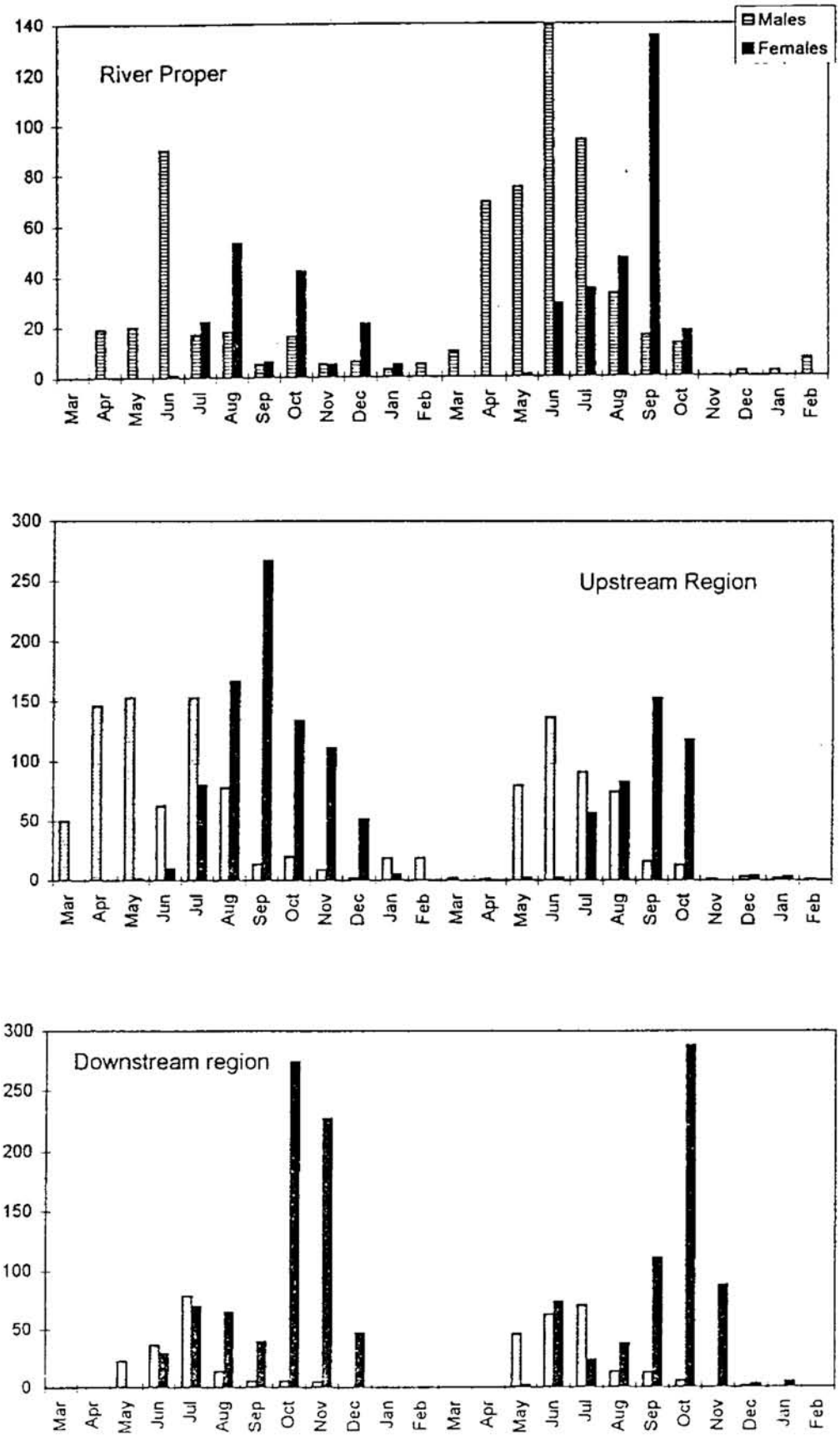


Fig. 5.2 Number of males and females of *Macrobrachium rosenbergii* collected from different regions of the lake during March 94- February 96.

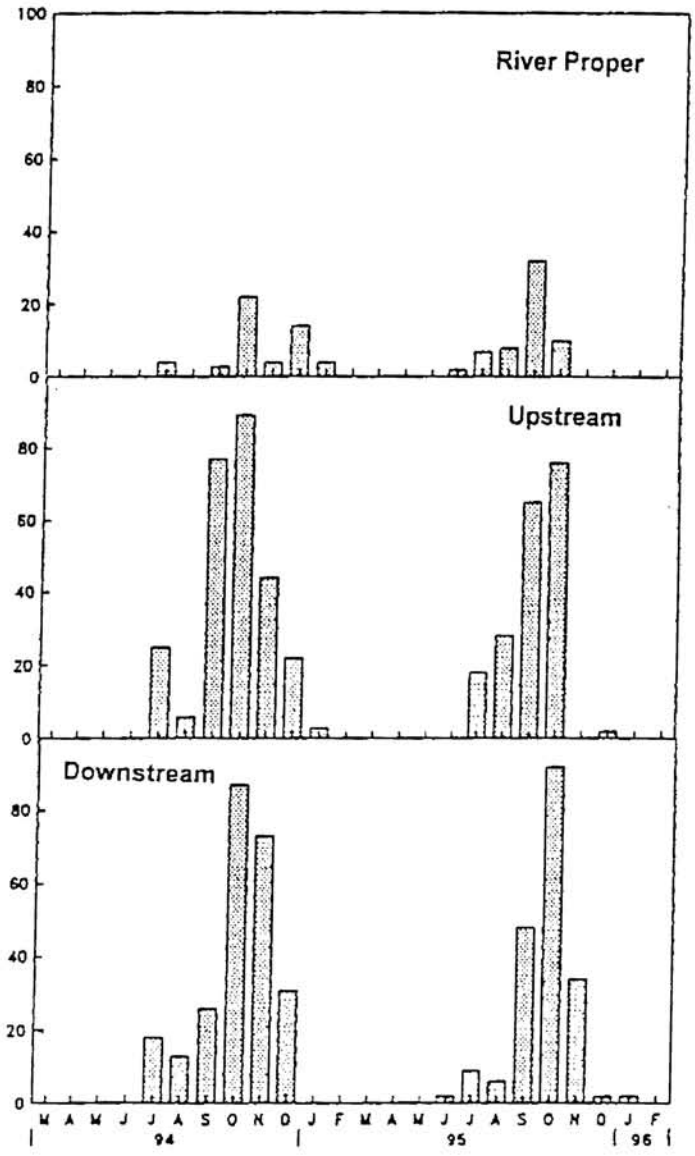


Fig. 5.3 Monthly occurrence of berried females of *Macrobrachium rosenbergii* in the exploited stock of Vembanad lake

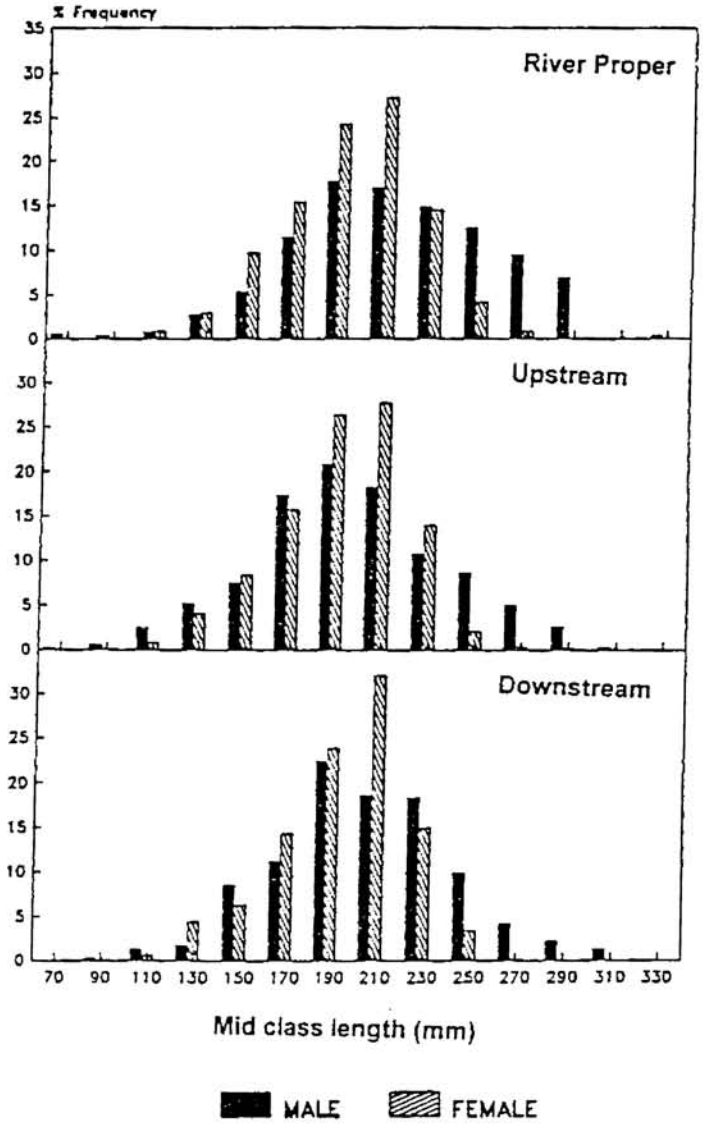


Fig. 5.4 Length frequency distribution of males and females of *Macrobrachium rosenbergii* in three regions of Vembanad lake

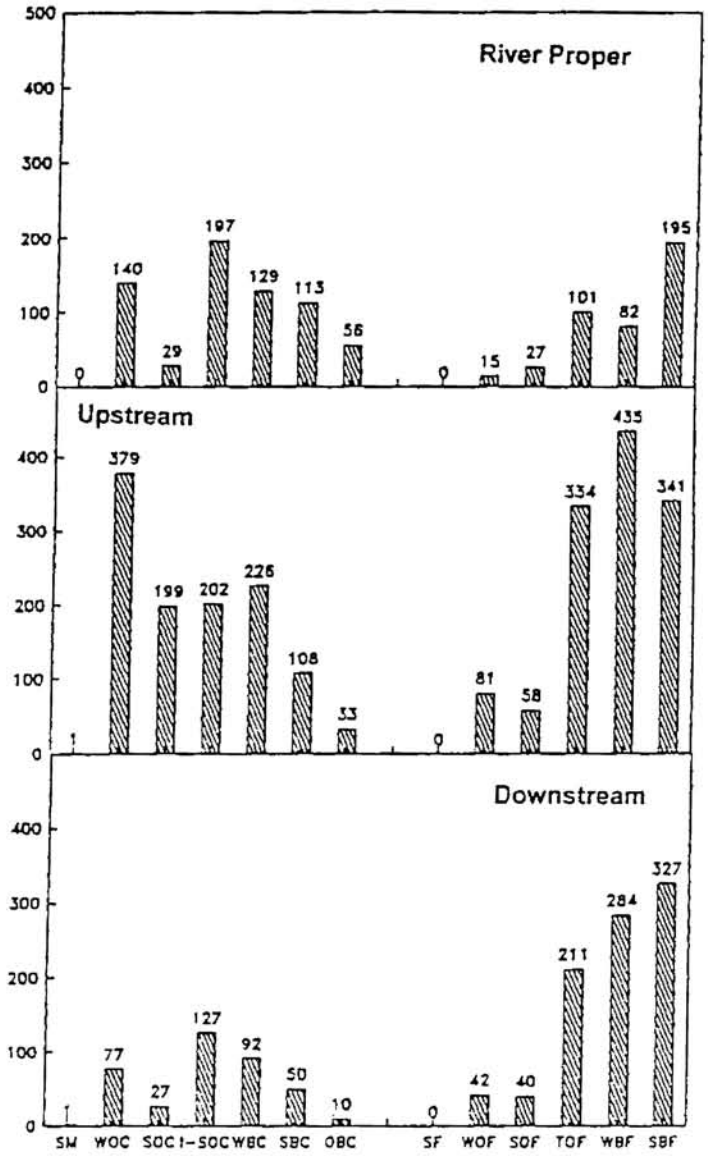


Fig. 5.5 Numerical abundance of different male and female morphotypes of *Macrobrachium rosenbergii* in three regions of Vembanad lake

Chapter 6

Biochemical Characterisation of Male Morphotypes of *Macrobrachium rosenbergii* (De Man)

Sexually mature male population of *Macrobrachium rosenbergii* belonging to same age group has been differentiated into three distinct morphotypes such as Small Males (SM), Orange Clawed Males (OC) and Blue Clawed Males (BC) representing three phases in the developmental pathway of males (Brody *et al.*, 1980; Cohen *et al.*, 1981). Besides, the two transitional stages of both OC and BC are also distinguishable from the fully differentiated males (Kuris *et al.*, 1987; Harikrishnan and Kurup, 1997a). A review of literature showed that no concerted attempt has so far been made to evaluate the biochemical variation if any, taking place in these morphotypes commensurate with the change in phases of reproduction and somatic growth as shown by these morphotypes, though the biochemical aspects of *M. rosenbergii* were studied by Maugle *et al.* (1980), Rubbi *et al.* (1985), Ghosh and Ray (1992), Sherief *et al.* (1992) and Sherief and Xavier (1994). Therefore, an attempt was made to explain the biochemical basis of morphotypic differentiation seen in male population of *M.rosenbergii*. Similar studies in female morphotypes of *M.rosenbergii* has not been attempted as there is no report assigning them to either reproductive or somatic growth phases as in the case of male morphotypes. Sarojini *et al.* (1982, 1985) and Mirajkar *et al.* (1983) studied the biochemical aspects of *M.kistnensis* with respect to reproductive stages while Joseph *et al.* (1991) studied the same in *M.idella* in relation to different biotypes.

Materials and Methods

Prawns for the present study were collected from a polder based monoculture grow out of *M. rosenbergii* situated adjoining to the Vembanad lake on the day of harvest. The samples from the culture system were collected to ensure the uniformity in age and sampling of morphotypes were done based on the existing information (Brody *et al.*, 1980; Cohen *et al.*, 1981;Kuris *et al.*, 1987; Harikrishnan and Kurup, 1997a). The specimens so collected were transported to the laboratory in live condition and segregated into different morphotypes (Kuris *et al.*, 1987; Harikrishnan and Kurup 1997a). Length and weight of different morphotypes were measured (Table 6.1) and specimens were sacrificed and muscle and hepatopancreas were taken for analysis, whereas, each samples of testes were collected from three specimens. A weighed portion of the sample was kept in a hot air oven at temp.70^{0}C (Sherief *et al.*, 1992) and dried to constant weight in order to determine the moisture content. Protein (Micro- Kjeldahl's Method), carbohydrates and lipids were estimated following AOAC (1976), Heath and Barnes (1970) and Folch *et al.* (1957) respectively. RNA and DNA were extracted from the tissues and estimated using following procedure of Schneider (1957). 0.5 g sample was homogenised in 2.5 ml 10% TCA, centrifuged and the residue so obtained was washed once with 2.5 ml TCA. The final residue after removal of acid soluble compounds was extracted twice with 5 ml 95% ethanol and centrifuged. The lipid free tissue residue was suspended in 1.3 ml of water and 1.3 ml of 10% TCA and the mixture was heated for 15 min at 90 ^{0}C and centrifuged. In order

to estimate DNA, 1 ml of the nucleic acid extract was mixed with 2 ml diphenyl amine reagent and heated for 10 min in boiling water bath and absorbency was read at 600 nm along with standard (Calf thymus DNA). Whereas in the case of RNA,0.5 ml of nucleic acid extract was diluted to 5 ml and heated with 5 ml Orcinol reagent and absorbency was read at 660 nm. The results of the biochemical studies were analyzed statistically using ANOVA and t-test (Snedecor and Cochran, 1967).

Results

a) Muscle tissue

The mean values of protein, carbohydrates, lipids, DNA, RNA and RNA/DNA ratios estimated from the body muscle tissue of different morphotypes are given in Table 6.2. Results of analysis of variance showed that there was significant difference ($P<0.01$) in protein, DNA, and RNA contents of muscle among various male morphotypes (Table 6.2). Highest values of DNA and RNA were recorded in SOC and t-SOC on the contrary, least was in WBC and SM. Results of pair-wise analysis showed that muscle protein and DNA contents of orange clawed male SOC and its transitional stage, t-SOC showed significant difference from that of Blue Clawed male (SBC) and the transitional stages of latter viz. WBC and OBC (Table 6.5). On the contrary, no significant difference could be seen in the muscle protein content of SM with other morphotypes studied (Table 6.5).

b)Hepatopancreas

Mean values of various biochemical constituents estimated from the hepatopancreas of male morphotypes of *M.rosenbergii* are presented in Table 6.3. In general, the moisture and protein content were found to be lower in hepatopancreas than in muscle, but the lipid content was higher. Results of ANOVA showed that there was significant difference ($P<0.05$) in carbohydrate and RNA contents of hepatopancreas in various morphotypes (Table 6.3). Carbohydrate levels in the hepatopancreas of SM showed significant difference from that of SOC, t-SOC and WBC and similar results could be seen between SOC and SBC as well as t-SOC and SBC (Table 6.5). t-SOC also showed significant difference in RNA content of the hepatopancreas with that of SM and SBC. Similarly, SOC and SBC were also found to differ significantly with regard to carbohydrate content of hepatopancreas (Table 6.5).

c) Gonads

Higher values of protein and lipids were recorded in SBC while the carbohydrates values were high in t-SOC (Table 6.4). RNA content in gonads of WBC and SBC was very high, on the contrary, lower values could invariably be observed in SM, WOC and SOC. Results of the ANOVA revealed that DNA and RNA content of the gonads of male morphotypes showed significant difference ($P<0.01$) (Table 6.4). SM showed significant difference in gonadal RNA content with all other morphotypes (Table 6.5). Similarly RNA content of gonads of WOC also differed significantly from all other morphotypes except SOC. RNA content of gonads of SOC showed significant difference with all the

three BC morphotypes, whereas t-SOC showing significant difference only with WBC (Table 6.5).

