STUDIES ON BIOCHEMICAL COMPOSITION OF HAEMOLYMPH AND MUSCLE OF PENAEID PRAWNS, *METAPENAEUS MONOCEROS* (FABRICIUS), *PENAEUS MONODON* FABRICIUS; AND *P. INDICUS* H. MILNE EDWARDS

GIDDA MAHESWARUDU, M. Sc.

THESIS SUBMITTED TO THE ANDHRA UNIVERSITY FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY

WALTAIR MARCH 1991 INDIA

Dedicated to
My Mother
Late Smt. G. SARASWATHY

C O N T E N T S

DECLARATION

I declare that the present work is original and has not been published or submitted in part or in full for any degree or prize.

G. Maheswarudu

(G. MAHESWARUDU)

WALTAIR

Dt. 6-4-1991

CERTIFICATE

Certified that this is a bona fide research work of

Mr. G. MAHESWARUDU

K. Srinivasa Rao

(K. SRINIVASA RAO)

Director of Research

WALTAIR

Dt. 6.4.1991

P R E F A C E

Decapod crustaceans, comprised of the familiar forms such as prawns, lobsters and crabs, constitute an important group in the exploited and exported fishery resources of India. Among these crustaceans, prawns, particularly the penaeid prawns, are the most commercially exploited group of paramount importance by virtue of their esteemed food value all over the world. The capture fishery for prawns is carried out on a commercial scale in the sea and at subsistance level in the estuaries and backwaters. With the introduction of mechanised trawling and modern processing technology, capture and utilisation of prawns in India witnessed a phenomenal expansion during the past four decades. Consequently, in the marine fisheries of India, penaeid prawns stand third in the order of abundance with a production of 1,46,753 tonnes during 1989. In the same year, a total of 56,830 tonnes of prawns and prawn products valued at Rs. 470.33 crores were exported from India.

As the exploitation of prawns in the capture fishery is stepped up, their catch over the years in several of the fishing grounds along the coast stabilised at the optimum level of sustained production, but for a decreasing trend in certain centres. Several studies conducted on the intensive fishing and resource characteristics indicated that further increase of fishing effort in

the grounds exploited at present may not yield enhanced catch. In this context, the strategies employed to conserve the resources are judicious management of the exploited stocks, extension of range of exploitation to underexploited resource and more importantly development and promotion of culture fisheries.

Aquaculture of prawns has now been recognised as a definite means of augmenting prawn production and consequently, this sector is rapidly developing and expanding in all the maritime states of the country.

One of the prominent features observed in the capture and culture fisheries of the prawns in India, is the wide fluctuation in their production. Such fluctuations have serious drawbacks on the economy of the fishing industry. Several biotic and abiotic factors are known to influence the production of prawns. While the several ongoing studies, are concerned with the biology, stocksize and fishery characteristics of the constituent species in the fishery, investigations on the physiological and biochemical changes taking place under the different culture conditions are rather scarce. However, it is well known that these changes in the penaeid prawns are partly due to oscillations between marine and brackishwater environments. Changes take place even in a stable environment due to cercadian rhythm, moulting cycle and developmental changes due to growth and reproduction. In nature,

where temperature, salinity, photophase etc., vary simultaneously in a non-programmed manner, the animals adjust their life processes through a complex physiological and behavioural pattern. Similarly, biochemical changes in the biological systems play a significant role in the activities of these animals. The knowledge concerning these aspects in respect of the penaeid prawns of India is rather meagre. In view of the paucity of the available information the present investigation on the biochemical composition of the three commercially important penaeid prawns, namely, **Metapenaeus monoceros, Penaeus monodon** and **P. indicus** is taken up and the results are embodied in this thesis.

The thesis deals with the biochemical composition of the most important tissues, haemolymph and muscle, of **M. monoceros, P. monodon** and **P. indicus** in the wild state and under cultured conditions in the brackishwater ponds. Observations on the sex-wise, length-weight relationships in these prawns are integrated to provide a meaningful interpretation. Similar studies were made on variation in the biochemical composition of haemolymph and muscle in relation to sex, size, weight and condition factor. The intra and inter-relationships between the different factors operating at the different phases of growth and maturation of gonads are investigated to bring out the significant factors. There were no earlier studies on these lines in literature. The information gathered is useful to evaluate culture strategies under varying

conditions of the environment. This knowledge would also be useful in manipulating the growth and reproduction which are vital to the success of culture practices.

ACKNOWLEDGEMENTS

I take this opportunity to record my deep sense of gratitude and indebtedness to **Prof. K. Srinivasa Rao**, M.Sc., Ph.D., Department of Zoology, under whose able guidance the present investigation has been successfully carried out. It gives me great pleasure to acknowledge the different kinds of help starting from the proposal of the research problem, criticism and advice offered during the course of analysis and the patience and care with which the manuscript has been reviewed by him.

I am grateful to **Prof. P.V. Bhavanarayana**, former Head of the Department of Zoology and to **Prof. R. Madhavi**, Head of the Department of Zoology for providing the necessary facilities.

I thank **Prof. P. Chandra Mohan, Dr. D.V. Rama Sarma, Dr. A.V. Raman, Dr. B.V.S.S.R. Subba Rao, Dr. Y. Prabhakara Rao** and other staff members of the Zoology Department; **Dr. K. Satyanarayana Rao**, Research Officer, Wood Preservation Centre (Marine), Waltair and **Dr. K. Kameswara Rao**, Department of Environmental Sciences for their encouraging words which helped in successful completion of this thesis.

I wish to express my thanks to **Dr. K. Phaniprakash**, Dept. of Zoology for his help during spectrophotometer operation; **Dr. T. Satyanarayana Rao**, Dept. of Geology, who helped me in haemolymph samples analysis on Flame photometer; **Sri Krishna Reddy**, Agriculture Officer, Dept. of Water & Soil Chemistry, Agriculture Research Institute, Rajendranagar, Hyderabad for his valuable help and advice during haemolymph samples analysis on Atomic absorption spectrophotometer.

I am thankful to my colleague **Dr. B. Rambhaskar**, for accompanying me to Kakinada to attend the painstaking field work at the fish farm. I thank my co-scholars **Mr. V.V.K. Durga Prasad, Dr. M. Rama Murthy, Dr. D. Panduranga Rao, Mr. J.D. Suseel Kumar, Mr. K.V. Subba Rao, Dr. T. Ravi Varma, Dr. M. Balaji, Dr. B. Viswanadham,**

Mr. D. Venu, Dr. (Mrs.) Rafia Sultana, Dr. K. Lakshmi, Mrs. K. Asha Jyothi for their co-operation during the present study.

I express my gratefulness to **Dr. (Mrs.) T. Rajyalakshmi**, Retired Principal Scientist, Central Institute of Brackish Water Aquaculture, under whom my research career was initiated and for her constant encouragement rendered during the present study.

I am very much grateful to **Dr. P. Vedavyasa Rao**, Principal Scientist, Officer-in-charge of Mangalore Research Centre of Central Marine Fisheries Research Institute, Mangalore for his valuable advice while going through the manuscript.

I thank **Dr. K. Gopala Rao**, In-charge, and **Sri D. Munichandra Reddy**, Asst. Research Officer of Brackishwater Fish Farm of Andhra Pradesh Agricultural University, Kakinada for their help in obtaining haemolymph and muscle samples of prawns at the time of harvesting; and **Sri Reuben**, Scientist, S.G. and **Sri M. Chandra Sekhar**, Technical Assistant of Waltair Research Centre of CMFRI for their help in getting live-prawns from the trawl catches off Visakhapatnam.

I am thankful to **Dr. T. Panduranga Rao**, In-charge Director of CIFT, Cochin for providing laboratory facilities to carry out biochemical analysis of haemolymph at the regional centre of CIFT, Kakinada.

I thank **Dr. K.A. Narasimham**, Principal Scientist and **Dr. V. Sreeramachandra Murthy**, Scientist, S.G. of Kakinada Research Centre of CMFRI., for their help and encouragement during field work at Kakinada.

I am thankful to **Dr. K. Radhakrishna**, Asst. Director General, Marine Fisheries, Indian Council of Agricultural Research; **Dr. G. Luther**, Principal Scientist, **Dr. G. Sudhakara Rao**, Scientist, S.G., and **Sri Y. Appanna Sastry**, Scientist, S.G., CMFRI, Waltair for providing library facilities and for their encouraging words during the present study.

I am thankful to my colleague and wellwisher **Sri N. Rama Moorthy**, for taking pains in getting the manuscript neatly typed and for the encouragement given by him. All my colleagues of Mandapam Regional Centre of CMFRI, have extended co-operation during the preparation of the thesis, to whom I am very thankful.

I am thankful to the Indian Council of Agricultural Research for the award of Senior Research Fellowship during the tenure of the present investigation.

I thank the authorities of Andhra University for providing necessary facilities to carry out present investigation.

I am very much grateful to my brother-in-law **Dr. G. Rama Moorthy**, M.B.B.S., Rangaraja Clinic, Anakapalle for looking after my health and for his encouragement; my brother, **Sri G. Venkata Ramaiah**, M.Sc. (Ag.), Chief Agricultural Officer, The A.C.S. Ltd., Thummapala, who encouraged me initially to take interest in the present study, and for looking after my welfare; my sister-in-law, **Mrs. G. Rajyalakshmi** for her affection and co-operation; my wife **Mrs. Lakshmi Janardhani** for helping me in statistical analysis and for her constant encouragement and co-operation; and to all my family members for their encouragement during the course of the study.

Finally, I am thankful to M/S **parks**-Electronics for getting my thesis neatly typed.

G. MAHESWARUDU

GENERAL INTRODUCTION

In nature, the littoral penaeid prawns of India belonging to the genera **Penaeus** and **Metapenaeus** complete their life cycle in two different ecosystems. Inhabiting the marine ecosystem in the adult phase, they grow, mature and breed; the larval development up to the early post-larval stage also takes place in this ecosystem. As they grow to advanced postlarvae and juveniles, they migrate to the highly dynamic, productive and low saline coastal waters which serve as nursery grounds. After living in this ecosystem for certain period where they grow fast and attain the secondary sexual characters, they migrate to the marine ecosystem, where they attain maturity and reproduce, and to complete the life cycle. Penaeid prawns are remarkably adopted to changing ecological conditions by a harmonious blend of metabolic processes in the different organ systems. Moreover, these prawns, like other crustaceans, are involved in the unique processes of moulting, which involves casting off of their exoskeleton and resynthesis. While several investigations on the biological aspects such as age and growth, food and feeding, reproduction and moulting; fishery and population characteristics and culture are available (George, 1970a, 1970b, 1970c, 1972, 1978; Mohamed, 1970a, 1970b; Rao, 1968, Kurian and Sebastian, 1975; Silas **et al.**, 1984; Silas, 1985; Sudhakara Rao, 1988a, 1988b, 1988c, 1989; and Lalitha Devi, 1989), information on the biochemical make-up and the processes taking place continuously, trading-off the different metabolites required by the various tissues

and orgns to perform their different functions, is scarce. Nevertheless, in the context of intensive exploitation of these prawns in the capture fishery and intensive cultivation an understanding of this biochemical constituents and its systematic variation during the different phases of their life cycle provides an insight into the adjustments made continuously by these animals. The studies on these aspects in crustaceans were mainly due to Renaud (1949), Vinogradov (1953), George and Patil (1956), Barnes **et al** (1963) and Pillay and Nair (1973). Recently Ceccaldi (1982) summarised the contributions of physiology and biochemistry to the progress in aquaculture.

More than any other organ tissues, haemolymph, muscle and hepatopancreas are known to be intensively involved in the sysnthesis, storage and active mobilization of the metabolites. The first recorded observation on crustacean blood was made by Carus (1824) (according to George and Nichols, 1948). Subsequently studies on crustacean blood and related tissues were made by Lockhead and Lockhead (1941) and George and Nichols (1948).

The occurrence of an estuarine and marine phase in the life cycle of penaeid prawns prompted the scientists in the beginning of the 20th century to investigate on the mechanism of osmoregulation of prawns in these environments. Panikkar (1941) found that **Leander serratus** (= **Palaemon serratus**), **L. squilla** (= **P. squilla**) and **Palaemonetes varians** were hypotonic regulators in the sea water

and hypertonic in the low saline waters. The same trend of osmoregulation was reported in **Metapenaeus monoceros, M. dobsoni, Penaeus indicus** and **P. carinatus (= P. monodon)** by Panikkar and Viswanathan (1948) and Panikkar (1951). Osmotic concentration of haemolymph in various growth stages of **Penaeus japonicus** was studied by Iwata and Shigueno (1980). The osmoregulatory ability and ionic regulation of the australian penaeid prawns in the juveniles as well as in the adult stages were dealt with by Dall (1981), Dall and Smith (1981). The other noteworthy studies relating to osmotic and ionic regulation in other crustaceans were by Williams (1960), Dall (1974a) and Read (1984). Recently the osmoregulatory ability of **Penaeus monodon** and **P. indicus** was studied by Diwan **et al** (1989) and Diwan and Laxminarayan (1989).

During the moult cycle the composition of haemolymph shows remarkable changes. The two major changes that occur during the intermoult cycle are the increase in haemolymph concentration before ecdysis and uptake of water during the process of ecdysis. Besides this, calcium and magnesium are removed from the exoskeleton and stored in the haemolymph and hepatopancreas. Protein content and other dissolved substances also vary during the intermoult cycle. Changes in haemolymph composition due to impact of moult cycle have been reported in penaeid prawns as well as in other crustaceans by Bursey and Lane (1971), Kanazawa **et al.** (1976), Kulkarni (1984), Lucu (1990), Teshima and Kanazawa (1976), Teshima **et al.** (1977) and Vijayan (1988). Further, the composition of haemolymph

varies with the environment as well as with the sex, size and weight (Gilbert, 1959; Horn and Kerr, 1963) and the nutritional conditions of the animal (Cruz Ricque **et al.** 1989; Dall, 1974b; Djangmah, 1970; Hagerman, 1983; Munoz and Ceccaldi, 1983; Stewart **et al.**, 1967). Interspecific variation of haemolymph composition is also reported by several authors (Balazs,**et al.**, 1974; Leone, 1953).

Proteins are one of the important constituents of crustacean tissues, greatly influenced by the nutritional status of the animal and varies as a function of the nutritional state (Dall, 1974b; Fair and Sick, 1982; Rajamani, 1982; Stewart **et al.**, 1966). The total protein in the haemolymph varies according to the sex (Balazs **et al.**, 1974; Horn and Kerr, 1963) and at interspecific levels (Balazs, **et al.**, 1974; Leone, 1953) and related to the environmental salinity (Pequeux **et al.**, 1979). Electrophoretic studies made on prawns and crabs by Thomas (1982) and Kannupandi and Paulpandian (1975) respectively have revealed the existence of heterogeneity in haemolymph proteins.

In crustaceans carbohydrate is utilized as oxidative metabolite as well as in the synthesis of the chitin of the integument. A major part of the carbohydrate is lost as chitin at each moult especially in organisms with short moult cycle like penaeid prawns. As dietary carbohydrate is utilized for both chitin synthesis and oxidative metabolism, haemolymph carbohydrate

is subjected to variation under the influence of various biological activities such as moulting and reproduction (Bursey and Lane, 1971; Diwan and Usha, 1987; Vijayan, 1988). Haemolymph carbohydrate level is also found to vary when the animal is under starvation and stress (Dall, 1974b; Raja **et al.**, 1976 and Smith, 1982).

Since calcium is the major component of crustacean integument, it plays a significant role in the structure of exoskeleton. During ecdysis calcium is reabsorbed from the exoskeleton minimising its loss and stored either in haemolymph or in hepatopancreas (Gibson and Barker, 1979). After moulting, the absorbed calcium is mobilized to incorporate into exoskeleton. Thus, calcium level in the haemolymph varies with the stage of moult cycle of the animal (Bursey and Lane, 1971). In the haemolymph, calcium exists in two states, namely, bound calcium and free calcium (Kannan and Ravindranath, 1981). It is reported that the haemolymph calcium fluctuates with the salinity of the medium (Dall, 1974a; Dall and Smith. 1981; Vedavyasa Rao **et al.**, 1981).

Potassium in the haemolymph is known to enhance the cell potassium stability and to improve the neuromuscular efficiency (Dall, 1974a). The different aspects of its regulations in penaeid prawns were studied by Dall and Smith (1981), Santos and Salomao (1985) and Wright **et al.** (1984).

In crustaceans, the major portion of the haemolymph protein (80-95%) is haemocyanin (Wieser, 1965). Copper constitutes 0.17% of haemocyanin and the copper level in the haemolymph varies with the protein level in the haemolymph. Hence, factors that influence the haemolymph protein concentration also affect the haemolymph copper concentration. Although the amount of ionic copper in the haemolymph is negligible (Arumugam and Ravindranath, 1983; Djangmah, 1969) it is periodically monitored by the hepatopancreas. Since the haemolymph protein varies under the influence of the various physiological activities such as moulting and reproduction, and during starvation, haemolymph copper also varies accordingly (Djangmah,1970; Hagerman, 1983; Horn and Kerr, 1963; Kerr, 1969 and Stewart **et al.**, 1967).

In the body of the penaeid prawns the abdominal muscle constitutes 50% of the total weight, having the property of the excellent flavour and delicious taste. In the early period of the 20th century, nutritive values and biochemical composition of Indian prawns were reported by Appanna and Devadatta (1942), Chari (1948), Gopalakrishna (1951) and Shaikhmahmud and Magar (1957). Borgstrom (1962) reviewed the literature on the nutritive aspects of shellfish which also covered prawns. Biochemical composition of prawns varies due to biotic as well as abiotic factors. Biotic factors such as moulting, maturation and inadequate food influence the composition of the muscle. Similarly, abiotic factors like high

salinity and high temperature bring out the biochemical changes in the muscle. Diwan and Usha (1987), Kanazawa **et al.** (1976), Teshima and Kanazawa (1976) and Teshima **et al.** (1977), studied the biochemical composition of the muscle during the moult cycle. The biochemical changes occurring during the reproductive cycle in some of the penaeid prawns were followed by Asokan and George (1984), Pillay and Nair (1973), Read and Caulton (1980), and Vijayakumaran (1990). During starvation of the animal and adverse ecological conditions organic reserves in the muscle are decreased due to oxidation of metabolites to meet the energy requirement (Rajamani, 1982; Torres, 1973). Besides, the muscle composition is found to vary with the size (Clarke , 1977; Krishnamoorthy **et al.**, 1982; Mauchline and Fisher, 1969; Raymont **et al.**, 1971; Stein and Murphy, 1976); sex (Ameer Hamsa, 1981; Du Preez and McLachlan, 1983) and at interspecific levels (Kannupandi and Paulpandian, 1975; Shaikhmahmud and Magar, 1957; Thomas, 1982).

In culture conditions, the quality and quantity of feed offered to the stocked population affect the biochemical composition of muscle (Bottino **et al**, 1980; Clarke and Wickins, 1980; Krishnamoorthy **et al.**, 1982; Martin, 1980; O'Leary and Matthews, 1990; Rajamani, 1982). It is also shown that the polluted waters bringforth changes in the composition of the muscle. Thus, Srinivasulu Reddy **et al.** (1989), made a study on the changes of lipid components in the muscle of **Metapenaeus monoceros** and

Penaeus indicus exposed to phosphamidon and found that significant decrease of total lipids and glycerol in the muscle.

In crustaceans, eggs contain rich organic reserves like protein, carbohydrate and lipid to meet the energy demand during the different stages of embryonic development as well as larval stages until the larva starts feeding on its own. In the penaeid prawns, embryonic development in the egg after its release takes place for a period of 12-17 hours, before it hatches out as nauplius. The nauplius larva metamorphoses into protozoea larva after passing through 6 sub-stages in a span of 48 hours, depending upon the organic reserves stored in the egg to meet the energy requirement. The protozoea larva develops filter feeding habit and feeding on phytoplankton, undergoes further metamorphosis. During ovarian development of the female prawn, organic reserves such as protein, carbohydrate and lipid undergo a cyclic change increasing stage I to IV and then decrease in stage V after spawning (Barnes **et al**, 1963; Diwan and Nagabhushanam, 1974; Kulkarni and Nagabhushanam, 1979; Pillay and Nair, 1973; Sunil Kumar Mohamed, 1989; Victor, 1987). According to Asokan and George (1984), Read and Caulton (1980), Sarojini and Jahagirdar (1983) and Vijayakumaran (1990) organic reserves are mobilized from muscle to the gonad during ovarian development through haemolymph. Some of the workers (Fyffe and O'Connor, 1974; Kerr, 1969 and Wolin **et al.,** 1973) are of the view that lipovitellin is synthesized outside the

ovary and is mobilized to the gonad. In contrary to this concept the studies made by Lui **et al.** (1974), on **Procambarus** sp. and Eastman-Reks and Fingerman (1985) on **Uca pugilator** have revealed that the crustacean ovary is capable of synthesizing lipovitellin. In crustaceans many workers have reported that the gonad index indicates the reproductive activity of the animal (Abdul Rahaman, 1966; Diwan and Nagabhushanam, 1974; Kulkarni and Nagabhushanam, 1979; Pillay and Nair, 1971; Subrahmanyam, 1963b; Victor, 1987).

Biochemical composition of larvae during metamorphosis and starvation was studied by Anger **et al** . (1983), Anger (1986) and Anger and Harms (1990).

In the brackishwater pond, the prawn production varies from crop to crop during a year due to the prevailing ecological conditions, feeding strategies and other managerial precautions followed. Biochemical constituents of haemolymph as well as muscle of the prawns are shown to vary from crop to crop. A knowledge of this aspect would thus help to determine conditions of the prawns and select the species which are hard and capable of growing fast utilizing the various nutrients. Panikkar (1968) suggested that maximum growth of prawns can be obtained in isosmotic media as prawns need not spend energy for osmotic regulation. Isosmotic points of **P. monodon** and **P. indicus** were determined by Diwan **et al** (1989) and Diwan and Laxminarayan (1989) respectively.

Very few studies on biochemical composition of haemolymph and muscle of penaeid prawns have been carried out in India. Most of these studies are essentially experiment oriented (Asokan and George, 1984; Diwan and Usha, 1987; Diwan **et al.**, 1989; Diwan and Laxminarayan, 1989; Kulkarni and Nagabhushanam, 1979 ; Nagabhushanam and Kulkarni, 1982) except a few which are related to field studies (Rajamani, 1982, Subhash Chander, 1986 and Vedavyasa Rao **et al**, 1983).

In view of the paucity of information on this aspect and recognising its great utility in species selection and management of the culture, an attempt is made to study the biochemical variations of the haemolymph and muscle of **M. monoceros**, **P. monodon** and **P. indicus** from different ecological habitats. It is hoped that results of the study would contribute further to the knowledge of biology and culture of these penaeid prawns.

CHAPTER 1

MATERIAL AND METHODS

Location and collection of live specimens

Live prawns for the present study were collected during 1984-1985 from the capture fisheries of the inshore waters of Visakhapatnam and from the culture fisheries carried out in the brackishwater ponds (Department of Fisheries, Andhra Pradesh Agricultural University, Kakinada) at Kakinada.

Visakhapatnam is located in Andhra Pradesh on the east coast of India (17°42'N latitude and 83°20'E longitude) (Fig. 1). About 200 small mechanised boats and 100 large trawlers are operated from Visakhapatnam Fishing Harbour, mainly for shrimps. Small mechanised boats (10-11 m) are operated in the fishing grounds which extend up to 50 km north and south of Visakhapatnam along the coast up to a distance of 15 km off the coast. Large trawlers are employed in the farther and deeper grounds located away in the north of Visakhapatnam extending up to the head of the bay. Live specimens for the present study were collected from the trawl catches of the small mechanised boats.

The constituent species of the prawn fishery at Visakhapatnam are grouped into 4 categories:

(1) 'Tigers' comprising of **Penaeus monodon, P. semisulcatus** and **P. japonicus;**
(2) 'Whites' formed of **P. indicus, P. merguiensis** and **P. penicillatus;**
(3) 'Browns' constituted by **Metapenaeus monoceros, M. ensis** and **M. affinis;** and

(4) 'Flowers' including **Metapenaeus dobsoni** and **M. brevicornis. M. monoceros, P. indicus** and **P. monodon** which are of commercial importance were used for the present study. Live specimens of **M. monoceros** and **P. indicus** were available in the trawl catches of small mechanised boats which are performed single day trip.

Live prawns were collected immediately after hauling of the net. They were transferred to a plastic bucket which contained sea water collected from the same fishing ground. To avoid oxygen depletion, the sea water in the bucket was changed frequently until the boat reached shore. The prawns were transported quickly to the laboratory in live condition and transferred into aquarium tanks of 60 x 30 x 30 cm size containing 54 litres of sea water collected from the same locality from where the prawns were caught. Adequate aeration was provided to the water in the tank. In each tank about 10 prawns were kept and allowed for 1 to 2 hours to recover from the stress of transport before sacrificing them for haemolymph sampling.

All the specimens of **M. monoceros** and **P. indicus** collected off Visakhapatnam were sexually mature. Females in all the stages of maturity were represented.

Kakinada is located in Andhra Pradesh on the east coast of India (16°60'N latitude and 82°14'E longitude) (Fig. 2). Kakinada bay which is spread over an area of 130 sq km receives fresh

water from the irrigation canals (Gaderu, Coringa, Mattlapalem Creek and Kakinada Commercial Canal) of Godavari river. Prevalence of low salinity due to influx of fresh water from irrigation canals, habitation of mangrove vegetation around the bay and consequent availability of rich organic carbon and nutrients in the soil together provide congenial conditions to form nursery grounds where the juveniles of prawn and fish are available in large numbers. There are a number of brackishwater farms ideally suitable for prawn culture around the bay.

Brackishwater fish farm of Andhra Pradesh Agricultural University (APAU) is situated on the northern side of the entrance of the Commercial canal into the bay. A creek which opens into the commercial canal provides water to the feeder canal of the fish farm. The fish farm consists of 7 rectangular ponds (area range 0.03 to 0.18 ha), 4 on one side and 3 on the other side situated parallel to the feeder canal. The low lying areas around the fish farm get inundated during high tide. These areas form a good nursery ground to collect seed of various cultivable prawns and fishes.

At this fish farm, experiments on different aspects of culture of prawns and fin-fishes are carried out to develop suitable technology for adoption and propagation in this area.

The culture operation entails preparation of the field by drying, liming (250 kg/ha/crop), and manuring (raw cow dung

1000 kg/ha/crop; single superphosphate 125 kg/ha/crop; and urea 25 kg/ha/crop). Prawn seed (15 to 20 mm total length) are collected from the surrounding low lying areas during low tide and stocked in the nursery for 30 days. The seed when they attain a size 40 to 50 mm (total length) are transferred into the grow-out pond. Stocking is done at the rate of 30,000/ha. Water level in the pond is maintained between 60 and 80 cm by regulating the sluice gate during low tide and high tide. Supplementary feed, constituted by borken rice, deoiled rice bran and groundnut oil cake is offered to the stocked population at appropriate rate. Besides this, animal protein in the form of clam meat is also given. Stock is harvested after 90 days. The total duration of culture is 120 days including the nursery and farming period in grow-out pond.

Haemolymph samples of **P. monodon** and **P. indicus** were collected immediately after capture in the field during harvesting of three successive crops (November 1984, March 1985 and November 1985) from brackishwater ponds.

Intermoult specimens

In order to avoid any variation in haemolymph composition and muscle composition due to the moult cycle, haemolymph samples and muscle samples of **M. monoceros, P. monodon** and **P. indicus** were collected from the selected, disinfected, active and healthy animals which are in the intermoult stage. The intermoult

specimens were selected on the basis of the following method of Scheer (1960) developed for natantians.

Stage		Characteristics
A	(early postmoult)	Integument soft, parchment-like, internal cones of setae of uropods absent
B	(late postmoult)	Integument firm but yielding to pressure, internal cones of setae appear but incomplete
C_a	(early intermoult)	Integument firm to hard, internal cones of setae nearing completion
C_b	(late intermoult)	Integument hard, internal cones of setae complete, slight separation of epidermis from cuticle between setae
D_o	(beginning premoult)	New setae present at base of old, epidermis clearly separated from cuticle, bases of new setae at the outer surface of the epidermis
D_1	(early premoult)	New setae in course of development
	D_1'	New setae extending partly into old, their bases beginning to invaginate below the surface of the epidermis
	D_1''	New setae extending well into old, their bases invaginated into the epidermis for approximately 1/4 the length of the setae
	D_1'''	Bases of new setae invaginated for approximately $\frac{1}{2}$ the length of the setae

D_2	(middle premoult)	Epidermis with a clearly developed cuticular layer
D_3	(late premoult)	Epidermis with a chitinous pigmented cuticular layer
D_4	(final premoult)	The old carapace separates readily from the new cuticle on slight pressure

Specimens which were in stage C_a (early intermoult) and C_b (late intermoult) were selected for the present study by observing setae on the pleopods (Schafer, 1968) under microscope in the laboratory. In the field, the intermoult specimens were selected from the hardness of the integument.

Method of collection of haemolymph

Before extracting haemolymph, the external water present on the surface of the prawns was removed by blotting with a filter paper. 1 ml disposable hypodermic syringe fitted with 24 gauge needle after rinsing with anticoagulant (1% sodium citrate) was used for the withdrawal of haemolymph. The needle was carefully inserted into the pericardial region through the intersegmental membrane between the cephalothorax and the first abdominal segment. The withdrawn fluid was gently emptied into a labelled glass vial containing 1% sodium citrate (anticoagulant) and thoroughly shaken for uniform mixing. Care was taken not to withdraw the tissue particles with the haemolymph as well as to

cause minimum stress to the animal. Glass vials with haemolymph were preserved in an ice box containing adequate ice until further analysis in the laboratory.

Morphometric measurements

After extraction of haemolymph, morphometric measurements such as total length, carapace length, weight, sex and stage of maturity (in the case of mature females) of each specimen were recorded. The total length (from tip of the rostrum to the tip of the telson) and carapace length (distance between postorbital notch and the posterior mid dorsal margin of the carapace) were measured on a measuring board and divider respectively. Fresh weight upto the nearest 100 mg was recorded by using a pan balance made by Avery. The different stages of maturity of female prawns were determined by observing the size and colour pattern of the ovary as given below (Rao, 1968).

Stage of ovary development		Description of the ovary
I	Immature	Confined to the abdomen, translucent
II	Early maturing	Anterior and middle lobes are developing; light yellow to yellowish green
III	Late maturing	Anterior and middle lobes are fully developed; light green and visible through the exoskeleton

IV	Maturing	Dark green and clearly visible through the exoskeleton
V	Spent recovering	Ovary is visible through exoskeleton; with anterior, middle and posterior lobes but without any mature ova. As the ovary after spawning resembles the early maturing stage in the gonad observation, the size of the prawn was used to distinguish this stage from the immature virgin females. Those above 150 mm total length for **P. indicus** and 130 mm for **M. monoceros** were considered to belong to this stage.

Subrahmanyam (1967) reported that the length at first maturity for **P. indicus** was 140 mm (total length) and that of a spent female was 150 mm (total length). Nalini (1976) determined length at first maturity as 118 mm (total length) for **M. monoceros.** According to Nalini (1976) and Sudhakara Rao (1989) who studied **M. monoceros** supporting the fishery at Kakinada, it was found that a majority of mature specimens were at 130 mm total length. On the basis of these observations the females of **P. indicus** measuring above 150 mm and those of **M. monoceros** of above 130 mm size were treated as spent recovering specimens.

While sampling from brackishwater ponds, haemolymph samples were collected from as many specimens as possible. Out

of these a small number of specimens were used for determining biochemical composition of muscle. All morphometric measurements were taken of the specimens used for biochemical study of muscle. Only carapace length was measured of each specimen used for haemolymph extraction.

Preparation of material for biochemical analysis

Muscle :

After measuring all morphometric characters, head of the each specimen was removed, weight of the abdomen was measured, oven dried at 80°C for 48 h and reweighed. Difference between wet and dry weight of each abdomen was recorded as water content, which gives percentage of water content on wet weight basis.

Exoskeleton of each abdomen was separated and abdominal muscle was ground to fine powder with mortar and pestle. Each abdomen muscle powder was transferred into a cleaned, dried and labelled glass vial and then stored in a deep freezer (-12°C) until further analysis was carried out.

Gonad:

Gonad was separated from each female prawn and wet weight (nearest 10 mg) was measured. After oven drying at 80°C for 48 h, the dry weight was recorded to calculate the percentage

of water content as done earlier for muscle. The entire dry gonad was made into powder, transferred into labelled vial and was stored in a deep freezer.

Biochemical Analysis

Haemolymph :

The haemolymph was analysed for protein, carbohydrate, copper, calcium and potassium contents. The details of the different methods used to estimate the various constituents of haemolymph are given below:

Protein estimation:

Biuret method (Gornall **et al.**, 1949)

Principle : Two carbamyl groups present in protein molecules combine with copper and potassium of the biuret reagent to form a blue coloured compound. The colour formed is proportional to the amount of the carbamyl groups present in the protein.

Reagent : 1. 1N NaOH: 4 g of NaOH pellets was dissolved in 100 ml of distilled water

2. Biuret reagent : 1.5 g of cupric sulphate ($CuSO_4 . 5H_2O$) and 6.0 g of sodium potassium tartrate ($KNaC_4H_4O_6 . 4H_2O$) were dissolved in 500 ml of distilled water. 300 ml of 10% 1N sodium hydroxide solution was added and made upto 1000 ml with distilled water.

Procedure

Preparation of standard graph : 25 mg of bovine serum albumin fraction was dissolved in 5 ml of 1N NaOH to be used as protein standard. 0.2 ml, 0.4 ml, 0.6 ml, 0.8 ml and 1.0 ml of the protein standard solution was taken in separate test tubes and these different solutions were made up to 2 ml with 1N NaOH. 8 ml of biuret reagent was added to the solution in each test tube, mixed well and allowed to stand at room temperature. After 30 minutes, their optical densities were measured at 540 nm on a spectrophotometer (Model UNICAM SP. 600). Blank having 2 ml of 1N NaOH and 8 ml of biuret reagent was set up. Standard graph was drawn by plotting the concentration of protein on X-axis and optical density on Y-axis.

Estimation of protein from sample :

1. 0.05 ml of haemolymph was taken by a micropipette and poured into 1 ml of deproteinizing agent (80% ethanol).
2. Centrifuged at 3000 rpm for 5 minutes, discarded the supernatant and 2 ml of 1N NaOH was added to dissolve the precipitate.
3. After 10 minutes, 8 ml of biuret reagent was added, mixed well and allowed to stand at room temperature.
4. Blank was set up simultaneously having 2 ml of 1N NaOH and 8 ml of biuret reagent.
5. After 30 minutes, optical density was measured in a spectrophotometer at 540 nm against the blank.

6. Referred the standard graph and protein concentration was found.

Estimation of Carbohydrate :

Anthrone reagent method (Roe, 1955):

Principle : Sulphuric acid in anthrone reagent hydrolyses di and oligosaccharides into monosaccharides; and dehydrates all monosaccharides into furfural derivatives. These two compounds react with a number of phenolic compounds and one such is anthrone which produces a complex coloured product. The intensity of colour is proportional to the amount of saccharides present in the sample (Roe, 1955).

Reagents: 1. Anthrone reagent: 50 mg of anthrone and 1 g of thiourea were dissolved in 100 ml of 66% sulphuric acid (A.R.:1.84 sp. gr.).

2. Glucose standard: 100 mg of D-glucose was dissolved in 100 ml of saturated benzoic acid.

3. Deproteinizing agent: 80 ml of absolute ethanol was diluted to 100 ml with distilled water (80% ethanol).

Procedure:

1. 0.2 ml of haemolymph was taken and added to 1.8 ml of deproteinizing agent.
2. Centrifuged at 2500 rpm for 5 minutes and the supernatant was collected.

3. 10 ml of anthrone reagent was added to 1 ml of haemolymph filtrate, 1 ml of standard glucose; and 1 ml of distilled water (blank).
4. Mixture was heated in water bath for 10 to 15 minutes and cooled in dark at room temperature for 30 minutes.
5. Optical density was measured at 620 nm and total carbohydrate content was calculated using the following equation:

$$\frac{\text{Optical density of the sample}}{\text{Optical density of the standard}} \times \text{Concentration of the standard} \times \frac{\text{dilution factor}}{(10)^x} \times 100 = \text{mg\%}$$

Estimation of potassium, calcium and copper contents:

0.1 ml of haemolymph was digested in 1 ml of concentrated nitric acid. This solution was made up to 10 ml in a volumetric flask with deionised water. The 10 ml solution was used as sample solution for estimation of potassium, calcium and copper contents in the haemolymph.

Potassium content was estimated by feeding the sample solution into flame photometer against blank and standard potassium solution. Deionised water was used as blank.

Calcium and copper concentrations were measured by aspirating the sample solution into the air acetylene flame of Atomic Absorption Spectrophotometer (Model SHIMAOZU, TYPE AA-640-12)

against blank and standard solutions of calcium and copper. Deionised water was used as blank.

Potassium and calcium contents were expressed as mg/100ml and copper content value was given as µg/ml.

Muscle:

Protein, carbohydrate and lipid contents in the muscle were estimated. Toshniwal (Model No PBI/X) single pan electrical balance was used to weigh muscle sample in required quantities like 20 mg, 25 mg, and 50 mg for protein, carbohydrate and lipid estimations respectively.

Protein estimation:

Biuret method (Gornall **et al.**, 1949):

Preparation of reagents and standard graph was done as mentioned earlier for estimation of protein in haemolymph.

Procedure :

1. 20 mg sample was homogenized in a Potter-Remi homogenizer with 5 ml of 10% trichloroacetic acid (deproteinizing agent) for 3 minutes.
2. Centrifuged for 5 minutes at 3000 rpm, supernatant was discarded and precipitate was dissolved in 8 ml of 1N NaOH.
3. 2 ml sub-sample of (2) was taken to which 8 ml of biuret reagent was added (after 10 minutes).

4. 2 ml of 1N NaOH added to 8 ml of biuret reagent was taken as blank.
5. After 30 minutes, optical density was measured in a spectrophotometer at 540 nm against the blank.
6. Protein content was determined by referring to the calibration on the standard graph.

Carbohydrate estimation:

Phenol-sulphuric acid method (Dubois **et al.**, 1956):

Reagents:

1. Chloroform : methanol (2:1) : 20 ml of chloroform was mixed with 10 ml of methanol.
2. 10% Trichloroacetic acid : 10 g of trichloroacetic acid was dissolved in 100 ml of distilled water.
3. 5% Phenol reagent : 5 g of phenol reagent was dissolved in 100 ml of distilled water.
4. Sulphuric acid : Concentrated sulphuric acid (AR:1.84 sp.gr.).

Procedure:

Preparation of standard graph: 100 mg of D-glucose was dissolved in 100 ml of distilled water (1mg/ml). From this solution 1 ml was taken, made up to 10 ml with distilled water which was used as standard (100 µg/ml). 0.1 ml, 0.3 ml, 0.5 ml, 0.7 ml and 0.9 ml of glucose standard solution was taken in separate test tubes, these solutions were made up to 1 ml with 10% trichloroacetic acid

individually. 1 ml of 5% phenol reagent and 5 ml of sulphuric acid were added to each solution and allowed to stand for 30 minutes. All solutions were shaken well to get uniform mixing and placed in water bath for 10 minutes. After cooling, optical density of each solution was measured at 490 nm in a spectrophotometer against blank which was with 1 ml of trichloroacetic acid, 1 ml of phenol reagent and 5 ml of sulphuric acid.

Slope was drawn by plotting carbohydrate concentration on X-axis and optical density on Y-axis.

Estimation from sample:

1. 25 mg of sample was homogenized with 2 ml of 2:1 chloroform: methanol solution, centrifuged and supernatant was discarded (lipid extracted out).
2. 10 ml of 10% trichloroacetic acid was added, allowed to stand in a water bath for 45 minutes and filtered through Whatman No. 1 filter paper.
3. Filtrate was made up to 10 ml out of which 1 ml of sub-sample was taken to which 1 ml of phenol reagent and 5 ml of concentrated sulphuric acid were added and allowed to stand for 10 minutes.
4. Mixed solution of (3) was shaken well and placed in a water bath for 10 minutes (end colour of solution was yellow-orange).
5. Blank was set up with 1 ml of distilled water, 1 ml of phenol reagent and 5 ml of concentrated sulphuric acid.

6. Optical density was measured at 490 nm in spectrophotometer against blank.
7. Carbohydrate content was determined by referring to the calibration on the standard graph. The reading on the graph was multiplied by 40 to obtain carbohydrate content in mg/100mg of sample.

Lipid estimation:

Sulpho-phosphovanillin method (Barnes and Blackstock,1973):

Principle:

The quantitative determination of lipid by sulpho-phospho-vanillin method depends on the reaction of lipids extracted from the sample using chloroform methanol mixture, with sulphuric acid, phosphoric acid and vanillin to give a red complex.

Reagents:

1. Chloroform : methanol (2:1) : 20 ml of chloroform was mixed with 10 ml of methanol.
2. 0.9% Sodium chloride : 900 mg of sodium chloride was dissolved in 100 ml of distilled water.
3. Phosphovanillin reagent : 800 ml of orthophosphoric acid was added to 200 ml of distilled water. 2 g of vanillin reagent was dissolved in this solution.

Procedure:

Preparation of standard graph : Standard solution was prepared by dissolving 10 mg of cholesterol in 10 ml of 2:1 -chloroform : methanol solution. 0.1 ml, 0.2 ml, 0.3 ml, 0.4 ml and 0.5 ml of standard solution was taken in separate test tubes and all test tubes were kept in desiccator over silica gel for drying. After drying, lipid was digested by adding 0.5 ml of concentrated sulphuric acid and keeping in water bath for 10 minutes. 5 ml of vanillin reagent was added to each test tube, mixed well with the solutions in all test tubes and allowed to stand for 30 minutes. Optical density of the different concentrations was measured at 520 nm in spectrophotometer against blank. 0.2 ml of chloroform was taken in test tube and allowed to evaporate. 0.5 ml of concentrated sulphuric acid and 5 ml of vanillin reagent were added for use as blank.

The relationship between cholesterol concentration on X-axis and optical density on Y-axis was drawn as a sloping straight line.

Estimation from the sample :

1. 50 mg of sample was homogenized with 10 ml of 2:1 - chloroform : methanol solution for 10 minutes by using Remi motor and solution was filtered through Whatman No. 1 filter paper.
2. Filtrate was made up to 10 ml with chloroform, 2 ml of 0.9%

sodium chloride was added, mixed well and kept at 4°C in refrigerator over night.

3. Lower phase of solution was separated into a cleaned test tube and made up to 10 ml with chloroform.
4. 0.5 ml of sub-sample was taken and dried in desiccator over silica gel.
5. Lipid was digested by adding 0.5 ml of concentrated sulphuric acid and kept in a water bath for 10 minutes.
6. 5 ml of vanillin reagent was added to the digested lipid and after 30 minutes optical density was measured at 520 nm in spectrophotometer against blank.
7. Lipid content was determined by referring to the standard graph and the reading was multiplied with 40 to get lipid content in mg/100 mg of sample.

Gonad

Protein, carbohydrate and lipid contents of gonad were estimated by following the same methods which were used in muscle analysis. In the process of protein estimation, lipid interference was eliminated by treating with acetone. 3 ml of acetone was added to 20 mg of sample. After 10 minutes the mixture was centrifuged and the supernatant was discarded. During carbohydrate estimation lipid was eliminated with the treatment of 2:1 chloroform : methanol solution.

Water analysis

At the time of sampling from brackishwater ponds, temperature, salinity, dissolved oxygen and pH content of pond water were observed by using the following methods:

Since live prawns were collected from commercial trawl net catches from the inshore waters off Visakhapatnam, water sampling was not done due to lack of facilities for bottom water sampling and other practical difficulties.

Temperature :

Water temperature was recorded by dipping the centigrade thermometer bulb into the pond water directly and temperature was recorded up to 0.1°C accuracy.

Salinity :

Pond water was collected into a 1 litre polythene water sample bottle and brought to the laboratory where salinity was estimated by using electronic battery operated salinometer. Electrodes were dipped into the water and then needle reflection in the meter was noted to record salinity in ppt.

Estimation of dissolved oxygen :

Dissolved oxygen content in the water was estimated by following Winkler's method (1888). Pond water was collected in 125 ml reagent bottle without allowing air bubbles into the bottle.

Dissolved oxygen was fixed by adding first divalent manganous solution (Winkler's A) and then potassium iodide (Winkler's B) to the water. Precipitating manganous hydroxide was evenly dispersed by shaking and water sample was brought to the laboratory for further analysis. Concentrated sulphuric acid of 36N (Winkler's C) was added to the sample. In the presence of iodide, the oxidised manganese again reverts to the divalent state and iodine which is equivalent to original dissolved oxygen content of the water is liberated. The liberated iodine content was estimated by titrating against standard sodium thiosulphate (hypo) solution using starch as indicator.

The dissolved oxygen content was expressed as ml/l.

Estimation of pH or hydrogen ion concentration :

Litmus paper was dipped into the pond water, allowed to develop colour, which was compared with the given standard colour grades. The pH value corresponding to the colour grade was recorded.

Statistical methods

The range (R), mean value ($\bar{x}$) and standard deviation (SD) of each haemolymph constituent and muscle constituent for both sexes of all three species were calculated. Student's 't' test (Simpson et al., 1960) was employed to find out the level of

statistical significance of the observed differences between different sets of data about the haemolymph and muscle composition.

To find out intra-specific variation of haemolymph and muscle constituents student's 't' test was used. Test of significance was considered (Simpson **et al.**, 1960) at 0.05 probability level.

Relationships of haemolymph constituents with length, weight and condition factor; muscle constituents with length, weight and condition factor were worked out by least square method and regression lines were drawn for relationships which were significant at 0.05 probability level.

Analysis of covariance (Snedecor and Cochran, 1967) was employed for comparison of morphometric relationships between sexes at 5% probability level.

Analysis of variance (Simpson **et al.**, 1960) was used to find out significant differences between haemolymph constituents and muscle constituents of prawns of different crops.

Details of data analysis and the method followed were mentioned in the relevant chapters wherever necessary.

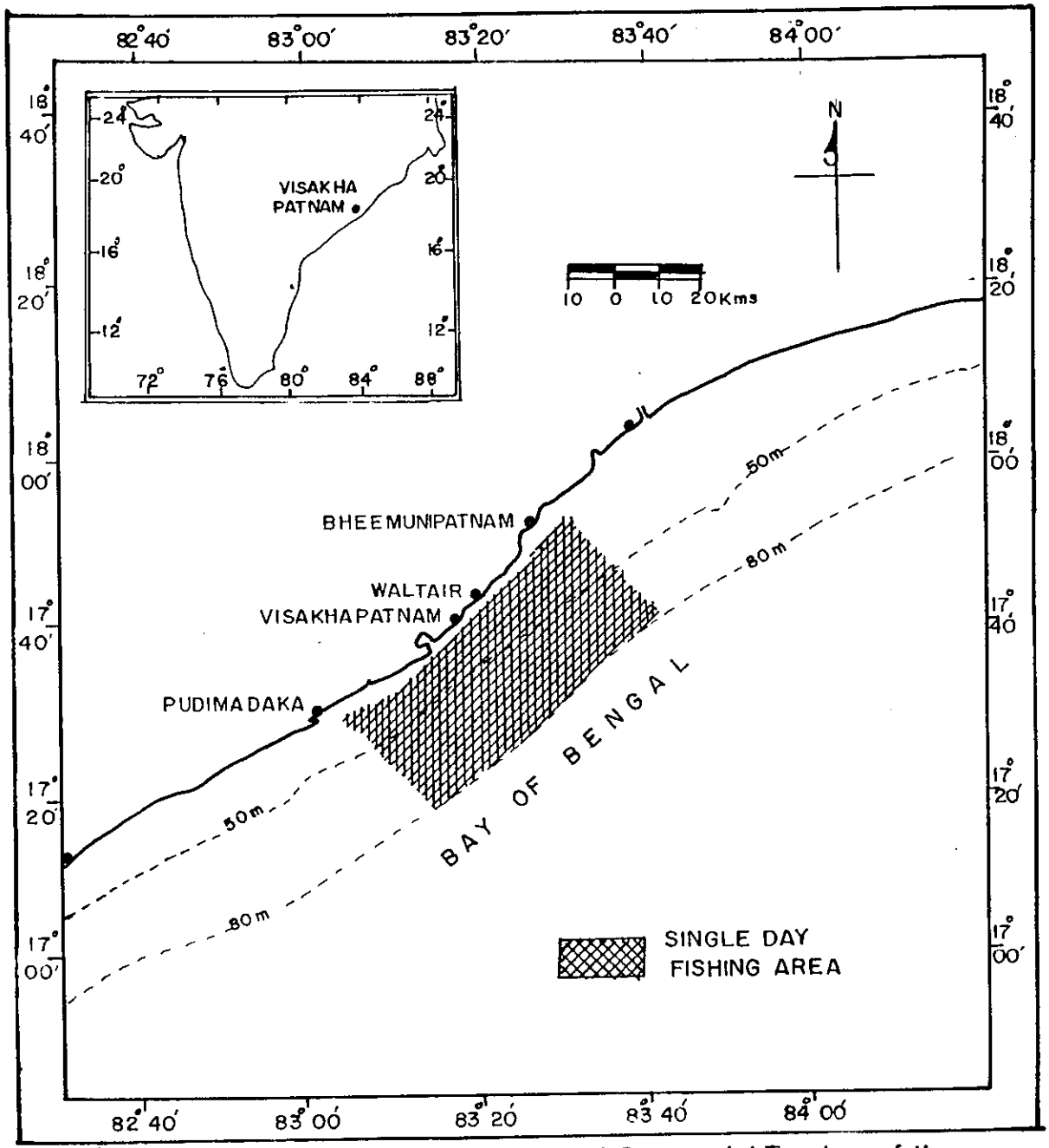

Fig 1 . Area of Fishing operation by small Commercial Trawlers of the Visakhapatnam base.

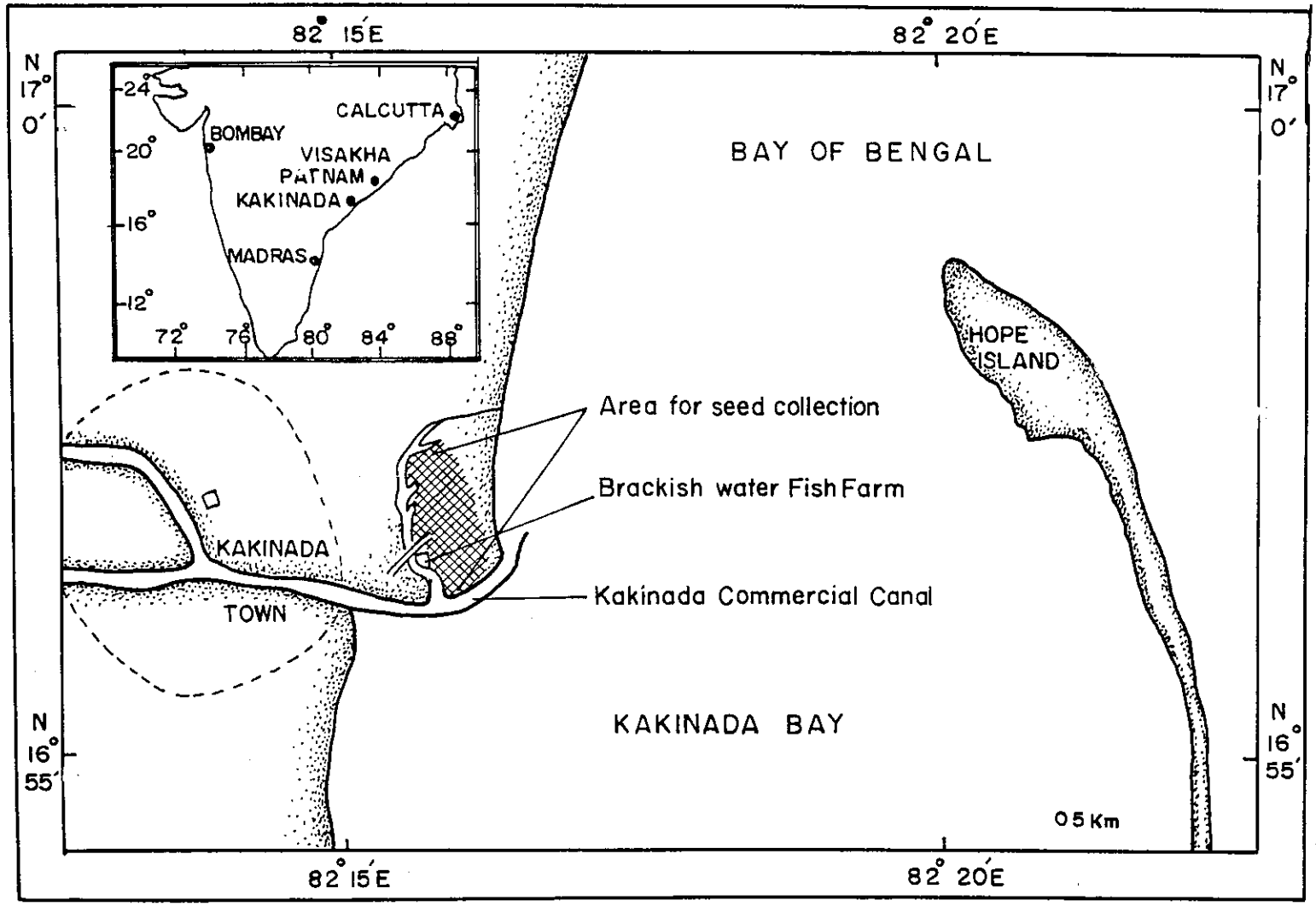

Fig 2. MAP OF STUDY AREA SHOWING BRACKISH WATER FISHFARM AT KAKINADA

CHAPTER 2

LENGTH-WEIGHT AND CARAPACE-TOTAL LENGTH RELATIONSHIP

INTRODUCTION

The length-weight relationship of prawn is calculated with a three fold aim. Firstly, to derive a mathematical relationship between two variables, length and weight, so that the other one could be computed from the known one. Secondly, to measure the variation from the calculated weight for length of individual prawn as an indication of fatness or general well-being or gonad development. Thirdly, to obtain yield estimates by analytical models. Similarly, carapace length-total length relationship is needed to compare interregional and interseasonal catch statistics; results of various haematological characteristics and proximate biochemical composition based on size from different regions since results are reported based on total length and carapace length according to convenience.

The total length-weight relationship of **Metapenaeus monoceros** in juveniles ranging in total length from 25 to 105 mm from Cochin backwaters was studied by George (1959). Sudhakara Rao (1988) made a detailed study covering the entire length range on total length-weight relationship and other dimensional relationships like total length-tail weight and total length-carapace length of **M. monoceros** from Kakinada coast. Rao (1967) derived equations for total length-weight relationship, carapace length-total length relationship and carapace length-weight relationship of

Penaeus monodon from Chilka lake and **Penaeus indicus** from Chilka lake as well as from Gopalpur backwaters. Subrahmanyam and Ganapati (1975) studied the biology of **P. monodon** from Godavari estuarine system and gave an account on linear relationships. Recently, Subramanian (1987) gave an account on carapace length-tail length and carapace length-weight relationship of **P. indicus** in Parangipettai coastal ecosystem. Morphometric studies on other penaeid prawns were made by Rajyalakshmi (1961); Ramamurthy and Manickaraja (1978); Thomas (1975); Sukumaran and Rajan (1981).

Outside India, the study on the same lines was done by Hall (1962); Penn and Hall (1974); and Farmer (1986).

In this chapter, total length-weight relationship, carapace length-weight relationship and carapace length-total length relationship of **P. monodon** from the brackishwater ponds, and of **P. indicus** from the brackishwater ponds as well as from the marine environment and of **M. monoceros** from the marine environment are dealt.

RESULTS

During this study, measurements of morphometric characters of 63 females (102 to 188 mm size) and 53 males (105 to 158 mm) of **M. monoceros**; 25 females (122 to 181 mm) and 22 males (137 to 169 mm) of **P. indicus** from the marine environment; 28 females (91 to 149 mm) and 16 males (104 to 139 mm) of **P. indicus** from the brackishwater ponds; and 13 females (102 to 166 mm) and 23 males (103 to 171 mm) of **P. monodon** from the brackishwater ponds were considered for determining the various relationships.

Total length-weight relationship

Scattergram of individual values of lengths and their corresponding weights of each species is plotted (Figs. 3-6). Since the relationship was found to be exponential, total length-weight relationship was calculated by transforming the exponential relationship:

$$W = aL^b$$

(where W= weight of the prawn, L= total length of the prawn and 'a' and 'b' are constants) to the logarithmic form:

$$\text{Log } W = a + b \text{ Log } L$$

which gives a straight line relationship (Figs. 3-6). The constants 'a' and 'b' were calculated by following least square method. Analysis of covariance (F value) showed that the difference between regression coefficients of the two sexes was

statistically significant in the case of **M. monoceros** and **P. indicus** collected from both the marine and brackishwater environments (Table 1). Hence, separate equations were derived for the two sexes. In the case of **P. monodon**, difference between the sexes was not significant statistically allowing pooling up of the data of the two sexes to obtain a single relationship (Table 1). It may be seen from the scattergrams (Figs. 3-6) that females of **P. indicus** and **M. monoceros** from the marine environment are heavier than the males; while males of **P. indicus** from the brackishwater are heavier than the females from the same environment.

The logarithmic and exponential relationships between total length and weight of all the three species are as follows:

M. monoceros

Males : $\text{Log } W = -5.8076 + 3.3207 \text{ Log } L$ ($r = 0.9915$)

Females : $\text{Log } W = -6.4281 + 3.6208 \text{ Log } L$ ($r = 0.95$)

Males : $W = 0.0000014\ L^{3.3207}$

Females : $W = 0.00000037\ L^{3.6208}$

P. monodon

$\text{Log } W = -5.1648 + 3.0207 \text{ Log } L$ ($r = 0.9336$)

$W = 0.0000068\ L^{3.0207}$

P. indicus (marine water)

Males : $\text{Log } W = -6.5773 + 3.6666 \text{ Log } L$ ($r = 1.0000$)

Females : $\text{Log } W = -5.9472 + 3.3853 \text{ Log } L$ ($r = 0.9737$)

Males : $W = 0.00000026\ L^{3.6666}$

Females : $W = 0.0000011\ L^{3.3853}$

P. indicus (brackishwater)

Males : $\text{Log } W = -4.8102 + 2.8291 \text{ Log } L \quad (r = 0.8179)$

Females : $\text{Log } W = -5.7498 + 3.2769 \text{ Log } L \quad (r = 0.9972)$

Males : $W = 0.000015\ L^{2.8291}$

Females : $W = 0.0000017\ L^{3.2769}$

Analysis of covariance (F) was employed to test whether or not the regression of total length-weight in the case of **P. indicus** from brackishwater ponds and marine environment was significantly different between the two sexes. No significant difference was found (Table 4).

Carapace length-weight relationship

Carapace length-weight relationship was calculated for all the three species separately for the two sexes as in the case of total length-weight relationship.

Analysis of covariance showed no significant difference of regression coefficients between the sexes for all the three species (Table 2). Hence, a common equation for the two sexes was derived for each species. Scattergrams of carapace length-weight relation and the straight line relationship of logarithmically transformed data of all the three species are given in figures 4, 7 and 8. The carapace length-weight relationships of all the three species with logarithmic and exponential forms are as follows:

M. monoceros

Log W = -2.4481 + 2.4438 Log CL (r = 0.9647)

$W = 0.003563\ CL^{2.4438}$

P. monodon

Log W = -2.7493 + 2.6571 Log CL (r = 0.9372)

$W = 0.001781\ CL^{2.6571}$

P. indicus (marine water)

Log W = -2.0353 + 2.2660 Log CL (r = 0.9595)

$W = 0.00921\ CL^{2.2660}$

P. indicus (brackishwater)

Log W = -2.5126 + 2.5363 Log CL (r = 0.9778)

$W = 0.003071\ CL^{2.5363}$

A comparative study of carapace length-weight relationship of **P. indicus** from brackishwater and from marine environments showed significant difference between the two stocks (Table 4).

It may be seen that for a given carapace length, weight is more for **P. indicus** in marine environment than in brackishwater. Similarly, carapace length-weight relationship curves show that for a given carapace length, weight is more for **P. monodon** than for **P. indicus** and **M. monoceros.**

Carapace length-total length relationship

Scattergrams of carapace length-total length relationship in all the three species and of the two sexes showed linear

relation. Regression coefficients were calculated by following least square method for the two sexes separately.

Analysis of covariance (F) was employed to know whether or not the difference of regression coefficients between the two sexes is statistically significant. Analysis of covariance (Table 3) showed that there was no significant difference between the sexes in **P. monodon**, **P. indicus** (marine) and **P. indicus** (brackishwater). The data of the two sexes are pooled to obtain a common equation for each species.

In the case of **M. monoceros**, analysis of covariance (Table 3) showed siginificant difference between the sexes and hence the data of the two sexes are treated separately. The regression lines for observed values of carapace length-total length of all the three species (Figs. 9 and 10) showed that carapace length of **P. monodon** and **M. monoceros** are having almost same total lengths but **P. indicus** is having more total length than that of the other two species for the same carapace length. This might be attributed to the relatively larger rostrum in **P. indicus.**

The equations derived for carapace length-total length relationship of the different species are as follows:

M. monoceros

Males : TL = 23.4344 + 3.398 CL

Females : TL = 44.6835 + 2.69 CL

P. monodon

TL = 10.7251 + 3.8243 CL

P. indicus (marine water)

TL = 50.3698 + 2.9980 CL

P. indicus (brackishwater)

TL = 29.6425 + 3.4902 CL

Analysis of covariance of the relationship between carapace length-total length of **P. indicus** (marine) and that of **P. indicus** (brackishwater) was found to be significant (Table 4).

DISCUSSION

Several authors from India as well as outside India studied morphometric relationships of penaeid prawns. Rao (1967) derived separate equations of total length-weight relationship for **P.indicus** and **P. monodon.** Sudhakara Rao (1988) dealt with total length-weight relation for the two sexes separately in **M. monoceros.** In the present study also it is found necessary to separate the two sexes in the case of **P. indicus** from marine as well as from brackishwater pond. The relationship observed in the case of **M. monoceros** in the present study is in agreement with those of the above authors. However, Rajyalakshmi (1961) combined the two sexes in the case of **Metapenaeus brevicornis** but separated the '0' year group and adults; George (1959) studied by combining two sexes of **M. monoceros** juveniles.

Combining the two sexes regarding total length-weight relationship in the case of **P. monodon** is not in agreement with the observation of Rao (1967) who treated the data separately for the two sexes in the case of **P. monodon** from Chilka lake. Several authors (George, 1959; Rajyalakshmi, 1961; Subrahmanyam, 1963a) combined the two sexes of other penaeid prawns.

From the analysis of data on total length-weight relation three facts emerge out. Firstly, for a given total length, **P. monodon** is having more weight than the other two species

(**P. indicus** and **M. monoceros**). Secondly, females of **P. indicus** (marine) and **M. monoceros** are heavier than males after the onset of maturation. Thirdly, male of **P. indicus** (brackishwater) is heavier than female up to 130 mm total length. Similar results were reported by Penn and Hall (1974) who concluded that for a given carapace length, **Penaeus esculentus** is heavier than **Penaeus latisulcatus** from Shark bay, Western Australia. Sudhakara Rao (1988) also reported that males of **M. monoceros** are heavier than females before puberty and females exceed males with the onset of maturation. However, Penn and Hall (1974) reported that males of **P. latisulcatus** and **P. esculentus** are heavier than females (not related to maturity).

