GROWTH AND REPRODUCTION OF THE PENAEID PRAWN *METAPENAEUS DOBSONI* (MIERS) IN BRACKISHWATER ENVIRONMENT

THESIS SUBMITTED

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C. VASUDEVAPPA

POST-GRADUATE PROGRAMME IN MARICULTURE
CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
Cochin - 682 031, India

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D E D I C A T E D

T O

M Y

P A R E N T S

C E R T I F I C A T E

This is to certify that the thesis entitled **"Growth and reproduction of the penaeid prawn Metapenaeus dobsoni (Miers) in brackishwater environment"** is the bonafide record of the research work carried out by **Shri. C. Vasudevappa,** under my guidance and supervision in the Post-graduate programme in Mariculture, CMFRI, and that no part thereof has been presented for the award of any other degree.

Dr. C. Suseelan
Senior Scientist &
Officer In-charge PGPM
Central Marine Fisheries
Research Institute
Cochin-682 031.

Cochin - 682 031
October 1, 1992.

DECLARATION

I hereby declare that this thesis entitled **"Growth and reproduction of the penaeid prawn Metapenaeus dobsoni (Miers) in brackishwater environment"** has not previously formed the basis for the award of any degree, diploma, associateship or other similar titles or recognition.

C. VASUDEVAPPA

Cochin-682 031
October 1, 1992.

CONTENTS

PREFACE

Prawn farming has assumed considerable importance all over the world as an alternate means of increasing prawn production. In many countries it has been taken up on industrial level and more and more water areas are brought under scientific farming. The present global shrimp production through aquaculture is estimated at about seven lakh tonnes from a total cultivated area of about 10 lakh hectares (Anon., 1991a). In India, the annual prawn production through aquaculture amounts to about 35,000 tonnes which is obtained exclusively by culturing in brackishwater systems. Though there are nearly a million hectares of cultivable brackishwater areas available in the country (Alagarswami, 1988), prawn farming is practiced at present only in about 65,000 hectares. Over 80 per cent of the prawn production through aquaculture is generated from the traditional farming practices. Modern scientific farming has not picked up desired momentum eventhough proper shrimp farming technology is developed in the country indigenously (James, 1992). This shows that there is urgent need to gear up programmes for prawn farming on scientific lines so that more and more brackishwater areas could be brought under culture.

At present, prawn farming is attempted largely on a couple of large growing species like Penaeus monodon and P.indicus on account of many advantages inherent in these species. Serious attempts to develop proper culture technology

for smaller varieties of prawns have not been made in the country eventhough many suitable species occur in our coastal waters.

Metapenaeus dobsoni is an important species contributing to the capture and traditional culture fisheries of the southwest coast of India. Though smaller in size, its demand for export to countries like Japan is ever on the increase. The production of this species from the sea has been stagnating in many areas of the coast due to continuous exploitation over the past 3-4 decades. Realising the imperative need for developing proper culture technology for this species, a detailed study of the two important aspects such as growth and reproduction of the species in brackishwater environment has been taken up and the results obtained are presented in this thesis. A knowledge on the growth of the species in brackishwater is of vital importance to assess its productive potential in culture systems. Similarly, an understanding of various aspects of rerproduction such as maturation, spawning and larval development in brackishwater is of great significance in developing less expensive hatchery techniques and domesticating the species for large-scale farming.

The thesis is presented in six chapters. **Chapter I** comprises an introduction with a comprehensive review of published information on the subject. **Chapter II** describes the methodology adopted for studying the growth pattern and reproduction in field as well as laboratory conditions and the

ecological factors influencing the same.

The results of investigations are elaborated and discussed in **Chapters III, IV and V.** In Chapter III, the observations on the ecological characteristics of the two selected perennial prawn culture fields, namely, Kannuvilakettu and Thoppilkettu and a cocount grove canal system used for field culture experiment, situated in the Vypeen island near Cochin are described. The monthly/fortnightly variations of the physico-chemical and biological characteristics observed during the prawn filtration/culture period have been discussed and compared between the systems.

Chapter IV deals with the growth of M.dobsoni in different field conditions and in different salinity levels in the laboratory. Based on the growth rates estimated from the field, the harvestable size and the time required for attaining the same have been determined. The optimum salinity conditions to promote maximum growth, food utilization, biomass production, moulting and survival have been worked out based on laboratory experiments. Details such as the biochemical variations in the muscle tissue of prawns grown in different salinities, the length-weight relationship, the size, count and meat recovery relationships are also elucidated.

Chapter V describes the result of studies on reproduction of the species in the brackishwater. The morphology and anatomy of male and female reproductive systems

of the species are described for the first time. The maturation process in different salinities is described in detail for both male and female prawns and the minimum salinity at which normal maturation occurs has been identified. Detailed accounts on spermatogenesis, spermatophore formation and oogenesis are provided and the similarities and differences noticed with the same in other related species compared. Biochemical variations in protein, free amino acid, carbohydrate and lipid of muscle, haemolymph, hepatopancreas and ovary with reference to maturation of prawn in brackishwater have been evaluated and briefly discussed. The incidence of mature male and female prawns in the brackishwater culture systems in relation to the prevailing environmental conditions is pointed out along with other details such as size at maturity, fecundity and gonado-somatic index. The results of laboratory experiments on maturation, spawning, egg hatching,early larval development, rematuration of ovary and spawning under different salinity conditions are also dealt with in detail.

Chapter VI gives a summary of the results, which is followed by an exhaustive bibliography.

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CHAPTER I. INTRODUCTION

Prawns occupy an important position among the fishery resources all over the world. It is an important protein rich food cherished by the rural as well as urban population. Hunting for prawns has been the traditional occupation of the coastal fisherfolk from time immemorial. With the increased demand for prawns as an esteemed food of gourmet in many of the economically advanced countries like Japan and USA, the production and utilization of this resource grew rapidly during the past few decades. This has led to the development of an organised industry for prawn products in most of the maritime countries of the Indo-Pacific. World Fisheries Statistics (Anon., 1991a) reveals that the global prawn production has reached the level of 2.44 million metric tons in 1989, fetching export earnings to the tune of about 15,500 million dollars to the developing countries. The insatiable demand of this high valued commodity in World markets triggered intensive exploitation of prawns through the highly advanced fishing techniques in many of the Asian countries at present, with the result, the coastal shrimp stocks are said to be over-exploited. India, once occuping the top rank in prawn production in the world, is now relegated to the second position (Tharakan 1991), with a total annual production of about 3 lakh tonnes in 1991 (Anon 1992). In the national development programmes, the country has assigned top priority for enhancing prawn production in order to augment the export earnings, which

during the year 1990-91 has touched Rs. 1394 crores (Anon., 1991b). The stagnating situation of prawn landings from capture fisheries of most of the maritime states in the country compels to look for additional ways and means of prawnproduction for sustained development of the seafood export industry of the country. Prawn farming is considered as an important and alternate means of increasing production in the country, as also in many other developing countries of the Far East.

The success of prawn farming largely depends on a sound knowledge of the biology of the candidate species. In India, scientific investigations on the biology of prawns dates back to the middle of seventeeth century. Since then, a wealth of information has been generated on various aspects of the biology of commercially important species of prawns along the Indian coast and the result of these studies have been consolidated and documented in a series of species synopsis published in the proceedings of the World Scientific Conference on 'The Biology and Culture of Shrimps and Prawns' held at Mexico in 1967 (Mistakidis, Ed., 1968, 1969, 1970). Subsequent to this, many others have also added to our knowledge on the biology of commercially important prawns, the notable contributions being those of Jones 1967; George et.al., 1967; Rao, 1968, 1973a,b, 1974, Pillay and Nair, 1971; Kuttyamma 1973; Kurup and Rao, 1974; George and Rao, 1974; Ramamurthy et.al., 1978; Kagwade, 1980; Suseelan and Kathirvel, 1982 a,b. Achuthankutty and Nair 1983, Sukumaran, 1983; Sukumaran et.al., 1987 from the west coast and Rajalakshmi, 1961. 1964;

Subramanyam, 1965,1973; Thomas, 1974, Rao, 1978, 1979, 1989; Ramakrishnaiah, 1979, Lalitha Devi 1987. and Shankaralingam (1989) from the east coast of India.

As is the case in most tropical regions, the prawn fisheries of India is multispecies in nature. Though most of the species have many biological features in common, individual variations are also noticed in many respects. The commercial species supporting the fishery belong to two major categories namely, the penaedian prawns and the caridean prawns. Among penaedians, members of the family Penaeidae are the most highly preferred for export on account of their larger size and higher unit value as compared to other categories. The penaeid prawns constitute the backbone of the seafood export industry of the country. The tremendous growth achieved by the seafood export industry of the country has been brought about by the increased production of these prawns through the application of modern fishing and processing techniques. It is also said that the fishing industry of our country is mainly shrimp based and therefore considerable importance is attached to this variety of prawns for research and development programmes.

Almost all species of penaeid prawns are basically marine. They breed in the sea at varying depths and complete metamorphosis in this environment. While vast majority of the species complete the life cycle in the sea itself, some tend to migrate to estuarine environment at postlarval stages and stay in this environment for varying periods and then return to the sea for maturation and breeding.

The estuarine phase of penaeid prawns is taken advantage of for brackishwater farming (Mohamed and Rao 1971), besides large-scale exploitation of juveniles from the brackishwater environment by various traditional fishing methods in many South East Asian countries (Pillay, 1992). In India, the extensive brackishwater systems available on the west and east coast serve as good nursery grounds for many coastal species of penaeid prawns contributing to the fishery (George, 1962; Panikkar and Menon, 1956; Rao, 1965; Subramanyam, 1968; Mohamed and Rao, 1971; Selvakumar et.al., 1977; Achuthankutty and Nair, 1983; Achuthankutty, 1987). Most of our commercial prawns can be considered as potential species for farming as they are evolved with a natural life cycle which is preadapted for estuarine life in the younger stages and they could also withstand wider range of environmental changes (Mohamed and Rao, 1971). Brackishwater prawn farming has been in vogue since very ancient times in some parts of the country. The paddy field prawn filtration process (Chammenkettu) of Central Kerala (Menon, 1954; Gopinath, 1956; Raman and Menon, 1963; George et. al., 1968; George, 1974; George, 1975), the prawn and fish culture practice in Bheries of West Bengal (Pillay, 1954) and the prawn filtration in Khar lands of Karnataka (Nagaraj and Neelakantan, 1982) and 'Gazani' lands of Goa are some of the traditional farming practiced even today. Encouraged by the success achieved in some of the East Asian countries in scientific prawn farming, various governmental organisations and universities in the country have undertaken several research

programmes at laboratory as well as field levels during the past two decades (Alagaraswami 1988). This has enabled to develop viable technology for brackishwater shrimp farming in the country on commercial scale. All the important cultivable species of penaeid prawns have been bred in captivity, their larvae reared successfully and the hatchery technique for production of seed perfected and simplified to a great extent. The eyestalk ablation technique has been effectively applied to induce maturation and spawning in many species of penaeid prawns under controlled environmental conditions. Considerable advancement has also been made towards broodstock development through artificial insemination (Muthu, 1983; Kulkarni and Nagabhushanam, 1979; Nagabhushanam and Kulkarni, 1982). The technical feasibility and economic viability of intensive culture of prawns have also been established to popularise prawn farming in the country (James, 1992).

A perusal of works relating to culture of prawns would reveal that most of the research efforts made in the country in this direction were only on few selected large growing species like Penaeus monodon and P. indicus. According to Mohamed and Rao (1971), the cultivable species available in India are several which qualify themselves to be ideal candidates for brackishwater aquaculture. The growing demand for large as well as small varieties of prawns in the international markets calls for concerted efforts to develop suitable culture technology for the smaller varieties of prawns also, which have hitherto remained neglected. Metapenaeus

dobsoni, Pl.1), popularly called 'Poovalan Chammeen' in Malayalam, is one of such smaller varieties of penaeid prawns which possess immense potentiality for brackishwater culture especially in the southwest coast of India. This is one of the most dominant species in the Kerala coast, which has been supporting a commercial fishery of high magnitude for the past several decades. This coastal specis has been subjected to intensive exploitation in the sea as well as estuarine systems, with the result the production along the Kerala coast has declined considerably in recent years (Suseelan et.al., 1992). It is needless to emphasise therefore, that urgent steps are needed to conserve this resource in its natural habitat in order to obtain the maximum sustainable yield. The only possible way of enhancing its production to meet the ever increasing demand for export is through farming. Lack of adequate information on biological features relevant to brackishwater culture prompted a detailed study on the two important aspects such as growth and reproduction of the species in the brackishwater environment, with a view to domesticate it and increase it's production through brackishwater farming and generate employment opportunities in the coastal rural sector.

M.dobsoni is a widely distributed species along the Indian coast with it's maximum abundance in the southwest coast (George, 1969). Its contribution to the commercial fishery is highest along the Kerala and Karnataka coasts (George et.al., 1988; Suseelan et. al., 1992). Menon (1952, 1955, 1957) made pioneering studies on the life history and biology of the

species from Kerala coast, which marked the beginning of systematic investigations on penaeid prawns in Indian waters. Subsequently, Menon and Raman (1961), George (1961, 1962, 1967a,b), Banerji and George (1967), George et.al. (1968), Rao (1968), Mohamed et.al. (1968), Kuttyamma (1973), Kurup and Rao (1974), George and Rao (1967) and Kuttyamma and Antony (1975) have added to the knowledge on the binomics, fishery and population characteristics of the species from Kerala coast, Ramamurthy et.al.(1978), Radhakrishnan (1982), Sukumaran (1983, 1987), Sukumaran et. al. (1988) from Karnataka coast, Achuthankutty and Parulekar (1986 a,b,c) from Goa waters and Lalithadevi (1987) and Shankaralingam (1989) from the east coast.

Alagaraja et.al. (1984), George et.al. (1988) and Smitha and Devaraj (1990) carried out stock assessment of the species from Kerala and Karnataka coasts. Many workers have studied the postlarval recruitment, distribution pattern and biology of the species in it's estuarine habitat, of which the contributions of Menon and Raman (1961), George (1968), Mohamed et.al. (1968), Mohamed and Rao (1971), Rao (1973 a,b), Kuttyamma (1975), George and Suseelan (1982) and Suseelan and Kathirvel (1982 a) from Cochin backwaters and the adjoining traditional prawn culture systems, Suseelan and Kathirvel (1982 b) and Nair et.al. (1982) from Ashtamudi lake, Menon (1980) from Korapuzha estuary, Anil (1985) from Sunkeri backwaters of Kaliestuary of Karnataka, Achuthankutty et.al. (1977), Selvakumar et al. (1977), Achuthankutty and Nair (1983) and Achuthankutty (1987, 1988)

from the estuaries of Goa, Jones and Sujanasingani (1954) and Ramakrishnaiah (1979) from Chilka lake, Subramanyam (1965) and Ganapati and Subramanyam (1966) from Godavary estuary, Manickam and Srinivasagam (1972) and Raj (1976) from Pulicat lake are note worthy.

The dominance of the species in the traditional prawn culture systems of central Kerala was pointed out with observations on it's growth in the culture systems by Menon(1954). Gopinath (1956), Raman and Menon (1963), Mohamed et.al. (1967), George et.al. (1968) and George (1975) have also added information on growth of the species in the brackishwater systems of Kerala. Nagaraj and Neelakantan (1982) and Pai et.al. (1982), describing the brackishwater prawn culture practices in the paddy fields of Karnataka, worked out the economics of culture operations of this and other related species.

Balasubramanian et.al. (1979), Nair et.al. (1982), Nair et.al. (1983) and Nair et.al. (1987) studied through laboratory experiments the feeding behaviour and preying efficiency and the length-weight relationship and growth under different levels of feeding. Sumitra Vijayaraghavan and Vijayakumaran (1976) and Thomas et.al. (1984) evaluated the caloric content and energy conversion in the species. Kuttyamma (1982) studied the effect of salinity on growth of some penaeid prawns including M.dobsoni. Royan et.al. (1987) pointed out the advantages of using adult Artemia as feed for juveniles. Lazarus and Nandakumaran (1990) reported on the growth rate of

M.dobsoni during it's culture in polyethylene film-lined ponds at Calicut.

Effect of salinity and temperature, individually or in combination, on growth and other biological features of marine and brackishwater invertebrates and fishes have been demonstrated by many workers and the same have been reviewed by Kinne (1970). Gunter (1950), Pearse and Gunter (1957), Williams (1960), Zein-Eldin (1963), Zein-Eldin and Griffith (1969), Gracer and Neal (1972) and Venkataramaiah et.al. (1972) have carried out detailed investigations on the influence of different salinity levels on growth and survival of penaeid postlarvae and juveniles. These studies have indicated that low salinities favoured faster growth and better survival for postlarval and juvenile penaeid prawns. The cumulative effect of salinity and temperature on growth, survival and food intake and food conversion efficiency have been reported by Zein-Eldin and Aldrich (1965) and Venkataramaiah et.al. (1972, 1975), Venkataramaiah (1974). In India, Nair and Krishnankutty (1975) investigated on the effect of salinity on postlarval and juvenile growth in P.indicus in Cochin backwaters. Raj and Raj (1982) studied the effect of different salinities ranging between 5 and 45 ppt, on growth and survival of postlarval P.indicus, P.monodon and P.semisulcatus and demonstrated that salinities between 15 and 25 ppt promoted better growth and survival. Kalyanaraman (1983) studied the effect of salinity on feed intake, growth, conversion efficiency and proximate composition of juvenile P.indicus. The effect of salinity

variations on growth and survival of P.monodon have been studied through field culture experiments by Chakraborti et.al. (1986) and by laboratory experiments by Navas and Sebastian (1989).

For successful shrimp farming a clear knowledge on the nutritional requirements of the species cultured is an essential prerequisite. With the growing importance of shrimp farming, world-wide interest has been evinced in recent years for the development of proper feed and many valuable contributions have been made in this respect by many workers, like Khannappa (1977), Deshimaru and Shigeno (1972), Balaz et.al. (1973), Colvin (1976a,b), Sedgwick (1979), Alava and Lim (1983), Kanazawa et.al. (1979) etc. New (1976) and Kanazawa (1985) have reviewed the dietary studies on shrimp and prawn nutrition. Information on nutritional aspects from India is due to the works of Qasim and Easterson (1974), Royan et.al. (1977,1987), Ponnuchamy (1981), Sumitra Vijayaraghavan et.al. (1982), Ali (1982 a,b), Vijayaraghavan and Ramdhar (1982), Goswami and Goswami (1982) who have dealt with the effect of different levels of protein, carbohydrate, starch etc. in the diet and the different levels of feeding on food conversion efficiency and growth in penaeid prawns.

Salinity exerts significant effect on physiological system of the animal (Aiken 1978). In crustaceans, moulting is the end point of a series of physiological events to achieve general body growth (Passano, 1960). The extent of the effect of environmental factors varies from species to species (Conan,

1965). Salinity, through it's osmotic effects, plays an important role in controlling physiological state of the animals (Zein-Eldin and Aldrich, 1965). Zein-Eldin (1963) studied the combined effect of temperature and salinity on moulting and growth of P.aztecus. Later on, the work done by Bookhout (1972) on Pagurus alatus, Rothilsberg (1979) on Pandalus jordani and Stirts and Turner (1981) on Emerita talpodia showed the influence of salinity on moulting and growth. Vijayan (1988) observed a faster moulting rate at 15 ppt salinity than all the other tested salinities in P.indicus.

Salinity has been reported to influence the biochemical composition of haemolymph, muscle and other tissues of the animal. Lecal (1958) showed that the electrophoretic pattern of serum protein of Blennius pavo was considerably modified within an hour of transfer from salt to freshwater, but after a day it was almost completely reverted to it's original pattern, once adaptation to the new environment was completed. Free amino acids are reported to vary with salinity (Richard and Cecealdi 1974) in the muscle and hepatopancreas of P.kerathurus. Duchatean and Florkin (1961) reported that muscle and blood of crabs and lobsters become enriched with free amino acid when animals were transferred from brackishwater to full marine water, of which concentration of lysine was more striking. Larserre and Gillies (1971) observed immense decrease in muscle free amino acid content of euryhaline intertidal teleosts (Crenimugil labrosus and Paralichtyes lethostiama) upon transfer from 200 ppt sea water to freshwater. Salinity also exerts

influence on composition of lipids. The rotifers fed with Chlorella cultured in sea water have more nutritional value especially in high unsaturated fatty acid content than those fed with Chlorella reared in freshwater. It is fairly established that the concentration of W3 unsaturated fatty acids which are important constituents of phospholipids are comparatively higher in marine forms than freshwater forms (Kanazawa et.al., 1971). The effect of salinity on minerals is more striking. The marine prawns are known to possess high calcium, sodium and chloride than that of freshwater forms (Gilles, 1979).

The reproductive physiology of crustaceans has been extensively studied all over the world and more interest is evinced along this line in recent years on account of it's importance in broodstock management of cultivable species. A clear understanding of the morphology, anatomy and histology of male and female reproductive systems is imperative in this context. In penaeid prawns, the morphology of female reproductive system is better studied than in males. Detailed studies on the structure of male and female reproductive systems have been carried out in P.japonicus (Hudinaga, 1942), P.setiferus (King, 1948), P.stylifera (Shaikhmahmud and Tembe, 1958 and Rao, 1969), P.duorarum (Cummings, 1961), P.indicus (Subramanyam, 1965 and Mohamed 1989), P.merguiensis (Tuma, 1967) and P.monodon (Motoh 1978, 1979). Many have contributed to the knowledge on gametogenesis in penaeid prawns through histological studies, of which the works of Ryan (1967), Chandran (1968), Pillay and Nair (1971), Diwan and Nagabhushanam

(1974) in crabs and Hudinaga (1942), King (1948), Shaikhmahmud and Tembe (1958), Shaikhmahmud (1961) Cummings (1961), Motoh (1979), Subramanyam (1965), Tan-Ferman and Pudadera (1989), Joshi et.al. (1982), Yano (1985) and Mohamed (1989) are noteworthy. Comprehensive accounts on the oogenesis have been given by Raven (1961), Norrevang (1968) and Adiyodi and Subramoniam (1983). According to Papathanasiou and King (1984), the process of vitellogenesis takes place in three distinct stages. First, a stage of germ cell division and formation of oogonia, then a stage of yolk deposition (vitellogenesis) and finally a postvitellogenic stage. Works on spermatogenesis are very meagre and limited to the description of spermatogonia, spermatocyte and spermatid stages in the process of formation of decapod sperm (King, 1948; Mathews, 1951; Pillai, 1960; Kon and Honma, 1970; Amato and Payen, 1978; Chow et.al., 1982). In India, studies on spermatogenesis are limited to the work of Shaikhmahmud and Tembe (1958) in P.Stylifera, Subramanyam (1965) and Mohamed (1989) in P.indicus. The present status of knowledge on spermatogenesis and sperm formation in crustacea has been reviewed by Pochon-Masson (1983) and Adiyodi (1985) with emphasis on spermatozoan morphology.

Most of the decapod crustaceans transfer sperm from male to female during copulation via a specialized sperm jacket known as spermatophore. The structure of spermatophore and thelyca has been studied in great detail by Perez Farfante (1975) in species of genus Penaeus. The process of spermatophore formation in the vas deferns of P.kerathurus has

been described in detail by Malek and Bawab (1974 a,b). Histological characters of spermotophore layers of Scylla serrata has been described by Uma and Subramoniam (1979).

Studies on the reproductive cycle and associated biochemical changes have been pioneered by Giese and Pearse (1974). Among crustaceans, most of these studies are centered on the changes in metabolites like protein, lipid and carbohydrate in relation to different stages of maturity. In brachyuran crabs the studies of Rahaman (1967), Chandran (1968), Adiyodi (1968), Pillay and Nair (1973), Diwan and Nagabhushanam (1974) and Varadarajan and Subramoniam (1982) are important. Similar investigations on penaeid prawns are few. Pillay and Nair (1973) studied the variation in biochemical components of ovary, muscle and hepatopancreas in relation to reproductive phases in M.affinis. Lawrence et.al. (1979) reported the percentage composition of protein, carbohydrate and lipid in ovary and hepatopancreas of ablated and unablated females of P.vannamei, P.stylirostris and P.setiferus. Read and Caulton (1980) reported on changes in body composition in relation to moulting and ovarian development in P.indicus from the South African coast. Castille and Lawrence (1989) studied the relationship between maturation and biochemical composition of gonad and digestive gland in P.aztecus and P.setiferus. The variation in lipid profile of ovary and hepatopancreas during maturation in P.japonicus has been delineated by Teshima et. al. (1989). Biochemical changes associated with maturation in Indian species have been reported by Kulkarni and Nagabhushanam

(1979) in P.hardwickii, Achuthankutty and Parulekar (1984) in M.affinis, M.dobsoni, P.merguiensis and P.stylifera and Mohamed and Diwan (1992) in P.indicus. A very few studies are on record on haemolymph. Changes in the serum protein during the reproductive cycle has been studied by Barlow and Ridgway (1969) in Homarus americanus, Dietz (1982) in Macrobrachium rosenbergii and Yano (1988) in P.japonicus. The variation in haemolymph lipid concentration in relation to maturation in penaeid prawns has been studied by Gehring (1974), Middleditch et. al. (1980), Teshima and Kanazawa (1983) and Galois (1984).

The first captive spawning of penaeid prawn was demonstrated by Fuginaga in 1934 using a mature P. japonicus collected from the sea (Hudinaga 1942). However, successful maturation and spawning in captivity was achieved only after three and a half decades by Shokita (1970) in P.latisulcatus. Since then several attempts in this line were made in different parts of the world and as many as 23 penaeid species have been successfully matured of which 14 spawned in captivity (Primavera, 1984). A few instances of natural maturation and spawning of unablated captive P.monodon in seawater ponds and tanks have been reported by Chen (1976) and Liao (1977) from Taiwan, Primavera and Yap (1989) from Philippines and Aquacop (1979) from Tahiti. Ryther (1979) observed that in China P.orientalis routinely matured in captivity. According to Primavera (1978), the SEAFDEC laboratory succeeded in maturing and spawning of P.merguiensis, P.indicus and Matapenaeus spp. in running seawater system. At Conway, U.K., Beard et. al.,

(1977) reared many generations of P.merguiensis in captivity in rectangular concrete tanks with subgravel filters.