Discussion

In the present study, the protein content in the muscle of different morphotypes was found varying from 16.2 to 20.3% and this in comparison to Sherief *et al.* (1992) is lower. Significant differences in protein, DNA and RNA content of muscle in various morphotypes may serve as an index of difference in cellular activity (Lemmens, 1995) which would manifest the possibilities of heterogeneous growth rates in various morphotypes of *M. rosenbergii* as reported by Kuris *et al.* (1987). RNA content can be directly related to the protein synthesis (Ikeda, 1989). Interestingly among male morphotypes studied, high protein and RNA values were observed in the muscle tissue of SOC and this manifest the possibilities of higher rate of protein synthesis. The same has been recorded in the case of juvenile spider crab, *Hyas araneus* (Anger and Hirche, 1990). Similarly, muscle DNA content was also higher in SOC and t-SOC which fully corroborates with the observations of Bulow (1970) and Anger and Hirche (1990) who reported that increase of DNA can well be taken as an indication of faster growth rate of fishes and crustaceans. Among the various morphotypes, SOC and its transitional stages are reported to be the fastest growing animals (Karplus *et al.*, 1987; Kurup et al., 1997a) and the highest protein, RNA and DNA content of the body muscle recorded in this morphotypes fully explain the biochemical basis of the above biological manifestation exhibited by SOC.

Mean values of protein, DNA and RNA content in muscle tissue were found to be lower in SM, which occupies the initial stage of morphogenetic pathway. Growth of SM is also reported to be very slow as they convert a large part of their energy for mating attempts using a sneak mating behaviour (Teleckey, 1984; Ra'anan and Sagi 1985). In BC morphotypes and its transformation stages, protein, DNA and RNA values were found to be increasing gradually. Ghosh and Ray (1992) observed 1.242 mg/100 mg and 0.51 mg/ 100 mg RNA and DNA respectively in muscle tissue of *M. rosenbergii* and this in comparison with the present study is on a higher side. This difference may be attributed to the stages of maturity of the animal used for the study. Anger and Hirche (1990) also observed a decrease in RNA-DNA ratio with the advancements of developmental stages in crabs. However, in the present study RNA-DNA ratio in the muscle of male morphotypes did not show any specific pattern commensurate with the stages of morphogenesis as observed by Anger and Hirche (1990).

Though the lipid content in muscle, hepatopancreas and gonads does not show remarkable difference among the morphotypes, the values were low in SM and thereafter gradually increasing trend commensurate with the advancement of developmental pathway could be discernible. An exception to this trend was in WBC, in which lipid was found to be less when compared to t-SOC and SBC, and this finding would lend to support the possibility of an alternative transformation pathway from SM to WBC as proposed above. SM showed changes in regard to colouration similar to that of BC when it was

maintained with females in the absence of a dominant BC male (Sureshkumar and Kurup, 1998) and this finding will also support the above inference. Sherief *et al.* (1992) reported lower values of lipids in stunted males and this finding fully conform to the present observation.

Hepatopancreas plays a significant role in the food assimilation and mobilization of energy during moulting, pigmentation, gluconeogenesis and carbohydrate storage (Dall and Moriarty, 1983; Skinner, 1985; Ghidalia, 1985). Significant variations ($P<0.05$) in carbohydrate level and RNA content of the hepatopancreas observed in the present study will lend support the difference in growth, pigmentation and relative size of hepatopancreas among various male morphotypes as reported by Cohen *et al.*, 1981; Kuris *et al.*, 1987; Sagi and Ra'anan 1988. Juinio et al.(1992) reported a rapid increase in total DNA and RNA in postmoult *Homarus americanus* immediately after ecdysis with an increased availability of food. In *M.rosenbergii* hepatopancreas of SOC is higher when compared to other morphotypes and this coupled with higher RNA content as observed would suggest the possibility of better food assimilation and carbohydrate storage and a corresponding activity of hepatopancreas of SOC which in turn contribute to the higher somatic growth (Dall and Moriarty, 1983; Sagi and Ra'anan, 1988). Carbohydrate content of hepatopancreas of SOC and t-SOC also showed significant variation with SBC and this findings would also support the structural and functional variations of hepatopancreas between OC and BC males (Sagi and Ra'anan 1988), commensurate with the respective growth and reproductive stages represented by these morphotypes.

Protein content in hepatopancreas was found to be lower when compared to body muscle as reported previously (Sherief and Xavier 1994). In the muscle tissue of *M.rosenbergii* the protein content is distinctly higher than lipid content (Sherief *et al.*, 1992) and similar observation could be made in penaeid prawns also (Achuthankutty and Parulekar, 1984). In the present study lipid content in hepatopancreas was much higher than protein content and this fully conform to Sherief and Xavier (1994).

In the present study a gradual increase in RNA content of the gonad could be observed from SM to SBC, which occupies the initial and penultimate stages respectively of male morphogenesis of *M. rosenbergii* (Table 6.4) However, a decrease in RNA content of gonad of OBC, which forms the terminal stage is noteworthy. This observation is in agreement with that of Ra'anan and Sagi (1985) who reported that OC have a reduced reproductive ability when compared to BC, the latter is reported to be reproductively very active. RNA content of SM was apparently the lowest among all the morphotypes studied and conversely this finding may not be conforming to their high reproductive activity using a sneaking mating strategy as reported by Ra'anan and Cohen (1985). Although the RNA content in the gonad of WOC and SOC were found to be relatively higher than SM, however, these are reproductively submissive (Ra'anan and Sagi, 1985). It would thus appear that the gonads of OC males are also endowed with the high cellular activity identical with that of SM, however, the reproductive submissiveness shown by this group manifested by non-protection or grooming of female prior to mating, fatally hurting its counter parts, etc. (Ra'anan and Sagi, 1985) may be taken as

the a reason for the reduced reproductive activity. RNA synthesis in gonads was found to be controlled by androgenic hormones before meiotic prophase (Pochon-Masson 1983). The significant difference in the RNA content in gonads of male morphotypes encountered in the present study may be due to the varying activity of androgenic glands as opined by Sagi (1988).

A clear and specific variation in biochemical contents in different male morphotypes of *M.rosenbergii* could be observed in the present study and this manifest the possibility of biochemical characterisation. However, Cohen *et al.* (1981) are of the opinion that neither genetic difference nor parental manipulation can account directly for male polymorphism. Differential growth rates exhibited by male morphotypes can well be explained with the help of difference noticed in the protein, RNA and DNA content of the muscle tissue. Faster somatic growth encountered in SOC can be correlated with the high carbohydrate and RNA content of hepatopancreas of the group and this finding would also unravel the physiological adaptation seen in this group for rapid assimilation of food. According to Sagi and Ra'anan (1988) in male morphotypes of *M.rosenbergii* there exists an antagonism in energy demand between the somatic growth and reproductive activity and the results of the present biochemical evaluation showed that the antagonism between energy demand of morphotypes characterised with somatic growth is very much perceptible rather than in morphotype which are reproductively very active.

Table 6.1 Total length and weight of male morphotypes of *Macrobrachium rosenbergii* used for biochemical analysis

	SM	WOC	SOC	t-SOC	WBC	SBC	OBC
Total length							
Minimum	88.00	135.00	155.00	172.00	130.00	192.00	211.00
Maximum	121.00	206.00	299.00	221.00	272.00	311.00	311.00
Mean	107.89	165.50	201.92	199.22	186.50	249.55	271.50
Total weight							
Minimum	5.70	25.80	33.20	41.00	27.10	68.10	102.50
Maximum	16.50	105.90	224.80	120.00	191.10	294.10	286.20
Mean	11.10	46.87	89.90	82.57	72.00	186.24	217.47

Table 6.2 Biochemical composition of muscle tissue of various male morphotypes of Macrobrachium rosenbergii

Morpho-types	Moisture (%)	Protein (%)	carbohydrates (%)	lipids (%)	DNA (mg/g)	RNA (mg/g)	RNA/DNA Ratio
SM	76.12+/-1.50 (9)	18.50+/-0.97 (9)	1.04+/-0.15 (9)	1.62+/-0.22 (9)	0.306+/-0.05 (8)	0.412+/-0.11 (8)	1.334+/-0.18 (8)
WOC	75.19+/-1.09 (10)	18.99+/-0.95 (10)	1.15+/-0.29 (10)	1.66+/-0.31 (10)	0.440+/-0.02 (4)	0.510+/-0.05 (4)	1.166+/-0.17 (4)
SOC	75.20+/-1.14 (11)	19.10+/-1.20 (11)	1.25+/-0.26 (11)	1.75+/-0.25 (11)	0.688+/-0.02 (6)	1.020+/-0.18 (6)	1.489+/-0.29 (6)
t-SOC	75.20+/-0.73 (9)	18.62+/-0.50 (9)	1.30+/-0.35 (9)	1.79+/-0.31 (9)	0.652+/-0.12 (14)	0.977+/-0.30 (14)	1.492+/-0.34 (14)
WBC	76.01+/-0.95 (12)	17.71+/-0.71 (12)	1.13+/-0.16 (12)	1.72+/-0.28 (12)	0.362+/-0.09 (8)	0.441+/-0.09 (8)	1.292+/-0.27 (8)
SBC	75.91+/-0.99 (11)	17.83+/-0.81 (11)	1.21+/-0.16 (11)	1.88+/-0.34 (11)	0.407+/-0.07 (18)	0.641+/-0.10 (18)	1.626+/-0.38 (18)
OBC	76.48+/-1.20 (6)	17.52+/-0.58 (6)	1.46+/-0.41 (6)	1.94+/-0.44 (6)	0.371+/-0.05 (4)	0.482+/-0.06 (4)	1.298+/-0.01 (4)
MSS Bet.Samples	2.457 df=6	3.963 df=6	0.1410 df=6	0.1100 df=6	0.239 df=6	0.545 df=6	0.221 df=6
MSS within samples	1.320 df=61	0.829 df=61	0.0740 df=61	0.1010 df=61	0.007 df=55	0.032 df=55	0.102 df=55
F- ratio	1.8614+	4.7805**	1.9054+	1.0891+	34.1429**	17.0313**	2.1667+

Values are presented as AVG+/-SD
Values in parenthesis denotes the number of observations
\+ Not Significant (P>0.05)
** Significant at 1% level (P<0.01)

SM- Small Males
WOC- Weak Orange Clawed Males
SOC- Strong Orange Clawed Males
t-SOC Pretransforming Strong Orange Clawed Males
WBC- Weak Blue Clawed Males
SBC- Strong Blue Clawed Males
OBC- Old Blue Clawed Males

Table 6.3 Biochemical composition of hepatopancreas of male morphotypes of Macrobrachium rosenbergii

Morphotypes	Moisture (%)	Protein (%)	Carbohydrates (%)	Lipids (%)	DNA (mg/g)	RNA (mg/g)	RNA/DNA Ratio
SM	53.86+/-2.28 (9)	9.22+/-1.64 (9)	1.89+/-0.34 (9)	29.45+/-1.87 (9)	0.371+/-0.13 (8)	0.532+/-0.21 (8)	1.453+/-0.26 (8)
WOC	53.22+/-2.55 (10)	8.90+/-2.34 (10)	2.00+/-0.39 (10)	30.22+/-1.90 (10)	0.438+/-0.08 (4)	0.530+/-0.03 (4)	1.243+/-0.16 (4)
SOC	53.04+/-2.73 (11)	9.34+/-1.67 (11)	2.37+/-0.35 (11)	31.06+/-2.12 (11)	0.537+/-0.10 (6)	0.744+/-0.18 (6)	1.381+/-0.17 (6)
t-SOC	52.91+/-3.24 (9)	9.21+/-1.41 (9)	2.28+/-0.35 (9)	29.73+/-2.36 (9)	0.536+/-0.17 (14)	0.716+/-0.14 (14)	1.555+/-0.76 (14)
WBC	53.58+/-2.12 (12)	9.88+/-1.66 (12)	2.11+/-0.37 (12)	28.80+/-2.49 (12)	0.351+/-0.10 (8)	0.414+/-0.06 (8)	1.281+/-0.35 (8)
SBC	53.29+/-3.04 (11)	8.77+/-2.04 (11)	1.93+/-0.23 (11)	29.73+/-2.87 (11)	0.385+/-0.13 (14)	0.468+/-0.19 (18)	1.355+/-0.31 (14)
OBC	54.37+/-2.81 (6)	9.67+/-1.95 (6)	2.06+/-0.44 (6)	28.89+/-2.30 (6)	0.395+/-0.04 (4)	0.497+/-0.12 (4)	1.252+/-0.18 (4)
MSS Bet.Samples	1.786 df=6	1.607 df=6	0.333 df=6	6.448 df=6	0.049 df=6	0.160 df=6	0.197 df=6
MSS within samples	7.918 df=61	3.693 df=61	0.149 df=61	5.829 df=61	0.024 df=51	0.023 df=55	0.209 df=51
F ratio	0.2256+	0.4351+	2.2349*	1.1062+	2.0417+	6.9565**	0.9426+

values presented as AVG+/-SD
Values in paranthesis denotes number of samples
\+ Not Significant
* Significant at 5% level (P<0.05)

SM- Small Males
WOC- Weak Orange Clawed Males
SOC- Strong Orange Clawed Males
t-SOC Pretransforming Strong Orange Clawed Males
WBC- Weak Blue Clawed Males
SBC- Strong Blue Clawed Males
OBC- Old Blue Clawed Males

Table 6.4 Biochemical composition of gonads of different male morphotypes of Macrobrachium rosenbergii

Morphotypes	Moisture (%)	Protein (%)	Carbohydrates (%)	Lipids (%)	DNA (mg/g)	RNA (mg/g)	RNA/DNA Ratio
SM	75.08+/-1.18 (9)	18.36+/-1.12 (6)	1.06+/-0.47 (10)	3.50+/-0.38 (6)	0.439+/-0.01 (4)	0.493+/-0.03 (4)	1.126+/-0.11 (4)
WOC	75.19+/-1.03 (10)	17.01+/-0.52 (10)	1.37+/-0.38 (12)	3.58+/-0.28 (6)	0.534+/-0.01 (4)	0.610+/-0.03 (4)	1.141+/-0.02 (4)
SOC	74.71+/-0.68 (11)	18.77+/-0.56 (14)	1.69+/-0.36 (14)	3.68+/-0.28 (10)	0.530+/-0.09 (6)	0.697+/-0.12 (6)	1.322+/-0.12 (6)
t-SOC	74.70+/-1.15 (9)	18.52+/-0.92 (18)	1.76+/-0.47 (10)	3.80+/-0.10 (8)	0.635+/-0.11 (14)	0.942+/-0.17 (14)	1.495+/-0.21 (14)
WBC	74.45+/-0.93 (12)	18.35+/-1.14 (8)	1.45+/-0.38 (12)	3.72+/-0.24 (6)	0.751+/-0.09 (8)	1.065+/-0.11 (8)	1.567+/-0.25 (8)
SBC	73.95+/-0.73 (11)	18.95+/-0.95 (10)	1.58+/-0.40 (12)	3.81+/-0.29 (4)	0.643+/-0.16 (18)	1.159+/-0.31 (18)	1.800+/-0.81 (18)
OBC	74.38+/-1.06 (6)	18.07+/-1.32 (8)	1.22+/-0.48 (8)	3.77+/-0.39 (6)	0.891+/-0.07 (4)	0.916+/-0.07 (4)	1.029+/-0.01 (4)
MSS Bet.Samples	1.805 df=6	0.961 df=6	0.381 df=6	0.080 df=6	0.070 df=6	0.319 df=6	0.366 df=6
MSS within samples	0.999 df=63	0.682 df=67	0.196 df=71	0.095 df=39	0.015 df=51	0.032 df=51	0.259 df=51
F- ratio	1.8068+	1.4080+	1.9439+	0.8889+	4.6667*	9.4167**	1.4131+

Values presented are AVG+/-SD
Values in paranthesis denotes number of observations
\+ Not Significant (P>0.05)
* Significant at 5% level (P<0.05)
** Significant at 1% level (P<0.01)

SM- Small Males
WOC- Weak Orange Clawed Males
SOC- Strong Orange Clawed Males
t-SOC Pretransforming Strong Orange Clawed Males
WBC- Weak Blue Clawed Males
SBC- Strong Blue Clawed Males
OBC- Old Blue Clawed Males

Table 6.5 Results of pairwise analysis using t-test on various biochemical components showing variation in different morphotypes of Macrobrachium rosenbergii