The carapace length-weight relationship of the two sexes was combined by Hall (1962) in the case of 24 species of penaeid prawns from Singapore waters. Several other workers also followed the same method. Such studies were made by Farmer (1986) on **Penaeus semisulcatus, Metapenaeus affinis** and **Parapenaeopsis stylifera** from Kuwait and Bahrain waters; Thomas (1975) on **P. semisulcatus** from Mandapam region; Rao (1967) on **P. monodon** from Chilka lake; and Subramanian (1987) on **P. indicus** from brackishwater as well as from marine water. In the present study also the data of the two sexes of all the three species was combined regarding carapace length-weight relationship as was done by earlier workers, excepting Rao (1967) who treated

the two sexes separately in the case of **P. indicus** from Chilka lake.

The calculated regression coefficient value for carapace length-weight relation of **P. monodon** (2.6571) was comparable with the values of 2.640 and 2.4842 given by Hall (1962) and Rao (1967) respectively. Regarding **P. indicus** from brackishwater, the calculated regression coefficient value 2.5363 was comparable with the values, 2.8174 and 2.9222 given by subramanian (1987) and Hall (1962) respectively.

The total length-weight relationship differed significantly between the two sexes in the case of **P. indicus** and **M. monoceros.** However, the carapace length-weight relationship showed no significant difference between the two sexes. Similar trend was also observed by Rao (1967) in **P. monodon.**

From the present study of carapace length-weight relation two facts emerge out. Firstly, for a given carapace length, **P. monodon** is having more weight compared to the other two species and secondly for a given carapace length, specimens of **P. indicus** from marine water are heavier than the specimens from brackishwater due to onset of maturity.

The present study of total length-weight relationship and carapace length-weight relationship agrees with the statement "The relationship between weight and length is affected by allometric

growth, and so weight is rarely proportional to the cube of the length as it would be if growth was isometric" given by Hartnoll (1982) for crustaceans.

Sudhakara Rao (1988) studied total length and carapace length relation of **M. monoceros** by treating sexes separately. Penn and Hall (1974) derived equations of carapace length-total length for two sexes separately of the Western Australian prawns, **P. latisulcatus** and **P. esculentus.** Ramamurthy and Manickaraja (1978) studied the carapace length-total length relationship of **Metapenaeus dobsoni, M. affinis** and **P. stylifera** by deriving equations separately for the two sexes. Sukumaran and Rajan (1981) derived separate equations for sexes of **Parapenaeopsis hardwickii** for total length and carapace length. Similarly, in the present study sexwise treatment of carapace length-total length relationship of **M. monoceros** is in agreement with the observation of the above said authors.

The present study of giving a combined equation for both the sexes of **P. monodon** and **P. indicus** from marine as well as brackishwater is in agreement with earlier studies made by Farmer (1986) on **P. semisulcatus, M. affinis** and **P. stylifera** from Kuwait and Bahrain waters; Thomas (1975) on **P. semisulcatus** from Indian waters; Rao (1967) on **P. indicus** and **P. monodon** from Chilka lake; and Subramanian (1987) on **P. indicus** from estuarine and marine waters.

In the present carapace length-total length relationship study, it has been found that for a given carapace length, **P. monodon** and **M. monoceros** are having almost same total length but **P. indicus** is having more total length than other two species and this is attributed to the lengthy rostrum.

Table 1. Comparison of the regression lines of total length-weight relationship of **M.monoceros, P.monodon** and **P.indicus**

	d.f. n-1	x^2	xy	y^2	b	Deviation from regressions d.f.	S.S.	M.S.
M. monoceros								
Within males	52	0.0823	0.2733	0.9269	3.3207	51	0.0193	0.0003
Within females	62	0.1522	0.5511	1.9633	3.6208	61	0.0321	0.0005
						112	0.0514	0.0004
Pooled (within) common	114	0.2345	0.8244	2.8902	3.5155	113	0.0080	0.00007
						1	-0.0434	-0.0434
Slope between	1	0.1280	0.3889	1.1822				
Total	115	0.3625	1.3060	4.7031		114	0.0021	
Adjusted means						1	0.0059	0.0059
Comparison of slopes : F = 0.0434/0.0004 = 108.5 (d.f. = 1, 112) significant								
Comparison of elevation : F = 0.0059/0.00007 = 84.28 (d.f. = 1, 113) significant								
P. indicus (marine water)								
Within males	21	0.0123	0.0451	0.1461	3.6666	20	0.1653	0.0082
Within females	24	0.0423	0.1432	0.5113	3.3853	23	0.0265	0.0011
						43	0.1918	0.0044
Pooled (within) common	45	0.0546	0.1883	0.6574	3.4487	44	0.008	0.0001
						1	-0.1838	-0.1838
Slope between	1	0.0060	0.0243	0.0982				
Total	46	0.0606	0.2126	0.7556		45	0.0097	
Adjusted means						1	0.0017	0.0017
Comparison of slopes : F = 0.1838/0.0044 = 41.7727 (d.f. = 1, 43) significant								
Comparison of elevation : F = 0.0017/0.0001 = 17.0 (d.f. = 1, 44) significant								

contd.....

Table 1 (contd.)

	d.f. n-1	x^2	xy	y^2	b	Deviation from regressions d.f.	S.S.	M.S.
P. monodon								
Within males	22	0.0805	0.2525	0.9757	3.1366	21	0.1836	0.0087
Within females	12	0.0686	0.1884	0.5315	2.7463	11	0.0140	0.0012
						32	0.1976	0.0061
Pooled (within) common	34	0.1491	0.4409	1.5072	2.9570	33	0.2034	0.0061
						1	0.0058	0.0058
Slope between	1	0.0096	0.0385	0.1542				
Total	35	0.1587	0.4794	1.6614		34	0.2132	
Adjusted means						1	0.0098	0.0098
Comparison of slopes : F = 0.0058/0.0061 = 0.9508 (d.f. = 1, 32) not significant								
Comparison of elevation : F = 0.0098/0.0061 = 1.6065 (d.f. = 1, 33) not significant								
P. indicus (brackishwater)								
Within males	15	0.0199	0.0563	0.2381	2.8291	14	0.0788	0.0056
Within females	27	0.1029	0.3372	1.1110	3.2769	26	0.0060	0.0002
						40	0.0848	0.0021
Pooled (within) common	42	0.1228	0.3969	1.3491	3.2320	41	0.0662	0.0016
						1	-0.0186	-0.0186
Slope between	1	0.0000	0.0033	0.0001				
Total	43	0.1228	0.3936	1.3492		42	0.0876	
Adjusted means						1	0.0214	0.0214
Comparison of slopes : F = 0.0186/0.0021 = 8.8571 (d.f. = 1, 40) significant								
Comparison of elevation : F = 0.0214/0.0016 = 13.3750 (d.f. = 1, 41) significant								

Table 2. Comparison of the regression lines of carapace length-weight relationship of **M.monoceros, P.monodon** and **P.indicus**

	d.f. n-1	x^2	xy	y^2	b	Deviation from regressions		
						d.f.	S.S.	M.S.
M.monoceros								
Within males	52	0.1166	0.3053	0.9269	2.6192	51	0.1275	0.0025
Within females	62	0.3171	0.7496	1.9630	2.3659	61	0.1910	0.0031
						112	0.3185	0.0056
Pooled (within) common	114	0.4337	1.0549	2.8899	2.4323	113	0.3240	0.0028
						1	0.0055	0.0055
Slope between	1	0.2954	0.7269	1.7889				
Total	115	0.7291	1.7818	4.6788		114	0.3243	
Adjusted means						1	0.0003	0.0003
Comparison of slopes : F = 0.0055/0.0056 = 0.9821 (d.f. = 1, 112) not significant								
Comparison of elevation : F = 0.0003/0.0028 = 0.1071 (d.f. = 1, 113) not significant								
P. indicus (marine water)								
Within males	21	0.0223	0.0565	0.1582	2.5336	20	0.0150	0.0007
Within females	24	0.0845	0.2016	0.5285	2.3857	23	0.0475	0.0020
						43	0.0625	0.0014
Pooled (within) common	45	0.1068	0.2581	0.6867	2.4166	44	0.0629	0.0014
						1	0.0004	0.0004
Slope between	1	0.0233	0.0528	0.1203				
Total	46	0.1301	0.3109	0.8070		45	0.0640	
Adjusted means						1	0.0011	0.0011
Comparison of slopes : F = 0.0004/0.0014 = 0.2857 (d.f. = 1, 43) not significant								
Comparison of elevation : F = 0.0011/0.0014 = 0.7857 (d.f. = 1, 44) not significant								

contd....

Table 2 (contd.)

	d.f. n-1	x^2	xy	y^2	b	Deviation from regressions d.f.	S.S.	M.S.
P.monodon								
Within males	22	0.1019	0.2513	0.8056	2.4661	21	0.1858	0.00884
Within females	12	0.0635	0.1669	0.5190	2.6283	11	0.0803	0.0073
						32	0.2661	0.0083
Pooled (within) common	34	0.1654	0.4182	1.3246	2.5284	33	0.2672	0.00809
						1	0.0011	0.0011
Slope between	1	0.014	0.0537	0.2065				
Total	35	0.1794	0.4719	1.5311		34	0.2897	
Adjusted means						1	0.0225	0.0225
Comparison of slopes : F = 0.0011/0.0083 = 0.1323 (d.f. = 1, 32) not significant								
Comparison of elevation : F = 0.0225/0.00809 = 2.7812 (d.f. = 1, 33) not significant								
P.indicus (brackishwater)								
Within males	15	0.0425	0.0982	0.2634	2.3105	14	0.0365	0.0026
Within females	27	0.1613	0.4196	1.1112	2.6013	26	0.0196	0.0007
						40	0.0561	0.0014
Pooled (within) common	42	0.2038	0.5178	1.3746	2.5407	41	0.0590	0.0014
						1	0.0029	0.0029
Slope between	1	0.0009	0.0014	0.0025				
Total	43	0.2047	0.5192	1.3771		42	0.0602	
Adjusted means						1	0.0012	0.0012
Comparison of slopes : F = 0.0029/0.0014 = 2.0714 (d.f. = 1, 40) not significant								
Comparison of elevation : F = 0.0012/0.0014 = 0.8571 (d.f. = 1, 41) not significant								

Table 3. Comparison of the regression lines of carapace length-total length relationship of **M.monoceros, P.monodon** and **P.indicus**

	d.f. n-1	x^2	xy	y^2	b	Deviation from regressions d.f.	S.S.	M.S.
M.monoceros								
Within males	52	569.8	1936.3	7204.7	3.398	51	624.7	12.2
Within females	62	2547.7	6854.3	20730.4	2.690	61	2289.6	37.5
						112	2914.3	26.02
Pooled (within) common	114	3117.5	8790.6	27935.1	2.8197	113	3147.7	27.85
						1	233.4	233.4
Slope between	1	1965.2	5247.2	14010.7				
Total	115	5082.7	14037.8	41945.8		114	3175.1	
Adjusted means						1	27.4	27.4
P.indicus (marine water)								
Within males	21	83.8	293.2	1699.0	3.4988	20	673.1	33.65
Within females	24	522.0	1660.4	5455.0	3.1808	23	173.52	7.54
						43	846.62	19.68
Pooled (within) common	45	605.8	1953.6	7154.0		44	853.97	19.40
						1	7.35	7.35
Slope between	1	177.1	393.6	874.4				
Total	46	782.9	2347.2	8028.4		45	991.29	
Adjusted means						1	137.32	137.32

Comparison of slopes : F = 233.4/26.02 = 8.9 (d.f. = 1, 112) significant

Comparison of elevation: F = 27.4/27.85 = 0.98 (d.f. = 1, 113) not significant

Comparison of slopes : F = 7.35/19.68 = 0.3734 (d.f. = 1, 43) not significant

Comparison of elevation: F = 137.32/19.40 = 7.0783 (d.f. = 1, 44) significant

Contd....

Table 3 (contd.)

	d.f. n-1	x^2	xy	y^2	b	Deviation from regressions d.f.	S.S.	M.S.
P.monodon								
Within males	22	503.47	1794.52	7925.47	3.5643	21	1529.25	72.821
Within females	12	319.23	1330.76	6233.23	4.1686	11	685.74	62.34
						32	2214.99	69.21
Pooled (within) common	34	822.7	3125.28	14158.7	3.7988	33	2286.35	69.28
						1	71.36	71.36
Slope between	1	71.3	293.72	1210.05				
Total	35	894.0	3419.0	15368.75		34	2293.17	
Adjusted means						1	6.82	6.82
Comparison of slopes : F = 71.36/69.21 = 1.0310 (d.f. = 1, 32) not significant								
Comparison of elevation: F = 6.82/69.28 = 0.0976 (d.f. = 1, 33) not significant								
P.indicus (brackishwater)								
Within males	15	152.0	451.5	1561.44	2.9703	14	220.30	15.736
Within females	27	554.11	2019.75	7701.25	3.6450	26	339.19	13.045
						40	559.49	13.987
Pooled (within) common	42	706.11	2471.25	9262.69	3.4998	41	613.78	14.970
						1	54.29	54.29
Slope between	1	1.04	-3.07	8.94				
Total	43	707.15	2468.18	9271.63		42	656.89	
Adjusted means						1	43.11	43.11
Comparison of slopes : F = 54.29/13.987 = 3.8814 (d.f. = 1, 40) not significant								
Comparison of elevation: F = 43.11/14.97 = 2.8797 (d.f. = 1, 41) not significant								

Table 4. Comparison of the regression lines of morphometric relationships between **P.indicus** (marine water) and **P.indicus** (brackishwater)

	d.f. n-1	x^2	xy	y^2	b	Deviation from regressions d.f.	S.S.	M.S.
Carapace length-total length relationship								
Marine water	46	782.9	2347.2	8028.4	2.9980	45	991.29	22.028
Brackishwater	43	707.15	2468.18	9271.63	3.4902	42	656.89	15.640
						87	1648.18	18.944
Pooled (within) common	89	1490.05	4815.38	17300.03	3.2316	88	1738.21	19.752
						1	90.03	90.03
Slope between	1	1713.55	6576.03	25237.64				
Total	90	3203.60	11391.41	42537.67		89	2031.91	
Adjusted means						1	293.7	293.7
Comparison of slopes : F = 90.03/18.9445 = 4.7523 (d.f. = 1, 87) significant								
Comparison of elevation: F = 293.7/19.752 = 14.8693 (d.f. = 1, 88) significant								
Carapace length-weight relationship								
Marine water	46	0.1301	0.3109	0.8070	2.3897	45	0.0640	0.0014
Brackishwater	43	0.2047	0.5192	1.3771	2.5363	42	0.0602	0.0014
						87	0.1242	0.0014
Pooled (within) common	89	0.3348	0.8301	2.1841	2.4793	88	0.1259	0.0014
						1	0.0017	0.0017
Slope between	1	0.3395	1.021	3.0708				
Total	90	0.6743	1.8511	5.2549		89	0.1732	
Adjusted means						1	0.0473	0.0473
Comparison of slopes : F = 0.0017/0.0014 = 1.2142 (d.f. = 1, 87) not significant								
Comparison of elevation: F = 0.0473/0.0014 = 33.7857 (d.f. = 1, 88) significant								

Contd....

Table 4 (contd.)

	d.f. n-1	x^2	xy	y^2	b	Deviation from regressions d.f.	S.S.	M.S.
Total length-weight relationship (male)								
Marine water	21	0.0123	0.0451	0.1461	3.6666	20	-0.0192	-0.0009
Brackishwater	15	0.0199	0.0563	0.2381	2.8291	14	0.0788	0.0056
						34	0.0596	0.0017
Pooled (within) common	36	0.0322	0.1014	0.3842	3.1490	35	0.0648	0.0018
						1	0.0052	0.0052
Slope between	1	0.0792	0.2796	0.9818				
Total	37	0.1114	0.3810	1.3660		36	0.0629	
Adjusted means						1	0.0019	0.0019
Comparison of slopes : F = 0.0052/0.0017 = 3.0588 (d.f. = 1, 34) not significant								
Comparison of elevation: F = 0.0019/0.0018 = 1.0555 (d.f. = 1, 35) not significant								
Total length-weight relationship (female)								
Marine water	24	0.0423	0.1432	0.5113	3.3853	23	0.0265	0.0011
Brackishwater	27	0.1029	0.3372	1.1110	3.2769	26	0.0060	0.00023
						49	0.0325	0.0006
Pooled (within) common	51	0.1452	0.4804	1.6223	3.3085	50	0.0328	0.0006
						1	0.0003	0.0003
Slope between	1	0.1737	0.6325	2.3027				
Total	52	0.3189	1.1129	3.9250		51	0.0411	
Adjusted means						1	0.0008	0.0008
Comparison of slopes : F = 0.0003/0.0006 = 0.5 (d.f. = 1, 49) not significant								
Comparison of elevation: F = 0.0008/0.0006 = 1.3333 (d.f. = 1, 50) not significant								

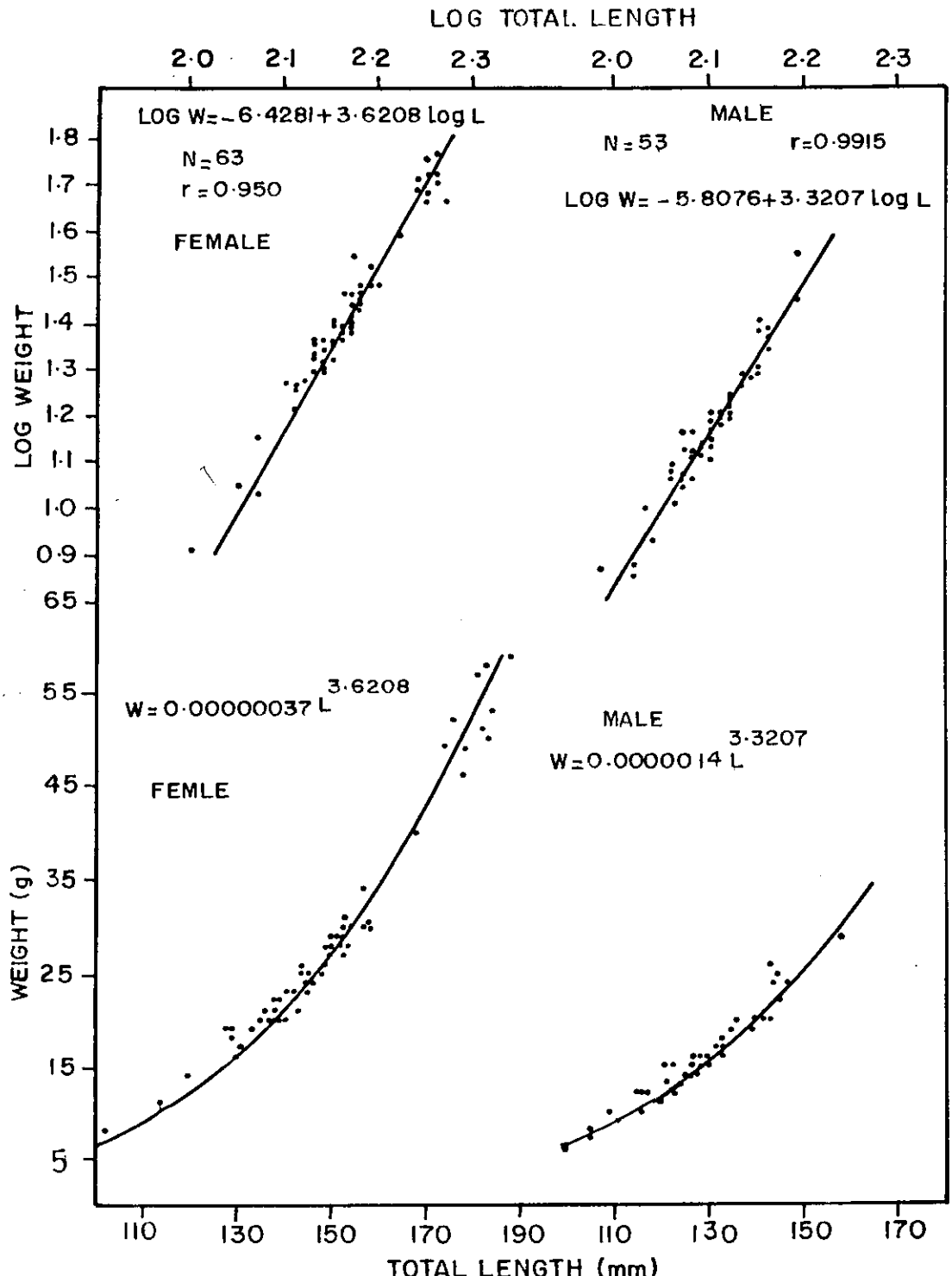

Fig.3. Relationship between Total Length and Weight of M.monoceros

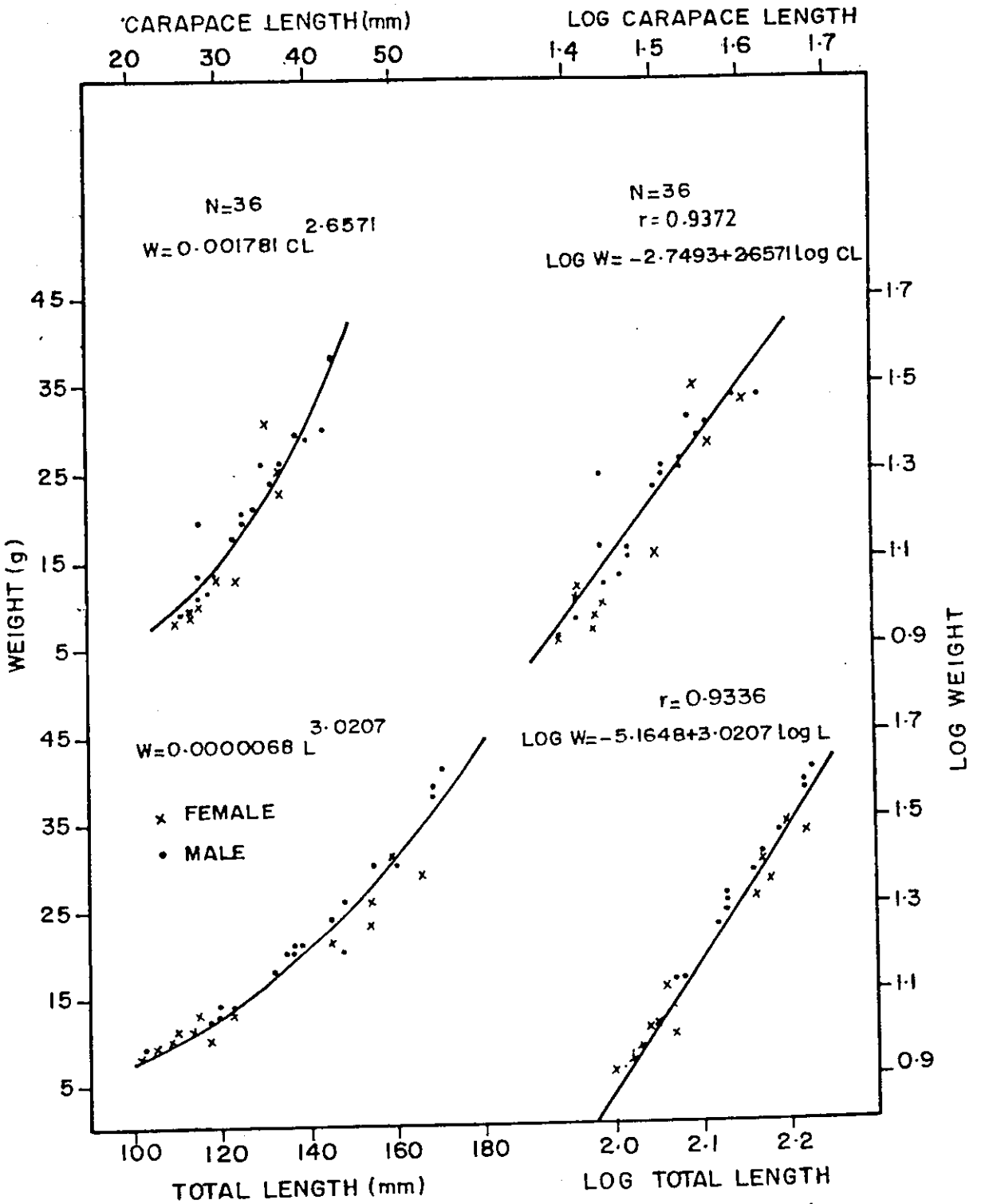

Fig. 4. Relationships of Carapace Length and Total Length with weight of P. monodon

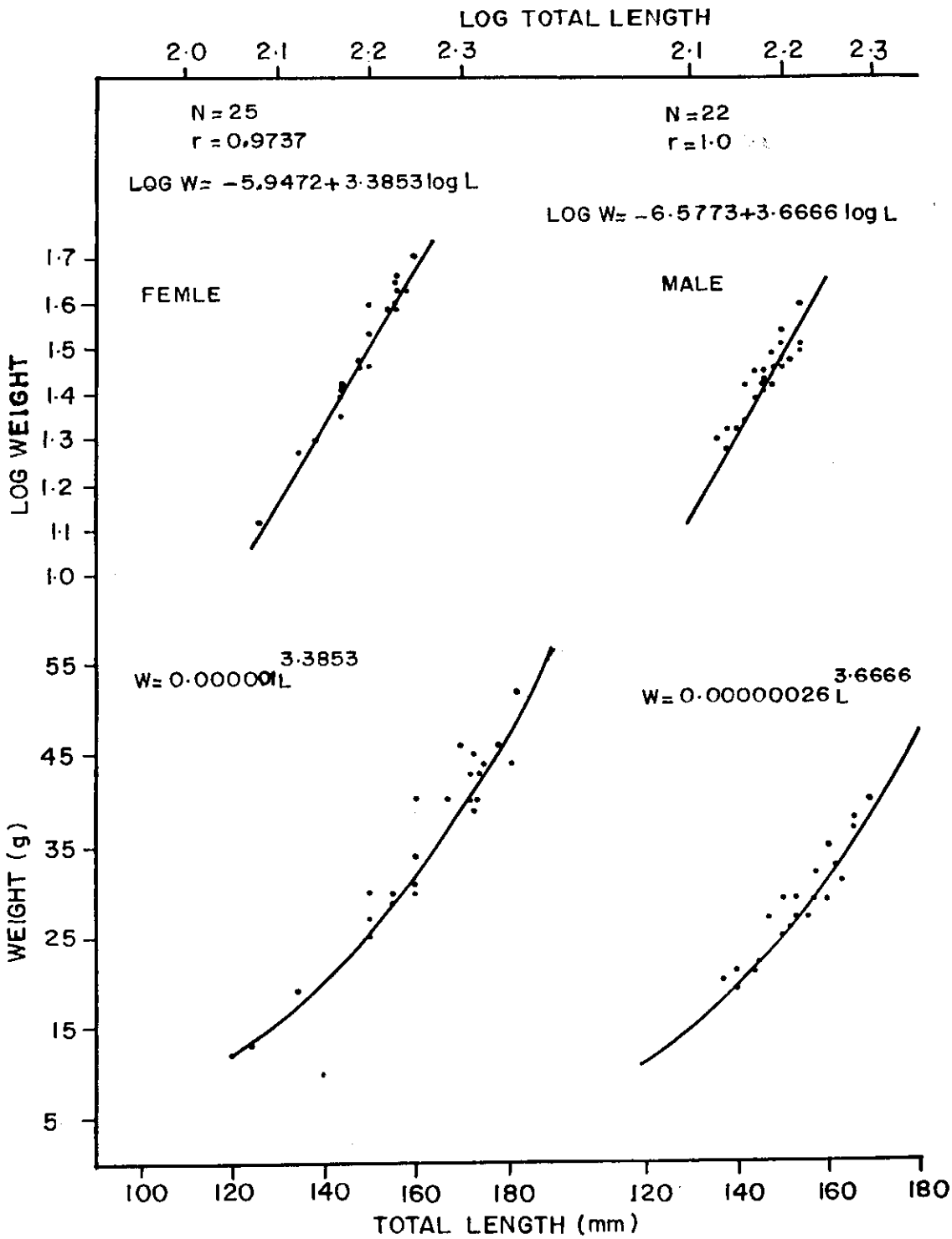

Fig.5. Relationship between Total Length and Weight of P. indicus (Marine)

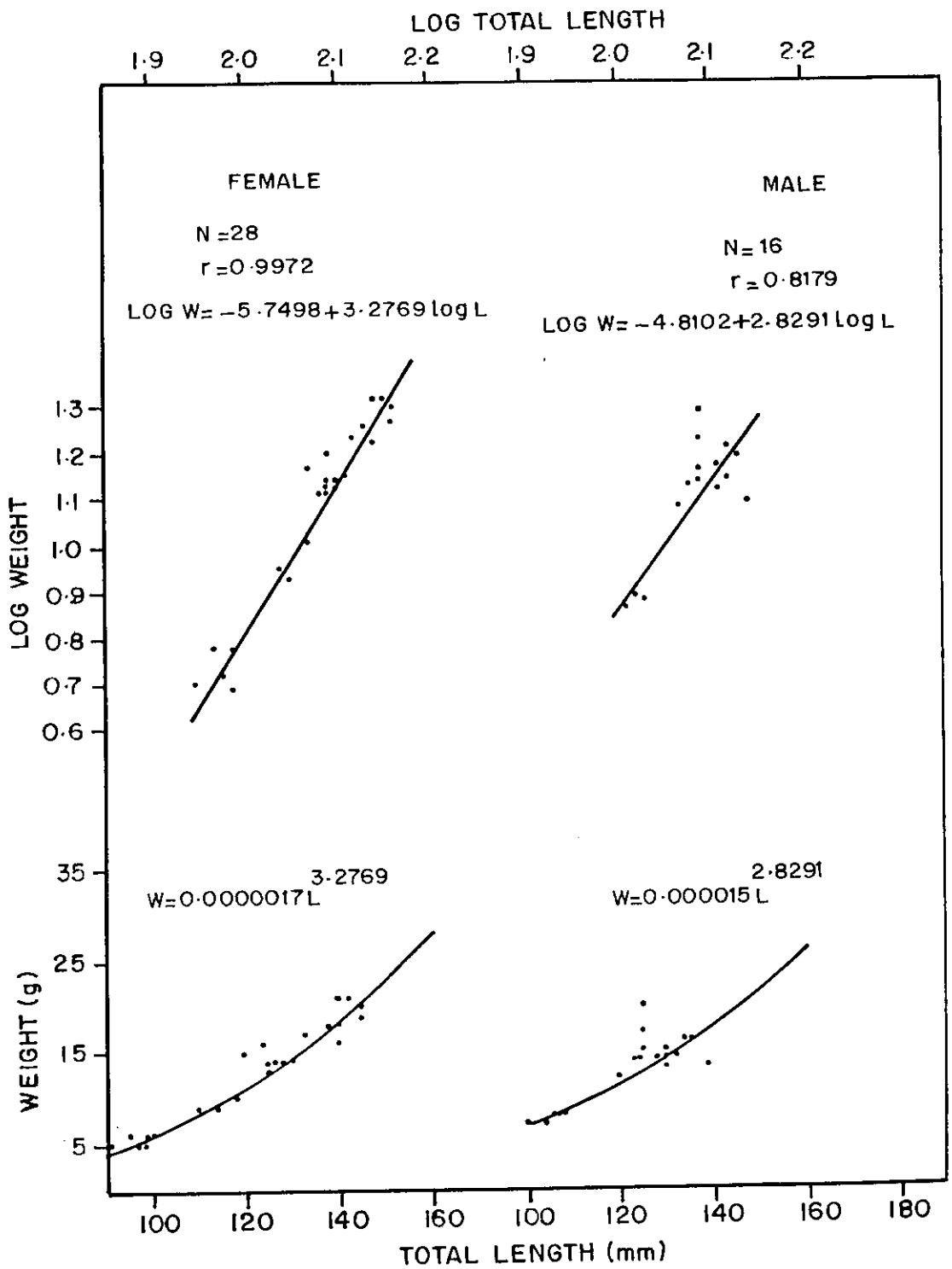

Fig.6. Relationship between Total Length and Weight of P. indicus (Brackishwater)

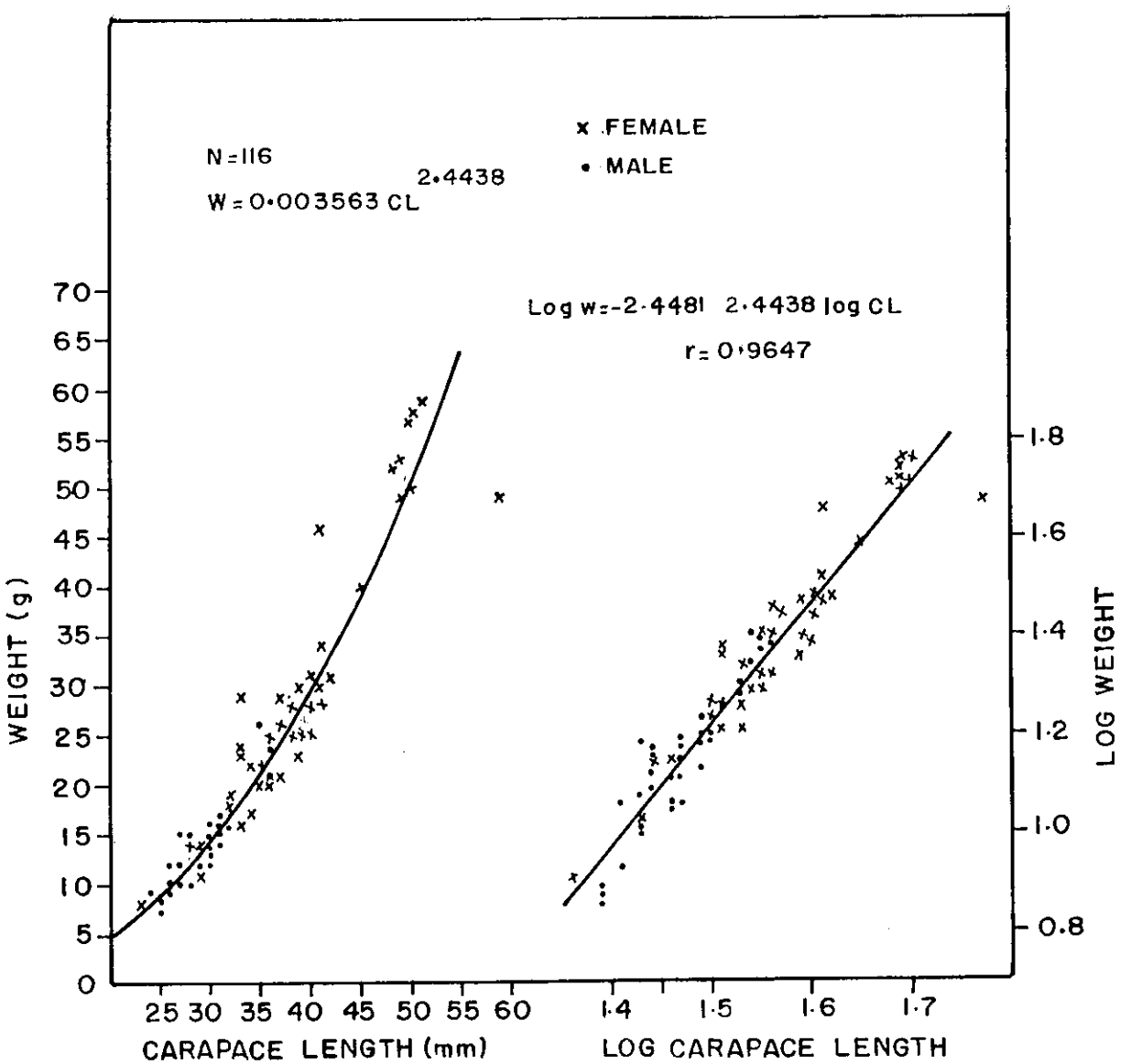

Fig.7. Relationship between Carapace Length and Weight of M. monoceros

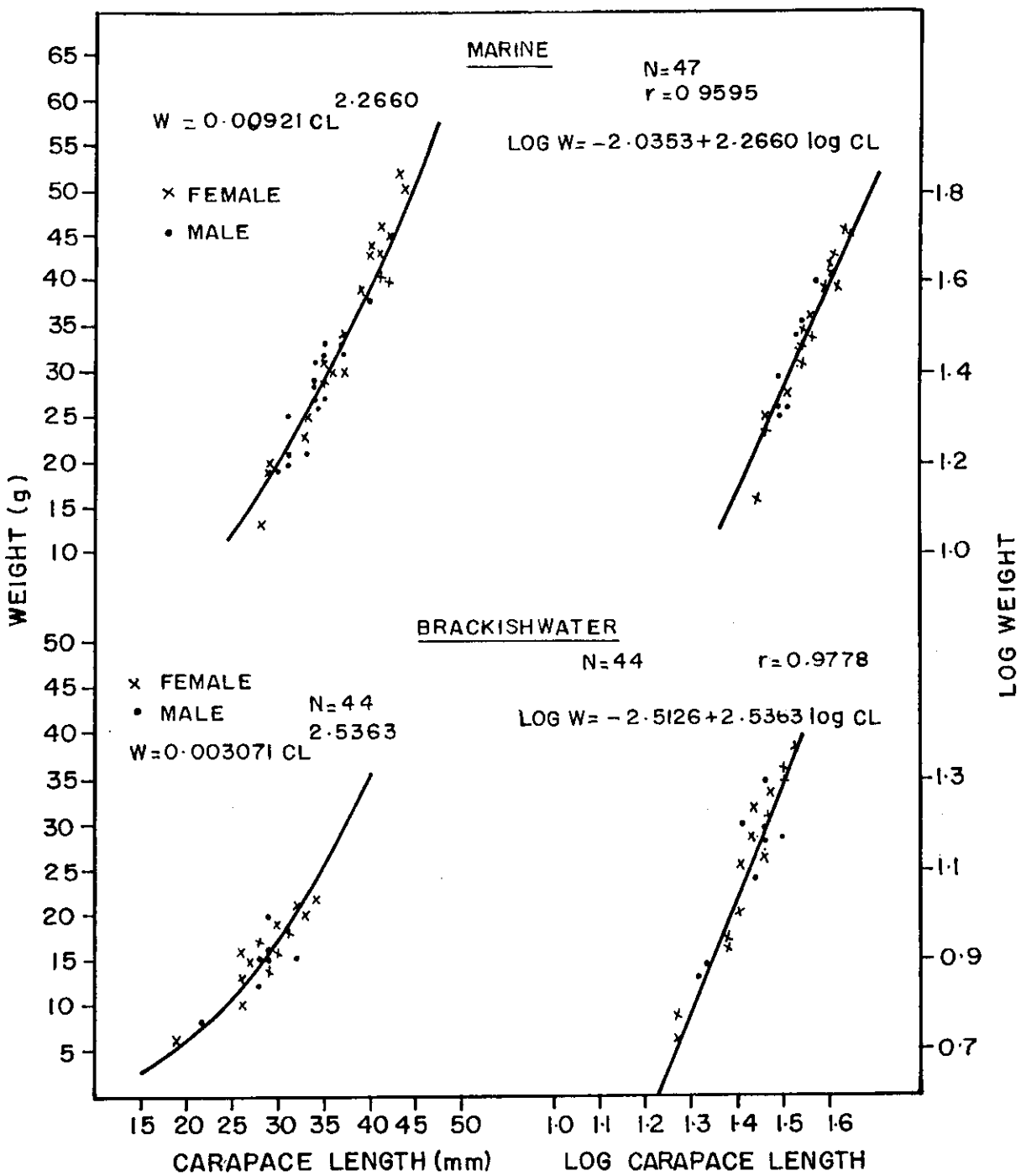

Fig.8. Relationship between Carapace Length and Weight of P. indicus

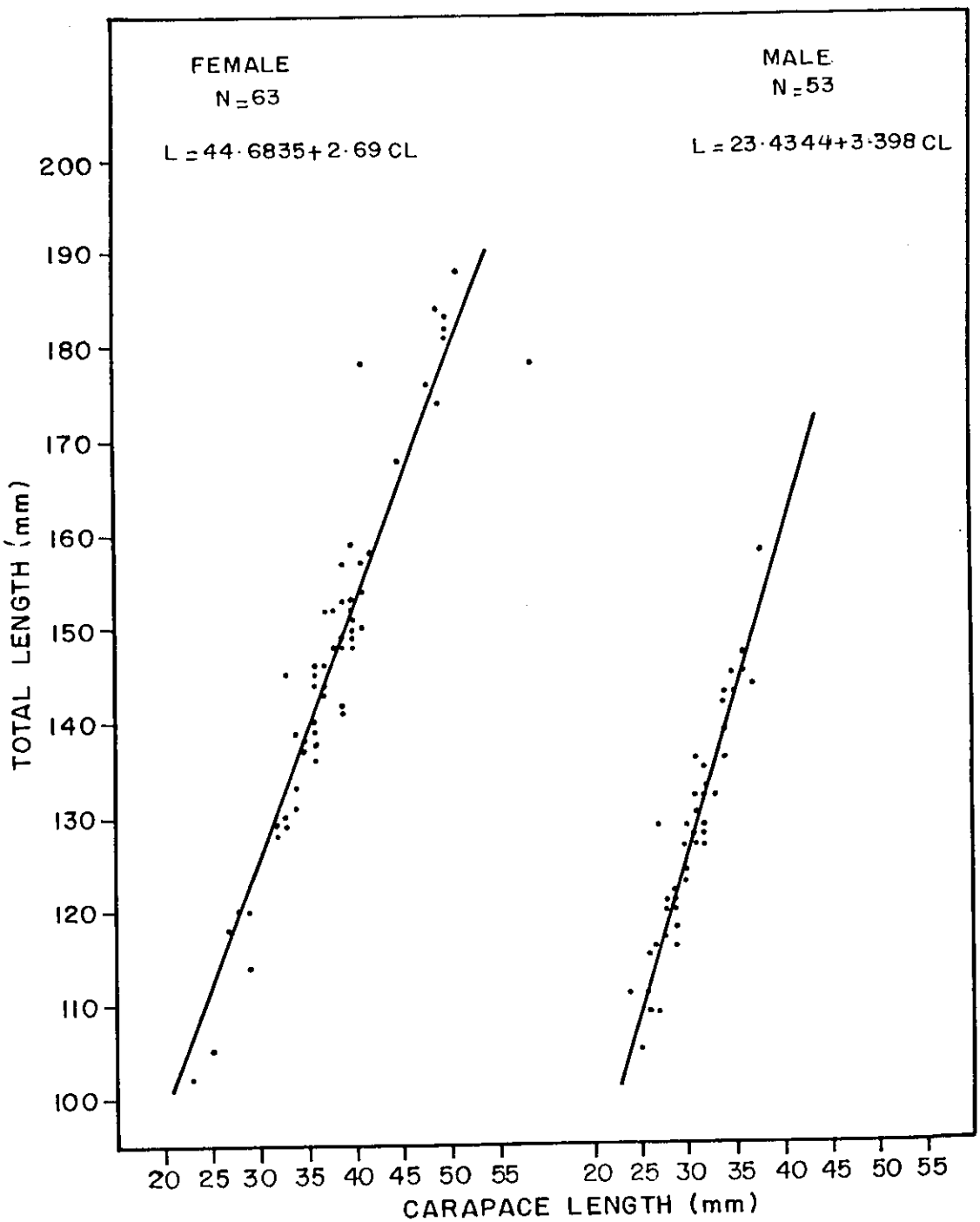

Fig.9. Relationship between Carapace Length and Total Length of M. monoceros

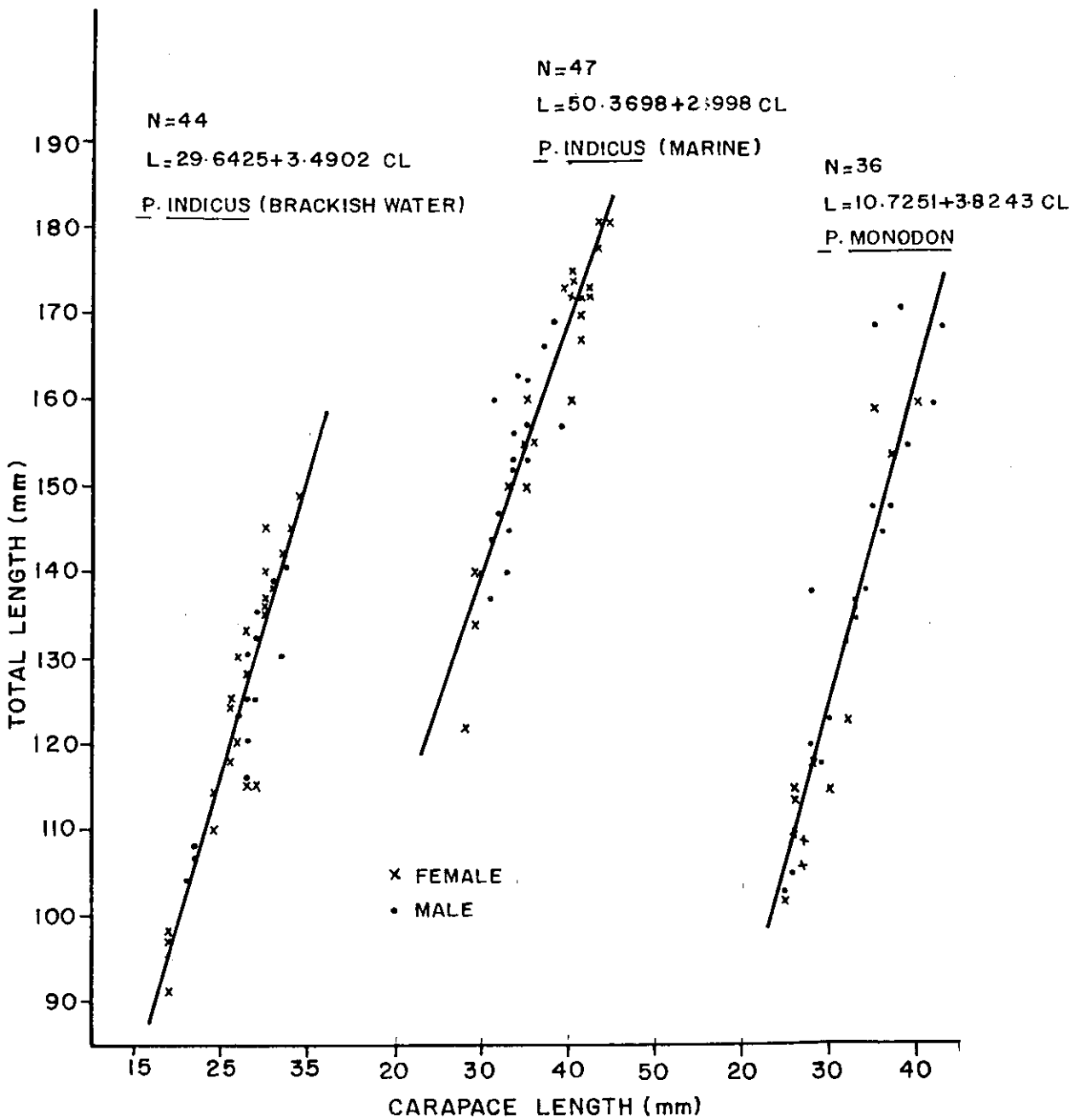

Fig.10· Relationship between Carapace Length and Total Length of P. indicus and P. monodon

CHAPTER 3

BIOCHEMICAL COMPOSITION OF HAEMOLYMPH IN RELATION TO SEX, SIZE, WEIGHT AND CONDITION FACTOR

INTRODUCTION

In prawns haemolymph is a medium of transport for carrying the different metabolites produced by the synthesis organs to the active sites of the different organ systems. It is a storage depot for different organic and inorganic constituents and as an oxygen carrier plays an important role in the respiratory activity and consequently prawn physiology. Haemolymph composition is affected by abiotic factors like salinity, temperature and dissolved oxygen as well as biotic factors such as type of food that the prawn feeds on, moult cycle, maturation process, sex, size, weight and condition factor. It is a well known fact that haemolymph composition is determined primarily by moult cycle and maturation process. Intensive study on these aspects of the different penaeid prawns was made in the different regions. Since the information on variation in haemolymph composition in relation to sex, size, weight and condition factor of penaeid prawns of India is scanty, the present study is an attempt to elucidate how far these factors affect the haemolymph composition.

Panikkar and Viswanathan (1948) studied the active regulation of chloride in **Metapenaeus monoceros.** Dall (1964) gave an account of blood constituents of **Metapenaeus mastersii.** Carbohydrate and calcium metabolism of **Metapenaeus** sp. was studied by Dall (1965a and 1965b). Balazs **et al.** (1974), made a comparative study of serum constituents of **Penaeus marginatus** and

Macrobrachium rosenbergii. Preliminary study on the osmoregulation of **Penaeus stylirostris** was done by Rodriguez (1976). Vedavyasa Rao **et al.** (1981), studied the fluctuation of calcium level in haemolymph of **P. indicus** from a brackishwater pond. Ionic regulation against salinity range was reported by Dall and Smith (1981) in commercially important penaeid prawns from Australia. Osmoregulatory ability in the juveniles in relation to habitat preference of Australian penaeid prawns was also studied by Dall (1981). Variation in biochemical composition of haemolymph due to toxicants was reported by Reddy **et al.** (1986), in **M. monoceros.** Osmoregulatory ability in relation to varying salinities was studied by Diwan **et al.** (1989a and 1989b) in **P. monodon** and **P. indicus.** Osmoregulatory capacity of **Macrobrachium petersi** at different stages of its life cycle was reported by Read (1984). Effect of salinity on haemolymph composition was studied by Ferraris **et al.** (1986), in **P. monodon.** Kulkarni **et al.** (1980), studied blood glucose level in relation to salinity in **Parapenaeopsis hardwickii.** Smith (1982) explained the increase in glucose level of haemolymph as due to stress in the pink shrimp **Penaeus duorarum.**

Investigations on haemolymph composition in relation to abiotic and biotic factors were carried out in the other crustaceans by Gilbert (1959), Stewart **et al.** (1966), Kerr (1969), Bedford (1972), Lin and Cohen (1973), Lock Wood and Inman (1973), Dall

(1974a and 1974b), Kannupandi and Paulpandian (1975), Spaargarden (1975), Dall (1975), Sevilla (1975), Raja **et al**, (1976), Bedford and Leader (1977), Nammalwar (1978), Pequeux **et al.** (1979), Ohidalia **et al.** (1981), Walters and Uglow (1981), Fair and Sick (1982), Kobayashi (1982), Adegboye (1983), Hagerman (1983), Arumugam and Ravindranath (1983) and Digby (1984).

Table 1. Comparison of the regression lines of total length-weight relationship of **M.monoceros, P.monodon** and **P.indicus**

	d.f. n-1	x^2	xy	y^2	b	Deviation from regressions d.f.	S.S.	M.S.
M. monoceros								
Within males	52	0.0823	0.2733	0.9269	3.3207	51	0.0193	0.0003
Within females	62	0.1522	0.5511	1.9633	3.6208	61	0.0321	0.0005
						112	0.0514	0.0004
Pooled (within) common	114	0.2345	0.8244	2.8902	3.5155	113	0.0080	0.00007
						1	-0.0434	-0.0434
Slope between	1	0.1280	0.3889	1.1822				
Total	115	0.3625	1.3060	4.7031		114	0.0021	
Adjusted means						1	0.0059	0.0059
Comparison of slopes : F = 0.0434/0.0004 = 108.5 (d.f. = 1, 112) significant								
Comparison of elevation : F = 0.0059/0.00007 = 84.28 (d.f. = 1, 113) significant								
P. indicus (marine water)								
Within males	21	0.0123	0.0451	0.1461	3.6666	20	0.1653	0.0082
Within females	24	0.0423	0.1432	0.5113	3.3853	23	0.0265	0.0011
						43	0.1918	0.0044
Pooled (within) common	45	0.0546	0.1883	0.6574	3.4487	44	0.008	0.0001
						1	-0.1838	-0.1838
Slope between	1	0.0060	0.0243	0.0982				
Total	46	0.0606	0.2126	0.7556		45	0.0097	
Adjusted means						1	0.0017	0.0017
Comparison of slopes : F = 0.1838/0.0044 = 41.7727 (d.f. = 1, 43) significant								
Comparison of elevation : F = 0.0017/0.0001 = 17.0 (d.f. = 1, 44) significant								

contd.....

Table 1 (contd.)

	d.f. n-1	x^2	xy	y^2	b	Deviation from regressions d.f.	S.S.	M.S.
P. monodon								
Within males	22	0.0805	0.2525	0.9757	3.1366	21	0.1836	0.0087
Within females	12	0.0686	0.1884	0.5315	2.7463	11	0.0140	0.0012
						32	0.1976	0.0061
Pooled (within) common	34	0.1491	0.4409	1.5072	2.9570	33	0.2034	0.0061
						1	0.0058	0.0058
Slope between	1	0.0096	0.0385	0.1542				
Total	35	0.1587	0.4794	1.6614		34	0.2132	
Adjusted means						1	0.0098	0.0098
Comparison of slopes : F = 0.0058/0.0061 = 0.9508 (d.f. = 1, 32) not significant								
Comparison of elevation : F = 0.0098/0.0061 = 1.6065 (d.f. = 1, 33) not significant								
P. indicus (brackishwater)								
Within males	15	0.0199	0.0563	0.2381	2.8291	14	0.0788	0.0056
Within females	27	0.1029	0.3372	1.1110	3.2769	26	0.0060	0.0002
						40	0.0848	0.0021
Pooled (within) common	42	0.1228	0.3969	1.3491	3.2320	41	0.0662	0.0016
						1	-0.0186	-0.0186
Slope between	1	0.0000	0.0033	0.0001				
Total	43	0.1228	0.3936	1.3492		42	0.0876	
Adjusted means						1	0.0214	0.0214
Comparison of slopes : F = 0.0186/0.0021 = 8.8571 (d.f. = 1, 40) significant								
Comparison of elevation : F = 0.0214/0.0016 = 13.3750 (d.f. = 1, 41) significant								

Table 2. Comparison of the regression lines of carapace length-weight relationship of **M.monoceros, P.monodon** and **P.indicus**

	d.f. n-1	x^2	xy	y^2	b	Deviation from regressions d.f.	S.S.	M.S.
M.monoceros								
Within males	52	0.1166	0.3053	0.9269	2.6192	51	0.1275	0.0025
Within females	62	0.3171	0.7496	1.9630	2.3659	61	0.1910	0.0031
						112	0.3185	0.0056
Pooled (within) common	114	0.4337	1.0549	2.8899	2.4323	113	0.3240	0.0028
						1	0.0055	0.0055
Slope between	1	0.2954	0.7269	1.7889				
Total	115	0.7291	1.7818	4.6788		114	0.3243	
Adjusted means						1	0.0003	0.0003
Comparison of slopes : F = 0.0055/0.0056 = 0.9821 (d.f. = 1, 112) not significant								
Comparison of elevation : F = 0.0003/0.0028 = 0.1071 (d.f. = 1, 113) not significant								
P. indicus (marine water)								
Within males	21	0.0223	0.0565	0.1582	2.5336	20	0.0150	0.0007
Within females	24	0.0845	0.2016	0.5285	2.3857	23	0.0475	0.0020
						43	0.0625	0.0014
Pooled (within) common	45	0.1068	0.2581	0.6867	2.4166	44	0.0629	0.0014
						1	0.0004	0.0004
Slope between	1	0.0233	0.0528	0.1203				
Total	46	0.1301	0.3109	0.8070		45	0.0640	
Adjusted means						1	0.0011	0.0011
Comparison of slopes : F = 0.0004/0.0014 = 0.2857 (d.f. = 1, 43) not significant								
Comparison of elevation : F = 0.0011/0.0014 = 0.7857 (d.f. = 1, 44) not significant								

contd....

Table 2 (contd.)

	d.f. n-1	x^2	xy	y^2	b	Deviation from regressions d.f.	S.S.	M.S.
P.monodon								
Within males	22	0.1019	0.2513	0.8056	2.4661	21	0.1858	0.00884
Within females	12	0.0635	0.1669	0.5190	2.6283	11	0.0803	0.0073
						32	0.2661	0.0083
Pooled (within) common	34	0.1654	0.4182	1.3246	2.5284	33	0.2672	0.00809
						1	0.0011	0.0011
Slope between	1	0.014	0.0537	0.2065				
Total	35	0.1794	0.4719	1.5311		34	0.2897	
Adjusted means						1	0.0225	0.0225
Comparison of slopes : F = 0.0011/0.0083 = 0.1323 (d.f. = 1, 32) not significant								
Comparison of elevation : F = 0.0225/0.00809 = 2.7812 (d.f. = 1, 33) not significant								
P.indicus (brackishwater)								
Within males	15	0.0425	0.0982	0.2634	2.3105	14	0.0365	0.0026
Within females	27	0.1613	0.4196	1.1112	2.6013	26	0.0196	0.0007
						40	0.0561	0.0014
Pooled (within) common	42	0.2038	0.5178	1.3746	2.5407	41	0.0590	0.0014
						1	0.0029	0.0029
Slope between	1	0.0009	0.0014	0.0025				
Total	43	0.2047	0.5192	1.3771		42	0.0602	
Adjusted means						1	0.0012	0.0012
Comparison of slopes : F = 0.0029/0.0014 = 2.0714 (d.f. = 1, 40) not significant								
Comparison of elevation : F = 0.0012/0.0014 = 0.8571 (d.f. = 1, 41) not significant								

Table 3. Comparison of the regression lines of carapace length-total length relationship of **M.monoceros, P.monodon** and **P.indicus**

	d.f. n-1	x^2	xy	y^2	b	Deviation from regressions d.f.	S.S.	M.S.
M.monoceros								
Within males	52	569.8	1936.3	7204.7	3.398	51	624.7	12.2
Within females	62	2547.7	6854.3	20730.4	2.690	61	2289.6	37.5
						112	2914.3	26.02
Pooled (within) common	114	3117.5	8790.6	27935.1	2.8197	113	3147.7	27.85
						1	233.4	233.4
Slope between	1	1965.2	5247.2	14010.7				
Total	115	5082.7	14037.8	41945.8		114	3175.1	
Adjusted means						1	27.4	27.4

Comparison of slopes : F = 233.4/26.02 = 8.9 (d.f. = 1, 112) significant

Comparison of elevation: F = 27.4/27.85 = 0.98 (d.f. = 1, 113) not significant

P.indicus (marine water)								
Within males	21	83.8	293.2	1699.0	3.4988	20	673.1	33.65
Within females	24	522.0	1660.4	5455.0	3.1808	23	173.52	7.54
						43	846.62	19.68
Pooled (within) common	45	605.8	1953.6	7154.0		44	853.97	19.40
						1	7.35	7.35
Slope between	1	177.1	393.6	874.4				
Total	46	782.9	2347.2	8028.4		45	991.29	
Adjusted means						1	137.32	137.32

Comparison of slopes : F = 7.35/19.68 = 0.3734 (d.f. = 1, 43) not significant

Comparison of elevation: F = 137.32/19.40 = 7.0783 (d.f. = 1, 44) significant

Contd....

Table 3 (contd.)

	d.f. n-1	x^2	xy	y^2	b	Deviation from regressions d.f.	S.S.	M.S.
P.monodon								
Within males	22	503.47	1794.52	7925.47	3.5643	21	1529.25	72.821
Within females	12	319.23	1330.76	6233.23	4.1686	11	685.74	62.34
						32	2214.99	69.21
Pooled (within) common	34	822.7	3125.28	14158.7	3.7988	33	2286.35	69.28
						1	71.36	71.36
Slope between	1	71.3	293.72	1210.05				
Total	35	894.0	3419.0	15368.75		34	2293.17	
Adjusted means						1	6.82	6.82
Comparison of slopes : F = 71.36/69.21 = 1.0310 (d.f. = 1, 32) not significant								
Comparison of elevation: F = 6.82/69.28 = 0.0976 (d.f. = 1, 33) not significant								
P.indicus (brackishwater)								
Within males	15	152.0	451.5	1561.44	2.9703	14	220.30	15.736
Within females	27	554.11	2019.75	7701.25	3.6450	26	339.19	13.045
						40	559.49	13.987
Pooled (within) common	42	706.11	2471.25	9262.69	3.4998	41	613.78	14.970
						1	54.29	54.29
Slope between	1	1.04	-3.07	8.94				
Total	43	707.15	2468.18	9271.63		42	656.89	
Adjusted means						1	43.11	43.11
Comparison of slopes : F = 54.29/13.987 = 3.8814 (d.f. = 1, 40) not significant								
Comparison of elevation: F = 43.11/14.97 = 2.8797 (d.f. = 1, 41) not significant								

Table 4. Comparison of the regression lines of morphometric relationships between **P.indicus** (marine water) and **P.indicus** (brackishwater)

	d.f. n-1	x^2	xy	y^2	b	Deviation from regressions d.f.	S.S.	M.S.
Carapace length-total length relationship								
Marine water	46	782.9	2347.2	8028.4	2.9980	45	991.29	22.028
Brackishwater	43	707.15	2468.18	9271.63	3.4902	42	656.89	15.640
						87	1648.18	18.944
Pooled (within) common	89	1490.05	4815.38	17300.03	3.2316	88	1738.21	19.752
						1	90.03	90.03
Slope between	1	1713.55	6576.03	25237.64				
Total	90	3203.60	11391.41	42537.67		89	2031.91	
Adjusted means						1	293.7	293.7
Carapace length-weight relationship								
Marine water	46	0.1301	0.3109	0.8070	2.3897	45	0.0640	0.0014
Brackishwater	43	0.2047	0.5192	1.3771	2.5363	42	0.0602	0.0014
						87	0.1242	0.0014
Pooled (within) common	89	0.3348	0.8301	2.1841	2.4793	88	0.1259	0.0014
						1	0.0017	0.0017
Slope between	1	0.3395	1.021	3.0708				
Total	90	0.6743	1.8511	5.2549		89	0.1732	
Adjusted means						1	0.0473	0.0473

Comparison of slopes : F = 90.03/18.9445 = 4.7523 (d.f. = 1, 87) significant

Comparison of elevation: F = 293.7/19.752 = 14.8693 (d.f. = 1, 88) significant

Comparison of slopes : F = 0.0017/0.0014 = 1.2142 (d.f. = 1, 87) not significant

Comparison of elevation: F = 0.0473/0.0014 = 33.7857 (d.f. = 1, 88) significant

Contd....