In India, Raje and Ranade (1972 a,b) succeeded in the laboratory spawning of M.monoceros, P.merguiensis, M.affinis and P.stylifera and studied their larval development. Subsequently, similar success has been achieved by Thomas et. al. (1974) in P.stylifera and Thomas, Kathirvel and Pillai (1974 a,b,c) in P.acclivirostris, M.affinis, Thomas et. al. (1974) and M.dobsoni under laboratory conditions. Muthu et. al. (1974) recorded the spawning of P.indicus and gave a note on the eggs and larvae. Successful attempt to breed and study the larval development have been made by Devarajan et. al. (1978) in P.semisulcatus, Silas et. al. (1978) in P.monodon, Rao (1978) in M.brevicornis, Gopalakrishnan et. al. (1985) in M.kutchensis and Nandakumar et. al. (1989) in M. moyebi. Few nonconventional penaeid prawn species such as Metapenaeopsis stridulans, M. hilarula, Parapenaeopsis maxillipedo, P.uncta and Trachypenacus pescadorensis have also been bred and larval stages studied (Anon, 1998).

Eyestalk ablation technique was employed for the first time to induce maturation in P.duorarum by Caillouet (1972) who attempted bilateral eye ablation, which did not induce spawning. It was Alikunhi et. al. (1975) who could successfully induce maturation and spawning in P.monodon and P.meiguiensis through eyestalk extirpation. Later, Arnstein and Beard (1975) could successfully induce maturation and spawning through unilateral eyestalk ablation in P.orientalis,

P.occidentalis and P.monodon with good larval survival. From then on, the method of unilateral eyestalk ablation was successfully used in many countries to induce maturation and spawning of captive panaeids (Aquacop, 1977 and 1979; Wear and Santiago, 1976; Santiago, 1977; Primavera et. al., 1978; Primavera and Yap, 1979; Rordriguez, 1981; Halder, 1978; Emmerson, 1980; Lumare, 1981). In India, Muthu and Laxminarayana (1977) employed eyestalk ablation technique in penaeid prawns (P.indicus, P.monodon, M.dobsoni and P.stylifera) and induced them to mature and spawn under laboratory conditions. They have also reviewed the works on induced maturation of penaeid prawns in the country and elsewhere. Recently (Anon., 1986) breeding and successful larval development have also been reported in P.latisulcatus through eyestalk ablation.

Studies on in-vitro fertilization and the use of hormonal injections to induce maturation in penaeid prawns have also been carried out with varying degrees of success in recent years. Clarke Jr. (1973) succeeded in achieving in-vitro fertilization with non-motile spermatozoa of brown shrimp P.aztecus, while, Nair (1987) obtained similar result in the banana prawn P.merguiensis. Kulkarni et. al. (1979) showed that progesterone stimulated oogenesis in P.hardwickii. Nagabhushanam and Kulkarni (1982) used vertebrate male steroid hormones such as testosterone acetate and androgen and found that these hormones have inhibiting effect on ovarian maturation. Yano (1985) induced ovarian maturation and spawning in the Greasy back shrimp M.ensis by adminstering progesterone.

The available literature on the reproductive biology of panaeid prawns indicates that breeding and metamorphosis are essentially completed in the marine environment. However, a few exceptions to this have been reported from Australia among species of genus Metapenaeus. Morris and Bennet (1951) reported that, M.bennette, which normally breeds in the sea, spawned in Tuggerah Lake at a time when the mouth of the system was blocked and metasaline conditions existed. Racek (1972), observed maturation of this species in culture ponds where salinity was almost similar to that of sea. According to Potter et. al. (1986), M.dalli bred in deeper waters of the Swan River estuary, where high salinity conditions (35-37 ppt) existed during summer months and completed the life history in the same environment. The absence of this prawn in the commercial catches of adjoining coastal waters (Penn, 1977) has been taken as an added evidence to believe that the prawn completed its entire life cycle in the estuary. De Bruin (1965) recorded mature females of M.elegans from low salinity lagoons of Srilanka.

Attainment of maturation of penaeid prawns in culture ponds has also been reported by a few workers during pond culture experiment in other parts of the world. Johnson and Fielding (1956) could propagate the white prawn P.aztecus in captivity using prawns raised in coastal ponds. Jhingran (1974) observed M.brevicornis maturing in experimental brackishwater ponds of Japara, Indonesia. Rodriguez (1981) made observations on growth and sexual maturation of P.kerathurus in salt ponds. Using P.indicus raised in brackishwater ponds,

Primavera et. al. (1982) compared the maturation, spawning, fecundity and hatching rates of ablated and unablated females. Yano (1984) observed maturation of Kuruma prawn P.japonicus in earthern culture ponds. Maturation and spawning of P.monodon in varying salinities ranging from 15-35 ppt have also been reported by the SEAFDEC (Anon., 1983).

Rematuration and spawning experiments have been conducted in recent years from different parts of the world, with varying degrees of success, in many penaeid prawn species such as P.monodon, P.stylirostris and P.vannamei (Aquacop,1979; Emmerson, 1980; Beard and Wickins, 1980), P.japonicus (Lumare, 1981; Yano, 1984), P.semisulcatus (Browdy & Samocha, 1985) and P.canaliculatus (Choy, 1987).

Influence of various environmental parameters such as pH, temperature, salinity photoperiod etc., on maturation and spawning of penaeid prawns have been discussed by many workers like Wickins (1976 a,b), Muthu et. al. (1984), Crocos and Kerr (1986) and Primavera (1986) to mention a few.

Though the natural breeding ground of M.dobsoni is considered to be the inshore sea (Menon, 1952), instances of occurrence of mature females in brackishwater systems during high salinity period have been reported by few workers (George, 1974, Rao and Kathirvel, 1973; Silas et. al., 1982). Rao and Kathirvel (1973) collected mature females of M.dobsoni from Cochin backwaters and bred them in the laboratory. Though the eggs hatched out, the larvae did not show normal development.

Silas et. al. (1982) observed maturation of M.dobsoni females in brackishwater ponds (28.0-29.0 ppt) and experimentally demonstrated successful spawning in salinities ranging from 28.0 to 34.8 ppt. Stray instances of the occurrence of mature females in estuarine environment have also been reported in other related species. Muthu and Manickam (1973) collected mature males and females of M.burkenroadi from Chilka lake and presumed the possibility of breeding of the species in the lake. Krishnamurthy and Ganapati (1985) encountered P.indicus specimens with ovary in early maturing stage in the brackishwater pond at Vallarpadam island in Cochin backwaters where the salinity ranged from 18.9 to 21.5 ppt. Though these authors have tried to make the specimens mature in the same salinities, no sign of improvement was observed in the gonadal condition of the animal. More recently Kathirvel and Selvaraj (1989) observed maturing females of Kuruma prawn (P.japonicus) in earthern ponds having brackishwater conditions (12.04-16.50 ppt) at Muthukadu near Madras.

CHAPTER II. MATERIAL AND METHODS

The material for the field study were obtained from two perennial prawn culture systems, namely, Kannuvilakettu and Thoppilkettu and a coconut-grove canal system situated in the Vypeen island near Cochin (Fig. 1). These brackishwater systems are located at about 15 kms from the Cochin bar mouth and connected to Cochin backwaters by a network of canals running a distance of about 2 km. These culture systems also lie close to the Arabian sea (about 2 km) and form a part of the extensive areas used for brackishwater farming.

Kannuvilakettu (Pl.2a,b) is one of the large perennial prawn culture fields around Cochin having a water spread of 77.6 hectare (ha). The depth of water varies from 1 to 3 meter (m). The inflow and outflow of water in this system is regulated through two sluice gates fixed at the southern and northern portions. Thoppilkettu (Pl.3), is a medium sized culture system having an area of 13.6 ha. The depth of water varies from 1 to 2.5 m and the water exchange is regulated through a sluice gate located at the southern end of the system. Both these systems are operated by two different groups of persons who obtain the culture rights through bidding from the actual owners. The prawn culture practice is mostly traditional in nature, and involves autostocking of young prawns, through the incoming tides and periodical harvesting carried out according to the lunar phase called "thakkum" (Menon, 1954; George, 1967,1968). Early juveniles of large growing species

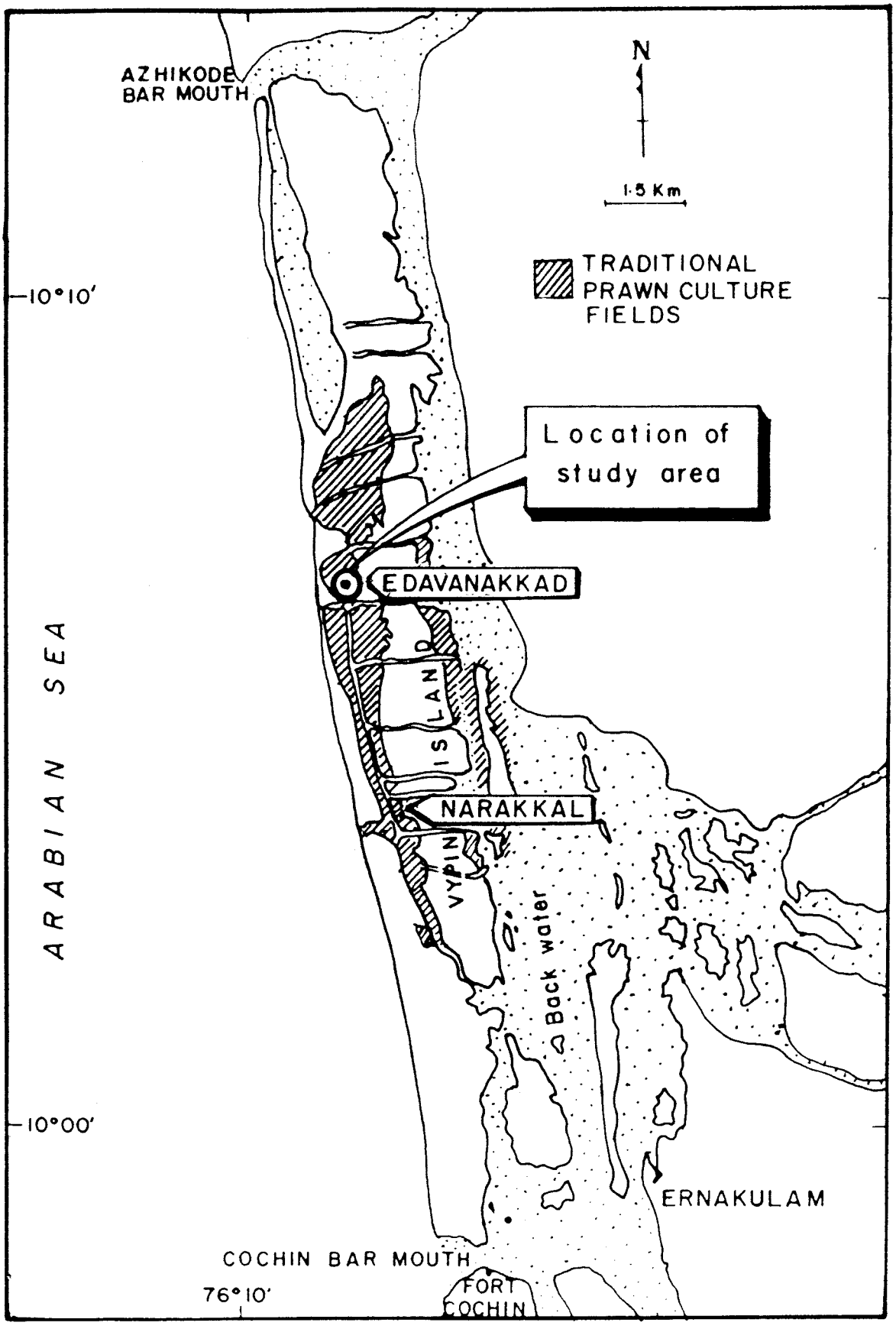


Fig.1: Map showing the location of study area.

like Penaeus indicus are also stocked additionally to improve the yield. Normally artificial feeding is not resorted to, in this culture practice. The prawn filtration (harvesting) is carried out almost throughout the year with peak activities during January to June. A rectangular bagnet of 5-6 m length, having a mesh size of 20-25 mm at the mouth and 5-8 mm at the codend, is used for prawn filtration. The net is fixed at the mouth of the sluice gate and operated during the lowtide period. A hurricane lamp is hung at the inner mouth of the sluice gate to attract prawns. Generally good catches are obtained 3-5 days before and after fullmoon and newmoon days.

In most of the islands situated in Cochin backwaters, vast networks of coconut grove canal systems exist besides extensive areas of paddy-cum-prawn filtration fields. These shallow man-made canals constructed between rows of coconut trees are permanently connected to the Cochin backwaters through feeder canals and have tide-fed water of about 0.5-1.5 m deep. The canals are not effectively used for any aquaculture purpose. The only culture practice that is in vogue is that in some areas, along with autostocking, juveniles of fast growing species like P.indicus are stocked additionally and raised to marketable size during January to July. In order to understand the growth potential of M.dobsoni in this ecosystem, a portion of the coconut-grove canals lying inbetween Kannuvilakettu and Thoppilkettu was selected and used for experimental culture. The desired portion of the canal was separated by putting an embankment (Pl.4 a,b). At the centre of this embankment a

wooden sluice gate with a wire-mesh shutter made of wooden frame was fixed in order to regulate the water level and also to prevent the entry of undesired organism/escape of stocked prawns. The total length of the canal used was 120 m, with an average width of 2.45 metres. The total area worked out to 294 sq m. The depth of the water varied from 0.5-1.2 m depending on the tidal phase.

Field studies:

The data on growth and reproduction of M.dobsoni and on environmental features of culture systems were collected at fortnightly intervals for a period of 20 months from January 1990 to August 1991 from Kannuvilakettu and 10 months from August 1990 to May 1991 from Thoppilkettu. The field culture experiment in the coconut-grove canal system was conducted for a period of 140 days from the end of January to the beginning of June 1991. Details of this culture experiment are described in chapter III.

On each observation day, a random sample of 0.5-1.0 kilogram (kg.) M. dobsoni was collected from each of the prawn culture fields, usually the collections were made in the late evening hours coinciding with the time of harvesting. The prawns preserved in ice were brought to the laboratory for further analysis. Concomitantly water samples were also collected from the culture systems after recording the water temperature. In order to get an average picture of the hydrographic condition of the whole culture system, water

samples were taken from four different areas of each of the farms and the mean values of the various parameters worked out. The water samples for oxygen determination were fixed at the farm-site itself and all the samples were brought to the laboratory for chemical analysis. In the coconut-grove canal system, fortnightly prawn sampling was conducted by random cast netting. On each sampling day atleast 20 males and 20 females were caught and transported to the laboratory in live condition for detailed biological investigations. Water and soil samples from three different areas of the canal system were also collected after noting the water temperature. Oxygen samples were fixed at the farm site itself. All these samples were brought to the laboratory for analysis. Zooplankton samples were collected once a fortnight in the morning hours from all the three systems studied for a period of 6-8 months from January to August 1991. The samples were collected with a tow net of 30 cm diameter made of organdi cloth. For each sample, one horizontal haul was made by dragging the net fully submerged under water for a distance of 20m, keeping the dragging time as constant as possible. The plankton collected was fixed in 5 per cent formalin and brought to the laboratory for analysis.

In the laborabory, the prawn samples were analysed in fresh condition for length, weight and maturity stage of individual prawn sex-wise. The 'length' of the prawn refers to the total length measured from tip of rostrum to the tip of telson with the abdomen fully extended and was recorded for the nearest millimeter. The weight of individual prawn was recorded

to nearest milligram using a high precision electronic monopan balance (Mettler model) after blotting the prawn. In the case of female prawns, the impregnated condition was also noted besides length and weight measurements. The different maturity stages in males were determined based upon the nature of externally visible sexual characters such as spermatophore mass at the base of the fifth walking leg and petasma, while in females, the maturity stages were determined based upon the colour and size of ovary seen by cutting open the animal or by seeing through the exoskeleton against light in the case of live prawns. After recording all the required data of individual prawns, the total weight of male and female prawns present in the sample were also noted separately.

The length measurements taken for the three culture systems were analysed for studying the growth in the natural environment. The measurements were grouped into 5 mm size-classes and length frequency distribution worked out fortnightly as well as monthly. The data pertaining to Kannuvilakettu and Thoppilkettu were used for studying the monthly modal progression and the growth estimated using ELEFAN computer programme based on von Bertalanffy's growth equation (Pauly and David 1981), separately for the two sexes. In the case of coconut grove culture system, the growth in terms of length and weight was worked out from the progression of fortnightly mean values calculated sex-wise for the individual samples.

The length-weight relationship was estimated sex-wise from a total of 1948 prawns ranging in size from 22 to 80

mm for males and from 23 to 105 mm for females using the log form of the allometric growth equation $w = a\ L^b$ where w = Expected weight, L = total length and a and b are constants calculated by the least square method. The estimations were carried out using suitable computer programme.

For studying the relationship between size, count and meat recovery, prawns ranging in size from 41-80 mm for males and 41 to 100 mm for females were selected and a minimum of 10 prawns in each of the 5mm size groups were analysed. The total length and total weight of individual prawns of each size group were recorded sex-wise and then weighed headless, peeled & deveined. The measurements of individual prawns were computed for mean values of each of the size groups.

The water samples collected during the entire period of study were analysed for salinity, pH and oxygen, while only the samples collected during January to August 1991 were analysed for parameters such as nitrate, nitrite, ammonia, phosphate and silicate. The soil samples collected from coconut-grove canal system were anslysed for organic carbon and organic matter. Details of analytical procedures adopted for the different parameters are described elsewhere in this chapter. The zooplankton samples collected was made up to 100ml in a measuring cylinder and after allowing it to settle for about 24 hours the settling volume was noted. The sample was then analysed qualitatively and the numerical abundance of various component groups worked out by sorting out the entire sample or a sub-sample if the sample was large.

For studying the gametogenesis, biochemical aspects, fecundity and gonado-somatic index, live prawns in different maturity stages were collected from Kannuvilakettu during night and transported to the laboratory in wide mouthed plastic seed transportation bins. In the laboratory, the animals were maintained alive for 10-24 hours in rectangular fibre glass tanks of 200 litres capacity and used for various purposes.

The morphology of male and female reproductive systems was studied based on fully mature specimens in the fresh condition. The reproductive systems were carefully dissected out and drawn using camera lucida.

The size measurements of ova were taken based on samples taken from the middle lobe of the ovary after hardening in 5 per cent formaldehyde. From each sample representing a maturity stage, atleast 300 ova were measured using an occular micrometer. Each individual ovum was measured along the longest and shortest axis and the mean size was calculated as given by Rao (1968). For determining the Gonado-somatic Index (GSI) the female prawns at diffeent maturity stages were weighed individually to the nearest milligram after blotting the animal. The ovaries were carefully dissected out and weighed to the nearest milligram. The gonado-somatic index was estimated using the following method described by Giese and Pearse (1974).

$$GSI = \frac{\text{wet weight of ovary (g)} \times 100}{\text{wet weight of the animal (g)}}$$

For studying the histological details of spermatogenesis, spermatophore formation and oogenesis, the gonads in different stages of maturity were dissected out and desired parts of testis, vas deferens and terminal ampoule in the case of males and the middle lobe of ovary in the case of female fixed in Bouins fluid in separate vials for 24-48 hours. The spermatophore was extruded from the animal by electrically stimulating (12 V current) the animal at the base of the fifth walking leg (Sandifer et al., 1984) using an electro-cautery apparatus and the same fixed in Bouins fluid for histological sectioning.

The samples were washed thoroughly in running tap water to remove excess picric acid. They were then dehydrated using ascending alcohol series (30 - 100% ethanol) and cleared in two changes of xylene. In the case of male reproductive organs the samples were cold-impregnated using xylene and wax shavings in 1:1 ratio for 2-3 hours due to the hard nature of tissue. The solvent was evaporated out by placing the tissue in an oven at 58°C. The tissue was then transferred through two changes of moulten wax (Paraffin wax with cresin, M.P. 58-60°C) and blocks prepared using paper boats. Serial sections of blocks were cut at approximately 5-8 μ thickness using a rotary microtome. The serial sections were spread over clean, labelled slides using distilled water and affixed to slides by placing on slide warmer. Once the sections were spread properly and adhered to the slides, the excess water was drained off and the slides allowed to dry at 40°C. These slides were used

for histological staining. The sections on the slides were deparaffinised in two changes of xylene and brought down to 70 per cent alcohol through two changes in each of 100 per cent and 90 per cent ethanol. The slides were then stained with Harry's Hematoxylin and counter stained with 1 per cent aqueous Eosin solution. The slides were dehydrated by passing them through ascending alcohol series (70-100% ethanol) and cleared in two changes of xylene. After clearing, the slides were mounted using DPX mountant. The slides of male reproductive organs were stained with Mallory's triple stain also, in addition, for differentiating the various parts.

After careful microscopic examination of the slides, photomicrographs were taken using an Olympus universal research microscope (Vannox Model M 10 AD) equipped with an automatic exposure system. Black and white (35 mm, ORWO 100 ASA) and colour film (35 mm, KODAK 100 ASA) were used for taking the photomicrographs.

The bio-chemial components of four selected body tissues namely haemolymph, muscles, hepatopancreas and gonad were studied for females of all maturity stages and mature males. In immature males the study was restricted to haemolymph, muscle and hepatopancreas only. The tissue samples were analysed for total protein, total free amino acid, total carbohydrate and total lipids. Apart from this, all tissues except haemolymph were also analysed for moisture levels in female prawns.

After blotting the live prawn, haemolymph was collected by direct cardiac puncture using a hypodermic syringe fitted with a No.22 needle. The glass syringe and the needle used, were rinsed with an anticoagulant (10% trisodium citrate) prior to each collection. The haemolymph thus collected was stored at -20°C in sterilized glass vials after closing its mouth. The dissected samples of muscle, hepatopancreas and gonad, were dried at 60°C to a constant weight and mascerated to a fine powder using an agate mortar and pestle. The samples after labelling were stored in a dessicator with silica gel for further analysis. The estimation of various biochemical components was replicated six times and the results analysed statistically by ANOVA for testing the significance of biochemical variation with maturity stages. The analytical details of various biochemical parameters are given below.

Total protein:

Total protein was estimated by the Biuret method of Gornall et al. (1949) using crystalline bovine serum albumin (sigma) as standard. A known aliquot of dried muscle, hepatopancreas and gonad tissue and a known volume of haemolymph was deproteinised using 80 per cent ethanol. After centrifuging for 5 minutes, the precipitate obtained was dissolved in 1N Sodium hydroxide. Then, 8 ml of Biuret reagent was added and the colour developed was read at 540nm using a ECIL UV spectrophotometer against a reagent blank. The protein was estimated using standard graph.

Total Free amino acids

The method of Yemm and Cocking (1955) was used to analyse the total free amino acids. The standard solution was prepared from standard A-Glysine standard and standard B-Glutamic acid standard (1 ml.of final standard solution = 0.0006 mg amino acid nitrogen). To 1 ml each of deproteinised sample, 1 ml of standard solution and 1 ml of distilled water 0.5 ml of citrate buffer, 1.2 ml of solution C [50 ml of ninhydrin solution (500 mg in 10ml methyl cellosolve) + 250 ml of Potassium cyanide solution (5ml of 0.01 M Potassium cyanide in 250 ml methyl cellosolve] were added and heated in boiling water bath for 15 minutes. After cooling at room temperature for 5 minutes, 2.3 ml of 60 per cent ethanol was added and the optical density determined at 570 nm in a spectrophotometer and amino acid nitrogen in the sample was calculated.

Total carbohydrates:

The method described by Dubois (1956) was used. After deproteinizing the sample, 0.5 ml of the supernatant was made up to 1 ml using distilled water. To this, 1ml of phenol reagent and 5 ml of concentrated sulphuric acid was added and after 10 minutes, it was boiled in boiling water bath for 20 minutes. The absorbance was read at 490 nm and the total carbohydrate calcuated using a glucose standard.

Total Lipids:

The lipid was estimated using Sulphophosphovanillin method of Barnes and Black Stock (1973). After deproteinizing

the sample, 0.5 ml of the supernatant was evaporated to dryness in a water bath and 0.5 ml of concentrated sulphuric acid added. Again it was kept in a boiling water bath for 100 minutes. To a known quantity of the acid digested solution, 2.5 ml of phospho-vanillin reagent was added. The colour was compared with cholesterol standard prepared in chloroform Methanol mixture (2:1) and total lipid calculated.

Moisture content

Pre-weighed wet samples of muscle, hepatopancreas and gonad were kept in a hot air oven at 60 ^{o}C till constant weights were obtained. The loss in weight was taken as the moisture content and expressed as percentage. (AOAC, 1965).

Laboratory experiments

The laboratory studies were intended to study the growth of the species, moulting periodicity, maturation, spawning and embryonic as well as early larval development at different salinity conditions.