Combination	Muscle Protein		Muscle DNA		Muscle RNA		Hepatopancreas Carbohydrates		Hepatopancreas RNA		Gonad DNA		Gonad RNA	
	df	t	df	t	df	t	df	t	df	t	df	t	df	t
1 SM X WOC	17	1.0392 +	10	4.7153 **	10	1.1614 +	17	0.7262 +	10	1.4190 +	6	8.9805 **	6	4.7539 +
2 SM X SOC	18	1.1668 +	12	22.4763 **	12	7.3644 **	18	2.6182 *	12	3.5925 **	8	1.7747 +	8	2.9502 +
3 SM X t-SOC	16	0.3155 +	20	7.5512 **	20	4.9376 **	16	2.3475 *	20	4.5752 **	16	3.2813 **	16	4.8679 *
4 SM X WBC	19	2.0611 +	14	1.2364 +	14	0.5050 +	19	1.4404 +	14	1.0356 +	10	6.3096 **	10	10.8084 *
5 SM X SBC	18	1.5971 +	24	3.5927 **	24	5.2732 **	18	0.4032 +	24	0.1524 +	20	2.3561 *	20	3.8120 **
6 SM X OBC	13	2.0810 +	10	1.9475 +	10	1.1231 +	13	0.8564 +	10	0.5955 +	6	7.1500 **	6	9.4342 *
7 WOC X SOC	19	0.2340 +	8	21.0484 **	8	4.9655 **	19	1.9113 +	8	2.0954 +	8	0.0880 +	8	1.2753 +
8 WOC X t-SOC	17	0.9686 +	16	3.3848 **	16	2.9369 **	17	1.5469 +	16	2.5531 *	16	1.6866 +	16	3.6077 *
9 WOC X WBC	20	3.4516 **	10	1.3120 +	10	1.3056 +	20	0.6424 +	10	3.2870 **	10	4.3909 **	10	9.0003 **
10 WOC X SBC	19	2.8634 **	20	0.9286 +	20	2.5395 *	19	0.5098 +	20	0.6133 +	20	1.2211 +	20	2.8905 +
11 WOC X OBC	14	3.2205 **	6	2.2385 +	6	0.6289 +	14	0.2524 +	6	0.4844 +	6	4.9801 **	6	7.1387 +
12 SOC X t-SOC	18	1.0668 +	18	0.9917 +	18	0.3087 +	18	0.4184 +	18	0.3603 +	20	1.9224 +	20	2.9887 +
13 SOC X WBC	21	3.3229 **	12	9.6390 **	12	7.2913 **	21	1.4463 +	12	4.4628 **	12	4.2080 **	12	6.8972 **
14 SOC X SBC	20	2.8204 **	22	13.3791 **	22	6.3437 **	20	2.7665 *	22	2.9592 **	22	1.4905 +	22	2.6022 +
15 SOC X OBC	15	2.8945 *	8	16.9830 **	8	5.1982 **	15	1.2913 +	8	2.1724 +	8	3.6135 **	8	2.9343 +
16 t-SOC X WBC	19	3.1432 **	20	5.4062 **	20	4.7365 **	19	1.0225 +	20	5.6710 **	20	2.3914 *	20	3.0451 +
17 t-SOC X SBC	18	2.4244 *	30	7.1541 **	30	4.3560 **	18	2.5309 *	30	3.9632 **	30	0.0347 +	30	0.4285 +
18 t-SOC X OBC	13	5.1838 **	16	6.2009 **	16	4.4030 **	13	1.4255 +	16	3.9131 **	16	2.5805 *	16	0.3846 +
19 WBC X SBC	21	0.3696 +	24	1.2257 +	24	4.8416 **	21	1.3463 +	24	0.7506 +	24	1.8241 +	24	1.9737 +
20 WBC X OBC	16	0.5373 +	10	0.1574 +	10	0.7653 +	16	0.2485 +	10	1.4938 +	10	0.0200 +	10	3.6718 +
21 SBC X OBC	15	0.7849 +	20	0.9239 +	20	3.0669 **	15	0.7523 +	20	0.2734 +	20	1.3221 +	20	0.4646 +

\+ Not Significant
* Significant at 5% level (P>0.05)
** Significant at 1% level (P>0.01)

SM- Small Males
WOC- Weak Orange Clawed Males
SOC- Strong Orange Clawed Males
t-SOC Pretransforming Strong Orange Clawed Males
WBC- Weak Blue Clawed Males
SBC- Strong Blue Clawed Males
OBC- Old Blue Clawed Males

Section 4

Seed Production of *Macrobrachium rosenbergii* (de Man)

Chapter 7

Reproductive Capability of Male Morphotypes of *Macrobrachium rosenbergii* (de Man) and Their Performance in Brood Stock Rearing and Larval Production

Introduction

Seed production of *Macrobrachium rosenbergii* has met with different levels of success in India (Nair, 1993a; Sebastian and Nair, 1995; Kurup, 1994), however, the non availability of mother prawns from the natural habitat pose as a major bottleneck in the year round production of seed in commercial hatcheries. The male population of *M.rosenbergii* is distinguishable as three morphotypes viz. Blue Clawed (BC), Orange Clawed (OC) and Small Males (SM) which are probably representing the three maturation stages of males (Cohen *et al.*, 1981) which are characterised with difference in social hierarchy and participation in courtship and mating (Ra'anan and Sagi, 1985; Kuris *et al.*, 1987). Therefore identification of most reproductively active male morphotype and delineation of its optimum ratio which can produce maximum oviposition will be quite useful for the brood stock development in commercial hatcheries.

Generally brood stock for the hatchery operation is collected from grow-out ponds or from wild population(New, 1995; Harikrishnan and Kurup, 1997b). Brood stock rearing of *M.rosenbergii* in the hatchery premises could be practised for year round supply of mother prawns (Varghese *et al.*, 1992; Daniels *et al.*, 1992; Malecha, 1983). Effect of temperature (Daniels *et al.*, 1992), dietary protein (Murugadas and Pandian, 1991), eye stalk ablation

(Marian and Murugadas, 1991; Ang *et al.*, 1992) on the maturation of various species of *Macrobrachium* were studied extensively.

Materials and Methods

Live specimens of different morphotypes of male *M.rosenbergii* such as Small Males (SM), Orange Clawed Males (OC) and Blue Clawed Males (BC) were collected from Vembanad lake, and spent females were procured from a commercial Macrobrachium hatchery to ensure uniformity in stages of maturation. Experiments were designed with a view to ascertain the success of oviposition in the sex ratio maintained between male and female from 1:2 to 1:8 in BC, 1:2 to 1:7 in OC and 1:2 and 1:3 in SM. Experiments were conducted in one ton FRP tanks provided with broken tiles and PVC pipes kept submerged for giving shelter in order to minimise stress and continuous aeration was also provided. Tank management was done following standard procedures (Ra'anan and Sagi, 1985). The small males when stocked in higher ratios with females, a change in colour pattern similar to that of BC was perceptible and therefore, the results of the same have not been included here. The period taken for oviposition was reckoned as the period from the commencement of the experiment till the day on which appearance of the berry (Shed berries were not counted) could be noticed. Period of incubation was taken as the days from the berry formation till hatching whereas, total number of zoea produced was counted soon after the completion of hatching and percentage of larval survival was calculated from the number of post-larvae produced from each experiment. The individuals of each tank were observed on a daily basis for registering

moulting and oviposition. The berried females were removed immediately and the experiments were continued for a period of 25 days. The berried females so developed were kept in 400L round FRP tanks having 5 ppt sea water for hatching. The larval rearing was done following the standard procedures (Sebastian and Nair, 1995). The number of larvae obtained per gram body weight of the berried female, the period of incubation and the survival of the larvae were recorded. The data so gathered in respect of percentage of moulting in females, percentage of fertilisation among moulted females and total females, period for oviposition, period of incubation, zoea produced and survival of zoea in different combinations of BC, OC and SM morphotypes were tested using ANOVA and t-test (Snedecor and Cochran, 1967).

Results

Results of the experiments carried out under different sex ratios of three morphotypes of males of *M.rosenbergii* with females are given in the Table 7.1. BC produced more number of berried females (51.04%) whereas OC (12.59%) and SM (35.5%) showed lower performance. The average number of zoea produced by females treated with blue male (M=52,471 larvae/100 gm body weight) were distinctly higher when compared to females treated with OC (41,475 larvae/ 100 gm body weight) and SM (M=31,578 larvae/100 gm body weight). Percentage of oviposition among females and the larvae produced by females kept with different morphotypes showed significant variation (Table 7.2). Result of t-test to quantify the variation in different parameters observed during the present experiment in respect to different morphotypes are presented in the Table 7.3.

Discussion

Blue clawed males showed superior performance in terms of fertilisation and number of zoea produced. It would thus appear that among various male morphotypes of *M.rosenbergii* blue clawed males are reproductively more active as evident from high rates of fertilisation, larval production and larval survival. When BC males were maintained in the ratio 1:4, 100% fertilisation of the moulted females could be observed. Besides, the highest percentage development of berried females could also be noticed in this combination. This clearly substantiates the suitability of BC males in the brood stock development due to their superior reproductive activity. Among the various ratios of BC studied, the results were found to be excellent in 1:4 and this finding is very much in agreement with the report of Varghese *et al.* (1992) who stated that sex ratio of 1:3.75, 1:4 and 1:4.75 were suitable for maximum oviposition in *M.rosenbergii*. Malecha *et al.* (1983) also recommended a sex ratio 1:4 or 1:5 for maximum oviposition in *M.rosenbergii*. However, the morphotypic difference in *M.rosenbergii* has totally been ignored in all these studies and therefore the reproductive activity of various male morphotypes could not be adjudged from these studies.

In the present study successful fertilisation could also be seen in OC males and this observation would suggest the reproductive potential of this morphotype in the absence of a dominant male morphotype (Table 7.1). However, shedding of berries due to non-fertilisation was also observed in few

females treated with OC males. On the contrary, small males could fertilise 75% of females which are found moulted when kept with them. The results of ANOVA and t-test (Table 7.2 and 7.3) revealed that significant difference could be noticed in the percentage of development of berried females between BC and OC whereas the difference was found insignificant between BC and SM as well as OC and SM. These observations clearly support the earlier findings that the BC and SM are reproductively active while OC is reproductively submissive and it becomes active only in the absence of BC (Ra'anan and Sagi, 1985; Kuris *et al.*, 1987).

The total number of females moulted in each experimental protocol was analysed statistically using ANOVA and the results (Table 7.2) showed that there is no significant variation in the total number of females moulted when these were kept along with different morphotypes of males. In *M.rosenbergii* mating occurs only between hard shelled male and soft shelled female ie. female just completed the premating moult (Rao, 1965; New and Singholka, 1985). The experimental condition provided for each morphotype for oviposition were identical and therefore it may be inferred that the rate of moulting may be independent of the presence of reproductively active male morphotypes. However, a higher percentage of moulting could be noticed in the experimental protocol of all morphotypes in which lower sex ratios were maintained. This may be due to the possibility of attaining faster growth as a result of less competition for food and space and also due to least disturbance from other individuals.

The result of analysis of variance and t-test on percentage of oviposition, period for oviposition, incubation period, pre-zoea produced and

survival among the three morphotypes of *M.rosenbergii* are presented in Tables 7.2 and 7.3. It could be seen that the percentage of berried females developed out of total moulted females and total stocked females and also the prezoeal production showed significant differences among various male morphotypes. This finding would strongly support earlier observations that the three morphotypes are well distinguishable in their reproductive capacity and activity (Kuris *et al.*, 1987). A high degree of reproductive success viz. attractiveness for females, advantage in agnostic behaviour with other males and high survival probability of fertilised females after mating are reported in BC by Ra'anan and Sagi (1985). The post larvae produced showed significant difference between BC and OC as well as BC and SM whereas there is no significant difference between OC and SM. This result further supports the suitability of BC in brood stock development of *M.rosenbergii*. Time taken for oviposition, period of incubation and rate of survival of larvae have showed no significant difference in females treated with different morphotypes (Table 7.2&7.3). This may be due to the relationship of former two characters with the maturity and physical condition of female and latter to the efficiency of larval rearing techniques being followed in the hatchery. Survival of the larvae also showed no significant difference among the various treatments, however, the average survival is found to be higher in treatments with BC parentage.

The OC males of *M.rosenbergii* were further classified into Weak Orange Clawed (WOC), Strong Orange Clawed (SOC) and Pre-transforming SOC (t-SOC) according to the propodus colouration (Kuris *et al.*, 1987). In the present study the success of oviposition varied between 0% to 25% in WOC,

0% to 33.33% in SOC and 0% to 50% in t-SOC in various combinations, however there was no significant variation ($F=1.536$, $P>0.05$) among them. Therefore, various OC morphotypes were pooled and treated as OC males. Varghese *et al.* (1992) introduced more than one male with females in the same tank itself in order to adjust the sex ratio for the optimisation of sex ratio, regardless of morphotypic variation. It may be inferred that by doing so a condition might have existed in which one dominant male can suppress the reproductive activity of the rest of males and therefore effective sex ratio can vary considerably and consequently the higher number of individuals may interfere in moulting as well as mating. Varghese *et al.*(1992) registered low rates of fertilisation in *M.rosenbergii* and this may be due to the presence of higher percentage of OC among the experimental males due to the maintenance of higher stocking rate. In the present study the percentage of oviposition in females treated with OC males ranged from 0 to 50 which is very much in agreement with Ra'anan and Sagi (1985) who recorded 37% and 16.6% successful fertilisation in OC in absence and presence of BC respectively.

Small males performed successfully in the sex ratio 1:3 and the result appeared as intermediate between that of BC and OC in the same sex ratio. This observation clearly substantiates the earlier finding that the chances of successful mating in SM males by performing the sneak copulation strategy (Ra'anan and Sagi, 1985). SM showed traces of colour development viz. appearance of bluish tint in the exoskeleton and strong blue colouration in propodus of the second peraeopod during the experiments and this would suggest the possibility of transformation of SM to BC in the presence of females

and also in the absence of dominant males. The small males showed strong colour changes when kept in higher sex ratios and therefore the results of these experiments were not considered for discussion in the present study.

Statistical analysis on success of fertilisation in different sex ratios using various morphotypes revealed that the reproductive activity of BC males varied significantly ($F=4.5058$, $P<0.05$) in different sex ratios. Pair-wise analysis of different sex ratios showed that there is no difference among the percentage oviposition in the lower sex ratios (1:2, 1:3, 1:4 and 1:5) whereas a significant difference could be observed between lower ratios and higher ratios. In OC ($F=0.4230$, $P>0.05$) there was no significant variation in success of oviposition at various sex ratios and this finding clearly substantiates the high reproductive activity of BC males at lower sex ratios. The sex ratio 1:4 with females showed 100% success in oviposition and therefore BC morphotypes at a sex ratio of 1:4 could be recommended for the brood stock development in commercial hatcheries of *M.rosenbergii*.