Table 4 (contd.)

	d.f. n-1	x^2	xy	y^2	b	Deviation from regressions d.f.	S.S.	M.S.
Total length-weight relationship (male)								
Marine water	21	0.0123	0.0451	0.1461	3.6666	20	-0.0192	-0.0009
Brackishwater	15	0.0199	0.0563	0.2381	2.8291	14	0.0788	0.0056
						34	0.0596	0.0017
Pooled (within) common	36	0.0322	0.1014	0.3842	3.1490	35	0.0648	0.0018
						1	0.0052	0.0052
Slope between	1	0.0792	0.2796	0.9818				
Total	37	0.1114	0.3810	1.3660		36	0.0629	
Adjusted means						1	0.0019	0.0019
Comparison of slopes : F = 0.0052/0.0017 = 3.0588 (d.f. = 1, 34) not significant								
Comparison of elevation: F = 0.0019/0.0018 = 1.0555 (d.f. = 1, 35) not significant								
Total length-weight relationship (female)								
Marine water	24	0.0423	0.1432	0.5113	3.3853	23	0.0265	0.0011
Brackishwater	27	0.1029	0.3372	1.1110	3.2769	26	0.0060	0.00023
						49	0.0325	0.0006
Pooled (within) common	51	0.1452	0.4804	1.6223	3.3085	50	0.0328	0.0006
						1	0.0003	0.0003
Slope between	1	0.1737	0.6325	2.3027				
Total	52	0.3189	1.1129	3.9250		51	0.0411	
Adjusted means						1	0.0008	0.0008
Comparison of slopes : F = 0.0003/0.0006 = 0.5 (d.f. = 1, 49) not significant								
Comparison of elevation: F = 0.0008/0.0006 = 1.3333 (d.f. = 1, 50) not significant								

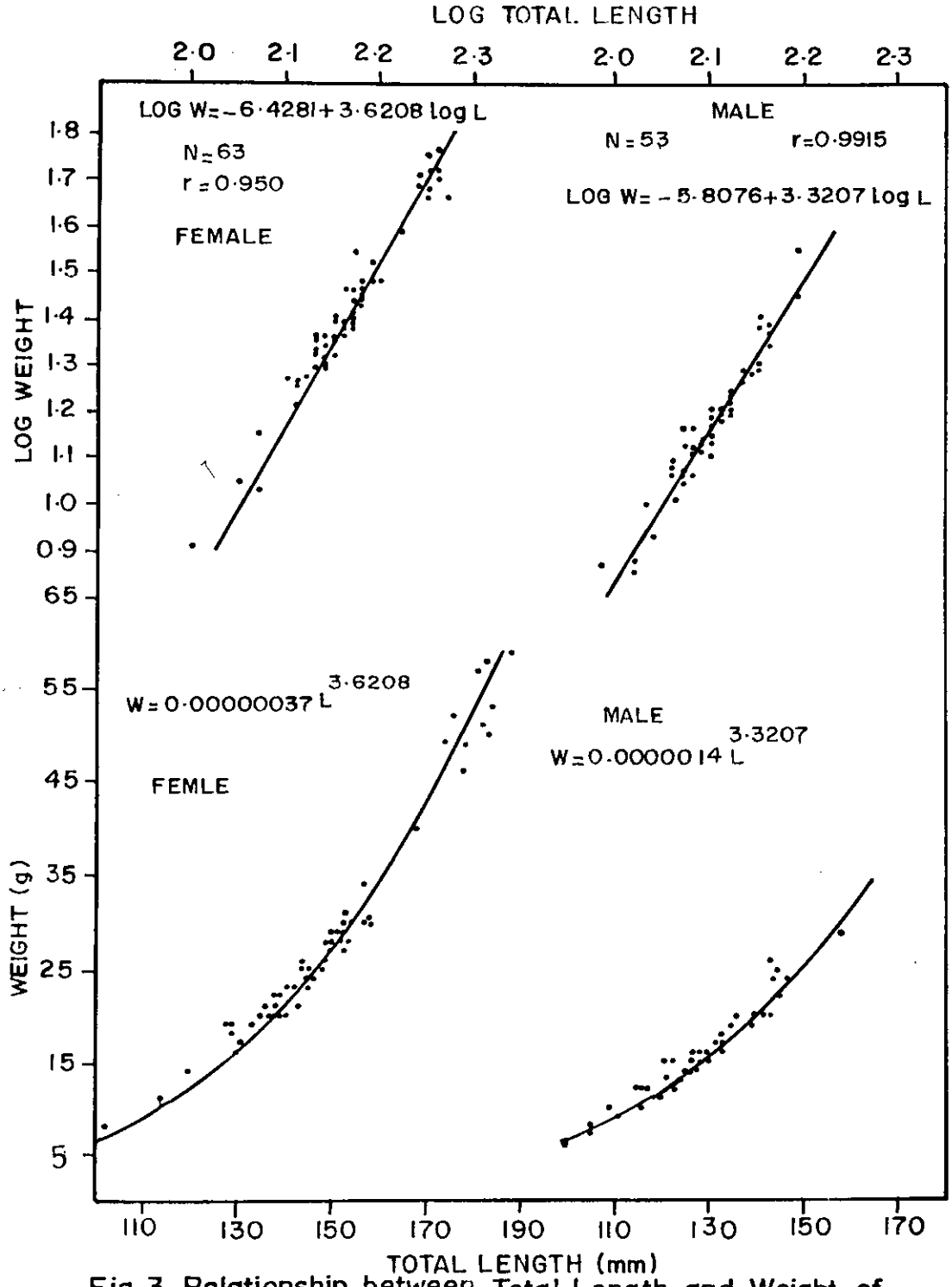

Fig.3. Relationship between Total Length and Weight of M.monoceros

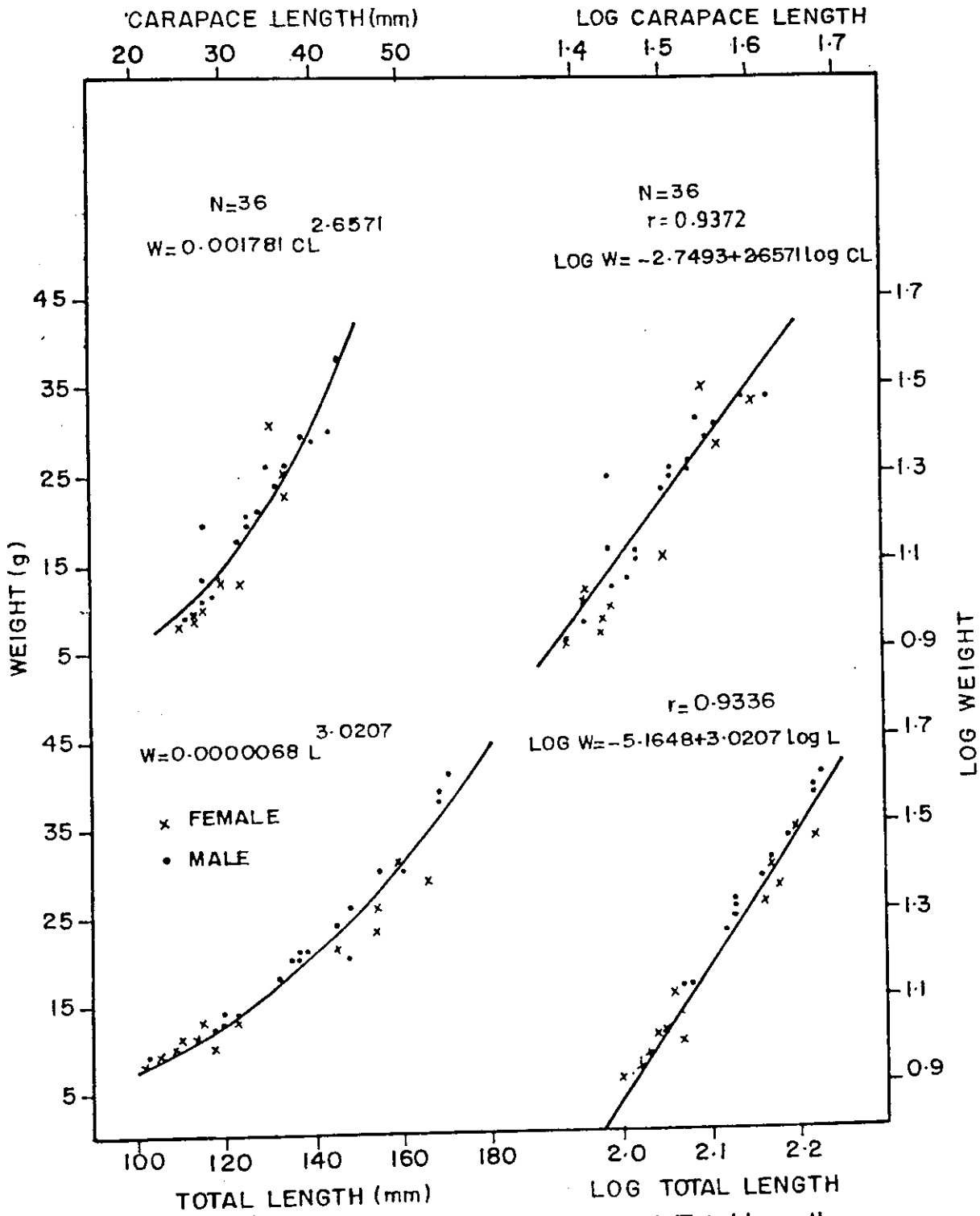

Fig. 4. Relationships of Carapace Length and Total Length with weight of P. monodon

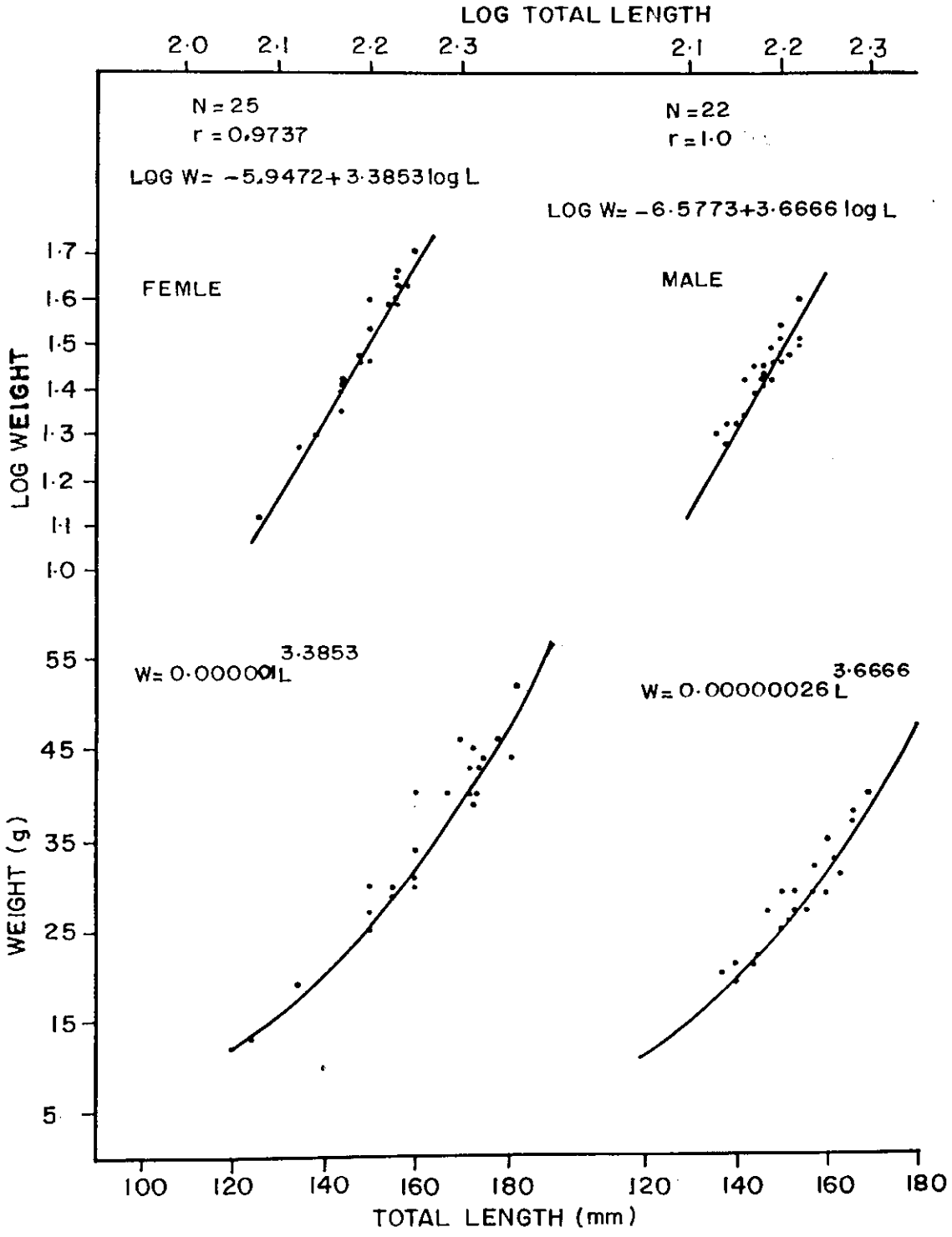

Fig.5. Relationship between Total Length and Weight of P. indicus (Marine)

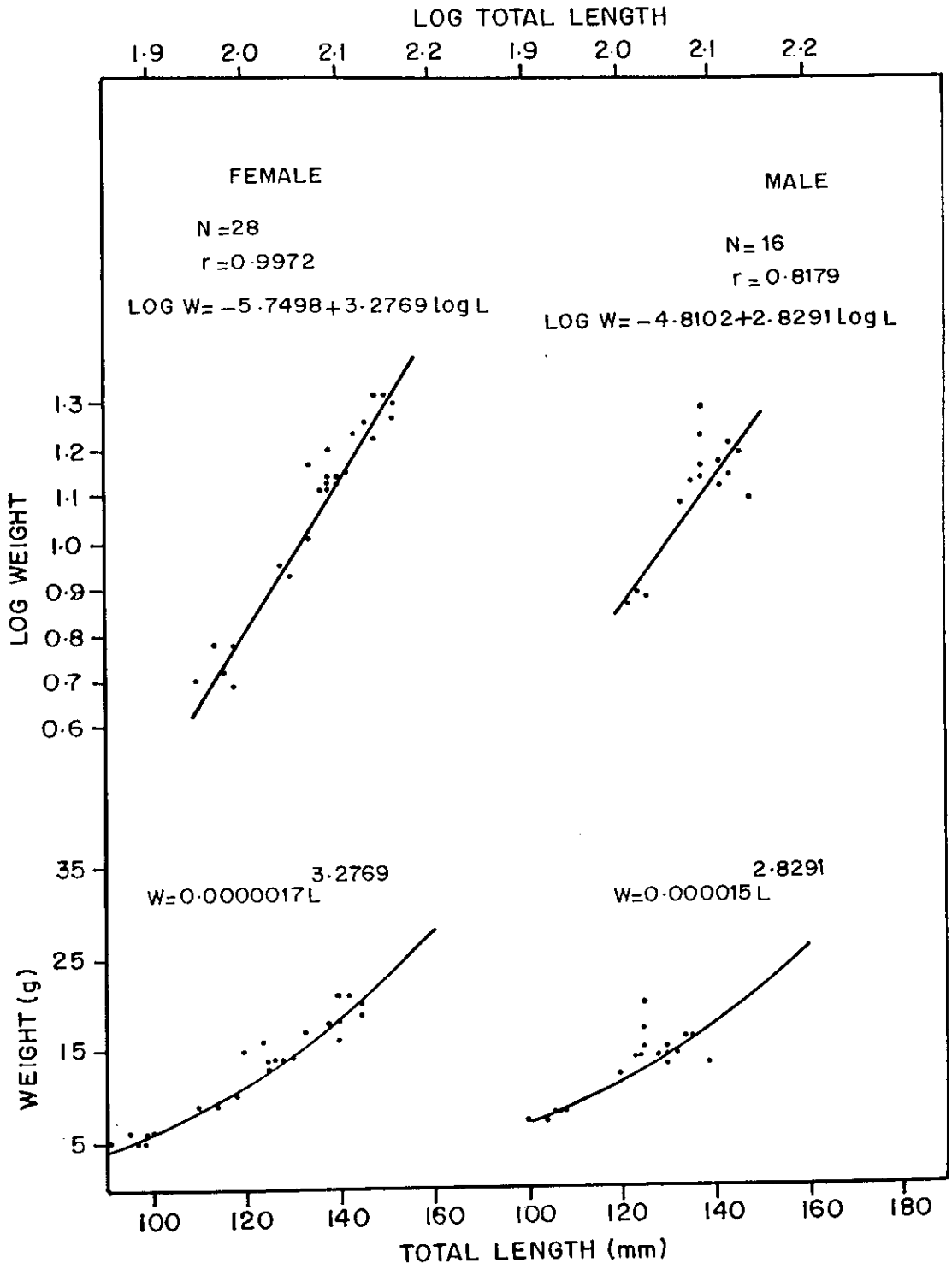

Fig.6. Relationship between Total Length and Weight of P. indicus (Brackishwater)

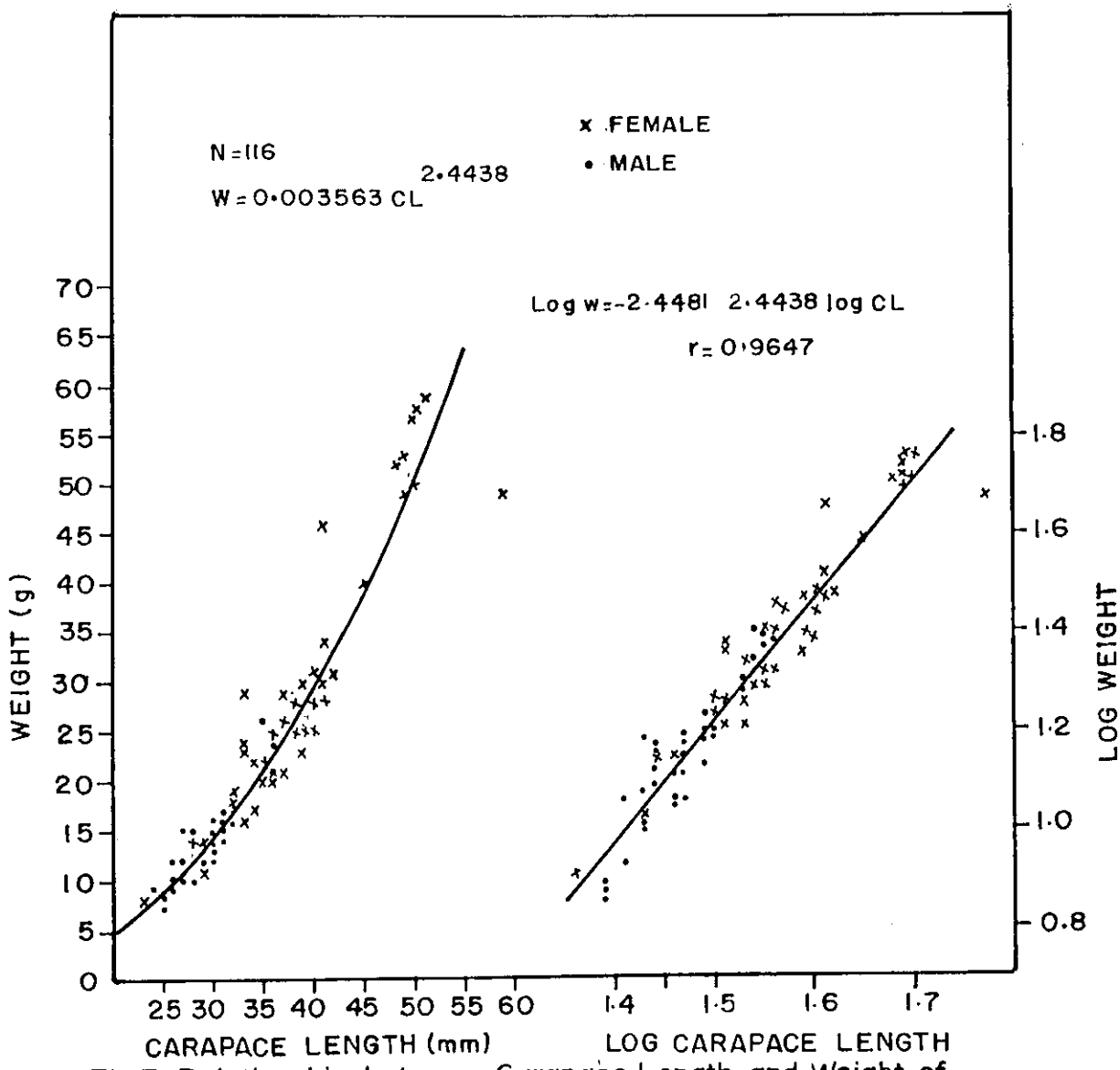

Fig.7. Relationship between Carapace Length and Weight of M.monoceros

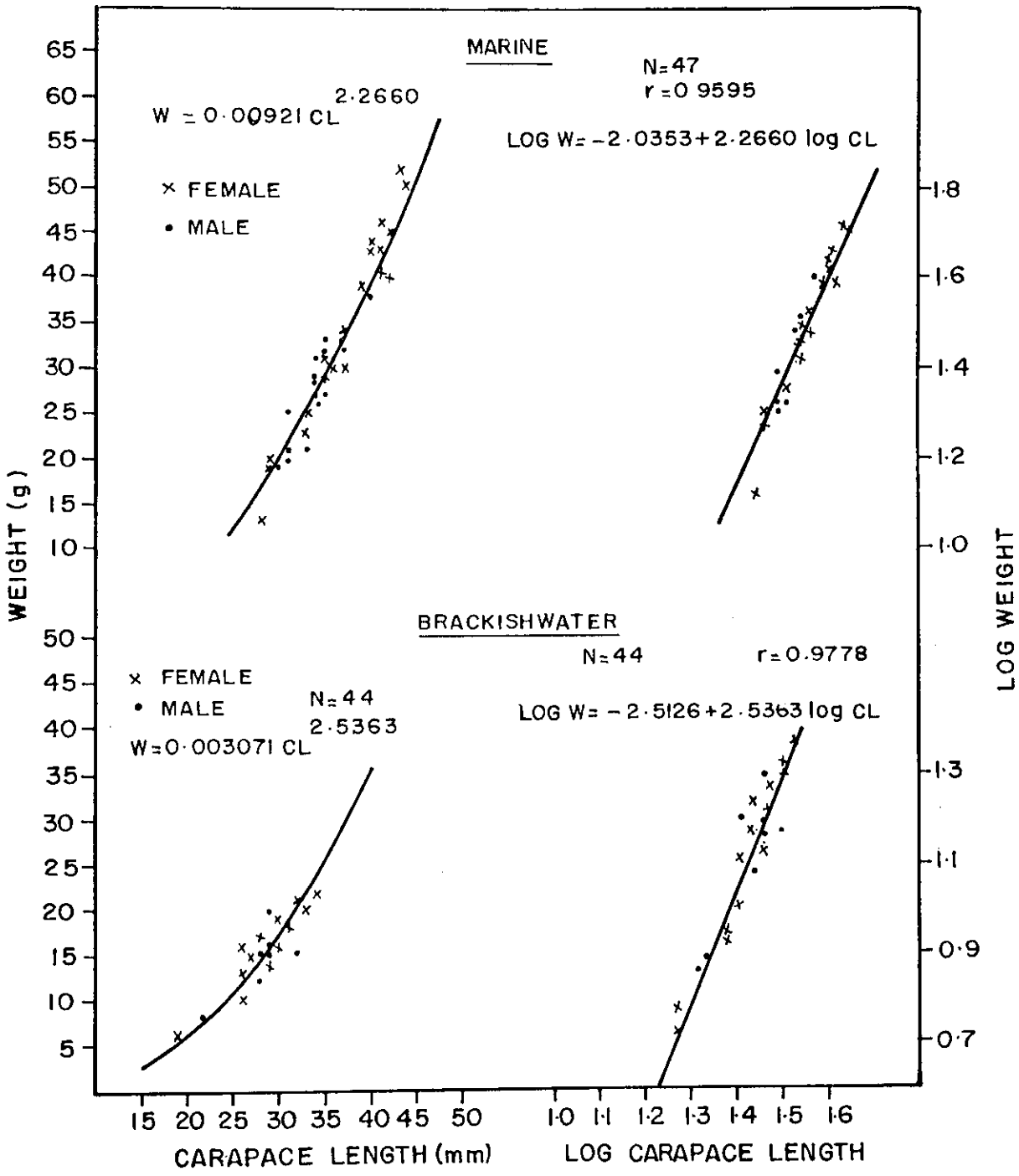

Fig.8. Relationship between Carapace Length and Weight of P. indicus

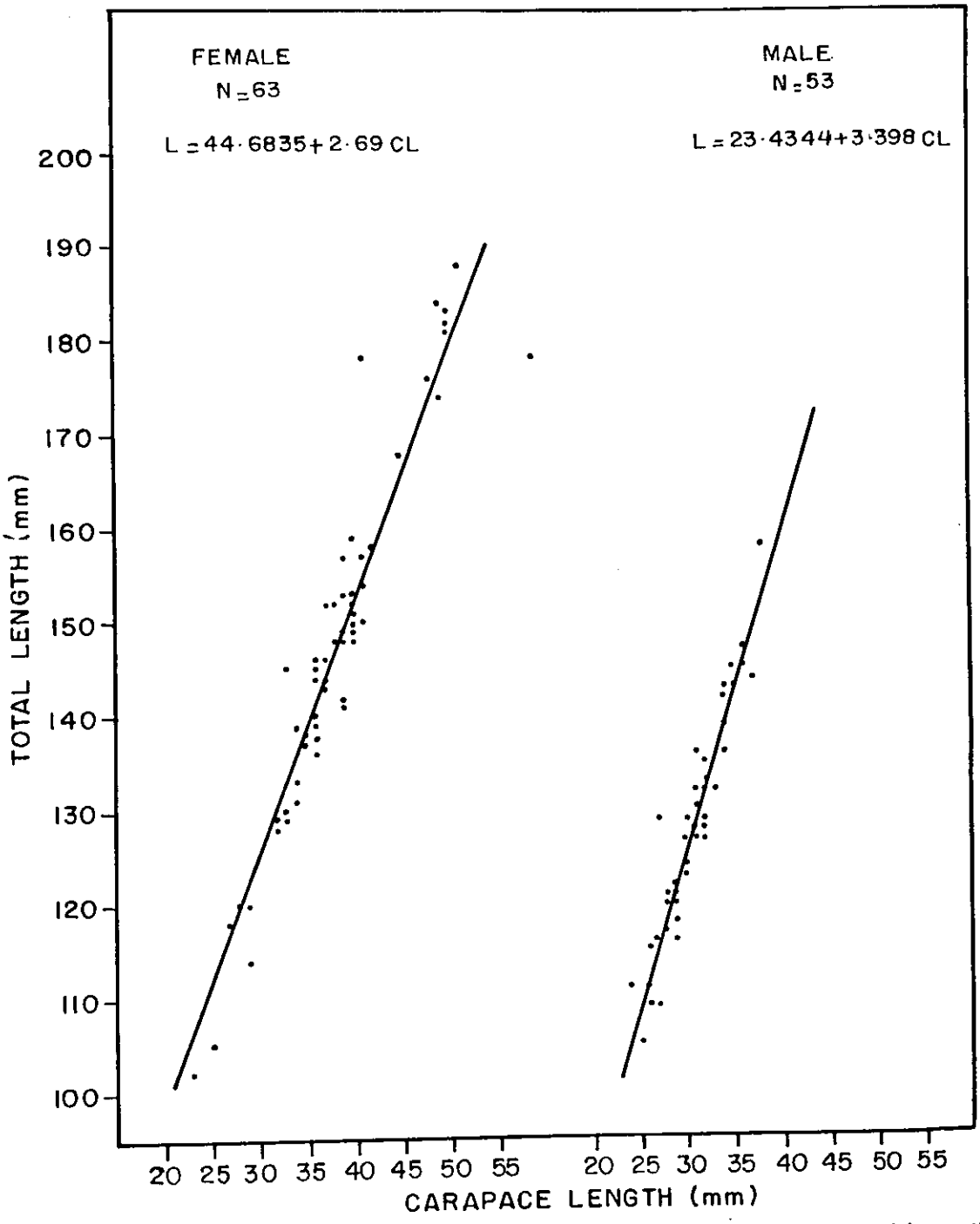

Fig.9. Relationship between Carapace Length and Total Length of M. monoceros

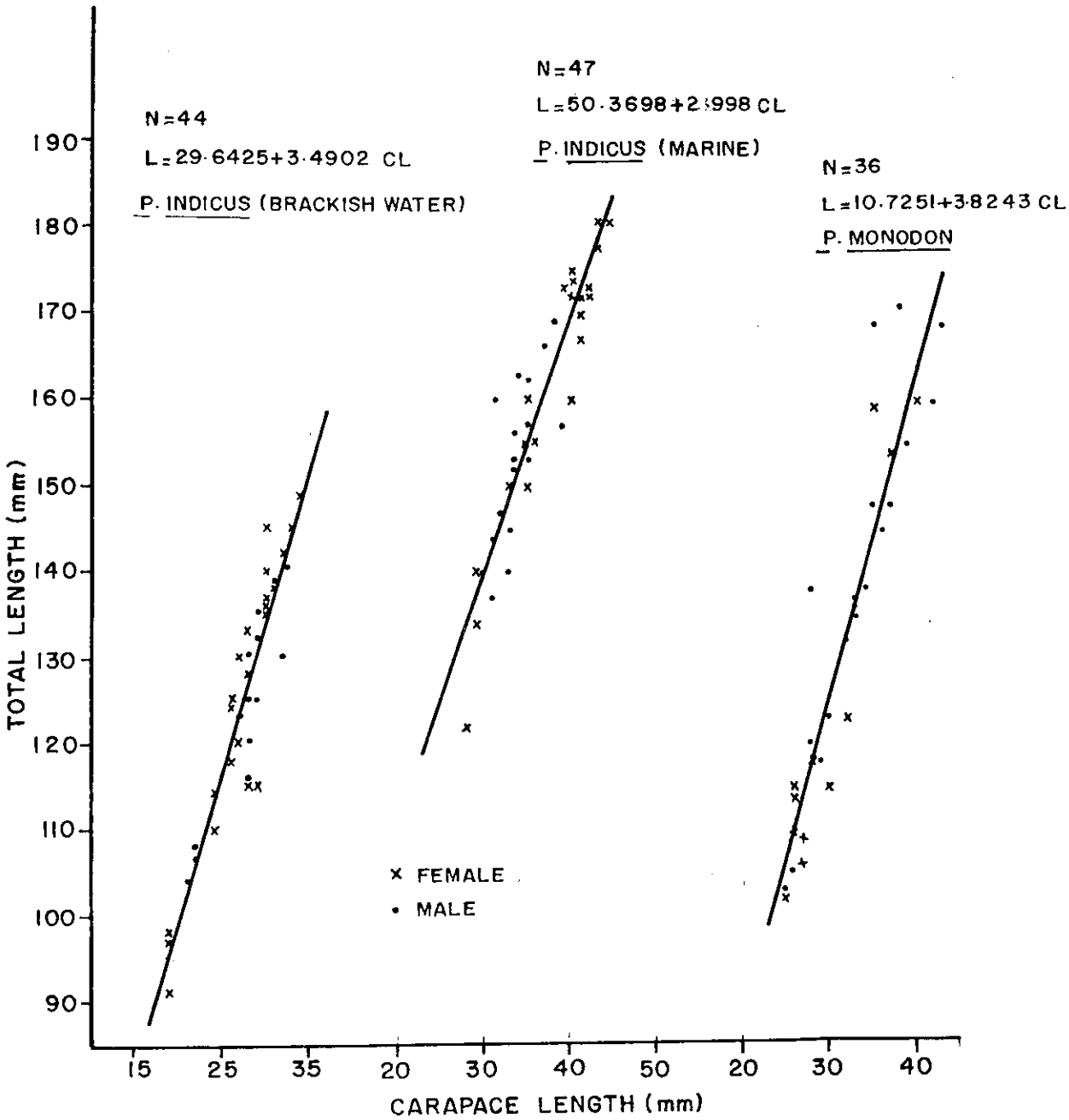

Fig.10· Relationship between Carapace Length and Total Length of P. indicus and P. monodon

CHAPTER 3

BIOCHEMICAL COMPOSITION OF HAEMOLYMPH IN RELATION TO SEX, SIZE, WEIGHT AND CONDITION FACTOR

INTRODUCTION

In prawns haemolymph is a medium of transport for carrying the different metabolites produced by the synthesis organs to the active sites of the different organ systems. It is a storage depot for different organic and inorganic constituents and as an oxygen carrier plays an important role in the respiratory activity and consequently prawn physiology. Haemolymph composition is affected by abiotic factors like salinity, temperature and dissolved oxygen as well as biotic factors such as type of food that the prawn feeds on, moult cycle, maturation process, sex, size, weight and condition factor. It is a well known fact that haemolymph composition is determined primarily by moult cycle and maturation process. Intensive study on these aspects of the different penaeid prawns was made in the different regions. Since the information on variation in haemolymph composition in relation to sex, size, weight and condition factor of penaeid prawns of India is scanty, the present study is an attempt to elucidate how far these factors affect the haemolymph composition.

Panikkar and Viswanathan (1948) studied the active regulation of chloride in **Metapenaeus monoceros.** Dall (1964) gave an account of blood constituents of **Metapenaeus mastersii.** Carbohydrate and calcium metabolism of **Metapenaeus** sp. was studied by Dall (1965a and 1965b). Balazs **et al.** (1974), made a comparative study of serum constituents of **Penaeus marginatus** and

Macrobrachium rosenbergii. Preliminary study on the osmoregulation of **Penaeus stylirostris** was done by Rodriguez (1976). Vedavyasa Rao **et al.** (1981), studied the fluctuation of calcium level in haemolymph of **P. indicus** from a brackishwater pond. Ionic regulation against salinity range was reported by Dall and Smith (1981) in commercially important penaeid prawns from Australia. Osmoregulatory ability in the juveniles in relation to habitat preference of Australian penaeid prawns was also studied by Dall (1981). Variation in biochemical composition of haemolymph due to toxicants was reported by Reddy **et al.** (1986), in **M. monoceros.** Osmoregulatory ability in relation to varying salinities was studied by Diwan **et al.** (1989a and 1989b) in **P. monodon** and **P. indicus.** Osmoregulatory capacity of **Macrobrachium petersi** at different stages of its life cycle was reported by Read (1984). Effect of salinity on haemolymph composition was studied by Ferraris **et al.** (1986), in **P. monodon.** Kulkarni **et al.** (1980), studied blood glucose level in relation to salinity in **Parapenaeopsis hardwickii.** Smith (1982) explained the increase in glucose level of haemolymph as due to stress in the pink shrimp **Penaeus duorarum.**

Investigations on haemolymph composition in relation to abiotic and biotic factors were carried out in the other crustaceans by Gilbert (1959), Stewart **et al.** (1966), Kerr (1969), Bedford (1972), Lin and Cohen (1973), Lock Wood and Inman (1973), Dall

(1974a and 1974b), Kannupandi and Paulpandian (1975), Spaargarden (1975), Dall (1975), Sevilla (1975), Raja **et al**, (1976), Bedford and Leader (1977), Nammalwar (1978), Pequeux **et al.** (1979), Ohidalia **et al.** (1981), Walters and Uglow (1981), Fair and Sick (1982), Kobayashi (1982), Adegboye (1983), Hagerman (1983), Arumugam and Ravindranath (1983) and Digby (1984).

RESULTS

Haemolymph composition in relation to sex

In the present study on sex related changes in haemolymph composition of **M. monoceros** and **P. indicus** from the marine environment; and **P. monodon** and **P. indicus** from the brackishwater ponds, all the samples were pooled together and separated on the basis of sex only.

Mean and range of each measured constituent along with standard deviation and number of specimens analysed are given in table 5. Student's 't' test was used to find out whether or not the differences between the two sexes were statistically significant. Five per cent probability level was considered to be significant statistically.

M. monoceros

Samples of haemolymph were collected from male (carapace length range 25-37 mm) and female (23-50 mm) prawns. No significant differences were found in protein, calcium, potassium and copper contents between the two sexes. Carbohydrate content was significantly different between the females which had more (37.42±25.09 mg/100ml) than the males (22.1±10.34 mg/100ml).

P. monodon

Samples of haemolymph were collected from prawns whose carapace length ranged from 24 to 47 mm for males and from 25 to 57 mm for females.

No significant difference was found between sexes with regard to protein, carbohydrate, calcium, potassium and copper contents.

P. indicus

Haemolymph was collected from samples of prawns from the marine water (carapace length range from 33 to 38 mm for male and 33 to 43 mm for female) and brackishwater ponds (20 to 30 mm for male and 19 to 34 mm for female).

In the marine environment no significant difference was found between the two sexes with regard to protein, carbohydrate, potassium and copper contents but calcium level varied between the two sexes as females had high calcium (8.92±3.83 mg/100ml) than the males (5.02±2.50 mg/100ml).

Samples from the brackishwater showed that protein, carbohydrate, calcium, potassium and copper contents did not vary significantly between the two sexes.

Student's 't' test showed that the difference in haemolymph constituents between the two sexes was not significant in the case of **M. monoceros**, **P. indicus** (marine), **P. monodon** and **P. indicus** (brackishwater). The two sexes were pooled and treated as homogeneous comparative study between species.

Details of a comparative study of haemolymph composition at intra and inter-specific levels is presented in table 6. No

significant difference was found in protein, calcium, potassium and copper levels between **M. monoceros** and **P. indicus** from marine waters. Carbohydrate content was more (69.62±8.97 mg/100ml) in **P. indicus** than in **M. monoceros** (30.21±20.88 mg/100ml).

A comparative study of haemolymph composition between **P. monodon** and **P. indicus** revealed that the latter had more of protein (129.13±34.65 mg/ml), carbohydrate (36.51±8.91 mg/100ml) and copper (14.70±4.1 µg/ml) than the levels of protein (112.91 ± 40.02 mg/ml), carbohydrate (30.93±11.99 mg/100ml) and copper (10.50±2.90 µg/ml) in the haemolymph of the former. Copper and carbohydrate levels differed much more significantly than protein level between these two species whereas calcium and potassium levels did not show significant differences.

All the constituents except protein differed significantly between **P. indicus** (marine) and **P. indicus** (brackishwater). Protein did not show significant difference at 5% probability level ($P < 0.1$). Carbohydrate (69.62±8.97 mg/100ml), potassium (8.56 ± 4.10 mg/100ml) and copper (17.50±3.90 µg/ml) levels were high in **P. indicus** (marine) than carbohydrate (36.51±8.91 mg/100ml), potassium (2.98±1.07 mg/100ml) and copper (14.70±4.10 µg/ml) levels of **P. indicus** (brackishwater). Calcium content showed reverse trend having high values (11.30±5.75 mg/100ml) in brackishwater specimens than in the specimens (6.87±3.47 mg/100ml) of marine waters.

From the study of haemolymph composition in relation to sex and variation in haemolymph composition at intra and inter-specific levels it was found that:

1. there was considerable variation in haemolymph constituents of individual prawns.
2. there was no significant difference between sexes of **P. monodon** and **P. indicus** in brackishwater ponds.
3. the carbohydrate level differed significantly between the two sexes in the case of **M. monoceros**; and there was significant difference in calcium level between the two sexes of **P. indicus** from marine water. In both instances females had higher values than males and this may be attributed to higher reproductive activity in the females in which organic reserves are mobilized from synthesis organ like hepato-pancreas to the gonad.
4. there was no significant difference in all the constituents except carbohydrate between **M. monoceros** and **P. indicus** from marine environment; but protein, carbohydrate and copper contents showed significant difference between **P. monodon** and **P. indicus** in brackishwater ponds. This may be attributed to the prevalence of homogeneous ecological conditions in the marine environment and greater variation in culture conditions.
5. there was variation in the levels of all constituents in

P. indicus from the two environments; it may be due to different phases in life cycle. Penaeid prawns migrate from brackishwater to sea for maturation and spawning. Physiology and ionic regulation of prawns vary due to onset of maturity and change in salinity of the environment respectively.

Haemolymph composition in relation to size

Since there were no large scale significant differences between the two sexes in haemolymph constituents (except carbohydrate in **M. monoceros** and calcium in **P. indicus**) the data were pooled together for the study of haemolymph composition in relation to size. Carbohydrate content differed significantly in **M. monoceros** between the two sexes and correlation coefficient values were also calculated accordingly. Carapace length in mm was used as the size variable. In the case of **P. indicus** (marine water), correlation between calcium and carapace length was not significant at probability level ($P < 0.05$) and hence data of the two sexes was pooled and treated.

Correlation coefficients between the different haemolymph constituents and size for all the species are given in table 7.

Protein content as a function of carapace length showed significant ($P < 0.01$) negative correlation in the case of **M. monoceros** and **P. indicus** (from marine and brackishwater) but in

the case of **P. monodon** there was no significant relationship although it was negative.

No statistical significance was found in the negative correlation between carbohydrate and carapace length in the case of **P. indicus** from marine water and brackishwater; significant ($P < 0.05$) and negative correlation was found in the case of **P. monodon**; but in the case of **M. monoceros** in which the relationship was significant in females only it was positive.

Calcium showed significant ($P < 0.01$) negative relationship with size in the case of **M. monoceros**; significant ($P < 0.001$) positive relationship in the case of **P. monodon** and **P. indicus** from brackishwater ponds; and positive relationship of no statistical significance in the case of **P. indicus** from marine water.

Potassium showed significant ($P < 0.05$) negative relationship in the case of **P. monodon** and **P. indicus** from brackishwater ponds whereas in the case of **M. monoceros** and **P. indicus** in the marine environment there was a positive relationship of no statistical significance.

No significant correlation was found between copper and carapace length in all the species except in the case of **P. indicus** from brackishwater ponds, in which the relationship was positive and significant ($P < 0.05$).

The facts that emerged out of the study are as follows:

1. Protein content decreased with size irrespective of environment
2. Carbohydrate content also decreased with size in all species except in the case of **M. monoceros**
3. Calcium content increased with size in brackishwater ponds

Haemolymph composition in relation to the weight

The data of the two sexes were pooled for the study of relationship between haemolymph constituents and weight of the prawns (except carbohydrate in **M. monoceros** and calcium in **P. indicus**) as in the size related study. Correlation coefficients and their statistical significance in the case of all parameters of all the species are given in table 8.

Negative correlation showing decrease of protein with weight was observed in all the species.

Carbohydrate showed decrease with weight in the case of **P. monodon** and **P. indicus** in brackishwater; while in the case of **P. indicus** and **M. monoceros** from marine water it showed positive correlation. The relationship was not significant in the case of **M. monoceros** (male); while it was significant in the females of **M. monoceros**

Calcium level was positively correlated with weight in the case of **P. monodon** (not significant) and **P. indicus** (significant)

from brackishwater ponds whereas negatively correlated with weight in **M. monoceros** and **P. indicus** (significant only in female) in the marine environment.

Positive relationship was observed between potassium and weight in the case of **M. monoceros** (significant) and **P. indicus** (not significant) from marine water but it was negative in the case of **P. monodon** (significant) and **P. indicus** (not significant) from brackishwater ponds.

Copper level was negatively correlated ($P < 0.05$) with weight in the case of **P. monodon** and positively correlated($P<001$) in the case of **P. indicus** from brackishwater. Positive trend was observed in the case of **M. monoceros** and **P. indicus** in marine water but not significant statistically.

The facts drawn out of the present study are as follows:

1. Protein level was negatively correlated with weight in all the species.
2. Carbohydrate content was negatively correlated in the brackishwater environment and positively correlated in the marine environment.
3. Calcium level was negatively correlated with weight in marine water and positively correlated in brackishwater.
4. Copper content was negatively correlated with weight in the case of **P. monodon** and positively correlated in the case of

P. indicus in brackishwater. In the case of **M. monoceros** and **P. indicus** from marine water the relationship was positive but not significant.

Crop-wise haemolymph characteristics in relation to carapace length

Since the relationship of haemolymph characteristics with carapace length and weight varied from species to species and from one environment to another environment, crop-wise differences in correlations between haemolymph characteristics on the one hand and carapace length and weight on the other were studied in the case of **P. monodon** and **P. indicus** (Tables 9 & 10). Data of males and females of each crop were pooled for statistical treatment.

P. monodon

Protein was positively correlated with carapace length in three crops (Crops I, III and IV) and showed negative correlation in the case of crop II. The relationship was significant in crop I, while in the case of the other three crops it was not significant.

Carbohydrate showed negative correlation in the case of crops I and II; positive correlation in the case of crop III; no correlation in crop IV because of all the individual samples having same content of carbohydrate. Th relationship was significant in crop I only.

Calcium was positively correlated in the case of crops I& IV and negatively correlated in the case of crops II and III but was significant in crop I only.

Potassium was positively correlated in all the four crops but was significant in crop III only.

Copper showed significant positive correlation in crops I, III and IV but though negatively correlated in crop II it was not significant.

P. indicus

Protein showed positive correlation in all the three crops but it was found to be not significant.

Carbohydrate showed negative correlation in crops I and II, positive correlation in crop III but found to be significant in crops II and III only.

No significant relationship was found between calcium and carapace length in all the three crops but positive correlation was observed in crops I and II, negative in crop III.

Potassium did not show significant relationship but it was found to be negative in crop II, and positive in crops I and III.

Copper was negatively correlated in crop I while in the other two crops (crop II and III) it showed positive relationship which was significant in crop III only.

Crop-wise differences in the relationships between haemolymph constituents and weight

P. monodon

Protein was positively correlated with weight in all the three crops but it was significant in crops III and IV only.

Carbohydrate showed positive relationship (not significant) in crops II and III only.

Calcium showed positive relationship in all the three crops but found to be significant in crop I only.

Potassium showed positive relationship in all the three crops (not significant).

Copper showed significant positive relationship in all the three crops.

P. indicus

Protein showed negative correlation in crop II and positive correlation in the other two crops (crops I and III) (not significant in any crop).

Carbohydrate showed negative correlation in crops I and II and positive correlation in crop III (not significant in any crop).

Calcium showed negative correlation in all the three crops but significant in crop II only.

Potassium showed negative correlation in crop I but positive correlation in crops II and III (significant in crop II only).

Copper was negatively correlated in crop I, positively correlated in crops II and III (significant in crop III only).

From the study of crop-wise differences in haemolymph composition in relation to carapace length and weight, it may be concluded that the relationships with carapace length and weight were dependent upon the prevailing culture conditions. Quality and quantity of feed given during the culture period were found to be the contributory factors for the well being of prawns (vide chapter 7).

Haemolymph composition in relation to condition factor

In fish, generally, physiological state of the animal is assessed by the measure of the condition factor drawn from length-weight relationship. Condition factor is the measure of deviation of the weight of an individual from the expected normal weight in the population for a given length. Good and poor condition factors indicate healthy and unhealthy condition of the individual fish. An attempt is made in the present study to find out the relationship between haemolymph constituents and condition factor of the prawn in the same fashion as it is done in the case of fishes.

In order to avoid the influence of the maturity on condition factor, only **P. indicus** and **P. monodon** from brackishwater ponds were selected for this study as they do not mature in brackishwater environment. Condition factor was calculated for each individual of **P. indicus** and **P. monodon** taking carapace length-weight relationship (vide chapter 2). Condition factor of each prawn was calculated by using the formula of Le Cren (1951):

$$Kn = 100W/CL^{b}$$

where Kn = condition factor, W = weight of the prawn, CL = carapace length of the prawn, b = exponent value derived for carapace length-weight relationship (b = 2.6304 for **P. monodon** and b = 2.5363 for **P. indicus**).

Since the difference in haemolymph constituent level between the two sexes was not significant, the males and females were pooled for statistical treatment. Initially relationships between carapace length and haemolymph characteristics were derived by following the least square method. The relationships are as follows:

P. monodon

Protein content (mg/ml) = 192.12-2.5002CL (r = -0.4480)

Carbohydrate content (mg/100ml) = 43.4559-0.4024CL (r = -0.3441)

Calcium content (mg/100ml) = 5.6169 + 0.0923CL (r = 0.1312)

Potassium content (mg/100ml) = 110.8497-0.1412CL (r = -0.4526)

Copper content (μg/ml) = -6.9038 + 0.2472CL (r = 0.2472)

P. indicus

Protein content (mg/ml) = 241.63-4.2347CL (r = -0.4906)

Carbohydrate content (mg/100ml) = 38.6414-0.1052CL (r =-0.0447)

Calcium content (mg/100ml) = -11.845 + 0.8741CL (r = 0.6329)

Potassium content (mg/100ml) = 5.6544-0.0977CL (r = -0.3762)

Copper content (μg/ml) = 0.6245 + 0.0316CL (r = 0.2925)

Each constituent level of haemolymph of individual prawn was corrected to a standard animal whose carapace length was 27.295 mm for **P. indicus** and 32.08 mm for **P. monodon** by using the following formula:

$$\text{Constituent content of standard animal} = \frac{S_1}{b \times CL} \; b \times \bar{CL}$$

Where S_1 = constituent level of individual prawn

b = regression coefficient value from regression

CL = carapace length of individual prawn

$\bar{CL}$ = carapace length of standard animal (average carapace length of total sample)

Corrected values of each constituent were plotted against condition factor for **P. indicus** and **P. monodon** . Correlation coefficient is shown in table 11.

Protein and carbohydrate were negatively correlated with condition factor but not significant statistically except in the case

of protein content in **P. monodon** where it was significant at $P < 0.02$ level.

Calcium content showed no relationship with condition factor.

Potassium level was found to be significantly correlated with condition factor in **P. monodon** ($P < 0.02$) whereas in **P. indicus** the relationship was not significant.

Copper showed no relationship with condition factor.

From this study it may be concluded that though protein and potassium in haemolymph of **P. monodon** showed weak relationships ($P < 0.02$) with condition factor, in general, there was no trend of the accumulation of haemolymph constituents or decrease in relation to condition factor.

DISCUSSION

In the present study of haemolymph composition, a wide range of protein concentration was found in **M. monoceros** (27.00-210.00 mg/ml), **P. monodon** (32.00-260.00 mg/ml), **P. indicus** from marine water (33.00-180.00 mg/ml) and **P. indicus** from brackishwater (60.00-180.00 mg/ml). Horn and Kerr (1963) also found considerable range of protein content (8.8-132 mg/ml) in the serum of **Callinectes sapidus** Rathburn. Kerr (1969) gave an account of wide range in protein level (12.0-117.0 mg/ml) of haemolymph in **Callinectes sapidus.** Balazs **et al.** (1974) reported serum protein range for **P. marginatus** (7.6-13.8 g/100ml) and **Macrobrachium rosenbergii** (10.4-14.4 g/100ml). According to Florkin (1960), protein content in decapoda varied from 0.7 to 8.8 g/100ml. Leone (1953) gave the range of protein concentration in the serum of decapod crustaceans, **Homarus americanus** (2.2-10.2 g/100ml), **Callinectes sapidus** (1.83-12.0 g/100ml), **Cancer magister** (1.16-13.75 g/100ml), **C. irroratus** (1.75-11.45 g/100ml) and **Libinia emarginata** (0.73-7.25 g/100ml).

As per Florkin (1960) carbohydrate level range in the haemolymph of freshly captured crustaceans was from 3 to 182 mg/100ml. Balazs **et al.** (1974), gave the range of serum glucose content as 10-68 mg/100ml and 44-110 mg/100ml for **P. marginatus** and **M. rosenbergii** respectively. In the present study the carbohydrate content in the haemolymph varied from 12.0-118.0 mg/100ml in **M. monoceros**, from 9.0-50.0 mg/100ml in **P. monodon**,

40.0-80.0 mg/100ml in **P. indicus** (marine) and 25.0-59.0 mg/100ml in **P. indicus** (brackishwater).

Calcium level in the prawns of the present study varied from 1.10-12.0 mg/100ml in **M. monoceros**, 2.00-27.0 mg/100ml in **P. monodon**, 3.00-14.0 mg/100ml in **P. indicus** (marine) and 3.90-23.0 mg/100ml in **P. indicus** (brackishwater). It is rather low compared to the values of 53.0-73.0 mg/100ml in **P. marginatus** and 66.0-112.0 mg/100ml in **M. rosenbergii** (fresh water) given by Balazs **et al.** (1974). Dall (1965b) gave calcium range (20.0-30.0 m-equiv/l) in the haemolymph of intermoult stage of **Metapenaeus** sp. Vedavyasa Rao **et al** (1981) reported calcium in the haemolymph of **P. indicus** from brackishwater ponds ranging from 0.30-0.80 mg/ml. Bursey and Lane (1971) reported a narrow range of calcium with low values of 13.0-16.30 M-equil/l) in the haemolymph of **Penaeus duorarum** during moult cycle. Adegboye (1983) reported mean calcium level as 41.76±1.41 mg/100ml in the haemolymph of fresh water crayfish **Procambarus acutus.**

Mean calcium level was high in **P. indicus** (11.30±5.75 mg/100ml) and **P. monodon** (10.42±5.29 mg/100ml) in brackishwater ponds compared to **P. indicus** (6.87±3.47 mg/100ml) and **M. monoceros** (6.0±2.90 mg/100ml) in marine water. Balazs **et al.** (1974) reported high mean level of calcium in **M. rosenbergii** (85 mg/100ml) from fresh water pond as well as **P. marginatus** (63 mg/100ml) from marine water. High calcium level in the

haemolymph of **P. indicus** and **P. monodon** from brackishwater ponds may be attributed to the application of lime (calcium hydroxide) in the pond to maintain pH and hygienic conditions in the pond. Dall and Smith (1981) and Vedavyasa Rao **et al.** (1981), reported that in penaeid prawns haemolymph calcium concentration increases with the concentration in the external medium associated with increasing salinity. Adegboye (1983) found positive relationship between haemolymph calcium and calcium content in the fresh water medium in the case of crayfish **Procambarus acutus.** The brackishwater ponds in the present study though less saline (19 ppt) than in the sea (33 ppt) it is rather high for brackishwater conditions due to lime application (250 kg/ha/crop). However, Ferraris **et al.** (1986), observed that calcium level in the haemolymph in **P. monodon** is well regulated lying between 6.4 and 10 mM when salinity of the medium was maintained in between 8.0 and 44.0 ppt.

In the present study potassium level was found to vary from 2.24 - 11.0 mg/100ml in **M. monoceros**; 0.8-7.68 mg/100ml in **P. monodon**; 2.80-12.80 mg/100ml in **P. indicus** from marine water; and 1.68-5.28 mg/100ml in **P. indicus** from brackishwater pond. The high values in the range observed in the present study are nearer to the 8.8-9.2 M-equiv/l in **P. duorarum** given by Bursey and Lane (1971). Bedford (1972) estimated potassium concentration in the haemolymph of grapsid crab, **Helice crassa** Dana as 10 mM/l.

Bedford and Leader (1977) reported potassium content as 12.2 mM/l in 100% sea water in the haemolymph of shore crab **Hemigrapsus edwardsi** and found that potassium content increases along with medium concentration from 25% of sea water to 100% sea water. Dall and Smith (1981) also reported that potassium level in the haemolymph of **Penaeus plebius, P. esculentus** and **P. merguiensis** increases with salinity. Bedford (1972) reported that in the grapsid crab, **Helice crassa** potassium concentration of haemolymph increased from 6.0-12.0 mM/l when animals were changed from freshwater to sea water. McFarland and Lee (1963) also found in euryhaline penaeids **Penaeus setiferus** and **P. aztecus** that potassium in serum was well regulated in brackishwater and sea water but potassium slightly decreased with the decrease in external salinity. The findings of the above authors are supporting the results of the present study, in which, higher mean potassium level in **M. monoceros** (5.89±2.03 mg/100ml) and **P. indicus** (8.56±4.10 mg/100ml) was found in the marine water than the level in **P. monodon** (3.17± 1.77 mg/100ml) and **P. indicus** (2.98±1.07 mg/100ml) from the brackishwater environment.

Kerr (1969) reported that copper level in haemolymph of **Callinectes sapidus** ranged in between 5.0 and 148.0 µg/ml and the same study revealed the existence of positive relation between copper level and protein content. Horn and Kerr (1963) gave the range of copper level in the haemolymph of the adult blue crab

Callinectes sapidus Rathbun as 8.0 to 176.0 µg/ml. Arumugam and Ravindranath (1983) reported mean total copper value in the haemolymph of **Scylla serrata** as 85.2±10.2 µg/ml. In the present study copper level in the haemolymph was found to range from 12.0 to 26.0 µg/ml in **M. monoceros**; 3.7 to 16.5 µg/ml in **P. monodon**; 10.00 to 26.0 µg/ml in **P. indicus** (marine water); and 7.5 to 27.5 µg/ml in **P. indicus** (brackishwater pond). These results are slightly lower than the results reported by the above said authors.

Mean copper level was higher in **M. monoceros** (16.4±3.2 µg/ml) and **P. indicus** (17.50±3.9 µg/ml) from the marine water than in **P. indicus** (14.7±4.1 µg/ml) and **P. monodon** (10.5±2.9 µg/ml) from the brackishwater ponds. It may be attributed to the high protein concentration in the mature marine prawns, **M. monoceros** and **P. indicus** than in the immature brackishwater prawns, **P. indicus** and **P. monodon.** Similar results were also reported in **Callinectes sapidus** by Horn and Kerr (1963) who found higher values in sponge females (93.15±26.48 µg/ml) than in non-sponge females (83.86±28.83 µg/ml).

No significant difference was found between the two sexes of **P. monodon** and **P. indicus** from brackishwater pond but carbohydrate content varied significantly ($P < 0.02$) between the two sexes of **M. monoceros.** Calcium level was significantly different

($P < 0.05$) between the two sexes of **P. indicus** from marine water. Females had higher values than males in both cases. This might be attributed to the demands of active maturation process in females. Similar results were reported by Horn and Kerr (1963) in the adult blue crab, in which, they found that mean values of protein (62.70 mg/ml) and copper (83.86 µg/ml) were higher in females than the protein (52.37 mg/ml) and copper (70.65 µg/ml) values in males. The study made by Balazs **et al.** (1974), in freshly captured specimens also revealed two facts:

1. mean serum glucose was more in the females of **P. marginatus** (38 mg/100ml) and **M. rosenbergii** (91 mg/100ml) than in the males of **P. marginatus** (13 mg/100ml) and **M. rosenbergii** (75 mg/100ml)
2. mean serum clacium level was considerably higher in the females of **P. marginatus** (65 mg/100ml) and **M. rosenbergii** (88 mg/100ml) than in the males of **P. marginatus** (61 mg/100ml) and **M. rosenbergii** (81 mg/100ml).

There are significant interspecific and intraspecific differences in the mean values of carbohydrate and protein levels. In brackishwater pond, **P. indicus** was having high levels of protein (129.13±34.65 mg/ml) and carbohydrate (36.51±8.91 mg/100ml) than the levels of protein (112.91±40.02 mg/ml) and carbohydrate (30.93±11.99 mg/100ml) in **P. monodon.** In the marine environment **P. indicus** is having more carbohydrate level (69.62±8.97 mg/100ml)

than the level (30.21±20.88 mg/100ml) in **M. monoceros.** Similar intraspecific variation of total protein in the sera of decapod crustaceans **Callinectes sapidus** (4.39 mg/100ml), **Cancer magister** (4.45 mg/100ml), **C. irroratus** (5.39 mg/100ml), **Libinia emarginata** (4.14 mg/100ml), **Homarus americanus** (4.28 mg/100ml) was reported by Leone (1953). Balazs **et al.** (1974), also reported variation in mean serum glucose level between **P. marginatus** (26 mg/100ml) and **M. rosenbergii** (83 mg/100ml). The studies made on the blood and muscle proteins of crabs by Kannupandi and Paulpandian (1975) revealed the existence of variation in protein fractions of closely related species.

No significant difference was found in calcium and potassium levels between **P. indicus** and **M. monoceros** in marine water and **P. indicus** and **P. monodon** in brackishwater. This might be due to possession of similar ionic regulatory capacity by these three species. Dall and Smith (1981) found similar potassium ion regulation among **P. merguiensis, P. esculentus** and **P. plebejus;** and also similar calcium ion regulation in **P. merguiensis, P. esculentus** and **Metapenaeus bennettae.**

Protein and carbohydrate contents of **P. indicus** from marine water and of **P. indicus** from brackishwater were significantly different. This might be due to variation in physiological activity between the sub-adult and adult phases in the life history of **P. indicus.**

Protein level showed negative correlation with carapace length and weight in all the three species irrespective of the environment. Carbohydrate content in haemolymph is negatively correlated with carapace length and weight in brackishwater and showed positive correlation with carapace length (except in **P. indicus**) and weight in marine water. Calcium content is positively correlated with carapace length and weight in brackishwater and negatively correlated with weight in marine water. Potassium showed negative correlation with length and weight in brackishwater and positive correlation with length and weight in marine water. Copper showed no apparent correlation with length and weight, except in **P. indicus** from brackishwater, in which, the relationship was positive (significant) with length and weight.

Cropwise correlation coefficient of haemolymph characteristics in relation to length and weight (Table 9 and 10) of **P. monodon** and **P. indicus** has revealed that relationship between these two variables vary from crop to crop. This might be due to the prevailing culture conditions and availability of quality of food which play a very important role in the well being of prawns. Similar results were reported by Stewart **et al.** (1967), in the lobster **Homarus americanus.** As per their study protein level was found affected by change in the diet; serum protein linearly related with the muscle percentage of live weight; and this relationship was not valid beyond maximum values of both variables (above 55 mg/ml for serum protein and above 24% of live animal for muscle

percentage). Statistical significance of relationship varied with type of food given in captive animals. In wild animals, the overall relationship was sound irrespective of location of collection, sex and season. Hagerman (1983) conducted a study on haemocyanin concentration of juvenile lobsters of **Homarus gammarus** in relation to feeding conditions and this study revealed that haemocyanin concentration has significantly decreased in starved animals. Haemocyanin concentration differed widely in the animals of two groups of which one group was fed with compounded pellet feed and the other group with bivalves.

The correlation coefficient between haemolymph characteristics and condition factor of **P. monodon** and **P. indicus** revealed no significant relation between two variables. As per available literature similar studies were not carried out elsewhere for comparison with the results of the present study.

Table 5. Comparison of haemolymph constituents between male and female of **M.monoceros, P.monodon and P. indicus**

Parameter		M. monoceros			P. monodon			P. indicus (marine)			P. indicus (brackishwater)		
		Male	Female	s	Male	Female	s	Male	Female	s	Male	Female	s
Carapace length (mm)	R	25-37	23-50		24-47	25-57		33-38	33-43		20-30	19-34	
Protein (mg/ml)	R	36.00-190.00	27.00-210.00		48.00-240.00	32.00-260.00		47.00-160.00	33.00-180.00		72.00-152.00	60.00-180.00	
	M±S.D	107.01±30.11	94.69±43.17	N.S.	117.2±37.46	108.9±42.20	N.S.	104.05±37.40	119.23±57.09	N.S.	129.80±29.40	128.67±40.78	N.S.
	N	49	59		51	55		18	13		21	31	
Carbohydrate (mg/100 ml)	R	12.00-48.00	14.70-118.0		9.00-50.00	9.00-45.00		50.00-71.00	40.00-80.00		28.00-52.00	25.00-59.00	
	M±S.D.	22.10±10.34	37.42±25.09	P<0.02	31.90±14.37	30.00±12.60	N.S.	67.18±0.5.36	73.19±12.18	N.S.	36.52±7.93	36.50±9.39	N.S.
	N	24	27		47	49		14	10		21	31	
Calcium (mg/100 ml)	R	3.00-12.00	1.10-10.80		2.00-15.00	3.00-27.00		3.00-10.00	6.00-14.00		4.00-23.00	3.90-20.25	
	M±S.D.	7.18±2.63	4.95±2.77	N.S.	8.42±3.74	12.14±5.67	N.S.	5.02±2.50	8.92±3.83	P<0.05	11.68±6.36	11.07±5.43	N.S.
	N	21	23		42	49		9	7		19	30	
Potassium (mg/100 ml)	R	2.24-11.00	3.00-9.40		1.40-7.68	0.80-6.80		2.80-12.80	3.60-11.20		1.68-4.20	1.80-5.28	
	M±S.D.	5.99±2.47	5.77±1.58	N.S.	3.25±2.01	3.02±1.72	N.S.	8.50±4.09	8.62±4.40	N.S.	2.66±0.90	3.19±1.13	N.S.
	N	21	23		42	49		9	7		19	30	
Copper (µg/ml)	R	13.50-22.50	12.00-26.00		4.50-16.50	3.70-14.00		10.00-20.50	16.50-26.00		8.90-19.50	7.50-27.50	
	M±S.D.	16.40±2.90	16.50±3.50	N.S.	10.80±2.80	10.20±3.00	N.S.	15.60±3.40	20.10±7.60	N.S.	14.79±3.20	14.60±4.70	N.S.
	N	12	14		42	49		9	7		19	30	

R = range; M±S.D = mean value ± standard deviation; N = number of individual samples analysed; s = significant level; N.S.= not significant at probability P< 0.05.

Table 6. Comparison of haemolymph constituents at intra and interspecific levels of **M.monoceros, P.monodon** and **P. indicus.** Values expressed as mean ± standard deviation. Number of samples analysed given in parentheses.