Studies on growth

The growth of the prawn was studied under six test salinity levels, viz., 5, 10, 15, 20, 25 and 30 ppt over a period of 56 days from January to March 1991. For this purpose the filtered seawater was stored in circular fibreglass pools of one ton capacity for 2-3 days. From the clear silt free seawater, the desired salinity level was prepared using the formula.

$$V = \frac{\text{desired salinity} \times 100}{\text{salinity of sea water}}$$

where V = volume of sea water of known salinity to be taken and diluted with freshwater to get one litre solution of desired salinity. The freshwater (tap water) required for this purpose was collected 2-3 days in advance and aerated vigorously till use. The experiment was conducted in triplicate using green plastic tubs of 40 litre capacity. In each tub 30 litres of rearing media was provided. The 18 tubs were arranged in rows of three in a three-tier system on two metal stands. The stands were placed in such a way that all the tubs received equal light conditions. The water in the tubs was aerated round the clock, using auto pressure control electric compressor. The tubs were kept covered with a mosquito netting cloth fixed with cloth hanging clips. The water in the tubs was changed fully once a week. The juvenile prawns for the experiment were collected from the Cochin backwaters using velon screen net. The animals were brought to the laboratory in seed transportation bins. They were maintained in the same salinity as that of the collection site for one day, giving continuous aeration after which they were acclimated to the desired salinity over a three day period. Feeding was done twice a day using a formulated pelletized feed at 15, 12.5, 10.0 and 7.5 per cents of the body weight per day, of surviving prawns, during 1st, 2nd, 3rd and 4th fortnight of the experiment. Every morning the accumulated faecal matter was removed from the tubs by siphoning out the same and the left over feed collected in the same manner and

dried in an oven at 60 C to constant weight. The dead prawns, if any, were also removed and discorded after noting their total length and weight. The length (mm) and weight (mg) of all prawns in various tubs were recorded once in a fortnight after blotting the animal. Salinity, pH, oxygen, ammonia and nitrite were determined at the beginning and end of every week, using the standard methods described. The temperature was monitored once in three days. At the end of the experiment, percentage survival, mean percentage gain in length/weight and the food utilization indices such as Feed Conversion Efficiency (FCE) and Protein Efficiency Ratio (PER) were calculated using the following equation;

$$\text{Percentage survival} = \frac{\text{Initial number} - \text{final number}}{\text{Initial number}} \times 100$$

$$\text{Mean percentage gain in length/weight} = \frac{\text{Mean final length/weight} - \text{Mean initial length/weight}}{\text{Mean initial length/weight}} \times 100$$

$$\text{FCE} = \frac{\text{Final wet weight of prawns (g)} + \text{Wet weight of dead prawns (g)} - \text{Initial wet weight of prawns (g)}}{\text{Total dry weight of food fed (g)} - \text{Total dry weight of food leftover (g)}}$$

$$\text{PER} = \frac{\text{Final wet weight of prawns (g)} - \text{Initial wet weight of prawns (g)}}{\text{Total protein intake (g)}}$$

The formulated pelleted feed was analysed for its proximate composition (moisture, protein, lipid, carbohydrate, ash and fibre) using the standard methods prescribed by AOAC (1965).

The results of growth experiment were statistically tested using Two-way ANOVA with multiple equal distribution in each cell to study the effect of different salinities on growth.

The moulting periodicity of the prawn was also studied simultaneously in salinities 5, 10, 15, 20, 25 and 30 ppt, respectively, in smaller tubs of 7 litre capacity. These experiments were done in triplicate with 5 litre rearing media maintaining one animal in each tub. Prawns in the size range 23.2 to 23.6 mm were used for this purpose. Continuous aeration was provided keeping the mouth of the tub covered with mosquito netting cloth. Feeding, cleaning and changing of water was done as explained for the growth experiment. Every morning the animals were observed for exuvia. This experiment was also conducted for 56 days.

Studies on maturation, spawning and early larval development

The experiments on laboratory maturation of the prawn were conducted during the period July and August 1990 and April to August 1991 as large sized impregnated female prawns were available in considerable numbers during this period only. For this study, the prawns were collected from coconut grove canal system, Kannuvilakettu and Thoppilkettu during night and transported to the laboratory in wide mouthed plastic seed transportation bins. The prawns were gradually acclimated over 24 hours and transferred to the experimental salinities. The experiments were carried out in 15, 20, 22, 24, 26, 28 and 30 ppt salinities on different occasions. Immature impregnated

female prawns larger than 70 mm were generally used for the experiment. Sometimes early maturing prawns (stage II) collected from Kannuvilakettu were also tried for further maturation and spawning. In most cases female prawns were reared with equal number of mature males. Whenever, the experimental animal was in stage II, a male prawn was not introduced along with female. The prawns were fed adlibitum with frozen clam meat. The feed was given in two ration, one in the morning and other in the evening. After siphoning out the faecal matter and the leftover food every morning, one-third of the water was replenished with freshly prepared experimental media. The maturation experiments were always carried out in duplicate and some times greater number of replicates were also maintained. The tubs were covered with corrugated paper sheets to reduce the light intensity. Continuous, round the clock aeration was provided and the pH of the experimental media was maintained above 8.0 using Sodium carbonate.

Any prawn showing signs of maturation was left alone in the tub and care was taken not to disturb it much. A continuous vigil was kept on the prawn from the time it attained stage III of maturation and every two hours the prawn was observed under diffused torch light for spawning. Once the prawn attained stage III of maturation, EDTA was added at 0.1g per 100 litres of water. The time taken for initiation of maturation, attainment of successive stages of maturation and spawning was noted. The spent female was transferred to another tub containing the same salinity medium immediately after

spawning. The total number of eggs released by the prawn was estimated based on average number of eggs of three 100 ml samples taken from the spawning tank after thoroughly mixing the water for even distribution of eggs. The estimation was made using the following equation.

$$\text{Average No. of eggs in the samples} \times \frac{\text{Volume of water in the tank (L)}}{0.1}$$

Prawns which failed to mature were reared until they moulted and subsequently discontinued. The spent females of successful experiments were used for rematuration or for estimation of biochemical components. The rematuration experiments were conducted in the same way as the maturation experiments, including monitoring of the water quality parameters.

Experiments on egg hatching, early larval development and their survival were conducted at 15, 16, 18, 20, 22, 24, 26, 28 and 30 ppt salinities, in 2-litre glass beakers, providing continuous aeration. Care was taken to maintain the salinity at desired level by adding required quantity of fresh water every day morning after determining the salinity level. The water temperature oxygen, pH, ammonia and nitrite were also recorded.

The analytical procedures followed for the estimation of salinity, oxygen, pH, ammonia, nitrate nitrite, phosphate and silicate are described below.

Salinity

The salinity of water samples was determined by Mohr's titration method (Strickland and Parsons, 1968). The water sample was collected atleast 5 cm below the surface. In order to standardise the silver nitrate, 10 ml of standard seawater was titrated against silver nitrate solution using potassium chromate as indicator. The standard seawater was obtained from Oceanography Institute, Copenhagen. A 10 ml of water sample was titrated against standard silver nitrate. Each sample was titrated twice and the salinity calculated from average titre value as below:

$$\text{Salinity (ppt)} = \frac{V_2 \times S}{V_1}$$

where V_1 = Volume of silver nitrate used for 10 ml of standard seawater.

V_2 = Volume of silver nitrate used for 10 ml of sample

S = 34.99, salinity of standard sea water

Oxygen

Modified Winkler's method was used for estimation of dissolved oxygen. The water samples collected in 125 ml corning bottle with BOD stopper, without bubbling of air while filling, was fixed using 1 ml of Manganous sulphate and 1 ml of alkali-iodine-azide solution. The stopper was carefully replaced without trapping air and the precipitate formed was dispersed uniformly by shaking. The precipitate was dissolved in the laboratory using 1 ml of concentrated sulphuric acid. The

solution was titrated against Sodium thiosulphate solution using starch as indicator. Sodium thiosulphate was standardised during every set of titration using Potassium dichromate of 0.025 N. The dissolved oxygen concentration was calculated as below.

$$D.O\ (mg/lit) = \frac{\text{Vol. of thiosulphate} \times N \times 8000}{S}$$

where N = Normality of thiosulphate, S = Volume in ml of sample

pH

The pH of water samples was measured using a digital pH meter. Every time before reading the pH of the sample, the pH meter was calibrated using buffers of 4.00, 7.00 and 9.20 pH. Then the pH of the water sample was read at room temperature.

Ammonia

Ammonia-nitrogen was estimated by the phenol-hypochlorite method of Solorzano (1969). To 50 ml of water sample and the same volume of blank, 2 ml of phenol solution, 2 ml of nitroprusside and 5 ml of oxidising agent (alkaline sodium citrate and sodium hypochlorite mixed in 10:2.5 ratio) were added with thorough mixing each time. After one hour, the absorbance was read at 640 nm using 10 cm cell. The stock solution (0.1 g Ammonium sulphate in 1000 ml deionised water, 1 ml = 1.5 μ g at/l) was diluted to get working standards and the colour developed was read at 640 nm. The absorbance of the sample was compared and ammonia level calculated from the calibrated graph.

Nitrate-nitrogen

Nitrate-nitrogen was estimated using cadmium reduction column as per Solyom and Carlberg (1975). 75 ml of sample was run through amalgomated cadmium column. First 10 ml of the sample flowing through the column was discarded and the next 10 ml was used to wash the flasks. To the 50 ml of sample collected in 2 flasks of 25 ml each, and to the blank sample, 0.5 ml of sulphanilamide reagent (8 gms in a mixture of 80 ml concentrated hydrochloric acid and 420 ml distilled water) was added. After 3 minutes and not later than 8 minutes 0.5 ml of N-1 napthyl ethylene diamine dihydrochloride (0.8 gm in 500 ml of distilled water) was added to the sample. The absorbance was measured against the blank at 545 nm and the amount of nitrate estimated in µg at/l.

Nitrite-nitrogen

Nitrite-nitrogen was determined by the Azo dye method. The procedure followed for nitrate nitrogen after reducing the sample through an amalgamated Cadmium reduction column, the earlier procedure described for nitrate was adopted. The quantity of nitrite was expressed in µg at/l.

Phosphate

The reactive phosphorous was estimated using the method of Murphy and Riley (1962) as described by Strickland and Parsons (1968). To 100ml of the sample (collected in a polythene bottle and a distilled water blank, 10 ml of mixed reagent (Ammonium molybdate + Sulphuric acid + Ascorbic acid +

Potassium antimony tartarate in distilled water) was added, After about 5 minutes and with in 2-3 hours the extinction was measured at 885 nm.

The stock phosphate solution (0.816 gms of anhydrous potassium dihydrogenphosphate in 1000 ml of distilled water, 1ml = 6 µg.at of phosphate-phosphorous) was diluted to get working standards and the colour developed. The concentration of the sample expressed in µg at/l was calculated from the standard curve.

Silicate

Silicate of water samples was determined using the method of Chow and Robinson as reported by Strickland and Parsons (1968). To 25 ml of the sample and a distilled water blank, 10 ml of acid molybdate solution was added and mixed thoroughly and allowed to stand for 10 minutes. Then 15 ml of reducing agent (Metol sulphate + oxalic acid + conc. sulphuric acid + distilled water) was added so as to make the total volume to 50 ml with immediate mixing. The flask was allowed to stand for 2-3 hours. The extinction was measured against the distilled water blank at 810 nm. The concentration of silicate in the sample was determined from the standard graph prepared using stock silicate solution (0.96 g of sodium silcofluoride dissolved in 50-100 ml of distilled water and made up to 1000 ml) and expressed as µg at/l.

Soil: Organic carbon

Organic carbon was estimated by adopting the method of Walkley and Black (1934). The sediment sample was dried, powdered and passed through 0.2 mm non-ferrous seive. To a carefully weighed amount of this sample (containing 10-25 mg carbon) 10 ml of Potassium dichromate solution was added and mixed. Then 20 ml of concentrated Sulphuric acid was added and mixed by gently rotating the flask and allowed to react for 20-30 minutes. The sample was diluted to 200 ml with distilled water and 10 ml of concentrated phosphoric acid was added. The sample was back titrated using 0.4 N ferrous ammonium sulphate solution to a brilliant green end point and percentage of carbon calculated using the formula.

$$\% C = \frac{3.951}{g}\left(1 - \frac{T}{S}\right) \quad \text{where}$$

g = sample weight in g.

S = ml ferrous solution for blank titration

T = ml ferrous solution for sample titration

CHAPTER III. ECOLOGICAL CHARACTERISTICS OF THE STUDY AREA

The abiotic environmental factors such as temperature, salinity, pH, oxygen, ammonia, nitrite and the nutrient parameter such as nitrate, phosphate and silicate are known to influence the survival, growth and reproduction of animals inhabiting the aquatic environment. In brackishwater culture systems, which are highly dynamic in comparison to the marine environment, the physico-chemical conditions are governed by the tidal flow, rainfall and the mixing of freshwater from the river systems. Among the biotic factors, the plankters are the main indicators of biological productivity of this environment. Keeping this in view, regular monitoring has also been undertaken on the ecological parameters of the perennial prawn culture fields - Kannuvilakettu and Thoppilkettu, in order to understand the extent of their influence on growth and maturation of M.dobsoni. Fortnightly samples collected for a period of 20 months from January 1990 to August 1991 from Kannuvilakettu and 11 months from August 1990 to June 1991 from Thoppilkettu were analysed for temperature, salinity, pH and oxygen. Parameters such as ammonia, nitrite, nitrate, phosphate and silicate were monitored for a period of 8 months from January - August 1991 for Kannuvilakettu and 7 months from January to July 1991 for Thoppilkettu. Quantitative and qualitative data on zooplankton were also collected for both the systems. As the main objective of zooplankton analysis was to find out the presence of egg and larval stages of M. dobsoni,

which normally require comparatively higher salinity condition (Silas et al., 1982), regular plankton collection were made for 7 months between January and July 1991 from Kannuvilakettu and six months between January and June from Thoppilkettu during which period the highest salinity conditions prevailed in these ecosystems.

Similar observations on the various ecological parameters were also made from the coconut grove canal system during the period of experimental prawn culture for ten fortnights between January and June 1991. In addition to the aforesaid parameters, organic carbon and organic matter content of soil were also recorded.

Perennial prawn culture fields

The monthly mean values of various ecological parameters for Kannuvilakettu and Thoppilkettu are given in Tables 1,2,3 and 4.

Temperature: The monthly mean temperature of Kannuvilakettu varied between 26.33°C in January 1990 and 33.10°C in May 1991. In both the years of study, comparatively higher temperature. (29.00-33.10 °C) prevailed during the warmer months of March to May. With the onset of monsoon, the temperature gradually declined and remained at lower levels throughout the monsoon and postmonsoon months (26.30-29.25 °C). In Thoppilkettu, the monthly mean temperature values ranged from 28.25°C in January 1991 to 33.00°C in May 1991. Here also the summer months of March to May recorded the maximum values (31.00-33.00 °C). In

TABLE 1: Monthly mean values of environmental parameters (temperature, salinity, oxygen and pH) of Kannuvilakettu prawn culture system.

Months	Temperature (°C)	Salinity (‰)	Oxygen (mg/l)	pH
Jan 1990	26.33	15.30	5.83	7.60
Feb	28.75	16.27	5.40	8.00
Mar	29.00	19.17	5.20	7.97
Apr	30.50	22.60	4.60	7.80
May	32.50	17.93	4.64	7.86
Jun	27.25	12.69	4.65	7.35
Jul	28.25	4.82	3.84	7.43
Aug	28.00	3.61	5.85	7.80
Sep	28.50	4.80	4.00	7.80
Oct	29.00	4.35	7.55	7.85
Nov	29.25	4.93	4.40	7.95
Dec	29.25	10.86	5.38	8.03
Jan 1991	28.50	15.10	6.23	7.55
Feb	28.50	16.33	6.97	7.73
Mar	31.00	17.64	6.19	7.41
Apr	32.75	18.45	5.23	7.99
May	33.10	19.26	5.15	8.08
Jun	28.10	10.61	3.78	8.19
Jul	26.90	3.92	4.44	8.07
Aug	26.30	2.45	6.12	8.04

TABLE 2: Monthly mean values of environmental parameters (Temperature, salinity, oxygen and pH) of Thoppilkettu prawn culture system.

Months	Temperature (°C)	Salinity (‰)	Oxygen (mg/l)	pH
Aug 1990	28.40	3.64	5.10	7.35
Sept	29.00	5.30	5.60	7.80
Oct	29.50	4.40	4.47	7.60
Nov	29.25	4.93	4.40	7.45
Dec	30.55	11.41	9.49	7.85
Jan 1991	28.25	15.61	3.78	7.99
Feb	28.50	16.27	5.81	7.78
Mar	31.00	17.75	6.58	7.25
Apr	32.75	18.68	6.32	7.94
May	33.00	19.01	5.91	8.06
Jun	28.50	11.50	4.68	7.86

September 1990 also a fairly high temperature (30.55 °C) prevailed. The temperature declined considerably (28.5 °C) in June, the beginning of southwest monsoon.

Salinity: The salinity showed wide fluctuations in both the systems. In Kannuvilakettu, it ranged from 2.45 ppt in August to 22.60 ppt in April. The salinity showed a steady declining trend with the commencement of monsoon and the consequent freshwater influx in June (10.61-12.69 ppt). The period July-November recorded extremely low values of salinity (2.45-4.93 ppt) due to the constant dilution of the backwater system. The salinity steadily increased from December onwards and stood at comparatively high level during the summer months of March to May (17.65-22.60 ppt). Thoppilkettu also showed more or less a similar trend, with salinity values fluctuating between 3.64 ppt in August and 19.01 in May.

Oxygen: The dissolved oxygen content of water remained above 3.0 mg/l in both the systems. The highest value recorded was 7.55 mg/l in Kannuvilakettu and 9.49 mg/l for Thoppilkettu. In most of the months the values ranged between 5.0 end 6.0 mg/l.

pH: The pH of water ranged from 7.35 to 8.19 in Kannuvilakettu and 7.25 to 8.06 in Thoppilkettu, thereby showing minor variations during different months. Relatively higher pH values were recorded during December 1990 (8.03) and May-August 1991 (8.04-8.19) in Kannuvilakettu. In Thoppilkettu, pH values as high as 8.06 was recorded only during May 1991.

Ammonia: The ammonia content of water fluctuated widely during the different months of observations, mean values ranging from 3.30 to 24.50 µg at/l in Kannuvilakettu. Remarkably higher values were recorded in March (24.50 µg at/l) and July (17.30 µg at/l) in this system. The range of ammonia content in Thoppilkettu was 2.00 to 9.10 µg at/l. Very low values (2.00-3.60 µg at/l) were recorded during April-May.

Nitrite: The monthly mean values of nitrite fluctuated narrowly between different months and ranged from 0.95 to 2.58 µg at/l in Kannuvilakettu and 1.20 to 4.50 µg at/l in Thoppilkettu.

Nitrate: The nitrate content of the water varied from 7.0 to 15.50 µg at/l in Kannuvilakettu and 2.30 to 17.15 µg at/l in Thoppilkettu. In both the systems the minimum values were recorded in April.

Phosphate: The phosphate content ranged from 1.40 to 5.28 µg at/l in Kannuvilakettu and 1.05 to 5.13 µg at/l in Thoppilkettu. The maximum values in both the systems were recorded in June, coinciding with the onset of monsoon.

TABLE 3: Monthly mean values of environmental parameters (ammonia, nitrite, Nitrate, Phosphate and Silicate) of Kannuvilakettu prawn culture system (Values expressed in µg at/l)

Months	Ammonia	Nitrite	Nitrate	Phosphate	Silicate
Jan 1991	9.10 ±1.51	2.25 ±0.10	12.38 ±2.63	1.68 ±0.41	57.25 ±12.20
Feb	8.70 ±1.64	1.83 ±0.24	10.50 ±3.00	2.18 ±0.22	52.25 ±8.02
Mar	24.50 ±13.34	2.50 ±0.10	11.50 ±2.52	1.40 ±0.36	45.00 ±6.83
Apr	3.30 ±1.67	2.58 ±0.33	7.00 ±1.15	1.50 ±0.88	67.00 ±10.03
May	7.45 ±1.00	1.75 ±0.21	9.50 ±3.00	2.63 ±0.70	93.75 ±24.55
Jun	8.70 ±3.62	1.22 ±0.12	12.80 ±3.42	5.28 ±1.14	169.17 ±28.66
Jul	17.30 ±12.65	0.95 ±0.42	13.00 ±2.16	2.60 ±0.55	58.50 ±17.97
Aug	6.10 ±2.97	1.05 ±0.21	15.50 ±0.50	2.25 ±0.64	74.50 ±9.19

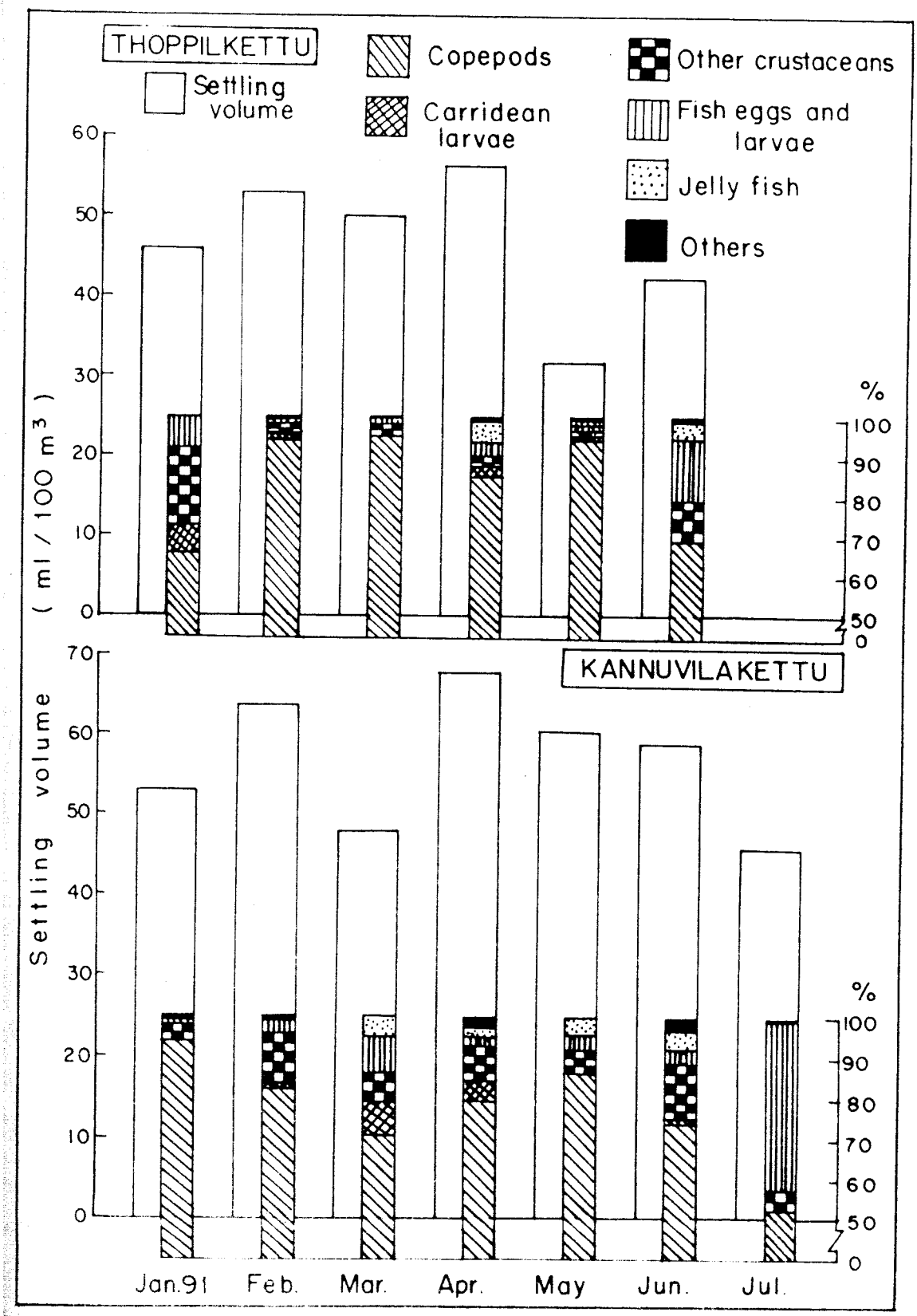
TABLE 4: Monthly mean values of water quality parameters (ammonia, nitrite, nitrate, phosphate and silicate) of Thoppilkettu prawn culture system (values expressed in µg at/l)

Months	Ammonia	Nitrite	Nitrate	Phosphate	Silicate
Jan 1991	9.10 ±1.51	4.50 ±3.00	10.80 ±10.16	1.05 ±0.11	41.25 ±14.82
Feb	8.55 ±0.02	1.65 ±0.57	5.15 ±2.45	1.60 ±0.22	62.75 ±4.11
Mar	8.00 ±6.99	1.20 ±0.32	7.90 ±3.06	1.23 ±0.26	51.00 ±10.13
Apr	2.00 ±0.13	2.45 ±0.10	2.30 ±1.76	1.33 ±0.56	57.75 ±10.21
May	3.65 ±3.12	1.20 ±0.92	5.35 ±1.08	1.93 ±0.33	55.75 ±12.28
Jun	7.35 ±0.98	4.20 ±2.10	17.15 ±11.39	5.13 ±1.15	151.00 ±9.20
Jul	6.80 ±0.10	1.80 ±0.10	5.50 ±1.84	2.00 ±0.99	115.00 ±9.90

Silicate: The silicate content ranged from 45.00 to 169.17 µg at/l in Kannuvilakettu and 41.25 to 151.00 µg at/l in Thoppilkettu, indicating relatively higher levels of silicate in the water throughout the study period. In this case also, the highest values were recorded in the month of June.

Zooplankton: The settling volume of zooplankton in Kannuvilakettu (Fig. 2) oscillated between 46.25 ml/100 m^3 in July and 68.10 ml/100 m^3 in April. The plankton biomass steadily increased in the initial two months and after a fall in March, reached the peak in April. In the subsequent month it gradually declined reaching the minimum in July. In all the months except in March and July, the settling volume recorded above 50 ml/100 m^3. In Thoppilkettu (Fig.2), the minimum and maximum values of settling volume were 31.85 ml/100 m^3 and 56.60 ml/100 m^3, which were attained in May and April respectively. There was an increasing trend during the initial four months in zooplankton production, while, the same was relatively less during the period May-June. When compared with Kannuvilaketu, the plankton production of this ystem was low and the values above 50 ml/100 m^3 were noticed only during two months (February and April).

Copepod constituted the major component of the zooplankton throughout the period of study in both the culture systems numerically. It formed 51.30 to 93.60 per cent in Kannuvilakettu and 66.20 per cent to 95.70 per cent in Thoppilkettu. Among the other groups represented in the zooplankton, fish eggs and larvae, carridean larvae, other



Monthly variation in settling volume and composition of zooplankton in perennial prawn culture systems.

crustaceans and jelly fish were recorded in varying proportions (Fig. 2).