Table 7.1 Mean values of percentages of females moulted, berries formed, duration of oviposition, incubation period, pre-zoea produced and larval survival in different sex ratios of various morphotypes of Macrobrachium rosenbergii

Sex ratio	Percentage of females moulted	Percentage of berries obtained (of moulted)	Percentage of berries obtained (of stocked)	average time for oviposition (Days)	Average weight of female (g)	Average period of incubation (Days)	Avg. No. of prezoea/ 100g body weight	Survival of larvae (%)
BLUE CLAWED MALES (BC)								
1:2 (4)*	87.50	87.50	75.00	11.25 (4)	67.5 (8)	17 (2)	47,199 (2)	21.4 (2)
1:3 (3)	88.89	88.89	77.79	12.33 (3)	62.0 (9)	17 (3)	61,703 (3)	21.4 (3)
1:4 (4)	81.25	100.00	81.25	15.25 (4)	80.0 (16)	18 (3)	62,000 (3)	35.0 (3)
1:5 (4)	75.00	66.67	50.00	15.00 (4)	53.3 (20)	18 (3)	57,411 (3)	23.8 (3)
1:6 (3)	55.56	58.33	33.33	13.66 (3)	56.0 (18)	20 (1)	45,652 (1)	26.1 (1)
1:7 (3)	52.38	41.67	19.05	16.00 (3)	53.5 (21)	19 (2)	46,520 (2)	27.3 (2)
1:8 (3)	50.00	41.11	20.83	15.33 (3)	55.8 (24)	19 (2)	43,814 (2)	24.6 (2)
ORANGE CLAWED MALES (OC)								
1:2 (3)	83.33	20.00	16.67	14.0 (1)	52.0 (6)	19 (1)	44,230 (1)	21.7 (1)
1:3 (4)	66.67	12.50	8.83	12.0 (1)	55.4 (12)	17 (1)	42,354 (1)	21.5 (1)
1:4 (6)	75.00	22.22	16.67	15.25 (4)	46.0 (24)	19 (1)	43,478 (1)	22.5 (1)
1:5 (3)	66.67	30.00	20.00	14.5 (2)	65.0 (15)	18 (1)	33,846 (1)	25.0 (1)
1:6 (3)	44.44	12.50	5.50	16.0 (1)	49.8 (18)	18 (1)	46,255 (1)	21.3 (1)
1:7 (2)	50.00	14.28	7.84	15.0 (1)	51.9 (14)	17 (1)	38.688 (1)	21.9 (1)
SMALL MALES (SM)								
1:2 (1)	50.0	Berry not formed		--	--	--	--	--
1:3 (2)	100	66.67	66.67	17.5 (4)	11.0 (4)	19 (1)	31,578 (1)	20.8 (1)

* Values in parenthesis denotes the number of observations

Table 7.2 Results of ANOVA of different parameters recorded with respect to various morphotypes of *Macrobrachium rosenbergii*

Parameters	n	df2	df1	SS	MSS bet. Samples	MSS Within Samp.	F-value	
% of moulting in females	15	14	2	2435.89	143.38	179.09	0.80	(NS)
% Oviposotion (of Moults)	15	14	2	7988.46	2021.44	328.80	6.15	(S)
% Oviposotion (of total)	15	14	2	5699.60	1050.08	299.95	3.50	(S)
Period for Oviposition	14	13	2	38.59	5.17	2.57	2.01	(NS)
Incubation period	14	13	2	12.36	0.46	1.05	0.44	(NS)
Prezoea produced	14	13	2	1.1E+09	3.1E+08	5.02E+07	6.20	(S)
Survival of larvae	14	13	2	78.19	9.96	5.30	1.88	(NS)

S-Significant at 5% level (P<0.05)
NS- Not Significant (P>0.05)

Table 7.3 Results of t-test of different parameters recorded with respect to various morphotypes of *Macrobrachium rosenbergii*

	Combination of various morphotypes					
	BC and OC		BC and SM		OC and SM	
	df	t-value	df	t-value	df	t-value
% Moulting in females	11	0.703 (NS)	7	0.777 (NS)	6	1.099 (NS)
% Oviposotion (of Moults)	11	4.3703 (S)	7	1.5591 (NS)	6	0.325 (NS)
% Oviposotion (of total)	11	3.5599 (S)	7	0.8775 (NS)	6	0.66 (NS)
Period for Oviposition	11	0.3827 (NS)	6	1.6515 (NS)	5	2.317 (NS)
Incubation period	11	0.5034 (NS)	6	0.6008 (NS)	5	1.036 (NS)
Prezoea produced	11	2.7854 (S)	6	2.2581 (S)	5	2.032 (NS)
Survival of larvae	11	1.7064 (NS)	6	1.0067 (NS)	5	1.042 (NS)

S-Significant at 5% level
NS- Not Significant

Chapter 8

Packing of mother prawns and zoea I of *Macrobrachium rosenbergii* for Safe Duration Transportation

Introduction

The mother prawns of *Macrobrachium rosenbergii* for the commercial hatcheries are mostly procured either from natural habitats (Harikrishnan and Kurup, 1997b) or grow-out ponds (New and Singholka, 1985). Since the hatcheries are distantly located from the regions of broodstock availability, berried prawns are subjected to transport over longer duration. Recently, a new practice of hatching the berry in collection site itself and transporting the early larvae to the hatchery have been observed. The earlier studies on this line are mainly focused on the transportation of juveniles and postlarvae of *M.rosenbergii* (Singholka 1982; Smith and Wannamaker, 1983; Alias and Siraj 1988; and Vadhyar *et al.*, 1992; Joshi and Raje, 1993), while Venkataswamy *et al.* (1992) conducted preliminary experiments on transportation of the broodstock of *M.malcomsonii*. Therefore, in the present study, an attempt was made to evolve safe duration for transportation of the broodstock as well as zoea 1 of *Macrobrachium rosenbergii* under different packing densities and oxygen to water ratio. The role of different coloured packages and perforated carrier tubes in safe duration for transportation were also investigated.

Materials and Methods

Brood stock transportation.

Berried prawns for the present study were collected from Vembanad lake and were acclimatised in well aerated ambient freshwater for five hours. Conditioning of the animals after acclimation were done by inserting a plastic tube on the rostrum and trimming of spines of the carapace so as to avoid puncturing of polythene bags. Experiments were designed to standardise number of animals per bag or weight of animals per litre to achieve best results for safe duration of more than one day in different ratios of oxygen and water. Animals were weighed and packed in transparent polythene bags of total effective capacity of 18L with oxygen to water ratio 2:1 and 1:1 and the bags so prepared were kept in darkness under ambient temperature. The containers were observed at every one hour intervals. Safe duration which was taken as the period at which the initial mortality has been observed, was arrived at in respect of different oxygen-water ratios and number of individuals per package. In the best combination so arrived at, the effect of colour of packing material and the perforated carrier tubes on safe duration have further investigated. Effect of different colouration of packing materials were studied by initially packing the animals in transparent polythene bags and placing them into green, blue and black plastic bags. Observations on mortality in these containers were made by removing the outer coloured bags. Perforated carry tubes were fabricated with the help of PVC pipes having three inch diameter and 10 inch length. The experiments were conducted in duplicate. The water quality parameters such as dissolved oxygen, pH and ammonia were also estimated initially as well as on termination of the experiments using standard

procedures (Strickland and Parsons, 1972; Greenberg *et al.*, 1993). Animals maintained as described above were kept for hatching following standard procedure (New and Singholka, 1985). Hatching rate was calculated from prezoea produced and the unhatched eggs and dead larvae. The results of the experiments were analysed statistically (Snedecor and Cochran, 1967)

Zoea 1 Transportation

Berried prawn collected from Vembanad lake were subjected to hatching in freshwater and the zoea 1 so produced were packed in transparent polythene bags of 18 l capacity under two ratios of oxygen and freshwater viz. 2:1 and 1:1. The corners were rounded off with rubber band to prevent animals getting trapped there. The top is twisted and sealed tightly with rubber band after the bag has been filled with oxygen to the desired quantity. The packing density selected was @1000, 2000 and 3000 zoea 1 per litre and the packages so prepared were kept in ambient temperature. A control was also kept by maintaining a density of @1000 larvae/l in an open aerated plastic bag. Each treatment consists of four polythene bags which were simultaneously maintained and observation from each bag were made at 12^{th}, 24^{th}, 36^{th} and 48^{th} hour to assess the survival of the prezoea along with the observation on water quality parameters. Packs were shaken at random with a view to simulate the conditions prevailing during actual transportation and also to avoid settling of the larvae. The result of the preliminary experiments showed that 1:1 oxygen water ratio with a packing density 2000 larvae/l have given better results and therefore, effect of container colouration was studied only in the above

combination. In order to study the effect of the colour of the packing material larvae were packed in transparent bags before inserting in the coloured bags viz. green, blue and black. All the treatments were carried out in triplicate. Dissolved oxygen and ammonia were estimated following Strickland and Parsons (1972) and Greenberg *et al.*(1993) whereas pH was recorded at the time of opening, using a digital pH pen. Mortality of larvae in every 6 hr. was enumerated for each combination and compared using analysis of variance and pair-wise analysis was performed using t-test (Snedecor and Cochran, 1967). Water quality parameters were also compared using analysis of variance and t-test (Snedecor and Cochran, 1967). Adequate data base required for perform ANOVA could not be generated with respect to broodstock transportation due to financial constraints and limitations in the infrastructural facilities, however, ANOVA was performed with the available data for a meaningful interpretation of the results.

Result

Brood stock transportation.

Among the berries having different stages of maturity used for packing experiments, neither hatching nor shedding could be observed in yellow and grey berries and therefore found to be suitable for transportation. On the contrary, orange berried prawns showed the tendency of shedding during oxygen packing, while hatching could be seen in black berried prawns and therefore caused total mortality of the brooder as well as newly hatched larvae.

In all the packing densities studied, animals kept in oxygen water ratio 1:1 was endowed with longer safe duration when compared to 2:1 (Table 8.1). A 30 hr safe duration could be achieved when the oxygen-water ratio was kept at 1:1 with a density of three animals per container and this would work out to be 29.78g body mass per litre (Table 8.1). Among the various combinations studied, three animals per bag under 1:1 oxygen water ratio gave good results and therefore found ideal for one day transportation. Based on above findings, further experiments on the effect of packing material were conducted only in this combination. Green, blue and black coloured packages found to have a safe duration of 38 hr, 36 hr and 42 hr respectively which are found to be on a higher side when compared to 30 hr registered in transparent bags (Table 8.2). When perforated carry tubes were used in transparent bags, a safe duration of 40 hr could be obtained which appears to be on a higher side when transparent bags without carry tubes were used for transportation (Table 8.2).

The final dissolved oxygen content was 2.1 ml/l in the bag with three animals under 2:1 oxygen water ratio whereas the same was 2.4 ml/l in the ratio 1:1 (Table 8.1). Final pH varied between 6.8 and 7.1 in various experiments when oxygen water ratio was maintained at 2:1 whereas values showed variation between 6.8 and 7.0 only in the ratio 1:1 (Table 8.1). In general, dissolved oxygen, pH and ammonia values were found to be within limit in all packing densities when oxygen water ratio was maintained at 1:1 when compared to 2:1 ratio (Table 8.1). Final values of ammonia was observed as 18.56, 21.58 and 14.95 mg/l when animals were kept in green, blue and black containers respectively against 25.98 mg/l estimated in transparent

bag (Table 2). However, ammonia content was found as low as 16.58 mg/l when perforated carry tubes were used in transparent bags.

Results of statistical analysis showed that there is significant difference in the safe duration ($P< 0.01$) and final ammonia content ($P<0.01$) in different packing densities and between different oxygen water ratio (Table 8.3). On the contrary, pH ($P>0.05$) and hatching rate ($P>0.05$) showed no significant variation in different packing densities as well as in different oxygen water ratio (Table 8.3). Final dissolved oxygen content also showed significant difference in packages with different oxygen water ratios whereas it was insignificant in different packing densities (Table 8.3). Variations in safe duration ($P<0.01$) and ammonia concentration ($P<0.05$) was significant when different container colouration were used, on the contrary, variations of dissolved oxygen and pH were insignificant (Table 8.4). Hatching rate showed significant difference ($P<0.01$) among different coloured packing materials studied. Blue colour registered lowest hatching rate of 77% whereas transparent and black registered highest of 82%, however, the variation in hatching rate with respect to container colouration showed no specific pattern. The results of pair-wise analysis using t-test revealed that there exists significant difference in the safe duration between transparent and black containers ($t=4.24$ $P<0.05$) and transparent container with carry tubes ($t=4.47$ $P<0.05$). Final ammonia content also showed significant difference when comparing transparent against green bags ($t=5.25$ P,0.05), black ($t=7.80$ $P<0.05$) and transparent bag with perforated carry tubes ($t=6.65$ $P<0.05$).

Hatching rate also showed significant difference between transparent and blue bags ($t=4.69$ $P<0.1$) and blue and black containers ($t=3.54$ $P<0.1$)

Zoea 1 Transportation

Details of survival rates of zoea 1 in different experimental protocols are presented in Table 8.5. In packing experiments in which the oxygen water ratio of 1:1 was maintained, a survival of 48.23% could be recorded at 48 hr. packing when density was maintained at 3000 larvae litre, and this in comparison with oxygen water ratio 2:1 is on a higher side (Table 8.5). Dissolved oxygen content during the experiments have showed a gradual decrease from initial 8.9 mg/l to 3.5 and 3.7 mg/l in packing density @3000 larvae/l in 2:1 and 1:1 oxygen water ratios respectively (Table 8.6). A decreasing trend in the order of 7.4 to 6.8 could be seen in the case of pH. (Table 8.7). Water became slightly acidic at 36 hr. in the trials when higher density (3000 larvae/l) was maintained. Ammonia concentration in the medium showed a direct relationship with the duration of experiment, on the contrary, rate of excretion of ammonia at different intervals studied showed a decreasing trend (Table 8.8).

Percentage mortality observed in every 6 hr. interval was compared using analysis of variance. The result revealed that in 2:1 oxygen water ratio ($F=16.078$; $P<0.001$) significant difference could be seen between control and different stocking densities studied (Table 8.9). Mortality of larvae in stocking densities of 1000 ($t=2.763$; $P<0.001$), 2000 ($t=4.280$; $P<0.001$) and 3000 larvae/l ($t=10.143$; $P<0.001$) showed a significant variation when

compared to that of control. The result of t-test showed a significant difference in the mortality between densities 1000 and 3000 larvae/l and 2000 and 3000 larvae/l, on the contrary, difference was insignificant between 1000 and 2000 larvae/l ($F= 0.866$; $P>0.05$). Similar results could also be obtained with the experiments at 1:1 stocking density (Table 8.10). For comparing the difference in mortality in 1:1 and 2:1 oxygen water ratio, t-test was used and the result ($t=0.422$; $P>0.05$) revealed that there is no significant difference between the different air water ratio.

Against this background stocking density @2000 in 1:1 air water ratio was taken as the best combination and this combination has been selected to study the effects of different colouration of packing on individuals.

High survival rates in coloured bags used for the packing experiments was quite discernible and among them black coloured bag gives the maximum survival rate (91.16%) (Table 8.11). Blue coloured bag (74.12%) showed an inferior performance when compared to control (95.06%) and transparent bag (74.25%). Lower dissolved oxygen and higher ammonia content were observed in transparent bag when compared to coloured bags (Table 8.12) on the contrary, low pH was recorded in blue bags.

Final dissolved oxygen content in various packing densities with 2:1($F= 10.735$; $P<0.001$) and 1:1 ratio ($F= 34.164$; $P<0.001$) showed significant difference. Whereas, final dissolved oxygen content between the two ratios were found to be insignificant ($t= 0.828$; $P>0.05$). Variation in pH in different packing densities with oxygen water ratio 2:1 ($F=24.696$; $P<0.001$) showed significant difference and similar was the result in the ratio 1:1 ($F= 13.102$; $P<0.001$). Similarly, ammonia level also showed significant difference at

various stocking densities in 2:1 (F= 6.287; P<0.001) and 1:1 (F= 6.214; P<0.001) ratios. Among the two ratios of 2:1 and 1:1 oxygen water studied, pH (t=0.228; P>0.05) and ammonia (F= 0.438; P>0.05) showed no significant difference.

Mortality showed significant difference (F=6.619; P<0.001) among the control, transparent and coloured bags. Pair wise analysis showed that mortality in transparent (t= 4.705; P<0.001), green (t= 4.815; P<0.001), blue (t= 4.307; P<0.001) and black (t= 3.766; P<0.001) bags showed significant difference when compared to that of control. On the contrary, the mortality in transparent and coloured bags showed no significant difference between them (Table. 8.13).

Among control, transparent and various coloured bags studied variation in dissolved oxygen (F=33.348; P<0.001) and pH (F=4.079; P<0.01) showed significant difference, on the contrary, ammonia concentration (F=2.978; P>0.05) showed no significant variation. Pair-wise analysis using t-test showed that physico-chemical parameters showed significant (P<0.01) difference between control and packed samples, on the contrary, the difference is insignificant (P>0.05) between transparent and coloured bags and among the different coloured bags studied.

DISCUSSION

Since there is a distinct localisation of source of berry, hatchery and farm sites, transportation of larvae and broodstock is indispensable in freshwater prawn aquaculture. Dissolved oxygen, Carbon dioxide, ammonia,

alkalinity and pH are factors of concern in transporting live organisms (Hattingh et al. 1975). Lowering of dissolved oxygen resulted in the respiratory stress as well as increase in the toxicity of un-ionized ammonia (Hora and Pillay, 1962). In the present study pH values were found to be decreased from an initial value of 7.4 to 6.8 and this may be due to the dissociation of carbonic acid to release bicarbonate and further dissociate to give carbonate and hydrogen ions (Alias and Siraj, 1988). In the experiments conducted on transportation of prawn larvae, the ammonia values were reported to be very high (Vadhyar *et al.*, 1992; Alias and Siraj, 1988), on the contrary, in the present experiments maximum ammonia concentration registered was 45.81mg/l and this in comparison with earlier report is found to be on a lower side. It may be due to the size and age of the animal and larger volume of the packing medium employed. The final ammonia content registered in the present study is found to be well below 80 mg/L which is found to be lethal to larvae of *M.rosenbergii* at a pH of 6.8 as reported by Armstrong et al. (1978). It may, therefore, be inferred that the increase in ammonia does not act as a stress factor in the experimental condition of the present study. The final value of dissolved oxygen, pH and ammonia is relatively higher in the packages when oxygen water ratio was maintained at 1:1. It would thus appear that the above parameters may not be attaining lethal limits due to the provision for dilution of the wastes and might have resulted in better survival. According to Vadhyar *et al.* (1992) the combined effect of low dissolved oxygen and high carbon dioxide, pH, and bacterial population of the packing medium can be attributed as the main reasons for the mortality of the prawn seeds under

oxygen packing for transportation rather that the stress caused by any of these parameters singly.

Significant variation was observed in safe duration ($P<0.01$) in different packing densities and also with respect to different oxygen water ratios. This variation can be attributed to the difference in body mass per unit volume of water caused due to variations in packing densities as well as difference maintained in the water oxygen ratios. The results of the experiments with different packing density showed that the period of safe duration is inversely proportional to the total body mass per litre of the carrying medium. This finding is favourably comparable to the observation of Alias and Siraj (1988) and Vadhyar *et al.* (1992).