Parameter	**M.monoceros**	**P.indicus** (marine)	s	**P.monodon**	**P.indicus** (brackishwater)	s	**P.indicus** (marine)	**P.indicus** (brackishwater)	s
Carapce length range (mm)	23-50	33-43		24-57	19.34		33-43	19-34	
Protein (mg/ml)	100.28±38.14 (108)	113.58±45.48 (31)	N.S	112.91±40.02 (106)	129.13±34.65 (52)	p< 0.02	113.58±45.48 (31)	129.13±34.65 (52)	N.S. (P< 0.1)
Carbohydrate (mg/100 ml)	30.21±20.88 (51)	69.62±8.97 (31)	P<0.001	30.93±11.99 (96)	36.51±8.91 (52)	P<0.01	69.62±8.97 (31)	36.51±8.91 (52)	P<0.001
Calcium (mg/100 ml)	6.01±2.90 (44)	6.87±3.47 (16)	N.S.	10.42±5.29 (91)	11.30±5.75 (49)	N.S.	6.87±3.47 (16)	11.30±5.75 (49)	P<0.01
Potassium (mg/100 ml)	5.89±2.03 (44)	8.56±4.10 (16)	N.S.	3.17±1.77 (91)	2.98±1.07 (49)	N.S.	8.56±4.10 (16)	2.98±1.07 (49)	P<0.001
Copper (µg/ml)	16.40±3.20 (26)	17.50±3.90 (16)	N.S.	10.50±2.90 (91)	14.70±4.10 (49)	P<0.001	17.50±3.90 (16)	14.70±4.10 (49)	P<0.05

s = significant level; N.S. = not significant at probability P 0.05 level

Table 7. Correlation coefficients of haemolymph characteristics in relation to the carapace length of **M.monoceros, P.monodon** and **P.indicus**

Parameter	**M. monoceros**			**P. monodon**			**P. indicus** (marine)			**P. indicus** (brackishwater)		
	n	r	s	n	r	s	n	r	s	n	r	s
Protein	108	-0.2774	P < 0.01	106	-0.0029	N.S.	31	-0.4621	P < 0.01	52	-0.9047	P < 0.001
Carbohydrate	24* 27**	0.5948* 0.1017**	P < 0.01* N.S.**	96	-0.02322	P < 0.05	24	-0.0267	N.S.	52	-0.1498	N.S.
Calcium	44	-0.4232	P < 0.01	91	0.3726	P < 0.001	16	0.0413	N.S.	49	0.7188	P < 0.001
Potassium	44	0.2190	N.S.	91	-0.2305	P < 0.05	16	0.3707	N.S.	49	-0.3076	P < 0.05
Copper	26	-0.0069	N.S.	91	0.1852	N.S.	16	0.2874	N.S.	49	0.3094	P < 0.05

n = number of prawns examined; r = correlation coefficient; N.S. = not significant at P 0.05 probability level; * = male; ** = female

Table 8. Correlation coefficients of haemolymph characteristics in relation to the weight of **M.monoceros, P.monodon** and **P.indicus**

Parameter	**M. monoceros**			**P. monodon**			**P. indicus** (marine)			**P. indicus** (brackishwater)		
	n	r	s	n	r	s	n	r	s	n	r	s
Protein	108	-0.3033	P < 0.01	34	-0.5984	P < 0.001	31	-0.4275	P < 0.02	36	-0.4338	P< 0.01
Carbohydrate	24*	0.17*	N.S.*	34	-0.5515	P < 0.001	24	0.1371	N.S.	36	-0.7733	P< 0.001
	27**	0.404**	P < 0.05**									
Calcium	44	-0.4555	P < 0.01	34	0.3152	N.S.	9*	-0.786*	P < 0.02*	36	0.5991	P < 0.001
							7**	-0.14**	N.S.**			
Potassium	44	0.3085	P< 0.05	34	-0.5525	P < 0.001	16	0.0527	N.S.	36	-0.0617	N.S.
Copper	26	0.1085	N.S.	34	-0.3250	P < 0.05	16	0.3756	N.S.	36	0.6224	P< 0.001

n = number of prawns examined; r = correlation coefficient; N.S.= not significant at 0.05 probability level; * = male; ** = female

Table 9. Crop-wise correlation coefficients of haemolymph characteristics in relation to the carapace length of **P.monodon** and **P. indicus** from brackishwater pond. Number of prawns examined is given in parentheses.

	P. monodon				*P. indicus*		
Crop	I	II	III	IV	I	II	III
Parameter	November 1984	November 1984	March 1985	November 1985	November 1984	March 1985	November 1985
Protein	0.4716[@] (35)	-0.0174 (22)	0.3663 (26)	0.3647 (22)	0.2225 (8)	0.1695 (18)	0.3608 (26)
Carbohydrate	-0.362* (35)	-0.0741 (22)	0.0204 (26)	0.0 (13)	-0.1792 (8)	-0.8381** (18)	0.4346* (26)
Calcium	0.5651** (29)	-0.1241 (15)	-0.0822 (26)	0.2566 (21)	0.7057 (8)	0.4877 (15)	-0.1405 (26)
Potassium	0.2324 (29)	0.2663 (15)	0.4214* (26)	0.3518 (21)	0.0135 (8)	-0.4969 (15)	0.1835 (26)
Copper	0.9194** (29)	-0.1374 (15)	0.6499 (26)	0.5030* (21)	-0.1367 (8)	0.5165 (15)	0.5302[@] (26)

* = significant at 0.05 probability level; @ = significant at 0.01 probability level; ** = significant at 0.001 probability level

Table 10. Crop-wise correlation coefficients of haemolymph characteristics in relation to the weight of **P.monodon** and **P.indicus** from brackishwater pond. Number of prawns examined is given in parentheses.

	P. monodon			*P. indicus*		
Crop	I	III	IV	I	II	III
Parameter	November 1984	March 1985	November 1985	November 1984	March 1985	November 1985
Protein	0.1954 (15)	0.6745* (10)	0.6609* (9)	0.0336 (8)	-0.4542 (10)	0.0973 (26)
Carbohydrate	0.2145 (15)	0.1435 (10)	0.0 (9)	-0.2594 (8)	-0.0279 (10)	0.0801 (26)
Calcium	0.5913* (15)	0.2376 (10)	0.0673 (9)	-0.6162 (8)	-0.7426* (10)	-0.1606 (26)
Potassium	0.0166 (15)	0.4954 (10)	0.5524 (9)	-0.0709 (8)	0.6921* (10)	0.2371 (26)
Copper	0.6341* (15)	0.7119* (10)	0.7173* (9)	-0.2070 (8)	0.6153 (10)	0.5131@ (26)

* = significant at 0.05 probability level; @ = significant at 0.01 probability level

Table 11. Correlation coefficients of haemolymph characteristics in relation to condition factor of **P.monodon** (standard animal, 32.08 mm CL) and **P.indicus** (standard animal, 27.29 mm CL) from brackishwater pond.

Parameter	P. monodon			P. indicus		
	n	r	s	n	r	s
Protein	34	-0.3851	P< 0.02	44	-0.1306	N.S.
Carbohydrate	34	-0.1128	N.S.	44	-0.1791	N.S.
Calcium	34	0.2916	N.S.	44	0.0662	N.S.
Potassium	34	-0.4005	P < 0.02	44	0.0471	N.S.
Copper	34	-0.1430	N.S.	44	0.2775	N.S.

n = number of prawns examined; r = correlation coefficient; s = significant level;
N.S. = not significant at 0.05 probability level

CHAPTER 4

BIOCHEMICAL COMPOSITION OF MUSCLE IN RELATION TO SEX, SIZE, WEIGHT AND CONDITION FACTOR

INTRODUCTION

Muscle in prawns constitutes 50% of its body weight. This property of the prawn coupled with the excellent flavour and taste of the muscle render it to become an item of high commercial importance among the marine products of commerce. The prawns are mobile and diadromous exhibiting various biological and physiological features associated with locomotion, supporting exoskeleton and as a storage material for energy reserves like protein, carbohydrate and lipid. In natural environment as well as culture ponds, prawn food is composed of organic and inorganic matter, either available in nature or given artificially. The grow-out ponds are potential reserves of protein, carbohydrate and lipid which are converted into muscle, the ultimate commercial product. It is a well known fact that muscle is composed of water, organic material such as protein, carbohydrate and lipid besides inorganic components like calcium, potassium, copper, etc. Muscle composition varies with sex, size, weight, maturation process, moult cycle and condition factor.

In penaeid prawns variation in muscle composition in relation to moult stage was studied and reported by different authors. To know the biochemical composition of muscle in relation to sex, size, weight and condition factor, data was analysed of samples of all the three species, collected during the course of the present study.

Appanna and Devadatta (1942) estimated nutritive values of **Metapenaeus** sp., **Parapenaeus** sp. and **Acetes** sp. from Bombay coast. Chari (1948) estimated nutritive values of **Penaeus monodon, Parapenaeopsis dobsoni, Penaeus semisulcatus** and **Trachypenaeus asper** from Calicut coast. Gopalakrishnan (1951) reported on chemical composition of **Penaeus indicus, P. carinatus, Metapenaeus monoceros** and **M. dobsoni** from Madras coast. Shaikhmahmud and Magar (1957) carried out studies on biochemical composition of **Penaeus penicillatus , Metapenaeus affinis, Parapenaeopsis stylifera, Hippolysmata ensirostris** and **Leander tenuipes** from the Bombay coast. Borgstrom (1962) reviewed the literature on nutritive aspects of shell fish. Pillai and Nair (1973) studied biochemical changes in gonads, muscle and hepatopancreas of **Uca annulipes, Portunus pelagicus** and **Metapenaeus affinis** during the reproductive cycle. Sumitra Vijayaraghavan and Easterson (1974) studied biochemical changes and energy utilisation during embryonic stages of the estuarine prawn, **Macrobrachium idella.** Kanazawa **et al.** (1976), reported about the variation in lipids and cholesterol contents in the tissues of prawn, **Penaeus japonicus** during the moult cycle. Teshima and Kanazawa (1976) studied the variation in lipid content and fatty acid composition in fresh water shrimp, **Palaemon paucidens** during the moult cycle. Teshima **et al.** (1977), studied the variation in lipid classes during the moult cycle of the prawn **Penaeus japonicus.** Martin (1980) observed growth rates of

Palaemon serratus fed with ten compounded diets containing linoleic and li nolenic acids in different proportions. Clarke and Wickins (1980) studied the lipid content and compostion of cultured **Penaeus merguiensis** fed with animal food. Seasonal and nutritional effects on the fatty acids of three species of shrimp, **Penaeus setiferus, P. aztecus** and **P. duorarum** from the Gulf of Mexico were reported by Bottino **et al.** (1980). Sarojini **et al.** (1982), studied biochemical changes in the fresh water prawn **Macrobrachium kistnensis**. Rajamani (1982) made biochemical studies on soft prawns of **Penaeus indicus** from brackishwater pond. Krishnamoorthy **et al.** (1982) studied the tissue cholesterol levels in commercial shrimp **Penaeus aztecus** during starvation as well as animals fed with different diets. Srinivasulu Reddy **et al.** (1989), studied the variation in lipid component in the muscle of **Metapenaeus monoceros** and **Penaeus indicus** when animals were exposed to lethal concentrations of phosphamidon.

Studies on other crustaceans on these aspects were made by Barnes **et al.** (1963); Pearse and Giese (1966); Mauchline and Fisher (1969); Torres (1973); Ferguson and Raymont (1974); Colving (1976); Hayashi (1976); Lawrence (1976); Stein and Murphy (1976); Takahashi and Yamada (1976); Clarke (1977); Johnson and Hopkins (1978); Ameer Hamsa (1981); Shibata (1983); DuPreez and McLachlan (1983); Anger **et al.** (1983); Iwata **et al.** (1983); Szaniawska (1983); Amsler and George (1985); Jacobi and Anger (1985); and Anger (1986).

RESULTS

Samples of prawn muscle of **M. monoceros** and **P. indicus** collected at different times off Visakhapatnam from the trawl catches were pooled sexwise and treated for the present study. Muscle samples of **P. monodon** and **P. indicus** from brackishwater ponds at Kakinada were collected during harvest time of 3 successive crops and were pooled sexwise for further analysis.

Samples of **M. monoceros** had carapace length ranging from 25-37 mm in males and 23-50 mm in females; weight range was 7.4-28.8 g in males and 8.3-58.8 g in females. **P. monodon** samples had carapace length ranging from 25-43 mm for males and 25-40 mm for females; weight range was 8.5-38.4 g for males and 8.3-29.0 g for females. The samples of **P. indicus** from the marine environment had carapace length ranging from 30-38 mm for males and 28-44 mm for females, weight range was 19.0-40.0 g for males and 13.3-50.5 g for females. Samples of **P. indicus** from brackishwater ponds had carapace length ranging from 21-32 mm for males and 19-34 mm for females; weight range was 7.3-19.6 g for males and 5.0-21.5 g for females. These samples were used for the present study on biochemical composition of muscle.

Water content in the muscle was expressed as percentage on wet weight basis. Protein, carbohydrate and lipid contents were expressed as mg/100mg of dry material.

Muscle composition in relation to sex

Range, mean, standard deviation and number of specimens in each sample for each parameter in the case of all the three species, are given sexwise in table 12. Student's 't' test was used for comparison of means of all parameters between the two sexes. The difference in each parameter between the two sexes was considered significant at the 5% probability level.

M. monoceros

No significant difference was found in water, carbohydrate and lipid contents between the two sexes but protein content varied significantly ($P < 0.01$) because females had more protein content (62.5±9.44 mg/100mg) than males (57.3±9.36 mg/100mg).

P. monodon

No significant difference was found between the two sexes in water, protein, carbohydrate and lipid contents.

P. indicus (marine water)

Difference in water, carbohydrate and lipid contents between the two sexes was not significant but portein content varied significantly ($P < 0.02$) between the two sexes as the females (59.08±14.23 mg/100mg) were observed to have more than the males (51.45±11.96 mg/100mg).

P. indicus (brackishwater)

No significant difference was found in water, protein, carbohydrate and lipid contents between the two sexes.

From the study of muscle composition in relation to sex, the following facts have emerged:

1. In brackishwater pond, muscle composition of **P. monodon** and **P. indicus** was not different significantly between the two sexes
2. In the marine environment, females of **M. monoceros** and **P. indicus** were having more protein content than males. This may be attributed to an active maturation process in females perhaps due to greater need to store energy reserves in the muscle for mobilizing them to the gonad during vitellogenesis.

Comparison of muscle composition at intra and inter specific levels

Since the difference in muscle composition between the two sexes was not statistically significant except protein content in **M. monoceros** and **P. indicus** (marine), the data of males and females of each species was pooled and treated for comparison at intra and inter specific levels. Student's 't' test was employed to find out significant difference in each parameter between the two species. Mean, standard deviation and number of samples analysed for each parameter of all the species studied; and significance of the difference between two species in the case of each parameter are given in table 13.

Mean muscle composition of all three species is shown in figure 11 on wet weight basis and dry weight basis. Since values

of parameters were expressed as mg/100mg on dry weight basis; protein, carbohydrate and lipid values were added and the same value was deducted from 100 and then the remaining balance was considered as the inorganic component of muscle on dry weight basis. The composition of muscle on wet weight basis showedwater content as percentage on wet weight basis, the balance after deducting water percentage from 100, was divided amongst protein, carbohydrate, lipid and inorganic matter according to their proportions on dry weight basis.

In the marine environment muscle composition between **M. monoceros** and **P. indicus** was compared. Protein ($P < 0.05$), carbohydrate ($P < 0.001$) and lipid ($P < 0.001$) contents were significantly different whereas no significant difference was found in water content. Protein content was more in **M. monoceros** (59.31±9.53 mg/100mg) than in **P. indicus** (55.51±13.63 mg/100mg). Carbohydrate (1.18±0.48 mg/100mg) and lipid (3.74±0.80 mg/100mg) contents were high in **P. indicus** than carbohydrate (1.61±0.68 mg/100mg) and lipid levels (3.26±0.79 mg/100mg) in **M. monoceros.**

In brackishwater ponds, water ($P < 0.001$), protein ($P< 0.01$) and carbohydrate ($P < 0.05$) contents were different significantly between **P. monodon** and **P. indicus.** Lipid level did not show variation between the two species. Water (76.60±2.0%) and carbohydrate (1.31±0.17 mg/100mg) contents were high in

P. monodon than the water (74.82±1.82%) and carbohydrate (1.22±0.17 mg/100mg) contents in **P. indicus.** High protein content (64.68±6.44 mg/100mg) was observed in **P. indicus** compared to **P. monodon** (57.97±10.80 mg/100mg).

Muscle composition of **P. indicus** between brackishwater and marine environment has revealed the following facts:

1. Water content was high in brackishwater (74.82±1.82%) than in marine water (71.82±1.93%).
2. Protein level was more in brackishwater (64.68±6.44 mg/100mg) than in marine water (55.51±13.63 mg/100mg).
3. Carbohydrate and lipid levels did not vary significantly.

From the comparison of muscle composition at intra and inter specific levelsthe following facts have emerged:

1. Muscle composition varied between **M. monoceros** and **P. indicus** in marine environment; and in brackishwater pond between **P. monodon** and **P. indicus.**
2. High water content was found in **P. indicus** from brackishwater pond than **P. indicus** in marine environment. This may be due to difference in the size of the prawns examined in the samples of the two environments. In small sized specimens more water content and less inorganic and organic matter was recorded in the samples from the brackishwater ponds.

4. High protein level was observed in P. **indicus** from brackish-water ponds than in **P. indicus** from marine water. This is due to maturity and immaturity of the specimens in the marine and brackishwater environments respectively. Also it may be due to artificial feeding in culture ponds. In nature, prawns store energy in the form of protein, which can be mobilized from muscle to ovary or testes during oogenesis and spermatogenesis respectively.

Muscle composition in relation to carapace length

As the protein content of muscle in the case of males and females of **M. monoceros** and **P. indicus** from marine water differed significantly, analysis of the data was made separately for males and females to study the relationship between muscle composition and carapace length. Water, carbohydrate and lipid contents did not vary between the two sexes of the two species. Hence, samples of both sexes were pooled for further analysis. Since muscle composition did not vary between the two sexes of **P. monodon** and **P. indicus** from brackishwater ponds, data of males and females on all parameters was pooled for analysis in the present study.

Correlation coefficients between the muscle components and carapace length are presented in table 14. Number of specimens examined and level of significance of the correlation between two variables are also shown in this table.

M. monoceros

Water, protein, carbohydrate and lipid contents have not shown any relationship with carapace length.

P. monodon

Water showed positive relation with low correlation ($P < 0.05$); protein did not show any relation; while carbohydrate and lipid showed highly significant positive correlations with carapace length. Relationships of carbohydrate and lipid levels with carapace length are shown in figure 12. Regression lines were drawn by following least square method for these two parameters.

The relationships are expressed as follows:

Carbohydrate (mg/100mg) = 0.7814 + 0.0166 CL (mm) ($r = 0.4923$)

Lipid (mg/100mg) = 0.1878 + 0.1066 CL (mm) ($r = 0.7018$)

P. indicus (marine water)

Water level showed positive relation with low correlation ($P < 0.05$). Protein in males showed weak correlation ($P < 0.02$) whereas in females no correlation of any siginificance. Carbohydrate also showed weak correlation ($P < 0.02$); while lipid did not show any relation of significance.

P. indicus (brackishwater)

Water and protein did not have a significant correlation

with carapace length whereas carbohydrate and lipid showed positive and significant correlation with carapace length.

The plot of carbohydrate and lipid contents against carapace length gave regression lines (Fig. 12) which are expressed as follows:

Carbohydrate (mg/100mg) = 0.7880 + 0.0159 CL (mm) ($r = 0.3700$)

Lipid (mg/100mg) = 2.2010 + 0.0599 CL (mm) ($r = 0.3030$)

The study of muscle composition in relation to carapace length was summarised as below:

1. No significant relation was found between muscle constituents and carapace length of **M. monoceros** and **P. indicus** in marine water.
2. Water and protein have not shown a significant relation but carbohydrate and lipid levels showed significant positive relation with carapace length of **P. monodon** and **P. indicus** in brackishwater ponds. From this it may be concluded that in these two species, inhabitants of brackishwater ponds have carbohydrate and lipid contents getting accumulated with the increase in size.

Muscle composition in relation to the weight

Muscle constituents did not show significant differences between the two sexes in all the species studied except protein

content in **M. monoceros** and **P. indicus** inhabiting marine water. Except protein level for **M. monoceros** and **P. indicus** (marine water) the remaining data of the two sexes was pooled for further analysis. Correlation coefficients between muscle constituents and weight gave the following results (Table 15):

M. monoceros

Water, protein, carbohydrate and lipid contents showed no significant correlation with weight.

P. monodon

Water and protein levels showed no significant correlation with weight whereas carbohydrate and lipid showed highly significant positive relation with weight. Regression lines are fitted for the scattergram of observed points of carbohydrate and lipid in relation to weight (Fig. 13). The relationships are expressed as follows:

Carbohydrate (mg/100mg) = 1.1619 + 0.0082 W(g) ($r = 0.4384$)

Lipid (mg/100mg) = 2.5859 + 0.0543 W(g) ($r = 0.6290$)

P. indicus (marine water)

Water showed positive correlation ($P < 0.01$) with weight. Protein in both male ($P < 0.01$) and female ($P < 0.001$) showed positive correlation, while carbohydrate showed weak correlation ($P < 0.05$) and lipid did not show any significant relationship.

P. indicus (brackishwater)

Water and protein did not show any significant correlation with weight whereas carbohydrate ($P < 0.01$) and lipid ($P < 0.001$) showed significant positive relation with weight.

Regression lines showing the relationships of carbohydrate and lipid with weight (Fig. 13) are expressed as follows:

Carbohydrate (mg/100mg) = 1.0577 + 0.0117 W(g) (r = 0.3188)

Lipid (mg/100mg) = 2.5675 + 0.0902 W(g) (r = 0.5298)

The results of the study of muscle composition in relation to weight, may be summarised as follows:

1. In the marine environment, water, protein and carbohydrate contents of **P. indicus** showed significant positive correlation while in **M. monoceros** the same muscle constituents have not shown any significant correlation with weight.
2. In **P. monodon** and **P. indicus** from brackishwater ponds, carbohydrate and lipid levels increased with weight.

Muscle composition in relation to condition factor

Physiological state of the prawn as indicated by the availability of energy reserves in muscle for metabolism can be assessed by an index of the condition of the prawn as measured by the length-weight relationship. Condition factor gives a measure of the deviation of the weight of an individual from the averge for a

given length (Le Cren, 1951). High and low condition factors are indications respectively of healthy and unhealthy conditions of the prawns. The influence of the constituents like water, protein, carbohydrate and lipid on changes in condition of the prawn are studied through the relationships between muscle constituents on the one hand and condition factor on the other hand. The results are presented below.

Maturation influences the condition of the prawn. To avoid the effect of maturity on the weight of the prawn, only immature prawns of **P. monodon** and **P. indicus** from brackishwater were selected. These two species do not attain maturity in brackishwater ponds. Migration to the sea is an essential phase in their life history for further maturation and spawning. Data on the sexes were pooled for statistical analysis.

The amount of a component in the muscle of the prawn varies with size of the prawn. In the study of effect of body constituents on condition of the prawn, corrections must be made for variation in size of prawn. Such corrections were made following the method of Caulton and Bursell (1977) for "estimation of the 'size specific' quantity of each constituent i.e., the mass of any constituent that a prawn of a given size would contain". Average carapace length of total prawns used in this study was taken as a standard for each species for purposes of comparison. muscle component of each individual prawn was corrected to the

standard carapace length (average) for the prawn and the method of correction was applied as explained below:

Initially regression coefficients were calculated for the exponential relationship between body constituents and carapace length of **P. monodon** and **P. indicus** by logarithmic transformation of the values of water, protein, carbohydrate and lipid contents (muscle components) and logarithmic transformation of the values of carapace length to obtain a straight line relationship. The least square technique was adopted. Then these linear regressions were transformed into exponential forms.

Water and protein were measured to the nearest 0.1 g while carbohydrate and lipid were measured to the nearest 1 mg. The linear equations and their exponential forms for the relationships between all the muscle components and carapace length are as follows:

P. monodon

$$\text{Log water} = -2.7425 + 2.5730 \log CL \quad (r = 0.9034)$$

$$\text{Water (g)} = 0.001809\ CL^{2.5730}$$

$$\text{Log protein} = -3.4055 + 25068 \log CL \quad (r = 0.8216)$$

$$\text{Protein (g)} = 0.00039\ CL^{2.5068}$$

$$\text{Log carbohydrate} = -1.4669 + 2.1182 \log CL \quad (r = 0.6370)$$

$$\text{Carbohydrate (mg)} = 0.034127\ CL^{2.1182}$$

$$\text{Log lipid} = -2.7723 + 3.2794 \log CL \quad (r = 0.8654)$$

$$\text{Lipid (mg)} = 0.001689\ CL^{3.2794}$$

P. indicus

Log water = -2.7127 + 2.5880 log CL (r = 0.9774)

Water (g) = $0.001937\ CL^{2.588}$

Log protein = -2.9631 + 2.3014 log CL (r = 0.9541)

Protein (g) = $0.001088\ CL^{2.3014}$

Log carbohydrate = -2.4325 + 2.8135 log CL (r = 0.9393)

Carbohydrate (mg) = $0.003694\ CL^{2.8135}$

Log lipid = -2.3139 + 3.0735 log CL (r = 0.8927)

Lipid (mg) = $0.004854\ CL^{3.0735}$

The quantity of each component in each individual prawn was corrected to the chosen standard carapace length using the formula:

$$S_2 = \frac{S_1}{CL^b} \times CL_{std}^b$$

where S_2 = corrected constituent level to standard level

S_1 = constituent level of individual prawn

CL_{std} = carapace length of the standard prawn (31.6737 mm for **P. monodon** and 26.9463 mm for **P. indicus**)

b = regression exponent value of concerned parameter

Corrected values of all the components in each individual prawn standardised with regard to carapace are plotted corresponding to the condition factor as a scattergram of X, Y

coordinates. Condition factor of each prawn was calculated by using the formula given by Le Cren (1951):

$$Kn = 1000\ W/CL^{b}$$

where W = weight of individual prawn (g)

CL = carapace length of the prawn (mm)

b = regression exponent value of carapace length-weight relationship (b = 2.5363 for **P. indicus** and 2.6304 for **P. monodon**)

Since the relationships between the muscle components and condition factor appears to be linear, no logarithmic transformation of the data was necessary to apply the least square method. The correlation coefficients and the significance of the relation between each muscle component and condition factor for **P. monodon** and **P. indicus** are given in table 16. The positive relationships between muscle components and condition factor were found to be highly significant in **P. monodon** and **P. indicus.** The relationships between water, protein, carbohydrate and lipid levels and condition factor for **P. monodon** and **P. indicus** are shown in figures 14 and 15. All constituents of muscle showed a linear relationship with condition factor in these two species.

The derived equations for the relationships between body constituents and condition factor of **P. monodon** and **P. indicus** are as follows:

P. monodon

Water (g) = 0.8258 + 6.3764 K (r = 0.9924; n = 34)

Protein (g) = 0.7739 + 0.7932 K (r = 0.5652; n = 34)

Carbohydrate (mg) = 0.0194 + 0.0172 K (r = 0.5552; n = 34)

Lipid (mg) = -0.0075 + 0.0787 K (r = 0.6940; n = 34)

P. indicus

Water (g) = -0.4296 + 3.3260 K (r = 0.9756; n = 44)

Protein (g) = 1.0332 + 0.3623 K (r = 0.4336; n = 44)

Carbohydrate (mg) = 0.0041 + 0.0113 K (r = 0.5517; n = 44)

Lipid (mg) = -0.0350 + 0.0524 K (r = 0.5717; n = 44)

From the study of body composition in relation to condition factor it has been found that muscle components like water, protein, carbohydrate and lipid are positively related with condition factor and that all the muscle components are contributory factors to the increasing weight with growth of **P. monodon** and **P. indicus** in brackishwater ponds.

DISCUSSION

In the present study the water content of individual prawns was found to range from 61.4 to 81.9% in **M. monoceros**; 72.20 to 80.66% in **P. monodon**; 67.78 to 77.65% in **P. indicus** (marine water); 70.80 to 79.30% in **P. indicus** (brackishwater). Appanna and Devadatta (1942) reported moisture content between 72.60% and 75.30% for Bombay prawns (**Metapenaeus** sp., **Parapenaeus** sp., **Parapenaeus** sp. and **Acetes** sp.). Gopalakrishnan (1951) observed water per cent of **Penaeus indicus, P. carinatus, Metapenaeus monoceros** and **M. dobsoni** from Madras coast in between 72.67% and 77.54%. Water content values reported by Shaikhmahmud and Magar (1957) for Bombay prawns (**Penaeus penicillatus, Metapenaeus affinis, Parapenaeopsis stylifera, Hippolysmata ensirostris** and **Leander tenuipes**) were in between 67.5% and 80.6%. Pillay and Nair (1973) reported water content range of **Metapenaeus affinis** to be from 63.5% to 75.6%. Ameer Hamsa (1981) reported average moisture content in the muscle of males and females of **Portunus pelagicus** to be 68.64% and 79.87% respectively. Du Preez and McLachlan (1983) gave water content range from 67.86% to 82.51% in the three spot swimming crab **Ovalipes punctatus.** The water content values observed in the present study are in agreement with the values reported by the other authors who worked on penaeid prawns and other crustaceans.

The difference in water content between the two sexes of all the three species was not significant. Similar result was also found in crayfish, **Orconectes propinquus** by Stein and Murphy (1976). No significant difference in water content was found between **M. monoceros** and **P. indicus** in marine environment but interspecific difference in water content was observed between **P. monodon** and **P. indicus** from a brackishwater pond, where water content was more in **P. monodon** (76.60 ± 2.0%) than (74.82 ± 1.82%) in **P. indicus.** The difference in water content between the two species in brackishwater pond was attributed to accumulation of organic and inorganic matter which depends upon the quality and quantity of the food available or supplied during rearing period. Food preferences vary between the two species. Food studies done by Rao (1967) also have revealed that food of animal origin formed 22.35% in **P. indicus** and 40.77% in **P. monodon.** However, Hall (1962) based on his studies, according to food preferences, divided 31 species of penaeid prawns into six groups where **P. monodon** and **P. indicus** were classified in one group which feed mainly on large crustaceans.

P. indicus in marine environment was having less water content (71.82 ± 1.93%) than in **P. indicus** (74.82 ± 1.82%) of brackishwater pond. This may be attributed to the existence of age difference between the two populations. In the brackishwater pond the size range and weight range of **P. indicus** was 19-34 mm

carapace length and 5.0-21.5 g weight whereas in marine environment the length range was 28-44 mm(CL) weighing 13.3-50.5 g. Stein and Murphy (1976) also found more water content in juveniles than in adults of crayfish, **Orconectes propinquus** because of accumulation of organic and inorganic matter with increase in size and hence weight.

In the penaeid prawns, protein is the major constituent of the muscle which contributes more than half of the total quantity. During the present study it was observed that individual variation is very high in protein level. Protein content ranged from 36.0 to 80.0 mg/100mg in **M. monoceros**; 36.0 to 86.0 mg/100mg in **P. monodon**; 36.0 to 78.0 mg/100mg in **P. indicus** (marine) and 53.0 to 74.0 mg/100mg in **P. indicus** (brackishwater). Similar variation of protein content was recorded in penaeid prawns as well as in other crustaceans by several other workers. Shaikhmahmud and Magar (1957) reported average protein content on dry weight basis between 51.3% and 66.1% for **Penaeus penicillatus, Metapenaeus affinis, Parapenaeopsis stylifera, Hippolysmata ensirostris** and **Leander tenuipes.** Pillay and Nair (1973) gave monthly average protein content to range from 43.04 to 66.84 mg/100mg for female **M. affinis.** Johnson and Hopkins (1978) reported monthly protein content to range from 55.4 to 58.2% in the mysid shrimp **Taphromysis bowmani.** Du Preez and McLachlan (1983) reported monthly mean protein variation in between 30.75% and 44.59% for the three spot swimming

crab, **Ovalipes punctatus.** Ferguson and Raymont (1974) gave the protein content range from 26.6 to 66.6% on dry weight basis for **Euphausia superba.**

Protein content did not vary significantly between sexes of **P. monodon** and **P. indicus** in brackishwater pond whereas it differed significantly between sexes in **P. indicus** and **M. monoceros** from the marine environment. In both the species, females contained more protein content than males. This may be attributed to the onset of full fledged maturation in the marine waters. Female requires more protein from muscle for the build up of gonad during vitellogenesis. In order to meet the demand of the gonad more protein is stored in the muscle. Similar trend was also observed in the three spot swimming crab, **Ovalipes punctatus** by Du Preez and McLachlan (1983) where build up of protein was observed in the female before the main breeding period. Barnes **et al.** (1963), also found similar kind of assimilation and storage of protein, carbohydrate and lipid in the loose connective tissue of **Balanus balanoides** and **B. balanus** during spring months, as they were found to feed on the spring diatom which was most abundant. These reserves are obviously used for gonadal development which lasts for a long time.

Significant differences were also found in protein level at intra and inter-specific levels. In marine water, **M. monoceros**

contained more protein (59.31 ± 9.53 mg/100mg) than **P. indicus** (55.51 ± 13.63 mg/100mg) and in brackishwater pond, **P. indicus** was having more protein content (64.68 ± 6.44 mg/100mg) than the protein level (57.97 ± 10.80 mg/100mg) of **P. monodon.** Similar differential protein levels were reported by other authors. Shaikhmahmud and Magar (1957) reported difference in protein content among **Penaeus penicillatus, Metapenaeus affinis, Parapenaeopsis stylifera, Hippolysmata ensirostris** and **Leander tenuipes.** Thomas (1982) electrophoretically separated protein fractions of abdominal muscle of four penaeid prawns. It revealed differences in protein structure in the muscles of **P. indicus, M. dobsoni, M. monoceros** and **M. affinis.** Kannupandi and Paulpandian (1975) studied the muscle proteins of **Ocypoda platytarsus, O. macrocera, Uca annulipes, U. triangularis, Thalamita crenata, Scylla serrata** and **Cardisoma carnifex.** They also found that total proteins in muscle clearly showed species specificity.

In the present study it has been found that **P. indicus** in brackishwater pond had more protein content (64.68 ± 6.44 mg/100mg) than in the marine waters (55.51 ± 13.63 mg/100mg). This might be due to onset of maturity in marine water where the prawn has to mobilize energy reserves from muscle to the gonad In the brackishwater pond all prawns were immature. Also due to availability of rich supplementary diet in culture ponds there seems to be more protein build up. Biochemical studies done by

Rajamani (1982) on soft prawns of **P. indicus** from culture ponds have revealed that under adverse ecological conditions and during shortage of food, prawns will become soft (less protein content) which is the indication of unhealthiness.

Carbohydrate level appears to be low in larvae, adults of other crustaceans and still lower in penaeid prawns (Anger **et al.**, 1983; Anger, 1986; Jacobi and Anger, 1985). In the present study the observed range of carbohydrate was from 0.60 to 3.00 mg/100mg in **M. monoceros**: 0.90 to 1.60 mg/100mg in **P. monodon**; 0.60 to 2.70 mg/100mg in **P. indicus** (marine) and from 0.68 to 1.56 mg/100mg in **P. indicus** (brackishwater). Similarly low carbohydrate was reported by various authors in other crustaceans. Johnson and Hopkins (1978) reported monthly average of carbohydrate between 1.9% and 2.5% on dry weight basis for mysid shrimp, **Taphromysis bowmani.** Du Preez and McLachlan (1983) reported a wide range of monthly average of carbohydrate level (0.63 to 21.68% on dry weight basis) in the three spot swimming crab, **Ovalipes punctatus.** Pears and Giese (1966) reported the carbohydrate range to be from 2.0 ± 0.3 to 3.4 ± 1.3% on dry weight basis in the Antarctic giant isopod **Glyptonotus antarcticus.** Ferguson and Raymont (1974) gave the carbohydrate range to be from 1.3 to 4.7% on dry weight basis for **Euphausia superba.**

Carbohydrate level did not vary between the two sexes of all the three species but found to be significantly different at inter-

specific level. In marine water, **P. indicus** contained more carbohydrate content (1.18 ± 0.48 mg/100mg) than **M. monoceros** (1.61 ± 0.68 mg/100mg); and in the case of **P. monodon** from brackishwater pond the carbohydrate content (1.31 ± 0.17 mg/100mg) was more than **P. indicus** (brackishwater) (1.22 ± 0.17 mg/100mg).

Lipid content of penaeid prawns and other crustaceans was reported by earlier workers on wet weight basis as well as on dry weight basis.

Appanna and Devadatta (1942) reported fat content as 3.08%, 2.68%, 2.08% and 2.86% on wet weight basis for **Metapenaeus** sp., **Parapenaeus** sp., **Parapenaeus** sp. and **Acetes** sp. respectively. Gopalakrishnan (1951) reported lipid content on wet weight basis for male and female prawns of **Penaeus indicus, P. carinatus** (= **P. monodon**), **Metapenaeus monoceros, M. dobsoni** off Madras to be between 0.89% and 1.15%. Gopakumar and Nair (1975) reported lipid content range from 0.7 to 1.2% on wet weight basis in the muscle of five Indian prawns. Hayashi (1976) reported total lipid content of the whole body to be between 0.9% and 3.3% on wet weight basis for 10 decapod species from different habitats. Teshima **et al.** (1977), found that lipid content varied from 1.04% (stage B) to 1.30% wet weight (stage D_2) in **P. japonicus** during moult cycle. Krishnamoorthy **et al.** (1982), found mean total lipid content in the muscle of male and female of **Penaeus aztecus** 6.82 ± 0.52 mg/g and 8.38 ± 0.31 mg/g (on wet weight basis) respectively.

Shibata (1983) reported lipid content to range from 1.11% to 3.95% on wet weight basis during fishing season. It lasts for three months (December to February). Diwan and Usha (1987) gave total lipid range in the muscle of **P. indicus** during moult cycle to range from 914.3 ± 5.54 mg/100g (stage D_4) to 1223.1 ± 19.06 mg/100g (stage D_1). Srinivasulu Reddy **et al.** (1989), in their toxic studies, reported total lipid levels as 15.19 mg/g and 14.94 mg/g on wet weight basis for control animals of **P. indicus** and **M. monoceros** respectively.

In the present study the total lipid content was expressed on dry weight basis. The total lipid content was found to range from 1.60 to 4.90% in **M. monoceros**; 2.60 to 5.10% in **P. monodon**; 1.70 to 5.80% in **P. indicus** from marine water; and 1.80 to 5.60% in **P. indicus** from brackishwater. Shaikhmahmud and Magar (1957) reported lipid content (on dry weight basis) to be between 2.9% and 5.3% for **Penaeus penicillatus, Metapenaeus affinis, Parapenaeopsis stylifera, Hippolysmata ensirostris** and **Leander tenuipes.** Barnes and Blackstock (1973) found lipid content to range between 2 and 5% (on dry weight basis) in decapod crustaceans. Pillay and Nair (1973) reported total lipid content in the abdominal muscle of female **M. affinis** to range from 1.32% to 4.84% (on dry weight basis). Maghraby **et al.** (1976), reported lipid content to range from 1.20 to 3.40% (on dry weight basis) in **M. monoceros.** The results of the present study are in agreement with those of the earlier workers.

The observed mean value of lipid content was 3.26 ± 0.79% in **M. monoceros**; 3.60 ± 0.68% in **P. monodon**; 3.74 ± 0.80% in **P. indicus** (marine); and 3.83 ± 0.80 in **P. indicus** (brackishwater). These values are in agreement with those given by Colvin (1976) who found lipid content as 3.94% (on dry weight basis) in cultured **P. indicus**. The value was found to increase up to 6% when prawns were fed with supplementary feed constituted by seed oils. However, Clarke and Wickins (1980) reported high lipid content (6.79%) (on dry weight basis) in the male prawns of **P. merguiensis** fed with animal food. The high lipid content is of the whole animal, whereas in the present study abdominal muscle only was used (Hepatopancreas and gonad were excluded).

No significant difference in the lipid content between sexes of all the three species was found. Similar trend was also found in Penaeus **indicus, P. carinatus, Metapenaeus monoceros** and **M. dobsoni** by Gopalakrishnan (1951).

Lipid content varied significantly ($P < 0.001$) between **M. monoceros** (3.26 ± 0.79 mg/100mg) and **P. indicus** (3.74 ± 0.80 mg/100mg) in marine water. Similar type of lipid content variation at interspecies level was found by Shaikmahmud and Magar (1957) among **Penaeus penicillatus, Metapenaeus affinis, Parapenaeopsis stylifera, Hippolysmata ensirostris** and **Leander tenuipes.**

In immature prawns of **P. indicus** and **P. monodon** from brackishwater ponds, it is noticed that carbohydrate and lipid

accumulated as a function of size and weight. On the other hand no relation is found between protein content and size and weight. Similar trend was also observed in penaeid prawns and other crustaceans by earlier workers. In the euphausid **Meganyctiphanes**, lipid content increased with body weight (Mauchline and Fisher, 1969). Raymont **et al.** (1971), found increasing lipid content with increase in body size in **Euphausia superba** but there was no relation between protein and body size. Ferguson and Raymont (1974) reported increasing lipid content with body size and decrease of protein, carbohydrate with body weight in Antarctic krill, **Euphausia superba.** Krishnamoorthy **et al.** (1982), found that muscle cholesterol increased linearly with the weight of female prawns of **Penaeus azetecus** when animals are fed with animal diet. However, Clarke (1977) reported that total lipid content is negatively correlated with fresh weight in immature prawns of **Chorismus antarcticus.**

In the present study good correlation existed between biochemical constituents of body and condition of **P. monodon** and **P. indicus** (brackishwater). Of the different muscle constituents, water and lipid showed very good correlation with condition factor of the prawn. It is followed by protein and carbohydrate. Literature on penaeid prawns does not throw light on these aspects. Since lipid and carbohydrate are low, the available energy reserve in the muscle appears to be protein only. Protein is low in

calorific value when compared to lipid. During adverse ecological conditions and under stress of starvation, the energy demand is met by protein affecting the condition of the prawn. Similar study on young **Tilapia rendalli** (Caulton and Bursell, 1977) showed good correlations between body constituents and condition of the fish. Their study revealed that water content is directly proportional to the condition (showing linear relationship). Curvilinear relationship between protein and fat on the one hand with condition factor on the other was also observed. Rajamani (1982) also found more non protein nitrogen in soft prawns of **P. indicus** (brackishwater pond) under adverse conditions. His assumption is that non protein nitrogen accumulates when protein is catabolised during adverse ecological conditions. His experiments with soft prawns showed that prawns fed with protein rich food recovered from 'soft' condition and the prawns fed with carbohydrate rich food have not recovered from soft condition. Torres (1973) also found increase of free aminoacid levels in the abdominal muscle of **Penaeus kerathurus** during starvation. He also suggested that the increase of free aminoacid is due to catabolism of abdominal muscle protein. The study made by Anger (1986) on the spider crab, **Hyas araneus** larvae also revealed that protein and lipid serve as metabolites during starvation but the prawn derives more energy from protein oxidation. From this study it may be concluded that in **P. monodon** and **P. indicus** the most available energy reserve is

protein and the protein content in the muscle is an index of the health of the prawn under culture (brackishwater).

Protein is a major constituent of the muscle in P. **monodon** and P. **indicus** which are known to prefer animal matter than vegetable matter. Hall (1962) made studies on the feeding habits of prawns from brackishwater ponds and stated that P. **monodon** and P. **indicus** prefer large crustaceans.

As P. **indicus** and P. **monodon** prefer protein rich food, prawn production can be increased from brackishwater ponds by formulating supplementary feed which contain a high proportion of protein than the other ingredients.

Table 12. Comparison of muscle constituents between male and female of **M.monoceros**, **P.monodon** and **P.indicus**

Parameter		M. monoceros			P. monodon			P. indicus (marine)			P.indicus (brackishwater)		
		Male	Female	S	Male	Female	S	Male	Female	S	Male	Female	S
Carapace length (mm)	R	25-37	23-50		25-43	25-40		30-38	28-44		21-32	19-34	
Weight (g)	R	7.4-28.8	8.3-58.8		8.5-38.4	8.3-29.0		19.0-40.0	13.3-50.5		7.3-19.6	5.0-21.5	
Water (%)	R	61.40-76.10	65.90-81.90		72.20-79.27	72.71-80.66		67.78-75.25	68.82-77.65		70.86-78.30	70.80-79.30	
	M±S.D.	72.09±2.25	72.20±2.63	N.S.	76.72±1.81	76.41±2.34	N.S.	71.42±1.70	72.17±2.08	N.S.	74.83±1.64	74.82±1.94	N.S.
	N	53	63		21	13		22	25		16	28	
Protein (mg/100 mg)	R	36.00-74.00	42.00-80.00		45.00-86.00	36.00-67.00		36.00-78.00	36.00-78.00		53.00-70.00	53.00-74.00	
	M±S.D.	57.30±9.36	62.50±9.44	P< 0.01	60.80±10.89	53.38±9.29	N.S.	51.45±11.96	59.08±14.23	P< 0.02	63.18±5.72	65.53±6.76	N.S.
	N	53	63		21	13		22	25		16	28	
Carbonydrate (mg/100 mg)	R	0.90-2.70	0.60-3.00		0.90-1.60	1.08-1.56		0.60-2.10	0.50-2.70		1.04-1.56	0.68-1.56	
	M±S.D.	1.56±0.65	1.66±0.70	N.S.	1.32±0.19	1.32±0.12	N.S.	1.09±0.37	1.23±0.56	N.S.	1.26±0.13	1.20±0.19	N.S.
	N	53	63		21	13		22	25		16	28	
Lipid (mg/100 mg)	R	1.80-4.90	1.60-4.50		2.60-4.20	2.70-5.10		1.70-5.40	2.10-5.80		2.20-5.60	1.80-5.60	
	M±S.D.	3.32±0.62	3.20±0.90	N.S.	3.72±0.70	3.43±0.62	N.S.	3.73±0.74	3.76±0.87	N.S.	3.74±0.81	3.89±0.80	N.S.
	N	53	63		21	13		22	25		16	28	

S = significant level; R = range; M±S.D. = mean value±standard deviation; N = number of individual samples analysed; N.S. = not significant at probability 0.05 level

Table 13. Intra and interspecific comparison of muscle constituents of **M. monoceros, P. monodon** and **P. indicus.** Values expressed as mean ± standard deviation. Number of samples analysed is given in parentheses.

Parameter	**M.monoceros**	**P.indicus** (marine)	S	**P.monodon**	**P.indicus** (brackishwater)	S	**P.indicus** (marine)	**P.indicus** (brackishwater)	S
Carapace length range (mm)	23-50	28-44		25-43	19-34		28-44	19-34	
Weight range (g)	7.4-58.8	13.3-50.5		8.3-38.4	5.0-21.5		13.3-50.5	5.0-21.5	
Water (%)	72.13±2.50 (116)	71.78±1.94 (47)	N.S.	76.60±2.00 (34)	74.82±1.82 (44)	P < 0.001	71.82±1.93 (47)	74.82±1.82 (44)	P < 0.001
Protein (mg/100 mg)	59.31±9.53 (116)	55.51±13.63 (47)	P < 0.05	57.97±10.80 (34)	64.68±6.44 (44)	P < 0.01	55.51±13.63 (47)	64.68±6.44 (44)	P < 0.001
Carbohydrate (mg/100 mg)	1.61±0.68 (116)	1.18±0.48 (47)	P < 0.001	1.31±0.17 (34)	1.22±0.17 (44)	P < 0.05	1.18±0.48 (47)	1.22±0.17 (44)	N.S.
Lipid (mg/100 mg)	3.26±0.79 (116)	3.74±0.80 (47)	P < 0.001	3.60±0.68 (34)	3.83±0.80 (44)	N.S.	3.74±0.80 (47)	3.83±0.80 (44)	N.S.

S = significant level; N.S. = not significant at probability 0.05 level

Table 14. Correlation coefficients of muscle characteristics in relation to the carapace length of **M.monoceros, P.monodon** and **P.indicus.**

Character	M.monoceros			P.monodon			P.indicus(marine)			P.indicus(brackishwater)		
	n	r	s	n	r	s	n	r	s	n	r	s
Water	116	0.0038	N.S.	34	0.2113	P < 0.05	47	0.2120	P < 0.05	44	0.1324	N.S.
Protein	53*	0.1110*	N.S.*	34	0.1765	N.S.	22*	0.5327*	P<0.02*	44	0.0054	N.S.
	63@	0.0321@	N.S.@				25@	0.0406@	N.S.@			
Carbohydrate	116	-0.0700	N.S.	34	0.4923	P<0.001	47	0.2569	P<0.02	44	0.3700	P<0.001
Lipid	116	0.0356	N.S.	34	0.7018	P<0.001	47	0.0583	N.S.	44	0.3030	P < 0.01

n = number of individual prawn samples analysed; r = correlation coefficient; s = significant level; N.S. = not siginficant at 0.05 probability level; * = male; @ = female

Table 15. Correlation coefficients of muscle characteristics in relation to the weight of **M.monoceros, P.monodon** and **P.indicus**

Character	M. monoceros			P. monodon			P. indicus(marine)			P.indicus(brackishwater)		
	n	r	s	n	r	s	n	r	s	n	r	s
Water	116	0.0793	N.S.	34	0.1149	N.S.	47	0.3146	P< 0.01	44	0.1480	N.S.
Protein	53*	0.0422*	N.S.*	34	0.0220	N.S.	22*	0.6473*	P<0.01*	44	0.1750	N.S.
	63@	0.2304@	N.S.@				25@	0.6419@	P < 0.001@			
Carbohydrate	116	0.1887	N.S.	34	0.4384	P< 0.001	47	0.2337	P < 0.05	44	0.3188	P < 0.01
Lipid	116	0.0312	N.S.	34	0.6290	P< 0.001	47	0.0248	N.S.	44	0.5298	P < 0.001

n = number of individual prawn samples analysed; r = correlation coefficient; s = significant level; N.S. = not significant at 0.05 probability level; * = male; @ = female

Table 16. Correlation coefficients of muscle characteristics in relation to condition factor of **P.monodon** (standard animal, 31.67 mm CL) and **P.indicus** (standard animal, 26.94 mm CL) from brackishwater pond

Parameter	P. monodon			P. indicus		
	n	r	Significant level	n	r	Significant level
Water	34	0.9924	$P < 0.001$	44	0.9756	$P < 0.001$
Protein	34	0.5652	$P < 0.001$	44	0.4336	$P < 0.01$
Carbohydrate	34	0.5552	$P < 0.001$	44	0.5517	$P < 0.001$
Lipid	34	0.6940	$P < 0.001$	44	0.5717	$P < 0.001$

n = number of individual prawn samples analysed; r = correlation coefficient

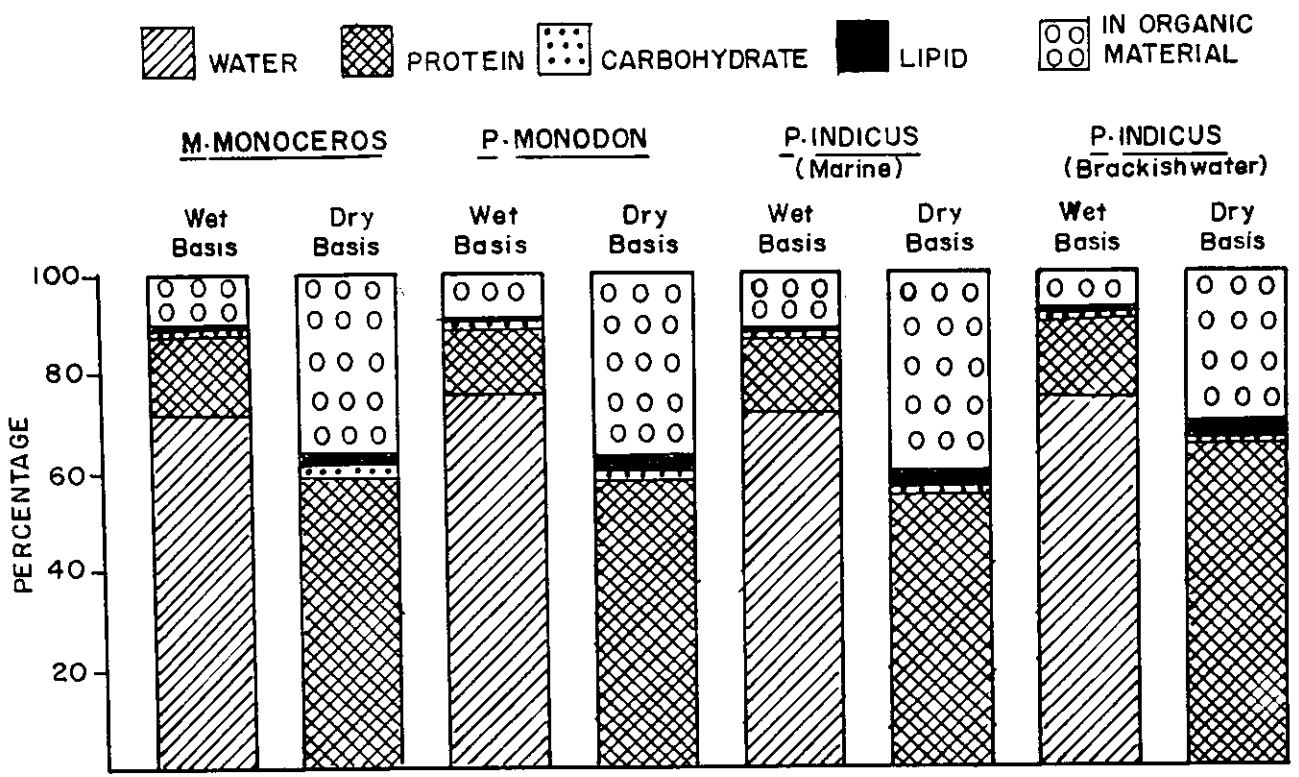

Fig. 11 - Mean Muscle Composition on Wet weight basis and Dry weight basis of M. monoceros, P. monodon P. indicus (Marine) and P. indicus (Brackishwater)

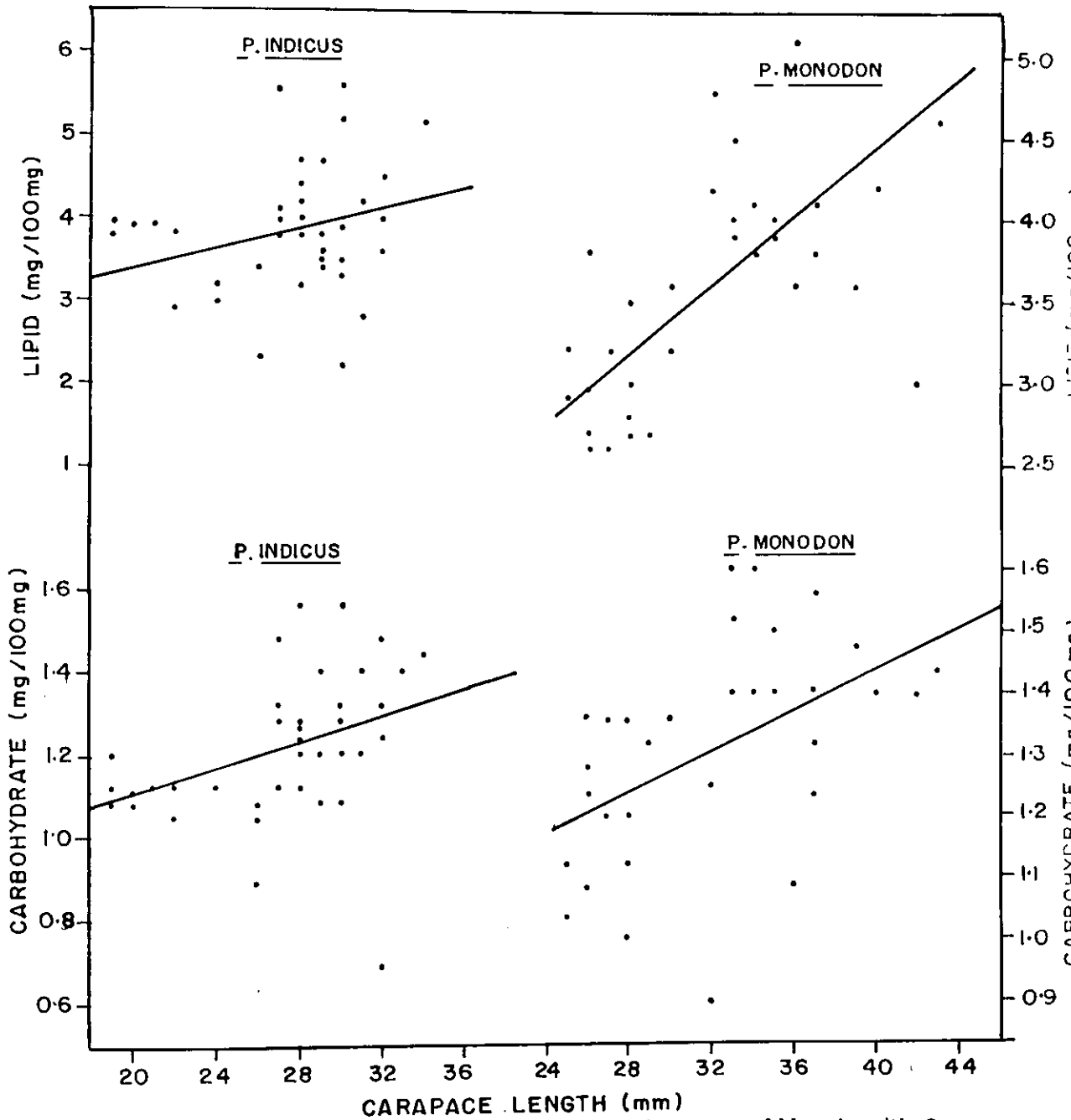

Fig.12. Relationships of Carbohydrate and Lipid Contents of Muscle with Carapace Length of P. monodon and P. indicus in Brackishwater Pond.

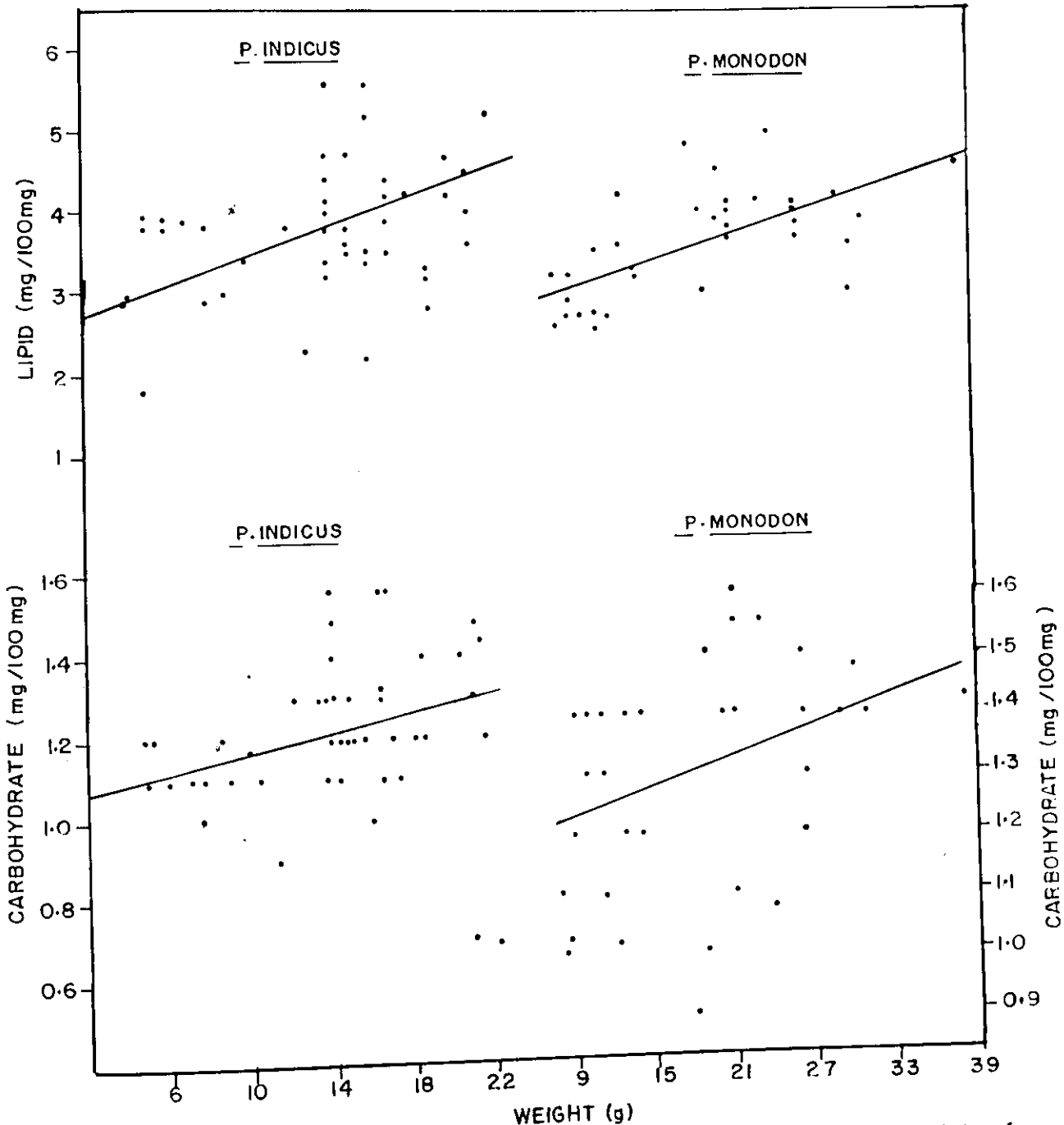

Fig.13. Relationships of Carbohydrate and Lipid Contents of Muscle with Weight of P. monodon and P. indicus from Brackishwater

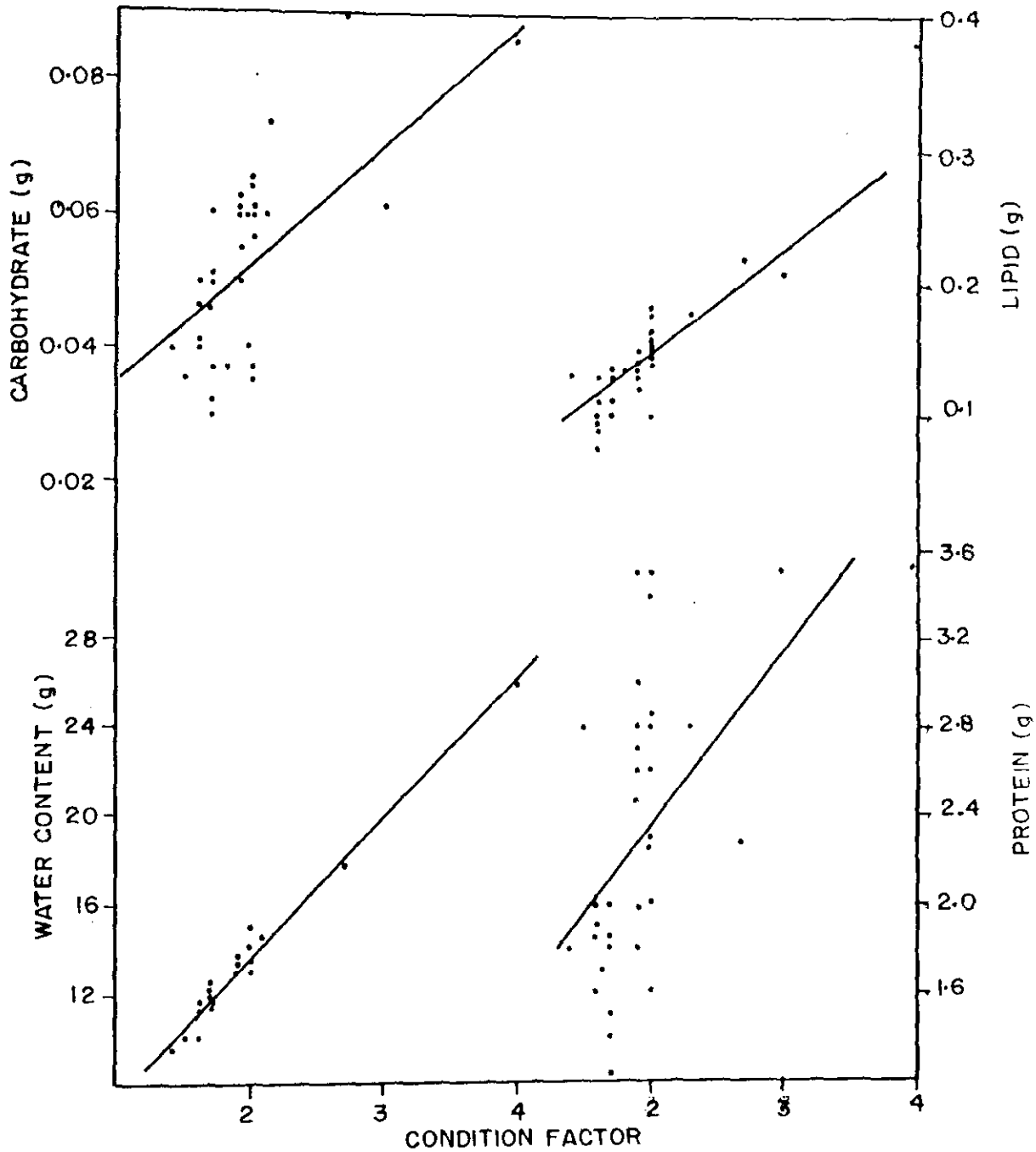

Fig 14 Relationship between mass of Water, Protein, Carbohydrate and Lipid present in size specific P. monodon of 31·6737mm in Carapace Length but of varying Condition (N = 34)

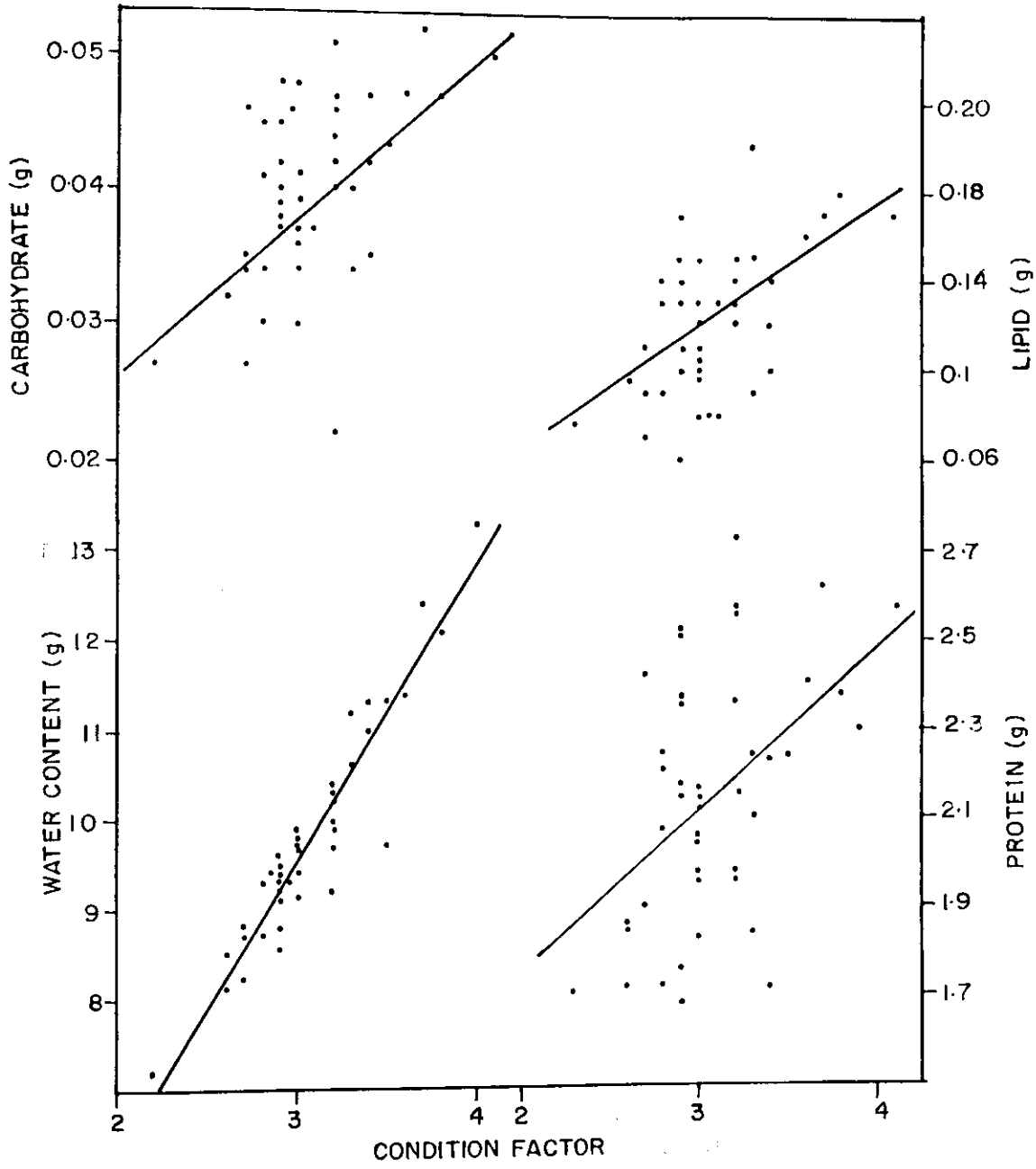

Fig.15. Relationship between mass of Water, Protein, Carbohydrate and Lipid present in size specific P. indicus of 26·9463 mm in Carapace Length but of varying Condition (N = 44)

CHAPTER 5

INTRA AND INTER-RELATIONSHIPS OF HAEMOLYMPH AND MUSCLE CHARACTERISTICS

INTRODUCTION

Various physiological changes that undergo during the life cycle of prawns, reflect in the haemolymph and muscle characteristics. Either positive or negative correlations are found between haemolymph characteristics and muscle characteristics which depend upon mobilization or accumulation of organic reserves in the muscle. During adverse ecological conditions and starved conditions muscle protein is oxidised to meet the energy requirement. During maturation process, organic reserves are mobilized from storage organs like hepatopancreas and muscle to gonad. During the process of starvation and maturation negative correlation is found between muscle constituents and haemolymph constituents.