Conconut grove canal system

Water and soil samples collected in triplicate from three different sampling points of the canal system (near the sluice gate, middle part and the northern end) were analysed in the laboratory. The water samples were analysed fortnightly for salinity, oxygen, pH, ammonia, nitrite, nitrate, phosphate and silicate (Table 5). While the soil samples were analysed for organic carbon (Fig. 3B). The water temperature was noted at the sampling site itself. The plankton samples collected in the morning hours were analysed qualitatively and quantitatively in the laboratory.

Temperature: The temperature of the canal system varied between 28 and 33^{o}C. The lowest value was recorded during the second fortnight (February) and ninth fortnight (May-June). The highest temperature was recorded during the seventh fortnight (April-May). However, during a greater part of the experimental period, the temperature ranged from 28 to 30^{o}C.

Salinity: The most widely fluctuating parameter was salinity. The salinity which was 14.52 ppt at the beginning of the experiment, gradually increased with time but for a marginal decline (16.52 ppt) in the sixth fortnight (April) and touched the maximum of 18.62 ppt in the eighth fortnight (May). Further, with the onset of monsoon in the first week of June, the salinity drastically decreased and reached 8.03 ppt in the

TABLE 5: Fortnightly mean values of environmental parametes of coconut grove canal system.

Months & fortnights.	Temperature °C	Salinity °/oo	Oxygen mg/l	pH
Jan -II	28.5 ±0.20	14.52 ±0.24	5.67 ±0.12	7.30 ±0.08
Feb-I	28.5 ±0.2	15.17 ±0.22	4.52 ±0.18	7.32 ±0.11
Feb-II	28.0 ±0.4	16.14 ±0.31	6.31 ±0.10	7.81 ±0.10
Mar-I	29.0 ±0.3	17.13 ±0.32	4.26 ±0.16	7.64 ±0.21
Mar-II	30.0 ±0.2	17.09 ±0.17	4.51 ±0.20	7.58 ±0.19
Apr-I	31.0 ±0.4	17.06 ±0.26	5.80 ±0.21	7.76 ±0.22
Apr-II	31.5 ±0.5	16.52 ±0.27	6.58 ±0.09	7.81 ±0.20
May-I	33.0 ±0.2	17.50 ±0.16	9.26 ±0.18	8.65 ±0.16
May-II	32.0 ±0.3	18.62 ±0.31	7.74 ±0.31	8.01 ±0.11
Jun-I	28.0 ±0.5	8.03 ±0.21	4.77 ±0.42	7.91 ±0.31
Jun-II	29.5 ±0.2	2.87 ±0.26	5.42 ±0.36	7.27 ±0.26

able 5: Contd.

onths & ortnights	Concentration (ug at/l) of Ammonia	Nitrite	Nitrate	Phosphate	Silicate
an - II	10.86 ± 1.22	3.73 ± 0.61	13.60 ± 2.47	3.10 ± 0.58	52.00 ± 9.54
eb - I	17.60 ± 10.12	3.13 ± 0.31	59.47 ± 9.07	4.30 ± 1.31	40.60 ± 4.04
eb - II	15.20 ± 4.69	2.73 ± 1.03	23.20 ± 6.59	2.52 ± 0.53	31.67 ± 3.21
ar - I	19.20 ± 10.74	2.93 ± 1.04	42.26 ± 13.14	2.22 ± 0.42	28.66 ± 8.62
ar - II	12.40 ± 10.58	1.00 ± 0.20	8.13 ± 0.81	1.84 ± 0.11	26.00 ± 9.17
pr - I	9.53 ± 6.65	1.07 ± 0.12	9.07 ± 1.86	2.15 ± 0.16	34.33 ±10.97
pr - II	3.67 ± 1.14	0.53 ± 0.23	4.27 ± 0.90	2.05 ± 0.14	41.00 ±13.75
ay - I	1.80 ± 0.12	2.60 ± 0.92	26.00 ± 5.29	2.01 ± 0.33	28.67 ± 8.02
ay - II	1.53 ± 1.03	0.67 ± 0.23	7.13 ± 3.64	2.23 ± 0.91	32.00 ± 4.58
un - I	27.93 ± 2.30	2.60 ± 0.20	6.87 ± 2.34	3.40 ± 1.19	131.67 ±12.90
un - II	2.53 ± 2.08	2.53 ± 2.08	25.47 ± 4.99	3.28 ± 0.40	137.33 ±27.68

ninth fortnight. The salinity continued to decline and touched the minimum of 2.87 ppt in the tenth fortnight (June).

Oxygen: The mean oxygen values of the canal system varied between 4.26 and 9.26 mg/l. Higher oxygen levels (7.74-9.26 mg/l) were noticed during the seventh and eighth fortnights and in the rest of the period the values remained at 4.26 to 6.58 mg/l.

pH: The mean pH values ranged from 7.27 in the tenth fortnight (June) to 8.65 in the eighth fortnight (May). On most occasions, it ranged between 7.27 and 8.00 indicating a slight alkaline nature of the culture medium.

Ammonia: The mean values of ammonia widely fluctuated between 1.53 and 27.93 µg at/l. The ammonia levels remained high (9.53-19.20 µg at/l) during the first five fortnights (January-April) while during the rest of the period they remained relatiely low (1.53-3.67 µg at/l).

Nitrite: Nitrite values showed very little variation throughout the experimental period and ranged from 0.53 to 3.73 µg at/l.

Nitrate: The nitrate values were relatively high (13.60-59.47 µg at/l) during the first three fortnights (January-March), eighth fortnight (May) and tenth fortnight (June). Comparatively lower concentrations of nitrate (4.27-9.07 µg at/l) were recorded during rest of the period.

Phosphate: As compared to nitrate, the mean concentration of phosphate was quite low and it varied between 1.84 µg at/l in the fourth fortnight (March) and 4.30 µg at/l in the first fortnight (January-February). During the rest of the period, the phosphate concentration varied between 2.00 and 3.40 µg at/l, indicating an almost stable nutrient level.

Silicate: Moderately high to very high concentration of silicate was noticed during the culture period. High values of silicate were recorded during the first eight fortnights (January-may) and the silicate concentration was very high (131.67-137.33 µg at/l) in the ninth and tenth fortnight (May-June) due to land drainage with the onset of monsoon.

Organic carbon and organic matter of soil:

The percentage of organic carbon (Fig. 3B) showed very little variation during the experimental period. It ranged from 1.10 to 3.51 per cent. The percentage of organic carbon was less than 1.5 per cent at the beginning (January) and during the last three fortnights (May -June). During the rest of the period, the organic carbon varied between 2.22 to 3.51 per cent. The percentage of organic matter which is a derivative of organic carbon showed a similar trend as that of organic carbon and varied between 1.86 and 5.95 per cent.

Zooplankton: The settling volume of zooplankton (Fig. 3A) showed significant variation from 42.4 to 212.2 ml/100 m^3. Fluctuating between 49.5 and 70.7 ml/100 m^3 during the first five fortnights (January-April), the zooplankton volume showed a rapid increase to reach the maximum in the ninth and tenth

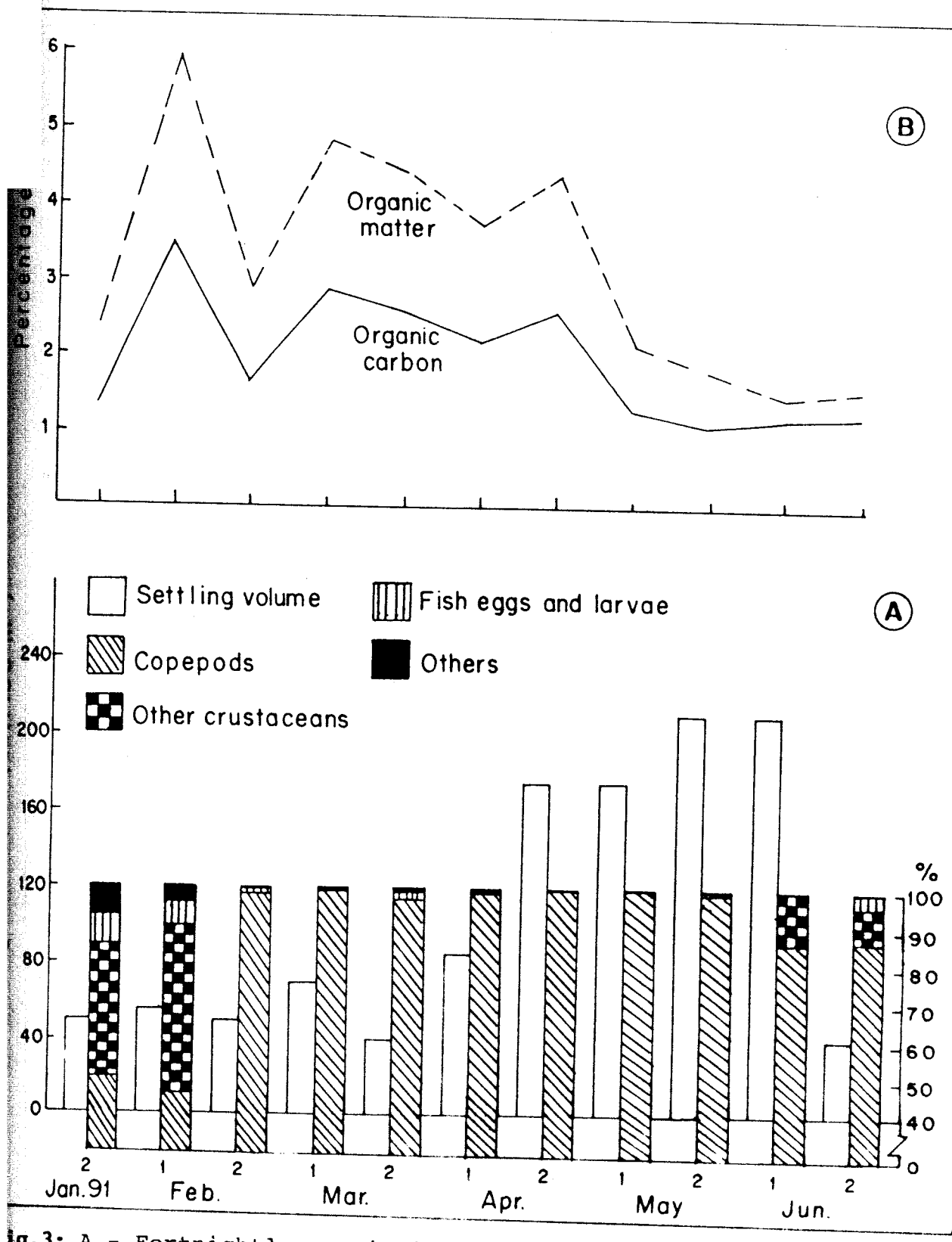


Fig.3: A - Fortnightly variation in settling volume and composition of zooplankton in coconut grove canal system.

B - Fortnightly variations in organic carbon and organic matter content of the bottom soil of coconut grove canal system.

fortnight. Observations on the numerical abundance of zooplankton (Fig. 3A) indicated that copepods dominated throughout the period of experiment, as in the perennial prawn culture systems, and varied from 46.0 to 99.9 per cent. Copepods were of relatively lower magnitude (46.0-49.6 %) during the first two fortnights (January-February) and during the rest of the period they accounted for 86.4 to 99.9 per cent of the total zooplankton. The other important groups represented were fish eggs and larvae, carridean larvae, other crustaceans and jelly fish.

CHAPTER - IV GROWTH

In the culture of penaeid prawns many criteria are considered to qualify a species to be suitable for culture. Among the biological factors that make the prawn suitable for culture, growth is the most important one. The rate of growth as well as the marketable size an animal attains in captivity in the shortest period of time are essential pre-requisites for adopting the species for commercial culture. Though M. dobsoni has been supporting a lucrative capture fishery as well as traditional culture fishery in Kerala, a lot of uncertainities prevail regarding its growth potential in brackishwater systems. In the present study, an attempt has been made to probe into this aspect by carrying out systematic field and laboratory investigations under brackishwater conditions and the results obtained are described in this chapter. The field studies have been undertaken from the two selected perennial prawn culture systems, namely, Kannuvilakettu and Thoppilkettu, through regular monitoring of the culture fishery and by conducting a short-term field culture experiment in the neighbouring coconut grove canal system. Details of the food utilization, moulting phenomenon and body growth have been studied through a series of laboratory experiments in order to supplement the field results.

FIELD STUDIES

Growth in perennial prawn culture fields

Using the fortnightly length measurement data collected for over 20 months from Kannuvilakettu and 10 months

from Thoppilkettu as input, the growth rates were estimated. A total of 12,570 prawns were measured for this purpose from Kannuvilakettu and 4302 from Thoppilkettu. From the fortnightly/monthly size frequencies and the estimated mean sizes, the growth pattern was studied sex-wise.

Size distribution:

At Kannuvilakettu, the prawns had a size range of 23 to 80 mm in males and 20 to 98 mm in females. In males, the bulk of the populaton was composed of 51 to 65 mm size group and the prawns smaller than this size occurred in very low numbers almost throughout the period of study. During the year 1990, the general size of males was smaller in most of the months as compared to 1991. The female prawns were mainly represented by 51 to 75 mm size group. The smaller females of less than 50 mm were recorded almost throughout the year, but in very low proportion. During the entire period of the year 1990, except in July, and from January to March 1991, the proportion of larger females above 75 mm size remained generally low. However, it increased in proportion considerably in July 1990 and from April to August 1991.

In Thoppilkettu, the size of prawn ranged from 43 to 89 mm in males and 37 to 105 mm in females. The males were mainly represented by the size group 51 to 65 mm. Individuals below 50 mm size, were recorded in very low magnitude during the period from December 1990 to May 1991. Prawns above 65 mm size were recorded in fairly good numbers almost throughout the

period of study. Majority of the females belonged to 61 to 65 mm size group. Smaller prawns measuring less than 60 mm size formed considerable proportion of the catch between December 1990 and May 1991, while between August and November 1990 they were of a lesser proportion.

Mean sizes

The monthly mean sizes of M.dobsoni in Kannuvilakettu varied from 49.6 to 68.3 mm for males and 51.5 to 76.2 mm for females (Table 6). During 1990, the mean size of male remained more or less steady between 51.3 and 54.0 mm during the period January to June. The maximum of 68.1 mm was recorded in the month of July and the mean size suddenly dropped to 49.6 mm in the following month (August), indicating active recruitment of the juveniles into the culture system. Until March 1991, the mean sizes were moderate, ranging from 51 to 57 mm. Relatively higher values of mean size (61 to 67mm) were recorded during the period April to August 1991. In the case of females also, more or less the same trend of mean size distribution was observed with comparatively higher values than in males as is the normal case. The maximum sizes of the prawn for both the years was observed in the month of July; the values recorded being 74.2 mm in 1990 and 76.2 mm in 1991. The distribution of monthly mean sizes does not indicate any definite trend due to the continuous recruitment of the prawns into the system brought about by the regular letting-in process.

TABLE 6: Monthly mean sizes (mm) of M. dobsoni in Kannuvilakettu prawn culture system.

Months	Males	Females
Jan 1990	52.71	55.12
Feb	51.32	52.97
Mar	52.85	54.74
Apr	53.11	54.27
May	53.72	53.85
Jun	53.99	58.83
Jul	68.12	74.15
Aug	49.58	52.66
Sep	55.54	63.71
Oct	56.79	67.63
Nov	NA*	NA
Dec	55.20	58.29
Jan 1991	52.35	54.68
Feb	50.61	51.45
Mar	56.04	58.79
Apr	63.43	73.27
May	61.15	64.00
Jun	65.65	70.07
Jul	67.33	76.23
Aug	60.57	68.60

NA* = Sample not available

TABLE 7: Monthly mean size (mm) of M. dobsoni in Thoppilkettu prawn culture system.

Months	Males	Females
Aug 1990	76.32	87.85
Sep	75.66	85.71
Oct	66.76	73.23
Nov	64.90	74.51
Dec	54.26	56.61
Jan 1991	59.05	65.40
Feb	57.29	60.62
Mar	59.79	61.55
Apr	61.33	66.06
May	61.04	63.59

In Thoppilkettu (Table 7), the monthly mean sizes ranged from 54.3 to 76.3 mm in males and 60.6 to 87.9 mm in females. In August 1990, the mean size of male was 76.3 mm, which in the subsequent month, gradually reduced reaching the minimum value of 54.3 mm in December 1990. In the subsequent period, the mean sizes oscillated between 59.1 and 61.3 mm until May 1991. In the case of females till December 1990 with the maximum value of 87.9 mm in August 1990 more or less, the same trend was maintained. In January 1991, the mean size increased to 65.4 mm, which after a slight reduction in the following month, gradually increased to 66.1 mm by April and declined again in the following month as in the case of males.

Estimation of Growth

The size frequency distribution of fortnightly prawn samples collected from Kannuvilakettu were combined and converted into monthly size frequency distributions using a suitable computer programme and the same plotted separately sex-wise for the year 1990 and 1991 (Fig. 4 and 5). The modal progression was traced using ELEFAN computer programme devised based on von Bertalanffy's growth equation. From this, monthly growth rates of both males and females were computed (Tables 8 and 9). As Thoppilkettu was observed only for 10 months spread over two calander years (August 1990 to May 1991) the growth rates have been estimated for the entire period of study without splitting year-wise (Fig. 6 and Table 10).

Growth in Kannuvilakettu

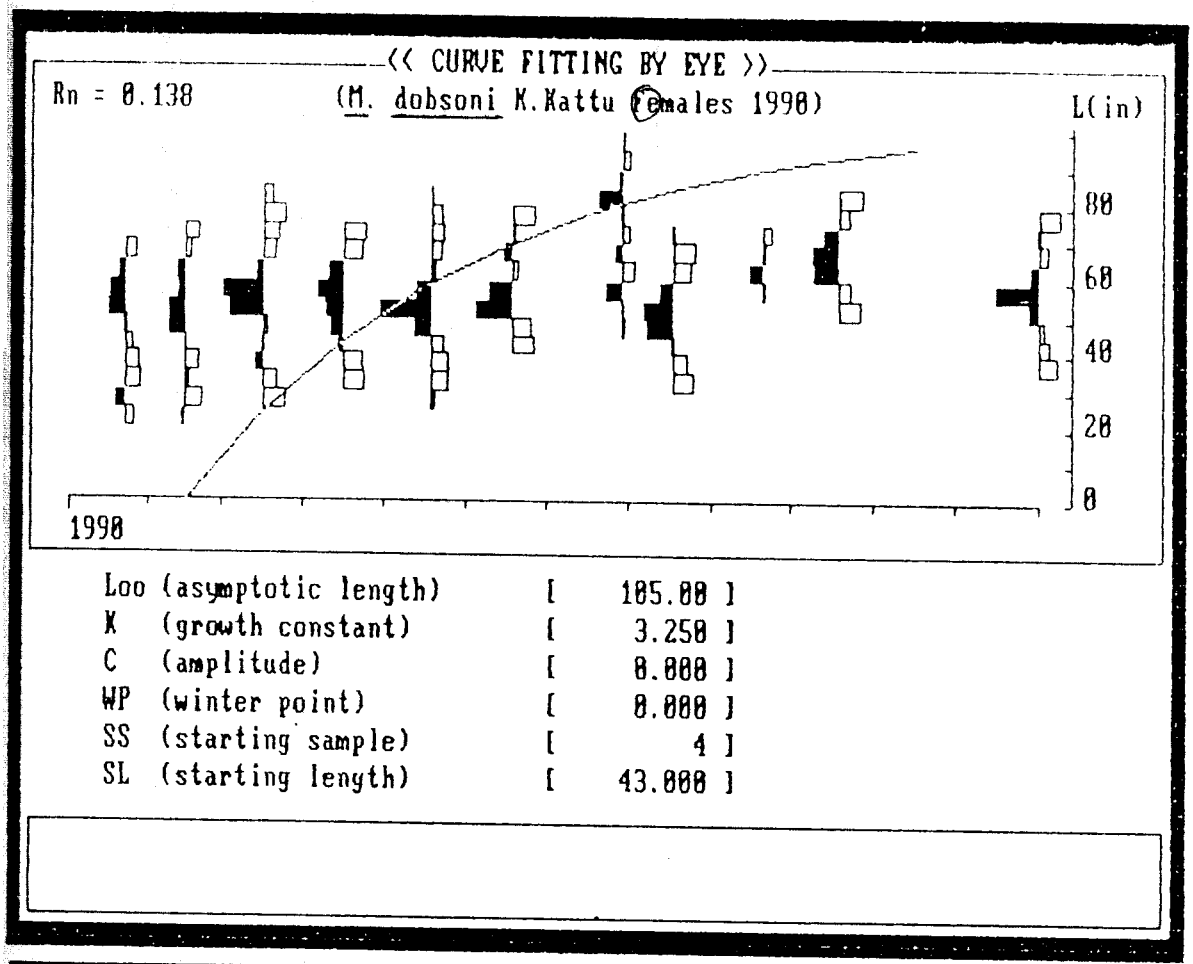
Males

During the year 1990 (Fig. 4A) prawns of an estimated size of 21.8 mm were recruited into the fishery and they grew to 76.5 mm size in 10 months, attaining a total growth of 54.7 mm. In the first two months, the estimated growth rate was above 10mm/month. This steadily decreased in the subsequent months, registering growth rates ranging from 6.4 to 8.1 mm, 3.8 to 4.8 mm, 2.2 to 3.0 mm and 1.3 to 1.8 mm during every two months of the succeeding period. During the year 1991 (Fig. 4B), the juvenile males got recruited into the culture field at an estimated size of 29.8 mm in February 1991, which attained a size of 80.3 mm by September 1991. The prawn gained a total growth of 50.5 mm in 7 months period, thereby showing a faster growth as compared to the growth recorded in the previous year. The growth rate was above 10 mm/month in the first two months and the same decreased at a lower rate than in 1990.

Since the estimated initial modal sizes for the two years were significantly different, the average modal size and monthly growth rates were estimated after computing the comparable sizes aginst age for the year 1991, assuming the age difference at recruitment as 15 days. The results (Table 8) indicated that the juveniles which got recruited at an average size of 22 mm in February '90, required 10 months period to attain the maximum of 76.49 mm size. As the growth estimates for 1990-91 were restricted to 7 months only, from February to September, the values for the remaining three months do not

TABLE 8: Estimated monthly growth rate of M. dobsoni males in Kannuvilakettu prawn culture system based on length frequency studies using ELEFAN

Months	1990		1991		Average	
	Modal size (mm)	Monthly growth rate (mm)	Modal size (mm)	Monthly growth rate (mm)	Modal size (mm)	Monthly growth rate(mm)
Feb	21.76	--	29.76	--	22.61	--
Mar	34.30	12.54	42.35	12.59	34.78	12.17
Apr	45.11	10.81	53.90	10.95	45.00	10.22
May	53.18	8.07	61.54	8.24	52.75	7.75
Jun	59.62	6.44	68.16	6.62	58.87	6.12
Jul	64.43	4.81	73.16	5.00	63.53	4.66
Aug	68.27	3.84	77.17	4.01	67.23	3.70
Sep	71.22	2.95	80.28	3.11	71.22	3.99
Oct	73.42	2.22	-	-	73.42	2.20
Nov	75.17	1.75	-	-	75.17	1.75
Dec	76.49	1.32	-	-	76.49	1.32



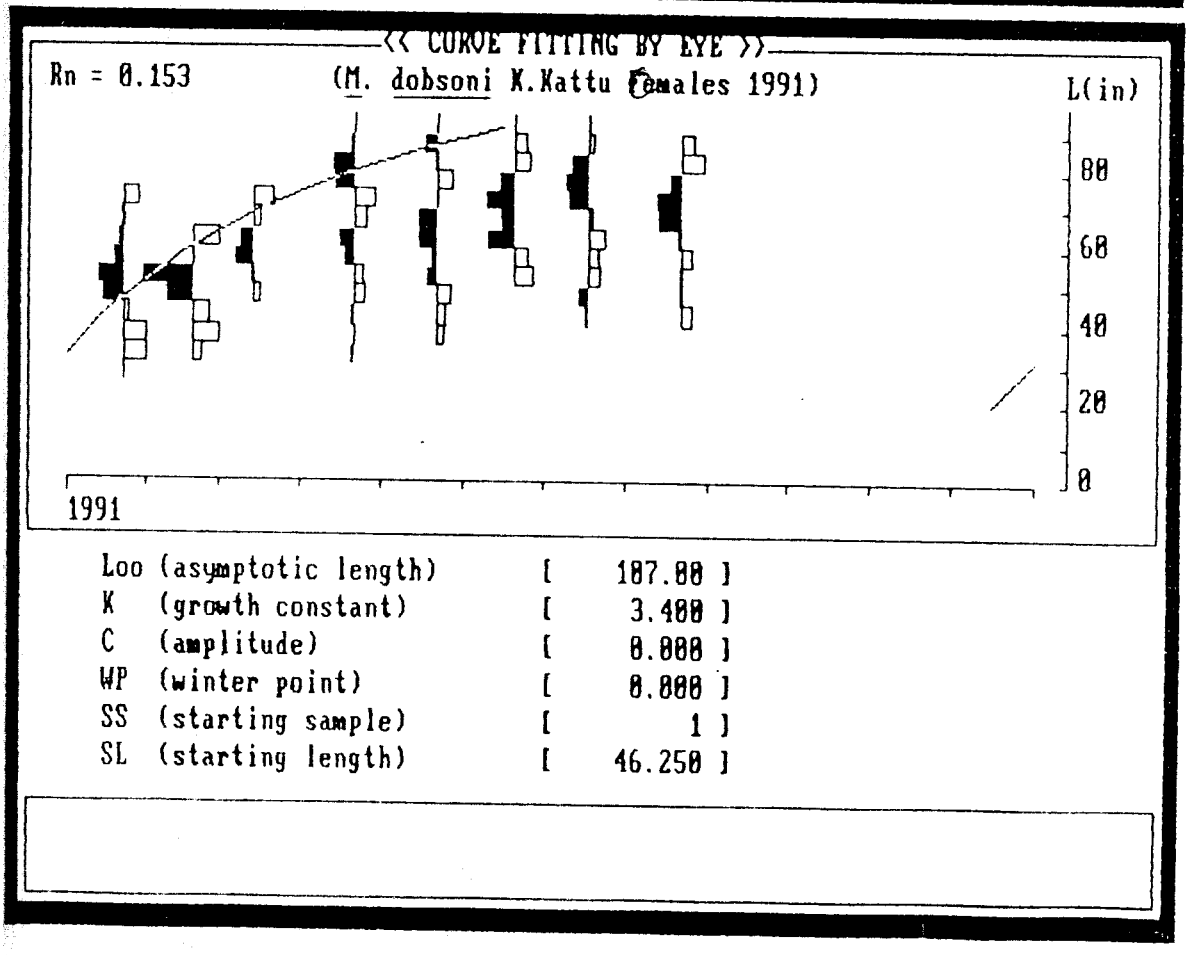


Fig.4: Growth curve of M. dobsoni males in Kannuvilakettu.