The results of the experiments conducted to assess the effect of different coloured packages on the safe duration for transportation showed that there is a significant difference ($P<0.01$) among the different colours studied and maximum safe duration could be encountered in black containers. An enhancement in the safe duration from 30 hr in transparent bags without carry tubes to 40 hr in transparent bags with carry tubes could also be observed (Table 8.5). These results revealed the fact that the animal kept in black containers as well as in perforated carry tubes were subjected to minimum stress and therefore showed a substantial increase in the safe duration. According to Rao (1965) and Raman (1967), *M.rosenbergii* is a nocturnal animal and always prefer darker habitat and again characterised with the sluggish behaviour. It may therefore be seen that the above conditions will

totally match with requirements preferred by the animal, and therefore effected in the better performance. The final ammonia content were also found to be relatively low in black bags as well as in containers having perforated tubes which would also manifest the possibility that the activity of the animals kept in these containers were very low.

The result of the investigations on the packing of zoea 1 revealed that the density of packing is a critical factor influencing the survival of the larvae during transportation. A direct relationship could be observed between mortality and packing density, and this is favourably comparable with the earlier reports (Alias and Siraj, 1988; Vadhyar *et al.*, 1992). The mortality rate at packing density @2000 showed no significant difference with 1000 larvae/l. Similarly, variations in mortality rate between 2:1 and 1:1 oxygen water ratio was also found to be insignificant. It would thus appear that packing density @2000 larvae/l with an oxygen water ratio 1:1 is suitable for the transportation of zoea 1 of *M. rosenbergii.* In a given container the quantity of water when packed in the oxygen water ratio 1:1 will be higher when compared to the ratio 2:1 and hence higher number of larvae can be transported.

The time span between 1st and 2nd zoeal stage of *Macrobrachium* spp. is regarded as critical period and same for *M. rosenbergii* is found to be 5 days (Pandian, 1987). Furthermore, zoea must reach estuarine water for the successful development (Ling and Merican, 1961). Since feed was not administered during the experiments there is a possibility of larvae to become more cannibalistic, if moulted during the packing. Therefore, all the experiments were conducted in freshwater in order to prevent the moulting of

the larvae. Majority of the berry procurement centres were located in the freshwater regions and in such areas larvae could only be packed in freshwater. During commercial level larval rearing light feeding or no feeding is practised in the first 1 to 3 days since embryological food reserves are still being utilised by the newly hatched 1st stage (Malecha, 1983).

Levels of dissolved oxygen, pH and ammonia showed significant variation in different stocking densities and this is well in agreement with earlier studies (Hora and Pillai, 1962; Alias and Siraj, 1988; Vadhyar *et al.*, 1992). The final ammonia content recorded during the present study is well below 80 mg/l , the lethal limit of ammonia for *M. rosenbergii* (Armstrong *et al.*, 1978). The final values of dissolved oxygen, pH and ammonia between oxygen water ratio 2:1 and 1:1 showed no significant variation and this can be due to the maintenance of similar biomass per litre water.

Eventhough a distinct improvement in the survival rates could be seen when different coloured bags were used for packing, however, the variation was found to be not statistically significant among them. Therefore it can be concluded that the colour of the bag is not an important factor influencing the survival of the larvae of *M. rosenbergii* during transportation. Survival of the larvae is found to be higher when larvae were packed in black containers in the oxygen water ratio 1:1 with a stocking density of 2000 larvae per litre. The results of physico-chemical parameters also lend to support the above finding as it showed no significant variation in different coloured bags.

Table 8.1 Results of experiments in transparent package with different oxygen-water ratios

No. of Berries	Total Weight	Weight per liter	First morality observed	*Dissolved Oxygen	*pH	*Ammonia mg/l	Hatching rate
Oxygen Water Ratio 2:1 (6L water and 12L Oxygen)							
1	98 g	16.33	44 Hr.	2.3	6.9	9.56	--
2	182 g	30.33	32 Hr.	1.8	7.0	12.30	73%
3	265 g	44.17	28 Hr.	2.1	7.1	36.82	81%
4	285 g	47.50	24 Hr.	1.1	6.8	45.81	76%
Oxygen Water Ratio 1:1 (9L water and 9L Oxygen)							
1	135 g	15.00	52 Hr.	2.2	6.8	9.78	--
2	178 g	19.78	40 Hr.	2.4	6.9	10.59	88%
3	268 g	29.78	30 Hr.	2.4	7.0	25.98	82%
4	312 g	34.67	24 Hr.	2.8	7.0	38.90	74%

* Initial Values of Dissolved Oxygen - 8.7 mg/l, pH - 7.4 and Ammonia - 0.08 mg/l

Table 8.2 Results of experiments with three animals under different coloured packing in oxygen-water ratio 1:1

Packing Colour	Total Weight	Weight per liter	First morality * observed	Dissolved * Oxygen	*pH	*Ammonia mg/l	Hatching rate
Transparent	268 g	29.78	30 Hr.	2.4	7.0	25.98	82%
Green	284 g	31.56	38 Hr.	2.5	7.1	18.56	78%
Blue	271 g	30.11	36 Hr.	2.6	6.9	21.58	77%
Black	279 g	31.00	42 Hr.	2.4	6.9	14.95	82%
With Carrier Tubes	266 g	29.56	40 Hr.	2.4	7.0	16.58	79%

* Initial Values of Dissolved Oxygen - 8.7 mg/l, pH - 7.4 and Ammonia - 0.08 mg/l

Table 8.3 Results of analysis of variance (two way) carried out on various parameters observed during the packing of the broodstock of Macrobrachium rosenbergii with respect to oxygen water ratio and stocking density

	Source of Variation	Degrees of freedom	Sum of squares	Mean sum of squares	F-ratio
Safe Duration	Oxygen-water ratio	1	81.00	81.00	10.31*
	Packing density	7	1303.00	186.14	23.69*
	Error	7	55.00	7.86	
	Total	15	1439.00		
Dissolved Oxygen	Oxygen-water ratio	1	1.56	1.56	6.12*
	Packing density	7	0.25	0.04	0.14+
	Error	7	1.79	0.26	
	Total	15	3.60		
pH	Oxygen-water ratio	1	0.01	0.01	0.80+
	Packing density	7	0.24	0.03	4.84+
	Error	7	0.05	0.01	
	Total	15	0.30		
Ammonia	Oxygen-water ratio	1	92.54	92.54	8.56*
	Packing density	7	3017.30	431.04	36.87*
	Error	7	75.68	10.81	
	Total	15	3185.52		
Hatching Rate	Oxygen-water ratio	1	65.33	65.33	1.98+
	Packing density	5	98.00	19.60	0.60+
	Error	5	164.67	32.93	
	Total	11	328.00		

* Significant at 1% level (P<0.01)
\+ Not Significant (P>0.01)

Table 8.4 Results of analysis of variance carried out on various parameters observed during the packing of the broodstock of Macrobrachium rosenbergii in different coloured packages

	Source of Variation	Degrees of freedom	Sum of squares	Mean sum of squares	F-ratio
Safe Duration	Between samples	4	169.60	42.40	7.57*
	Within Samples	5	28.00	5.60	
	Total	9	197.60		
Dissolved Oxygen	Between samples	4	0.06	0.02	1.25+
	Within Samples	5	0.06	0.01	
	Total	9	0.12		
pH	Between samples	4	0.06	0.02	0.53+
	Within Samples	5	0.14	0.03	
	Total	9	0.20		
Ammonia	Between samples	4	152.85	38.21	19.11**
	Within Samples	5	10.00	2.00	
	Total	9	162.85		
Hatching Rate	Between samples	4	42.40	10.60	5.30*
	Within Samples	5	10.00	2.00	
	Total	9	52.40		

* Significant at 5% level (P<0.05)
** Significant at 1% level (P<0.01)
\+ Not Significant (P>0.01)

Table 8.5 Mean survival of early larvae of Macrobrachium rosenbergii obtained in different water-oxygen ratios and packing density

	12 hr.	24 hr.	36 hr.	48 hr.
1:2 Water:Oxygen (6L water and 12L Oxygen)				
Control	100.00	99.49	96.85	94.70
1000/L	97.47	97.63	83.63	75.94
2000/L	97.26	94.12	76.75	69.41
3000/L	82.60	74.70	59.72	44.14
1:1 Water:Oxygen (9L water and 9L Oxygen)				
Control	100.00	97.83	97.33	95.06
1000/L	99.32	98.06	87.12	80.12
2000/L	94.51	92.30	79.64	74.25
3000/L	91.67	73.81	62.42	48.23

Table 8.6 Dissolved oxygen recorded during the packing experiments with different water-oxygen ratios with early zoea larvae of Macrobrachium rosenbergii

	12 hr.	24 hr.	36 hr.	48 hr.
1:2 Water:Oxygen (6L water and 12L Oxygen)				
Control	8.5	8.3	9.1	8.6
1000/L	7.4	7.2	6.4	5.4
2000/L	7.2	6.4	5.4	4.8
3000/L	7.2	6.1	4.5	3.5
1:1 Water:Oxygen (9L water and 9L Oxygen)				
Control	8.5	8.7	8.7	8.5
1000/L	7.2	6.8	6.2	5.5
2000/L	7.1	6.4	5.2	4.8
3000/L	6.9	5.8	4.9	3.7

Initial dissolved oxygen 8.9 mg/l, pH 7.6, ammonia 0.07mg/l.

Table 8.7 Final pH recorded during the packing experiments with different water oxygen ratios with early zoea larvae of Macrobrachium rosenbergii

	12 hr.	24 hr.	36 hr.	48 hr.
1:2 Water:Oxygen	6L water and 12L Oxygen			
Control	7.8	7.8	7.6	7.4
1000/L	7.6	7.4	7.1	7.1
2000/L	7.6	7.2	7.1	7.1
3000/L	7.2	7.0	6.9	6.8
1:1 Water:Oxygen	9L water and 9L Oxygen			
Control	7.8	7.6	7.5	7.3
1000/L	7.5	7.4	7.2	7.1
2000/L	7.4	7.3	7.2	7.1
3000/L	7.4	7.2	7.0	6.9

Initial dissolved oxygen 8.9 mg/l, pH 7.6, ammonia 0.07mg/l.

Table 8.8 Ammonia excreted during the packing experiments with different water oxygen ratios with early zoea larvae of Macrobrachium rosenbergii

	12 hr.	24 hr.	36 hr.	48 hr.
1:2 Water:Oxygen	(6L water and 12L Oxygen)			
Control	3.45	8.24	12.55	16.80
1000/L	4.89	9.86	12.92	17.66
2000/L	7.56	14.86	22.45	25.84
3000/L	9.23	16.44	24.82	28.32
1:1 Water:Oxygen	(9L water and 9L Oxygen)			
Control	3.80	8.14	13.20	18.51
1000/L	5.82	10.29	13.86	16.99
2000/L	8.96	16.75	21.84	24.93
3000/L	10.24	15.88	22.84	27.50

Initial dissolved oxygen 8.9 mg/l, pH 7.6, ammonia 0.07mg/l.

Table 8.9 Result of analysis of variance and t-test of mortality in control and various stocking densities with water to oxygen ratio 1:2

Source	df	SS	MSS	F	Prob.
bet. samples	3	1619.08	539.69	16.08	P<0.001
within samples	44	1477.04	33.57		
Total	47	3096.12			

Combination	df	t	P
Control X 1000L/l	16	2.763	P<0.001
Control X 2000L/l	18	4.280	P<0.001
Control X 3000L/l	22	10.143	P<0.001
1000L/l X 2000L/l	21	0.867	
1000L/l X 3000L/l	16	3.708	P<0.001
2000L/l X 2000L/l	18	3.049	P<0.005

Table 8.10 Result of analysis of variance and t-test of mortality in control and various stocking densities with water to oxygen ratio 1:1

Source	df	SS	MSS	F	Prob.
bet. samples	3	1447.87	482.62	20.29	P<0.001
within samples	44	1046.70	23.79		
Total	47	2494.57			

Combination	df	t	P
Control X 1000L/l	18	2.568	P<0.001
Control X 2000L/l	21	4.588	P<0.001
Control X 3000L/l	21	10.281	P<0.001
1000L/l X 2000L/l	20	1.114	
1000L/l X 3000L/l	16	4.464	P<0.001
2000L/l X 2000L/l	19	3.996	P<0.001

Table 8.11 Mean survival of the early post larvae of Macrobrachium rosenbergii packed in different coloured packing materials

Stocking @2000 larvae/l water: Oxygen 1:1 9L Water : 9L Oxygen

	12 hr.	24 hr.	36 hr.	48 hr.
Control	100.00	97.83	97.33	95.06
Transparent	94.51	92.30	79.64	74.25
Green	95.49	94.62	88.64	86.55
Blue	92.41	89.38	86.99	84.12
Black	98.89	97.55	93.17	91.16

Table 8.12 Water quality parameters recorded during the experiments with early post larvae of Macrobrachium rosenbergii packed with different coloured packing materials.

Stocking @2000larvae/l water: Oxygen 1:1 (9L Water : 9L Oxygen)

a) Dissolved oxygen

	12 hr.	24 hr.	36 hr.	48 hr.
Control	8.5	8.7	8.7	8.5
Transparent	7.1	6.4	5.2	4.8
Green	7.2	6.7	6.3	5.8
Blue	7.3	6.7	6.2	5.7
Black	7.3	6.8	6.2	5.8

b) pH

	12 hr.	24 hr.	36 hr.	48 hr.
Control	7.8	7.6	7.5	7.3
Transparent	7.5	7.4	7.2	7.1
Green	7.6	7.6	7.3	7.2
Blue	7.5	7.4	7.2	7.0
Black	7.6	7.4	7.4	7.1

c) Ammonia content

	12 hr.	24 hr.	36 hr.	48 hr.
Control	3.80	8.14	13.20	18.51
Transparent	8.96	16.75	21.84	24.93
Green	8.45	15.92	20.86	22.8
Blue	8.68	14.56	19.82	21.45
Black	8.32	14.53	16.37	20.96

Initial dissolved oxygen 8.9 mg/l, pH 7.6, ammonia 0.07mg/l.

Table 8.13 Result of analysis of variance and t-test on mortality in control and various coloured containers

Source	df	SS	MSS	F	Prob.
bet. samples	4	632.47	158.12	6.619	P<0.001
within samples	55	1313.79	23.89		
Total	59	1946.26			

Combination	df	t	P
Control x Transparent	21	4.705	P<0.001
Control x green	21	4.815	P<0.001
Control x blue	22	4.307	P<0.001
Control x black	22	3.766	P<0.001
Transparent x green	19	0.282	
Transparent x blue	20	0.068	
Transparent x black	20	0.536	
green x blue	21	0.425	
green x black	22	0.307	
blue x black	22	0.445	

Chapter 9

Two Phase Larval Rearing of *Macrobrachium rosenbergii* (De Man) Adopting Clear Water System

Introduction

Larval culture of *Macrobrachium rosenbergii* (De Man) is being carried out by adopting different techniques (Ling,1969a; Fujimura and Okamoto, 1972; Malecha, 1983; Daniels *et al.*, 1992). In India, the seed production of this species is being done on a semi commercial level by the modified closed clear water system (Sebastian, 1994). However, the average survival in successful runs in the above system is reported to be less than 20% and this could be attributed to the various problems associated with poor water quality management and primary failure in maintaining the tank hygiene which may eventually lead to the infestation of protozoans or bacteria. In the present study an attempt has been made to evolve a new management system for rearing the larvae of *M.rosenbergii* with slight modification of the clear water system (Aquacop, 1977;1983).

Materials and Methods

Larval rearing experiments were conducted in round FRP tanks of two different capacities, ie 200-450 L and 400-1000 L having an inner smooth surface with oxford blue coloration, the former were used in phase I while the latter in phase II respectively. In phase I the rearing was continued for 10 days under opaque roofing where there was only low light intensity and thereafter the larvae have been serially transferred to the bigger tanks of phase II which

were kept under translucent roofing. Initial six runs were carried out by adopting the new management system successfully at the *Macrobrachium* hatchery of School of Industrial Fisheries. Later this system has been transferred to a commercial hatchery of Kerala from where results of 6 runs were incorporated. Mother prawns of *M.rosenbergii* in the weight range of 70-124 gm were collected from the Vembanad lake and transported and while reaching the hatchery quarantine measures were applied (New and Singholka, 1985). Hatching was performed in 5 ppt saline water in 50 L plastic buckets. Prezoeal stage larvae were stocked in tanks of phase I @ 80-130 larvae/l. Duplicates were also kept along with all experiments. Salinity was maintained at 12±2 ppt in both phases. Feeding was commenced from the second day by giving frozen Artemia nauplii and from the third day onwards, feed was particulated by mixing 'thelly' (*Metapenaeus* sp.) meat and egg and coagulated by steam cooking. Cod-liver oil and vitamins were also added and the feed was prepared into suitable size by passing through test sieves. Prepared suspension feed was given four times daily and live Artemia nauplii was fed one time at 8 pm (Adisukresno *et al.*, 1980, Lin and Ishiwata, 1993 a&b). Feed size used were 200µ (2 to 4 day), 400µ (5 to 10 day), 600µ (11 to 24 day) and 800µ (24 day onwards). Daily observations on temperature, salinity, pH and ammonia were made following standard procedures (Strickland and Parsons,1972). In the evening bottom and sides of the larval culture tanks were thoroughly scrubbed in order to remove algae and other organic accumulations with the help of a sponge mop (Daniels *et al.*,1992), 50% of the rearing medium was exchanged with freshly prepared saline water of 12 ppt in phase I while in phase II 30% exchange was given. After ten days, the tanks of

the second phases were provided with PVC frames/webbing for facilitating larval settlement and the post larvae so settled were harvested in three to four batches from individual tanks. The population size in the first phase was recorded daily by taking multiples of 50 ml samples while in the second phase the survival was computed from the number of post larvae segregated from the individual tanks. The survival registered among various stocking densities were compared using ANOVA (Snedecor and Cochran, 1967).