Among haemolymph constituents and muscle constituents, different degrees of relationships are usually found between one haemolymph characteristic and another; between one muscle characteristic and another; and between muscle characteristics and haemolymph characteristics. In haemolymph positive correlation is usually found between protein and copper because copper is bound with haemocyanin; while negative correlation is found between calcium and potassium.

In muscle, negative correlation is found between water content and lipid content because the former is less than latter when lipid accumulates.

Studies on the relationship between protein and copper in the haemolymph of crustaceans were made by Arumugam and Ravindranath (1980, 1983); Kerr (1969); Djangmah (1970); and Wieser (1965).

In crustaceans, protein-calcium relation was studied by Sitaramaiah and Krishnan (1965); Kannan and Ravindranath (1980, 1981).

The relationship between water and lipid levels of muscle was explaind by Clarke (1977) in **Chorismus antarcticus.**

In the present study to elucidate the intra and inter-relationships of haemolymph and muscle characteristics, the data from haemolymph samples and muscle samples of **M. monoceros, P. monodon** and **P. indicus** was processed and analysed.

RESULTS

Intra-relationships of haemolymph characteristics

In the present study, relationships between all the five haemolymph characteristics namely, protein, carbohydrate, calcium, potassium and copper content of the different species, namely, **M. monoceros, P. monodon** and **P. indicus** were examined statistically. Those relationships of statistical significance were examined more closely. The five characters gave ten combinations of interrelationships for each species. Number of specimens used, values of correlation coefficient and their statistical significance are given in table 17. Samples of the two sexes were pooled in this study.

M. monoceros

Protein showed significant +ve correlation($P < 0.01$) with copper. The relationships of protein with the remaining parameters were not significant.

Carbohydrate showed significant ($P < 0.01$) negative correlation with calcium whereas no significant relationship was found with the other parameters.

Though calcium showed negative correlation with potassium and copper, the relationships were not significant statistically.

Potassium showed significant ($P < 0.02$) negative correlation with copper.

P. monodon

Protein showed significant correlations with the other parameters. It is positively correlated with carbohydrate ($P < 0.05$), potassium ($P < 0.001$) and copper ($P < 0.001$); and negatively correlated with calcium ($P < 0.001$).

Carbohydrate showed significant ($P < 0.001$) positive correlation with potassium and copper but the correlation with calcium was not significant.

Significant ($P < 0.01$) negative relationship was found between calcium and potassium and no relationship was found between calcium and copper.

Potassium showed positive and significant ($P < 0.001$) correlation with copper.

P. indicus (marine water)

Protein showed positive significant relationships with carbohydrate ($P < 0.01$) and copper ($P < 0.02$); while no significant relationships were found with calcium and potassium.

No significant relationships were found between carbohydrate and the other three remaining parameters, namely calcium, potassium and copper.

Calcium showed negative correlation with potassium and positive correlation with copper but statistically not significant.

No significant relationship was found between potassium and copper.

P. indicus (brackishwater)

Protein showed significant negative and postive relationships with calcium ($P < 0.001$) and potassium ($P < 0.001$) respectively. The relationships of protein with the other parameters were not significant.

Carbohydrate showed significant ($P < 0.001$) -ve correlation with copper and the relationships with other parameters were not significant.

Significant ($P < 0.01$) negative correlation was found between calcium and potassium whereas the relationship between calcium and copper was not significant.

No relationship was found between potassium and copper.

The present study showed the following relationships:

1. In the marine environment, the positive relationship between protein and calcium of **M. monoceros** and **P. indicus** was not significant; whereas in **P. monodon** and **P. indicus** from brackishwater pond, the same relationship was negative and significant. The relationship between protein and calcium in **M. monoceros, P. monodon** and **P. indicus** is depicted in figure 16.

2. Correlation between protein and potassium of **M. monoceros** and **P. indicus** in the marine environment was not significant but was negative. In the brackishwater ponds the same relationship in **P. monodon** and **P. indicus** was significant and positive (Fig. 17).

3. Significant positive correlation was found between protein and copper in all the three species (not significant in **P. indicus** of brackishwater pond) (Fig. 18).

4. Negative correlation was found between calcium and potassium in all the three species in both the environments (Fig. 19).

Intra-relationships of muscle characteristics

All the four muscle characteristics namely, water, protein, carbohydrate and lipid contents were correlated with each other for all three species. On the whole six combinations were used for each species and correlation coefficient value, number of samples used and level of significance between each combination are given in table 18.

M. monoceros

Water showed significant positive ($P < 0.01$) correlation with carbohydrate and negative correlation with lipid ($P < 0.02$). No significant relationship was found between water and protein.

Protein was negatively correlated with carbohydrate and lipid but no relationship was significant.

Carbohydrate showed significant positive correlation ($P < 0.01$) with lipid.

P. monodon

No correlation was found between water and other parameters.

Protein was positively correlated with lipid ($P < 0.05$) but the relationship with carbohydrate was not significant.

No significant correlation was found between carbohydrate and lipid.

P. indicus (marine water)

Water had not shown significant correlation with the other parameters.

Protein was positively correlated with carbohydrate ($P < 0.01$) and no relation was found between protein and lipid.

Carbohydrate had not shown significant relationship with lipid.

P. indicus (brackishwater)

Though water showed negative correlation with all the other parameters, only the relationship between water and lipid was significant.

Protein showed positive significant correlation ($P < 0.05$) with carbohydrate and no relation was found between protein and lipid.

No correlation was found between carbohydrate and lipid.

From the study of intra-relationships of muscle characteristics the following observation was made:

The relationship between water and lipid was negative in all the three species but only significant in **M. monoceros** and **P. indicus** (brackishwater) and not significant in **P. monodon** and **P. indicus** (marine). The relationship between water and lipid of all three species is shown in figure 20.

Inter-relationships between haemolymph characteristics and muscle characteristics:

Correlations were worked out between haemolymph characteristics and muscle characteristics. Correlation coefficients were calculated for the relationship between muscle protein and haemolymph protein; muscle carbohydrate and haemolymph carbohydrate (Table 19).

M. monoceros

Significant negative correlation was found between haemolymph protein and muscle protein. ($P < 0.05$).

Haemolymph carbohydrate showed significant ($P < 0.01$) negative relationship with muscle carbohydrate.

P. monodon

No significant correlation was found between haemolymph characteristics and muscle characteristics.

P. indicus (marine water)

Haemolymph protein showed significant ($P < 0.001$) negative correlation with muscle protein.

Significant ($P < 0.02$) negative correlation was found between muscle carbohydrate and haemolymph carbohydrate.

P. indicus (brackishwater)

No significant correlation was found between haemolymph protein and muscle protein.

Carbohydrate of haemolymph had positive significant ($P<0.01$) correlation with muscle carbohydrate.

From the study of inter-relationships between haemolymph characteristics and muscle characteristics it has been found that negative correlation was found between haemolymph protein and muscle protein in **M. monoceros** and **P. indicus** (marine); positive correlation between haemolymph protein and muscle protein in **P. monodon** and **P. indicus** (brackishwater) (Fig. 21).

DISCUSSION

In decapod crustaceans 80-95% of the haemolymph protein is haemocyanin (Weiser, 1965). Crustacean haemocyanin contains 0.17% of copper (Mangum, 1983). Ionic copper in the haemolymph is negligible because ionic copper is regulated by hepatopancreas (Djangmah, 1970; Arumugam and Ravindranath, 1983). Since ionic copper in the haemolymph is monitored periodically, existing copper is protein bound copper (with haemocyanin). So, copper level in haemolymph varies with the haemolymph protein level. Relationship between protein and copper of haemolymph in decapod crustaceans was reported by several authors. Kerr (1969) reported that significant increase in protein and copper levels in the haemolymph of female blue crab, **Callinectes sapidus** during oocyte maturation. In the same study, copper followed the same trend as protein. Arumugam and Ravindranath (1980) found that haemolymph copper is bound with protein and ionic or free copper is absent in the haemolymph of **Scylla serrata.** Djangmah (1970) observed depletion of protein as well as copper levels in the blood of **Crangon vulgaris** during starvation. In the present study the observed correlation between protein and copper contents in the haemolymph of **M. monoceros, P. monodon** and **P. indicus** is in accordance with the above said observations in crustaceans made by earlier workers.

In crustacean haemolymph, calcium exists in two states free calcium and bound calcium. Bound calcium may be bound to

proteins, lipids and acidic mucosubstances (Kannan and Ravindranath, 1981). Sitaramaiah and Krishnan (1965) found bound calcium to be in between 4.1% and 10.4% in the haemolymph of **Emerita asiatica**, during the different stages of moult cycle. Kannan and Ravindranath (1980) reported that free calcium ranges from 5.56% to 20.6% of total calcium in the haemolymph of **Scylla serrata**. In the present study, significant negative correlation was observed between protein and calcium of haemolymph in **P. monodon** and **P. indicus** in brackishwater pond, whereas in **M. monoceros** and **P. indicus** in marine water the same relation was positive but not significant. This may be due to the negative correlation between protein and free calcium as free calcium is more in the haemolymph of **P. monodon** and **P. indicus** due to application of lime (250 kg/ha/crop) in brackishwater pond. In **M. monoceros** and **P. indicus** the positive correlation was perhaps due to a high content of bound calcium. Kannan and Ravindranath (1980) also found variation of free and bound calcium with protein having negative and positive correlations respectively in **Scylla serrata** during time of a day.

Positive significant correlation was found between protein and potassium in the haemolymph of **P. monodon** and **P. indicus** in brackishwater pond and the same relation was negative but not significant in **M. monoceros** and **P. indicus** in marine water. This was perhaps due to existing negative correlation between calcium

and potassium levels in the haemolymph of all the three species found in the present study.

The relationship between water content and lipid content of muscle was negative. This was due to reduction of water level when lipid content accumulated in the muscle. However, -ve trend was observed by Clarke (1977) in **Chorismus antarcticus.**

Significant negative correlation was found between haemolymph protein and muscle protein in **M. monoceros** and **P. indicus** (marine) whereas the same relation was positive but not significant in **P. monodon** and **P. indicus** in brackishwater pond. This may be due to mature prawns of **M. monoceros** and **P. indicus** in marine water and immature prawns of **P. monodon** and **P. indicus** in brackishwater pond.

During maturation process protein is mobilized from muscle to ovary or testis through haemolymph. Asokan and George (1984) also found depletion of muscle protein in female prawns of **P. indicus** during ovarian development. Vijayakumaran (1990) also found depletion of protein in the muscle during maturation process in **P. indicus.**

Table 17. Correlation coefficients between different haemolymph characteristics of **M.monoceros, P.monodon** and **P.indicus**

S.No.	Parameter X	Parameter Y	**M.monoceros**			**P.monodon**			**P.indicus**(marine)			**P.indicus**(brackishwater)		
			n	r	s	n	r	s	n	r	s	n	r	s
1.	Protein	Carbohydrate	50	-0.2200	N.S.	99	0.2269	P< 0.05	24	0.5502	P< 0.01	52	-0.0719	N.S.
		Calcium	44	0.0182	N.S.	91	-0.4365	P< 0.001	16	0.1240	N.S.	49	-0.5307	P< 0.001
		Potassium	44	-0.1532	N.S.	91	0.5597	P < 0.001	16	-0.0931	N.S.	49	0.5474	P<0.001
		Copper	26	0.5198	P<0.01	91	0.3612	P<0.001	16	0.5762	P<0.02	49	0.2433	N.S.
2.	Carbohydrate	Calcium	33	-0.4659	P<0.01	83	0.0138	N.S.	16	0.4249	N.S.	49	0.1490	N.S.
		Potassium	33	0.2279	N.S.	83	0.3799	P<0.001	16	0.2143	N.S.	49	-0.2316	N.S.
		Copper	26	0.3425	N.S.	83	0.4228	P<0.001	16	0.2519	N.S.	49	-0.5366	P<0.001
3.	Calcium	Potassium	44	-0.2615	N.S.	91	-0.3267	P < 0.01	16	-0.014	N.S.	49	-0.3590	P< 0.01
		Copper	26	-0.3107	N.S.	91	0.1518	N.S.	16	0.2480	N.S.	49	-0.0783	N.S.
4.	Potassium	Copper	26	-0.4605	P < 0.02	91	0.3608	P<0.001	16	0.2690	N.S.	49	0.2300	N.S.

n = number of samples analysed; r = correlation coefficient; s = significant level; N.S. = not significant at 0.05 probability level

Table 18. Correlation coefficients between different muscle characteristics of **M.monoceros, P.monodon** and **P. indicus**

S.No.	Parameter X	Parameter Y	**M.monoceros**			**P.monodon**			**P.indicus**(marine)			**P.indicus**(brackishwater)		
			n	r	s	n	r	s	n	r	s	n	r	s
1.	Water	Protein	116	0.0229	N.S.	34	0.2258	N.S.	47	0.2813	N.S.	44	-0.0981	N.S.
		Carbohydrate	116	0.4802	P<0.001	34	0.1106	N.S.	47	0.0944	N.S.	44	-0.0757	N.S.
		Lipid	116	-0.2385	P<0.02	34	-0.2043	N.S.	47	-0.0406	N.S.	44	-0.3111	P<0.05
2.	Protein	Carbohydrate	116	-0.1165	N.S.	34	-0.1928	N.S.	47	0.4183	P<0.01	44	0.3063	P<0.05
		Lipid	116	-0.1338	N.S.	34	0.3476	P<0.05	47	-0.0203	N.S.	44	0.0236	N.S.
3.	Carbohydrate	Lipid	116	0.2589	P<0.01	34	0.0839	N.S.	47	0.0860	N.S.	44	0.2516	N.S.

n = number of samples analysed; r = correlation coefficient; s = significant level; N.S. = not significant at 0.05 probability level

Table 19. Correlation coefficients between different haemolymph characteristics and muscle characteristics of **M.monoceros, P.monodon** and P.indicus

S.No.	Parameter X	Parameter Y	**M. monoceros** n	r	s	**P. monodon** n	r	s	**P. indicus** (marine) n	r	s	**P. indicus** (brackishwater) n	r	s
1.	Haemolymph Protein	Muscle Protein	107	-0.2057	P < 0.05	34	0.0543	N.S.	31	-0.7008	P < 0.001	44	0.1591	N.S.
2.	Haemolymph carbohydrate	Muscle Carbohydrate	50	-0.4251	P < 0.01	34	-0.2887	N.S.	24	-0.4553	P < 0.02	44	0.5567	P < 0.001

n = number of samples analysed; r = correlation coefficient; s = significant level; N.S. = not significant at 0.05 probability level

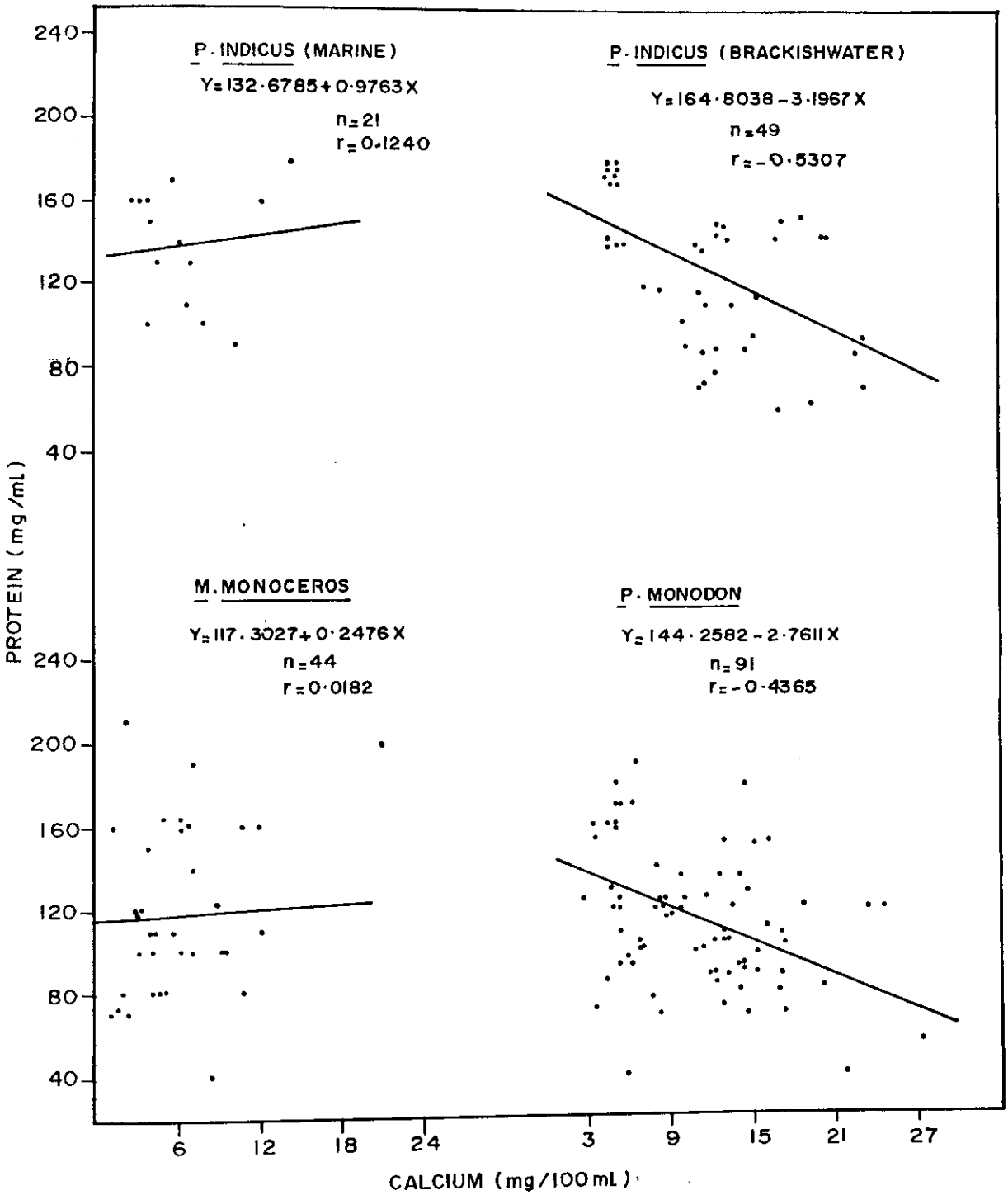

Fig-16. Relationship between Calcium Content and Protein Content in the Heamolymph of M monoceros, P monodon and P indicus

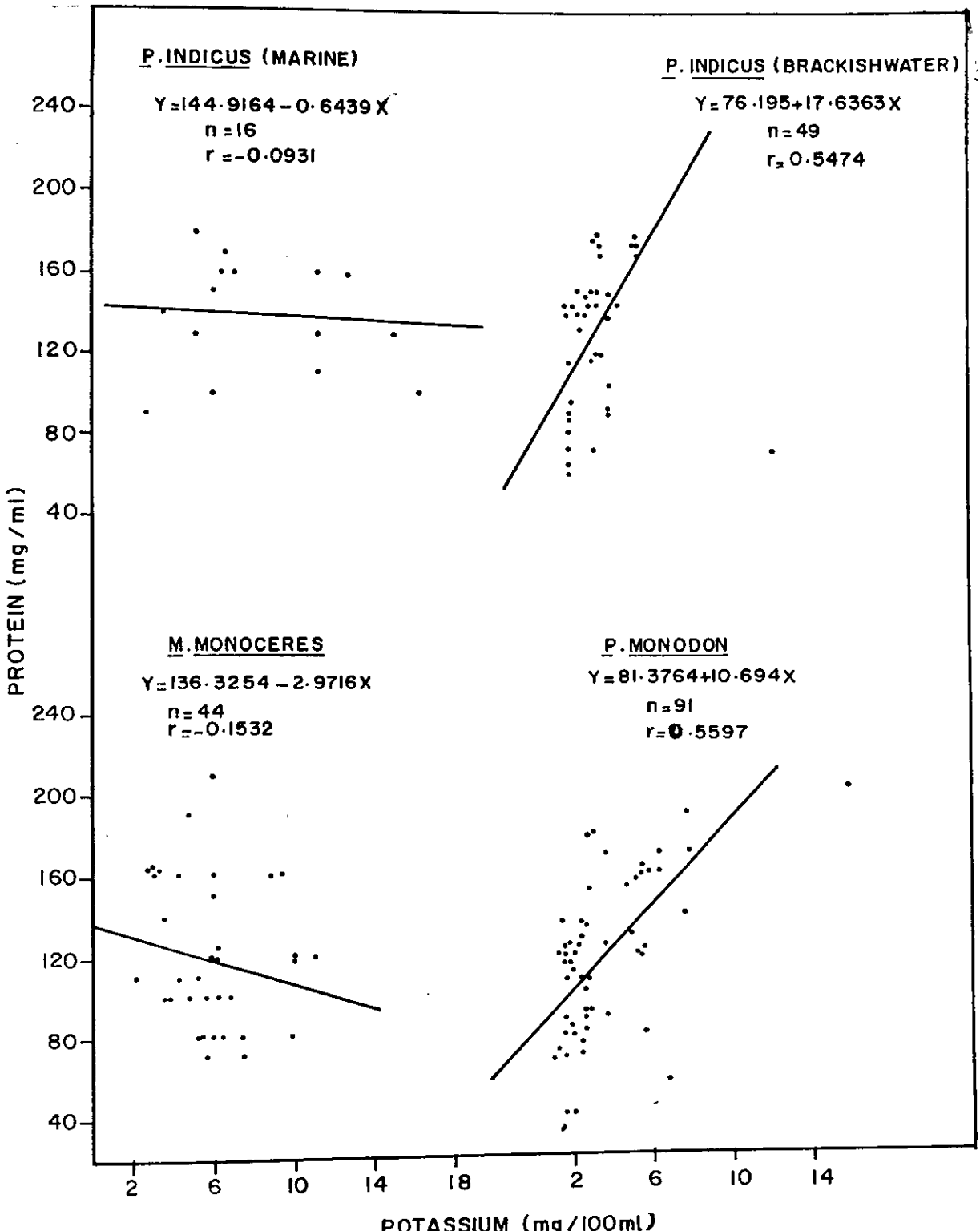

Fig.17. Relationship between Potassium Content and Protein Content in the Heamolymph of M. monoceros, P. monodon and P. indicus

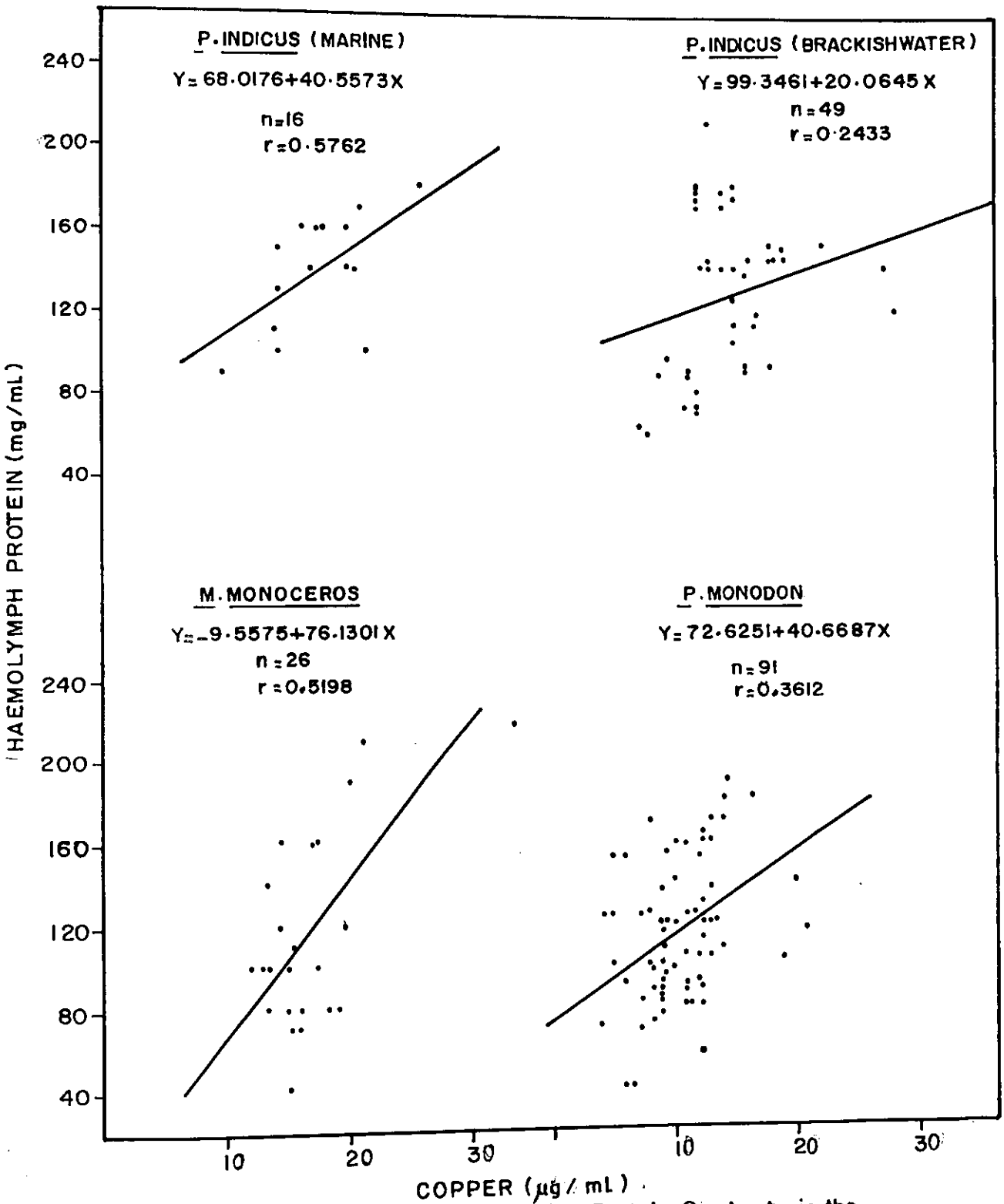

Fig.18. Relationship between Copper and Protein Contents in the Heamolymph of M. monoceros, P. monodon and P. indicus

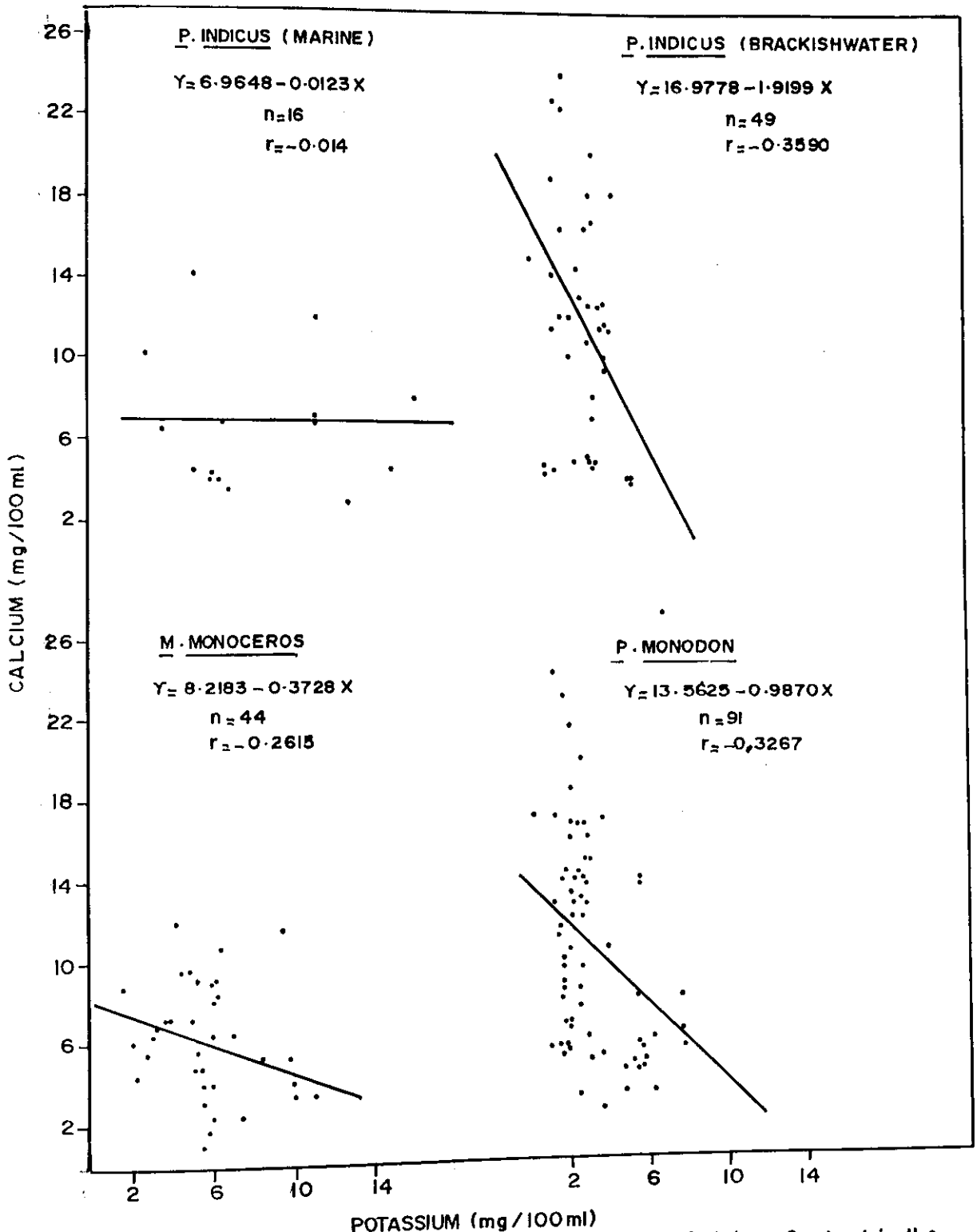

Fig.19. Relationship between Potassium Content and Calcium Content in the Heamolymph of M. monoceros, P. monodon and P. indicus

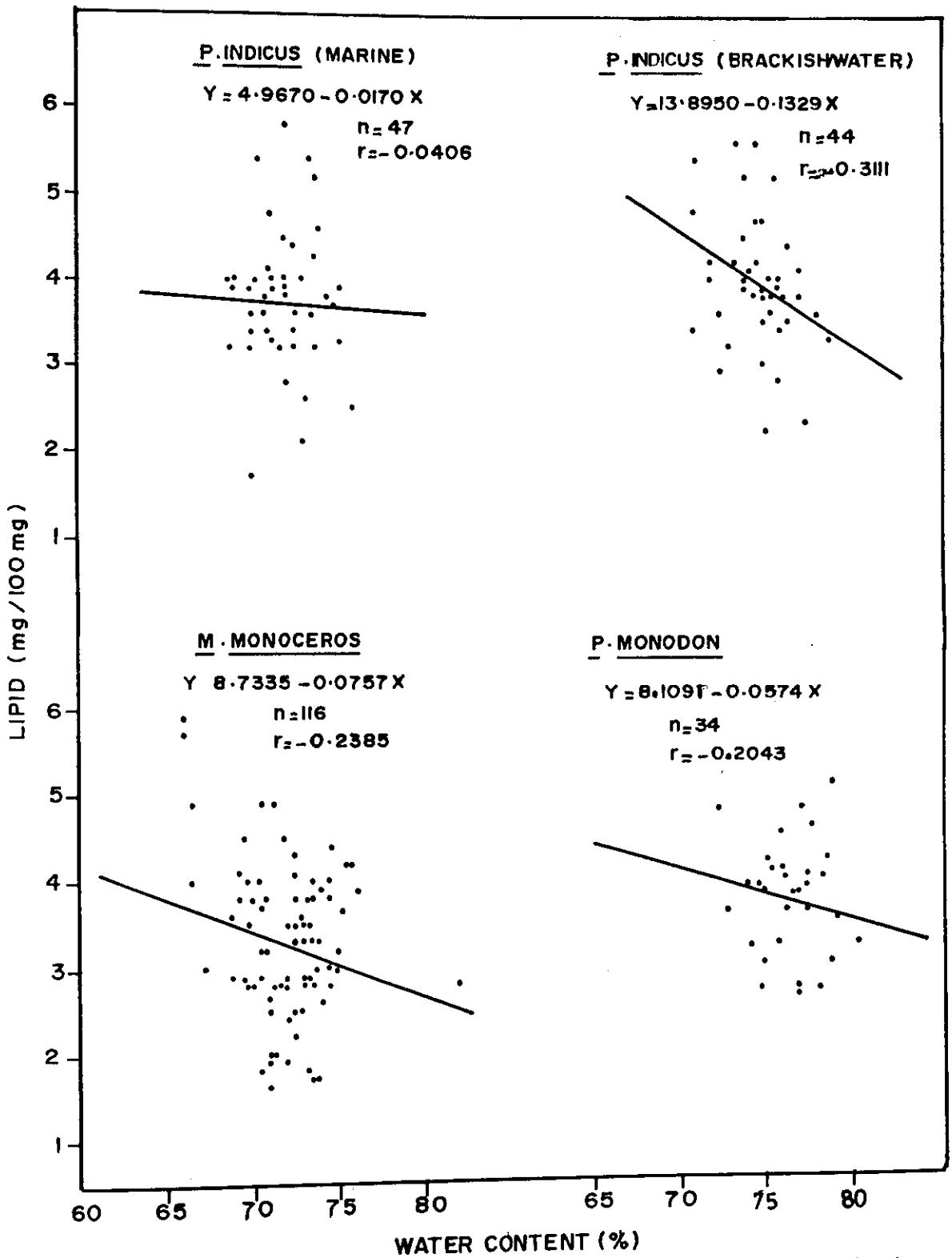

Fig. 20. Relationship between Water Content and Lipid Content in the Muscle of M. monoceros, P. monodon and P. indicus

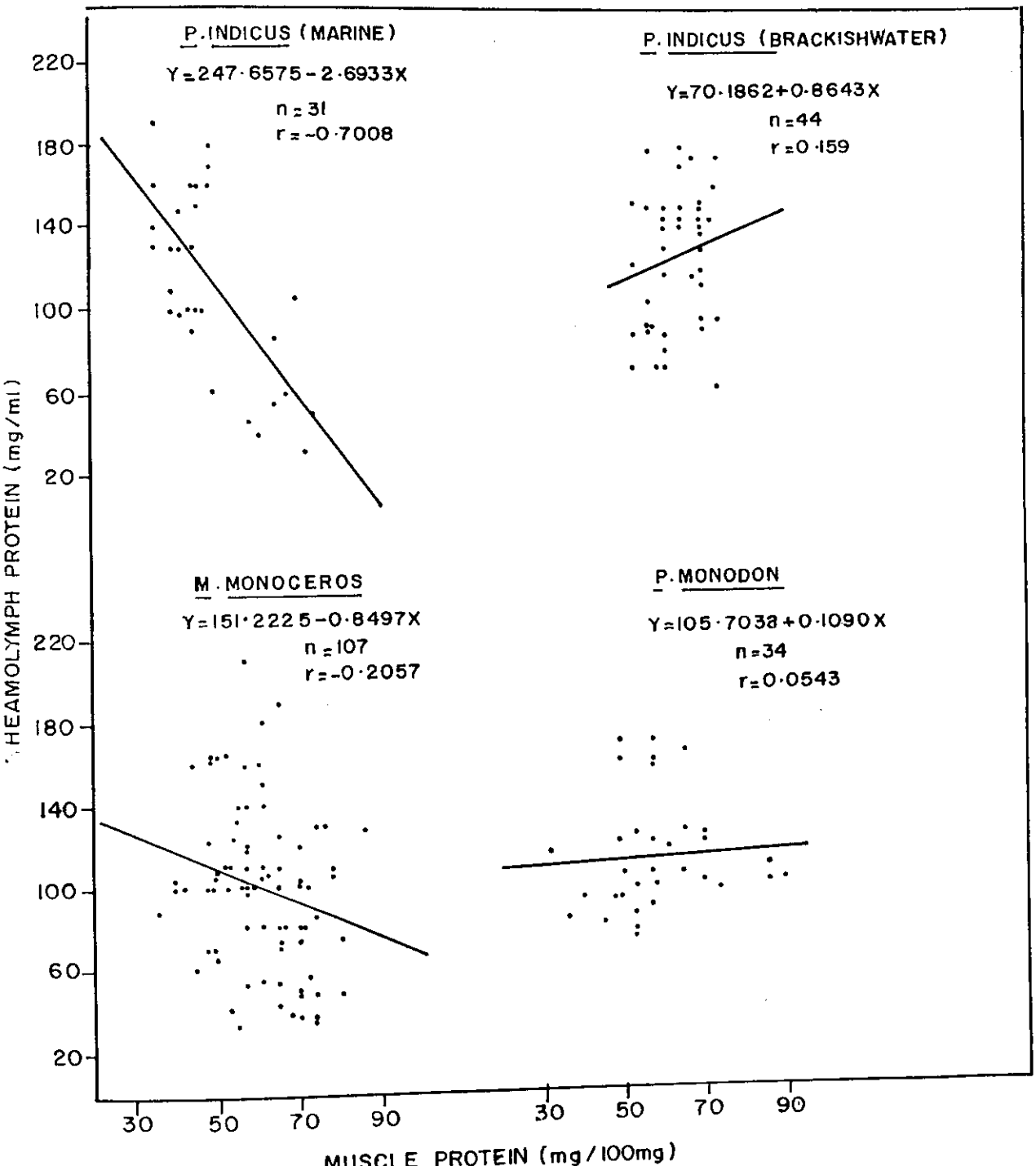

Fig.21. Relationship between Muscle Protein and Heamolymph Prptein of M.monoceros, P.monodon and P.indicus

CHAPTER 6

VARIATION IN BIOCHEMICAL CONSTITUENTS OF HAEMOLYMPH, MUSCLE AND GONAD DURING OVARIAN DEVELOPMENT

INTRODUCTION

In invertebrates, eggs are composed of rich organic reserves like protein , carbohydrate and lipid to meet the energy demand during the different stages of embryonic development as well as larval stages until larva starts feeding on its own. The accumulation of organic reserves as observed in the egg are gradual from the intra-ovarian ovary stage of the gonad, which can be traced through successive stages of ovarian development.

In penaeid prawns, after spawning, embryonic development takes place over a period of 12-17 hours to hatch out as nauplius. Nauplius is the larval stage which metamorphoses into protozoea larva after passing through 6 sub-stages of nauplius in a span of 48 hours, depending upon the organic reserves stored in the egg, to meet the energy requirement. Protozoea develop filter feeding habit; strain phytoplankton; ingest, digest and assimilate organic reserves before undergoing further larval metamorphosis. Right from the embryonic development to the protozoea stage, all the energy requirement is met by the oxidation of organic reserves in the egg. During ovarian development of the female prawn, well marked physiological changes, which are manifested morphologically, take place to enable their recognition with naked eye. Colour changes from transparent to deep green and volume increases several fold from stage I to stage IV. Organic reserves which undergo a cyclic

change increase from stage I to IV and then fall down in stage V after spawning.

In the present study the different stages of ovarian development and the associated biochemical changes taking place in haemolymph, muscle and gonad of the female prawns of **Penaeus indicus** and **Metapenaeus monoceros** were studied. The samples are obtained from trawl catches off Visakhapatnam and the results of laboratory and statistical analysis are presented in this chapter.

Kerr (1969) reported on the variation in haemolymph protein and copper in relation to maturity-stages of female **Callinectes sapidus.** Development of yolk protein in crustacean oocytes of **Uca pugilator, Cambarus clarkii** and **Libinia emarginata** was explained by Wolin **et al.** (1973). Lui **et al.** (1974), described biosynthesis of lipovitellin in the ovary of the crayfish **Procambarus.** Fyffe and O'Connor (1974) made immunological study on **Procambarus** sp., and found that the blood borne female specific protein was identical to oocyte lipoprotein.

Annual reproductive cycle of **Penaeus indicus** was reported by Subrahmanyam (1963b) Seasonal biochemical changes in the ovary of **Balanus balanoides** and **B. balanus** was studied by Barnes **et al.** (1963). Changes in biochemical composition of eggs during development in **Balanus balanoides** and **B. balanus** was reported by Barnes (1965). Reproductive and nutritive cycles of **Portunus pelagicus** was studied by Abdul Rahaman (1966). Pillay and Nair

(1971) studied reproductive cycles of **Uca annulipes, Portunus pelagicus** and **Metapenaeus affinis** by employing gonad index method. During reproductive cycle, biochemical changes in gonad, hepatopancreas and muscle of **Uca annulipes, Portunus pelagicus** and **Metapenaeus affinis** were studied by Pillay and Nair (1973). Biochemical changes in the gonads during reproductive cycle of the fresh water crab, **Barytelphusa cunicularis**, was reported by Diwan and Nagabhushanam (1974). Biochemical changes and energy utilisation during embryonic stages of **Macrobrachium idella** were studied by Sumitra Vijayaraghavan and Easterson (1974). Variation in biochemical composition, calorific value and energy utilisation during embryonic stages of **Emerita holthuisi** were studied by Sumitra Vijayaraghavan **et al.** (1976). Biochemical composition of the muscle and mass changes during ovarian development of **P. indicus** were studied by Read and Caulton (1980). Nagabhushanam and Kulkarni (1982) studied endocrine regulation of reproduction in the marine female prawn **P. hardwickii.** Reproductive biology of penaeid prawns was reviewed by Vedavyasa Rao (1983). Literature on oogenesis, oviposition and oosorption of crustaceans was summarised by Adiyodi and Subramoniam (1983)Reproductive and lipid cycles in the atyid prawn, **Caridina rajadhari** were explained by Victor (1987).

RESULTS

Variation in haemolymph constituents during ovarian development :

During the process of ovarian development , organic reserves are mobilised from the synthesis organ like hepatopancreas to the gonad where they accumulate in the ova gradually from maturity-stage I to IV. The transport medium to carry all these reserves is the haemolymph and sometimes energy reserves are mobilised directly from haemolymph itself to gonad. To know the changes in haemolymph under the influence of gonad development, the haemolymph of each individual female prawn of **M. monoceros** and **P. indicus** was analysed and grouped together according to stage of maturity.

As haemolymph composition changes with size of the prawn (Chapter 3) the concentration of each haemolymph constituent was corrected to the standard size of **M. monoceros** and **P. indicus** chosen for the present study. Based on the studies and results reported earlier on size at first maturity, observations on gonad development during present study, standard animal size was considered as 36 mm carapace length for **M. monoceros** and 37 mm carapace length for **P. indicus.** The idea behind the selection of the size of standard prawn is that the female prawn by the time attains standard size could have passed all five maturity stages of gonad development.

Initially equations were derived for the relationships of carapace length and all haemolymph constituents for **M. monoceros** and **P. indicus** by following least square method. The derived equations for all haemolymph constituents in relation to carapace length are as follows:

M. monoceros

Protein (mg/ml) = 152.9621 - 1.4994 CL (n = 59; r = -0.2284)

Carbohydrate (mg/100ml) = 5.3928 + 0.8607 CL (n = 27; r= 0.1017)

Calcium (mg/100ml) = 14.9443 - 0.2707 CL (n = 23; r =-0.2707)

Potassium (mg/100ml) = 11.1477 - 0.1457 CL (n = 23; r = -0.1457)

Copper (μg/ml) = 3.0073 - 0.0369 CL (n = 14; r = -0.2461)

P. indicus

Protein (mg/ml) = 625.59 - 13.4350 CL (n = 12; r = -0.8559)

Carbohydrate (mg/100ml) = 160.44 - 2.4062 CL (n= 10; r= -0.5764)

Calcium (mg/100ml) = 39.3259 - 0.8687 CL (n = 7; r= - 0.3708)

Potassium (mg/100ml) = -50.085 + 1.675 CL (n = 7; r = 0.6131)

Copper (μg/ml) = 0.4805 + 0.0437 CL (n = 7; r = 0.0437)

All individual heamolymph constituent values were corrected to the standard prawn of both **M. monoceros** and **P. indicus** by following the given formula:

$$S_2 = \frac{S_1}{b \times CL} \times CL_{std} \times b$$

Where S_2 = Corrected haemolymph constituent level to standard prawn size

S_1 = Observed haemolymph constituent level

CL = Carapace length of observed prawn

CL_{std} = Carapace length of standard prawn (36 mm CL for **M. monoceros** and 37 mm CL for **P. indicus**)

b = Value taken from regression equation for each constituent

All corrected values of each parameter were sorted out according to stage of maturity. Mean, standard deviation and number of samples analysed for each maturity-stage are given in table 20 for both species. Student's 't' test was employed to find out the significant difference of each parameter between maturity-stage I and IV in **M. monoceros** and between stage V and IV in **P. indicus** as haemolymph samples were not available for immature specimens (maturity stage I).

M. monoceros

Protein and calcium levels increased from stage I to III and then decreased. Carbohydrate showed an increasing trend from stage I to IV. Though there was slight increase in the levels of potassium and copper from stage I to II there is an overall decreasing trend from stage I to IV in these two components of haemolymph.

P. indicus

Protein, carbohydrate, potassium and copper increased from maturity-stage II to IV and then declined in stage V. Calcium level

has shown a decreasing trend from stage II to IV and the same trend continued up to stage V also.

From the study of haemolymph composition in relation to maturity cycle the following facts have been found:

Protein, carbohydrate and copper levels showed an increasing trend during ovarian development in **P. indicus**; and in **M. monoceros**, protein and carbohydrate showed an increasing trend whereas copper showed a decreasing trend. This is perhaps due to transportation of energy reserves from synthesis and storage organs like hepatopancreas and muscle to gonad during vitellogenesis.

Variation in muscle characters during ovarian development

To know the variation in biochemical composition of muscle during ovarian development, results of analysis of samples of muscle of female prawns of **M. monoceros** and **P. indicus** are presented below.

Caulton and Bursell (1977) explained the importance of expressing the biochemical composition of muscle in absolute values for comparing changes in the biochemical composition of animals in relation to different physiological phenomena. In the present study all biochemical parameters are expressed in absolute values. As muscle constituents vary with size of the prawn, individual values of all parameters were corrected to a standard size and compared

according to the maturity-stage of the ovary. The standard carapace lengths considered in the present study were 36 mm and 37 mm respectively of **M. monoceros** and **P. indicus.**

Values of weight, water and protein were measured in grams; and carbohydrate and lipid values were measured in milligrams. From the observed values of the sample analysed, absolute values of each constituent of individual prawn were calculated. Water content was deducted from the total weight of the prawn. The remaining muscle content consisted of organic and inorganic material. From the remaining material, relative proportions of protein, carbohydrate and lipid values were determined on dry weight basis.

While correcting the values of muscle components to the standard carapace length, the relationship between carapace length and each constituent was obtained first (least square method). Since the relationships between carapace length and muscle constituents are exponential, all the values of both X and Y parameters were transformed into log values. Linear regression equations were derived first and then converted into exponential forms.

The derived expressions in the case of **M. monoceros** and **P. indicus** are as follows:

M. monoceros

Log weight = -2.3237 + 2.3659 log CL (n = 63; r = 0.950)

Weight (g) = $0.004745\ CL^{2.3659}$

Log water = -2.7349 + 2.5364 log CL (n = 63; r = 0.954)

Water (g) = $0.001841\ CL^{2.5364}$

Log protein = -3.5146 + 2.6261 log CL (n = 63; r = 0.8967)

Protein (g) = $0.0003057\ CL^{2.6261}$

Log carbohydrate = -1.1273 + 1.9996 log CL (n = 63; r = 0.55)

Carbohydrate (mg) = $0.0745\ CL^{1.9996}$

Log lipid = -1.945 + 2.7177 log CL (n = 63; r = 0.795)

Lipid (mg) = $0.0113\ CL^{2.7177}$

P. indicus

Log weight = -2.2227 + 2.3857 log CL (n = 25; r = 0.9539)

Weight (g) = $0.006144\ CL^{2.3857}$

Log water = -2.6326 + 2.5564 log CL (n = 25; r = 0.973)

Water (g) = $0.00233\ CL^{2.5564}$

Log protein = -5.0203 + 3.66 log CL (n = 25; r = 0.868)

Protein (g) = $0.00000954\ CL^{3.66}$

Log carbohydrate = -2.4268 + 2.8322 log CL (n = 25; r = 0.6718)

Carbohydrate (mg) = $0.003742\ CL^{2.8322}$

Log lipid = -1.3963 + 2.4993 log CL (n = 25; r = 0.7590)

Lipid (mg) = $0.0401\ CL^{2.4993}$

All individual values of each parameter were corrected to a standard prawn by following formula:

$$S_2 = \frac{S_1}{CL^b} \times CL_{std}^b$$

Where S_1 = = observed absolute value of the character

Where S_2 = corrected absolute value of the concerned character

CL = observed carapace length of individual prawn

CL_{std} = carapace length of standrad prawn (36 mm for **M. monoceros** and 37 mm for **P. indicus**)

b = regression exponent value from derived equation of relationship between concerned character and carapace length.

All corrected individual values of each parameter were seggregated as per maturity-stage of gonad. Mean, standard deviation for each constituent of all stages were calculated and presented in table 21. Biochemical composition in the different stages of maturity is shown on percentage basis for both species in the same table. Student's 't' test was employed to find out the statistical significance of the differences observed of each constituent between the different maturity-stages I-IV. Values of weight, water and protein content decreased from maturity-stage I to IV and then increased up to a level equal to maturity-stage II in both the species.

Carbohydrate and lipid were found to decrease initially from stage I to stage II and then increased up to stage IV. There was a decrease after stage IV in **P. indicus**. In **M. monoceros**, lipid was

found to have the same trend as in **P. indicus**, whereas carbohydrate decreased from stage I to IV and then increased in stage V.

Weight was lost due to decrease of water and protein in the muscle. It is perhaps due to mobilisation of protein content from muscle to gonad. When the muscle composition is considered on percentage basis; water, protein and carbohydrate decreased from stage I to IV and then increased. Simultaneously, lipid increased from stage I to IV and then declined.

Statistically no significant difference was found between muscle characters of maturity-stge I and IV of both species except water content in **M. monoceros** at 1% probability ($P < 0.01$) level.

Variation in gonad characters during ovarian development

Since the gonad is the principal organ which accomplishes all the physiological activities concerning ovarian development, it undergoes changes morphologically as well as biochemically during vitellogenesis. The present study was taken up to elucidate changes in gonad characters during ovarian development. After spawning the ova were studied separately.

A total of 28 gonads of **M. monoceros** in five maturity-stages, and 21 gonads of **P. indicus** belonging to the five maturity-stages were analysed. The results are given below.

Values of all the biochemical constituents of the gonad are given in absolute values. As gonad grows three dimentionally, the

relationships between carapace length and gonad constituents are exponential. Hence, all the values of each parameter and measurements of carapace length were converted into log values to obtain straight line relationships. All linear equations were again transformed into the exponential forms as given below:

M. monoceros

Log weight = 0.8368 + 1.4335 log CL (n = 28; r = 0.5054)

Weight (mg) = $6.8678\ CL^{1.4335}$

Log water = 0.0712 + 1.8050 log CL (n = 28; r = 0.6348)

Water (mg) = $1.1781\ CL^{1.8050}$

Log protein = 0.6965 + 1.0730 log CL (n = 28; r = 0.3071)

Protein (mg) = $4.9716\ CL^{1.0730}$

Log carbohydrate = -5.7274 + 4.275 log CL (n = 28; r = 1.0000)

Carbohydrate (mg) = $0.000001873\ CL^{4.275}$

Log lipid = -1.8527 + 2.1715 log CL (n = 28; r = 0.6099)

Lipid (mg) = $0.0140378\ CL^{2.1715}$

P. indicus

Log weight = -2.0709 + 3.2928 log CL (n = 21; r = 0.3509)

Weight (mg) = $0.0084\ CL^{3.2928}$

Log water = -2.1532 + 3.2468 log CL (n = 21; r = 0.3600)

Water (mg) = $0.007027\ CL^{3.2468}$

Log protein = -4.9621 + 4.6359 log CL (n = 21; r = 0.438)

Protein (mg) = $0.0000109\ CL^{4.6359}$

Log carbohydrate = $-4.9784 + 3.7866 \log CL$ ($n = 21$; $r = 0.3564$)

carbohydrate (mg) = $0.00001\ CL^{3.7866}$

Log lipid = $-1.5842 + 2.0753 \log CL$ ($n = 21$; $r = 0.1901$)

lipid (mg) = $0.0260\ CL^{2.0753}$

All the observed individual values of all the parameters were corrected to the chosen standard carapace length using the formula:

$$S_2 = \frac{S_1}{CL^b} \times CL_{std}^b$$

Where S_2 = corrected absolute value of character to the standard prawn

S_1 = observed absolute value of the concerned character

CL = observed carapace length of individual prawn

CL_{std} = carapace length of standard prawn (36 mm for **M. monoceros** and 37 mm for **P. indicus**)

b = regression exponent value from derived equation for relationship between concerned character and carapace length.

All corrected individual values of each parameter were seggregated as per maturity-stage of gonad. Mean and standard deviation for each character in all stages of maturity were calculated (Table 22). Maturity-stage-wise biochemical composition of the gonad according to standard size is given on percentage basis. Student's 't' test was employed to find out statistical significance

of differences in each parameter between maturity-stages I and IV. All parameters in both the species were significantly differed between these two maturity-stages. In **M. monoceros**, weight, water and protein values showed highly significant ($P < 0.001$) differences compared to carbohydrate and lipid levels ($P < 0.01$). In **P. indicus**, the differences were all significant at 1% probability level ($P < 0.01$) in all the parameters between maturity-stage I and IV.

In both the species, weight, water, protein, carbohydrate and lipid values increased from stage I to IV and then decreased in stage V. The decline in stage V was less than the value in stage II in **M. monoceros** and almost equal to the level of stage II in **P. indicus.**

In the gonad, ova diameter increases from stage I to IV. When it is fully mature and spawned the empty gonad after spawning the ova is called spent recovery (stage V). During ova development all organic reserves accumulate in the gonad with increasing size of ova. Hence, all organic reserves are found to increase from stage I to IV and then decrease in stage V due to the release of all ova from the gonad.

Biochemical composition on percentage basis of each maturity stage is also given in table 22 for both the species. It was found that there was decrease of water level from stage I to IV and then an increase in stage V in both the species. Simultaneously, protein,

carbohydrate and lipid levels increased from stage I to IV and then declined in stage V.

Comparison of gonad characters between **M. monoceros** and **P. indicus** is given in table 23. Gonad characters at maturity stage IV were compared between **M. monoceros** and **P. indicus** by using student's 't' test and the same study revealed the existence of difference in weight, water and lipid levels of gonad between these two species. Weight, water and lipid levels were more in **P. indicus** than in **M. monoceros** because of the difference in the standard size between the two species.

The degree of accumulation or increase in gonad constituents from stage I to IV of **M. monoceros** and **P. indicus** are given in table 23. All parameters were found to increase at a higher rate in **P. indicus** than in **M. monoceros.** This may be attributed to the difference in growth rate of the prawn and consequent difference in length-weight relationship between these two species.

Comparison of biochemical composition on percentage basis is also shown in table 23. In maturity-stage I, biochemical composition in both the species was identical whereas in maturity-stage IV more of protein and carbohydrate were found in **M. monoceros** than in **P. indicus.** This may be attributed to the relatively longer duration found in the early larval development in **M. monoceros** than in **P. indicus.**

DISCUSSION

Bennet and Giese (1955) explained gonad index as a function of reproductive activity in western sea urchins. In crustaceans also similar type of observations were made by several workers. Subrahmanyam (1963a) found high gonad index in **P. indicus** during part of the year and he related this period to the breeding activity of this species. The study made by Pillay and Nair (1971) on **Uca annulipes, Portunus pelagicus** and **Metapenaeus affinis** also revealed the existence of relation between gonad index and the breeding season. Gonad index was related to breeding peaks in **Portunus pelagicus** by Abdul Rahaman (1966). In atyid prawn **Caridina rajadhari**, gonad index was observed during the different spawning seasons by Victor (1987). Diwan and Nagabhushanam (1974) observed high gonad index during maximum breeding acitivity of fresh water crab, **Barytelphusa cunicularis.** Kulkarni and Nagabhushanam (1979) found increase in gonad index from stage I to IV and then decrease in stage V in female prawn of **Parapenaeopsis hardwickii.** In the present study also gonad weight of a standard prawn was found to increase from stage I to IV and then decrease in stage V.

During ovarian development all organic reserves were found to accumulate in the gonad with increase in ova diameter. In the present study water, protein, carbohydrate and lipid levels were found to increase from stage I to IV and then declined in stage V. Results of a similar type were reported by Kulkarni and

Nagabhushanam (1979) in the penaeid prawn **Parapenaeopsis hardwickii.** Diwan and Nagabhushanam (1974) found high contents of protein, fat and glycogen during ripening of the gonad and decrease in all contents at the end of spawning season in the fresh water crab **Barytelphusa cunicularis.** Victor (1987) also found increase in lipid level of gonad of atyid prawn **Caridina rajadhari** during spawning months. Increase of protein and lipid values of gonad in **U. annulipes, P. pelagicus** and **M. affinis** was reported by Pillay and Nair (1973). Barnes **et al.** (1963), also found increase in protein and lipid levels of ovary during breeding season in **Balanus balanoides** and **B. balanus.**

In the present study, water percentage in gonad was found to decrease from stage I to IV and then increase in stage V. Similar result was also reported by Pillay and Nair (1973) in three decapod crustaceans.

Though all biochemical constituents accumulated from stage I to IV in the gonad of **M. monoceros** and **P. indicus,** the main component of gonad was protein. In a ripe ovary protein constituted 20% of ovary weight, followed by lipid, which contributed between 4 and 5%. Carbohydrate content was less than 2%. Hence, in penaeid prawns, the energy reserve of protein and lipid in the egg was to be utilised during later embryonic development. Sumitra Vijayaraghavan **et al.** (1976), also found during embryonic

development of **Emerita holthuisi** that the primary source of energy was from protein oxidation. Secondary and tertiary sources were from lipid and carbohydrate. Sumitra Vijayaraghavan and Easterson (1974) found that protein contributes 67.4% of the total energy available for embryonic development of **Macrobrachium idella.** Amsler and George (1985) found that during embryonic development of **Euphausia superba,** twice as much protein than lipid was used and the same study revealed that protein and lipid contributed equally to the energy requirements. The energy requirement study made by Vijayakumaran (1990) on **P. indicus** during embryonic development revealed that protein and lipid contribute to the required energy equally.