A - For the year 1990; B- For the year 1991.

represent the average for the two years. The average growth rates thus arrived at, appear to be in close confirmity with the growth rates estimated for the year 1990.

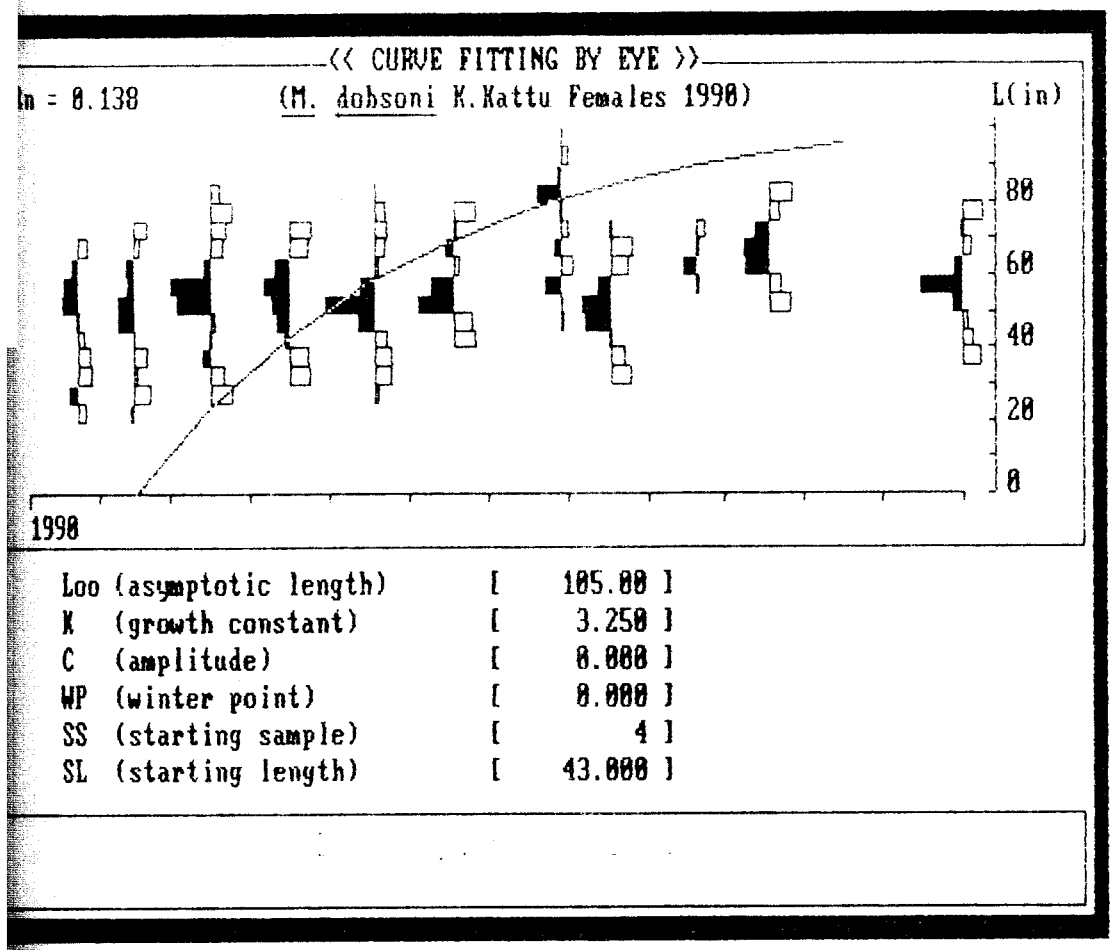
Females

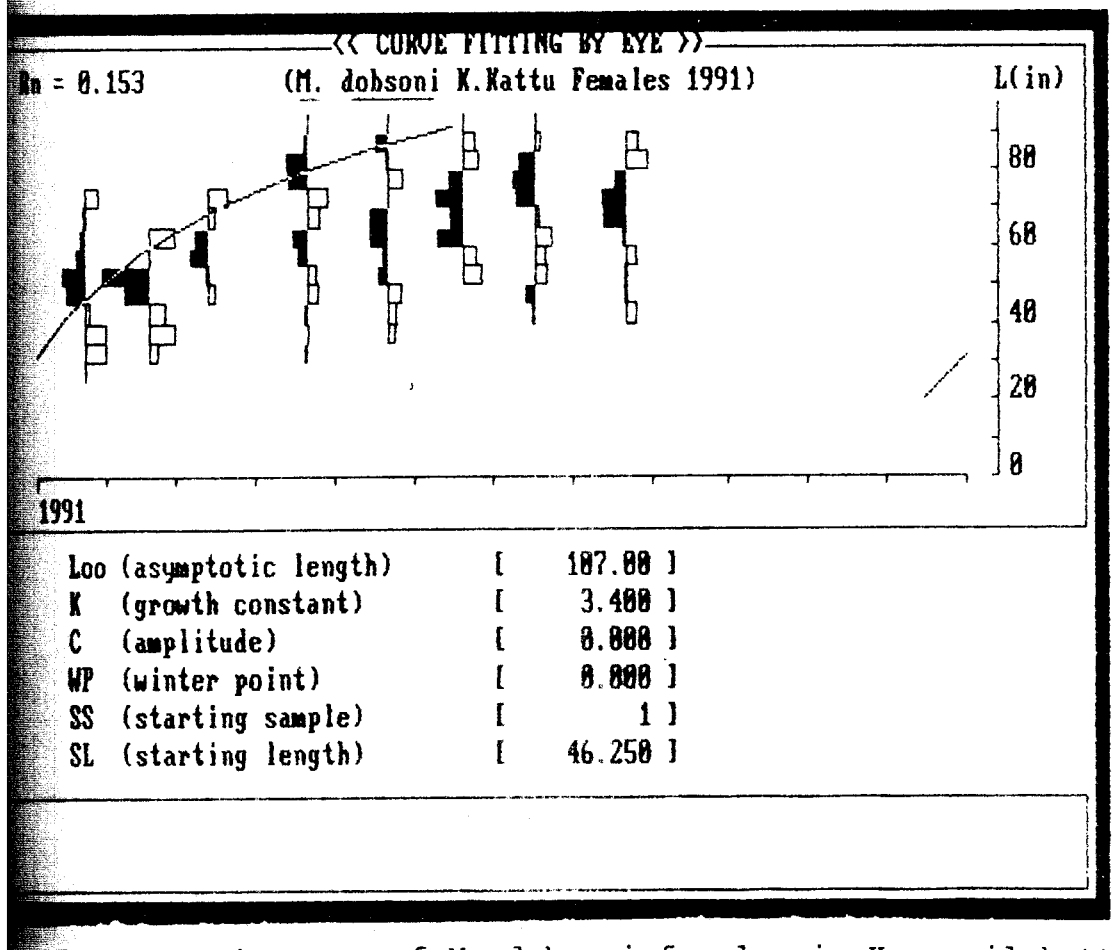
During the year 1990 (Fig. 5 A) the female prawns got recruited into the culture system at an estimated size of 23.3 mm in March '90, and they attained the maximum size of 95.8 mm in 8 months period. During the first month, a relatively high growth rate of 19.7 mm was recorded which got reduced to 14.5 mm and 11.5 mm during the second and third months, respectively. From the fourth month (July) onwards, a significant reduction in growth rate was noticed. The lowest growth rate of 2.9 mm/month was recorded in the eighth month (November) when the prawn attained the maximum estimated size of 95.8 mm.

With an estimated size of 20.5 mm, the juveniles got recruited into the system in December '90 (Fig 5 B) and grew at a much faster rate during the subsequent 6 months. The prawn attained the maximum estimated size of 91.1 mm in a period of 6 months. The growth rate was comparately faster than during the preceeding year. It is also noteworthy that during the first month of this period, the growth rate recorded was as high as 22.2 mm/month. In the next two months, the growth rate stood above 10 mm/month and subsequently showed a decline to reach the minimum of 5.3 mm/month in the sixth month (September '91), when the prawn attained the maximum size of 91.1 mm.

TABLE 9: Estimated monthly growth rate of *M. dobsoni* females in Kannuvilakettu prawn culture system based on length frequency studies using ELEFAN

	1990		1991			Average	
Months	Modal size (mm)	Monthly growth rate (mm)	Months	Modal size (mm)	Monthly growth rate (mm)	Modal size (mm)	Monthly growth rate(mm)
Mar	23.30	-	Dec 90	20.45	--	21.88	--
Apr	43.00	19.70	Jan 91	42.65	22.20	42.83	20.95
May	57.54	14.54	Feb	58.43	15.78	57.99	15.16
Jun	68.99	11.45	Mar	69.58	11.15	69.29	11.30
Jul	77.43	8.44	Apr	78.97	9.39	78.20	8.91
Aug	84.08	6.65	May	85.80	6.83	84.94	6.74
Sep	89.13	5.05	Jun	91.12	5.32	90.13	5.19
Oct	92.85	3.72	-	-	-	92.85	2.72
Nov	95.78	2.93	-	-	-	95.78	2.93





g.5: Growth curve of M. dobsoni females in Kannuvilakettu.
A - For the year 1990; B - For the year 1991.

Since there was little variation, in the initial modal sizes between the two years of observation, the mean value of the two corresponding modal sizes was calculated and used for tracing the average monthly growth rates (Table 9). It is apparent from the above analysis that when the prawn gets recruited at a size of 21.9 mm, it takes 8 months to reach the size of 95.8 mm, showing growth rates of 21.00 mm, 15.2 mm, 11.3 mm in the first, second and third months respectively and thereafter much lower growth rates.

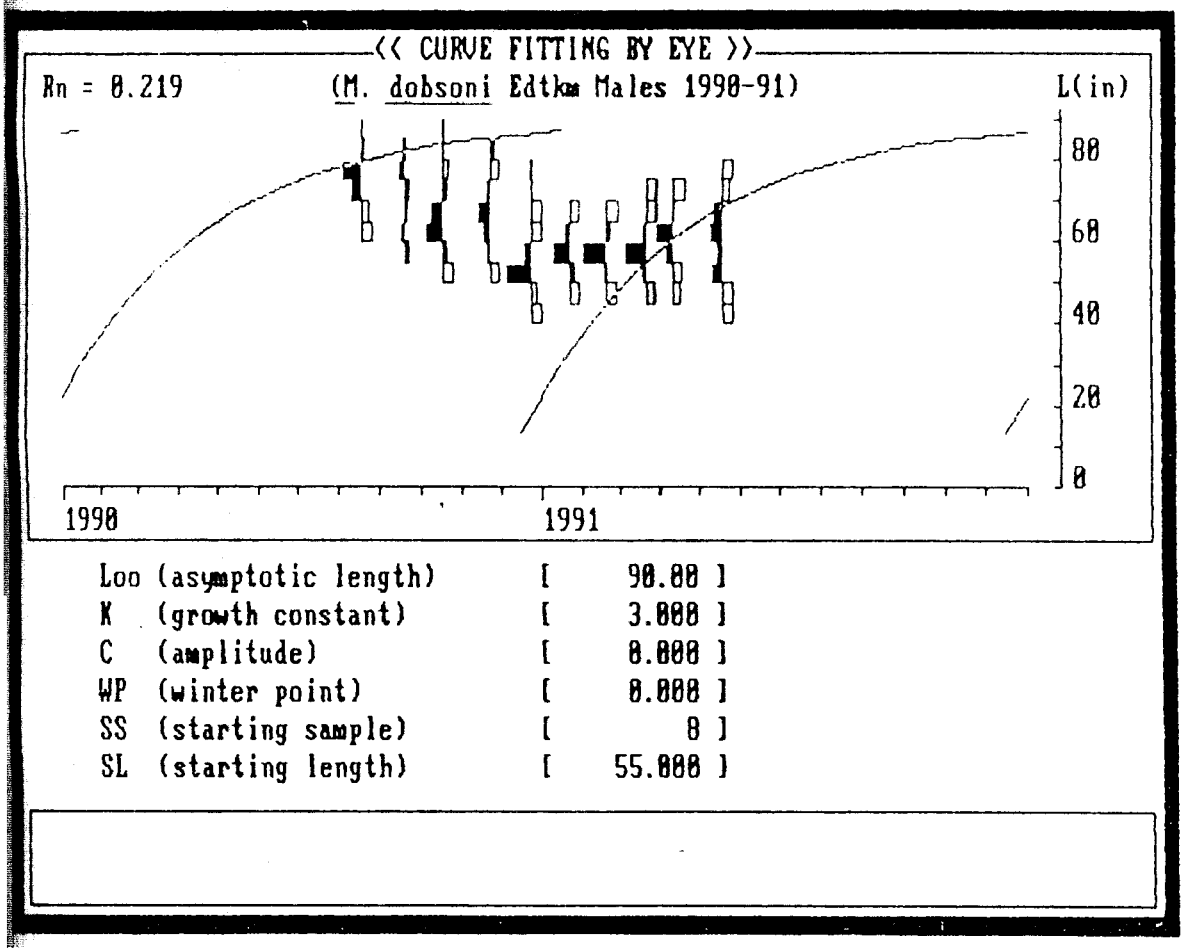
Thoppilkettu

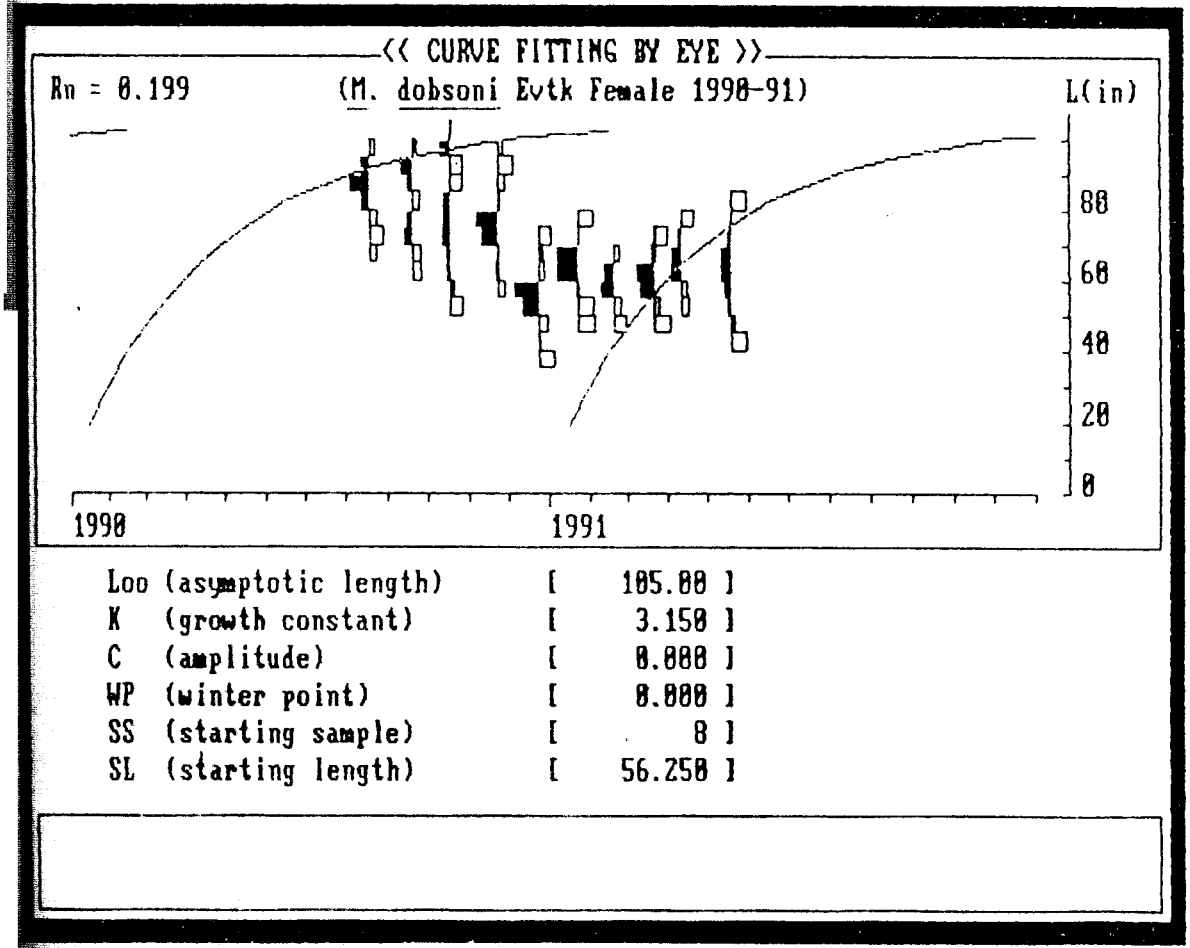
It can be seen that (Table 10, Fig. 6) the male prawns with an initial estimated size of 26.6 mm grow rapidly in the first month at a growth rate of 15.6 mm. In the second month, the animal has grown at a rate of 10.9 mm and thereafter the growth gradually declined as in the previous cases. The final size of 87.5 mm was attained after a total period of 10 months.

In the case of females also (Table 10, Fig. 6), with an initial size of 19.6 mm, the growth rate was very high amounting to 20.1 mm. In the following two months the growth rate slowed considerably varying from 12.1 to 14.0 mm. From the fourth month onwards, however, there was a considerable decline in the growth increment. The animal attained the maximum size of 102.2 mm after a total period of about 13 months. The growth rates recorded during the last three months were very low and they ranged from 0.9 to 1.4 mm/month, which was the poorest growth rate ever recorded for the species during the entire study period in the field.

TABLE 10: Estimated monthly growth rate of *M. dobsoni* in Thoppilkettu prawn culture system based on length frequcny studies Using ELEFAN

Months	Male		Female	
	Modal size (mm)	Monthly growth rate (mm)	Modal size (mm)	Monthly growth rate (mm)
Jan 1990	26.59	--	19.58	--
Feb	42.16	15.57	39.63	20.05
Mar	53.01	10.85	53.66	14.03
Apr	62.29	9.28	65.72	12.06
May	69.16	6.87	74.68	8.96
Jun	74.60	5.44	81.80	7.12
Jul	78.62	4.02	87.09	5.29
Aug	81.81	3.19	91.30	4.21
Sep	84.23	2.42	94.51	3.21
Oct	86.03	1.80	96.91	2.40
Nov	87.45	1.42	98.81	1.90
Dec	-	-	100.22	1.41
Jan	-	-	101.34	1.12
Feb	-	-	102.20	0.86





g.6: Growth curve of M. dobsoni in Thoppilkettu for the year 1990-91.

GROWTH IN COCONUT GROVE CANAL SYSTEM

Experimental culture of M. dobsoni in coconut grove canal system was undertaken to know the growth potential of the species in a more dynamic environment similar to the open brackishwater system, and also to explore the possibility of utilizing these canal net works for commercial shrimp farming. The portion of the canal selected for this experiment was cleared of predatory and weed fishes by the following method. Keeping the sluice gate fully closed, the water present in the canal was pumped out during the low tide period at night upto a water depth of 4 to 6". In the early morning hours, after cast netting the larger fishes, quick lime and Ammonium sulphate were applied each at the rate of 600 kg/ha. All the dead fishes and other organisms were removed after about 8 hours and in the next day water was letin during high tide period. In order to overcome the chemical effect, the water of the canal was repeatedly flushed out and letin for the next five days keeping a wire-mesh screen at the mouth of the small sluice gate.

Stocking of prawn seed

Juveniles of M. dobsoni were collected from the shallow near shore areas of Cochin backwaters around Narakkal using a velon screen net and transported to the experimental site in wide-mouth seed transportation bins. On reaching the site, the prawn seed were carefully released into the canal system. The size of the prawn at the time of stocking varied from 24 to 30 mm, with the estimated mean sizes of 28.5 mm for males and 28.1 mm for females. A total of 3000 juveniles were

stocked on 26.1.1991 which worked out to a stocking rate of 10.2 prawns/sq.m. No supplementary feeding was made during the experiment.

Sampling

The experiment was carried out over a period of 10 fortnights (140 days) from 26.1.1991. The prawns were sampled once in a fortnight by cast netting. Each time a minimum of 20 males and 20 females were collected and brought to the laboratory for length and weight measurements.

Growth of prawn

Details of sample size, mean length, mean weight and growth increments are given in Tables 11 and 12.

Males: With a stocking size of 28.5 mm, the male prawns grew to a mean size of 73.7 mm in 140 days (Table.11). The fortnightly growth increment in terms of percentage gain in length was maximum during the first fortnight (35.1%). It considerably reduced in the next two fortnights (16.8-17.7%). From the fourth to tenth fortnight, the length increase recorded was 5-10 times lower than the initial growth (7.8-3.5%). The estimated daily growth was as high as 0.72 mm/day during the first fortnight. This gradually reduced in the subsequent period and recorded 0.17 mm growth/day towards the end of the experiment.

The mean weight of prawn at the time of stocking was 0.232 gms which increased to 2.634 gms in 140 days of rearing. The fortnightly percentage gain in weight indicated that, the

TABLE 11: Growth pattern of *M. dobsoni* males in the coconut grove canal system.

Time (days)	Sample size (N)	Mean length (mm)	Mean weight (g)	Fortnightly growth		Growth/day	
				Length (%)	Weight (%)	Length (mm)	Weight (g)
0	25	28.5 ±3.2	0.232 ±0.081	-	-	-	-
14	20	38.5 ±3.4	0.401 ±0.120	35.1	73.2	0.72	0.012
28	20	45.3 ±3.6	0.688 ±0.159	17.17	71.7	0.55	0.021
42	24	52.9 ±4.5	0.966 ±0.193	16.8	40.2	0.40	0.020
56	26	57.0 ±2.9	1.370 ±0.156	7.8	41.9	0.36	0.029
70	22	59.9 ±3.5	1.486 ±0.239	5.1	8.5	0.21	0.009
84	20	62.9 ±4.0	1.625 ±0.265	5.0	9.4	0.22	0.010
98	20	65.8 ±2.8	1.835 ±0.195	4.6	12.9	0.20	0.015
112	20	68.5 ±1.7	2.151 ±0.205	4.1	14.8	0.19	0.023
126	20	71.2 ±1.9	2.391 ±0.199	3.9	11.2	0.19	0.017
140	20	73.7 ±2.3	2.634 ±0.329	3.5	10.2	0.17	0.017

weight increased with time at a much faster rate than length of the animal. The gain in weight was as high as 73.2 per cent in the first fortnight and 71.7 per cent in the second fortnight. During the third and fourth fortnights, the weight gain stood between 40 and 42 per cent which steeply reduced to 8.5 per cent in the fifth fortnight. After the minimum level of weight gain at a size of about 60 to 63 mm, the prawn showed increased weight gain of 10 to 15 per cent during the later period of the experiment. During the first fortnight, the prawn showed a daily growth rate of 0.012 g. It increased to 0.021 g/day during the second fortnight and maintained almost the same level in the third fortnight. The growth rate further rose to the maximum level of 0.029 g/day during the fourth fortnight. Subsequently, the weight gain/day registered a steep fall reaching the minimum growth rate of 0.009 g/day, corresponding with the animals size of 60 mm. The growth again showed a gradual increase and touched 0.023 g/day during the eighth fortnight. Again the growth rate decreased and maintained at 0.017 g/day during the ninth and tenth fortnights.

Females: The females with a mean stocking size of 28.1 mm showed differential growth rates in different fortnights and reached the size of 79.2 mm at the end of 140 days. The growth rates recorded were always higher than in males. The results presented in Table 12 indicated that the fortnightly percentage gain in body length was maximum during the first fortnight (44.5 %). This decreased gradually to the minimum of 3.1 per cent during the tenth fortnight. In the second fortnight also, the

TABLE 12: Growth pattern of *M. dobsoni* females in the coconut grove canal system.

Time (days)	Sample size (N)	Mean length (mm)	Mean weight (g)	Fortnightly growth		Growth/day	
				Length (%)	Weight (%)	Length (mm)	Weight (gm)
0	25	28.1 ±3.4	0.233 ±0.110	-	-	-	-
14	20	40.6 ±3.7	0.457 ±0.159	44.5	96.1	0.89	0.016
28	20	50.9 ±3.1	0.795 ±0.146	25.4	74.0	0.74	0.024
42	20	55.7 ±4.3	1.154 ±0.246	10.9	45.2	0.34	0.026
56	25	60.2 ±3.8	1.578 ±0.271	8.1	36.8	0.32	0.020
70	21	64.2 ±2.5	1.839 ±0.204	6.6	16.5	0.29	0.019
84	22	68.3 ±3.9	2.089 ±0.343	6.4	13.6	0.29	0.018
98	21	71.5 ±2.5	2.472 ±0.265	4.7	18.3	0.23	0.027
112	20	74.1 ±2.8	2.850 ±0.327	3.6	15.2	0.19	0.027
126	20	76.8 ±2.9	3.143 ±0.329	3.6	10.3	0.19	0.021
140	20	79.2 ±3.2	3.445 ±0.400	3.1	9.6	0.17	0.022

fortnightly percentage increase in length was relatively high (25.4%). The growth increment of 10.9% noticed during the third fortnight gradually decreased and touched the minimum in the last fortnight. The daily growth, which was 0.89 mm and 0.74 mm in the first and second fortnights, respectively, showed a sharp decline during the third fortnight and reached a growth rate of 0.34 mm/day. From this period onwards the growth/day decreased gradually and touched the minimum of 0.17 mm/day during the tenth fortnight of the experimental period.