RESULTS

Variations of the physico-chemical parameters in 12 runs of larval rearing were as follows: temperature 23.8-29.6 ^{0}C, salinity 13.5-14.5 ppt, pH 7.5-8.4 and ammonia 0.01-0.05 ppm. Details on initial stocking density, survival in phase I and II and overall percentage survival of the 12 runs are presented in Table 9.1. In Phase I, survival percentage varied from 49.09 to 92.5% (M=72.54%) when the initial stocking density was maintained from 80 to 130 larvae/l. In the phase II, it varied from 19.06 to 47.41% (M=32.42%) with a stocking rate of 27-48 larvae/l. And overall survival percentage of 14.88 to 36.75%(M=23.00%) was thus obtained. All the runs were successfully completed without encountering any eventualities. Results of the ANOVA revealed that there was no significant difference in the survival percentages in phase I ($F=2.254$, $P>0.05$), phase II ($F=1.4411$, $P>0.05$) and overall ($F=1.2875$, $P>0.05$). The first and final settlements of post larvae were noticed on 22-24 and 33-36 days respectively and the number of post larvae produced varied from 7.5-18 /l(Table 9.1).

DISCUSSION

Larval rearing of *M.rosenbergii* adopting clear water technique is considered to be an improvement over green water system and widely employed by incorporating minor modifications with varied levels of success. New and Singolka (1985) reported PL production in the range 10-20/L whereas according to Sandifer and Smith (1976) it varied from 6.6-40.6/L and the results of the present study are comparable with the above results. However, Aquacop(1977,1983) could achieve a production of 32-60 larvae/l in mass larval rearing in clear water rearing system while Malecha (1983) and Chineah (1982) reported it as 30 and 52 larvae/l respectively. The results of the present study while making comparison with the above is on a lower side. Suharto *et al.*(1982) could achieve a survival rate up to 84.6% when the larval raring was carried out in small FRP conical tanks of 50 L capacity with an initial stocking density of 200 larvae/l and this is comparable with the survival rate registered in phase I of the present study in which 49.09 to 92.5% could be obtained with an initial stocking density of 80 to 130 larvae/l. However, in bigger tanks of phase II only 19.06 to 47.41 with a mean survival of 32.42% was achieved in the present study against 62.5% as reported by Suharto *et al.*(1982).

In India, green water and modified clear water systems are being adopted with different degrees of success in the seed production of *M.rosenbergii* in a semi commercial level. Although the production output in the commercial hatcheries in the successful runs is only around 20% with an

initial stocking density of 60/l which would work out to be 12.0 larvae/l (Sebastian and Nair,1995), higher survival of 75% could also be obtained (Sebastian, 1994). In the conventional clear water closed larval rearing system being mostly adopted in India, the full cycle is completed in one and the same tank with or without a biofilter (Sebastian *et al.*, 1993). Failures in production cycle in the commercial hatcheries of India either due to protozoan infestation and or bacterial infections (Sebastian, 1994; Rao and Tripathi, 1993) are regular features and these lead to erratic seed supply and therefore, none of the hatcheries could achieve the designated production capacity. On the contrary, all the 12 runs carried out by adopting the two phase system could successfully be completed without encountering the problem of total mortality and therefore the accomplishment of production cycles could be considered as an advantage over the prevailing system. It may therefore, be inferred that steady production could be accomplished in the two phase system mainly due to the changes made in the rearing tank after 10 days and also on account of water exchange @50 and 30% in the first and second phases respectively. The higher rate of water exchange favoured in maintaining not only a clear water but also a clean system free of excessive levels of heterotrophic bacteria and also characterized with minimum organic load in the culture tanks (Daniels *et al.*, 1992) in contrast to the poor hygiene normally seen in the rearing tanks as well as rearing medium of conventional systems. Besides, the problem of severe fluctuations invariably observed in regard to pH, ammonia and nitrite in the conventional systems (Rao and Tripathi, 1993) could also be set right to certain extent in the present system as the sublethal levels especially of total ammonia and nitrite can reduce the growth rate of larvae and can also increase their

susceptibility to parasites and diseases (Daniels *et al.*, 1992). The results of the present study also fully conform to Baticados *et al.* (1990) who concluded that prevention of disease through rigorous water management and sanitation was the best methodology for the control of pathogens.

The time taken for a larval batch to metamorphose varies according to the efficiency maintained with regard to water quality management and feeding and in properly maintained systems, most of the larvae should have metamorphosed into post larvae by day 25-28 (New and Singolka, 1985). In the present study the first and final settlement of the post larvae were observed on the days of 22-24 and 33-36 respectively. However, the settlement of about 60-75% of post larvae could be observed by days 27-30 and therefore appears that the system is almost comparable with the one as envisaged by New and Singolka(1985). Sandifer and Smith (1976) reported the first and final settlement days as 20-24 and 34-45 days respectively and this in comparison with the present finding shows that the duration of the final settlement is very lengthy in the former. On the contrary, the appearance of the post larvae on day 19 has been reported (Aquacop,1983) against day 22 observed in the present study. Nair and Hameed (1992) reported the initial and final settling days as 24-30 and 36-51 when rearing was accomplished in synthetic sea water. It would thus appear that in the presently evolved two phase system, the time taken for the metamorphosis of larvae and its completion were also relatively short in comparison with other reports (Sandifer and Smith. 1976; Nair and Hameed, 1992) and therefore it would be advantageous in making the operations economically more viable when compared to other conventional

systems. Nevertheless, the water requirement of this system is very high, especially when compared to the clear water closed system and therefore the two phase larval rearing system can be recommended to only those hatcheries where both sea water and freshwater are available to the desired level. By fixing the rearing duration in first and second phases as 10 and 30 days respectively, a tank ratio of 1:3 could be maintained serially whereby it would be possible to accomplish at least 18 full runs per annum. On completion of every 10 day the larvae of the first phase tanks can serially be transferred into the tanks of phase II where the rest of the cycle can be completed within another 30 days. The tanks of phase I so emptied shall be thoroughly cleaned, disinfected and sun dried with a period of 3-4 days and used for the stocking of the successive batches. It would thus be possible to maintain continuous production provided there are sufficient stocking material at the changing phases and a management system so evolved shall be useful in utilizing the full tank capacity and achieving the designated capacity of the hatchery. As there was no difference in the survival percentages under different stocking densities studied in phase I, it may be possible for further enhancement of stocking densities to 500-700/l as suggested by Rao and Tripathi(1993). Appropriate modifications can be made in the two phase rearing system so evolved based on evaluation of the results gathered in the preliminary trials whereby the post larval production may be further improved.

Table 9.1 Stocking densities and survival percentages in first and second phases, post larval settling time and overall survival of Macrobrachium rosenbergii in two-phase clear water system

Experimental Protocol	1**	2**	1	2	1	2	1	2	1	2	1	2
Stocking density*	80		90		100		110		120		130	
First Phase												
Initial stocking density *	80	80	90	90	100	100	110	110	120	120	130	130
Final density*	74	58	72	70	80	92	54	74	72	86	96	70
Survival (%)	92.50	72.50	80.00	77.78	80.00	92.00	49.09	67.27	60.00	71.67	73.85	53.85
Average survival (%)	72.54											
Second phase												
Initial stocking density *	37	29	36	35	40	46	27	37	36	43	48	35
Total post larvae produced (No./liter)	9.63	7.50	8.11	10.00	12.50	18.38	12.80	14.85	10.21	16.37	9.15	14.63
Second phase survival (%)	26.01	25.86	22.53	28.57	31.25	39.95	47.41	40.14	28.37	38.06	19.06	41.79
Average survival (%)	32.42											
First appearance of post larvae (in days)	24	25	22	24	22	24	24	23	22	23	23	24
Completion of larval settlement (in days)	33	36	34	35	35	35	35	34	34	34	36	34
Overall survival (%)	24.08	18.75	18.02	22.22	25.00	36.76	23.27	27.00	17.02	27.28	14.08	22.51
Average survival (%)	23.00											

* Stocking density in larvae per liter
** 1 and 2 denotes replicates

Chapter 10

Effect of container colouration on the larval culture of *Macrobrachium rosenbergii*.

Introduction

A positively skewed size distribution curve with time is an inherent character of natural as well as domesticated population of *Macrobrachium rosenbergii,* especially in males. From zoea I onwards, the larvae showed variation in relative growth (Malecha, 1983; Howlader and Kiortsis, 1978; Sankaran and Nair, 1992) and therefore non-uniformity in larval moulting might have caused difference in growth and heterogeneity in size of post larvae which were initially categorised as 'jumpers' and 'laggards' (Karplus and Hulata, 1995) and subsequently as 'morphotypes' in grownup population (Kuris *et al.*, 1987). The hatching from a clutch over a period of 96-hrs. leads to an initial dispersal in the number of larval stages (Malecha, 1983). Skinner (1985) stated that larval stages in some crustaceans moult very frequently, passing from one proecdysis to the next without an intervening anecdysis when they are growing in optimal environmental conditions. In *M.rosenbergii,* uniform moulting cannot be observed from a mass culture system due to the variation in general health and well being and therefore, uniformity in moulting stage can be taken as a criterion for predicting post larval production from a larval rearing cycle (Howlader and Kiortsis, 1979; Sankaran and Nair, 1992). Under controlled conditions the transition from a free swimming larva to crawling adult like post larva takes place over a period of 15 days (Ling, 1969a) and it may extend up to 36 to 42 days in *M.rosenbergii* (Suharto *et al.*, 1982; Adisukresno *et al.*, 1980). The difference in the time taken for the completion

of larval stages can mainly be attributed to the effects of different physico-chemical parameters on growth and moulting (Malecha, 1983).

The progression of larval metamorphosis (Malecha, 1983; Sankaran and Nair, 1992) with respect to varying physico-chemical parameters of the rearing medium is yet to be reported. The light intensity induces excitation and adversely affect the feeding of larva of *M.rosenbergii* (Lin and Omori, 1993) however, the optimal spectral quality required for the successful larval development is quite unknown (New, 1995). Against this background an investigation was carried out to assess the effect of different container colouration on the survival and metamorphosis of the larvae of *M.rosenbergii*. The results of the present study will be useful for the selection of tanks with appropriate colouration for the commercial level seed production of *M.rosenbergii*.

Materials and Methods

Larval rearing experiments were undertaken by using different coloured plastic and FRP containers having an effective capacity of 50 litre, following standard methods (Rao and Tripathi, 1993) at the prawn hatchery of the School of Industrial Fisheries. Larvae were stocked @50 larvae per litre and fed with newly hatched Artemia nauplii and egg-prawn custard (Rao and Tripathi, 1993; Sebastian and Nair, 1995). Colour of the tanks used were green, light blue, red, white, deep blue, dull white and black. Light intensity of different coloured tank was measured on a bright day at 2.00 PM using Lutron LX-101 Lux Meter and the results are presented in Table 10.1 for differentiating the light intensity in different containers. Samples of 25 animals

were randomly collected on every 5th day from the tanks till completion of the larval metamorphosis.

11 larval stages were identified following the morphological variation before transforming into post larvae as described by Ling (1969a) and Uno and Kwon (1969) and recently by Malecha (1983), New and Singholka (1985) and Rao and Tripathy (1993). Frequency of distribution of larval stages in different coloured tanks were assessed on a daily basis and from the data so obtained the mean stage and standard deviation were worked out and presented. Since the PL were not further classified, a decrease in the mean deviation could be seen after 25th day and therefore mean deviation and coefficient of variation (Gupta, 1981) of larval stages up to 25th day were subjected to discussion. The initial appearance of post larvae ('scout PL time', Malecha, 1983), completion of metamorphosis of >95% larvae (95% PL drop time, Malecha, 1983) and the percentage survival were recorded from each tank. Performance of different coloured containers were compared with respect to survival, scout PL time, 95% PL drop time and uniformity in larval stages.

Results

During the larval rearing period, temperature of the rearing medium varied from 25-30^{0}C, however, at the observation time the variations in different tanks were below 1^{0}C. Maximum pH recorded during the rearing period was 8.2 from black coloured tank while, lowest of 7.3 was recorded in deep blue tank.

The experiments were conducted in duplicate and the days at which the initial and final settlement were reported in different coloured tanks are presented in Table 10.2. The rate of metamorphosis and survival recorded in different coloured containers are given in Table 10.3. Survival of the larvae recorded from various tanks with different colours are given in Table 10.3 and Fig. 10.1. Final survival was highest in red tank (34.12%) followed by deep blue (26.80%) followed by black (18.56%) and green tanks (18.52%) whereas, survival was relatively poor in dull white tank (12.52%), white tanks (12.80%) and light blue (13.88%).

Significant variation could be noticed in respect of time taken for the first appearance of post larvae and completion of larval metamorphosis in different coloured containers (Table 10.2). Post larvae appeared first in deep blue and light blue coloured tanks on 22^{nd} day whereas, it was delayed up to 24^{th} day in white, dull white and black coloured tanks. Time taken for the 95% PL drop time varied from 36^{th} to 42^{nd} day in different containers (Table 10.2).

Post larval stage was found to be the median stage at 35^{th} day of culture in green, deep blue and black tanks showing faster rate of metamorphosis (Table 10.3). On the contrary, in white, light blue and dull white tanks, 11^{th} stage larva was found to be the median stage on 35^{th} day which indicated that the rate of metamorphosis was very slow. The progression of mean stages were faster in deep blue, black and red tanks when compared to other colours studied (Table 10.3).

Invariably in all the tanks, standard deviation showed an increasing trend up to 20-25^{th} day showing an initial increase in the dispersal of larval stages in the population, however, a decreasing trend could be observed

subsequently (Table 10.3). Coefficient of Variation showed a gradual decrease in light blue, deep blue, white and green tanks whereas an initial increase and a subsequent decrease was observed in black, dull white and red tanks (Table 10.3, Fig. 10.2). Mean deviation of larval stages showed an increasing trend up to 15th day except in dull white in which a decreasing trend could be discernible after 10th day (Table 10.3, Fig. 10.3).

Discussion

Salinity was maintained at 12 ppt which was found to be optimal for the larval rearing of *M.rosenbergii* (Ling, 1969a; Rao and Tripathi, 1993) while, fluctuation of temperature and pH were found to be within tolerable limits (New and Singholka, 1985; Rao and Tripathi, 1993) in the rearing medium. Extreme temperature and pH were not observed in any of the tanks during the present study. It may therefore, be inferred that the variation encountered in the survival and metamorphosis cannot be attributed to adverse physico-chemical parameters of the rearing environment. The difference observed in the larval survival and metamorphosis in different containers may be due to the difference in the light intensity variation observed in the tanks against the colour variations of the tank.

All the 11 larval stages described by Uno and Kwon (1969) could easily be identified following the descriptions of New and Singholka (1985), Malecha (1983) and Rao and Tripathi (1993). Gomez-Diaz and Kasahara (1987) described six new zoeal instars besides 11 instars which have already been described. Since the morphological distinction of additionally reported

stages lack clarity and therefore, in the present study, these stages were not given proper emphasis.

In the present study, survival of the larvae varied from 12.52 to 34.12% and the post larvae so obtained was in the range 6.26 to 17.03 per litre. This is favourably comparable with the report of New (1988) from Thailand where a post larval production of 10-20/l could be obtained when an initial stocking density of 30-50L/l was maintained. However, the post-larval production/litre in the present experiments was much low when compared to Chineah (1982) and Suharto *et al.* (1982). An inverse relationship could be obtained when survival was correlated with light intensity ($r= -0.599$; $P<0.05$) which showed a relatively good survival in diffused light. Invariably, survival was highest in red and deep blue coloured tanks in which the light intensity was very low when compared to other coloured tanks studied (Table 10.3). This is favourably comparable with New (1995) from Thailand who reported that good results were obtained in tanks covered to minimise the bright light in backyard hatcheries.

'Scout PL time' was found to fall in a narrow range between 22 to 24 days whereas '95% PL drop time' varies considerably from 36 to 42 days. The scout PL time was comparable with Sandifer and Smith (1979), Nair and Hameed (1992). On the contrary, the 95% PL drop time was found comparatively low in the present study. 95% PL drop time in deep blue coloured tanks was 36 days and this was found to be comparatively earlier when compared to other coloured tanks. But white tanks have shown a lengthy 95% PL drop time of 42 days, besides having low survival and less uniformity in larval metamorphosis, and therefore it can reasonably be assumed that this

colour is not at all suitable for larval culture of *M.rosenbergii* .This may be due to the higher light intensity in the white tanks which may lead to lower feeding rate and consequent growth retardation as suggested by Lin and Omori (1993). The 95% PL drop time was found to be relatively lower in dark containers which fully agrees with the observation of Lin and Omori (1993).

With the progression of larval metamorphosis, an increase in mean deviation could be noticed, corresponding to the dispersal seen in the number of larval stages (Table 10.3). This is well in agreement with Malecha (1983) who reported that the larval stage frequency is skewed right with the advancement of rearing. A marked variation in the mean deviation in different coloured containers could be discernible and this can be taken as an index of variation due to the effect of container colouration on the frequency of larval moulting which may ultimately result in the spread of number of stages.