It was found that protein and carbohydrate concentrations were more in **M. monoceros** than in **P. indicus.** This is perhaps due to the longer duration of nauplius stage (44-60 hours) in **M. monoceros** (Mohamed **et al.**, 1979) than in **P. indicus** (40-50 hrs) reported by Muthu **et al.** (1979). In both the species, nauplius larva survives on energy reserves from egg until it becomes protozoea.

In muscle, weight, water and protein levels decreased from stage I to IV and then increased in stage V. Weight loss is mainly due to water and protein loss. Carbohydrate and lipid levels showed an increasing trend from stage I to IV and then declined

(except carbohydrate in **M. monoceros**). Similar results were also observed by Read and Caulton (1980) in **P. indicus** where he found that during ovarian development, body mass and water declined, while the mass of organic body constituents like protein and lipids have increased. Asokan and George (1984) also found decrease of protein in the muscle of **P. indicus** during ovarian development. Vijayakumaran (1990) also found decrease of water and protein concentrations in the muscle of **P. indicus** with maturity.

In the present study it was observed that protein in muscle was found to decrease with maturation; while it increased in gonad. This is perhaps due to mobilisation of protein from muscle to gonad. Sarojini and Jahagirdar (1983) also found mobilisation of SH-linked proteins and lipids from muscle to ovary through blood in hermit crab, **Pagurus kulkarni.**

In the present study haemolymph protein level increased from stage I to III and then declined up to stage V in both species. Copper level showed the same trend of increasing initially and then declining. Similar observation was made by Kerr 1969) in **Callinectes sapidus** where he found that protein and copper levels of haemolymph have increased from stage I to IV and then decreased. His assumption was that difference between the protein content and maximal amount of protein which may be associated with copper in the form of haemocyanin (0.2:100, copper : protein ratio) is

due to lipoprotein synthesising outside the ovary and mobilisation to the gonad during vitellogenesis. He identified the serum lipoprotein to be identical to the lipovitellin. The immunological study made by Fyffe and O'Connor (1974) on **Procambarus** sp. also revealed that sexually mature female crayfish possess a blood-borne female specific protein which is identical to an ovarian protein. Wolin **et al.** (1973), used cytochemical techniques in **Uca pugilator, Cambarus clarkii** and **Libinia emarginata** and found that a protein serologically identical to the lipovitellin of yolk spheres was present in the haemolymph of aforesaid three crustaceans. They concluded that yolk spheres develop in eggs through micropinocytotic uptake of lipovitellin from the haemolymph. Contrary to the above results reported by several authors, the studies made by Lui **et al.** (1974), on **Procambarus** sp. **in vitro**, revealed that ovary is capable of synthesising both lipid and protein components of the lipovitellin. Hence, ovary need not incorporate such moieties from haemolymph. However, in the present study haemolymph protein was found to increase from stage I to III and then decrease. This may be attributed to mobilisation of protein to gonad. Simultaneously, decrease in muscle protein was also observed. Although it is not possible to conclude at this stage, whether the protein in the haemolymph or from the muscle is mobilised to the gonad; it appears that both haemolymph and muscle play an important role in the protein mobilisation to the gonad during its maturation process.

Table 20. Variation of haemolymph constituents during ovarian development in female prawn of **M.monoceros** (standard animal, 35 mm CL), and **P. indicus** (standard animal 37 mm CL). Number of samples analysed is given in parentheses.

Haemolymph constituent	Maturity-stages I	II	III	IV	V	Remarks
			M. monoceros			
Protein (mg/ml)	84.00±32.94 (8)	85.20±55.25 (18)	102.05±40.88 (16)	80.32±21.85 (15)	36.05±3.18 (2)	N.S.*
Carbohydrate (mg/100 ml)	18.20±0.00 (1)	37.15±15.52 (9)	23.08±8.49 (8)	38.72±26.17 (9)	-	N.S.*
Calcium (mg/100 ml)	2.60±0.00 (1)	3.75±3.18 (8)	5.85±2.91 (9)	4.66±2.23 (5)	-	N.S.*
Potassium (mg/100 ml)	6.50±0.00 (1)	6.86±1.67 (8)	4.51±1.25 (9)	5.56±0.69 (5)	-	N.S.*
Copper (µg/ml)	18.25±0.00 (1)	18.74±4.7 (6)	13.97±1.45 (4)	13.55±1.06 (3)	-	N.S.*
			p. indicus			
Protein (mg/ml)	-	68.10±47.65 (2)	155.32±40.21 (4)	114.36±63.65 (6)	44.90±0.00 (1)	N.S.**
Carbohydrate (mg/100 ml)	- -	79.60±0.00 (1)	79.37±3.43 (4)	80.30±5.22 (4)	78.00±0.00 (1)	N.S.**
Calcium (mg/100 ml)	-	15.90±0.00 (1)	5.75±1.54 (2)	10.38±4.01 (3)	6.00±0.00 (1)	N.S.**
Potassium (mg/100 ml)	-	5.80±0.00 (1)	9.0±6.39 (2)	9.89±3.37 (3)	7.00±0.00 (1)	N.S.**
Copper (µg/ml)	-	19.10±0.00 (1)	20.40±2.60 (2)	19.60±1.15 (3)	18.00±0.00 (1)	N.S.**

* = comparison between maturity-stages I & IV; ** = comparison between maturity-stages IV & V; N.S.= not significant at $P < 0.05$ level

Table 21. Variation in muscle characters during ovarian development in female prawn of **M.monoceros** (standard animal, 36 mm CL) and **P.indicus** (standard animal, 37 mm CL). Absolute values expressed as mean ± standard deviation. Maturity-stage wise composition also shown on percentage basis.

Character	Maturity stages					Remarks*
	I	II	III	IV	V	
			M.monoceros			
	n = 11	n = 18	n = 17	n = 15	n = 2	
Weight (g)	24.35±2.15	22.88±2.80	21.62±2.53	23.34±1.81	23.99±0.52	N.S.
Water (g)	18.39±1.63 75.52%	16.29±2.01 71.19%	15.48±2.08 71.60%	16.19±1.72 69.36%	17.10±0.82 71.27%	P< 0.01
Protein (g)	4.23±0.75 17.37%	3.88±0.58 16.95%	3.33±0.71 15.40%	4.00±0.62 17.13%	4.03±0.29 16.79%	N.S.
Carbohydrate (mg)	123.38±29.00 0.50%	102.77±56.00 0.44%	104.39±53.00 0.48%	104.96±26.91 0.44%	136.69±83.00 0.56%	N.S.
Lipid (mg)	224.78±64.0 0.92%	179.27±58.00 0.78%	185.21±53.00 0.85%	237.69±73.00 1.01%	185.46±54.00 0.77%	N.S.
			P. indicus			
	n = 3	n = 4	n = 7	n = 6	n = 5	
Weight (g)	33.65±2.55	32.68±1.64	33.44±2.86	32.78±2.34	33.51±2.46	N.S.
Water (g)	26.15±1.57 77.71%	23.36±1.46 71.48%	23.88±2.33 71.41%	23.20±1.73 70.77%	24.02±1.92 71.68%	N.S.
Protein (g)	7.08±2.76 21.04%	5.37±0.73 16.43%	4.68±1.28 13.99%	5.19±0.36 15.83%	5.33±0.83 15.90%	N.S.
Carbohydrate (mg)	151.37±105.0 0.44%	97.28±48.0 0.29%	102.49±23.0 0.30%	127.03±55.0 0.38%	100.34±43.00 0.29%	N.S.
Lipid (mg)	331.57±47.0 0.98%	290.45±60.0 0.88%	360.69±102.0 1.07%	375.06±65.0 1.14%	352.53±152.0 1.05%	N.S.

* = comparison between maturity stages I & IV; N.S. = not significant at probability 0.05 level
n = number of samples analysed

Table 22. Variation in gonad characters during ovarian development in female prawn of **M.monoceros** (standard animal, 36 mm CL) and **P.indicus** (standard animal, 37 mm CL). Absolute values expressed as mean ± standard deviation. Maturity-stage wise composition is also shown on percentage basis.

Character	Maturity-stages I	II	III	IV	V	Remarks*
			M. monoceros			
	n = 3	n = 8	n = 8	n = 6	n = 3	
Weight (g)	0.508±0.15	1.172±0.18	1.366±0.56	1.477±0.22	0.634±0.11	P< 0.001
Water (g)	0.358±0.10 70.47%	0.787±0.09 67.15%	0.833±0.30 60.98%	0.948±0.15 64.18%	0.439±0.09 69.24%	P< 0.001
Protein (mg)	81.28±20.00 16.00%	233.51±82.00 19.92%	323.01±161.0 23.64%	336.11±89.0 22.75%	111.63±19.0 17.60%	P< 0.001
Carbohydrate (mg)	2.03±0.90 0.39%	5.95±2.10 0.50%	12.9±3.9 0.94%	18.1±6.0 1.22%	2.36±1.2 0.37%	P< 0.01
Lipid (mg)	14.73±4.5 2.89%	35.67±8.5 3.04%	45.16±21.4 3.30%	66.61±26.2 4.50%	19.93±9.50 3.14%	P< 0.01
			P.indicus			
	n = 3	n = 3	n = 7	n = 6	n = 2	
Weight (g)	0.408±0.20	0.504±0.19	1.595±0.91	2.398±0.651	0.599±0.080	P< 0.01
Water (g)	0.308±0.15 75.49%	0.373±0.11 74.00%	1.160±0.75 72.72%	1.569±0.43 65.42%	0.458±0.06 76.46%	P< 0.01
Protein (mg)	65.28±20.0 16.00%	91.29±59.0 18.11%	230.23±95.0 14.43%	449.76±154.0 18.75%	91.02±16.0 15.19%	P< 0.01
Carbohydrate (mg)	2.65±1.2 0.64%	3.70±2.2 0.73%	10.20±4.5 0.63%	21.54±5.9 0.89%	3.82±0.6 0.63%	P< 0.01
Lipid (mg)	12.24±10.0 3.00%	17.91±10.0 3.55%	58.18±30.0 3.64%	111.79±31.0 4.66%	17.96±1.9 2.99%	P< 0.01

* = comparison between maturity-stages I & IV; N.S. = not significant at probability 0.05 level;
n = number of samples analysed

Table 23: Comparison of gonad characters of standard female prawn between **M. monoceros** (standard length 36mm CL) and **P. indicus** (standard length 37 mm CL). Values expressed as mean ± standard deviation. Maturity-stage wise composition is also shown on percentage basis.

	M. monoceros			**P. indicus**			
Gonad Character	Maturity-stage I n = 3	Maturity-stage IV n = 6	Accumulation by percentage	Maturity-stage I n = 3	Maturity-stage IV n = 6	Accumulation by percentage	Significant level *
Weight (g)	0.508 ± 0.15	1.477 ± 0.22	190.7	0.408 ± 0.20	2.398 ± 0.651	487.7	$P < 0.02$
Water (g)	0.358 ± 0.10 70.47%	0.948 ± 0.15 64.18%	164.8	0.308 ± 0.15 75.49%	1.569 ± 0.43 65.42%	409.4	$P < 0.02$
Protein (mg)	81.28 ± 20 16.00%	33 6.11 ± 89 22.75%	313.5	65.28 ± 20 16.00%	449.76 ± 154 18.75%	588.9	N.S.
Carbohydrate (mg)	2.03 ± 0.9 0.39%	18.1 ± 6.0 1.22%	791.6	2.65 ± 1.2 0.64%	21.54 ± 5.9 0.89%	712.8	N.S.
Lipid (mg)	14.73 ± 4.5 2.89%	66.61 ± 26.2 4.5%	352.2	12.24 ± 10 3.00%	111.79 ± 31 4.66%	813.3	$P < 0.05$

* = comparison of maturity-stage IV between **M. monoceros** and **P. indicus**; N.S. = not significant at probability 0.05 level

CHAPTER 7

VARIATION IN THE COMPOSITION OF HAEMOLYMPH AND MUSCLE OF PRAWNS CULTURED DURING DIFFERENT SEASONS

INTRODUCTION

In brackishwater pond, prawn production is subject to variation from crop to crop during a year due to prevailing ecological conditions as well as quality and quantity of supplementary feed given during the farming period. Though feed is given in required quantities at appropriate time, water parameters like salinity, temperature, dissolved oxygen and pH vary from crop to crop due to natural fluctuation or depending on the quality of water supplied to the pond. It is now a known fact that the composition of haemolymph and muscle of prawns vary according to the ecological conditions as well as nutritional conditions. In brackishwater pond three crops of prawn are harvested in a year. A study of the variation in the composition of haemolymph and muscle in the prawns cultured during different seasons would enable the determination of optimum ecological conditions for better prawn production. Samples of haemolymph and muscle of **P. monodon** and **P. indicus** during November 1984, March 1985 and November 1985 were collected for biochemical analysis.

Information on biochemical composition of haemolymph and muscle of penaeid prawns grown in brackishwater ponds under culture conditions is scarce. Vedavyasa Rao **et al** (1981) studied calcium fluctuation in exoskeleton, muscle and haemolymph of **Penaeus indicus** from a brackishwater pond. Subhash Chander (1986) studied ecophysiology of **Penaeus indicus** in the grow-out system.

RESULTS

Variation in water characteristics between different crops

Values of all hydrological parameters on the different sampling days are given in Table 24.

Water temperature was almost same during November 1984 (26.0°C) and November 1985 (26.5°C) whereas in March 1985 (29.0°C) it was slightly high.

Salinity also did not vary much between November 1984 (12.8°/$_{oo}$) and November 1985 (12.0°/$_{oo}$) but it was high in March 1985 (19.0°/$_{oo}$).

pH ranged from 7.0 to 7.9 during these observation days.

Dissolved oxygen in November 1984 was also similar (6.0 ml/l) to the value of November 1985 (6.2 ml/l) but it was slightly high in March 1985 (7.6 ml/l).

From the above observations it is obvious that higher values of all water parameters were found in March 1985 compared to the values of November 1984 and November 1985.

Variation in haemolymph composition between the different crops

Mean, standard deviation and number of specimens examined of **P. monodon** and **P. indicus** in all three crops are presented in Table 25. Carapace length range of the prawns from which haemolymph was extracted in each crop for both the species is also

given in the same table. Analysis of variance (F-test) was employed to find out the significance of the differences in the parameters of haemolymph between the different crops.

P. monodon

Protein, carbohydrate, calcium, potassium and copper levels were significantly ($P < 0.005$) different between the three crops.

During November 1984, samples were collected from two separate ponds and the results were treated separately. Significant difference was found in the case of carbohydrate ($P < 0.001$), calcium ($P < 0.001$) and copper ($P < 0.001$) between the two samples. Protein and potassium of the two samples did not vary.

Results of all parameters during 1984 were almost similar to the results of November 1985. The sample collected in March 1985 had high mean values of protein, copper and potassium and low mean value of calcium compared to the mean values of other two crops obtained in the month of November.

P. indicus

Protein, carbohydrate, calcium and copper contents were significantly different at 5% probability level ($P < 0.005$) compared to potassium which was significant ($P < 0.01$) at 1% probability level between the three crops.

High mean values of protein, copper and potassium and low mean value of calcium were found during March 1985 compared to other two crops.

The comparative study of haemolymph characteristics between the different crops, shows that high values of protein, potassium, copper and low value of calcium in the haemolymph of **P. monodon** and **P. indicus** coincide with the presence of high hydrological values during March 1985.

Variation in muscle characteristics between the different crops

Mean, standard deviation and number of specimens examined of **P. monodon** and **P. indicus** are shown in table 26. Carapace length range and weight range of the prawns used of both species are also given in the same table.

Analysis of variance (F-test) was employed to find out significance of the difference in each parameter between the different crops.

P. monodon

Water and carbohydrate levels have not shown significant differences. Protein ($P < 0.05$) showed less difference whereas lipid level was found to be highly significant ($P < 0.005$) between the three crops.

Comparatively high values of protein, carbohydrate and lipid contents were found in the crop of November 1984. This was partly due to analysis of bigger prawns (carapace length range 32-43 mm; weight range 18.3-29.6 g) compared to the prawns of the other two crops.

P. indicus

Carbohydrate level showed a difference, significant at 5% probability ($P < 0.005$) while lipid was significant at 1% probability ($P < 0.01$). Water and protein content did not show significant differences between the three crops.

Mean values of protein, carbohydrate and lipid were observed to be high during 1984 compared to the other two crops. This may be attributed to the larger size of specimens used for analysis (carapace length range 27-34 mm weight range 13.9-21.5 g) compared to the prawns of the other two crops.

From the comparative study of muscle characteristics between the different crops, high mean values of protein, carbohydrate and lipid values were observed in **P. monodon** and **P. indicus** in the crop obtained in November 1984. This is due to larger size of the specimens compared to the other samples. If size range and weight range were considered, samples analysed during March 1985 were for small prawns. If comparisons were made between prawns of similar size range in all the three crops, high values would have been found in both **P. monodon** and **P. indicus** of March 1985.

DISCUSSION

Salinity of the brackishwater ponds depends on the characteristics of the hydrography of Kakinada bay, which is under the influence of the southwest and northeast monsoons and discharge of freshwater from irrigation canals of river Godavari. During June-September, salinity is as low as 4.0 to 12.0 ppt and from November to May salinity gradually increases and sometimes it reaches up to 60 ppt in May (Rajyalakshmi **et al.**, 1986). As the feeder canal to the brackishwater pond passes through the Kakinada Commercial canal, salinity level in the bay is reflected in the brackishwater pond (Rambhaskar, 1985). Salinity increased from 12.00 ppt to 19.00 ppt during November 1984 to March 1985. The crop harvested in November 1984 was reared in the medium having salinity of below 12.00 ppt; while salinity range of the pond in 1985 was from 12.00 ppt to 19.00 ppt. Since application of manures, as well as supplementary feed and stocking density are uniform during all the three crops, variation in haemolymph composition and muscle composition of **P. monodon** and **P. indicus** can be attributed to the changes in water salinity.

Panikkar (1968) suggested that maximum growth of prawns can be obtained in isosmotic media, as prawns need not spend energy in doing osmoregulation. Since the oxygen requirement of the prawn would be low under isosmotic conditions, natural

mortality of prawn due to oxygen depletion is low. He further remarked that under isosmotic conditions maximum number of prawns can be cultured in a given volume of water. Diwan **et al.** (1989) found isosmotic point at 23.5 ppt for **P. monodon.** For juveniles and adults of **P. indicus**, isosmotic salinity is at 14.00 ppt and 17.00 ppt respectively (Diwan and Laxminarayan, 1989). The prevailing salinity range (12.00-19.00 ppt) during the farming period of March 1985 crop is nearer to the isosmotic points of **P. monodon** and **P. indicus.** The high values of protein and copper in the haemolymph of prawns harvested in March 1985 indicate the healthy condition of the prawns. From this observation it can be suggested that ideal season to take up prawn culture around Kakinada bay is from December to March, in extensive prawn farming. The conditions can be brought under control accordingly in intensive prawn farming.

During March 1985, high values of potassium in the haemolymph of **P. monodon** and **P. indicus** reflect the prevailing high salinity of the pond condition. Similar observation was made by Dall (1981) in the case of **Penaeus plebejus, P. esculentus** and **P. merguiensis.**

Low value of calcium was found in March 1985, this may be attributed to the existence of a negative correlation between calcium and potassium contents of haemolymph. However,

Vedavyasa Rao **et al.**(1981) observed that haemolymph calcium of P. **indicus** and pond water calcium are positively correlated with salinity of the brackishwater.

High values of biochemical constituents of muscle were observed during November 1984 due to the largeness of the specimens compared to the specimens in the other two crops. Lipid and carbohydrate in the muscle showed positive correlation with length and weight of the prawn (Chapter 4).

Table 24. Variation in water characteristics of brackishwater pond during different sampling days

Water parameter	Date of observation				
	27-11-1984	28-11-1984	19-3-1985	6-11-1985	8-11-1985
Temperature (°C)	26.0	26.2	29.0	26.2	26.5
Salinity (°/$_{oo}$)	12.8	13.0	19.0	12.0	12.2
pH	7.8	7.8	7.9	7.0	7.0
Dissolved oxygen (ml/l)	6.0	6.2	7.6	6.2	6.0

Table 25. Variation in haemolymph characteristics of P.monodon and P.indicus from brackishwater pond during different crops. Values expressed as mean ± standard deviation. Number of samples analysed is given in parentheses.

Characteristic	Date of observation				Results of F-test
	27-11-1984	28-11-1984	19-3-1985	6-11-1985	
			P.monodon		
Carapace length range (mm)	30-48	32-49	24-46	26-57	
Protein (mg/ml)	98.71±23.32 (35)	93.77±34.12 (22)	151.39±21.02 (26)	98.00±35.38 (22)	P < 0.005
Carbohydrate (mg/100 ml)	16.11±4.53 (35)	38.95±5.98 (22)	39.25±3.17 (26)	40.00±0.00 (13)	P < 0.005
Calcium (mg/100 ml)	9.51±3.84 (29)	15.90±6.08 (15)	5.33±1.67 (26)	14.03±1.98 (21)	P < 0.005
Potassium (mg/100 ml)	1.90±0.49 (29)	2.21±1.32 (15)	5.38±1.23 (26)	2.95±0.92 (21)	P < 0.005
Copper (µg/ml)	8.82±2.43 (29)	11.02±2.75 (15)	11.51±3.23 (26)	11.45±2.49 (21)	P < 0.005
			P. indicus		
	28-11-1984	19-3-1985	6-11-1985		
Carapace length range (mm)	27-34	19-24	26-33		
Protein (mg/ml)	93.00±30.29 (8)	160.33±18.49 (18)	120.92±27.11 (26)		P < 0.005
Carbohydrate (mg/100 ml)	53.34±3.61 (8)	39.52±1.39 (18)	29.11±1.79 (26)		P < 0.005
Calcium (mg/100 ml)	18.78±3.51 (8)	4.43±0.42 (15)	12.87±3.39 (26)		P < 0.005
Potassium (mg/100 ml)	2.02±0.47 (8)	3.72±1.88 (15)	3.03±0.78 (26)		P < 0.01
Copper (µg/ml)	10.29±3.27 (8)	13.13±1.17 (15)	12.98±4.11 (26)		P < 0.005

Table 26. Variation in muscle characteristics of **P.monodon** and **P.indicus** from brackishwater pond during different crops. Values expressed as mean ± standard deviation.

Characteristic	Date of observation 27-11-1984	19-3-1985	8-11-1985	Results of F-test
		P. monodon		
	n = 15	n = 10	n = 9	
Carapace length range (mm)	32-43	25-30	26-42	
Weight range (g)	18.3-29.6	8.3-13.6	10.5-31.1)	
Water (%)	77.20±1.06	76.71±2.06	75.58±2.76	N.S.
Protein (mg/100 mg)	63.06±15.84	55.80±5.97	50.44±5.38	$P < 0.05$
Carbohydrate (mg/100 mg)	1.38±0.18	1.24±0.12	1.27±0.16	N.S.
Lipid (mg/100 mg)	4.16±0.42	3.02±0.36	3.34±0.63	$P < 0.005$
		P. indicus		
	28-11-1984	19-3-1985	6-11-1985	
	n = 8	n = 10	n = 26	
Carapace length range (mm)	27-34	19-24	26-33	
Weight range (g)	13.9-21.5	5.0-9.1	10.4-21.1	
Water (%)	74.29±1.59	74.04±1.63	75.21±1.90	N.S.
Protein (mg/100 mg)	67.62±7.65	66.80±5.02	62.96±6.18	N.S.
Carbohydrate (mg/100 mg)	1.47±0.08	1.12±0.05	1.20±0.14	$P < 0.005$
Lipid (mg/100 mg)	4.51±0.98	3.38±0.66	3.87±0.61	$P < 0.01$

N.S. = not significant at 0.05 probability level

SUMMARY

The thesis deals with the studies on the biochemical composition of haemolymph and muscle of **Metapenaeus monoceros, Penaeus monodon** and **P. indicus** inhabiting the different ecosystems. It includes data on the biochemical make up and changes occurring in the haemolymph and muscle in relation to sex , size, weight, condition factor, ovarian maturation and under different ecological conditions. The intra and inter-relationships of haemolymph and muscle characteristics in the three species are dealt with in detail.

The total length-weight relationship has revealed significant differences between the sexes of **M. monoceros, P. inidicus** (marine) and **P. indicus** (brackishwater) whereas no significant difference is noticed between the sexes of **P. monodon.** Females of **P. indicus** (marine) and **M. monoceros** are found to be heavier than males of **P. indicus** (marine) and **M. monoceros.** Similarly, the males of **P. indicus** are heavier than the females in the brackishwater environment. In the study of carapace length-weight relationship analysis of covariance has shown that there is no significant difference in regression coefficients of both sexes of **M. monoceros, P. monodon, P. indicus** (marine) and **P. indicus** (brackishwater). For a given carapace length, **P. monodon** weighs more than the other two species and **P. indicus** from the marine habitat weighs more than those from the brackishwater habitat. The carapace length-total length relationship has not shown any significant

variation between the sexes of **P. monodon**, **P. indicus** (marine) and **P. indicus** (brackishwater) whereas in the case of **M. monoceros** it differs significantly between the sexes. For a given carapace length, total length is more for **P. indicus** than in the other two species because of the lengthy rostrum in **P. indicus.**

Considerable variation in haemolymph constituents of individual prawns was observed. In the brackishwater pond haemolymph constituents did not vary significantly between the sexes of **P. monodon** and **P. indicus.** However, females of **M. monoceros** and **P. indicus** from the marine region were having more carbohydrate and calcium levels respectively. The high level of carbohydrate in females of **M. monoceros** might be due to higher reproductive activity when organic reserves were mobilised from the storage organ like hepatopancreas to the gonad, through haemolymph.

Comparative study of haemolymph characteristics at intra and interspecific levels revealed that there was no significant difference in all the parameters except in carbohydrate between **M. monoceros** and **P. indicus** from the marine source. Significant variation in protein, carbohydrate and copper levels were recorded between **P. monodon** and **P. indicus** in brackishwater environment. This may be due to prevalence of homogeneous ecological conditions in marine environment and greater variation in culture conditions. There was

significant difference in all the constituents between **P. indicus** (marine) and **P. indicus** (brackishwater) due to different phases in life cycle.

Correlation between haemolymph characteristics and length showed negative correlation between protein and length in all the three species. In the case of carbohydrate, it was negative in all species except in **M. monoceros.** Calcium was found to be positively correlated in **P. monodon** and **P. indicus** from the brackishwater whereas it was negatively correlated in **M. monoceros** and positively correlated in **P. indicus** from the marine water.

Correlation of haemolymph characteristics and weight showed a negative correlation between protein content and weight in all the three species. Carbohydrate level was negatively correlated in **P. monodon** and **P. indicus** from brackishwater and positively correlated in **M. monoceros** and **P. indicus** from the marine region. Calcium content was negatively correlated in **M. monoceros** and **P. indicus** of marine water and positively correlated in **P. monodon** and **P. indicus** in brackishwater. Copper content was negatively correlated with weight in **P. monodon** and positively correlated in **P. indicus** from brackishwater as well as in marine water. There was positive correlation between copper content and weight of the prawns of **M. monoceros** from the marine water though not significant statistically.

Fluctuations of haemolymph characteristics with length and weight in the prawns obtained in different crops in the brackishwater pond is perhaps due to the high variability of ecological conditions in the ponds and the quality and quantity of feed given during the culture period.

Study of the correlation between haemolymph characteristics and the condition factor in immature prawns of **P. monodon** and **P. indicus** from the brackishwater pond, no significant relationships were observed.

Muscle composition did not vary between the sexes of **P. monodon** and **P. indicus** in brackishwater. In the marine environment females of **M. monoceros** and **P. indicus** were having more protein than males perhaps due to higher maturation activity in the former.

Muscle composition varied significantly between **M. monoceros** and **P. indicus** in marine water and between **P. monodon** and **P. indicus** in brackishwater. Higher water content was recorded in **P. indicus** obtained from brackishwater than in **P. indicus** from the marine water, perhaps due to the smaller size of the prawns in the former environment. Higher protein level was recorded in **P. indicus** from the brackishwater than from the marine water might be due to supplementary feeding in the former environment.

From the study of muscle composition in relation to carapace length it was observed that there is no significant correlation

between muscle constituents and carapace length of **M. monoceros** and **P. indicus** in marine water. Simlarly, protein and water levels have not shown significant correlation with carapace length of **P. monodon** and **P. indicus** in brackishwater pond. However, carbohydrate and lipid levels have shown positive correlation with the carapace length of **P. monodon** and **P. indicus** from the brackishwater pond.

In the marine environment, water, protein and carbohydrate in the muscle of **P. indicus** showed significant positive correlation with weight whereas no such correlation was observed in the case of **M. monoceros.** In the brackishwater, carbohydrate and lipid levels increased positively with increase in weight of **P. monodon** and **P. indicus.**

Correlation of muscle characteristics with condition factor of **P. monodon** and **P. indicus** from the brackishwater ponds has revealed significant positive correlation between all muscle characteristics and condition factor.

A study of intra and inter-relationships of haemolymph and muscle characteristics showed positive correlation between protein and calcium content of haemolymph in **M. monoceros** and **P. indicus** from marine water. The correlation was negative in **P. monodon** and **P. indicus** from the brackishwater. This may be due to positive correlation between protein level and bound calcium level. Potassium

content was negatively correlated with protein content in **M. monoceros** and **P. indicus** of marine water, while a positive correlation with protein content was observed in **P. monodon** and **P. indicus** from the brackishwater ecosystem concurrent with a negative relationship between potassium and calcium levels. A positive correlation between protein content and copper content of haemolymph was observed in all the three species because copper is bound with protein content (haemocyanin) in the haemolymph.

The intra- correlation study of muscle characteristics revealed negative correlation between water level and lipid level of all the three species because water content was replaced by lipid content in the muscle. In the study of inter-relationships between haemolymph characteristics and muscle characteristics it was observed that there were significant negative correlations between muscle protein and haemolymph protein of **M. monoceros** and **P. indicus** in marine environment and positive correlations between the two parameters in the case of **P. monodon** and **P. indicus** in brackishwater. It was interpreted that protein was mobilised from muscle to the ovary or testes through haemolymph in **M. monoceros** and **P. indicus** in marine water. In **P. monodon** and **P. indicus** of brackishwater protein content was found to accumulate in the muscle from haemolymph.

Protein and carbohydrate contens in the haemolymph showed an increasing trend during ovarian development in the standard

prawn of **M. monoceros** and **P. indicus.** Copper level showed an increasing trend in **P. indicus** and decreasing trend in **M. monoceros.**

In a standard female prawn of **M. monoceros** and **P. indicus** absolute values of weight, water and protein of muscle decreased whereas lipid level increased during ovarian development. Carbohydrate increased in **P. indicus** and decreased in **M. monoceros.**

When composition of muscle of a standard prawn of **M. monoceros** and **P. indicus** on percentage basis was observed, water, protein and carbohydrate levels were found to be decreasing with the accumulating lipid during ovarian development.

Gonad characters (absolute values) like weight, water, protein, carbohydrate and lipid showed an increasing trend during ovarian development in females of **M. monoceros** and **P. indicus.** It was observed that protein either from the muscle or from the haemolymph gets mobilised to the gonad.

When biochemical composition of gonad on percentage basis was examined, water decreased from maturity-stage I to IV and then increased, whereas protein, carbohydrate and lipid levels increased from maturity-stage I to IV and then declined.

A comparative study of gonad characters between **M. monoceros** and **P. indicus** revealed significant difference between the two species. All gonad characters were high in **P. indicus** than in

M. monoceros. All gonad characters increased in faster rate in P. **indicus** than in **M. monoceros** due to difference in growth rate between the two species.

When biochemical composition of gonad on percentage basis was observed, it was found that the composition was identical in maturity-stage I whereas in maturity-stage IV, more protein and carbohydrate levels were found in **M. monoceros** than in **P. indicus.** It may be due to relatively longer duration of the early larval development in **M. monoceros** than in **P. indicus.**

Haemolymph and muscle composition of **P. monodon** and **P. indicus** cultured during different seasons in the brackishwater ponds were compared. Study analysis of variance revealed that all haemolymph characteristics of **P. monodon** and **P. indicus** differed significantly. Muscle protein and lipid of **P. monodon** and carbohydrate and lipid levels of **P. indicus** also differed significantly. High values of protein, copper and potassium in the haemolymph of **P. monodon** and **P. indicus** coincided with the presence of high hydrological values during March, 1985.

Variation in haemolymph and muscle composition between the three crops was related with the changes in water parameters. It was observed that prevailing salinity range during December to March is nearer to the isosmotic points of **P. monodon** and **P. indicus** and high values of protein and copper levels in the

haemolymph were observed during this period. From this observation it was concluded that the period from December to March is ideal to take up prawn culture in brackishwater ponds around Kakinada bay. High values of potassium in the haemolymph was observed at higher salinity of the pond water.

REFERENCES

Abdul Rahaman, A. 1966. Reproductive and nutritional cycles of the crab **Portunus pelagicus** (Linnaeus) (Decapoda: Brachyura) of the Madras Coast. **Proc. Ind. Acad. Sci.**, 65:76-82.

Adegboye, D., 1983. Calcium homeostasis in the crayfish. **5th Int. Symp. on Freshwater crayfish** (Abst.); A VI. West Port CT (USA) : 137-153.

Adegboye, J.O.D., 1983. The relationship between medium calcium and haemolymph calcium concentrations of the crayfish during the mid-intermoult stage. **ibid.**, 173-180.

Adiyodi, R.G. and Subramoniam, T., 1983. Oogenesis, oosorption and oviposition in crustacea. In: K.G. Adiyodi and R.G. Adiyodi (Eds.) **Reproductive Biology of Invertebrates.** John Willey & Sons Ltd., London. Vol. 1: 443-495.

Ameer Hamsa, K.M.S., 1981. Chemical composition of the swimming crab **Portunus pelagicus** Linnaeus. **Indin J. Fish.**, 25(1&2)(1978) : 268-270.

Amsler, M.O. and George, R.Y., 1985. Changes in the biochemical composition of **Euphausia superba** Dana embryos during early development. **Polar Biol.**, 4: 61-63.

Anger, K., 1986. Changes of respiration and biomass of spider crab (**Hyas araneus**) larvae during starvation. **Mar. Biol.**, 90: 261-269.

Anger, K. and Harms, J., 1990. Elemental (CHN) and proximate biochemical composition of decapod crustacean larvae. **Comp. Biochem. Physiol.**, 97B: 69-80.

Anger, K., Laasch, N., Puschel, C. and Schorn, F., 1983. Changes in biomass and chemical composition of spider crab (**Hyas araneus**) larvae reared in the laboratory. **Mar. Ecol. Prog. Ser.**, 12(1) : 91-101.

Appanna, T.C. and Devadatta, S.C., 1942. Comparative studies on the nutritive value of fish and prawns muscle. **Curr. Sci.**, 11 : 333-335.

Arumugam, M. and Ravindranath, M.H., 1980. Significance of the variation in haemolymph copper-protein ratio in the crab, **Scylla serrata** (Forskal) during different hours of the day. **Experientia**, 36(11): 1306-1307.

Arumugam, M. and Ravindranath, M.H., 1983. Nature and distribution of copper in green lagoon crab **Scylla serrata** (Forskal). **J. exp. mar. Biol. Ecol.**, 70: 271-280.

Asokan, P.K. and George, M.J., 1984. Comparative studies on protein, carbohydrate and fat contents in **Penaeus indicus** during ovarian maturation in nature and induced maturation experiments. **CMFRI. SPL.** Publ., 19: 30-36.

Balazs, G.H., Olbrich, S.E. and Tumbleson, M.E., 1974. Serum constituents of the Malaysian prawn (**Macrobrachium rosenbergii**) and pink shrimp (**Penaeus marginatus**). **Aquaculture**, 3: 147-157.

Barnes, H., 1965. Studies in the biochemistry of cirripede eggs. I. Changes in the general biochemical composition during development of **Balanus balanoides** and **B. balanus**. **J. mar. biol. Ass. U.K.**, 45: 321-339.

Barnes, H., Barnes, M. and Finlayson, D.M., 1963. The seasonal changes in body weight, biochemical composition and oxygen uptake of two common boreo-arctic cirripedes, **Balanus balanoides** (L.) and **B. balanus** (L.) da Costa. **J. mar. biol. Ass. U.K.**, 43: 185-211.

Barnes, H. and Blackstock, J., 1973. Estimation of lipids in marine animals and tissues : Detailed investigation of the sulphophosphovanillin method for 'total' lipids. **J. exp. mar. Biol. Ecol.**, 12: 103-118.

Bedford, J.J., 1972. The composition of the blood of the grapsid crab, **Helice crassa** Dana. **J. exp. mar. Biol. Ecol.** 8(2): 113-119.

Bedford, J.J. and Leader, J.P., 1977. The composition of the haemolymph and muscle tissue of the shore crab, **Hemigrapsus edwardsi,** exposed to different salinities. **Comp. Biochem. Physiol.** 57A(3): 341-345.

Bennet, J. and Giese, A.C., 1955. The annual reproductive and nutritional cycles in two western sea-urchins. **Biol. Bull.,** 109: 226-237.

Borgstrom,G.1962. Shellfish protein - nutritive aspects. In : **Fish as Food.** Geroge Borgstrom (Ed.) Academic Press, New York and London, Vol. II: 115-147.

Bottino, N.R., Gennity, J., Lilly, M.L., Simmons, E. and Finne, G., 1980. Seasonal and nutritional effects on the fatty acids of three species of shrimp, **Penaeus setiferus, P. aztecus** and **P. duorarum. Aquaculture.** 19: 139-148.

Bursey, C.R. and Lane, C.E., 1971. Ionic and protein concentration changes during the molt cycle of **Penaeus duorarum. Comp. Biochem. Physiol.,** 40A: 155-162.

*Carus, D.G.G., 1824. Von den ausseren Lebensbeding gungen der weiss und kaltblutigen Thiere. **Leipzig,** 80-87.

Caulton, M.S. and Bursell, E., 1977. The relationship between changes in condition and body composition in young **Tilapia rendalli** Boulenger. **J. Fish. Biol.,** 11: 143-150.

Ceccaldi, H.J., 1982. Contribution of physiology and biochemistry to progress in aquaculture. **Bull. Japan. Soc. Sci. Fish.,** 48(8): 1011-1028.

Chari, S.T., 1948. Nutritive value of some of the west coast marine food fishes of the Madras Province. **Indian J. Med. Res.**, 36: 253-259.

Clarke, A., 1977. Seasonal variations in the total lipid content of **Chorismus antarcticus** (Pfeffer) (Crustacea : Decapoda) at South Georgia. **J. exp. mar. Biol. Ecol.**, 27(1): 93-106.

Clarke, A. and Wickins, J.F., 1980. Lipid content and composition of cultured **Penaeus merguiensis** fed with animal food. **Aquaculture**, 20(1): 17-27.

Colvin, P.M., 1976. The effect of selected seed oils on the fatty acid composition and growth of **Penaeus indicus**. **Aquaculture** 8: 81-89.

Cruz-Ricque, L.E., Guillaume J. and Van Wormhoudt, A., 1989. Effect of squid extracts on time course appearance of glucose and free aminoacids in haemolymph in **Penaeus japonicus** after feeding: Preliminary results. **Aquaculture**, 76: 57-65.

Dall, W., 1964. Studies on the physiology of a shrimp, **Metapenaeus mastersii** (Haswell) (Crustacea : Decapoda : Penaeidae). 1. Blood constituents. **Aust. J. Mar. Freshw. Res.**, 15: 145-161.

Dall, W., 1965a. Studies on the physiology of a shrimp, **Metapenaeus** sp. (Crustacea:Decapoda:Penaeidae). IV. Carbohydrate metabolism. **ibid.**, 16: 163-180.

Dall, W., 1965b. Studies on the physiology of a shrimp, **Metapenaeus** sp. (Crustacea:Decapoda:Penaeidae). V. Calcium metabolism. **ibid.**, 16: 181-203.

Dall, W. 1974a. Osmotic and ionic regulation in the western rock lobster **Panulirus longipes** (Milne Edwards). **J. exp. mar. Biol. Ecol.**, 15: 97-125.

Dall, W., 1974b. Indices of nutritional state in the Westerson rock lobster, **Panulirus longipes** (Milne Edwards). I. Blood and tissue constituents and water content. **ibid.**, 16: 167-180.

Dall, W., 1975. Blood carbohydrates in the Western rock lobster, **Panulirus longipes** (Milne Edwards). **ibid.**, 18: 227-238.

Dall, W., 1981. Osmoregulatory ability and juvenile habitat preference iin some penaeid prawns. **ibid.**, 54: 55-64.

Dall, W. and Smith, D.M., 1981. Ionic regulation of four species of penaeid prawn. **ibid.**, 55: 219-232.

Digby, P.S.B., 1984. Calcification in the shore crab, **Carcinus maenas** (L.) pH and the precipitation of carbonates from sea water and blood. **J. mar. biol. Asso. U.K.**, 64: 233-248.

Diwan, A.D. and Laxminarayana, A., 1989. Osmoregulatory ability of **Penaeus indicus** H. Milne Edwards in relation to varying intensities. **Proc. Indian Acad. Sci.**, 98: 105-111.

Diwan, A.D., Laxminarayana, A. and Kakati, V.S., 1989. Osmoregulatory ability of **Penaeus monodon** (Fabricius) in relation to varying salinities. **Indian J. Fish.**, 36(1): 53-57.

Diwan, A.D. and Nagabhushanam, R., 1974. Reproductive cycle and biochemical changes in the gonads of the fresh water crab, **Barytelphusa cunicularis** (Westwood). **ibid.**, 21(1): 164-176.

Diwan, A.D. and Usha, T., 1987. Mobilisation of organic reserves during moult cycle in the prawn, **Penaeus indicus** (H. Milne Edwards). **Indian J. Mar. Sci.**, 16: 65-68.

Djangmah, J.S., 1970. The effects of feeding and starvation on copper in the blood and hepatopancreas and on blood proteins of **Crangon vulgaris** (Fabricius). **Comp. Biochem. Physiol.**, 32: 709-731.

Dubois, M., Gilles, K.A., Hamilton, J.K., Rebers, P.A. and Smith, F., 1956. Colorimetric method for determination of sugars and related substances. **Analyt. Chem.**, 28: 350-356.

Du Preez, H.H. and McLachlan, A., 1983. Seasonal changes in biochemical composition and energy content of the three-spot swimming crab, **Ovalipes punctatus** (De Haan) (Crustacea: Brachyura). **J. exp. mar. Biol. Ecol.**, 72(2): 189-198.

Eastman-Reks, S.B. and Fingerman, M., 1985. **In vitro** synthesis of vitellin by the ovary of the fiddler crab, **Uca pugilator. J. Exp. Zool.**, 233: 111-116.

Fair, P.H. and Sick, L.V., 1982. Serum amino acid concentrations durign starvation in the prawn, **Macrobrachium rosenbergii**, an an indicator of metabolic requirements. **Comp. Biochem. Physiol.**, 73B(2): 195-200.

Farmer, A.S.D., 1986. Morphometric relationships of commercially important species of penaeid shrimp from the Arabian Gulf. **Kuwait Bulletin of Marine Sciences.** 7: 1-21.

Ferguson, C.F. and Raymont, J.K.B., 1974. Biochemical studies on marine zooplankton XII. Further investigations on **Euphausia superba** Dana. **J. mar. biol. Ass. U.K.**, 54: 719-725.

Ferraris, R.P., Estepa, D.P., Ladia, J.M. and De Jesus, E.C., 1986. Effect of salinity on the osmotic, chloride, total protein and calcium concentrations in the haemolymph of the prawn, **Penaeus monodon** (Fabricius). **Comp. Biochem. physiol.**, 83A(4): 701-708.

Florkin, M., 1960. Blood chemistry. In : **The Physiology of Crustacea**, T.H. Waterman (Ed.), Academic Press, New York, 141-159.

Fyffe, W.E. and O'Connor, J.D., 1974. Characterization and quantification of a crustacean lipovitellin. **Comp. Biochem. Physiol.**, 47B: 851-867.

George, J.C. and Patel, B.S., 1956. The seasonal variation in fat content of the liver and gonads in a marine and freshwater decapod. **J. Anim. Morph. Physiol.**, 3: 49-55.

George, K.V., 1978. Prawn farming. **CMFRI. Spl. Publ.**, 3: 116-121.

George, M.J., 1959. Notes on the bionomics of the prawn **Metapenaeus monoceros** Fabricius. **Indian J. Fish.**, 6(2): 268-279.

George, M.J., 1970a. Synopsis of biological data on the penaeid prawn **Metapenaeus dobsoni** (Miers, 1878). **F.A.O. Fish. Rep.**, 57(4): 1335-1358.

George, M.J., 1970b. Synopsis of biological data on the penaeid prawn **Metapenaeus affinis** (H. Milne Edwards, 1837). **ibid.**, 57(4): 1359-1375.

George, M.J., 1970c. Synopsis of biological data on the penaeid prawn **Metapenaeus monoceros** (Fabricius, 1798). **ibid.**, 57(4): 1539-1557.

George, M.J., 1972. On the food and feeding habits of **Metapenaeus monoceros** (Fabricius). **Coastal aquaculture in the Indo-pacific region.** T.V.R. Pillay (Ed.), Fishing News Books (London): 178P.

George, W.C. and Nichols, J., 1948. A study of the blood of some crustacea. **J. Morph.** 83: 425-440.

Gibson, R. and Barker, P.L., 1979. The decapod hepatopancreas. **Oceanogr. Mar. Biol. Ann. Rev.**, 17: 285-346.

Gilbert, A.B., 1959. The composition of the blood of the shore crab, **Carcinus maenas** Pennant, in relation to sex and body size. II. Blood chloride and sulphate. **J. exp. Biol.**, 36: 356-362.

Gopakumar, K. and Nair, M.R., 1975. Lipid composition of five species of Indian Prawn. **J. Sci. Food. Agric.**, 26: 319-325.

Gopalakrishnan, V., 1951. A note on the chemical composition of the penaeid prawns of Madras. **Curr. Sci.**, 20: 331.

Gornall, A.G., Bardawill, C.J. and David, M.M., 1949. Determination of total serum protein by means of biuret reaction. **J. Biol. Chem.**, 177: 751-766.

Hagerman, L., 1983. Haemocyanin concentration of juvenile lobsters (**Homarus gammarus**) in relation to moulting cycle and feeding conditions. **Mar. Biol.**, 77(1): 11-17.

Hall, D.N.F., 1962. Observations on the taxonomy and biology of some Indo-west pacific peaneidae (Crustacea : Decapoda). **Fish. Publ. Colonial. Off.**, London, 17: 1-229.

Hartnoll,, R.G., 1982. "Growth". In : **Biology of Crustacea.** Dorothy E. Bliss (Ed.), 2: 111-196.

Hayashi, K., 1976. The lipids of marine animals from various habitat depths. 6. On the characteristics of the fatty acid composition of neutral lipids from decapods. **Bull. Fac. Fish. Hokkaido Univ.**, 27(1): 21-29.

Horn, E.C. and Kerr, M.S., 1963. Hemolymph protein and copper concentrations of adult blue crabs (**Callinectes sapidus** Rathbun). **Biol. Bull.**, 125: 499-507.

Iwata, J. and Shigueno, K., 1980. Osmotic concentration of hemolymph in various growth stages of **Penaeus japonicus. Bull. Jap. Soc. Sci. Fish.**, 46: 1547.

Iwata, K., Arita, T. and Iino, K., 1983. Seasonal changes in energy reserves of **Scopimera globosa** (Crustacea : Ocypodidae) with special reference to its wandering behavior. **Zool. Mg.**, 92(3): 306-316.

Jacobi, C.C. and Anger, K., 1985. Growth and respiration during the larval development of **Hyas coarctatus** (Decapoda : Majidae). **Mar. Biol.**, 87: 173-180.

Johnson, J.T. and Hopkins, T.L., 1978. Biochemical components of the mysid shrimp **Taphromysis bowmani** Bacescu. **J. exp. mar. Biol. Ecol.**, 31: 1-9.

Kanazawa, A., Teshima, S., Sakamoto, Y., Guary, J.C.B., 1976. The varation of lipids and cholesterol contents in the tissues of prawn, **Penaeus japonicus** during the molting cycle. **Bull. Jap. Soc. Sci. Fish.,** 42(9): 1003-1007.

Kannan, K. and Ravindranath, M.H., 1980. Changes in protein-calcium association during different hours of a day in the haemolymph of the crab **Scylla serrata** (Forskal). **Experientia.** 36(8): 965-966.

Kannan, K. and Ravindranath, M.H., 1981. 'Calcium'. In: **Manual of Research methods for crustacean biochemistry and physiology. , CMFRI. Spl. Publ.**, 7: 77-87.

kannupandi, T. and Paulpandian, A.L., 1975. Studies on the blood and muscle proteins of crabs of Porto Novo. **Bull. Dep. Mar. Sci.**, University of Cochin, 7(3): 609-622.

Kerr, M.S., 1969. The hemolymph proteins of the blue crab, **Callinectes sapidus.** II. A lipoprotein serologically identical to oocyte lipovitellin. **Develop. Biol.**, 20: 1-17.

Kobayashi, M., 1982. Influence of body size on haemoglobin concentration and resistance to oxygen deficiency in **Daphnia magna. Comp. Biochem. Physiol.**, 72A(3): 599-602.

Krishnamoorthy, R.V., Venkataramaiah, A., Lakshmi, G.J. and Patricia Biesiot., 1982. Effects of starvation and of algae-feeding on the tissue cholesterol levels in commercial shrimp **Penaeus aztecus** Ives. **Proc. Symp. Coastal Aquaculture.**, 1: 215-222.

Kulkarni, G.K. and Nagabhushanam, R., 1979. Mobilization of organic reserves during ovarian development in a marine penaeid prawn, **Parapenaeopsis hardwickii** (Miers) (Crustacea: Decapoda: Penaeidae). **Aquaculture.**, 18: 373-377.

Kulkarni, G.K., Nagabhushanam, R. and Joshi, P.K., 1980. Blood glucose in marine penaeid prawn **Parapenaeopsis hardwickii** : Circadian rhythmicity and influence of salinity. **Indian J. Mar. Sci.**, 9(2): 126-127.

Kulkarni, K.M., 1984. Osmotic and ionic regulation during the moulting cycle of the sand crab, **Emerita holthuisi. Comp. Physiol. Ecol.**, 9:340-342.

Kurian, C.V. and Sebastian, V.O., 1975. **Prawn and Prawn fisheries of India.** Hindusthan Publishing Corporation (India): 286 p.

Lalitha Devi, S ., 1989. Observation on the fishery and biology of penaeid prawns from Godavari estuary. **Indian J. Fish.**, 35(1): 52-63.

Lawrence, J.M., 1976. Organic composition and energy content of the hepatopancreas of the hermit crabs (Coenobita) from Eniwetok Atoll,, Marshall Islands (Decapoda : Paguridea). **Crustaceana**, 31(2): 113-118.

*Le Cren, E.D., 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in perch **(Perca fluviatilis). J. Anim. Ecol.**, 20: 201-219.

Leone, C.A., 1953. Preliminary observations on intraspecific variation of the level of total protein in the sera of some decapod crustacea. **Science**, 118: 295-296.

Lin, S. and Cohen, H.P., 1973. Crayfish ventral nerve cord and haemolymph : content of free aminoacids and othermetabolites. **Comp. Biochem. Physiol.** 45B(1): 249-263.

Lockhead, J.R. and Lockhead, M.S., 1941. On the blood and related tissues in artemia (Crustacea : Anostraca). **J. Morph.**, 68: 593-631.

Lock Wood, A.P.M. and Inman, C.B.E., 1973. The blood volume of some amphipod crustaceans in relation to the salinity of the environment the inhabit. **Comp. Biochem. Physiol.**, 44A(3): 935-941.

Lucu, C., 1990. Ionic regulatory mechanisms in crustacean gill epithelia. **ibid.**, 97A: 297-306.

Lui, C.W., Sage, B.A. and O'Connor, J.D., 1974. Biosynthesis of lipovitellin by the Crustacean ovary, **J. Exp.Zool.**, 188: 289-296.

Maghraby, A.M., Ezzat, A. and Tabakal, T., 1976. Biochemical composition of **Metapenaeus monoceros** in Egyptian Mediterranean waters. **Ra pp. P.V.Reum. Cons. Int. Explor. Mer.**, 23: 75-78.

Mangum, C.P., 1983. Oxygen transport in the blood. In: **Biology of Crustacea**, Dorothy E. Bliss (Ed.), 5: 373-429.

Martin, B.J., 1980. Growth and fatty acids of **Palaemon serrtus** (Crustacea : Decapoda) fed with compounded diets containing different proportions of linoleic and linolenic acids. **Aquaculture**, 19: 325-337.

Mauchline, J. and Fisher, L.R., 1969. The biology of Euphausids. **Adv. mar. Biol.**, 7: 1-454.

McFarland, W.N. and Lee, B.D., 1963. Osmotic and ionic concentrations of penaeidean shrimps of the Texas Coast. **Bull. mar. Sci. Gulf Caribb.**, 13: 391-417.

Mohamed, K.H., 1970a. Synopsis of biological data on the jumbo tiger prawn, **Penaeus monodon** Fabricius, 1798. **F.A.O. Fish. Rep.**, 57(4): 1251-1266.

Mohamed, K.H., 1970b. Synopsis of biological data on the Indian prawn **Penaeus indicus** H. Milne Edwards, 1837. **F.A.O. Fish. Rep.,** 57(4): 1267-1288.

Mohamed, K.H., Muthu, M.S., Pillai, N.N. and Geroge, K.V., 1979. Larval development of **Metapenaeus monoceros** (Fabricius) In: Larval development of Indian Penaeid prawns. **Bull. Cent. Mar. Fish. Res. Inst.,** 28: 50-60.

* Munoz, P. and Ceccaldi, H.J., 1983. Effects du jeune sur less proteines de l' hemolymphe de **Penaeus japonicus.** RAPP: P.- V. REUN. CIESM., 28: 341-344.

Muthu, M.S., Pillai, N.N. and George, K.V., 1979. Larval development of **Penaeus indicus** H. Milne Edwards. In: Larval development of Indian penaeid prawns. **Bull. Cent. Mar. Fish. Res. Inst.,** 28: 12-22.

Nagabhushanam, R. and Kulkarni, G.K., 1982. Endocrine regulation of reproduction in the marine female prawn **Parapenaeopsis hardwickii** (Miers) (Crustacea : Decapoda : Penaeidae). **Proc. Symp. Coastal Aquaculture,** M.B.A.I., 1: 40-47.

Nalini, C., 1976. Observations on the maturity and spawning of **Metapenaeus monoceros** (Fabricius) at Cochin. **Indian J. Fish.,** 23(1&2): 23-30.

Nammalwar, P., 1978. Blood sugar estimation in the estuarine crab, **Scylla serrata** (Forskal). **Sci. Cult.,** 44(12): 543-544.

Ohidalia, W., Vendrely, R., Montmory, C., Coirault, Y. and Brouard, M.O., 1981. Coagulation in decapod crustacea comparative study of the clotting process in species groups A, B and C. **J. Comp. Physiol.,** 142(4): 473-478.

O'Leary, C.D. and Matthews, A.D., 1990. Lipid class distribution & fatty acid composition of wild and farmed **Penaeus monodon** (Fabricius), **Aquaculture,** 89: 65-81.

Panikkar, N.K., 1951. Physiological aspects of adaptation to estuarine conditions. **Proc. Indo-pacific Fish. Council** (1950), Cronulla, N.S.W., Australia. Sect. 3: 168-175.

Panikkar, N.K., 1968. Osmotic behaviour of shrimps and prawns in relation to their biology and culture. **F.A.O. Fish. Rep.,** 57: 527-538.

Panikkar, N.K. and Viswanathan, R., 1948. Active regulation of chloride in **Metapenaeus monoceros** Fabricius. **Nature,** 161: 137-138.

Pearse, J.S. and Giese, A.C., 1966. The organic constitution of several benthonic invertebrates from McMurdo sound Antarctica. **Comp. Biochem. Physiol.** 18: 47-57.

Penn, J.W., 1980. Observations on length-weight relationship and distribution of the red spot king prawn, **Penaeus longistylus** Kubo, in Western Australian waters. **Aust. J. Mar. Freshw. Res.** 31(4): 547.

Penn, J.W. and Hall, N.G., 1974. Morphometric data relating to commercial prawns from shark bay, Western Australia. **Fish. Res. Bull.,** 15: 1-12.

Pequeux, A., Vallota, A.C. and Gilles, R., 1979. Blood proteins as related to osmoregulation in crustacea. **Comp. Biochem. Physiol.,** 64A(3): 433-435.

Pillay, K.K. and Nair, N.B., 1971. The reproductive cycle of three decapod crustaceans from the south-west coast of India. **Curr. Sci.,** 40: 161-162.

Pillay, K.K. and Nair, N.B., 1973. Observations on the biochemical changes in gonads and other organs of **Uca annulipes, Portunus pelagicus** and **Metapenaeus affinis** (Decapoda : Crustacea) during the reproductive cycle. **Mar. Biol.,** 18: 167-198.

Raja, P.V., Ravindranath, M.H. and Ramalingam, K., 1976. Studies on autotomy in crustaceans. II. Changes in haemolymph sugars of shore crab, **Ocypode platytarsis** in response to autotomy and bleeding stress. **Physiol. Zool.**, 49(4): 389-397.

Rajamani, M., 1982. Biochemical studies on 'soft' prawns: I. Protein, nitrogen and non-protein nitrogen contents in **Penaeus indicus**. **Proc. Symp. Coastal Aquaculture**, M.B.A.I., 1: 349-353.

Rajyalakshmi, T., 1961. Observations on the biology and fishery of **Metapenaeus brevicornis** (M. edw) in the Hoogly estuarine system. **Indian J. Fish.**, 8(2): 383-402.

Rajyalakshmi, T., Maheswarudu, G., Reddy, D.M. and Joshi, H.C., 1986. An approach to environmental impact study in the Kakinada bay. **Environmental Biology Coastal ecosystem**: 125-140.

Ramamurthy, S. and Manickaraja, M., 1981. Relation between tail and total lengths and total and carapace lengths for three commercial species of penaeid prawns of India. **Indian J. Fish.**, 25(1&2): 233-236.

Rambhaskar, B., 1985. Haematology of **Chanos chanos** (Forskal) from brackishwater fish farms of Kakinada. Ph.D. Thesis, Andhra University, Visakhapatnam.

Rao, A.U.P., 1967. Some observations on the biology of **Penaeus indicus** H. Milne Edwards and **Penaeus monodon** Fabricius from the Chilka lake. **Indian J. Fish.**, 14: 251-270.

Raymont, J.E.G., Srinivasagam, R.T., and Raymont, J.K.B., 1971. Biochemical studies on marine zooplankton. IX. The biochemical composition of **Euphausia superba**. **J. mar. biol. Ass. U.K.**, 51: 581-588.

Read, G.H.L., 1984. Intraspecific variation in the osmoregulatory capacity of larval, post-larval, juvenile and adult **Macrobrachium petersi** (Hilgendorf). **Comp. Biochem. Physiol.** 78A(3): 501-506.

Read, G.H.L. and Caulton, M.S., 1980. Changes in mass and chemical composition during the moult cycle and ovarian development in immature and mature **Penaeus indicus** H. Milne Edwards. **ibid.,** 66A: 431-437.

Reddy, M.S., Venkateswarlu, Y., Nath, P.S. and Rao, K.V.R., 1986. Phosphamidon and lindane induced changes in the haemolymph biochemistry of a penaeid prawn, **Metapenaeus monoceros. Nat. Acad. Sci. Letters,** 10: 39-43.

* Renaud, L., 1949. Le cycle des reserves organiques chez less crustaces decapodes. **Annls. Inst. Oceanogr.,** Monaco, 24: 259-357.

Rodriguez, G.A. and Gartz, R.M., 1976. Preliminary study on the osmoregulation in **Penaeus stylirostris** (Stimpson). **Proc. Symp. on the Biol. and dynamics of prawn populations.** (1976), Guaymas. Son. Mexico. 1: 53-70.

Roe, J.H., 1955. The determination of sugar in blood and spinal fluid with anthrone reagent. **J. Biol. Chem.,** 212 : 335-343.

Santos, M. de C.F. and Salomao, L.C., 1985. Hemolymph osmotic and ionic concentrations in the gecarcinid crab, **Ucides cordatus. Comp. Biochem. Physiol.,** 81A: 581-583.

Sarojini, R. and Jahagirdar, V.G., 1983. Role of SH-linked proteins and saturated lipids on the ovarian maturation of the hermit crab, **Pegurus kulkarni. J. Adv.Zool.,** 4(2): 81-85.

Sarojini, R., Mirajdar, M.S. and Nagabhushanam, R., 1982. Biochemical changes in the freshwater prawn **Macrobrachium kistnensis. Biol. Bull. India,** 4(1): 31-35.

Schafer, H.J., 1968. The determination of some stages of the molting cycle of **Penaeus duorarum** by microscopic examination of the setae of the endopodites of pleopods. **F.A.O. Fish. Rep.** 57(2): 381-391.

Scheer, B.T., 1960. Aspects of the intermolt cycle in natantians. **Comp. Biochem. Physiol.**, 1: 3-18.

Sevilla, C., 1975. Study of organic constituents of the haemolymph in Oniscoidea (Crustacea : Isopoda). **Bull. Soc. Zool.** 100(4): 443-456.

Shaikhmahmud F. and Magar, N.G., 1957. Studies in the nutritive value of Bombay prawns : Part I: Chemical composition of prawns. **J. Sci. Industr. Res.** (India)., 16A: 44-46.

Shibata, N., 1983. Effect of fishing season on lipid content and composition of Antarctic krill. **Bull. Jap. Soc. Sci. Fish.**, 49(2): 259-264.

Silas, E.G., 1985. Hatchery production of penaeid prawn seed, **Penaeus indicus. CMFRI. Spl. Publ.**, 23: 41p.

Silas, E.G., George, M.J. and Jacob, T., 1984. A review of the fisheries of India : a scientific basis for the management of the resources. In: **Penaeid shrimps, their biology and management.** J.A. Gulland and B.J.B. Rothschild (Eds.), 83-103.

Simpson, G.G., Rowe, A. and Lewontin, R.C., 1960. **Quantitative Zoology**, Harcourt, Brace & World Inc., New York.

Sitaramaiah, P. and Krishnan, G., 1965. Calcium metabolism in **Emerita asiatica. Indian J. Exp. Biol.**, 4: 34-36.

Smith, A.C., 1982. Simple test for general stress in a Decapod crustacean, the pink shrimp, **Penaeus duorarum.** J. **Aquaricult. Aquat. Sci.**, 3(1): 11.

Snedecor, G.W. and Cochran, W.G., 1967. **Statistical methods.** (VI ed.), Oxford & IBH Publishing Co., New Delhi. 593p.

Spaargarden, D.H., 1975. Notes on the Osmotic and ionic regulation of brachyuran crabs from Curacago. **Neth. J. Sea Res.**, 9(3-4) : 273-286.

Srinivasulu Reddy, M., Veera Babu, G.R. and Ramana Rao, K.V., 1989. Changes of lipid components in midgut gland and muscle of penaeid prawns, **Metapenaeus monoceros** and **Penaeus indicus** exposed to phosphamidon. **Mahasagar**, 22(1): 43-46.

Stein, R.A. and Murphy, M.L., 1976. Changes in proximate composition of the crayfish **Orconectes poropinquus** with size, sex and life stage. **J. Fish. Res. Bd. Canada**, 33: 2450-2458.