The mean weight of female at stocking was 0.233 g his weight increased gradually with time and reached 3.445 g at end of 140 days of rearing period. The fortnightly weight n as compared to males, remained high almost throughout the iod of rearing excepting the ninth and tenth fortnights when was slightly low. The fortnightly growth increment was as as 96.1 and 74.0 per cent during the first and second night of growing period respectively. It gradually reased from 45.2 per cent in the third fortnight to 13.6 per in the sixth fortnight. Subsequently, it registered an rease again to reach 18.3 per cent. From this stage onwards, weight gain showed a gradual decrease touching the minimum .6 per cent during the tenth fortnight. The weight gain per in different fortnights varied between 0.016 g and 0.03 g day. The growth rate of 0.016 g/day during the first night showed a gradual increase and touched the maximum of g/day in the fourth fortnight. Subsequently, it fell ply to 0.019 g/day during the fifth fortnight. After a

marginal decrease in the sixth fortnight, it again increased and maintained at 0.027 g/day during the seventh and eighth fortnights. Further it decreased and maintained at 0.021 and 0.022 g/day during ninth and tenth fortnights, respectively.

Based on the results obtained on the daily growth rates of males and females in different fortnights, the average monthly growth rate of M.dobsoni in terms of length and weight were estimated and the results are depicted in Table 13 . From the table, it can be seen that male prawns of size 28.48 mm attained a size of 74.14 mm in 5 months. The growth rate of 17.6 mm during the first month reduced to 10.68 mm during the second month. Further, the growth rate varied between 6.38 and 5.22 mm during the next three months, indicating very little variation in the monthly growth rate during this period. In terms of weight, the growth rate varied between 0.320 and 0.682 g/month during the five-month growing period. The growth rate which was 0.496 g/month during the first month increased to the maximum of 0.682 g/month during the second month of growing period. During the third month, the growth rate drastically reduced and reached the minimum of 0.320 g/month. Once again, the growth rate showed an increase to 0.578 g/month during the fourth month and marginally decreased (0.510 g/month) in the last month. The average growth rate for the whole period was found to be 0.517 g/month.

The monthly growth rate of female prawns was generally higher than in males. In the first month, the maximum growth rate of 23.48 mm was observed. This drastically

TABLE 13: Estimated monthly growth rates of *M. dobsoni* in the coconut grove canal systems.

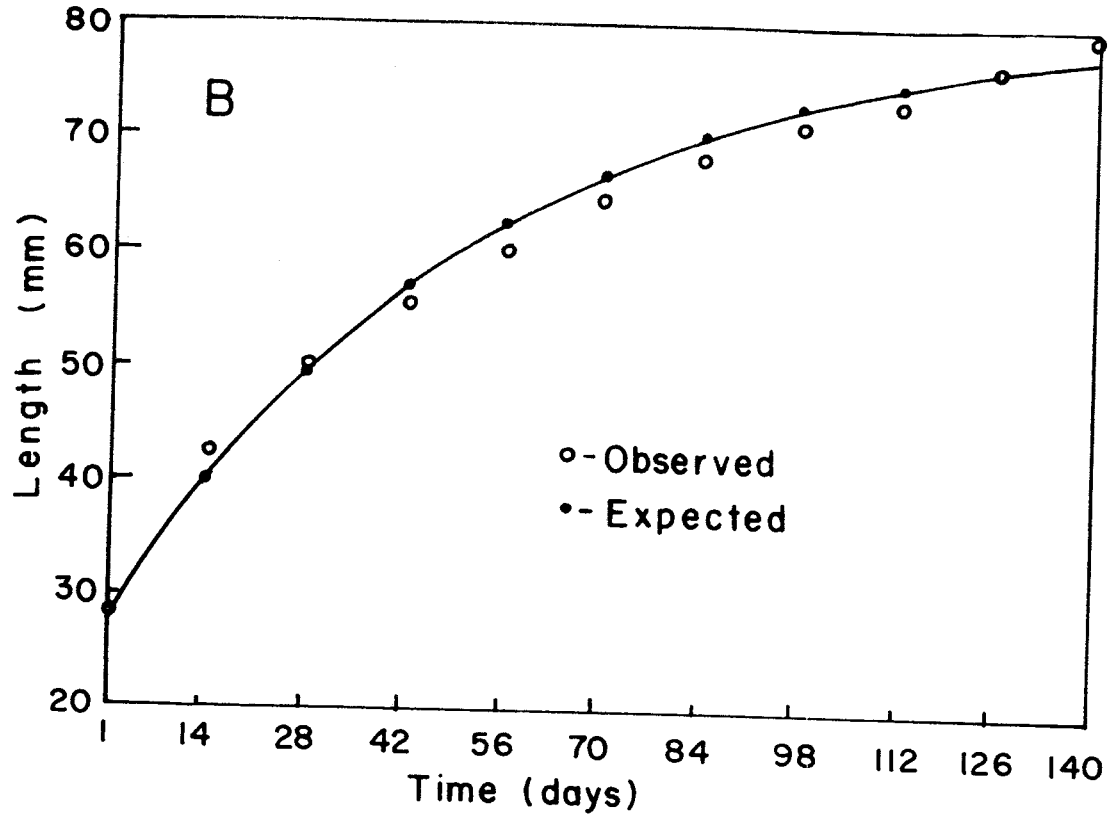
Particulars	Males		Females	
	Length (mm)	Weight (g)	Length (mm)	Weight (g)
Mean length/mean weight at stocking	28.48	0.232	28.08	0.233
Growth rate				
1st month	17.60	0.496	23.48	0.614
2nd month	10.68	0.682	9.72	0.808
3rd month	6.38	0.320	8.34	0.604
4th month	5.78	0.578	6.02	0.762
5th month	5.22	0.510	5.22	0.654
Average growth rate/month	9.13	0.517	10.56	0.688

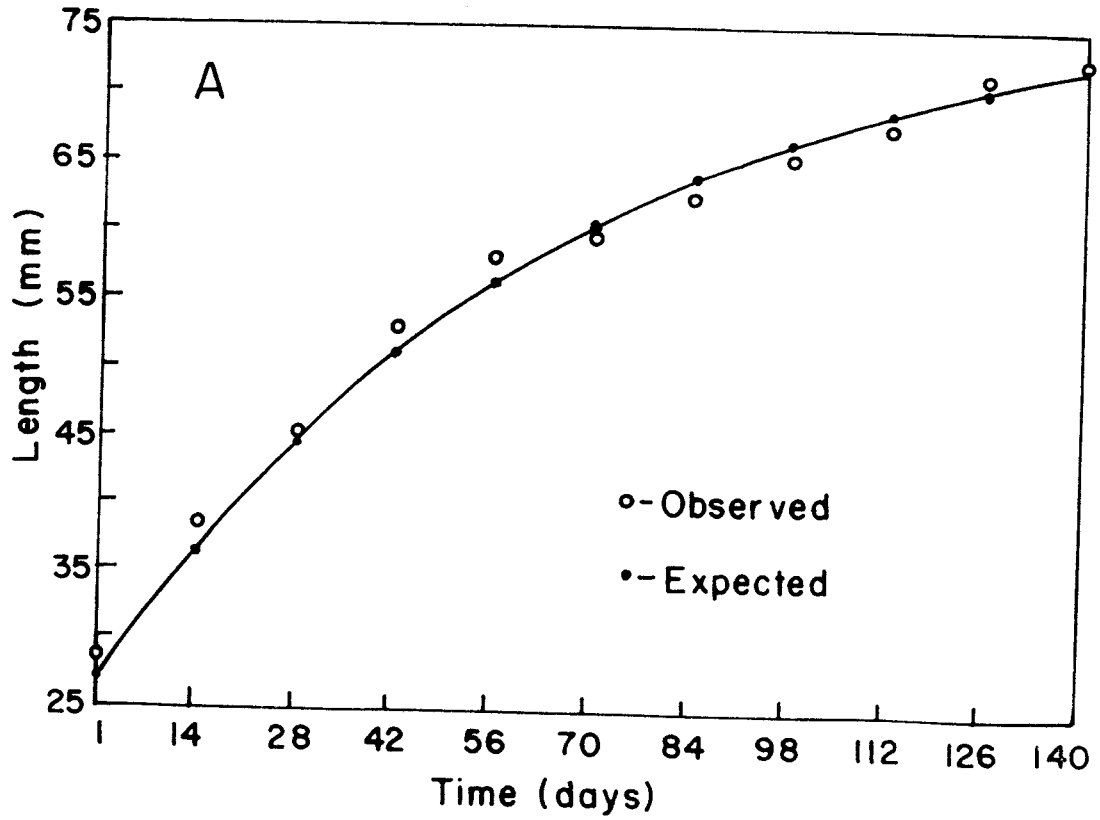
decreased in the second month to 9.72 mm. Subsequently, the growth rate gradually decreased and touched the minimum of 5.22 mm/month during the fifth month of rearing. The average growth rate for the whole period was found to be 10.56 mm/month which is more than that of males, indicating a faster growth rate for females as compared to males.

The growth rate of females in terms of weight was also generally greater than that of males throughout the five-month growing period. The growth rate which was 0.614 g/month during the first month increased and touched the maximum growth rate of 0.808 g/month during the second month. Subsequently, it decreased to the lowest growth rate of 0.604 g/month during the third month. From this stage, it showed an increase to 0.762 g in the fourth month which subsequently decreased to 0.654 g/month during the fifth month, indicating an uneven growth rate. The average weight gain/month for the five month period was estimated to be 0.688 g/month, which is higher than that of males (0.517 g/month).

Comparision of observed and estimated growth

Utilizing the observed mean growth data in terms of lengths, for males and females during the ten fortnights, the expected growth estimates were computed based on von Bertalanffy's growth equation. The observed lengths and expected lengths were plotted against time (fotnights) and the growth curve was fitted for the expected lengths (Fig. 7A and 7B).





1.7: Growth curves of M. dobsoni in coconut grove canal system.
A - Males; B - Females.

From the result (Fig. 7A) it can be seen that in males, the expected lengths are in close comparison with the observed lengths. The expected lengths were marginally lower than the observed lengths during the first to fourth, ninth and tenth fortnights. During the rest of the period (fifth to eighth fortnight) the estimated lengths were marginally higher. These results clearly indicate that the growth of males in coconut grove canal system behave well with the von Bertalanffy's growth equation.

In females also, the difference between expected lengths and observed lengths during different fortnights was marginal. However, the variation was slightly more than that noticed in males. The expected lengths were less than the observed lengths during the first, second and tenth fortnights. In the rest of the period, the expected lengths were marginally greater than the observed lengths. From Fig. 7B, it is clear that the females grow slightly faster than males in the coconut grove canal system and the growth falls in line with the von Bertalanffy's growth equation.

Length and weight relationship

The mean lengths were plotted against mean weight of M. dobsoni for both males and females (Fig. 8A and 8B). It is found that the length increased at a faster rate than the weight in the initial phase of growth. However, as the prawn grew older, the weight accumulation was observed to be much faster than the gain in length. Between the two sexes, females grew

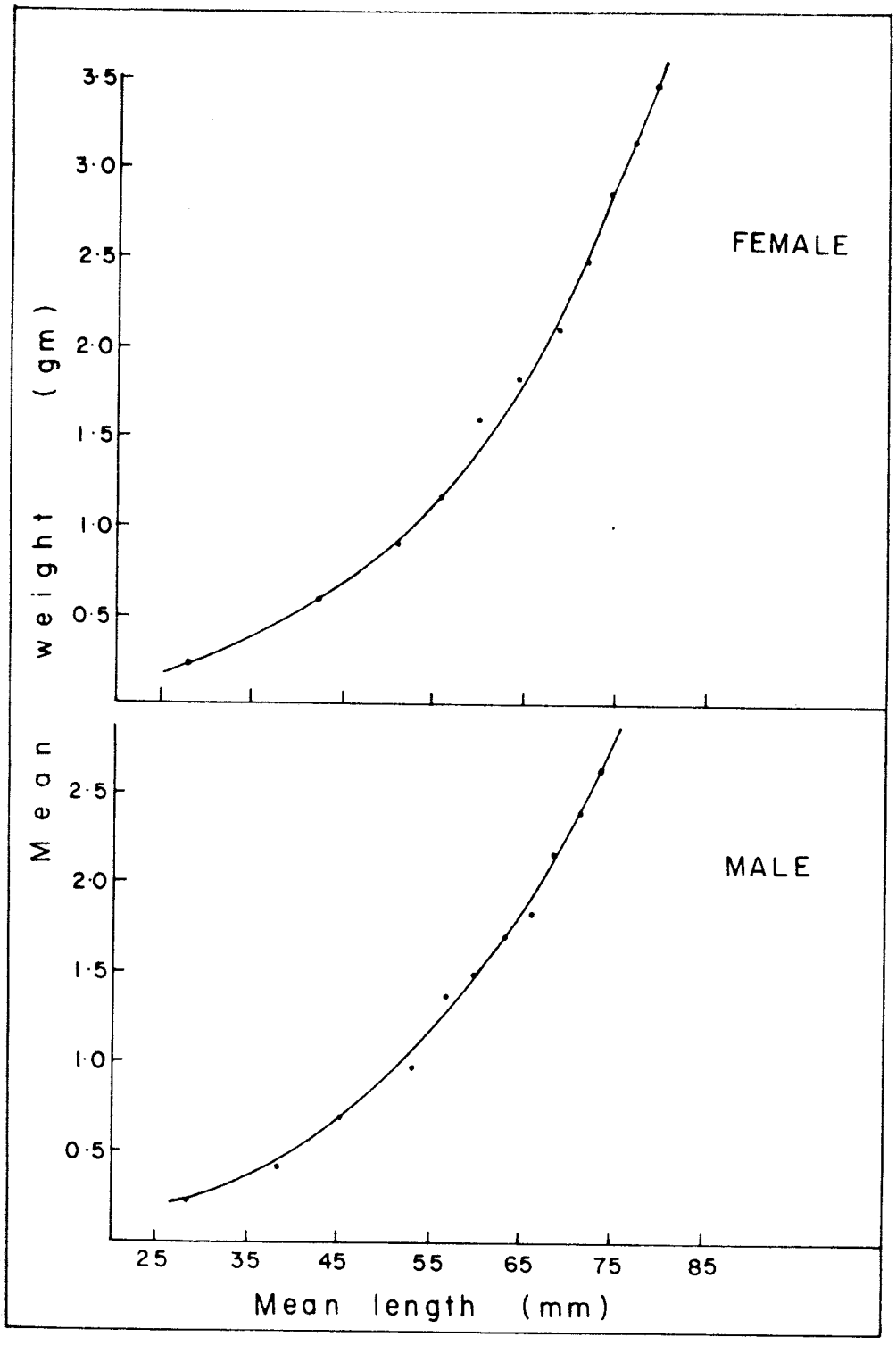


Fig.8: Length plotted against weight of M. dobsoni grown in the coconut grove canal system.

TABLE 14: Biomass production of M. dobsoni in the experimental culture in coconut grove system.

Particulars		Estimated values
Average initial weight of prawn (g)	... (b)	0.2324
Average final weight of prawn (g)	... (a)	3.0396
Increase in average weight (g)	... (a -b)	2.8072
Length of the trial (days)	... (x)	140
Average daily gain(mg/day)	... (*)	20.1
Stocking density (No./sq.m)	... (z)	10.2
Survival %	... (y)	72.4
Biomass increase (g/sq.m)	... (**)	20.0763
Biomass increase/day (g/sq.m)	... (c/x)	0.1434
Total area of the culture system (120x2.45 m)	...	294
Total biomass production in the culture system/140days (kg)	...	5.902
Production/hectare/140 days (kg)	...	200.76

* ... $\frac{(a-b)\ 100}{x}$ ** $C = \frac{azy}{100} - bz$

faster and showed a better length and weight relationship than males.

Biomass production

Based on the mean initial weight, mean final weight, rearing period, stocking density and survival percentage, the biomass production (New, 1976) in the coconut grove canal system was estimated and the details are presented in Table 14. The results indicate an average bio-mass production of 0.1434 g/sq.m/day in the coconut grove canal system when stocked with M. dobsoni at a stocking density of 10.2 prawns/sq.m. The total biomass production of prawns was estimated at 5.902 kg from the coconut grove canal network of 294 sq.m. area used for this experiment in 140 days growing period. This was very close to the observed production of 5.498 kgs. The production per hectare in 140 days culture period worked out to 200.76 kgs.

LABORATORY GROWTH STUDIES

Salinity is considered as the most important abiotic factor that influences the biology of penaeid prawns especially during their estuarine phase. The observations made in the perennial prawn culture fields on the growth of the prawn are of general nature which could only provide an over all performance with regard to growth in a highly dynamic environment. Precise information on the effect of different levels of salinities on the growth and survival of the prawns could be obtained only through systematic laboratory experiments to yield direct

results. As the estuarine salinity is known to range from almost zero level to the marine condition, an attempt has been made in the present study to understand the effect of six brackishwater salinity levels such as 5, 10, 15, 20, 25 and 30 ppt, on the growth, survival and moulting periodicity. During the growth studies, attempt has also been made to evaluate the various food utilization indices such as feed conversion efficiency, protein efficiency ratio of the animal and the biomass production in the different salinity conditions. The whole experiments lasted for four fortnight (56 days) from 6.1.91 to 3.3.91.

Juveniles of M. dobsoni collected by velon screen drag net from the brackishwater at about 3 km from Cochin bar mouth were brought to the laboratory in wide mouthed seed transportation plastic bins and used for the experiments. In the laboratory, a batch of almost uniform size prawn was separated and acclimated to the experimental media.

Acclimation: The salinity, oxygen and temperature of the site from where the seed were collected measured 19.8 ppt. 5.6 mg/l and 26.9^{o}C respectively. Prior to transferring the animals into the experimental tanks, the prawns were kept in water of the same salinity for 24 hours under laboratory conditions. The salinity was lowered step-wise by substituting sea water with equal volume of chlorine-free well aerated tap water. The salinity was increased in the same manner using normal seawater in place of tap water. Step-wise salinity changes (Table 15) required 30 hrs for getting 15 and 25 ppt salinities, 42 hours

TABLE 15: Schedule of salinity changes in the acclimation process (Initial salinity 20 ppt)

Date	Elapsed time (hours)	Desired Salinity (‰)					
		5	10	15	20	25	30
1-1-91	24	20	20	20	20	20	20
2-1-91	30	15	15	15	-	25	25
3-1-91	42	10	10	-	-	-	30
3-1-91	54	5	-	-	-	-	-

TABLE-16: Water quality parameters of the experimental media used for growth studies of M. dobsoni

Desired salinity levels (‰)	Range/ mean	Water quality parameters			
		Temperature (°C)	Salinity (‰)	Oxygen (mg/l)	pH
5	Range	26.8 - 27.5	4.95 - 5.83	4.45 - 6.19	7.14 - 7.92
	Mean	27.1 ± 0.7	5.29 ± 0.13	5.28 ± 0.46	7.53 ± 0.19
10	Range	27.0 - 27.4	9.51 -11.00	3.58 - 5.45	6.85 - 7.74
	Mean	27.2 ± 0.1	10.36 ± 0.23	4.95 ± 0.46	7.41 ± 0.20
15	Range	26.9 - 27.4	14.58 -16.30	4.35 - 6.24	6.87 - 7.74
	Mean	27.2 ± 0.2	15.6 ± 0.29	5.12 ± 0.42	7.37 ± 0.17
20	Range	26.9 - 27.5	19.38 -21.50	4.8 - 6.07	7.12 - 7.78
	Mean	27.2 ± 0.2	20.59 ± 0.38	5.14 ± 0.36	7.42 ± 0.14
25	Range	26.8 - 27.6	24.60 -26.52	3.97 - 6.41	7.17 - 7.76
	Mean	27.3 ± 0.2	25.46 ± 0.38	5.18 ± 0.60	7.43 ± 0.12
30	Range	26.9 - 27.5	29.46 -31.60	4.19 - 6.19	7.01 - 7.80
	Mean	27.2 ± 0.2	30.60 ± 0.29	5.34 ± 0.66	7.50 ± 0.16

for 10 and 30 ppt salinities and 54 hours for 5 ppt salinity. The total acclimation period lasted for 3 days. During the acclimation period, the prawns were fed with formulated pelleted feed at about 8 to 10 per cent of their body weight. On the last day after removing the faecal matter, the prawns were starved for one day.

Experimental procedure: The experiment was carried out in triplicate in round bottomed green plastic tubs of 40 litre capacity. After noting down the individual lengths and weights, 10 juvenile prawns were released into each tub having 30 litres of desired salinity medium. Feeding was done twice a day using small bits of pelleted feed at 15.0, 12.5, 10.0 and 7.5 per cent of the prawns' body weight per day during the first, second, third and fourth fortnights, respectively. Everyday feeding was done after removing the leftover food and faecal matter by siphoning. The entire rearing medium was changed once a week. At fortnightly intervals, the animals were measured to the nearest millimetre for length increase and weighed to the nearest milligram, after blotting excess moisture, using a Metler monopan balance for weight gain. Immediately after, they were released back into the respective experimental tanks.

Food and feeding schedule

A formulated pelletized feed was used for feeding the prawns throughout the experiment. Details of the feed ingredients used and the biochemical composition of feed are shown below.

Ingredients used for compounded feed

Components	Weight (g/100 g of feed)
Fish meal	25
Soyabean meal	25
Rice bran	10
Prawn waste	15
Sardine oil	2
Vegetable oil (Sunflower)	2
Tapioca	18
Vitamin mix	1
Mineral mix	2
Total	100

Vitamin mix (mg)	
B1	36
B2	36
Nicotin amide	300
Calcium pentathenate	165
Folic acid	0.5
B-12	0.05
C	450

Mineral mix (g)	
Dicalcium phosphate	1.0
Potassium dihydrogen orthophosphate	0.8
Zinc sulphate	0.05
Copper sulphate	0.05
Potassium iodide	0.10

For feed preparation, the individual feed ingredients were finely powdered, seived and mixed sprinkling vegetable oil and sardine oil. The feed was then steamed in a pressure cooker for about 10 minutes without closing the pressure grid. The steamed feed was pelletized using a domestic hand operated pelletizer with 2 mm diameter seive. The pellets were spread in a GI tray and dried in an oven at $50^{o}C$ for 24 hours. The dry pellets were stored in small plastic bags, in a dessicator for further use. The protein and carbohydrate

content of feed were in the order of 42.58 per cent and 37.52 per cent, respectively. The levels of moisture, lipid and crude fibre varied between 5.33 and 8.33 per cent. Ash content was about 15 per cent.

Proximate composition of feed (Percentage)

Protein	42.58
Lipids	8.33
Crude fibre	5.53
Ash	14.78
Moisture	6.04
NEE (Carbohydrate)	37.52
Organic matter	79.18

Water quality parameters

The range and mean values of temperature, salinity, oxygen and pH of the rearing media are shown in Table 16 and the variations in ammonia and nitrite levels in Table 17.

Temperature: The temperature of all salinity media varied between 26.8 and 27.6$_{o}$C, indicating very little variation in the same.

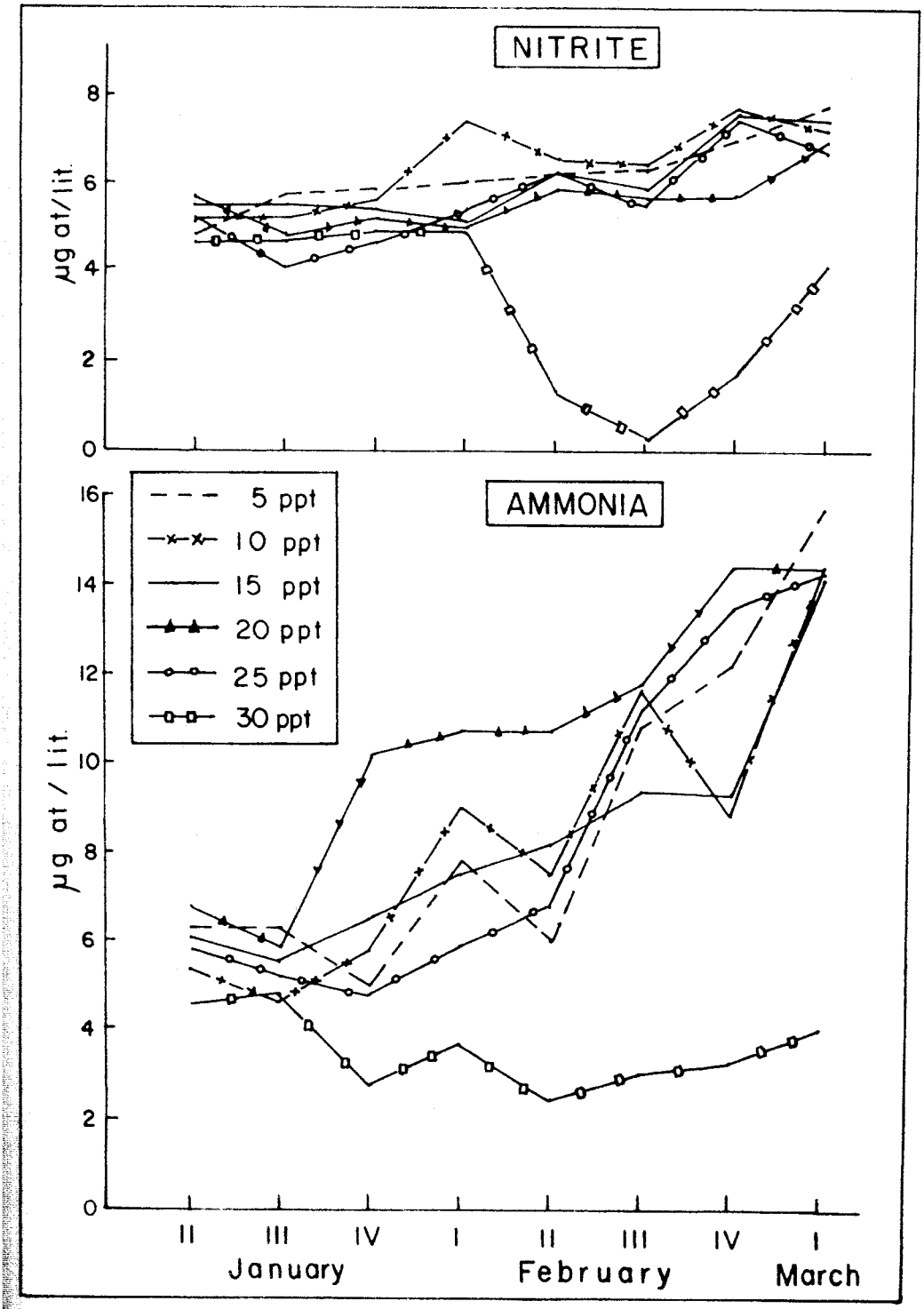
Salinity: The salinity was maintained almost at the desired levels. Due to evaporation, however, a range of variation of 0.86 to 1.60 ppt on the higher side of the desired levels was recorded in the different experimental media.