Coefficient of variation of larval stages showed a decreasing trend with the progression of larval stages. This is at variance with the observation of Sankaran and Nair (1992) who reported a gradual increase in coefficient of variation with the progression of larval rearing. A decreasing trend observed in the coefficient of variation may be due to the higher mortality rate, which may in turn remove the unhealthy larvae. Sankaran and Nair (1992) are of the view that the increase in the number of larval stages was due the occurrence of unhealthy larvae, which will not moult as frequently as the healthy larvae. Coefficient of variation also showed a negative correlation with light intensity ($r= -0.639$; $P<0.05$) and was found to be significant, which clearly shows that light intensity and spectral quality have profound influence on the larval metamorphosis in controlled conditions. While comparing the stages appeared

on 30th day in different tanks, it could be seen that in the present study the larvae were in more advanced stages against the presence of very earlier stages in the culture as reported by Sankaran and Nair (1992) which can be attributed to the selective mortality of the lower stages in the present study. This is further supported by the lower coefficient of variation. Coefficient of variation, which can be taken as an indication of uniformity in larval stages, showed highest uniformity after 25th day in deep blue tank, which further confirms its suitability for larval rearing. Whereas, white tank showed an inferior performance in respect of uniformity of larval stages.

Intensity of light inversely affect the feeding of larvae (Lin and Omori, 1993) which may influence the timely moulting and ultimately lead to differential growth. The physiological effects on the larvae when exposed to varying light intensity and spectral quality are not yet fully unravelled. Dark coloured tanks showed a superior performance with respect to survival, scout PL time, 95% PL drop and hence, are found to be suitable for larval rearing of *M.rosenbergii*. It may, therefore, be inferred that the selection of different coloured tanks for seed production is an important criteria for the successful and viable operation of commercial hatcheries. The results of the present study showed that deep blue coloured containers are relatively very efficient in getting more post larvae and therefore suitable for larval rearing of *M.rosenbergii* followed by red and black tanks, on the contrary, white, dull white and light blue coloured tanks showed inferior performance in post larval production. It would therefore be advisable to avoid tanks with white and light blue colouration for the larval culture of *M.rosenbergii* in commercial hatcheries.

Table 10.1 Light intensity recorded in rearing tanks having different colouration at 2 PM on a bright day

Location	Intensity (Lux)
1. Hatchery Premises	
Outside the hatchery	8,450
Inside the hatchery	3,750
2. Tanks	
Green	1,050
Light blue	1,200
Red	990
White	3,000
Deep blue	970
Dull white	2,800
Black	890

Table 10.2 Effect of container colouration on initial and final settlement of post larvae of Macrobrachium rosenbergii

Tanks	Initial Settlement (Days from starting)	Final Settlement (Days from starting)
Green	23	38
Light blue	22	39
Red	23	37
White	24	42
Deep blue	22	36
Dull white	24	39
Black	24	37

Table 10.3 Effect of container colouration on larval metamorphosis and survival of Macrobrachium rosenbergii

Green tank	5th day	10th day	15th day	20th day	25th day	30th day	35th day	38th day
Lowest stage	2	2	4	5	6	8	10	12
Highest stage	5	7	10	11	12	12	12	12
Mean stage	3.05	4.92	7.11	8.42	9.63	10.43	11.56	12.00
Median	3.0	5.0	7.0	8.5	10.0	10.5	12.0	12.0
Standard Deviation	0.69	1.12	1.59	1.56	1.64	1.34	0.73	0.00
Standard Error of Mean	0.15	0.22	0.30	0.32	0.33	0.36	0.24	0.00
Skewness	1.02	-0.81	-0.31	-0.32	-0.44	-0.27	-1.50	–
Coefficient of Variation	22.50	22.66	22.44	18.51	17.01	12.87	6.29	0.00
Mean Deviation	0.35	0.72	1.25	1.25	1.29	1.14	0.44	–
Survival (%)	93.21	87.55	83.21	62.18	48.44	36.12	23.68	18.52

Light Blue tank	5th day	10th day	15th day	20th day	25th day	30th day	35th day	39th day
Lowest stage	2	3	4	5	5	7	9	12
Highest stage	5	7	9	10	11	12	12	12
Mean stage	3.07	5.21	6.89	7.90	8.50	9.58	11.13	12.00
Median	3.0	5.0	7.0	8.0	8.5	9.0	11.0	12.0
Standard Deviation	0.73	0.92	1.29	1.33	1.53	1.39	0.92	0.00
Standard Error of Mean	0.20	0.21	0.30	0.30	0.31	0.32	0.24	0.00
Skewness	1.27	-0.46	-0.66	-0.39	-0.32	0.17	-0.94	–
Coefficient of Variation	23.77	17.61	18.66	16.88	18.03	14.48	8.22	0.00
Mean Deviation	0.36	0.63	0.95	1.00	1.25	1.11	0.67	–
Survival (%)	91.47	74.21	68.56	54.44	38.21	21.22	16.50	13.88

Red tank	5th day	10th day	15th day	20th day	25th day	30th day	35th day	37th day
Lowest stage	2	2	3	4	6	8	10	12
Highest stage	5	6	8	10	12	12	12	12
Mean stage	3.13	4.61	6.13	7.78	9.36	10.86	11.42	12.00
Median	3.0	5.0	6.5	8.0	9.0	11.0	11.5	12.0
Standard Deviation	0.80	1.20	1.65	1.66	1.59	1.20	0.67	0.00
Standard Error of Mean	0.16	0.25	0.34	0.39	0.30	0.26	0.19	0.00
Skewness	0.89	-0.54	-0.53	-0.81	-0.05	-0.86	-0.74	–
Coefficient of Variation	25.52	25.95	26.94	21.40	17.01	11.01	5.86	0.00
Mean Deviation	0.46	0.91	1.38	1.22	1.29	0.90	0.58	–
Survival (%)	91.12	87.62	73.11	60.42	49.74	44.68	38.59	34.12

White tank	5th day	10th day	15th day	20th day	25th day	30th day	35th day	40th day
Lowest stage	1	2	3	4	5	7	9	11
Highest stage	5	7	9	10	12	12	12	12
Mean stage	2.88	4.68	6.33	7.04	8.00	9.91	11.06	11.75
Median	3.0	5.0	7.0	7.0	8.0	10.0	11.0	12.0
Standard Deviation	0.93	1.25	1.71	1.60	1.72	1.41	1.00	0.45
Standard Error of Mean	0.22	0.25	0.31	0.33	0.34	0.30	0.25	0.13
Skewness	0.26	-0.31	-0.65	-0.07	0.56	-0.05	-0.60	-1.33
Coefficient of Variation	32.18	26.69	26.98	22.74	21.51	14.24	9.02	3.85
Mean Deviation	0.59	0.96	1.33	1.29	1.31	1.09	0.81	–
Survival (%)	86.72	75.11	52.73	32.11	22.96	20.20	16.41	12.80

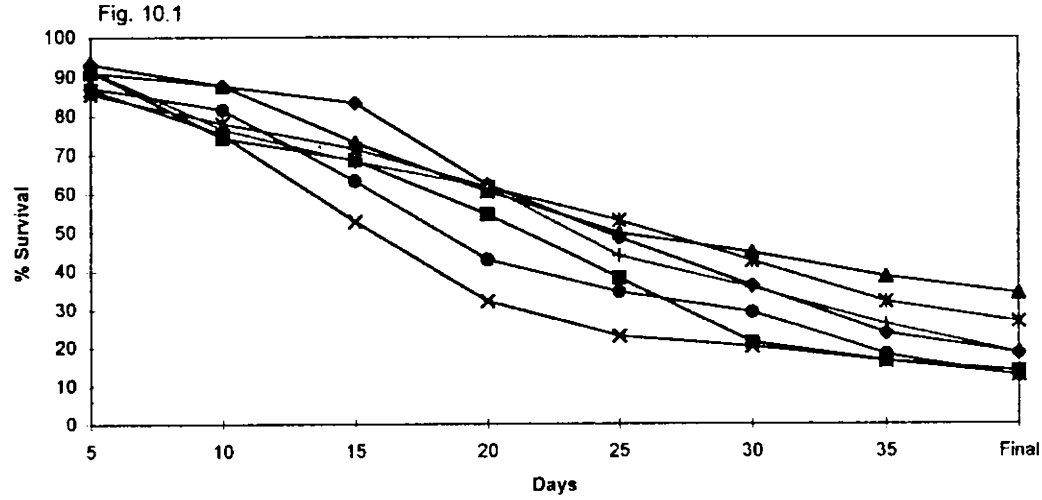
(Continued.....)

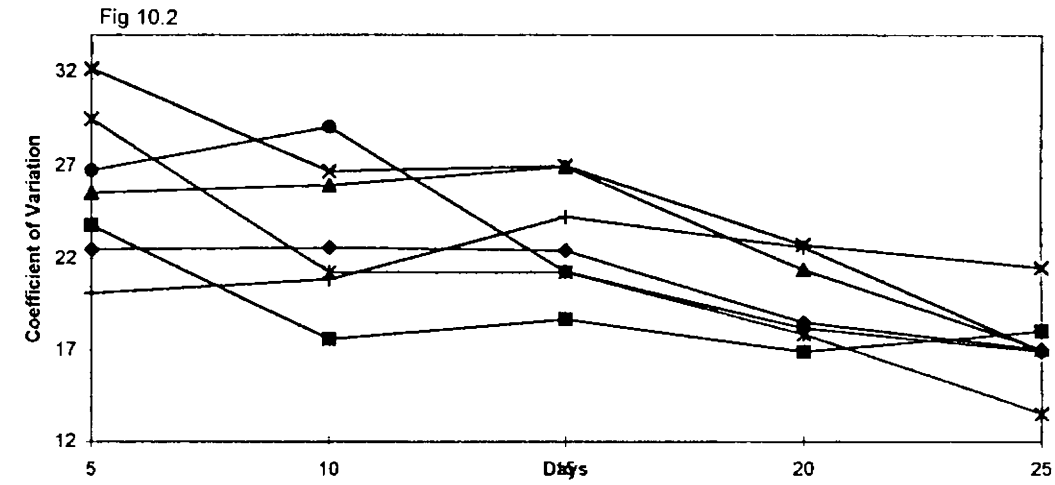
Table 10.3 (Contd.)

Deep Blue tank	5th day	10th day	15th day	20th day	25th day	30th day	35th day	36th day
Lowest stage	2	3	4	5	7	9	11	12
Highest stage	6	7	9	11	12	12	12	12
Mean stage	3.35	5.20	6.76	8.60	9.63	10.85	11.73	12.00
Median	3.0	5.0	7.0	9.0	10.0	11.0	12.0	12.0
Standard Deviation	0.99	1.11	1.44	1.54	1.30	0.99	0.47	0.00
Standard Error of Mean	0.22	0.25	0.35	0.34	0.30	0.27	0.14	0.00
Skewness	1.37	-0.44	-0.68	-0.69	0.10	-0.26	-1.19	–
Coefficient of Variation	29.50	21.25	21.25	17.86	13.50	9.10	3.98	0.00
Mean Deviation	0.55	0.80	1.06	1.20	1.00	0.77	0.27	–
Survival (%)	85.46	77.92	71.44	61.52	52.93	42.55	31.98	26.80

Dull White Tank	5th day	10th day	15th day	20th day	25th day	30th day	35th day	39th day
Lowest stage	1	2	4	5	6	8	10	12
Highest stage	4	7	9	10	12	12	12	12
Mean stage	2.71	4.61	6.54	7.16	8.76	9.87	11.15	12.00
Median	3.0	5.0	7.0	7.0	9.0	10.0	11.0	12.0
Standard Deviation	0.73	1.34	1.39	1.30	1.48	1.19	0.80	0.00
Standard Error of Mean	0.19	0.28	0.39	0.30	0.36	0.31	0.22	0.00
Skewness	-0.89	0.06	-0.09	0.52	0.33	0.59	-0.31	–
Coefficient of Variation	26.76	29.07	21.28	18.19	16.89	12.03	7.18	0.00
Mean Deviation	0.43	1.09	1.08	1.00	1.06	0.93	0.63	–
Survival (%)	87.22	81.44	63.21	42.77	34.56	29.27	18.16	12.52

Black tank	5th day	10th day	15th day	20th day	25th day	30th day	35th day	37th day
Lowest stage	2	3	3	4	6	8	10	12
Highest stage	4	7	9	10	12	12	12	12
Mean stage	3.00	5.33	6.48	6.96	8.75	10.53	11.50	12.00
Median	3.0	5.0	7.0	7.0	9.0	11.0	12.0	12.0
Standard Deviation	0.60	1.11	1.57	1.57	1.48	1.12	0.63	0.00
Standard Error of Mean	0.17	0.29	0.34	0.30	0.33	0.26	0.16	0.00
Skewness	0.00	-0.41	-0.64	-0.12	0.26	-0.47	-0.90	–
Coefficient of Variation	20.10	20.86	24.23	22.61	16.94	10.68	5.50	0.00
Mean Deviation	0.33	0.87	1.19	1.25	1.15	0.89	0.50	–
Survival (%)	91.75	76.42	68.25	61.54	43.79	35.66	26.22	18.56





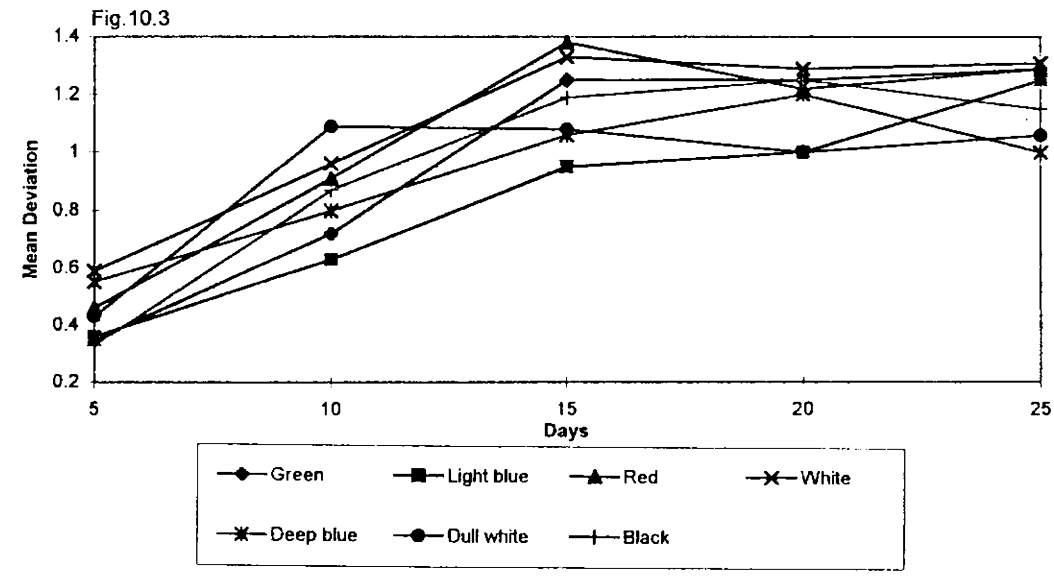


Fig. 10.1 Survival of larvae of Macrobrachium rosenbergii in different coloured containers

Fig 10.2 Coefficient of variation of larval stages of Macrobrachium rosenbergii during the rearing period in different coloured containers

Fig. 10.3 Mean deviation of larval stages of Macrobrachium rosenbergii during the rearing period in different coloured containers

Summary

Summary

Freshwater prawns of the genus *Macrobrachium* support a lucrative fishery in the inland water bodies of India, especially in Vembanad lake and adjoining rivers. Moreover, commercial farming of this group has been developing as a major industry on a global basis ever since the realisation of scientific techniques in seed production and innovative farming. Human interventions in the Vembanad lake of south-west coast of India, have brought out serious alterations in the ecology which in turn has adversely affected the exploited prawn fishery resource of this water body. Major conjectures exist behind the depletion of stock of freshwater prawns are the reduction brought about in the extent of its natural habitat owing to the intensification of agriculture, physical obstruction imposed on the migratory path of females, overfishing and pollution hazards. Recently, there has been a renewed interest is seen in the production of *Macrobrachium rosenbergii* by resorting to scientific farming in Kerala in general and polders adjacent to Vembanad lake in particular. Major constraints presently met with in the commercial farming of *M. rosenbergii* are the non-availability of seed in required numbers at right time and the highly skewed size disparity problems inherent in males of this species due to the differential growth associated with the developmental profile of male morphotypes and their dynamics of interaction.