Stewart, J.E., Cornick, J.W., Foley, D.M., Li, M.F. and Bishop, C.M., 1967. Muscle weight relationship to serum proteins, haemocytes and hepatopancreas in the lobster **Homarus americanus. ibid.,** 24(11): 2339-2354.

Stewart, J.E., Dingle, J.R. and Odense, P.H., 1966. Constituents of the haemolymph of the lobster, **Homarus americanus** Milne Edwards. **Canadian J. Biochem.**, 44: 1447-1459.

Subrahmanyam, C.B., 1963a. Notes on the bionomics of the penaeid prawn, **Metapenaeus affinis** (Milne Edwards) of the malabar coast. **Indian J. Fish.,** 10A(1): 11-22.

Subrahmanyam, C.B., 1963b. A note on the annual reproductive cycle of the prawn **Penaeus indicus** (M. Edw.) of Madras coast. **Curr. Sci.,** 32(4): 165-166.

Subrahmanyam, C.B., 1967. On the reproductive cycle of **Penaeus indicus** (M. Edw.). **J. mar. biol. Ass. India.** 7(2): 284-290.

Subrahmanyam, M., 1973. Fishery and biology of **Metapenaeus monoceros** (Fabricius) from the Godavari estuarine system. **Indian J. Fish.,** 20: 95-107.

Subrahmanyam, M. and Ganapati, P.N., 1975. The biology of the prawn, **Penaeus monodon** Fabricius from the Godavari estuarine system. **Bull. Dept. Mari. Sci.,** Univ. Cochin., 7: 653-670.

Subramaniam, P., 1987. Spawner-recruit distribution of **Penaus indicus** in Parangipettai coastal ecosystem. **J. mar. biol. Ass. India**, 29(1&2): 23-36.

Subhash Chander, 1986. Studies on ecophysiology of **Penaeus indicus** H. Milne Edwards in the grow-out system. Ph.D. Thesis, Univeristy of Cochin.

Sudhakara Rao, G., 1988a. Length-weight relationship and other dimensional relationships of **Metapenaeus monoceros** (Fabricius) from the Kakinada coast. **Indian J. Fish.**, 35(3): 211-215.

Sudhakara Rao, G., 1988b. Studies on the feeding biology of **Metapenaeus monoceros** (Fabricius) along the Kakinada coast. **J. mar. biol. Asso. India**, 30(1&2): 171-181.

Sudhakara Rao, G., 1988c. Exploitation of prawn resources by trawlers off Kakinada with a note on the stock assessment of commercially important species. **Indian J. Fish.**, 35(3): 140-155.

Sudhakara Rao, G., 1989. Studies on the reproductive biology of the brown prawn **Metapenaeus monoceros** (Fabricius, 1798) along the Kakinada coast. **ibid.**, 36(2): 107-123.

Sukumaran, K.K. and Rajan, K.N., 1981. Studies on the fishery and biology of **Parapenaeopsis hardwickii** (Miers) from Bombay area. **ibid.**, 28(1&2): 143-153.

Sumitra Vijayaraghavan and Easterson, D.C.V., 1974. Biochemical changes and energy utilization in developing stages of the estuarine prawn, **Macrobrachium idella** (Hilgendrof). **J. Mar. Biol. Ass. India**, 16(1): 275-279.

Sumitra Vijayaraghavan, Wafar, M.V.M. and Joseph P. Royan, 1976. Changes in biochemical composition and energy utilisation in developmental stages of the mole crab, **Emerita holthuisi** Sankolli. **Mahasagar**, 8(3&4): 165-170.

Sunil Kumar Mohamed, K., 1989. Studies on the reproductive endocrinology of the penaeid prawn, **Penaeus indicus** H. Milne Edwards. Ph.D. Thesis., University of Cochin.

Szaniawska, A., 1983. Seasonal changes in energy content of **Crangon crangon** L. (Crustacea : Decapoda). **Pol. Arch. Hydrobiol.**, 30(1): 45-56.

Takahashi, H. and Yamada, M., 1976. Lipid composition of seven species of crustacean plankton. **Bull. Jap. Soc. Sci. Fish.**, 42(7): 769-776.

Teshima, S. and Kanazawa, A., 1976. Variation in lipid during the molting cycle of a shrimp. **ibid.**, 42(10): 1129-1135.

Teshima, S., Kanazawa, A. and Okamoto, H., 1977. Variation in lipid classes during the molting cycle of the prawn **Penaeus japonicus**. **Mar. Biol.**, 39(2): 129-136.

Thomas, M.M., 1975. Age and growth, length-weight relationship and relative condition factor of **Penaeus semisulcatus** de Haan. **Indian J. Fish.**, 22(1&2): 133-142.

Thomas, M.M., 1982. Preliminary results of electrophoretic studies on marine prawns. **ibid.**, 28(1&2) : 292-294.

Torres, C., 1973. Variations du pool des acides amines libres du muscle abdominal de **Penaeus kerathurus** au cours du cycle d' intermu, et au cours du jeune. **Comp. Biochem. Physiol.** 45B: 1-12.

Vedavyasa Rao, P ., 1983. Reproductive biology of penaeid prawns. **Summer institute in hatchery production of prawn seed and culture of marine prawns.** (Technical Paper), CMFRI, Cochin.

Vedavyasa Rao, P., Diwan, A.D. and Kakati, V.S., 1981. Fluctuation in calcium levels in the exoskeleton, muscle and haemolymph of **Penaeus indicus**, cultivated in a brackishwater pond. **Indian J. Fish.**, 28(1&2): 160-167.

Victor, B., 1987. Reproductive and lipid cycles in the Atyid prawn **Caridina rajadhari** (Bouvier). **Indian J. Fish.,** 34(3): 333-336.

Vijayan, K.K., 1988. Studies on the physiology of moulting in the penaeid prawn, **Penaeus indicus** H. Milne Edwards. Ph.D. Thesis, University of Cochin.

Vijayakumaran, M., 1990. Energetics of a few marine crustaceans. Ph.D. Thesis, University of Cochin.

Vinogradov, A.B., 1953. Elementary composition of marine organisms. Elementary composition of Arthropoda. **Mem. Sears. Fdn mar. Res.,** 11: 375-429.

Walters, N.J. and Uglow, R.F., 1981. Haemolymph magnesium and relative heart activity of some species of marine decapod crustaceans. **J. exp. mar. Biol. Ecol.,** 55: 255-265.

Wieser, W., 1965. Electrophoretic studies on blood proteins in an ecological series of isopod and amphipod species. **J. mar. biol. Asso. U.K.,** 45: 507-523.

Williams, A.B., 1960. The influence of temperature on osmotic regulation in two species of estuarine shrimps (penaeus). **Biol. Bull.,** 119: 560-571.

Winkler, L.W., 1888. Die Bestimmung des Im Wasser gelosten sauerstoffes. **Dtsche. Chem. Ges. Ber.,** 21: 2843-2855.

Wolin, E.M., Laufer, H. and Albertini, D.F., 1973. Uptake of the yolk protein, lipovitellin by developing crustacean oocytes. **Develop. Biol.,** 35: 160-170.

Wright, D.A., Zanders, I.P. and Pait, A., 1984. Ionic regulation in three species of **Uca** : A comparative study. **Comp. Biochem. Physiol.,** 78A: 175-179.

---

* = not referred to in original

APPENDIX

J. Indian Soc. Coastal agric. Res., 4(1) 25-41, 1986

On the Culture of *Macrobrachium rosenbergii* (De Man) in Andhra Pradesh—India

T. RAJYALAKSHMI and G. MAHESWARDU
Department of Fishery Science, A. P. Agricultural University,
Kakinada-7, India

In Andhra Pradesh, India, large acreage of freshwater ponds seasonal, and perennial, have now been brought under freshwater fish cultivation. Large acreage traditionally under paddy cultivation also are being converted to fish farming using composite fish culture methods. Some of them can shift to freshwater prawn farming or partially incorporate, in separate monoculture of the species.

Macrobrachium rosenbergii has extensive natural fishery in some of the lakes and rivers but natural seed availability is not only rare but scarce too. Since 1970 techniques for hatchery rearing of post larvae have been developed by research organisations. Supply of stockable juveniles commenced by late 1970s.

The present study deals with experiments on post-larval production in small scale hatchery, costs of production, feed formulation using tubificid worms, water quality and survival. Experimental culture conducted in larger ponds with varying water and soil qualities, feeds growth and ultimate returns are also shown.

Incorporation of the species into mono or polyculture with fish in extensive system has a tremendous potential if a steady juvenile production is maintained. Thus, educating farmers on specific technologies, a good marketing system could lead to quick adoption by farmers to this extensive freshwater prawn farming of the fast-growing species such as *Macrobrachium rosenbergii* and the smaller riverine prawn of India, *Macrobrachium malcolmsonii*

Macrobrachium rosenbergii (De Man), the giant freshwater prawn is most common in the estuarine regions of the rivers both on East and West coasts of India, and in the Hooghly estuary in the North East. Chopra (1943), reported on the breeding habits of the species in South-West coast of India while John (1957), studied the fecundity potential and breeding migrations of the species in the same region. Rajyalakshmi (1961) for the first time, used ova-dimensions as a means of determining maturation and breeding periodicity in *Macrobrachium rosenbergii* and made observations on the salinity requirements for hatching in rivers. Raman (1967), made observations on breeding migrations and feeding of the species in the South-West coast of India. Rao (1967) studied the mating behaviour, breeding biology and age and growth of *Macrobrachium rosenbergii* of Hooghly estuary. Rajyalakshmi (1975), reported for the first time, the occurence of the species and its size composition in capture fisheries of certain paddy field drain channels opening into Kakinada Bay, in Andhra Pradesh.

Elsewhere in the world, with the studies conducted by Ling (1962, 1967 a

and 1967 b) in Malaysia and Fujimura (1966), Fujimura and Okomoto (1970), Fujimoto *et al.*, (1977) in Hawaii. considerable progress has been made on the culture aspects of the species such as production of juveniles, growth and production in grow-out ponds. An extensive review of work in United States of America has been given by various authors (Mayers 1974, Hagood and Willis 1976, Hanson and Goodwin 1977, among others) and that in United Kingdom (Wickins. 1978).

As compared to capture fisheries, the controlled production of juveniles and culture of *Macrobrachium rosenbergii* in freshwater ponds has received very little attention in India till 1970s (Rajyalakshmi, 1978). However, over a long time the species has been in extensive production in the freshwater impoundments of river Hooghly, at *Itindaghat*, in North-Eastern India. The juvenile stock is naturally recruited in these impoundments (Rajyalakshmi, unpublished doctoral thesis). In Andhra Pradesh, particularly. another large species of *Macrobrachium* viz., *M. malcolmsonii* has been introduced in experimental culture studies since 1968 in view of large natural stock of juveniles occuring at all the barriers (wiers) of rivers in this state (Ibrahim, 1962, Rajyalakshmi 1968 and 1972, and Rajyalakshmi *et al.*, 1982). Discovery of brood prawns of *Macrobrachium rosenbergii* in the paddy field drain channels which open in to the Kakinada Bay (Fig. 1) has led to an establishment of a small scale hatchery by the Central Inland Fisheries Research Institute (Anon, 1975 and 1976).

During the period 1975 to 1982 extensive grow-out ponds for fresh water fish have been excavated both in public and private sectors of Andhra Pradesh, the farm sizes ranging from 10 ha to 200 ha. Under these set of conditions incorporation of a variety, like the indigenous varieties of freshwater prawns in mixed culture has been receiving considerable attention. Fish farmers have now a growing awareness of the suitability of the giant prawn in this system. The demand for seed has gone up in 1980s. Keeping these points in view a few preliminary studies conducted by the authors since 1982 on hatchery production of juveniles and their introduction in different types of freshwater ponds, their growth and survival, potential for large scale introduction in farmers' ponds *etc.*, are discussed in this paper.

MATERIAL AND METHODS

Reproductive Biology and Brood Prawns

The maturity and breeding cycle of *Macrobrachium rosenbergii* have been well documented (Rajyalakshmi, 1961, and unpublished doctoral thesis 1976, Rao, 1967). In North-Eastern part or India females in berry are found from November and December to May and June. In peninsular India the maturity

and breeding commences from October and extends upto following June. Generally, berried females are found all the year round. As early as 1961, it was recorded that females need to migrate to tidal regions of the estuaries for hatching their larvae. The minimum size noted at maturity was 136 mm (total length). The females have a fecundity potential of 7000 to 1,11,400 in a size range of 136 to 250 mm (Rajyalakshmi, MS).

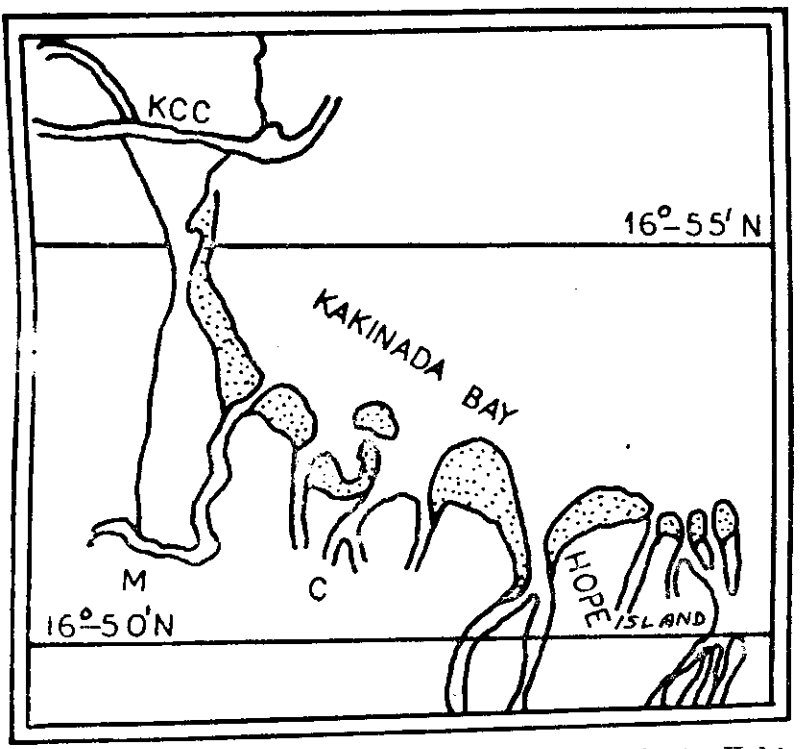

Fig. 1. Showing paddy field drain channels opening in to Kakinada Bay where brood prawns of *M. rosenbergii* occur. (KCC : Kakinada Canal, M: Matlapalem drain. C : Coringa drain.)

During the present study, females in berry which occur in capture fisheries as mentioned earlier, of Matlapalem, Koringa (Fig. 1) and other similar freshwater paddy field drain canals connected to Kakinada Bay (Long. 82° 18' E and Lat. 16°51' N to 17°N) are collected. These are brought alive to shore by fishermen and are purchased by the Department at a rate of Rs. 4-6 per female. Transportation is in live tin carriers, over a distance of 10-20 km to the hatchery. Some eggs (about 20-30%) are lost during the transport or discarded by the female itself. These females are tranferred to freshwater in fibre re-inforced plastic tanks, under aeration. Generally, females

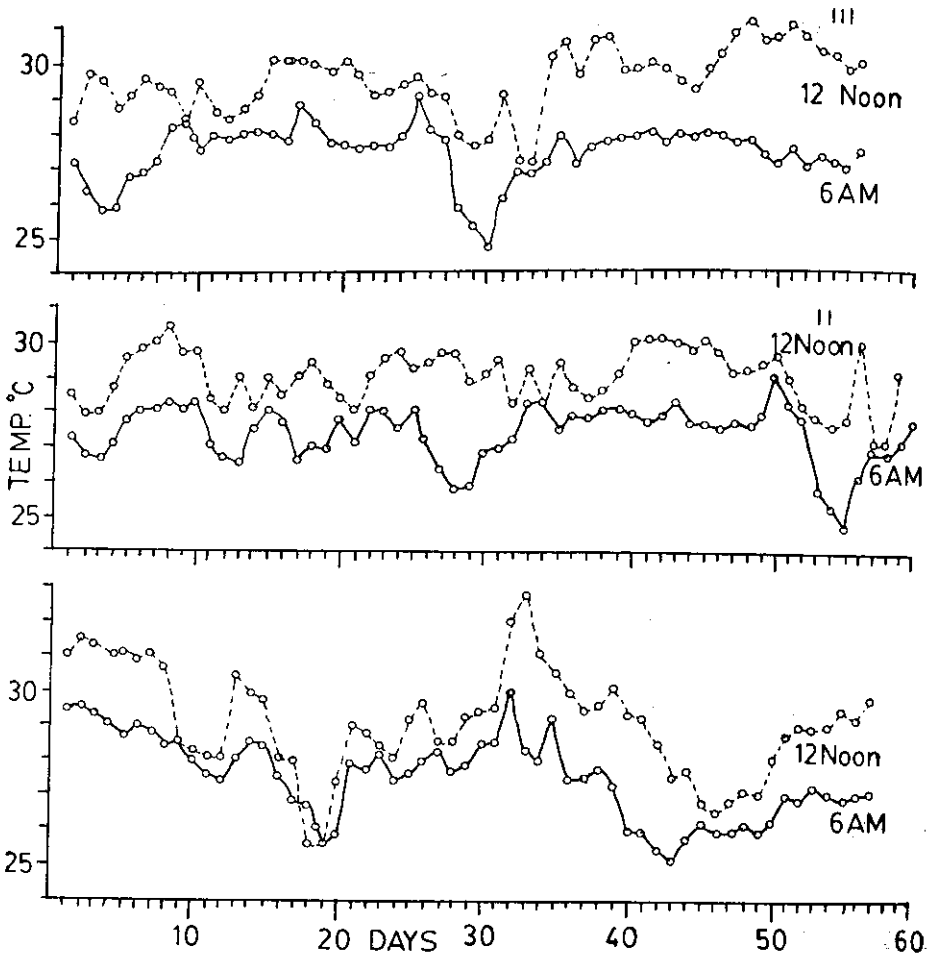

Fig. 2. Temperature profile in the experiments I to III.

with eggs in final stages of embryonic development are chosen, recognised by the colour of the eggs and the black eye spot which gives the egg mass a dark brown-black appearance. By selecting thus, prolonged (15 days or more) maintenance of brood prawns in early embryonic development in tanks, their mortality, loss of eggs and other adverse factors are thus sought to be reduced. Use of natural brood stock is being continued till the first generation of brood stock from post larvae stocked by this Department is ready.

Hatchery and Hatchery Management

Hatchery is located on the coastline along the Kakinada Bay of Andhra

Pradesh. The components of a hatchery are as follows : An asbestos roofed shed 30m long × 10m wide × 6m high is the main hatchery chamber. The walls are partially of brick (upto 1 m) and the remaining open part is made of iron mesh. This mesh has been covered over by removable bamboo mats to protect against the wind and dust in the coastal region. No temperature control measure is used. The equipment consisted of an oil free electrically operated compressor (5 HP) ; Pipe lines of hard PVC are fixed length-wise along the walls Secondary air control valves are fitted at intervals of 2m along the pipe. Air-lines are taken from these valves to all sections of hatchery.

Rectangular tanks of fibre re-inforced plastic (2m × 1m × 1m), circular plastic-lined pools of various sizes (3′ × 3′, 4′ × 10′) and concrete tanks (2.5′ × 4′) are used for storage of sea water and freshwater, maintenance of brood prawns and for larval rearing.

Water Management

Sea water collected from 2 km off-shore in the Kakinada Bay is transported on the departmental trawlers in repeated sea-trips once in 6 months and stored in the larger plastic pools. This water is aged over a period of one month using oyster shell powder as a buffer. After ageing, stored fresh (municipal tap) water is used for making up to required salinity. The water used in the zoeal rearing tanks is replaced upto 10% once in two days and fully replaced once a week. This used water is then taken to separate container for fresh biological filtration. This water is recycled back into the zoeal tanks after a month, thus eliminating frequent transportation of fresh sea water from off-shore. Thereby transportation costs are also reduced.

In each zoeal tank 3,000 l of water is maintained for each batch of freshly released zoeas.

Currently, attempts are being made to use hyper-saline water from a natural pond adjacent to the hatchery to eliminate the transportation of fresh sea water from off-shore and to introduce new water systems in the hatchery practices.

The water quality parameters regularly monitored at present are the salinity, temperature, pH, and dissolved oxygen.

Larval Rearing and Feed Maintenance

Each brood prawn is transferred 24 to 36 hours prior to hatching to a separate container, where water in low salinity (about 4 ppt) is maintained. When the zoea are released they are siphoned out and transferred to rearing tanks where water with salinity at 15 ppt is kept in readiness. Normally a

single air-line is supplied to each rearing tank containing 30,000-40,000 hatchlings.

The larval moults and full life cycle has been described by Ling (1967 a and 1976 b).

Feed is supplied to the zoea from the third day. Entire feeding schedule is based on tubificid worms. For maintenance of tubificid culture, a shallow ditch (1m wide × 10m length) lined with polythene sheets is maintained outside the hatchery, in the open. Mud is introduced into this ditch and it is then fertilized with dry pig manure. Tubificid worms, collected from drainage outlets of town (municipal) freshwater supply tanks are inoculated into the ditch. A freshwater tank maintained at an elevation at one and of the ditch keeps a slow drip type water flow, thereby maintaining continuous flow-through freshwater that is essential for the growth and multiplication of the worms. The excess water flows out from the other end of the ditch. The worms soon multiply and occupy the entire length of the ditch. Once in 3 months the ditch is emptied and a fresh culture is started.

Tubificid worms are taken out for each day's requirement, washed in clean freshwater to remove the mud and other organic load. They are chopped and sieved through mesh of 40 microns and 60 microns for supply to early zoeal stages, the mesh size increasing with growth of the zoea. Each time about 2 to 3 ml of feed are supplied to each larval tank twice to three times a day, as per the density of the stock. Before use the feed is dipped in 0.1% copper sulphate solution as a prophylactic measure.

An *Artemia* culture is also maintained in outdoor tanks (3′ × 3′) for continuous culture. Brine mixed with sea water is used in the tanks. Pig manure is introduced to maintain diatom culture in the pools. No aeration is done. Except for one attempt, Artemia was however, not used as a larval feed because of the high quantities required for feeding each batch of zoea. Further, the tubificid is readily accepted by the zoea.

For the present the hatchery programme is conducted in 4 to 6 tanks only with small number or berried females.

Culture Trials

Pond construction :

The current trends in construction of freshwater ponds, in general, in Andhra Pradesh are described below :

Construction of ponds in extensive scale by private enterpreneurs is of recent origin, particularly, in two districts of Andhra Pradesh.

Water resource being a primary consideration, a large inland swamp call-

ed Kolleru Lake has been first developed by the Department of Fisheries Government of Andhra Pradesh. The lake recedes in nonmonsoon months to+ 3 to + 1 flood-larval contours while in monsoon it rises to+ 7 to+10 contours (Rajyalakshmi, 1972). A series of 114 tanks have been excavated to a uniform depth of 1m as 10 acre and 40 acre pond units in the + 2 contour levels in many cases to protect the pond in flood times. Farmers adopted different methods, excavating only 30% of the pond area to form peripheral trenches leaving a central flat plateau where no excavation is done. The depth in trenches was 1.5 m such that a level of 2′ was present on the central area. The general depth, a however, varied from 1m to 1.5m from summer to monsoon. The pond sizes vary from 10-acre units to 100 acre units. In other regions of the state, ponds are excavated based on the above general principles, on lands adjacent to the extensive irrigation canal system of Rivers Godavari and Krishna. The total pond acreages are small, from 20 acres to 60 acres, each pond unit having 1—1.5 ha.

In all the above excavations, top soil has been removed. Pond slopes are maintained at 1:3 ratio and berm of 1m width is made between the pond slope and water edge. Compacting of pond walls is done.

Only one in-let pipe of concrete is maintained with velon mesh screens, the latter placed at one or two places along its length. The latest designs of water management incorporate pumping water into pipelines elevated to the bund level; the in-let was also placed at an elevation so that water can cascade down and provide flow as well as oxygenation. No out-let is provided for in any of the ponds, water being pumped out whenever required. Wind circulation helps to keep aeration, ponds being exposed with no shading of trees, or any such obstruction.

Water is drawn-in into the ponds in the month of June. During normal monsoon (rainy) season, water is not replenished upto October. Thereafter, once in a month water is replenished to cover any loss by evaporation.

The ponds are excavated generally in alluvial black loam soils. Coastal ponds have occasional patches of sand.

The characters of pond used for experiments 1-4 are shown in Table 1. One is a coastal pond, all the other 3 are located 10-20 km inland. All are fed by irrigation canal water. Despite this in ponds in the experiments 3 and 4 bottom waters are found to be saline.

Pond Preparation, Stocking and other Management

Pond Preparation :

The fertilizer treatment consists of addition of cowdung and lime or urea

Table 1. Results of Hatchery Experiments

Experiment No	Size of brood female (mm)	No./hatchlings released/Date of release	Date first release of post larva/ final release	Survival %	Water parameters in zoeal tanks		
					Average salinity (ppt)	Average DO (ppm)	Temperature range °C
1	140	30,000	2.8.82	5.9	15	8.4	30-32.8
		1-7-82	26.8.82				*25
2	150	40,000	2.10.82	4.8	15	8.0	30.5
		28.8.82	25.10.82				*24.6
3	160	50,000	4.11.82	5.6	15	8.1	25-30.8
		21.9.82	15.11.82				*24.8
4	158	50,000	.....mortality due to fungal incidence				24-26.8
5	160	55,000	1.12.82	2.0	15		18-22.4

*Dip in temperature caused by cyclonic storm.

and superphosphate plus lime in one major instalment of 25kg/pond before letting in water. The ponds are stocked one week later. Thereafter, fertilizer is added in water once a month or 15 days depending on the growth of phytoplankton or change in colour of the water. If water turns dark green, then partial exchange of water is done followed by addition of lime. The latter is meant to keep the pond clean, buffer the pH and raise the oxygen level.

The predators found in ponds are snakes, crabs, murrels and occasionally, larger cat fish such as *Wallago attu*. Constant attempts are made to remove them in sample netting.

Stocking :

Seven to ten days old post-larvae, at an average size of 8mm/12-15mg are stocked directly in experimental culture ponds for want of separate nursery tanks. For any future programme nursery tanks have to be extensively maintained.

Stocking is also done at a rate of 20,000/ha, on the basis of experience gained in experiments on culture of *Macrobrachium malcolmsonii* (Rajyalakshmi *et al.*, 1982). Post-larvae are transported in oxygen-filled polythene bags at a rate of 500 per 3 litres of water. Generally, packing is done either early in the morning or late in the evening as a measure of protection against rising temperatures during day time.

Feeding :

Supplemental feeding is given in the form of food balls placed in trays and arranged in several places in the pond particularly at the shallow edges.

Rice polish or rice bran is the base feed. Meat of freshwater snail, *Pila globosa* or trash fish is mixed with it. Feed is given at 5% of biomass in the early growth phase and 3% at later phase. In the farmers ponds this schedule is not strictly followed.

Sampling :

Sampling is done once in a month using cast net or by hand-picking. Because of heavy weed growth operation of nets is made difficult. Therefore hand-picking of prawns is done for taking length/weight measurement.

As in all other prawn ponds either of (*Macrobrachium malcolmsonii* or *Penaeus monodon*), it is found better to pump out all water for final harvesting at the end of 6 months when the culture trials are completed.

RESULTS

Hatchery Experiments

As stated, the work has been started in 1982 and the results of 4 to 5 trials conducted in hatchery are shown in Table 2. The Table 2 also shows the water quality parameters of each experiment. About 30,000 to 50,000 hatchlings are released per female in sizes of 140 to 160 mm, because of the 20-30% egg loss noticed during transportation. Each rearing cycle has taken a period of 31-55 days depending on the date of first metamorphosis to post-larvas. Final metamorphosis of the complete batch of post-larvae took a period of 3 weeks.

At a temperature range of 30-32.6°C, the first post-larvae emerged on 31st day. At 28-30.8 C a longer time of 30-36 days was taken, the length of rearing cycle increasing with further decline in temperature. Survival was 100% upto 6 to 7 days of rearing cycle. Thereafter, heavy mortality was noticed. During all the first 3 experiments, around 15th to 30th day of metamorphosis, a sudden cyclonic storm threatened the coastline with drastic fall in temperature (Fig. 2 . The temperature decline was 2 to 3°C of the average daily range. This resulted in heavy mortality of more than 50%. The final survival was thus between 4.82 to 5.9% only.

In three batches viz., a period of 120 days, about 8,000 post-larvae was produced. In the 4th experiment about 80% mortality resulted after a sudden incidence of fungal attack followed by multiplication of cope-pods in the tank. This batch was totally discarded to prevent further contamination.

Table 2. Characteristics of Ponds used In Culture Experiments

Experiment No	Location/number of pond	Pond size/ depth	Water resource	Water/quality parameters				Fertilization	Stocking rate	Remarks/ Feeds
				Salinity	pH	Temperature (°C)	DO_2 ppm			
1.	Government Farm, 20 km from Hatchery / one pond	0.19 ha 1m—1.25m	Irrigation Canal	...	7.8—9.2	30—18	6—8	Cow-dung and lime	20,000/ha	Weed-choked Manual removal from time to time
2.	Private sugar factory farm 12 km from hatchery/ 4 ponds	0.02 ha 1m	ground water and rain water	...	7.5—8.9	30—18	5—8	,,		Feed of rice polish+trash fish or Pila meat. Weeds present Rice bran
3.	Private coastal farm 15 km from hatchery/ 1 pond	0.02 ha 1.5m	Irrigation canal	Traces —2ppt because of ground seepage	7.8—9.0	30—18	5—6	,,		Free of weeds Rice bran Free of weeds Rice bran
4.	Private farm, 15 km from hatchery / one pond	0.02 ha 1m	,,	5—7 ppt bicause of ground seepage	7.5—8.5	26—18	5—8	,,		

A fifth batch began to be reared in the winter months of December to January (Temperature 22.4°C to 18°C) has shown high mortality at each moulting after the 10th day. The zoea have grown at a slow rate. Despite moulting, growth was not evident during the mid-phase *i.e.*, 15 to 20 days of rearing. Use of thermostats in the rearing tanks has raised the temperature to 0.5°C and resulted in some improvement in arresting mortality. This batch took 45 days for the first emergence of post-larvae.

As the post-larvae emerged they were acclimatized to freshwater over a 3 day period in a slow-drip flow and after one week of acclimatization and growth they are taken out and marketed or stocked in culture ponds. The post larvae showed high rate of cannibalism if kept for longer than 10 days in the rearing pools in the hatchery, the loss ranging from 8 to 10% in 7 to 10 days.

An interesting fact that was observed in all the experiments was that even from 10 to 15th day of rearing, some larvae showed faster growth rates and these metamorphosed in advance of others. These early fast growing forms when stocked in culture ponds turned out to be males that have grown to uniform sizes.

Culture In Grow-out Ponds

The details of size at stocking, density, grow-out duration ultimate growth and survival are given in Table 3.

Experiment 1 :

This was the first experiment of the Department in a single large pond of 0.02 ha (in a 28-acre farm). The pond was prepared by use of cow-dung and lime (burnt shell powder) at the rate of 25 kg/ha each. De-weeding of the pond was done prior to fertilization. Artificial hide-outs were arranged by way of hanging netting materials. Feed was given in basket-trays. A trial batch of 1,000 ten-day old post larva (10-12 mm in total length) were released into the ponds on August 21st. Monthly rate of growth was recorded by sampling (Table 3).

The average growth was 111.1 mm/15.27g (2nd month 50 days after stocking), 153.4mm/40.6 g (3rd month) and 161.5 mm/44.8 g (4th month). The best growth period tallied with late monsoon (August) and winter season (November) for this region. Water temperature ranged from 30.3°C to 18.0°C and pH 7.8 to 9.2.

As stated earlier, there was a distinct size difference in some of the zoea which metamorphosed early. The post-larvae stocked in this pond are the early-metamorphosed zoea of the first laboratory experiment. The sampled

Table 3. Details of Culture Experiments

Experiment No.	Date of stocking	Stocking density (Nos/ha)	Size at stocking (mm)	Growth			Estimated survival (%)	Male/Female ratio (%)	Remarks
				2nd month (mm/g)	3rd month (mm/g)	4th month (mm/g).			
1.	21.8.1982	20,000	10-12	111.1/15.27	153.4/40.6	161.5/44.8	70	75.25	
2.	3.11.1982	20,000	8	105.8/9.67	Experiment continuing		60	56.4 43.6	Slow growth rate
3.	2.11.1982	20,000	8	50/1.9	Experiment continuing		Not estimated due to deep water level	—	Date of stocking being in winter months of November in saline ponds
4.	5.11.1982	20,000	8	56/2.5	Experiment continuing		Not estimated	—	

stock consisted of over 70% of males in the population and probably this fact is the reason for their higher growth at each monthly sampling as compared to the following experiment.

Experiment 2 :

Experiment 2 was conducted in farmers' (sugarcane factory) ponds. Four similar-sized ponds excavated in soils of old factory ash and other waste overlaid by soil. Weeds have grown in the pond.

Post-larvae at an average size of 8 mm were stocked at a density of 20,000 /ha in each pond. These post-larvae were the late-metamorphosed first batch in the laboratory experiment. The average growth of prawn of all the 4 ponds from an initial size of 8 mm/6 mg was 99.4 mm/0.9g (1st month), 105.8mm/ 9.67g (2nd month). Survival is found to be 20% only. As compared to experiment 1, the growth rate was quite low.

The batch consisted mostly of females.

Experiments 3 and 4 :

Experiments 3 and 4 are in small nursery ponds 0.02 ha in size, to study the adaptation and growth in low-salinity waters. In these experiments the tiger prawn, *Penaeus monodon* and *Macrobrachium rosenbergii* were stocked together, *Penaeus monodon* grew from 30 mm (initial size) to 80 mm/4 5 g in one month. Survival was also good. *Macrobrachium rosenbergii* showed a growth increase of 56 mm/2.5 g in a period of 30 days after stocking.

The saline ground water in these ponds has seeped in from the surrounding regions which are swampy in nature occasionally submerged by tidal waters.

DISCUSSION AND CONCLUSIONS

The main aim of the study and presentation of this paper is to bring out the great potential that exists for culture of the giant freshwater prawn in India using available freshwater farm resources. The experimental studies conducted on hatchery rearing and field culture though preliminary in nature, strengthen the observations simultaneously being made by the other Research Institutes in India. A wide range of information is available on the biology of the species sampled from the capture fisheries in India. The extensive studies particularly in Hawaii clearly show that adoption of extensive *Macrobrachium rosenbergii* culture practices in the extensive pond systems of Andhra Pradesh might be very economic.

Experimental hatchery, modest in size has been started by Central Inland Fisheries Research Institute at Kakinada in 1976 (Anon, 1976). Since then

the production was reported to be in the range of 10,000 to 0.1 million juveniles per year. In 1982, the present department also took up this study producing 8,000 post-larvae in small four to five tank units in a period of 4 to 4½ months. Both these hatcheries are indoor semi-intensive type using filtered, aged sea water, aeration and live feeds of tubificid worms. The rearing containers are mainly plastic and concrete tanks.

No private hatcheries have yet taken up seed production operation since farmers are yet to get into the culture in a large way. However, the unit economics of a small hatchery (Table 4) indicates that such an enterprise can be considered beneficial to an enterpreneur.

The entire hatchery production is based on single feed viz., tubificid worms. The worms, collected from drainage canals of the city *i.e.*, drainage from drinking water system, are grown and multiplied in shallow earthen ditches. The ditch has a mud base fertilized with pig manure. A flowing water arrangement keep the worms alive and multiply. Brousing of larvae on diatoms which grow on walls of the plastic pools is incidental and no attempts are made to supply cultivated feeds of diatoms. Any other feed such as nauplii of *Artemia salina* could be highly cost-prohibitive.

The survival, growth and ultimate yield of post-larvae for experiment have indicated great potential for intensification of the hatchery practices. The physico-chemical water parameters, particularly temperature, is found to be a critical factor. Generally, Kakinada area of Andhra Pradesh has an almost equitable temperature range throughout the year with two exceptions. One critical period occurs in May-June in the peak summer months with the temperatures rising up to 44°C in some days. The 2nd critical period occurs in the months of September/October when cyclonic storms and gales occur resulting in drastic dip in temperature to 22-25°C. The average optimal range is at 28°C to 31°C in these studies. High mortality was recorded (Table 1) below and above this range of temperature. Temperature controls might be necessary at critical times, if large scale mortality is to be prevented in the future hatchery programme.

Use of fertilizers and feeds, their efficacy in extensive ponds are to be studied further. Adopting the practices advocated by research institutes in composite culture, the prawn ponds are also fertilized with cow-dung, superphosphate and urea at specified rates and dosages. In studies conducted on rearing *Macrobrachium malcolmsonii* it was observed that use of fertilizers/manures resulted in thick algal blooms (Rajyalakshmi, *et al.*, 1983). On the other hand, chopped meat of freshwater snail *Pila globosa* resulted in good acceptance by the prawns and no algal blooms occured in the ponds. Growth was also quite

Table 4. Unit Economics of *Macrobrachium rosenbergii* Seed Production

One Unit	:	3 Persons, 8 tanks
Breeders	:	16 Nos.
Period of culture	:	45 days
Seed rearing per tank	:	50 thousand
Final post larvae per tank	:	4,000 (Average)
		4,000 × 8 32,000 Nos.

Cost :

a.	Cost of 8 tanks (Cement)	:	Rs. 2400 Capital cost 2,400/-
	Variable costs :		
b.	Cost of labour (3 × Rs. 7.50 × 45 days)	:	1080
c.	Cost of brood prawns (16 × Rs. 5.00)	:	80
d.	Transportation of seawater/brood prawn etc.	:	200
e.	Cost of electric current	:	75
f.	Cost of shell lime, chemicals etc.	:	75
			1510 Variable cost 1,510/-

Returns :

a. Yield in No. 32,000 × Rs. 75 (per thousand) = Rs. 2,400/-
Net income per each production period = Rs. 900/-

(Note :—Cost of shed not included)

favourable. Because of the use of 2nd pair of chelipeds by the prawns for catching food and transferring it to the mouth directly, use of feed pellets might be more suitable in freshwater prawn culture.

A great amount of study still needs to be done on factors such as optimal depth in the prawn ponds, flow-in and flow-out of water, the frequency of replenishment or exchange. Studies are also to be conducted on stocking and harvesting factors so that, as seen in the case of culture of *Macrobrachium malcolmsonii*, a pattern of repeated harvesting with two to three stockings in a year can be adopted based on the short growing season of the species to optimise water utilization and production.

In the years 1976 to 1982 private enterpreneurs in Andhra Pradesh have gone in for composite fish farming in a very extensive way. At this date the

total acreage under private farming ventures might be around 1,500 ha. The farms constructed by Government of Andhra Pradesh and distributed to Fisheries Cooperatives (50 to 100 fishermen for management of 16 ha ponds and 2 fishermen for the newly excavated 1-ha ponds cover another 200 ha. All in all, the developments in this field are very fast. So far, the composite fish culture practices advocated by the National Institutes (Indian Council of Agricultural Research) are followed (Rajyalakshmi, 1982. Only one marketing channel is open for the farmers which is centralised in Calcutta city in North-Eastern India. Conditions are now favourable for diversification of culture, introducing species such as *Macrobrachium rosenbergii* and *Macrobrachium malcolmsonii* into the composite culture or developing a separate strategy for monoculture. Techniques of freshwater prawn culture have been developed in India (Rajyalakshmi, *et al.*, 1983) and the techniques adopted in the extensive grow-out systems of *Macrobrachium rosenbergii* in Hawaii (Fujimara and Okamoto, 1976, Hanson and Goodwin, 1977) can be adopted suitably modified for conditions in India. Some progressive farmers have begun to adopt this culture as an experimental measure. With the seed constraint removed, the switch-over to extensive farming of prawn could become more rapid.

REFERENCES

Anon, (1975). Annual Report of the Central Inland Fisheries Research Institute, Barrackpore (Project 6).

Anon, (1976). Ibid

Chopra, B.N., (1943). Prawn Fisheries in India. *Curr. Sci.* **12**(2) : 71

Forster, J.R.M , Wickins, J.F. Prawn Culture in the United Kingdom the status and p tential. *Lab Leafl. Fish. Lab. Lowestoft* (New series) : 27-32.

Fujimura. T. (1966) Notes on the development of a practical mass culturing technique of the prawn *Macrobrachium rosenbergii*. Indo-pacific Fisheries council (IPFC) of FAO Regional Office for Asia and Far East, Bangkok, Thailand, 12th session.

Fujimura, T., and Okomoto, H. (1970). Notes on progress made in developing a mass culturing technique for *Macrobrachium rosenbergii* in Hawaii. FAO Indo-Pacific Fisheries Council, 14th session, Bangkok Thailand, 18-27 Nov. 1970. 18 pp (mimeo)

Fujimoto, M., Fujimura, T. and Kato, K. (1977). Pond grow out systems Chapter VI. *In* (Editors) J.A. Hanson and H.L. Goodwin . Shrimp and prawn farming in Western Hemisphere State of the Art Reviews and status. Dowden, Hutchinson and Ross. Inc., Stroudsburg. Pennsylvania.

Hanson, J.A. and Goodwin, H.L. (1977). Shrimp and prawn farming in western Hemisphere. State of Art Reviews and Status. Dowden, Hutchinson and Ross., Inc. Stroudsburg, Pennsylvania.

Ibrahim, K.H. (1962). Observations on the fishery and biology of the freshwater prawn *Macrobrachium malcolmsonii* Milne Edwards of River Godavari. *Indian J. Fish* **9A**(2) : 433-467.

John, M.C. (1957). Bionomics and life history of *Macrobrachium rosenbergi* de Man. *Bull.*

Cen. Res. Inst. Univ. Trivandrum. Ser. C. **5** (1) : 93-102.

Ling, S.W. (1967). General biology and development of *Macrobrachium rosenbergii*. *FAO Fisheries Repor's* (57) vol. 3 : 589-606. Proceedings World Scientific Conference on Biology and culture of shrimps and prawns, Mexico, 12-21 June.

Ling, S.W. (1967 b). Methods of rearing and culturing *Macrobrachium rosenbergii*. *FAO Fisheries Reports* (5M) Vol. 3 : 589-619 proceedings of the World Scientific Conference on biology and culture of shrimps and prawns, Mexico city, Mexico, 12-24 June.

Rajyalakshmi, T. (1961). Studies on maturation and breeding in some estuarine Palaemonid prawns. *Proceedings of the National Institute of Science, India*. 27, B, **4** : 179-188.

Rajyalakshmi, T. (1968). Try prawns in tanks and inland waters. *Indian Fmg.* Nov : 37-43

Raj alakshmi, T. and Ranadhir, M. (1969). The commercial prawn *Macrobrachium malcolmsonii* (H. Milne Edwards) of River Godavari, a discussion on trends and characteristics of the population during 1963-66. *FAO Fisheries Reports* **57**(3) : 903-921. Proceedings of the World Conference on the Biology and Culture of Shrimps and Prawns. Mexico city. Mexico 12-21 June.

Rajyalakshmi, T. (1975). Environmental ecology of *Macrobrachium rosenbergii*. *Macrobrachium malcolmsonii* and *Metapenaeus monoceros* in certain drain channels opening into Kakinada Bay. *Bull. Dept. of Mar. Sci.*, **VII** (2) : 285-292.

Rajyalakshmi, T. (1979). The role of *Macrobrachium* species in freshwater aquaculture systems. Abstract P. 119. *In* : Symposium on Inland Aquaculture 8–14 February, *Central Inland Fisheries Research Institute Barrackpore.*

Rajyalakshmi, T., Rao, L.A , Rama Raju, T.S., SubbaRao, R. and Bose, P S. (in Press) Experiments in culture of *Macrobrachium malcolmsonii* Inland Aquaculture. *Central Inland Fisheries Research Institute, Barrackpore.*

Rajyalakshmi, T. (1981). Scope and prospects of Integrated fish culture in Andhra Prade h -a case study. *Lecture In* : Summer Institute on Farming Systems integrating Agriculture, Live Stock and Fish Culture, July 6-Aug 4. *Central Inland Fisheries Research Institute, Barrackpore, India.*

Rajyalakshmi, T. (1982). "Fisheries in Andhra Pradesh". Chapter in "Agriculture in Andhra Pradesh" vol. I. *The Society of Scientists for advancement of Agricultural (ED) K. Bhaskaram.*

Rajyalakshmi, T Ramachandra Reddy, O., Appa Rao, A. and Ramakrishna, R. (1983). Growth and production of Riverine prawn of India, *Macrobrachium malcolmsonii* H. Milne Edwards in pond culture, Andhra Pradesh, India. *The World Mariculture Society, 1982 sessions Washington DC.* Jan. 10-13.

Rajyalaksmi, T. (MS) "Contributions to the knowledge of the biology of some estuarine prawns" unpublished Doctoral thesis (Andhra University, Waltair) 1976.

Raman, K. (1967). Observation on the fishery and biology of the freshwater prawn *Macrobrachium rosenbergii* (de Man). *Proc. symp. Crustacea. Mar. Biol. Assoc. India.* Part III. 649-669.

Rao, Mallikarjuna. (1967). Studies on the biology of *Macrobrachium rosenbergii* (de Man) of the Hooghly estuary with notes on its fishery. *Proc. Nat. Inst. Sci.* India 33 B: 252-279.

Wickens, J.F. and Beard, T.W. (1978). Prawn culture research. Ministry of Agricultural, Fisheries and Food. *Lab-Leaft., Lowestft.* **42** : 1-42.

Environmental Biology
Coastal Ecosystem
125–140 (1986)

An approach to environmental impact study in the Kakinada bay

T. RAJYALAKSHMI, G. MAHESWARUDU*, D. M. REDDY**
AND H. C. JOSHI
Central Inland Fisheries Research Institute,
Puri Research Centre, Puri-2 and Barrackpore-743 101
*Department of Zoology,
Andhra University, Waltair-530 003
**Department of Fisheries Science,
A. P. Agricultural University, Kakinada-533 007

Key words : Environmental Impact, Kakinada bay.

Introduction

Studies on the hydrography, current patterns and upwelling, faunal distributions, fisheries, plankton and primay productivity and so on, have been carried out in different estuarine water systems of India for years past (Kemp, 1915; Sewell and Annanadale 1972; La Fond, 1954; Satyanarayana Rao, 1957; Ganapati and Ramasarma, 1965; Ramasarma and Ganapati, 1968; Jhingran and Natarajan, 1969; Rajyalakshmi, 1972 and 1975; Rajyalakshmi, and De, 1979, among others on the studies in the East Coast of India). These water bodies have been the mainstay for fisheries, for food and employment. In recent years, however, the emphasis on this broad use of the water has been shifted to its utilization for other activities such as dumping effluents from various industries and sewage and urban wastes. Therefore it has become important now that every time a use has been made or is envisaged for a limited or unlimited water body, an environmental impact study is done using a comprehensive approach. Such a study would lead to a better management of the system as a whole. This

impact study in general is an abatement approach because in general in India now, there are no water regulations for any user.

With the abatement approach in view, the authors have commenced a preliminary study on environmental impact in the Kakinada Bay with a small grant provided by the Andhra Pradesh State Board for the prevention and control of water pollution during 1981-83.

A few approaches have been applied : A. Traditional studies on hydrography and biological status of the bay; B. Tissue and sediment analysis to study toxic effects; and C. An analysis of the present status of the standing crops. Areas of high, medium and low impacts resulting from the various onshore activities and bay uses are shown diagrammatically.

Materal and Methods

Physiography of the study area

The Kakinada Bay situated between 82°15′ E and 82°22′ E Longitude and 16°51′ N and 17°N latitude is a small coastal feature on the mid-east coast of India. The bay is approximately 132 sq. km in extent bounded on its western edge by the mainland. On its east a 16 km long narrow sand bar is present taking origin and extending from the eastern tip of the Hope island separating the bay from the sea. On its north to north east, the bay opens to the Bay of Bengal by a wide mouth. On its southern and south western edge the bay is connected to the Godavari estuarine complex through a number of inter-connecting creeks and a few narrow rivers which traverse through the mangroves (Fig. 1).

Bottom topography and sediments

The depth charts do not indicate any wide or sudden fluctuations in the profile of the bottom topography. The bottom sediments are composed of sand, silt and clay in the finer fractions and shell fragments, wood material, terrigenous mineral and foraminifera composing the large fractions. Only one area, the Kakinada canal area is recognized as a rocky zone being boulder-lined. The major part of the bay is silty clay bed with occassional sand patches near the sand spit. Silty clay

prevails opposite the mouths of drains and canals at the south and west.

Tides, waves and surface drift in the Kakinada Bay:

The hydrodynamics of the bay and the adjacent Bay of Bengal have been studied by La Fond, 1954; Satyanarayana Rao, 1957 and Ramasarma and Ganapati, 1968. The tides are semi-diurnal. The maximum spring tide is 1·8 m and the minimum neap at-0·18m. A sand spit on

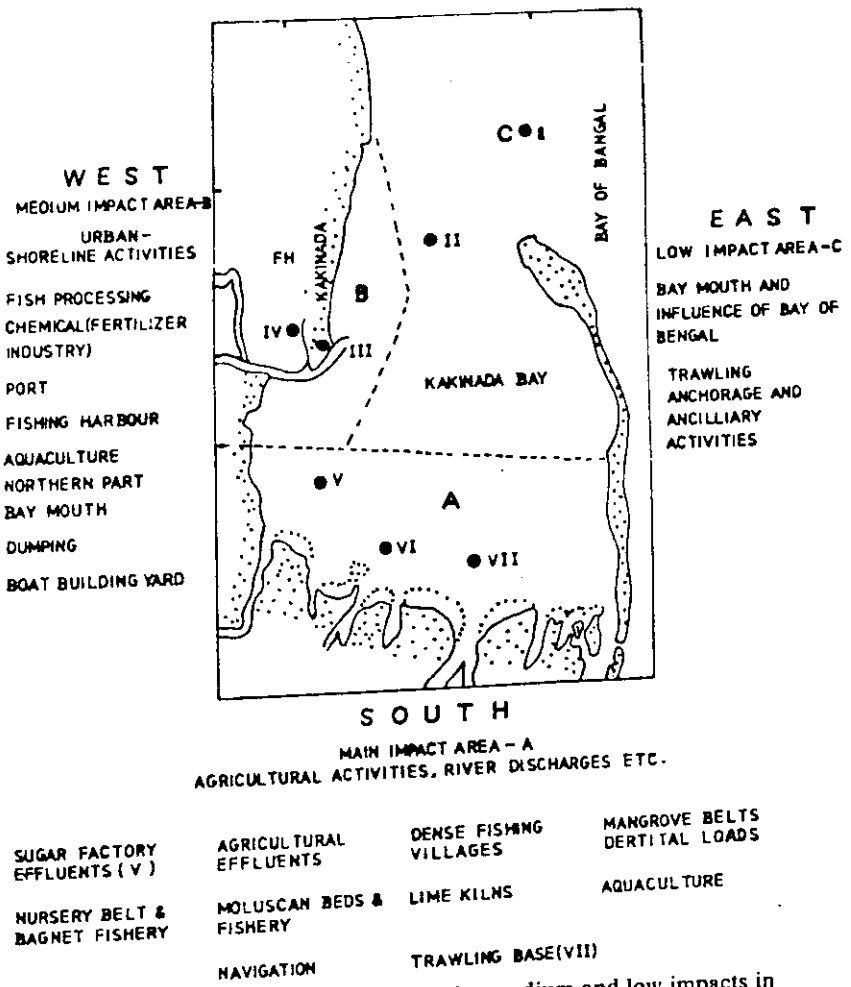

Fig. 1 Showing activities and areas of main, medium and low impacts in Kakinada bay.

Table :

Showing metals (Exchangeable) in mg/100 g soil at the 7 sampling stations in different months (other hydrographic parameters on the sampling date are also shown).

Date	Sampling station	Zinc (1 025)	Chromium (1·02)	Copper (1·02)	Cadmium (0·02)	Depth (m)	Temp. (°C) (Bottom)	Sal. (ppt) (Bottom)
30-8-82	V	0·302	0·12	0·12	0·03	1·5	28·0	15·06
16-9-82	VI	0·281	0·08	0·28	0·05	1·1	30·8	12·65
16-9-82	VII	0·18	0·05	0·15	nd	1·54	30·8	12·05
16-9-82	V	0·329	0·10	0·31	0·08	1·55	29·9	12·65
23-9-82	II	0·48	0·08	0·13	0·08	7·0	21·07	29·9
30-9-82	III	0·383	0 07	0·10	0·04	1·73	30·5	14·76
10-10-82	IV	0·180	0 06	0·08	nd	0·45	34·0	18·07
15-10-82	V	0·190	0 08	0·12	nd	1·4	29·9	25·28
15-10-82	VI	0·272	0·08	0·34	0·02	1·0	29·9	24·98
15-10-82	VII	0·224	0·08	0·17	0·02	1·4	29·9	31·6
25-10-82	IV	0·253	0·09	0·10	nd	0·4	34·0	5·44
25-10-82	III	1·54	0·12	0·21	0·06	1·9	30·1	5·74

(Continued)

(Contiue)

20-11-82	V	0·224	0·08	0·23	0·05	1·9	27·2	29·19
20-11-82	VI	0·256	0·08	0·21	nd	1·8	27·0	32·5
20-11-82	VII	0·21	0·06	0·25	nd	1·5	26·6	29·8
19-2-83	V	0·296	0·08	0·32	0·08	1·81	28·9	43·93
19-2-83	VI	0·344	0·09	0·33	0·07	1·5	28·4	47·54
19-2-83	VII	0·244	0·09	0·23	0·06	1·45	27·9	43·33
2-3-83	III	0·614	0·11	0·30	0·22	1·75	28·0	60·41
2-3-83	IV	0·192	0·03	0·11	nd	0·45	28·9	34·91
11-3-83	III	0·752	0·14	0·23	0·18	0·9	30·2	23·78
11-3-83	IV	0·458	0·05	0·07	0·09	0·25	31·4	14·16
14-3-83	I	0·385	0·12	0·45	0·09	25·0	27·0	61·9
14-3-83	II	0·426	0·07	0·26	0·11	7·0	26·9	60·71
2-4-83	III	1·077	0 12	0·34	0·31	1·2	28·5	52·65
2-4-83	IV	0·240	0·03	0·10	nd	0·42	29·9	40·92

nd : Not detected.

the eastern edge protects the bay and incidentally,limits the wave action. The waves entering the bay are refracted in such a way that they reach the southern and south-western sides and finally, before they reach the shore, loose much of their energy and do not produce any appreciable long shore currents (Bhavanarayana, 1974).

The surface drift, the general pattern of the littoral currents are mainly towards north during March to September and reverse during winter season and these factors influence the distribution inside the bay (Ramasarma and Ganapati, 1968). Although the sand-spit is found to be extending towards north, albeit at a slow rate (Varadarajulu *et al.* 1978), the Bay mouth has never been reported to be closed by any sand bar formations.

The bay is quite shallow especially on its southern and western sides with a depth of 1·8m during tides. The central and northern part have a depth range of 1·8m–9·5m.

With the construction of a 500 m long arm of the fishing harbour at the western edge of the Bay mouth, during 1983, the mouth area is now constricted.

Sampling stations and the sampling methods :

7 Sampling stations were identified in the bay (Fig.) on the basis of their location in relation to the broad uses of the Bay. The stations' location is arbitrary although fixed land marks are used to some extent.

The routine water and soil analysis are carried out in the Samalkot Agricultural Research Station of A. P. Agricultural University. sediment analysis for heavy metals etc. if any was carried out at CIFRI,s laboratory at Barrackpore by Atomic Absorption spectrometry.

The chlorinity was estimated by the standard titration method of Kundsen and salinities calculated from the Kundsen tables. Dissolved oxygen was estimated by the Winkler's method,

A sechi disc of 30 cm diameter was used for determining the transparency of the waters. The plankton collections were made with 1/2 meter

dia. townet of organdie cloth (160 cm in length) in a 5 minute haul at

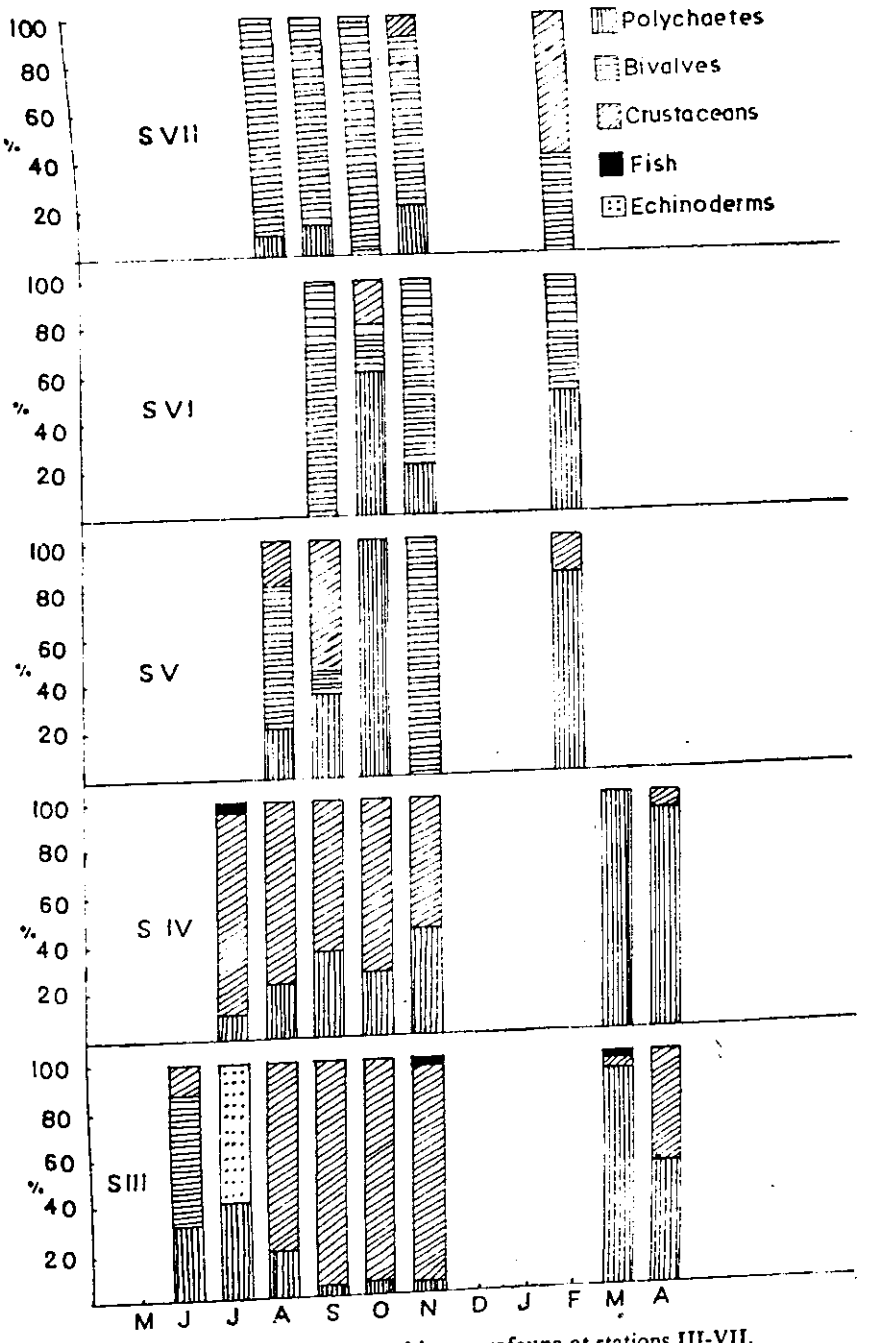

Fig. 2 Faunal composition of benthic macrofauna at stations III-VII.

a minimum speed of the out-board motor. Bottom fauna and soil samples were taken with a Ekman's dredge (dredge area 9052 cu cm). After washing, the settled volume is measured and numerical counts were made.

Large bottom fauna are taken with a 1 cm mesh net attached to a iron frame with a sharply toothed rake (1 1/2' × 1/2'), the net bag length being 1m. This gear is dragged over the shallow bottom for a distance of 10m.

For tissue analysis, an abundant endemic mollusc of the Bay, the blood clam *Anadera granosa* was used as a biological indicator. The samples were analysed by the Central Institute of Fisheries Technology at Kakinada. Water samples for metals analysis were not taken due to want of proper laboratory facilities.

Rainfall data for the pertinent period (1981-83) is obtained from the meteorological observatory, Hyderabad.

Towards assessing the present status and using it as base line data, description and discussion on the standing crops such as the major benthic fauna, the fisheries, status of aquaculture, of mangrove nursery area etc., are presented from the present incidental observations supplemented by the earlier recorded data (Radhakrishna and Ganapati, 1977; Rajyalakshmi *et al.*, 1972, 1975; Rajyalakshmi and Reddy, 1982; Narasimham, 1973; Sriramachandra Murthy *et al.*, 1979.

Results and Discussion

A. Traditional Studies

Physico–chemical and biological parameters at stations I-VII

Most of the stations, I and III-VII are rather shallow (with mean depths ranging from 2·0m to 3m). St. II is deeper with 7·9m depth range being the open sea area of the Bay. The sechi disc tranparency is high at St. I and II (300 cm) and low at St. V and VII because of the shallowness, but in some seasons the reading was very low at 18 cm when flood waters entered (S. W. monsoon) and where productivity was high (Station VII).

All stations showed alkaline readings of medium to high. The temperature and salinity seemed to be governed by the large inputs of waters from the R. Coringa on the south and the wide mouth of the Bay to the Bay of Bengal on the north. Kakinada canal on the west also brings in considerable freshwater inflows. The main monsoon is the south-west (June–September) and a minor north-east one (December-February). The current status of the hydrography of the Bay is described briefly as follows : Little or no thermal stratification was found except at St. I, the surface and bottom temperature differing by 3° C only. The general temperature range was 26·3°C–34°C (surface) and 26-6° C–30·7°C (bottom). The St. IV however had a difference of 6°C being a shallow pond area where evaporating effect was high. Steep chemical gradation is also absent indicating good mixing of layers.

The salinity variations were generally very wide. The salinity is uniformly high in summer months at both surface and bottom waters (34 ppt) due to cessasion of fresh water inflows from south, increase in neritic waters from the north and to some extent, evapooration factors (due to the shallowness of the bay) as shown by the high values in some parts of the year (particularly February) in all the stations. During south-west monsoon (June to September) in the southern part of the Bay, the salinity is as low as 4·7 to 12·0 ppt. During winter (October-February) the values started rising showing a post-monsoon recovery. In the shallow areas the values reached as high as 60·7 ppt.

The dissolved oxygen level remained high (6·0-13 2 ppm) at all the stations except at St. III where it declined to below 5 ppm. Variations during seasons was quite high especially at stations III to VI and between surface to bottom it was around 1 ppm, the St. III, V & VI showing lower values at the bottom than at the surface waters. This could be due to the accumulated detrital matter from the drains and the respiration of the large beds of *Modiolus*.

Plankton : The density of total plankton ranged from 0·5 to 85 ml/ per operation.

Phytoplankton : The phytoplankton diversity is primarily diatoms and only 6-8 species were found. The St. I and III showed higher density than the St. V to VII.

Zooplankton : The Zooplankton population is composed of copepods, Mysids, Decapod larvae, Fish eggs, Polychaetes, Gastropod larvae, *Sagitta*, Foraminifera and Tintinnids. The polychaeta and gastropod larvae were more prevalent at St. V & VII. St. III had a highly characteristic Tintinnid population as also, Foraminifera. In general this station was richer in planktonic content than all others due to its location between the Inflows from the sea and canal and the nutrient loads from the dumpings from adjacent godowns. Both phyto and zooplanktons showed a bimodal distribution with a major peak during March-May and minor one during October-November.