Oxygen: The dissolved oxygen varied from 3.58 to 6.41 mg/l in all the salinity media with mean oxygen values varying from 4.95 to 5.34 mg/l.

pH: The pH of the experimental media also showed a very narrow

TABLE 17: Variations in Ammonia and Nitrite levels of the experimental media used for growth studies of *M. dobsoni*

Salinity	Particulars	Ammonia (µg at/l) Beginning of the week	Ammonia (µg at/l) End of the week	Nitrite (µg at/l) Beginning of the week	Nitrite (µg at/l) End of the week
5	Range	0.30 - 1.80	6.20 -15.80	0.40 -1.20	5.40 - 7.70
	Mean	1.49 ± 0.74	9.76 ± 3.65	0.84 ±0.36	6.90 ± 0.85
10	Range	0.60 - 2.20	6.20 -16.40	0.40 -1.60	5.60 - 8.30
	Mean	1.65 ± 0.48	10.05 ± 3.49	0.94 ±0.44	7.21 ± 1.18
15	Range	0.80 - 2.00	7.00 -16.20	0.40 -1.80	5.90 - 8.60
	Mean	1.58 ± 0.40	9.94 ± 2.95	1.08 ±0.47	7.19 ± 0.97
20	Range	1.00 - 2.00	7.60 -16.40	0.80 -1.80	5.60 - 8.30
	Mean	1.71 ± 0.32	12.33 ± 4.22	1.33 ±0.37	6.81 ± 0.79
25	Range	1.20 - 2.40	7.00 -15.60	0.20 -1.80	5.10 - 8.30
	Mean	1.81 ± 0.39	10.25 ± 3.94	1.40 ±0.61	7.05 ± 1.05
30	Range	1.40 - 2.50	4.60 - 6.40	0.60 -2.00	2.30 - 7.10
	Mean	2.01 ± 0.42	5.58 ± 0.65	1.50 ±0.58	5.01 ± 2.05



9: Weekly accumulation of ammonia and nitrite in the experimental media during growth studies of M. dobsoni.

range, varying from 6.85 to 7.92 with the mean values ranging from 7.37-7.53.

Ammonia: In the beginning of every week, the ammonia concentration was considerably low in all the salinity media and it ranged from 0.30 to 2.5 /µg at/l. At the end of each week, however, it was noticed that ammonia level in the water was always higher, ranging from 4.6 to 16.4 µg at/l, the mean values ranging between 9.76 and 12.33 µg at/l in all the salinity media except 30 ppt salinity in which, the ammonia level was considerably low. A steadily increasing trend in the mean values of ammonia concentration noticed at the end of each week (Fig. 9) in all the salinities, indicated higher metabolic activity associated with the growth of the animal. The rise in ammonia concentration thus noticed, was maximum in 20 ppt salinity while it was the least in 30 ppt.

Nitrite: The nitrite concentration also showed more or less a similar trend (Fig. 9). In the beginning of each week, the nitrite level was relatively low, ranging between 0.2 and 2.0 µg at/l with the mean values of 0.84 to 1.50 µg at/l. At the end of each week, the values ranged from 2.3 to 8.6 µg at/l, the mean values being in the range of 6.81 to 7.21 µg at/l in all salinities except 30 ppt in which the mean value was relatively lower (5.01 µg at/l).

Survival: At the end of the first fortnight of commencement of the experiment (Table 18), total survival was noticed in all salinities except in 5 ppt and 30 ppt in which the percentage

TABLE 18: Percentage survival of *M. dobsoni* in different salinities during the laboratory growth studies.

Salinity (‰)	Number stocked/ survival rate(%)	Dates of observations				
		6-1-91	20-1-91	3-2-91	17-2-91	3 3-91
5	No.	30	29	28	26	26
	Survival	100.0	96.7	93.3	86.7	86.7
10	No.	30	30	28	24	24
	Survival	100.0	100.0	93.3	80.0	80.0
15	No.	30	30	28	25	24
	Survival	100.0	100.0	93.3	83.3	80.0
20	No.	30	30	29	28	27
	Survival	100.0	100.0	96.7	93.3	90.0
25	No.	30	30	29	26	24
	Survival	100.0	100.0	96.7	86.7	80.0
30	No.	30	20	9	3	3
	Survival	100.0	66.7	30.0	10.0	10.0

urvival was 96.7 and 66.7, respectively. A gradual reduction n the percentage survival was noticed in the subsequent ortnights. The rate of survival recorded at the end of second ortnight worked out to 93.3 to 96.7 per cent in all salinities pto 25 ppt and only 30 per cent in 30 ppt. The percentage urvival at the end of the third fortnight was further reduced o 80.0 to 93.3 in all salinities upto 25 ppt and a mere 10 per ent in 30 ppt salinity. The survival rate at the end of the xperiment remained more or less same (80-90 %) in 5 to 25 ppt alinities. The low survival recorded in 30 ppt continued to emain at the same level till the termination of the xperiment. It was observed that mortality of prawns occurred onsistently in 30 ppt salinity leading to a very poor survival owards the end of the experiment, probably due to poor intake f food.

rowth:

Details of length/weight increase observed in ifferent salinity conditions during successive fortnights of he experiment are summarised in Tables 19 and 20. The growth ttern is depicted in Fig. 10.

The mean size of prawns in all salinity media at the ommencement of the experiment varied between 23.37 and 23.87 m. At the end of the first fortnight of the experiment the ean size increased to a maximum of 32.75 mm in 10 ppt salinity id a minimum of 29.00 mm in 30 ppt. The 5 ppt salinity corded a daily mean length increase of 0.52 mm with a total

length gain of 30.58 per cent during the first fortnight. The corresponding values of 10 ppt salinity were 0.65 mm and 38.8 per cent, 15 ppt 0.59 mm and 34.4 per cent, 20 ppt 0.54 mm and 31.9 percent, 25 ppt 0.41 mm and 24.3 per cent and 30 ppt 0.39 mm and 23.1 per cent. At the end of second fortnight, the animals attained a maximum mean length of 38.33 mm in 10 ppt and a minimum of 30.44 mm in 30 ppt. In all the salinity media, except 20 ppt, the rate of daily length increase showed a reduction by 28.8 per cent (15 ppt) to 74.4 per cent (30 ppt). The daily mean length gain in 20 ppt increased marginally over that in the previous fortnight. The 5 ppt salinity recorded a daily mean length increase of 0.36 mm with a total length gain of 16.7 per cent. The corresponding values of 10 ppt salinity were 0.40 mm and 17.0 per cent, 15 ppt 0.42 mm and 18.5 per cent, 20 ppt 0.33 mm and 14.9 per cent, 25 ppt 0.42 mm and 20.5 per cent and 30 ppt 0.10 mm and 5.0 per cent. At the end of the third fortnight the animals grew to a maximum mean length of 44.08 mm in 15 ppt salinity and a minimum of 34.37 mm in 30 ppt salinity. The rate of daily length gain further declined by 2.8 per cent in 5 ppt, 7.5 per cent in 10 ppt, 3.0 per cent in 20 ppt and 31.0 per cent in 25 ppt salinities. The experiment also showed a marginal increase for the same (2.3 %) in 15 ppt and a significant increase (180 %) in 30 ppt salinities. The 5 ppt salinity recorded a daily mean length increase of 0.35 mm with a

ABLE 19: Groth in length (mm) of M. dobsoni in different salinities under laboratory conditions.

eriod days)	Growth parti- culars	Salinities (‰) 5	10	15	20	25	30
0	L	23.37 ±1.06	23.60 ±0.72	23.87 ±0.40	23.76 ±0.64	23.53 ±0.81	23.56 ±0.15
14	L	30.58 ±2.27	32.75 ±0.75	32.08 ±0.08	31.33 ±1.42	29.25 ±0.75	29.00 ±1.32
	L gain/day	0.52	0.65	0.59	0.54	0.41	0.39
	L gain %	30.58	38.77	34.39	31.86	24.31	23.09
28	L	35.67 ±1.51	38.33 ±0.63	38.00 ±1.15	36.00 ±0.43	35.25 ±2.40	30.44 ±1.92
	L gain/day	0.36	0.40	0.42	0.33	0.42	0.10
	L gain %	16.65	17.04	18.45	14.91	20.51	4.97
42	L	40.58 ±1.84	43.00 ±1.32	44.08 ±1.04	40.50 ±0.75	39.33 ±0.80	34.37 ±1.95
	L gain/day	0.35	0.33	0.43	0.32	0.29	0.28
	L gain %	13.77	12.18	16.00	12.50	11.58	12.91
56	L	44.20 ±2.08	46.72 ±0.53	47.58 ±1.08	44.45 ±1.00	43.30 ±0.70	37.00 ±1.41
	L gain/day	0.26	0.27	0.23	0.28	0.21	0.19
	L gain %	8.92	8.65	7.95	9.75	7.55	7.65
er- l	L gain	20.83	23.12	23.71	20.66	19.77	13.44
	L gain/day	0.37	0.41	0.42	0.37	0.35	0.24
	L gain %	89.13	97.97	99.33	86.85	84.02	57.05

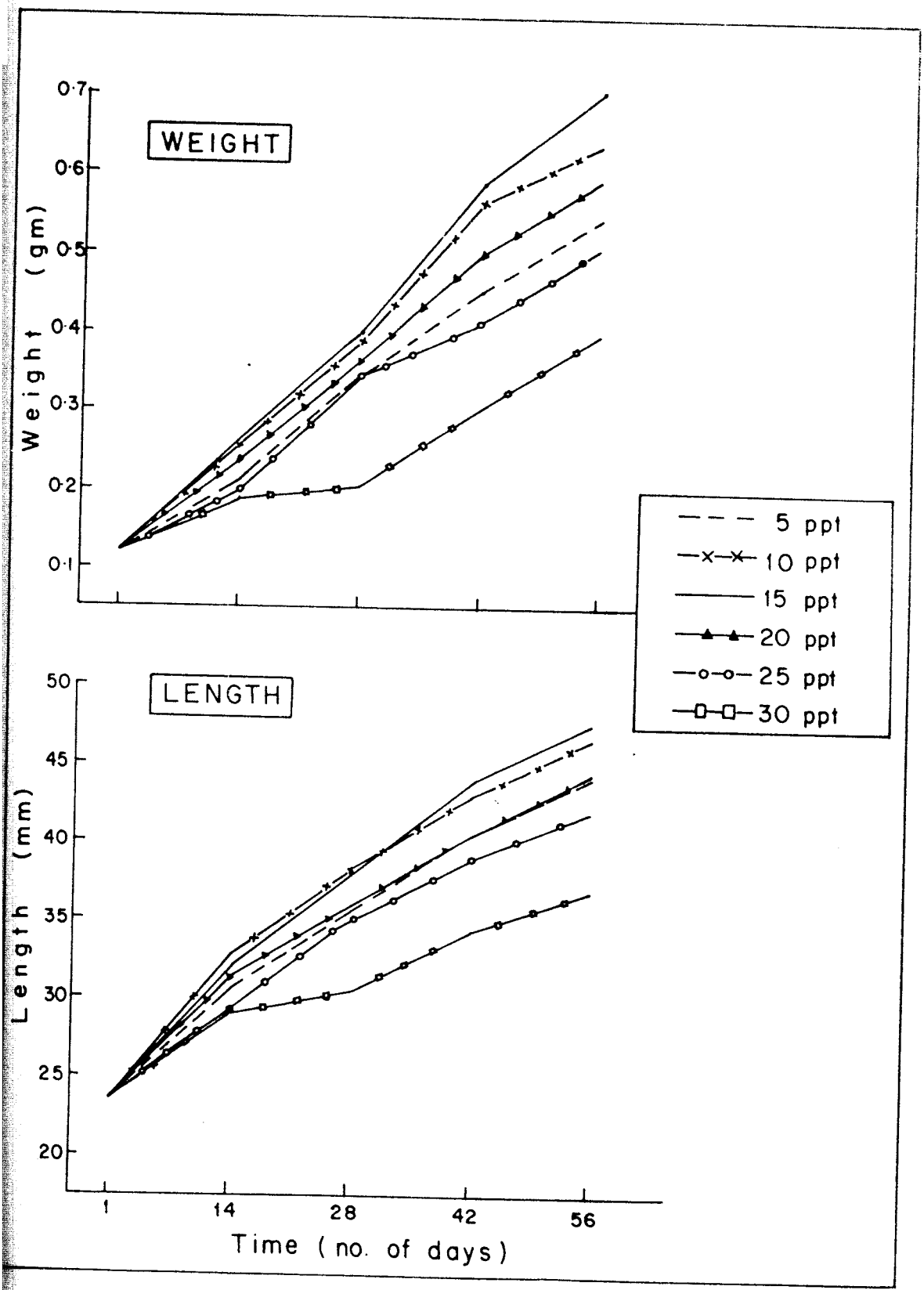
total length gain of 13.8 per cent. The corresponding values of 10 ppt salinity were 0.33 mm and 12.2 percent, 15 ppt 0.43 mm and 16.0 per cent, 20 ppt 0.32 mm and 12.5 per cent, 25 ppt 0.29 mm and 11.6 per cent and 30 ppt o.28 mm and 12.91 per cent. At the end of the fourth fortnight, the animals attained a maximum mean length of 47.58 mm in 15 ppt and a minimum of 37.00 mm in 30 ppt salinity. The rate of daily mean length gain further reduced in all the salinites, the reduction ranging from 12.5 per cent in 20 ppt to 46.5 per cent in 15 ppt. The 5 ppt salinity recorded a daily mean length increase of 0.26 mm with a total length gain of 8.9 per cent. The corresponding values of 10 ppt salinity were 0.27 mm and 8.7 per cent, 15 ppt 0.23 mm and 8.0 per cent, 20 ppt 0.28 mm and 9.8 per cent, 25 ppt 0.21 mm and 7.6 per cent and 30 ppt 0.19 mm and 7.7 per cent. It may be seen that after the 56 days of experimental rearing the prawns registered a net mean length increase of 20.83 mm in 5 ppt, 23.12 mm in 10 ppt, 23.71 mm in 15 ppt, 20.66 mm in 20 ppt, 19.77 mm in 25 ppt and only 13.44 mm in 30 ppt salinities. The daily mean length gain recorded was 0.37 mm, 0.41 mm, 0.42 mm, 0.37 mm, 0.35 mm and 0.24 mm in 5, 10, 15, 20, 25 and 30 ppt salinities, respectively. In the first five levels of salinity which recorded the maximum growth rates with relatively less variations, the percentage in the mean length gain worked out to 84.0 per cent (25 ppt) to 99.3 per cent (15 ppt). The 30 ppt salinity gave a poor performance of only 57.1 per cent increase during the entire period of experiment.

A perusal of Fig 10 would clearly indicate the trend of growth in different salinity media. The 10 ppt salinity gave the maximum growth during the first two fortnights and thereafter the maximum growth was recorded in 15 ppt salinity. The growth in 30 ppt salinity remained very low from the second fortnight onwards among the few surviving prawns.

The mean weight of the animal at the commencement of the experiment varied between 119.56 and 122.67 mg. At the end of the first fortnight of experiment the mean weight increased to a maximum of 258.05 mg in 15 ppt salinity and a minimum of 191.60 mg in 30 ppt. The 5 ppt salinity recorded a daily mean weight increase of 6.54 mg with a total weight gain of 76.6 per cent. The corresponding values of 10 ppt salinity were 9.57 mg and 111.6 per cent 15 ppt 9.79 mg and 113.3 per cent, 20 ppt 8.17 mg and 93.3 per cent, 25 ppt 6.44 mg and 67.5 per cent and 30 ppt 5.11 mg and 59.77 per cent. At the end of the second fortnight, the animals attained a maximum mean weight of 395.83 mg in 15 ppt and a minimum of 205.56 mg in 30 ppt. In all the salinity media except 30 ppt the rate of daily weight gain showed an increase by 0.5 per cent (15 ppt) to 62.1 per cent (25 ppt). The daily mean weight gain showed a considerable reduction of 80.4 per cent in 30 ppt, over that in the previous fortnight. The 5 ppt salinity recorded a daily mean weight gain

ABLE 20: Growth in weight (mg) of M. dobsoni in different salinities under laboratory conditions.

eriod days)	Growth parti- culars	Salinities (‰) 5	10	15	20	25	30
0	W	119.56 ±8.48	120.00 ±7.21	121.60 ±2.65	122.67 ±5.03	120.33 ±7.64	120.00 ±1.00
14	W	211.08 ±10.41	253.92 ±20.65	258.05 ±11.64	237.06 ±24.26	201.50 ±9.01	191.60 ±13.28
	W gain/ day	6.54	9.57	9.79	8.17	6.44	5.11
	W gain %	76.55	111.60	113.26	93.27	67.46	59.67
28	W	346.90 ±44.82	389.83 ±27.42	395.83 ±15.88	362.55 ±21.64	347.69 ±7.32	205.56 ±91.07
	W gain/ day	9.70	9.71	9.84	8.96	10.44	1.00
	W gain %	64.35	53.54	53.39	52.92	72.50	7.29
42	W	453.67 ±43.58	567.33 ±59.93	587.58 ±7.18	499.17 ±5.46	412.50 ±13.41	303.50 ±80.61
	W gain/ day	7.63	12.68	13.70	9.76	4.63	7.00
	W gain %	30.78	45.53	48.44	37.68	18.64	47.65
56	W	545.93 ±42.55	638.25 ±47.92	704.35 ±26.51	593.24 ±17.38	508.76 ±39.84	400.57 ±53.03
	W gain/ day	6.59	5.07	8.34	7.73	6.88	6.93
	W gain %	20.34	12.50	19.87	21.69	23.35	31.98
ver- 11	W gain	426.37	518.25	582.75	470.57	388.43	280.57
	W gain/ day	7.61	9.25	10.41	8.40	6.94	5.01
	W gain %	356.62	431.87	479.24	383.61	322.80	233.81



g.10: Fortnightly growth pattern of M. dobsoni in the laboratory under different salinity levels.

of 9.70 mg with a total weight gain of 64.4 per cent. The corresponding values of 10 ppt salinity were 9.71 mg and 53.5 per cent, 15 ppt 9.84 mg and 53.4 per cent, 20 ppt 8.96 mg and 52.91 per cent,25 ppt 10.44 mg and 72.5 per cent and 30 ppt 1.00 mg and 7.3 per cent. At the end of the third fortnight, the animals grew to a maximum mean weight of 587.58 mg in 15 ppt and a minimum of 303.50 mg in 30 ppt. In all the salinities except 5 and 25 ppt the rate of daily mean weight gain showed an increase by 8.90 per cent (20 ppt) to 600 per cent (30 ppt). A considerable reduction in the rate of daily weight gain was noticed in 5 ppt (21.3 %) and 25 ppt (55.7 %) salinities. The 5 ppt salinity recorded a daily mean weight gain of 7.63 mg with a total weight gain of 30.8 per cent. The corresponding values of 10 ppt salinity were 12.68 mg 45.5 per cent, 15 ppt 13.70 mg and 48.4 per cent, 20 ppt 9.76 mg and 37.7 per cent, 25 ppt 4.63 mg and 18.6 per cent and 30 ppt 7.00 mg and 47.7 per cent. At the end of the fourth fortnight, the animals attained a maximum mean weight of 704.35 mg in 15 ppt and a minimum of 400.57 mg in 30 ppt. The rate of daily mean weight gain declined in all salinities by 1 per cent (30 ppt) to 60.0 per cent (10 ppt) except in 25 ppt in which a considerable increase (48.6 %) over that of the previous fortnight was noticed. The 5 ppt salinity recorded a daily mean weight gain of 6.59 mg with a total weight

gain of 20.3 per cent. The corresponding values for 10 ppt salinity were 5.07 mg and 12.5 per cent, 15 ppt 8.34 mg and 19.9 per cent, 20 ppt salinity 7.73 mg and 21.7 per cent, 25 ppt 6.88 mg and 23.4 per cent and 30 ppt 6.93 mg and 32.0 per cent. From the table, it may be seen that after the 56 days of experimental rearing, the prawns registered a net mean weight gain of 426.37 mg in 5 ppt, 518.25 mg in 10 ppt, 582.75 mg in 15 ppt, 470.57 mg in 20 ppt, 388.43 mg in 25 ppt and 280.57 mg in 30 ppt. The daily mean weight gain recorded was 7.61 mg, 9.25 mg, 10.41 mg, 8.40 mg, 6.94 mg and 5.01 mg and the percentage weight gain was 356.6 per cent, 431.9 per cent, 479.2 per cent , 383.6 per cent, 322.8 per cent an' 233.8 per cent in 5, 10, 15, 20, 25 and 30 ppt salinities, respectively. The salinities 10 and 15 ppt, with mean weight gain of 431.9 and 479.2 per cent respectively, showed the maximum growth rate. The mean weight gain in 5, 20, and 25 ppt was relatively low varying from 322.8 to 383.6 per cent, while in 30 ppt it was the lowest (233.8%).

From Fig 10, it is clear that in the first five salinities the weight increase remained more or less uniform upto the end of second fortnight and thereafter the salinities 10 and 15 ppt showed higher weight gain as compared to the same

TABLE 21a: Two way ANOVA with multiple equal observations of length/ cell.

Source	df	SS	MS	F
FIRST	5	44.902	8.980	3.6283 **
SECOND	3	141.877	47.292	--
INTERACTION	15	37.125	2.475	--
CELL TOTALS	23	223.905	9.735	--
ERROR	48	27.332	0.569	--
TOTAL	71	251.236	---	--

TABLE 21b: Two way ANOVA with miltiple with equal observations of weight/cell

Source	df	SS	MS	F
FIRST	5	41191.938	8238.388	2.6146
SECOND	3	8389.125	2796.375	--
INTERACTION	15	47264.000	3150.933	--
CELL TOTALS	23	96845.063	4210.655	--
ERROR	48	20521.688	427.535	--
TOTAL	71	117366.750	--	--

(P at 0.05)

in 5, 20 and 25 ppt. Throughout the experimental period the animals in 15 ppt recorded the maximum weight gain. Similar to the observations on length increase, the few surviving prawns in 30 ppt salinity recorded the lowest weight gain throughout the experiment.

The results of two way ANOVA presented in Table 21a indicate a statistically significant variation in length attained by prawns in different salinities ($P < 0.05$). The weight difference between treatments (Table 21 b) was not statistically significant ($P > 0.05$) which may be due to greater variations between the replicates within each treatment.

Effect of salinity on food utilization and growth

The food utilization indices such as feed conversion efficiency (FCE) and protein efficiency ratio (PER) are direct indicators of growth performance of the animal. Feed conversion efficiency is an indicator of growth (weight gain) of prawn per unit intake of feed, while protein efficiency ratio is defined as the weight gain per unit intake of protein. Feed conversion efficiency is positively correlated with growth and PER. The fortnightly estimates of feed conversion efficiency and PER in different experimental salinities are given in Table 22. The feed which was given at 15 per cent of body weight during the first fortnight was reduced to 12.5 per cent, 10 per cent and 7.5 per cent during the second, third and fourth fortnights respectively, according to the consumption as observed daily.

TABLE 22: Feed conversion efficiency and protein efficiency ratio of M. dobsoni in different salinities in laboratory experiments.

No.of days	Salinity (‰)	Feed conversion efficiency(FCE)	Protein efficiency ratio (PER)
0-14	5	0.38	0.82
	10	0.55	1.30
	15	0.56	1.39
	20	0.46	1.09
	25	0.33	0.78
	30	0.35	0.09
15-28	5	0.38	0.82
	10	0.32	0.61
	15	0.32	0.60
	20	0.31	0.67
	25	0.45	0.99
	30	0.05	-1.44
29-42	5	0.24	0.39
	10	0.33	0.43
	15	0.36	0.57
	20	0.28	0.57
	25	0.15	0.13
	30	0.47	-1.45
43-56	5	0.20	0.47
	10	0.12	0.29
	15	0.20	0.34
	20	0.19	0.46
	25	0.22	0.25
	30	0.32	0.75
0-56	5	0.29	0.57
	10	0.30	0.60
	15	0.33	0.62
	20	0.29	0.62
	25	0.28	0.56
	30	0.28	-0.49

Feed conversion efficiency (FCE)

During the first fortnight of the experiment, the FCE ranged between 0.33 and 0.56. The best conversion efficiency was registered by the prawns reared in 10 ppt (0.55) and 15 ppt (0.56) salinities. The conversion efficiency was moderately high in 20 ppt (0.46) while in the other salinities (5, 25 and 30 ppt), the same was considerably low (0.33-0.38). The low feed efficiency (0.33) noticed during the first fortnight in 25 ppt shotup considerably during the second fortnight to the highest level (0.45). The conversion efficiency was the least (0.05) in 30 ppt salinity. Though in 5 ppt the same level of feed efficiency was maintained as compared to that of the previous fortnight, it decreased considerably in the remaining salinities (10, 15 and 20 ppt), ranging from 0.31 to 0.32. During the third fortnight, the FCE showed a decline in 5 ppt (0.24), 20 ppt (0.28) and 25 ppt (0.15) salinities, while in all other salinities, it showed an increase with maximum in 30 ppt (0.47) salinity. The feed conversion efficiency in 10 and 15 ppt ranged from 0.33 to 0.36. During the fourth fortnight, a general decline in the feed efficiency was noticed in all the salinities which ranged from a minimum of 0.12 in 10 ppt to a maximum of 0.32 in 30 ppt. In 5, 15 and 20 ppt salinities, the FCE practically remained the same (0.19-0.20).