No concerted attempts have so far been made to explicate the pattern of distribution of *Macrobrachium* spp. in Vembanad lake and also to understand the bearing of various physico-chemical parameters on the pattern of distribution. The biological and biochemical variations among different male

morphotypes of *M. rosenbergii* inhabiting the natural ecosystem are hitherto unknown. *M. striatus* has been conferred with a distinct species status quite recently, though earlier workers considered this only as a striped variety of *M. equidens*, and therefore the biology of this species remained unravelled. Although the seed production of *M. rosenbergii* became a reality, none of the hatcheries could so far been attained the designated production capacity due to the uncertainty met with the larval rearing cycles. Brood stock rearing technique has not been developed so far by giving adequate attention to variations shown by the male morphotypes in their reproductive capability. Against these backgrounds, an indepth investigation on the systematics and distribution of *Macrobrachium* spp. inhabiting Vembanad lake was attempted while bionomics of *M.rosenbergii* and *M.striatus* were studied in detail whereas, investigations on various aspects of seed production were focused only on *M.rosenbergii.*

A detailed survey was conducted at 29 selected stations representing 13 zones of the Vembanad lake and adjoining rivers to study the occurrence of various *Macrobrachium* spp. and characterise them allometrically giving due emphasis to morphotypic differentiation seen in *M.rosenbergii.* Six species under the genus *Macrobrachium* have been identified such as *M.rosenbergii, M.idella, M.equidens, M.striatus, M.scabriculum* and *M. rude.* Only males of *M.rude* could be collected during the present study and its availability could be recorded only from a single station. Morphotypes of males and females of *M.rosenbergii* could be identified in the exploited stock. An identification key was prepared on the basis of easily measurable and clearly distinguishable morphological characters.

Size structure of various male and female morphotypes of *M.rosenbergii* and their transitional stages collected from the Vembanad lake showed a considerable overlapping when compared to domesticated population. Total lengths of t-SOC and WBC ranged between 106 to 293 mm and 122 and 286 mm respectively showing distinct heterogeneous nature of size structure. Body dimensions showed linearity in all the male morphotypes except OBC whereas, among females all body dimensions of only TOF and SBF showed linearity while many of the relationships in WOF, SOF, and WBF were found to be non-linear.

Most of the morphometric measurements of *M. rosenbergii*, *M. idella*, *M. equidens* and *M. striatus* showed linearity, on the contrary, in *M.scabriculum* and *M.rude* a non-linear relationship could be discernible. Comparison of regression coefficients of relationship between rostral length, length of ischium, merus, carpus and total length of 2nd cheliped to total length and carapace length revealed that there exists species specific variation in growth of various body parts among the various species of *Macrobrachium* inhabiting Vembanad lake.

Sexual dimorphism in *Macrobrachium* spp. was quantified and the results show that among various species, *M.scabriculum* ($D=3.285$, $P<0.01$) showed maximum morphological difference between the sexes. Morphometric differences among different species was also brought out using D^2 analysis and the results revealed that difference between *M.rosenbergii* and other species was very high.

Vembanad lake has all the characteristics of a tropical positive estuary and this water body receives influx of freshwater from four major river

systems. Variation of temperature, salinity, pH and DO from 13 zones of the lake were recorded with a view to delineate the bearing of these parameters on the distribution and abundance of the *Macrobrachium* spp. in 29 stations representing the above zones of the lake. The commissioning and operation of Thanneermukkom salinity barrier caused severe alterations in the ecology as the lake has got separated into southern freshwater region and northern brackish water region. Surface temperature varied from 25 to 32^{0}C during the study period with highest temperature in March-April, however, it showed a steep decrease in July due to monsoon.

Highest salinity was recorded in March -April period in downstream region proximal to bar mouth, whereas, with the onset of monsoon the entire lake has transformed into freshwater body. The salinity intrusions to the upper stretch of the lake is well restricted due to the operation of salinity barrier and the highest salinity recorded from this region was only 8 ppt. Dissolved oxygen content ranged between 3.16 to 10.64 ml/l and generally low DO values were registered in most of the stations during pre-monsoon while in monsoon period higher values of DO could be recorded.

Macrobrachium spp. were found to be abundant in the downstream area during July to January, when the salinity was low, whereas, in the upstream area, their occurrence was registered in almost all months. Presence of *M.rosenbergii* could be seen in almost all stations of the lake with distinct peaks in monsoon and post-monsoon seasons. On the contrary, *M.idella*, which is the second commercially important species of Vembanad lake was available almost year round in downstream region though the salinity fluctuation in this part of the lake was invariably high. *M.equidens* showed a regular occurrence in the

'padal' catches during October to May periods, when salinity was high and also a positive correlation existed between its abundance and salinity which indicates that this species prefers high saline conditions as the habitat. A differential occurrence of *M. equidens* and *M. striatus* could be noticed during the present study in which the dominance of latter could be seen from June to November whereas the former was found abundant during December to May. This differential availability can be taken as an ecological tool for establishing their distinct taxonomic identity.

M.scabriculum does not constitute a subsistence or commercial level fishery in the Vembanad lake. This species showed more or less a regular occurrence in the southern part of the upstream region, however its occurrence in downstream region was well restricted to monsoon season and therefore would suggest that *M.scabriculum* is a pure freshwater species.

While examining the species abundance in a selected station at Kumbalam, it could be seen that highest number of *Macrobrachium* spp. were registered during October while it was lowest in May. Species richness was highest in January (0.830) and December (0.828) when the presence of all the species identified from the lake could be registered in the catches. Evenness index was maximum in April and May during when only *M.idella* and *M.equidens* were present and their numerical abundance was also appeared to be more or less similar. Highest Shannon Diversity Index could be registered in December (0.847) showing highest diversity of freshwater prawn community in the lake in this month.

Qualitative analysis of gut contents of *M.rosenbergii* and *M.striatus* showed that both the species are bottom feeders. *M.rosenbergii* showed a

preference to detritus while *M.striatus* preferred plant matter. The presence of animal matter as well as plant matter in the gut of *M.rosenbergii* revealed its omnivorous feeding nature. Both *M.rosenbergii* and *M.striatus* showed no specific seasonal variation in their food preference. In females of both the species a reduced feeding rate with the advancement of maturation could be observed. Gut content of SOC showed a higher percentage of animal matter and the gastrosomatic index was also high in this morphotype and this finding would lend to support the fast growing nature of this morphotype.

Gastrosomatic index of *M.rosenbergii* showed highest value in June 1994 in the first year whereas, in the second year it was in May 1995. In both the years, Gastrosomatic index of males and females showed a decreasing trend from May-June to December-January. Among the male morphotypes of *M.rosenbergii* studied, highest Gastrosomatic index was recorded in strong orange clawed males (SOC) (3.585) whereas among females, immature females (4.479) showed highest Gastrosomatic index. In males of *M. striatus* no such variation in gastrosomatic index could be seen and moreover the trend also showed no similarity between the two years, on the contrary, in females a gradual decrease could be observed from June to August and thenceforth increased up to March.

Among the females of both the species, five maturity stages were identified viz. immature, maturing, matured, berried and spent. Berries of *M. rosenbergii* were further divided into four stages based on the extent of embryonic development whereas, such variation in the development of *M.striatus* was not perceptible. In *M.rosenbergii* males cannot be classified into maturity stages on the basis of length groups as the morphotypes showed

difference in their reproductive capability. Three maturity stages were identified among males of *M.striatus* viz. immature, maturing and matured based on total length, nature of second cheliped and development of testis. By observing the percentage occurrence of males and females as well as different maturity stages and gonadosomatic index, the breeding season of *M.rosenbergii* and *M.striatus* were demarcated as July to December and September to January respectively. Numerical abundance of reproductively inactive morphotypes during the commencement of breeding season and a subsequent increase in the number of reproductively active morphotypes of *M.rosenbergii* along with the progression of the breeding season clearly manifests the possibility of morphotypic transformation undergone by males in the natural population. All the female morphotypes were found to be sexually active except small female and from the percentage occurrence of various maturity stages in different morphotypes it is postulated that unlike in males, morphotypic expression seen in females are manifestation of age rather than reproductive potential.

In both *M.rosenbergii* and *M.idella*, variations in GSI and HSI were prominent in females when compared to their male counterparts. HSI of females of both the species showed an inverse relationship with GSI. In males and females of *M.rosenbergii* GSI showed a gradual increase from April to October in both the years of study, on the contrary, HSI of males showed higher values during July to November in 1994 and in July and September-November in 1995. Among male morphotypes of *M.rosenbergii*, highest GSI was recorded in strong blue clawed males (SBC) (0.445), on the contrary, HSI was highest in SOC (6.351) manifesting higher reproductive capability of the former against the provision for higher somatic growth rate in the latter. A gradual increase in

GSI could be observed in both *M.rosenbergii* and *M.idella* commensurate with the advancement of embryonic development and this finding would suggest the possibility of rematuration of the ovary in the same season and therefore it is inferred that this species is characterised with more than one spawning in a breeding season.

Fecundity recorded in *M. rosenbergii* was found to fall in the range of 30,666 to 2,27,161 eggs per animal for the specimens ranging in size from 33.7 to 208.0g, whereas that of *M. striatus* it varied between 1,175 and 9, 625 in specimens ranging in size from 1.88 to 8.02g. Average fecundity was estimated to be 95,687 eggs and 9,625 in *M.rosenbergii* and *M.striatus* respectively. No significant variation could be noticed in the relative fecundity among different berry colour and different morphotypes however, the variation was significant among various length groups. In *M.striatus* also significant variation could be observed in the relative fecundity of different length groups. In both the species fecundity showed strong positive correlation with total length, carapace length and total weight and therefore, these characters can reliably be used for the indirect estimation of fecundity. The number of eggs per unit body length, carapace length and body weight was calculated as 447, 1623, and 896 in *M.rosenbergii* and 66, 229 and 1033 in *M.striatus.*

A specific pattern in the seasonal availability of *M.rosenbergii* could be discernible in all the three regions of the Vembanad lake which indicates the migratory nature of the stock. Females evinced a distinct migratory path when compared to males whereas, only a small portion of the male population was found to be migrating far down along with females. Sex ratio of *M.rosenbergii* in the Vembanad lake skewed considerably during

different months with a predominance of males from April-May to June-July and thenceforth females dominated the catch. Females outnumbered males when the overall sex ratio was worked out with a male to female ratio of 1:1.33 in *M. rosenbergii* and 1:1.29 in *M. striatus*. Return migration of the breeding stocks through Muvattupuzha and Pampa rivers were noticed during December-January periods. Occurrence of a resident stock of *M.rosenbergii* was delineated in the upstream region where salinity was invariably very low. Length frequency distribution of the population in three regions of the lake showed almost similar pattern with 180-200 mm and 200-220 mm as modal groups in males and females respectively. A regular occurrence of matured males and females of *M.striatus* at Kumbalam may be due to the higher salinity profile registered from this region.

A clear and specific variation in the biochemical composition viz. protein, carbohydrate, lipid, DNA and RNA were observed in the muscle tissue, hepatopancreas and gonads of male morphotypes of *M. rosenbergii*. Significant difference could be noticed in protein, DNA and RNA contents in muscle tissue, carbohydrate and RNA content in hepatopancreas and DNA and RNA content in gonads of various male morphotypes. Highest values of DNA and RNA were recorded from SOC and t-SOC whereas the least were in WBC and SM. The moisture and protein contents were found to be lower in hepatopancreas than in muscle. Faster somatic growth in SOC can well be explained with the help of higher values noticed in the protein, DNA and RNA content of muscle tissue. Carbohydrate content of hepatopancreas of SOC and t-SOC showed a significant variation from SBC which manifest the structural and functional variations of hepatopancreas of OC and BC of *M.rosenbergii*

commensurate with the respective growth and reproductive stages represented by these morphotypes. A clear and specific variation in biochemical contents in different male morphotypes of *M. rosenbergii* could be brought out in the present study and this would manifest the possibility of biochemical characterisation of male morphotypes and therefore the results of the present study would immensely be useful in providing biochemical explanation for morphotypic differentiation among male population of *M. rosenbergii*.

In the experiments conducted to evaluate the reproductive potential of various male morphotypes of *M.rosenbergii*, best results yielded in respect of oviposition (51.04%), hatchability of eggs (62,000 larvae per 100 gm body weight of berry) and survival of larvae (35.0%) in trials conducted with blue clawed (BC) males when the ratio was maintained at 1 male: 4 female. Whereas percentage of oviposition was least in the case of orange clawed males while small males showed intermediary performance at lower ratios. In trials with BC extrusion of eggs could be noticed within 16 days and period of incubation lasted for 15 to 19 days. When BC males maintained in the ratio 1:4 with female, the average prezoea produced and larval survival worked out to be 62,000/100g body weight and 35% respectively. SM showed an intermediary performance by showing 66.67% fertilisation of moulted females in lower ratios whereas, in higher ratios it showed a change in colour pattern like BC.

Among various berried females of *M.rosenbergii* used for packing experiments neither shedding nor hatching is observed in yellow and grey berries and therefore found to be suitable for packing especially for long duration transportation. Among various combinations tried, three animal per bag (@ 29.78 g berried prawn/litre) in the oxygen-water ratio 1:1 was found to

be ideal for transportation. The safe duration was substantially enhanced when coloured bags were used, among them black colour has given longer safe duration when compared to the other colours studied. The variations of dissolved oxygen, pH and ammonia were minimum in 1:1 oxygen water ratio when compared to that of 2:1 ratio.

Among various combinations tried for zoea I transportation of *M.rosenbergii*, a stocking density of 2000 larvae/l in 1:1 oxygen water ratio was found to be ideal. High survival rates was quite discernible when coloured bags were used for the packing and among them black coloured bag shown maximum survival rate (91.16%) during 48 hr. transportation with a stocking density @2000 larvae/litre.

Two phase clear water system developed for the larval rearing of *M.rosenbergii* is found to be superior over the existing system in respect to its functional efficiency, operational easiness and consistency in production. Rearing was completed in two phases which differ from each other with regard to degree of light intensity in rearing medium, size of rearing tank, percentage of water exchanged daily and duration of the rearing period. In phase I a higher stocking density of 80-130 larvae/L was maintained and a survival percentage of 49.09 to 92.5 (M=72.54%) could be registered after 10 days. While serially transferring to tanks of phase II, 19.06 to 47.41% (M=32.42%) survival was obtained. This would work out to be an overall survival of 14.88 to 36.75% (M=23.0%). First and final settlement of post larvae was noticed on days 22-25 and 33-36 respectively.

Experiments were carried out to assess the effect of different coloured containers on the survival and metamorphosis during the larval rearing

of *M.rosenbergii.* Highest number of PL were obtained in respect of red container, while, earliest settlement of PL could be observed in respect of Oxford blue tank. White container showed inferior performance in terms of both PL production and time taken for PL settlement. Dark coloured containers showed a superior performance with respect to survival and first and final settlement of post larvae and are found to be suitable for larval rearing and the results of the present study show that selection of tank colouration for seed production is an important criterion for the viable and successful operation of commercial hatcheries of *M.rosenbergii..*

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Publications

a) **Papers published**

1. **Sureshkumar,S. and B.M.Kurup**. (1996). Allometric relationships in *Macrobrachium rosenbergii* (de Man) reared in grow out pond under extensive system. pp 459-462 In: Proceedings of the Eighth Kerala Science Congress, Cochin, Publ. Govt of Kerala.

2. **Sureshkumar, S and B.M. Kurup** (1996) Economic feasibility of seed production of *Macrobrachium rosenbergii* in backyard hatcheries. Fishing Chimes September 1996 pp 24-27.

3. **Kurup, B.M., S.Sureshkumar and M. Harikrishnan** (1997) Observations on the commercial farming of *Macrobrachium rosenbergii* in padasekharams of Kuttanad. pp. 164-166 In: Proceedings of the Ninth Kerala Science Congress. Trivandrum, Publ. Govt. of Kerala.

4. **Kurup, B.M., S.Sureshkumar. and S. Prince** (1998). Preliminary observations on the larval rearing of *Macrobrachium rosenbergii* (de Man) using two phase clear water system. pp 1-7 In: Technological Advancements in Fisheries (M.S. Hameed and B.M.Kurup (Eds.) Publ. No. 1 School of Industrial Fisheries, Cochin University of Science and Technology.

5. **Suresh Kumar, S. and B.M. Kurup.** (1998). Prospects of Setting up of Back yard Hatcheries of *Macrobrachium rosenbergii* (de Man) for Self Employment and Rural Development pp 542-548 In: Technological Advancements in Fisheries (M.S. Hameed and B.M.Kurup (Eds.) Publ. No. 1 School of Industrial Fisheries, Cochin University of Science and Technology.

6. **Sureshkumar, S., B.M. Kurup** (1998) Explanation for the size heterogeneity associated with the male morphotypes of

Macrobrachium rosenbergii. pp 165-168. In: Proceedings of the Ninth Kerala Science Congress. Kozhikode, Publ. Govt. of Kerala.

b) Papers accepted

1. .**Kurup, B.M., M. Harikrishnan. and S. Sureshkumar** (1998) Population structure and yield characteristics of *Macrobrachium rosenbergii* reared in polders in Kuttanad under monoculture system. . Indian J. Mar. Sci. November issue. (in press)

2. **Sureshkumar, S. and B.M Kurup**. (1998) Comparative study on the reproductive potential of male morphotypes of *Macrobrachium rosenbergii* in brood stock rearing and larval production. Indian J. Mar. Sci. November issue. (in press)

3. **Sureshkumar, S. and B.M. Kurup**, (1998) Standardisation of methods of packing of mother prawns of *Macrobrachium rosenbergii* for safe duration transportation. In. Proc. Fourth Indian Fisheries Forum (in press).

4. **Kurup, B.M., M. Harikrishnan and S.Sureshkumar** (1998) Density dependent variation in male morphotypic composition of *Macrobrachium rosenbergii* (de Man) in domesticated and natural populations. In. Proc. Fourth Indian Fisheries Forum (in press).

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