Benthos : (Fig. 2) Benthos representing the biogenic capacity of the system showed the main differences between open Bay station I & II with sandy bottom and very little nutrient inflows; the farm (St. IV), with known nutrient inputs; western and southern stations (V-VII) where paddy drain effluents and other effluents from the populated villages along it are carried down. The station III, (where shipyard wastes and waste loads from the commercial canal are high) had highest density of benthic population, followed by the farm (St. IV) and St. V & VII. The overall density ranged from 3-4 806 *no.* 1 m^2.

Vascular plants : (Impact at St. V-VII) : Large quantities of floating *Eichhornia crassipes* entered the Bay at St. V-VII, descending from the drain channels at the south (Rajyalakshmi, 1975). Perhaps this abundance can be related to the release of excess nutrients, particularly phosphates from the paddy field effluents. High $P_2 O_5$ content was seen in the sediments at St. V & VI.

B. Sediment and tissue analysis

Sediment analysis : An attempt has been made to study the composition of the sediments at stations I-VII with particular emphasis on heavy metals, copper, zinc, cadmium and chromium. Of the four metals analysed cadmium and chromium were slightly on the higher side (Table 1). The sources of cadmium and chromium could be through the R. Godavari waters entering at the southern part, the minor port activities or the commercial canal in the south eastern side. Since the analysis of concentrations in water column have not been undertaken, this aspect cannot be fully interpreted

As biological indicator of toxic substanees in the tissues, a typical species of the Bay, the blood clam, *Anadora granosa* prevalent in the environment at St. V–VII showed a slightly higher level of cadmium than normal.

Although consumptions of blood clam or any mollusc is not common in the Bay region, apart from this public health aspect, the Bay ecosystem itself may be badly effected by the introduction of high levels of heavy metals especially in view of the complex nature of its current and other hydrographic factors. In the shallow waters of the Bay where the coastal grasses, mangrove shrubs make a significant contribution to the total carbon input it is essential to reduce such inputs.

C. An analysis of the standing crops

1. *Some faunal distributions and their importance (Impact at St. III, V–VI)* :

The extensive inter-tidal mud flats at the mouths of all the drain channels on the southern part of the Bay provide obviously very favourable habitat for a small species of bivalve mollusc, *Modiolus*. These favourable characteristics of the Bay are : 1. Shelter from the open sea; 2. Contact with diluted sea-freshwater; 3. Wide tidal variation that leaves the mud flats and the beds exposed to the air for several hours between each tide. 4. Loose spongy base formed by old beds of *Modiolus*.

The earlier studies were on the systamatics and ecology of the bottom fauna of the Bay (Radhakrishna and Ganapati, 1968) and on the bottom faunal distribution (Bhavanarayana, 1974). The present study almost 2 decades later indicates a few important differences such, as for example, 1. The high density *Modiolus* beds mentioned above; 2. The presence and distribution of the blood clam, *Anadora granosa* in the north western, southern and midcentral part of the bay.

The increase in the agriculture operations along both sides of all the creeks and drains opening into the south and south western Bay has resulted in greater in-flow of silt-laden waters with greater nutrient load to the intertidal region and further into the Bay.

Another dominant mollusc of the Bay, the window-pane oyster *Placenta placenta* (Radhakrishna and Ganapati, 1967; Narasimham, 1973) forms a contiguous bed (Sriramchandra Murthy *et al.*, 1969). The regions of fine clay mixed with varying quantities of silt rich in organic carbon (as is evident at St. V-VII of the present study) are found to be most productive ones in the bay (Radhakrishna and Ganapati, 1967).

From the above it appears that species-specific molluscan fishery impact might be on the increase in the southern parts of the Bay.

2. *Fisheries (A major resource and use)* :

The Bay fisheries are a major source of food and the fishing is artisan as well as it is done with small mechanised trawlers, which started operations since 1964. The catches showed that the bay has marine-dominant species composition and all the species are transients. The trawling in general is towards the mouth area corresponding to St. I & II. The southern part of the Bay (St. V & VI) is fished by the bag type of gear in view of its being more a juvenile prawn/fish ground (nursery) and a major molluscan fishing ground. At St. VII again trawling is present. This shows that the entire bay is a major fishing base. The total landings by trawling (mechanised boats) alone was recorded to be at 16, 210 t in the 1982-83 period at the Kakinada fishing harbour. The bay fishing employs more than 30,000 fishermen.

The impacts of onshore activities on the fisheries have not been studied in detail so far. However, at St. VI (R. Coringa) fish kills and bad odour have been reported on the days when effluents from the sugar factories (located 30 km away at Chellur) are released.

The impact of fishery on the bay itself is by way of trawling which constantly disturbs the bottom conditions; loads of unwanted fish also are dumped into the system.

3. *Aquaculture (Impact relating to St. IV)* :

Aquaculture is a new feature of the bay uses. Currently, all the excavated brackishwater fish farms are on the north western part

of the bay, in the reclaimed intertidal zone not extensive in acerage and situated at some distances from each other in a 40 km coastal stretch. The farms are only semi-intensive using both fertilization techniques as well as artificial feeding at a low level. None of the ponds use aeration systems and, release of water from ponds to the Bay could be twice in a month at low tides of the spring tide duration. The water retention time in a farm averages 15–20 days and water flow-in during the spring tide average 1–2 m^3 to a pond depth of 1 m.

The total production from all the farms on a maximum could be around 20t/year at present, the range being 0·3 t to 20t.

Conditions in the farms in regard to the volume, velocity and height of flow and ebb tides vary from season to season in relation to the fluctuations in the Bay. The environmental impact, in this case, from farm effluents, depends also on the management of the farm. Combined with the multiple uses of the bay water where the farms effluents are discharged, it is not quite evident at this stage whether the farms could yet be quite contributory to adverse environmental impact. At what level of increase in farm acreage (and hence water utilization) the critical level is reached when impact is felt, must be assessed yet. Margin must also be given for the possible expansion of the brackishwater aquaculture not only in the fringes (as existing today) but also to future development in the Bay itself (mariculture, by way of pens, cages etc.,).

4. *Mangrove systems (Impact relating to Sts. V - VII) :*

Mangrove ecosystems are known to be highly productive and in many areas are considered to be primary producers in estuarine food chains on which large commercial fisheries are based (Odum and Heald, 1975). The creeks/rivers at the southern end of the Bay drain extensive and thickly vegetated mangrove belts the large tree variety, the brush type or the submerged grasses. Almost all the rivers traversing these mangroves are quite deep and show no extensive siltation. Water currents also vary widely in these areas along with the tides except for the creeks connected to the R. Godavari (Ramasarma and Ganapati, 1968). There is also a steady salinity gradient.

The total area under mangrove bed might be more than 10,000ha around rivers and creeks draining to St. VI to VII. Some creeks (St. V) do not receive much flood water, therefore flow is directional towards the Bay exporting large amounts of vegetative detritus from the mangroves as shown in other studies elsewhere (Odum and De La cruz, 1967; Odum and Heald, 1975). Actual measurements of detritus production was however not done.

All the above characteristics seem to favour extensive prawn nursery system (McHugh, 1967). As reported by Ganapati and Subramanyam (1966), Rajyalakshmi (1972 and 1975), extensive juvenile prawn fisheries exist in the southern parts of the Bay. The smaller brush type vegetation adjacent to station IV-VII harbour postlarvae of particularly, *Penaeus monodon* (Rajyalakshmi and Reddy, 1982).

As shown earlier, in the recent decade there has been an organised reclamation of coastal land-particularly the mangrove-filled marshy intertidal zone at the north-western edges of the Bay for brackishwater aquaculture. The direct impact resulting from excavation is the loss of top soil and the mangroves, the latter of which act both as a rich feeding grounds and buffer zone against erosion and flood damage.

Conclusions

The lack of information, and methodology as is required from a multidisciplinary approach to the coastal environments results in our inability to predict with even 50% accuracy the effects of a particular action such as a construction of a structure or an establishment of an industry on the existing activities and status.

The Kakinada Bay is a typical estuarine system both "hydrographically and physiographically" (Ramasarma and Ganapati, 1968). Keeping the complex pattern of water circulation in the Bay in view, this small Bay is arbitrarily divisible into three broad areas to study interrelationships and impacts resulting from all man-made on-shore interferences and uses in the bay itself (Fig. 1).

So far no monitoring programmes are in operation in the Kakinada Bay which, as shown, is a multiple use system with high productivity indices. The type of approach to be used for an impact study, presented

in this paper, has been drawn up to provide trend type of information plus such of those data which can be used as base-line information for assessment of a short or long-term hazards to the Bay without bias towards any single use. Management programmes for the Bay must be developed on this basis.

Acknowledgements

The authors' grateful thanks are extended to the Chairman, A. P. State Board for Prevention and Control of Water Pollution, who has sanctioned funds for this project through the A. P. Agricultural University, Department of Fisheries Science.

Grateful thanks are also extended to Dr. A. V. Natarajan, Director, Central Inland Fisheries Research Institute, Barrackpore for permitting participation and contribution of this paper.

References

Bhavanarayana, P. V. : Some observations on the Benthic faunal distribution in the Kakinada Bay. In : Recent researches in Estuarine Biology.(Ed.) R.Natarajan. Hindustan Publishing Corporation, Delhi. 146-150 (1974).

Ganapati, P. N. and D. V. Ramasarma : Mixing and circulation in the Goutami Godavari estuary. *Curr. Sci.*, **34**, 631-632, (1965).

Ganapati, P. N. and M. Subramanyam : The prawn fishery in Godavari estuary. *J. Zool. Soc. India.*, **16**, (1+2), 11-20 (1966).

Jhingran, V. G. and A. V. Natarajan : A study of the Fisheries and Fish populations of the Chilka Lake during the period 1957-65. *J. Inland Fish. Soc.* India.. **1**, 49-126 (1969).

Kemp, S. : Fauna of the Chilka Lake. *Mem. Indian Mus.*, **5**(3), 199 (1915).

La Fond, E.C. : On upwelling and sinking off the east coast of India. *Mem. Oceanogr.* I. *Andhra Univ. Sers.*, 749, 117-121 (1954).

McHugh, J. L. : Estuarine nekton. In : Estuaries. (Ed.) G. H. Lauff (Washington D. C., A. A. A. S.). 581-620 (1967).

Narasimham, K. A. : On the molluscan fisheries of the Kakinada Bay. *Indian J. Fish.*, **20**, 209-214 (1973).

Odum, E. P. and A. A. De La cruz : Particulate organic detritus in a Georgia salt marsh-estuarine ecosystem. In : Estuaries. (Ed) G. H. Lauff, Washington D. C. A. A. A. S., **83**, 383 (1967).

Odum, E. P. and E. J. Heald : Mangrove forests and aquatic productivity. In : Coupling of land and water systems: Ecological studies. (Ed.) A. D. Hasler, Springer-verlag, New York (1975).

Radhakrishna, Y. and P. N. Ganapati : Fauna of the Kakinada. Bay *Bull. Nat. Inst. Sci.*, India, **38**, 689-699 (1967).

Rajyalakshmi, T. : The prawns and shrimp nursery areas in the lakes and estuaries of the East coast of India. In : Seminar on Mariculture and Mechanised fishing, Tamilnadu, Madras. 42-56 (1972).

Rajyalakshmi, T : Environmental ecology of *Macrobrachium rosenbergii*, *M. malcolmsonii* and *Metapenaeus monoceros* in certain drain channels opening into Kakinada Bay. *Bull. Dept. Mar. Sci. Univ. Cochin*, **2**, 285-292 (1975).

Rajyalakshmi, T. and P. K. De. The fisheries of open estuaries of India. Golden Jubilee Souvenir of CIFRI (ICAR), Barrackpore. Part II : 198-204 (1979).

Rajyalakshmi, T. and D. M. Redy : Culture of *Penaeus monodon* (Fabricius) in brackishwater and fresh water ponds in Andhra Pradesh, India. Abstracts. World Mariculture Society, USA (1982).

Ramasarma, D. V. and P. N. Ganapati : Hydrography of the Kakinada Bay. *Bull. Nat. Inst. Sci.* India, **38**, 49-79 (1968).

Sewell, S.R.B. and N. Annanadale : Fauna of the Chilka lake : The hydrography and invertebrate fauna of the Rambha bay in an abnormal year, **10**, 677 (1972).

Satyanarayana Rao, T. S. : Studies on the penetration of light in the Bay of Bengal part I–Transparency of the waters on the east coast of India and its significance. *Proc. Nat. Inst. Sci.* India, **23**, B 5-6, 195-190 (1657).

Sriramachandra Murthy, V., K. A. Narshimhan and W. Venugopalan. Survey of window pane oyster (*Placenta placenta*) resources in the Kakinada Bay. *Indian J. Fish*, **26**, (1 & 2), 125-132 (1979).

Varadarajulu, R., M. Harikrishna and M. S. S. Sarma. Some aspects of the coastal zone of Andhra Pradesh. In : National Seminar on "Protection of Marine Environment and Related Ecosystems". Sponsored by DST, New Delhi. National Institute of Oceanography, Dona Paula,Goa (1978).

J. Indian Soc. Coastal agric. Res., 5(1), 177-182. 1987.

A Study on Mangrove Ecology and Impact in Kakinada Bay

G. MAHESWARDU[1], D. M. REDDY and T. RAJYALAKSHMI[2]
Department of Fisheries Science,
A. P. Agricultural University,
Kakinada 7 Andhra Pradesh.

The southern shores of Kakinada Bay (Lat 82°15'—82°22' E and Long, 16°51—17°N) is a region of mudflats interspersed with creeks and rivers that traverse through dense mangrove forests. These forests extend south eastwards to the mouths of the Godavari estuarine system

The species comprising these are the larger tree varieties in dense formations about 10 trees/10 m^2, *viz.*, *Avicennia* sp, *Rhizophora* sp. and a few small shrubs these latter extend towards the Bay-side fringe. The beds get submerged to root level in the diurnal high tide and spring tides (tidal range 1—1.8 m with very little wave action). These areas contribute to a continuous, shallow, mud-covered, submerged nutrient zone which forms a nursery for a number of brackishwater fish and prawn species. The mangrove forests also contribute to heavy leaf-litter-detritus load to the Kakinada Bay through the creeks/rivers; The data indicates a medium-energy system.

Three rivers/creeks *viz.*, Matlapalem. Coringa and Garderu are sampled at their mouths very adjacent to mudflats (the intertidal zone) to study the chemistry of soils and waters, biological productivity (of plankton, benthic fauna and larger molluscan beds) and impact on Kakinada Bay.

The rivers also transport sugar mill effluents and contribute to adverse impacts on intertidal zone covering the mangrove based vegetation, fauna and the mud flats.

The southern fringes of the Kakinada Bay are predominantly mud-flats interrupted by creeks/rivers which traverse, at the bayward end, through dense forests of mangrove as mentioned by Ramasarma and Ganapathi (1968) in their study on the Bay hydrography. The larger trees are located at a height of 0 3 m in relation to creek river low water level but in high tide and spring tides major parts are innundated. A part of the system forms a fringe along the eroding creek/river banks with roots in the water but on the bay-ward side the trees are succeeded by vascular plants. the shrubs and grasses on the mudflats due, probably, to show encroachment and reclamation for human habitation and paddyfields, especially in Matlapalem creek (Rajyalakshmi, 1975). However, the creeks are highly saline in non-monsoonal seasons, deep with a directional flow towards the Bay.

The hydrobiological characteristics of this important ecological zone

1. Central Marine Fisheries Res. Institute, Cochin.
2. Puri Res. Centre of C. I F. R. I., Puri.

towards its lower reaches on Bay are studied with a view towards assessing their impact and contribution to the Bay productivity, particularly the food web, as a buffering zone at the intertidal region and its contribution as a juvenile nursery ground and molluscan fishery.

The major problem here is that the creeks and rivers are used, unauthorisedly, as effluent release grounds for sugar factory located about 30 km upstream. The periodical releases blacken the surface areas, particularly of Coringa river and if coinciding with high tide, the entire mangrove bed is covered over. It emanates noxious odour and fish kills extend into the Bay.

Earlier studies contributing to the ecology and species distribution of the Indian mangrove systems are those of Dwivedi (1973) and Dwivedi *et al* (1975) Untawale *et al* (1973 and 1977; Lakshmana Reddy and Rao 1986) among others. The present study, in addition to presenting the ecology of the region, is also an emphasis on environmental impact which formed a part of major study on environmental impact in Kakinada Bay (Rajyalakshmi *et al* 1985).

CLIMATOLOGICAL AND TIDAL FACTORS :

The climatological features of the Kakinada Bay- Godavari estuarine complex ranges from hot summer temperatures (35°C on an average) and humidity to declining temperature, of an order of 6-8° C. and heavy rainfall (South-west monsoon) from July to September and flooding of rivers, followed by post-monsoon recovery in salinity but further decline in temperature to around 22°C, from October to February. The average annual rainfall is 118 cm. Strong winds prevail in April-May.

The tides in the Bay are diurnal ; but two periods of highest high tides occur in the annual cycle, once in early May and another time, in November. The spring tides have a maximum tide of 1.8 m and minimum neap tide at -0.18 m.

No long-shore currents are present in this region but monsoon flood emanating from the rivers Gaderu and Coringa connected to Godavari, cause heavy churning action and bring in high sediment loads (Ramasarma and Ganapathi, 1968).

MATERIALS AND METHODS

Three sampling stations are established at the mouths i.e., in low shoreline of mangrove forests of the three major rivers and one major creek *viz*, Matlapalem creek (St. I), the R. Coringa (St II) and R. Gaderu St. III). The rivers are offshoot from R. Godavari. All three traverse through dense mangrove forests and shrub vegetation, the latter particularly in Matlapalem creek

(Rajyalakshmi, 1975). The sampling was conducted monthly for two years 1981-82 and 1982-83.

The water and soil samples were analysed for temperature, salinity, pH, EC, Dissolved oxygen and nurients using Standard methods (APHA. 1965). A 30 cm dia. Sechi disc was used for estimating transparency of waters. Plankton samles were obtained with a half meter tow net, towed for 10 minutes using a boat with outboard motor. Bottom soil samples for benthic fauna was obtained with Eckman's dredge (9052 cm^2 area). The samples were washed, settled volume is measured and numerical counts were made of the fauna. Larger fauna were obtained by a iron rake attached to a 1 m length mesh bag.

The mangrove density was estimated as 10 trees/ 10 m^2. The bed area itself was not covered in this study. The leaf-litter contribution is taken as approximate estimations in two estimations only, as 10 kg/m^2.

RESULTS AND DISCUSSION

The mangrove forest extends right upto the high tide end of the tidal mudflats at the mouths of the three rivers/creeks. The average depth ranged from 1.0 to 1.9 m. The water salinity was highly variable governed by the large inputs of freshwater from the two rivers particularly during July-September, when the salinity declined to 4.7 to 12 ppt. The post-monsoon recovery was sharp and rose to 32 ppt and occassionally upto 47.5 ppt due to capillary action from sediments. All the three stations showed alkaline ranges of pH, the total alkalinity at 60 (minimum) to 153 mg (maximum). The general temperature range was 26.6—30.5°C. The water transparency followed the pattern of floods, declining to 72 cm (monsoon) and rising sharply to to 300 cm (summer). The dissolved oxygen remained high in all the seasons at 6.4 to 14.8 ppm. The soil pH was in alkaline range 7.9—8.3 and EC at 1.6 to 6.1 mmhos/cm. The organic carbon was at 0.37—0 60 representing medium values for production. The phosphorus content was very high at 3.00—9.75 ppm reflecting high loadings, probably both from decompositions from mangrove beds and inputs from paddy field drainage. $CaCO_3$ was quite high.

At the three stations 5 species of phytoplankton *viz.*, *Chaetoceros* (3.7%), *Coscinodiscus* sp., (3.7%), *Fragilaria* sp. (0.76%), *Noctiluca* sp. (3%), Oikopleura (1.7—13%) were recorded. among others. Among zooplankton, copepods (72.7—78.6%) were predominant followed by mysids (2—10.4%, decapod larvae 6.8-9.4% polychaete larvae (1.7-2.3%), gastropod larvae(1%) and fish eggs and By others, all indicating chacteristic composition of saline dominant waters.

volume, plankton constituted 2.5 to 14.0 ml per operation. A biomodal distribution was evident with a major peak during March-May and minor one during October-November. Benthic macrofauna constitutel 2-9 no m^2, constituted by bivalves (20%), polychaetes (60 %), Isopods 20%). Occassionally decapods also occured. The general density was observed to be not high.

The data presented herein indicates that the mangrove forests here are of medium energy system controlled by the water levels, (diurnal tides and monsoonal floods) but weak wave action. This is the reason perhaps for the high tree populations as explained by Dwivedi *et al* (1975) for Orda swamp at Goa. But the presence of larger benthic molluscan beds indicates that the system is of medium energy resulting from stronger currents flowing in from the connections to R. Godavari.

Higher vascular plants such as *Eichhornia crassipes* entered the creek water and transported to the intertidal zone during monsoon floods.

Sediment analysis was reported earlier (Rajyalakshmi *et al*, 1985) wherein the presence of heavy metal and above normal concentrations of cadmium and chromium were shown. Similary a preliminary analysis of tissues of the mollusc, the blood clam *Anadora granosa* also recorded presence of higher concentrations of cadmium.

About a hundred yards away from mouths the mudflats merge into shallow fish grounds. The species composition being of *Modiolus* sp. *Anadara granosa* and the window pane oyster, *Placenta placenta* The last two are relatively lower in abundance being probably at the tail end of their distributional range (Rajyalakshmi 1985 a).

The sedimentation and nutrients flowing from the mangroves and the low to medium tidal effect from the Bay mouth seem to have resulted in suitable conditions for the formation of these beds which are commercially exploited for lime kilns. Further, suitable plankton feed has also resulted for these filter feeder from this nutrient load carried in by the tidal flows from the forests. While no detailed sampling and estimate has been made of the leaf-litter, an estimated amount of 10 kg/m^2 (dry matter) seem to be available. Untawale *et al.* (1977) reported deposits of organic detritus to the tune of 10 t/ha/yr, in muddy mangrove wet lands.

The increasing presence of *Modiolus* sp. beds might reflect also conditions of eutrophication in these areas due to high nutrient loads transported not only from mangroves but also the increasing number of paddy fields along the banks of the river. The presence of heavy metals is another hazard which might affect the mangroves also. Natarajan and Ghosh (1985) have reported concentrations of uranium in mangrove leaves. Similar adverse effect might

already be occurring by the sugar-mill effluent released from the upstream, which cover the mangrove roots during high tides, This leads oxygen depletion, among other effects and juvenile fish kills. Rajyalakshmi (1985), Ganapathi and Sabrahmanyam (1966) have all reported on the importance of this ecosystem as a nursery ground. This will ultimately adversely affect the commercial fishery of the Bay itself.

As a foremost step at conservation of this important ecosystem: (1) The organised reclamation of the zone for paddy fields brackishwater aquaculture and other uses must be prevented. Major effect of removal of mangrove forest would be on their action as buffer zones between land and water usages and the sea and preventing entry of unhindered sediment loads to the Bay (2) Replanting of natural seedlings in some of the existing bare patches preventing other uses (such as lime kilns) here. (3) Total prevention of releases of sugar mill and other industrial effluents. (4) Further detailed studies in the upper and middle zones of the main mangrove forest area must be conducted.

REFERENCES

APHA (1965). Standard methods for the examination of water and waste water. *American Public Health Association*, Inc. Newyork. p 769.

Dwivedi, S. N. (1973). Some biological problems of the west coast of India. *Mahasagar, Bul. Natl. Inst. Oceanogr.*, India 6 (2) : 112-119.

Dwivedi, S. N., Palurekar, A. H., Goswami, S. C. and Untawale, A. G (1975) Ecology of mangrove swamps of the Mandovi estuary, Goa, India. *Mahasagar, Bull. Nat. Inst. Oceanogr. India*

Ganapati, P. N. and Subrahmanyam, M (1966). The prawn fishery in Godavari estuary. *J. Zool. Soc. India*. 16 (1 & 2) : 11-20.

Lakshmana Reddy, D. and Rao, P. N. (1986). Conservation of the Nizampatnam mangroves-A part of the river Krishna estuarine system. *In : National conference on natural heritage Conservation. Berhampur (Orissa), organised by Orissa Environmental Society, DST, New Delhi, DOE, New Delhi.*

Natarajan, A. V. and Ghosh, A. (1985). Economic and evironmental considerations for a coastal ecosystem- A case study in respect of Sunderbans, West Bengal. *In : "Environmental Biology-Coastal Ecosystem". Proceedings of the Acad. Env. Biol., India.*

Ramasarma, D.V. and Ganapati, P. M. (1986). Hydrography of the Kakinada Bay. *Bull. Nat. Inst. Sci. India*. 38 : 49-79.

Rajyalakshmi, T. (1975). Environmental ecology of *Macrobrachium rosenbergii*, *M. malcolmsonii* and *Metapenaeus monoceros* in certain drain channels opening into Kakinada Bay. *Bull. Dept. Mar. Sci. Univ. Cochin. VII* (2) : 285-292.

Rajyalakshmi, T. (1985). Some observations on the faunal changes resulting from construction activities in the Kakinada Bay *Proc 73 rd Ind. Sci. Cong. Part IV. Section of Zoology, Entomology and Fisheries. Abstract.*

Rajyalakshmi, T. Maheswardu, G. and Reddy, D M. (1985). An approach to environmental

impact study in the Kakinada Bay. In : "*Environmental Biology coastal ecosystem*" *Proceeding of the Acad. Env. Biol India.*

Untawale, A. G., Dwivedi S. N. and Singbal, S. Y. S. (1973). Ecology of mangroves in Mandovi and Zuari estuaries and the interconnecting Cumbarjua canal of Goa. *Indian J. Mar. Sci.*, 2 : 47-53

Untawale, A. G., Balasubramanian, T. and Wafer, M. V. M. (1977). Structure and production in a detritus rich estuarine mangrove swamp. *Mahasagar, Bull. Nat. Inst. Oceanogr. India*, **10** (3 & 4) : 173-177.

[*Reprint From*: Journal, Bombay Nat. Hist. Society, Vol. 85 No. 3, Dec. 1988]

22. RARE OCCURRENCE OF SUNFISH *MOLA MOLA* (LINNAEUS) FROM THE COASTAL WATERS OFF VISAKHAPATNAM (BAY OF BENGAL)

(*With a photograph*)

The occurrence of sunfish in any sea is a rare event. It is so rare that even fishermen engaged in fishing throughout their lives find it totally strange when they come across one. On 6 May, 1986, a local fisherman reported to the Zoology Department of the Andhra University that a very strange looking fish was part of that day's catch. The local fisherman community had not seen the likes of it ever before. It turned out to be a sunfish, more specifically, *Mola mola*.

The occurrence of *M. mola* was first recorded in Indian waters by Khan (1975) from the Arabian Sea, near the Bombay coast. Earlier, Deraniyagala (1944) recorded one specimen from Ceylon (Sri Lanka) waters. There were some other reports of the occurrence of allied species (*Ranzania, Masturus*) of Molidae from the Arabian Sea by Kulkarni (1953), Chhapgar (1964) and Khan (1975). So far, *M. mola* has not been reported from the Bay of Bengal and the present finding is a matter of biological significance.

Description of the fish

Morphometric characters:

Total length	912 mm
Standard (preclaval) length	730 mm
Body depth	632 mm
Head length	280 mm
Eye diameter	55 mm
Snout length	130 mm
Length from tip of snout to origin of dorsal fin	630 mm
Length from tip of snout to origin of anal fin	640 mm
Length of dorsal fin	490 mm
Length of anal fin	480 mm
Length of pectoral fin	130 mm
Length from tip of dorsal fin to tip of anal fin	1350 mm
Vent diameter	40 mm
Length of gill opening	60 mm

Meristic characters:

Dorsal fin rays	15
Anal fin rays	13
Pectoral fin rays	12

The clavus was too thick to count the caudal fin rays.

Identity of the fish. The fish had all the characters of *M. mola*. The body was typically truncate without a caudal peduncle. It was laterally compressed with high dorsal and anal fins being situated far behind on the body. Pectoral fins were small and situated at the middle on the sides of the body behind the head. Pelvic fins were absent. Colour of the body was grey with silvery shade on the ventral side and dark shade on the dorsal side and fins (Photo. 1).

Very little is known about the life of sunfishes. There are some general accounts which state that they are oceanic and epipelagic. The inference was drawn because of the usual sighting of these fish basking in the surface waters, far away from the coast. It is possible that such basking fish are ill, riddled with parasites (Harbison 1987) or old. Young fish were found to be "active and alert" (Fraser-Bruner 1951). Harbison (loc. cit.) and his team of workers observed the swimming behaviour of *Masturus lanceolatus* (Molidae) at close quarters at a depth of 670 m. The graceful sculling movements of the fish at that depth, where they were more common than at the surface, and the relationship with certain type of food organisms like ctenophores and medusae, show that the natural habitat of the fish is meso-

Photo. 1. Sunfish *Mola mola* (L.)
Left: Entire fish; *Right*: Anterior region enlarged (Scale = 500 mm).
(*Photos*: B. Ram Bhaskar)

pelagic rather than epipelagic. Similarly *M. mola* was found to descend to a depth of 180 m (Harbison, loc. cit.).

The present specimen was also caught at a depth of about 200 m as reported by the fishermen. It was an unusual sight for the fishermen because they seldom cast their gear in such deep waters. Even on the few occasions when they do deep-sea fishing, the chances of a sunfish getting caught in their deep water gear (usually hook and line) are almost nil because of the alertness of the fish. These fish may be present in the mesopelagic relgons in considerable numbers but they are not well known because of negligible fishing in the region and that too by hook and line only, which may not catch the fish. It is not because they are not there but because we do not have the gear to catch them at such depths, that their appearance is such a rare event.

ACKNOWLEDGEMENTS

We thank Dr. K. Srinivasa Rao, Zoology Department, Andhra University for critical review of the manuscript. Encouragement and advice of Dr. G. Luther and Dr. G. Sudhakara Rao of Visakhapatnam Research Centre

of C.M.F.R.I. is gratefully acknowledged. Two of us (DPR and KPP) are thankful to C.S.I.R., New Delhi for providing financial assistance.

DEPARTMENT OF ZOOLOGY,
ANDHRA UNIVERSITY,
VISAKHAPATNAM-530 003,
ANDHRA PRADESH.
April 6, 1988.

B. RAM BHASKAR
D. PANDURANGA RAO
M. RAMA MURTY
G. MAHESWARUDU[1]
Y. V. K. DURGA PRASAD
K. PHANI PRAKASH
J. D. SUSHEEL KUMAR

[1] *Present address*: C.M.F.R.I., Mandapam Camp 623 520, Tamil Nadu.

REFERENCES

CHHAPGAR, B. F. (1964): Occurrence of the Oblong Sunfish *Ranzania truncata* (Retzius) in Bombay waters. *J. Bombay nat. Hist. Soc. 61*(2): 453-456.

DERANIYAGALA, P. E. P. (1944): Some whale sharks and sunfishes captured off Ceylon. ibid. *44* (3): 426-430.

FRASER-BRUNER, A. (1951): The ocean sunfishes (family Molidae). *Bull. Brit. Mus. Nat. Hist. 1*(6): 89-121.

HARRISON, G. R. (1987): Encounter with a sword fish (*Xiphias gladius*) and sharptail mola (*Masturus lanceolatus*) at depths greater than 600 metres. *Copeia 1987*: 511-513.

KHAN, M. Z. (1975): On the sunfish *Mola mola* (L), a new record from Indian waters. *Indian J. Fish. 22*(1 & 2): 295-296.

KULKARNI, C. V. (1953): Rare Ocean Sun-Fish—*Masturus lanceolatus* Lienard in Bombay waters. *J. Bombay nat. Hist. Soc. 51*: 948-950.

J. mar. Biol. Ass. India., 32 (1 & 2): 1-4

SEED PRODUCTION OF THE GREEN TIGER PRAWN, PENAEUS SEMISULCATUS IN NON-CIRCULATORY AND NON-AERATED SEA WATER IN AN OUT-DOOR TANK

G.Maheswarudu, N.N.Pillai, P.Vedavyasa Rao and P.E.Sampson Mantcka and M.R.Arputharaj

Regional Centre of the C.M.F.R.I., Mandapam Camp

INTRODUCTION

The community culture or Japanese method in large out door tanks and monoculture or separate tank culture, also known as 'Galveston' method of culture, in indoor tanks are the two basic hatchery systems currently employed for the production of penaeid prawn seed. Similarly, the advantages and disadvantages of establishment of sophisticated hatcheries capable of producing several millions of seed, and the small-size, low-cost hatcheries to meet the requirement of small-scale culture operation, are the two aspects which are being considered and discussed in the promotion and development of penaeid prawn culture in several of the developing countries including India. In the latter context, an experiment was conducted in the rearing of larvae and post larvae of the green tiger prawn, Penaeus semisulcatus, an important species, supporting the commercial prawn fisheries of the south-east coast of India and a species having great potential for culture in the sea water fed grow-out system, in an out door tank. The experiment was carried out as one of the series of hatchery runs to produce seed for ranching the species currently implemented at the

Regional Centre of the Central Marine Fisheries Research Institute (CMFRI), Mandapam Camp.

LARVAL AND POSTLARVAL REARING

A rectangular cement tank of 61-t capacity available in the open space at the marine aquarium complex of the Regional centre of CMFRI., was used for rearing the larvae and post larvae. The tank was cleared and sun-dried for two days. 26.5-t of unfiltered sea water and stored in an overhead tank was pumped into the tank on 1.7.88.

Five spawners ranging in size from 133 mm to 175 mm total length (weight 16 to 52 gr.), procured from the trawl net operated off Mandapam, was brought to the laboratory on 30.6.88. Following the procedured developed by the Institute (Silas et al.,1985) each of the spawners was kept in a conical bottom spawning tank of 250 l capacity containing 200 l of aerated sea water, to which EDTA was added to facilitate spawning.

As normally observed, all the five spawners liberated viable eggs during night time to produce a total of 6,87,637 active nauplii by the afternoon of 1.7.88. These nauplii were collected from the spawning tanks and transferred into the already prepared cement tank. The details of the rearing strateg followed in the experiment from N1 to PL25 over a period of 33 days are given in table 1.

On 2.7.88, when the nauplii reached Nauplius VI sub-stage, the sea water in the tank was fertilised with 3.8 g of pos

potassium nitrate (KNO3) and 1.8 g each of Potassium dihydrogen orthophosphate (KH2PO4), sodium silicate (Na2SiO3) and ethylene diamine tetra acetic acid (disodium salt) (CH2.N (CH2.COOH). CH2COONa)2.2H2O). Besides, 150 l of mixed phytoplanton culture dominated by Chaetoceros sp. was also added to facilitate phytoplankton bloom. The water level in the tank was raised from 26.5-t to 34.5-t. On the subsequent days of rearing between 3.7.88 and 9.7.88, when the nauplius VI, through metamorphosis, grew to postlarval I, the tank water was fertilised with the same dose of chemicals as above on 5.7.88 and the phytoplankton culture varying from 60 l to 100 l was added on 3.7.88, 4.7.88, 6.7.88 and 8.7.88 (Table.1). The addition of phytoplankton culture was nescessitated due to poor sun light on account of overcast climatic condition. During this period, the water quantity in the tank was also raised gradually to make up to 60-t by 9.7.88.

The monitoring of phytoplankton growth in the tank during the first 9 days of rearing showed relatively good growth of phytoplankton, the cell count of the dominant species of Chaetoceros being ranging from 1,160 to 31,160 cells/ml. An appreciable natural bloom of copepods also developed in the tank on 7.7.88 and this bloom was maintained through the rearing period. The observation on the gut and the long faecal filament extruded by the larvae indicated their feeding on the micro organisms developed in the tank.

When the larvae attained the postlarval I stage (9.7.88) the feeding strategy was changed from live food to compounded wet diet. The chicken egg and the minced meat of the prawn, Metapenaeopsis stridulans at the ratio of 1:5 were mixed, cooked and made to particulated size of about 100-200 u. 60 g of this feed was given to the postlarval population in the tank twice a day in the forenoon and afternoon. As the post larvae advanced to PL6 stage (15.7.88) another dry feed was prepared from prawn meat, squilla meat (each 30 % dry weight) and ground nut oil cake (40 % dry weight) using myda as binder. Each of these ingredients was mixed well and made into a paste, which was then extruded through a pelletizer, dried and powdered. From 15.7.88 onwards, the wet diet was replaced by this dry diet and offered to the post larvae at the rate of 50 g twice a day till the end of the rearing experiment. Through out the larval and postlarval rearing experiment over 33 days, the water in the tank was neither aerated nor the bottom sediment was removed. However, the water quality was maintained by replacing 10-t of water from the tank every day with an equal quantity of fresh sea water pumped from the over head tank between 10.7.88 and 19.7.88. From 20.7.88, the rate of exchange of sea water was increased to 12-t every day till the end of the experiment. The salinity of the water in the tank varied from 30.0 ‰ to 35.37 ‰ during the period of the experiment and the temperature from 29.8°C to 33.5°C. When the larvae were in the mysis I and II stages (6.7.88-8.7.88) the salinity of the tank water decreased from 31.6 ‰ to 30.0 ‰ due to rain. However, no larval mortality was observed due to this reduction in the salinity.

On 33 days of rearing in the tank, the post larvae attained a modal size of 16-20 mm (size range 11.0 mm to 30.0 mm). The water from the tank was then drained through an outlet and a total of 97,789 postlarvae were harvested. These were released into the Pillaimadam lagoon at Mandapam as part of the ranching programme. The overall survival rate from N to PL25 was 14.2 %.

REMARKS

The community culture method developed by Hudinaga and Kittaka (1967) is extensively follwed in Japan, where the present annual production of juveniles by this method is of the order of 600-700 million. Concrete tanks of 100-250 M^3 are used in this system to produce 10,000 to 15,000 PL20/M^3 over a period of 30 to 45 days. The survival rate from nauplius to PL20 is 25-60 % (Liao and Chao,1983). This method is relatively simple to operate, entail lower labour cost and man power and no separate algal culture facilities. However, the production and survival rate in this system are found to fluctuate widely and depend largely on the fertilisation strategy of water to develop phytoplankton bloom, their appropriate maintenance and water quality management.

In the present experiment, although the survival rate from nauplius to PL25 is only 14.2 %, it is interesting that this was achieved by rearing the larvae and postlarvae in a non-inculatory and non-aerated water. In India, prawn culture

is carried out at present in about 43,000 ha. It is being planned to expand it to over 10,000 more hectares. To meet the seed requirements for sustained culture in these areas, establishment of about 800 hatcheries have been envisaged. Besides the construction of large hatcheries, small-size, low-cost hatcheries, indegenous to the region has been given greater emphasis (Imre Csavas, 1988). In this context, the results of the present experiment indicate the possibility of construction and operation of small hatcheries following simple methods, even without aeration and water circulation, to meet the seed requirement of farmers engaged in smal or medium scale prawn culture operation. This hatchery system is of particular relevance in the south-east coast of India, where unpolluted and clean sea water is available and where the prawn culture is essentially based on pumped sea water to the grow out ponds and the hatchery could be constructed and operated as an integrated part of the entire culture system for advantage.

ACKNOWLEDGEMENT

The authors are grateful to Dr.P.S.B.R.James, Director, C.M.F.R.I., for his encouragement during the course of this work. They are also thankful to Mr.M.S.Muthu, Head of Crustacean Fisheries Division, CMFRI., for his valuable suggestions.

REFERENCES

Hudinaga,M and J.Kittaka, 1967. The large scale production of the yound kuruma prawn, Penaeus japonicus Bate. Inf. Bull. Planktol. Japan, Commemoration No. of Dr.Y.Matsue,pp.35-46.

Imre Csavas,1988. Fish Farming International, 15 (5) : 20-22; 15 (6) : 10-14.

Liao,I.C. and N.H.Chao, 1983. Development of prawn culture and its related studies in Taiwan. Intl. Biennial conference on Warm Water Aquaculture - Crustacea, Lale, Hawaii, USA, Feb. 9-11, 1983, 35 pp.

Silas,E.G., K.H.Mohamed, M.S.Muthu, N.N.Pillai, A.Laxminarayana, S.K.Pandian, A.R.Thirumavukkarasu and Syed Ahamed Ali, 1985. Hatchery production on penaeid prawn seed: Penaeus indicus. Spl. Pub. No:23.

. . .

Table 1. Details of rearing of larvae and postlarvae (N to PL25) of Penaeus semisulcatus in 61-t capacity out door cement tank by community culture method.

Date	larval/ postlarval stage	Rearing strategy
1.7.88	N1 and N2	6,37,637 numbers or N1 and N2 nauplii introduced into the out door cement tank, containing 26.5-t of unfiltered and stored sea water pumped from an over head tank.
2.7.88	N6	The tank water fertilised with potassium nitrate (3.8g), potassium dihydrogen orthophosphate, sodium silicate and ethylene diamine tetra acetic acid (each 1.9g); 150 l of phytoplankton predominated by Chaetoceros sp. added; water quality in the tank raised to 34.5-t.
3.7.88	P1	Water quantity increased to 40-t; 60-t phytoplankton culture added.
4.7.88	P2	Water quantity increased to 45.6-t; 100 l of phytoplankton added.
5.7.88	P2 and P3	Water quantity raised to 47-t; water fertilised with the same dosage of chemicals as on 2.7.88; overcast sky, poor sun light.

6.7.88	P3 and M1	water level raised to 49-t; 60 l of phyto-plankton added; overcast sky, poor sun light; rained during night.
7.7.88	M1 and M2	water level raised to 50-t; copepod bloom developed in the tank water.
8.7.88	M2 and M3	water quantity increased to 57-t; 80 l of phytoplankton added; raised during day time.
9.7.88	M3 and PL1	water quantity raised to 61-t.
10.7.88 to 14.7.88	PL1 - PL6	60 g. of wet compounded diet given twice a day in the forenoon and afternoon; 10-t of water in the tank exchanged with an equal quantity of fresh sea water pumped from the over head tank.
15.7.88 to 19.7.88	PL6 - PL11	50 g. of dry compounded idiet given twice a day in the forenoon and afternoon; water management as above.
20.7.88 to 1.8.88	PL11 - PL24	Feeding with dry compounded feed as above; 12-t of water in the tank exchanged with an equal quantity of fresh water pumped from the over head tank.
2.8.88	PL24 - PL25	Water drained from the tank and 97,789 numbers of post larvae harvested and ranched into Pillaimadam lagoon. Total duration of rearing:33 days; survival rate from N1 to PL25:14.2 %; no aeration provided throughout the rearing period nor the bottom sediment removed.

(Proc. Symp. on costal waters management, Anna Unvt.,1988, in Press)

SHRIMP RANCHING : AN APPROACH TO INCREASE PENAEID PRAWN PRODUCTION IN COASTAL WATERS

P.Vedavyasa Rao, N.N.Pillai, P.E.Sampson Manickam,
G.Maheswarudu and M.R.Arputharaj

Central Marine Fisheries Research Institute, Cochin-31

ABSTRACT

The exploitation of penaeid prawns in the coastal waters of India has reached the optimum level. To meet the ever increasing demand of this commodity in the internal as well as external markets, endeavours are made for the judicious management of the exploited resource, extending the range of operation to the under-exploited resource and for the development and promotion of their culture fisheries. One of the means of augmenting the production, that has emerged in recent years, is ranching of the seed produced in the hatchery into the natural environment. This system of artificial recruitment through released stocks which grow and subsequently get recruited into the fishery forms the basis of sea ranching fisheries. This communication discusses the attempts made on the ranching of Penaeus semisulcatus from Mandapam.

During April,1987 - August 1989, 1.5 million postlarval P.semisulcatus were released into the Gulf of Mannar/Pillaimadam salt water lagoon. Observations made on the released seed into the lagoon have shown that while a portion of the population migrates to the sea, a part remains in the lagoon and grows

to 75 mm average size during a period of two months. The feasibility and development of an organised shrimp ranching fisheries to augment the prawn production in the coastal waters are pointed out.

INTRODUCTION

In terms of production, the marine penaeid prawn catch of India, has been fluctuating between 83,539 t and 152,767 t with an average of 121,015 t during the past ten years (1978-'87). At several of the important prawn fishing centres along the coast, it is shown that the production has reached the optimum level and further increase of effort in the grounds exploited at present may not yield enhanced catch. In this context, the strategies considered to sustain and to increase the production are judicious management of the exploited resource; extension of range of exploitation to underexploited resource, and development and promotion of culture fisheries. As an offshoot of mariculture activities of penaeid prawns to augment the production, the release of hatchery and nursery raised postlarvae/juveniles into the natural environment has emerged as an important activity. This system of artifical recruitment through released stock which grow and subsequently get recruited into the capture fishery forms the basis of sea ranching fisheries.

In Japan, sea ranching of Penaeus japonicus was being carried out since 1978 (Uno,1984). Recently this activity has become extensive and intensive, the postlarvae released into the inlets, semi-open and open waters being 302 million in 1983. On the basis of several feasibility studies, it is proved that this system definitely helps to supplement the recruitment over those from the natural breeding population and consequently to increase the production.

Against the above background, a research programme on 'Sea ranching of marine prawns' has been initiated by the Central Marine Fisheries Research Institute for the first time in the country in 1985. Mandapam is selected as the main centre of the project in consideration of the topographical features of the area, prawn fishing activity and facilities available for larval production and monitoring of the resource. Penaeus semisulcatus that forms the main-stay of the prawn fisheries of the area, is selected as the candidate species for ranching.

SEA RANCHING TECHNIQUES

The sea ranching techniques involve four activities: hatchery production of postlarvae, nursery rearing, release of seed and monitoring of the released and exploited resources. Gravid female P.semisulcatus for spawning in the laboratory is obtained from the local commercial trawl fishing. Following the technology developed and perfected by the Institute for hatchery production of penaeid prawn seed, (Silas et al.,1985) the spawning and larval rearing are undertaken in the experimental hatchery upto postlarva I stage. Thereafter, the postlarvae are further reared in 6-t capacity rectangular cement tanks by feeding with egg-prawn meat compounded feed for 10-15 days. At this stage, they grow to 10-15 mm size and exhibit a 'clinging' behaviour to sea grasses. Besides, P.semisulcatus seed are also produced in 60-t capacity square cement tank following the community culture system, where the seed is raised to 25-30 mm size (Maheswarudu et al., [illegible], in press). The release of seed is carried out at this stage.

SITE OF RELEASE OF SEED

Selection of site for release of seed is important to ensure better survival and growth of the released stock. Preferably, the site should be a nursery ground providing congenial physico-chemical requirements, a better refuge from

predators and should provide adequate food for the seed to grow. Observations made earlier on the distribution pattern of P.semisulcatus at different phases of its life off Mandapam have indicated that the young ones of the species are abundant in the shallow inshore grounds where sea grasses grow luxuriantly. In this ecosystem, it spends a part of its life before getting recruited into the fishery in the deeper grounds of the area. In consideration of this aspect, the site of release of seed is selected on the seagrass beds available opposite the hatchery in the Gulf of Mannar. Another site selected has been the salt water lagoon at Mandapam (Fig.1). The lagoon extends about 6 km and spreads over 360 ha. at high water. During north-east monsoon the lagoon gets filled up with land drainage and tidal sea water. With the cessation of rains, the main water supply is maintained upto May/June when the bar mouth gets closed. Thereafter, the water held in the lagoon basin sustains at low level and is characterised by gradually increasing salinity till the onset of north - east monsoon. The lagoon supports a minor prawn fishery during December-April/May. Although, P.indicus and Metapenaeus burkenroadii form the dominant species in the fishery, P.semisulcatus also occurs occasionally in small quantities.

SEED RELEASED DURING APRIL'87 - AUGUST'89

During 1985, 5.84 lakh postlarval P.semisulcatus were produced in the temporary hatchery at Mandapam. Of these, 3.09 lakh postlarvae were released into the inshore waters of Palk Bay as a trial. Following the establishment of an experimental hatchery, and with the facilities available, over 2.56 million postlarvae were produced during April'87-August'89 and grown in the nursery tanks. Of these, 0.75 million seed were released into the Gulf of Mannar and 0.71 million into the salt water lagoon at Mandapam (Table,1). The remaining seed were used for culture in the sea water fed earthen ponds adjacent to the lagoon and for other studies concerning the growth and survival of the species at different salinities.

GROWTH AND RECRUITMENT

To understand the growth and recruitment pattern of the

released stock, regular monitoring of the catches from the lagoon was carried out. Besides, experimental fishing was also conducted in the lagoon. In August'88, 97,789 juvenile P.semisulcatus ranging in size from 11 to 30 mm were released into the lagoon. After a month of release, experimental fishing by a drag net was carried out at different locations in the lagoon. However, no catch of P.semisulcatus was encountered either during monitoring of the landings or in the experimental fishing, although a few specimens of M.burkenroadii and P.indicus were recorded. Another batch of seed (16-35 mm) numbering 70,366 were released into the lagoon on 3.10.88. After 24 hrs of release, a fixed bag net made of mosquito netting was operated at the bar mouth at regular intervals from 12.30 hrs on 4.10.88 to 02.00 hrs on 5.10.88, coinciding with the low and high tides. The net was operated against the current. Although about 5 kg of fish were caught in the first two hauls operated between 12.30 and 18.00 hrs, no prawns were encountered in these hauls. In the subsequent four hauls taken during the night hours (19.00-02.00 hrs), a total catch of 0.373 kg of P.semisulcatus (520 numbers), 10 kg of M.burkenroadii and 6.25 kg of fishes were obtained. In the nets operated during high tide no prawns were caught.

The percentage size composition of P.semisulcatus released on 1.8.88 and 3.10.88 and those obtained in the experimental fishing is depicted in fig.2. The size of P.semisulcatus caught in the experimental fishing ranged from 21 mm to103 mm. As these were caught during the low tide, it was inferred that they represented the emigrating population from the lagoon to the sea. As 46.5% of this population was composed of juveniles measuring between 21 and 35 mm and since the bulk of the population released on 3.10.88 belonged to this size group, it might further be inferred that they represented the population that was released into the lagoon on 3.10.88.

It was observed that the emigrating population was also composed of larger size prawns. In consideration of the fact that there was no report of any catch of P.semisulcatus in the commercial fishery in the lagoon in September'88 and since no juvenile prawns were encountered in the nets operated during high tide and since the larger prawns in each of the size group were represented by only a few numbers, it was obvious that they did not represent a population that had earlier immigrated from the sea, but might represent a segment of the population that was released in August'88 and stayed in the lagoon. Among them, the prawns belonging to the size group at 91-95 mm forming a minor mode (10.6%) might represent the major group of juveniles (16-20 mm) released into the lagoon on 1.8.88. The other size groups in the catch might represent the population that were growing at different rates. As the biological productivity of the lagoon is known to be relatively low, it is possible to get such wide variations in the growth rate of prawns. The inference that the prawns belonging to the size group at 91-95 mm represented the juveniles of 16-29 mm size group released in August is further supported by the observation reported by Sampson Manickam et al.(unpublished) who recorded a growth rate 1 mm per day during the first 60 days of culture of P.semisulcatus in a sea water earthen pond located adjacent to the lagoon. These observations thus indicate that while a portion of the released population in the lagoon migrates to the sea, a part remains in the lagoon and grows to 75 mm average size during a period of two months. Following this encouraging results, large scale ranching of P.semisulcatus into the lagoon is taken up from the centre.

MONITORING OF THE EXPLOITED RESOURCE

To study the effect of ranching on the prawn population and production of the area, regular monitoring the exploited resource is carried out from the landing centres at Mandapam and Pamban. P.semisulcatus is caught mainly by bottom trawl nets

operated by small machanised boats (9.14 - 9.75 m size). Besides, 'disco' nets (three walled entangling nets) were also employed to catch prawns. Generally the active fishing season is observed from April to October in the Palk Bay and from November to March in the Gulf of Mannar. The fishing range extends from close to the shore to about 50 m depth zone.

The important population parametres of P.semisulcatus observed during 1987 and 1988 are given in the table 2. The size of exploited population in this region ranged from 90 mm to 220mm total length, the principal modal size contributing to the fishery being 121-130 mm for males and 146-150 mm for females. Although the breeding activity of P.semisulcatus population was seen throughout the year, the peak breeding season during 1987 and '88 was observed during January-February and July-August. The peak recruitment of juveniles into the fishery was recorded in April-June in 1987 and April, May and Octover-December in 1988. As the quantum of seed released at present is small to identify and separate the naturally recruited and released population, these data would serve as base line information for further studies on the effect of sea ranching of shrimp on the local population.

GENERAL REMARKS

Application of sea ranching has great prospects to augment the resources, particularly in semi-open waters and in the mangrove ecosystems. The activity reported above forms only a preliminary attempt. Neverthless, it demonstrates the feasibility of sea ranching to supplement the natural recruitment, and in turn to augment the production. However, large-scale ranching is essential to register a perceptible resource improvement. In this context, it is worthwhile to consider a planned programme of ranching of surplus seed after meeting the requirements for farming or that produced during the off season in the hatcheries now set up/being set up at different maritime states to supplement the natural recruitment in the coastal waters. Information on the life history, population

dynamics of the species selected for ranching, and biotic and abiotic parameters of the ecosystem where release and capture of the stocks are considered, is also essential to develop an organised shrimp ranching fisheries.

ACKNOWLEDGEMENT

The authors are grateful to Dr.P.S.B.R.James,Director, Central Marine Fisheries Research Institute, for the encouragement and valuable suggestions offered during the course of the work.

REFERENCES

Maheswarudu,G.,N.N.Pillai, P.Vedavyasa Rao, P.E.Sampson Manickam and M.R.Arputharaj. Seed production of the green tiger prawn, Penaeus semisulcatus in a Non-circulatory and Non-aerated out door tank,(inpress). J.mar.biol. Ass.India.

Sampson Manickam,P.E.et.al.,(Unpublished). On the growth of Penaeus semisulcatus de Haan in sea water earthen pond, cement tank and at different salinities.(MS).

Silas,E.G., K.H.Mohamed,M.S.Muthu, N.N.Pillai, A.Laxmilarayana, S.K.Pandian, A.R.Thirunavukkarasu and Syed Ahamed Ali, 1985. Hatchery production of penaeid prawn seed: Penaeus indicus. CMFRI Special Publication. No.23: 41 pp.

Uno Yutaka,1984. An ecological approach to mariculture of shrimp: shrimp ranching fisheries. Proc. First International conference on the culture of penaeid prawns/shrimps. Iloilo city, Philippines,1984. SEAFDEC Aquaculture Department:37-45.

Table 1 : Number of Penaeus semisulcatus seed produced in the hatchery and released into the Gulf of Mannar/ Pillaimadam salt water lagoon at Mandapam during April 1987 - August'89.

Month	1987		1988		1989	
	Postlarvae produced	Seed released	Postlarvae produced	Seed released	Postlarvae produced	Seed released
January	...	...	38,490	25,950	25,200	10,185*
February	...	...	106,830	73,390*	30,000	1,000*
March	...	...	142,060	128,060*	79,600	172,870*
April	335,333	34,000	65,000	71,000*	79,600	...
May	108,100	11,050	32,500	...	...	...
June	63,244	98,354	307,179	234,965	...	...
July	162,046	...	197,740	57,820	241,640	24,900*
August	191,736	78,050	25,512	43,137 97,789*	...	38,400*
Septemeber	109,460	18,100	67,728	25,512	...	...
October	30,000	22,950	...	70,366*		
November	16,000	...	94,000	5,676*		
December	...	12,000	12,440	94,000 15,400*		
Total	1,015,919	274,504	1,089,479	943,065	456,040	247,355

* released at Pillaimadam salt water lagoon.

Table 2: Important population characters of Penaeus semisulcatus exploited from Gulf of Mannar at Mandapam region during 1987 and 1988

	1987	1988
1. Estimated catch (t)	219.9*	206.3
2. Catch per unit effort (kg/hr)	1.631	1.157
3. Size range (in mm)		
Male	90 - 160	90 - 160
Female	100-210	85 - 220
4. Principal modal size (mm) of the population		
Male	121 - 125	126 - 130
Female	146 - 150	146 - 150
5. Peak breeding season	Jan.-Feb. and July-August	Jan.-Feb. and July-August
6. Peak recruitment period	April,May and June.	April-May and October,November and December.

* Excludes the catch from July-October.

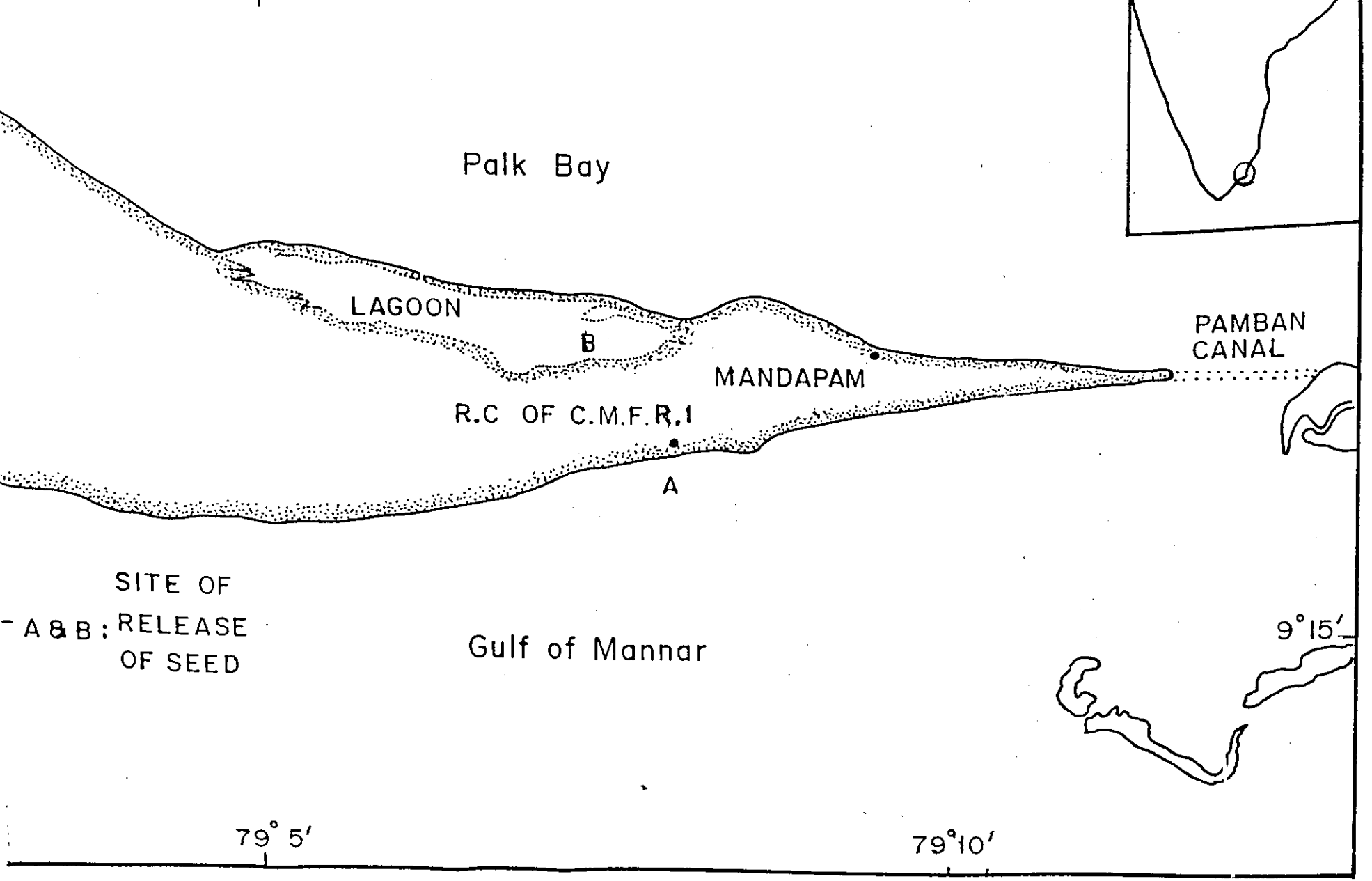

Fig.1. Map showing the site of release of seed.

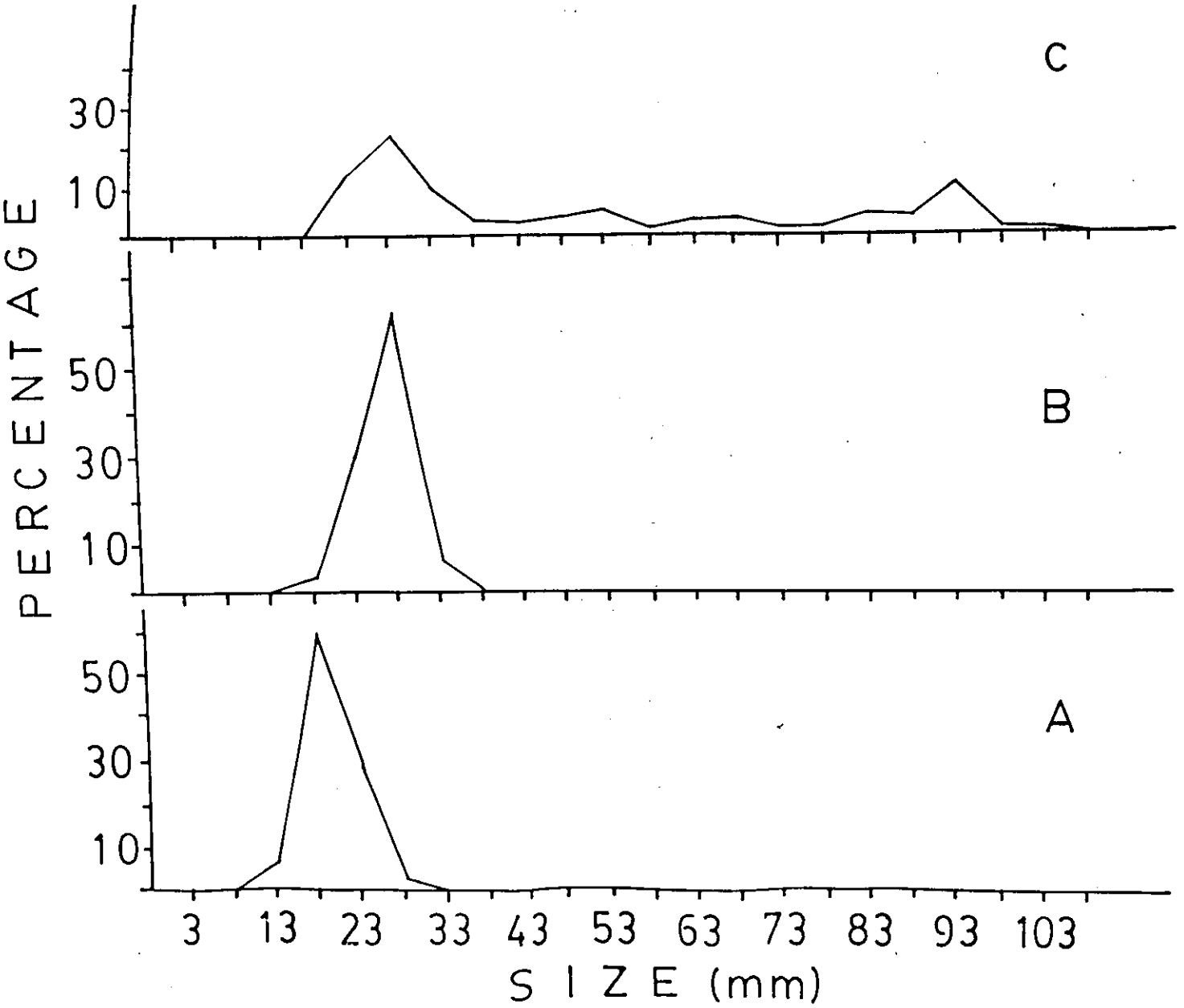

Fig.2. Size composition of Fenaeus semisulcatus released at Pillaimadam salt water lagoon on 1.8.88 (A) and 3.10.88 (B) and those obtained in the experimental fishing on 4&5.10.88 (C).