The feed conversion efficiency at the end of the feeding experiment (56 days) indicated a maximum of 0.33 in 15 ppt closely followed by 10 ppt salinity with 0.30 conversion efficiency. In all other salinities, the FCE remained more or

less uniform (0.28 - 0.29) at comparatively lower level.

Protein efficiency ratio (PER)

The PER is an indicator of the capacity of the animal to convert dietary protein into tissue growth. During the first fortnight, the PER varied from 0.78 to 1.35 in different salinities, the best ratio having been recorded in 15 and 10 ppt salinities (1.30-1.39). This was followed by the 20 ppt salinity in which the prawns showed a PER of 1.09. However, in 5 and 25 ppt salinities, it was less than 1.0 (0.78-0.82). In 30 ppt salinity, a very low PER of 0.09 was recorded. During the first and second fortnight, the PER recorded in the 5 ppt salinity was similar (0.82), but in 25 ppt the PER sharply increased to 0.99 as compared to the value (0.78) in the first fortnight. In the remaining salinities (10, 15 and 20 ppt), the PER showed a sharp decline and ranged between 0.60 and 0.67. In 30 ppt, the PER had a negative value because of mortality of prawns. During the third fortnight, the PER showed further decline and remained low in 5 to 20 ppt (0.39-0.57) salinities. In the case of 25 ppt salinity the PER in the third fortnight declined very sharply over the previous fortnight. Due to further reduction in survival, the PER in 30 ppt remained on the negative side during the third fortnight also. During the fourth fortnight, the PER showed a moderate increase in 5 ppt (0.47) and a sharp rise in 30 ppt (0.75). It was moderately high (0.46) in 20 ppt and remained low in 10, 15 and 25 ppt salinities.

The overall PER estimates for the entire experimental period indicated the highest value of 0.60-0.62 in 10, 15 and 20 ppt salinities. While, in 5 and 25 ppt salinities it remained almost same (0.56-0.57). In 30 ppt, the PER at the end of the experiment showed a negative value because of poor survival (10 %) of prawns.

Biomass production

Based on the weight gain recorded during the 56 days of rearing, stocking density and percentage survival in different salinities, the biomass production of M. dobsoni under laboratory condition has been studied using the method adopted by New, (1976) (Table 23). The total biomass increase per sq.m area was on the negative side in 30 ppt salinity due to poor survival (10 %). Among the other salinity levels in which the survival of the animals ranged 80-90 per cent, the maximum biomass production of 5.2047 g/sq.m was observed in 15 ppt salinity followed by production rates of 4.8339 g/sq.m in 20 ppt, 4.5857 g/sq.m in 10 ppt and 4.157 g/sq.m in 5 ppt salinities. The 25 ppt salinity recorded a low biomass production of 3.3803 g/sq.m.

Though the growth recorded was higher in 10 ppt as compared to that in 20 ppt, the biomass increase was better in 20 ppt than in 10 ppt, which may be attributed to better survival in 20 ppt (90 %) as compared to 10 ppt (80 %). From the above analysis it may be concluded that salinities ranging between 10 and 20 ppt provide the most suitable conditions

TABLE 23: Comparative growth and biomass production of M.dobsoni in different salinities in laboratory growth experiment

Particulars	Salinities (‰)					
	5	10	15	20	25	30
Average initial weight (g) .. (b)	0.120	0.120	0.121	0.123	0.120	0.120
Average final weight (g) .. (a)	0.546	0.638	0.704	0.593	0.509	0.456
Increase in av.weight(g).. (a-b)	0.426	0.518	0.583	0.470	0.389	0.336
Length of trial (days).. (x)	56	56	56	56	56	56
Average daily gain (mg/day) ..(*)	7.61	9.25	10.41	8.34	6.95	6.00
Initial stocking density (No/sq.m) .. (z)	11.77	11.77	11.77	11.77	11.77	11.77
Survival (%)..(y)	86.66	80.00	80.0	90.00	80.00	10.00
Biomass increase (g/sq.m) .. (**)	4.157	4.586	5.205	4.834	3.380	-0.876
Biomass increase/ day (g/sq.m/day)..(c/x)	0.0742	0.0819	0.0929	0.0863	0.0604	--

(*) $\frac{(a - b)\ 100}{x}$

(**) $c = \frac{azy}{100} - bz$

yielding maximum biomass, with the best performance in 15 ppt salinity.

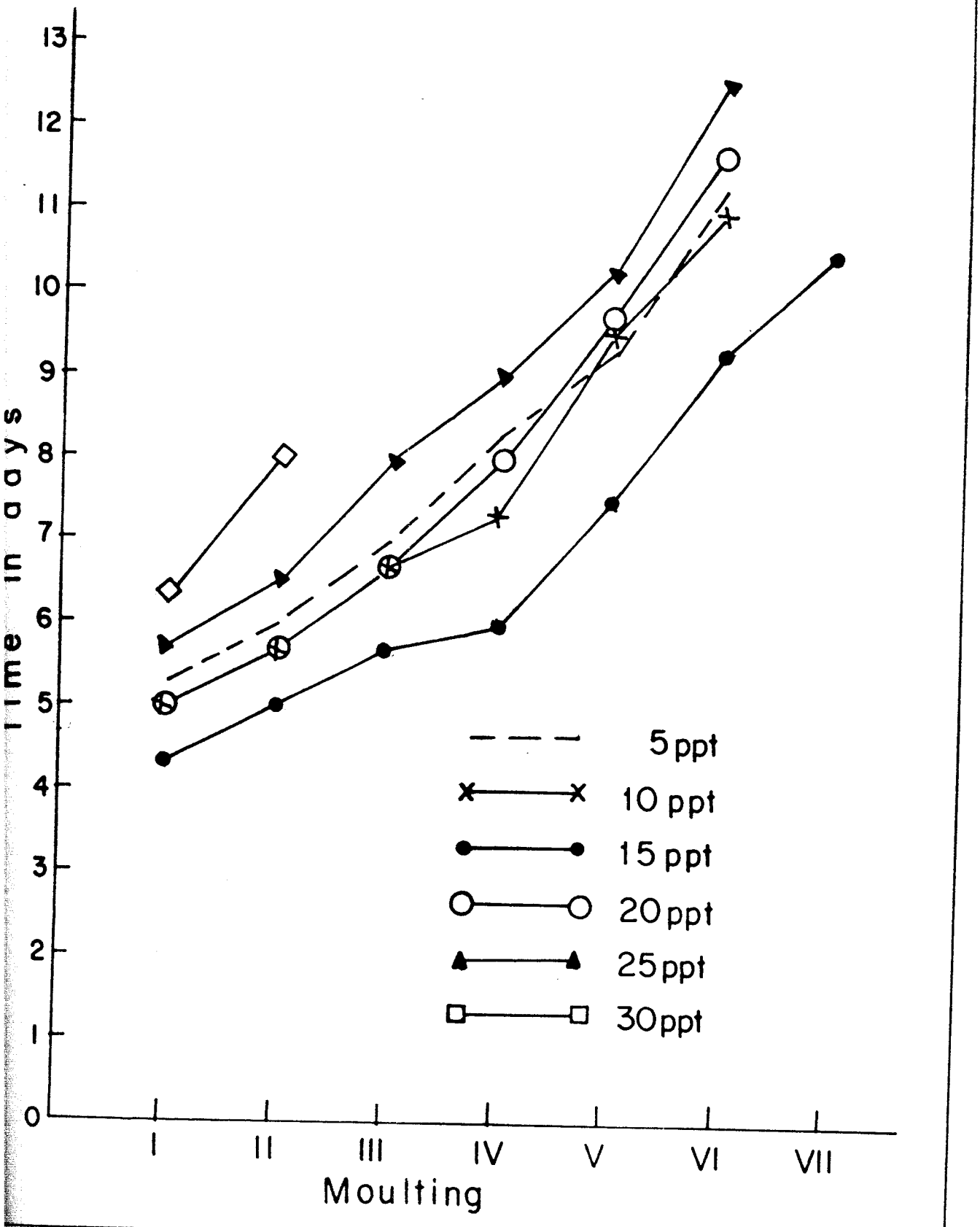
Effect of salinity on moulting periodicity

As moulting is very closely associated with growth of prawn, an attempt has been made to understand the effect of different salinities such as 5,10,15,20,25 and 30 ppt, on the moulting periodicity of M.dobsoni. For this, experiment in triplicate was conducted simultaneously with the growth studies using prawns ranging in length from 23.2 to 23.6 mm and in weight from 120.4 to 121.3 mg. The time taken for successive moultings in a total of seven moult cycles in different salinities are presented in Table 24 and the trend depicted in Fig.11.

It can be seen that the prawns moult frequently in salinities, but the time taken for successive moultings varied in different salinities. The animal took a minimum of 4.3 mean days in 15 ppt and a maximum of 6.3 mean days in 30 ppt for the first moulting. The mean days taken for the second moulting were the minimum in 10 and 20 ppt salinities. The mean days taken for the third moulting varied between 5.7 and 6.7 in 10, 15, and 20 ppt salinities whereas in 5 ppt it was 7.0, 20 ppt 8.0 and 30 ppt 10.0. The fourth moulting preceeded an intermoult period of 6 mean days in 15 ppt salinity, while in 10 and 20 ppt it was 7.3 and 8.0 days respectively. In all other salinities, the time taken was considerably more, ranging between 8.3 and 12.5 mean days. For the fifth moulting a minimum time of 7.5 mean days was recorded in 15 ppt salinity,

TABLE 24: Moulting periodicity in number of days of M. dobsoni in different salinities.

Salinity (‰)	Tub No.	Successive moultings						
		I	II	III	IV	V	VI	VII
5	Tub 1	5	-	-	8	10	12	-
	Tub 2	6	6	7	9	8	10	-
	Tub 3	5	6	7	8	10	12	-
	Mean	5.3	6.0	7.0	8.3	9.3	11.3	-
10	Tub 1	5	5	7	8	10	11	-
	Tub 2	5	6	7	7	-	-	-
	Tub 3	5	6	6	8	9	11	-
	Mean	5	5.7	6.7	7.3	9.5	11.0	-
15	Tub 1	4	5	6	-	-	9	11
	Tub 2	5	5	5	6	7	9	10
	Tub 3	4	5	6	6	8	10	-
	Mean	4.3	5.0	5.7	6.0	7.5	9.3	10.5
20	Tub 1	4	5	7	8	10	11	-
	Tub 2	6	6	6	8	9	11	-
	Tub 3	5	6	7	8	9	12	-
	mean	5.0	5.7	6.7	8.0	9.3	11.3	-
25	Tub 1	6	6	8	9	11	13	-
	Tub 2	5	-	-	9	10	12	-
	Tub 3	6	7	8	9	11	13	-
	Mean	5.7	6.5	8.0	9.0	10.3	12.6	-
30	Tub 1	6	8	10	12	13	-	-
	Tub 2	6	7	11	-	-	-	-
	Tub 3	7	9	9	13	14	-	-
	Mean	6.3	8.0	10.0	12.5	13.5	-	-



g.11: Moulting periodicity of M. dobsoni in the laboratory under different salinity conditions.

while, in 5, 10 and 20 ppt salinities the time taken was more or less uniformly higher (9.3-9.5 mean days). As usual, the maximum time lag was recorded in 25 and 30 ppt salinities. The longest mean intermoult period of 13.5 days was recorded in 30 ppt salinity. The sixth moulting took place in 9.3 days in 15 ppt salinity while in 5, 10 and 20 ppt, it occurred in almost the same period of time of 11.0 to 11.3 mean days. In 20 ppt the moulting was delayed by a little over a day. The seventh moulting was observed in 15 ppt salinity after a mean intermoult period of 10.5 days. It can be seen from the Table 24 that among all the different salinity media, the shortest intermoult period was recorded in 15 ppt salinity throughout the experiment, which ranged from 4.3 to 10.5 mean days showing progressive increase of intermoult period from the first to seventh moulting. In 10 and 20 ppt salinities, the time taken for the six successive moultings remained more or less same. The intermoult period was the longest in 30 ppt from beginning till end of the experiment.

The total time taken for completing six moultings in different salinites varied between 38 days in 15 ppt to 51 days in 25 ppt. In 30 ppt the animals could complete only five moults in 50.5 days. The mean weight attained by prawns in different salinities at the end of six moultings ranged from 462.31 mg in 5 ppt to 568.33 mg in 15 ppt. It was more or less uniform in 10 ppt (528.8 mg) and 20 ppt (545.1 mg) salinities, while in 25 ppt the mean weight was slightly low (499.64 mg).

Effect of salinity on biochemical composition

As the growth of prawn was observed to vary in different salinities, an attempt was made to correlate the differential growth rate with the biochemical composition of the muscle tissues of prawn raised in different salinities. The muscle tissue of six prawns raised in each of the salinities between 5 and 25 ppt, and three prawns raised in 30 ppt salinity were analysed for protein, carbohydrate, lipid and moisture. The results of the anlaysis are presented in Table 25, expressing the mean values in mg/100 mg dry tissue and the moisture in percentage. The extent of variation of each of the biochemical constituents between different salinities was tested statistically by ANOVA (Table 25).

The concentration of protein, varying between 58.50 mg and 68.50 mg, showed a steady increasing trend from 5 ppt to 20 ppt. In 25 ppt, the protein concentration dropped suddenly to 60.96 mg and increased again to 64.58 mg in 30 ppt salinity. The carbohydrate concentration showed a range of 0.07 mg in 10 ppt salinity to 0.21 mg in 20 ppt salinity. But for a decline in its level in 10 ppt salinity, the carbohydrate concentration maintained an increasing trend till 20 ppt salinity and thereafter it gradually declined. The lipid concentration maintained an upward trend from 5.97 mg in 5 ppt salinity to 8.51 mg in 25 ppt salinity. In 30 ppt salinity, however, a steep decline was noticed. The free amino acid content was highest in prawn of 5 ppt and the same after a steep fall in the beginning (10 ppt), declined gradually in all salinities, except

LE 25: Biochemical composition of muscle tissue of *M. dobsoni* grown in different salinities in the laboratoty.

ochemical ponents	Salinities (‰)					
	5	10	15	20	25	30
otein g/100mg dw)	58.50 ±2.91	59.38 ±4.47	64.74 ±4.59	68.51 ±4.46	60.96 ±3.40	64.58 ±2.13
rbohydrates g/100mg dw)	0.105 ±0.010	0.073 ±0.020	0.112 ±0.046	0.209 ±0.071	0.172 ±0.078	0.169 ±0.062
oids g/100mg dw)	5.971 ±0.340	7.23 ±0.50	7.35 ±0.99	7.48 ±1.10	8.51 ±0.70	7.08 ±1.24
e amino acid g/100mg dw)	0.774 ±0.121	0.373 ±0.114	0.333 ±0.080	0.111 ±0.039	0.232 ±0.081	0.095 ±0.010
isture (%)	76.97 ±0.12	74.57 ±0.41	73.18 ±0.83	71.95 ±0.42	70.10 ±0.14	69.07 ±0.45

ANOVA

chemical ponents	Source	df	ss	ms	F
tein	Treat	4	1260.430	315.107	18.63 **
	Error	25	422.938	16.918	
bohydrate	Treat	4	0.073	0.018	6.62 **
	Error	25	0.069	0.003	
id	Treat	4	21.017	5.268	8.64 **
	Error	25	15.236	0.609	
amino d	Treat	4	1.503	0.376	44.58 **
	Error	25	0.211	0.008	
ture	Treat	4	124.109	31.027	145.58 **
	Error	25	5.328	0.213	

t 0.01)

for a small rise in 25 ppt. The lowest free amino acid content of 0.095mg was recorded in 30 ppt. Moisture content was maximum (76.97%) in 5 ppt salinity which progressively diminished with the increase in salinity reaching the minimum of 69.07 per cent in 30 ppt salinity. The variation observed in all the above four biochemical constituents in different salinities have also proved to be statistically significant. ($P<0.01$).

Length-weight relationship

In normal and stable environmental conditions, the length-weight relationship of an animal can be expected to conform to the cubic relationship of length to weight. However, deviations from this normal pattern can occur due to differential growth rates caused by varying biotic and abiotic conditions of the environment to which the animal is exposed. In the case of M. dobsoni, the juvenile population inhabits a highly dynamic estuarine environment. In order to findout any possibility of changes in the length-weight relationship associated with change of salinity, which is the most highly fluctuating parameter of the estuarine environment, the length-weight data of 1912 prawns taken from the perennial prawn culture systems over different months have been analysed against three different salinity regimes from which the samples were drawn. The three different salinity regimes were 0-5 ppt, 10-15 ppt and 20-25 ppt, giving sufficient interval between them. As the animal has differential growth rate between sexes, the length - weight relationship has been worked out sex-wise.

Salinity	Sex	No.of prawns	'r'	Length-weight relationship
0-5	Male	240	0.9748	$W=0.0000140691\ L^{2.831855}$
	Female	426	0.9837	$W=0.0000127968\ L^{2.868963}$
10-15	Male	298	0.9881	$W=0.00000920456\ L^{2.908434}$
	Female	300	0.9893	$W=0.0000049805\ L^{3.069078}$
20-25	Male	315	0.9879	$W=0.0000103721\ L^{2.896303}$
	Female	369	0.9609	$W=0.0000140085\ L^{2.834686}$

The regression equation thus derived for the three different salinity regimes are expressed in the exponential form as above. It may be seen that the regression coefficient 'b' remained almost same (2.8319-2.8963) except in prawns sampled from 10-15 ppt salinity. In this case a higher 'b' value of 2.9084 was obtained for males and 3.0690 for females.

In order to test the variation of length-weight relationship regression lines for the prawns grown in different salinity regimes, ANCOVA Snedcor and Cochran,1967) was carried out and theresults are given in Tables 26 & 27a-d.

The regression coefficient of male (Table 26) in all the three salinity regimes (2.8319, 2.8963, 2.9084) does not vary significantly (F, 0.89953; d.f., 2.799), indicating almost a uniform length-weight relationship throughout the period of study.

In the case of female (Table 27a), on the contrary, the regression coefficient varied significantly as evident from

Comparison of length-weight relationship regression lines of males of M.dobsoni raised in different salinity regimes.

d.f.	Σx^2	Σxy	Σy^2	b	deviation from regression df	deviation from regression S.S	deviation from regression M.SS	F ratio
239	2.5495	7.2199	21.5173	2.8319	238	1.07135	0.0045	
247	13.8456	40.2691	119.9525	2.9084	246	2.83257	0.01151	0.89953
314	2.9965	8.6789	26.8300	2.8963	313	1.69280	0.005408	
					797	5.596727	0.007022	
800	19.3917	56.1679	168.2998		799	5.60936	0.0070204	
etween slopes					2	0.012633	0.0063165	

Comparison of length-weight relationship regression lines of females of M.dobsoni raised in different salinity regimes.

d.f.	Σx^2	Σxy	Σy^2	b	deviation from regression df	deviation from regression S.S	deviation from regression M.SS	F ratio
425	5.1424	14.7558	43.7456	2.8689	424	1.4043	0.003312	
313	27.2379	83.5951	262.7766	3.0691	312	6.2167	0.01993	17.33176
368	4.4179	12.5235	38.4460	2.8347	367	2.9459	0.008027	
					1103	10.5668	0.00958	
1106	36.7982	110.8745	344.9683	---	1105	10.8988	0.009863	
tween slopes					2	0.33208	0.16604	

Comparison of length-weight relationship regression lines of females of M.dobsoni raised in different salinity regimes.

	d.f.	Σx^2	Σxy	Σy^2	b	deviation from regression df	deviation from regression S.S	deviation from regression M.SS	F ratio
	425	5.142367	14.75584	43.74563	2.86896	424	1.40427	0.003312	0.52296
25	368	4.417951	12.5235	38.44603	2.83469	367	2.94585	0.008027	
						791	4.35012	0.00549951	
	793	9.560318	27.27934	83.19166	--	792	4.352996	0.0054962	
e between slopes						1	0.002876	0.002876	
	425	5.142367	14.75524	43.74563	2.86896	424	1.40427	0.003312	16.646868
5	313	27.23787	83.59513	262.7766	3.06908	312	6.21668	0.01993	
						736	7.62095	0.0103545	
	738	32.380237	98.35097	306.52223		737	7.79332	0.0102574	
e between slopes						1	0.17237	0.17237	
5	313	27.23787	83.59513	262.7766	3.06908	312	6.21668	0.01993	15.477134
5	368	4.417951	12.5235	38.44603	2.83469	367	2.94585	0.008027	
						679	9.16253	0.0134941	
	681	31.655821	96.11863	301,22263	--	678	9.37138	0.013781	
e between slopes						1	0.20885	0.20885	

a very high 'F' value (F 17.33176; d.f. 2, 1105). In order to findout which of the salinity groups show significant variation, the ANCOVA (Table 27 b,c,d) was carried out for the possible three combinations of salinity regimes, such as 0-5 ppt and 20-25 ppt, 0-5 ppt and 10-15 ppt and 10-15 ppt and 20-25 ppt. The test indicated that the regression coefficient of females grown in 0-5 ppt and 20-25 ppt did not vary significantly (F.0.52296; d.f., 1,792), whereas in the remaining two combinations of salinity regimes, the regression coefficient showed significant variation as evident from high 'F' value (F. 16.646868; d.f., 1,737 and F.15.477134, d.f., 1.678) in both the cases. From the above results it could be inferred that female prawns grown in 10-15 ppt salinity have a higher value of regression coefficient as compared to the same in 0-5 ppt and 20-25 ppt salinity regimes. However, in all the salinities, the value of 'b' remained very close to '3' indicating a perfect cubic relation of length to weight (isometric growth).

Size, count and meat recovery relationship

The catch of M.dobsoni either from wild or from culture fields also forms a part of the frozen sea foods exported by the industry. The quality of prawns for processing is largely determined on the basis of count per kg headon, headless or peeled & deveined. The economic returns of prawns in the processed form is directly proportional to the diminishing counts per kg. Keeping this in view, an attempt has been made to study the relationship of different size groups of the species with its count per kg in headon, headless and

-eled & deveined condition and also their wet weight recovery for males and females separately and the result are presented in Tables 28 and 29, and the trends depicted in Fig. 12 A,B.

Though in all the smaller size groups the count per kg of all the three different forms exhibited some deviations between the two sexes, the males showed higher count in the larger size groups beyond 60 mm size. The largest size group of 76-80 mm in male has given a count of 315 headon, 443 headless and 575 peeled & deveined prawns. In females, the corresponding size group has given a count of 313 headon, 439 headless and 572 peeled & deveined. A progresive reduction in the count per kg was noticed in all the three different forms with the increase of size in females. In the largest size group of 96 to 100 mm encountered in the perennial prawn culture system, the headon prawns numbered 156, headless 230 and peeled & deveined 284 per kg, indicating a highly satisfactory level of count per kg for the three different forms.

The relationship between size of prawn and the count per kg in headon, headless and peeled & deveined condition is given by the following linear equations.

Males	Females
Ho=17.279-2.739 ln Sz	ln Ho = 18.148 - 2.852 ln Sz
Hl=16.891-2.457 ln Sz	ln Hl = 18.299 - 2.796 ln Sz
Pd=18.312-2.731 ln Sz	ln Pd = 18.801 - 2.856 ln Sz

where Ho= headon, Hl = headless, Pd = peeled & deveined condition and Sz = Size of prawn.

TABLE 28: Counts of headon, headless and peeled & deveined prawns raised in brackishwater systems.

Size groups (mm)	Males - Count/Kg.			Females - Count/Kg.		
	Headon	Headless	Peeled & deveined	Headon	Headless	Peeled & deveined
41-45	1681	2381	3115	1709	2427	3205
46-50	1183	1675	2174	1198	1675	2207
51-55	978	1379	1786	948	1379	1758
56-60	739	1027	1350	754	1076	1381
61-65	602	871	1144	571	821	1044
66-70	502	732	965	433	629	820
71-75	389	547	708	376	554	707
76-80	315	443	575	313	439	572
81-85	-	-	-	271	400	509
86-90	-	-	-	235	354	444
91-95	-	-	-	180	267	333
96-100	-	-	-	156	230	284

Relative wet weight recovry of headon, headless and peeled & deveined prawns by size groups.

Total No. of animals studied.	Head on		Headless		Peeled & deveined	
	Mean Length (mm)	Mean wet weight (g)	Mean wet weight (g)	Wet weight recovery (%)	Mean wet weight (g)	Wet weight recovery (%)
10	44.0	0.595	0.420	75.6	0.321	54.0
10	48.6	0.845	0.597	70.7	0.460	54.4
14	53.3	1.023	0.725	70.9	0.560	54.7
14	58.1	1.353	0.974	72.0	0.741	54.8
15	62.7	1.662	1.148	69.1	0.874	52.6
11	67.5	1.991	1.367	68.7	1.036	52.0
10	72.2	2.572	1.828	71.0	1.412	54.9
5	78.0	3.180	2.258	71.0	1.738	54.7
10	42.5	0.585	0.412	70.4	0.312	53.3
10	48.0	0.835	0.597	71.5	0.453	54.2
10	52.8	1.055	0.725	68.7	0.569	53.9
10	58.1	1.326	0.929	70.1	0.724	54.6
14	62.9	1.751	1.218	69.6	0.0958	54.7
11	68.1	2.309	1.590	68.9	1.219	52.8
11	72.9	2.662	1.806	67.8	1.415	53.2
10	77.8	3.199	2.279	69.9	1.749	53.9
10	82.0	3.688	2.499	67.8	1.964	53.3
10	86.5	4.255	2.824	66.4	2.252	52.9
8	93.0	5.545	3.743	67.5	2.994	54.0
5	96.7	6.397	4.340	67.8	3.518	55.0

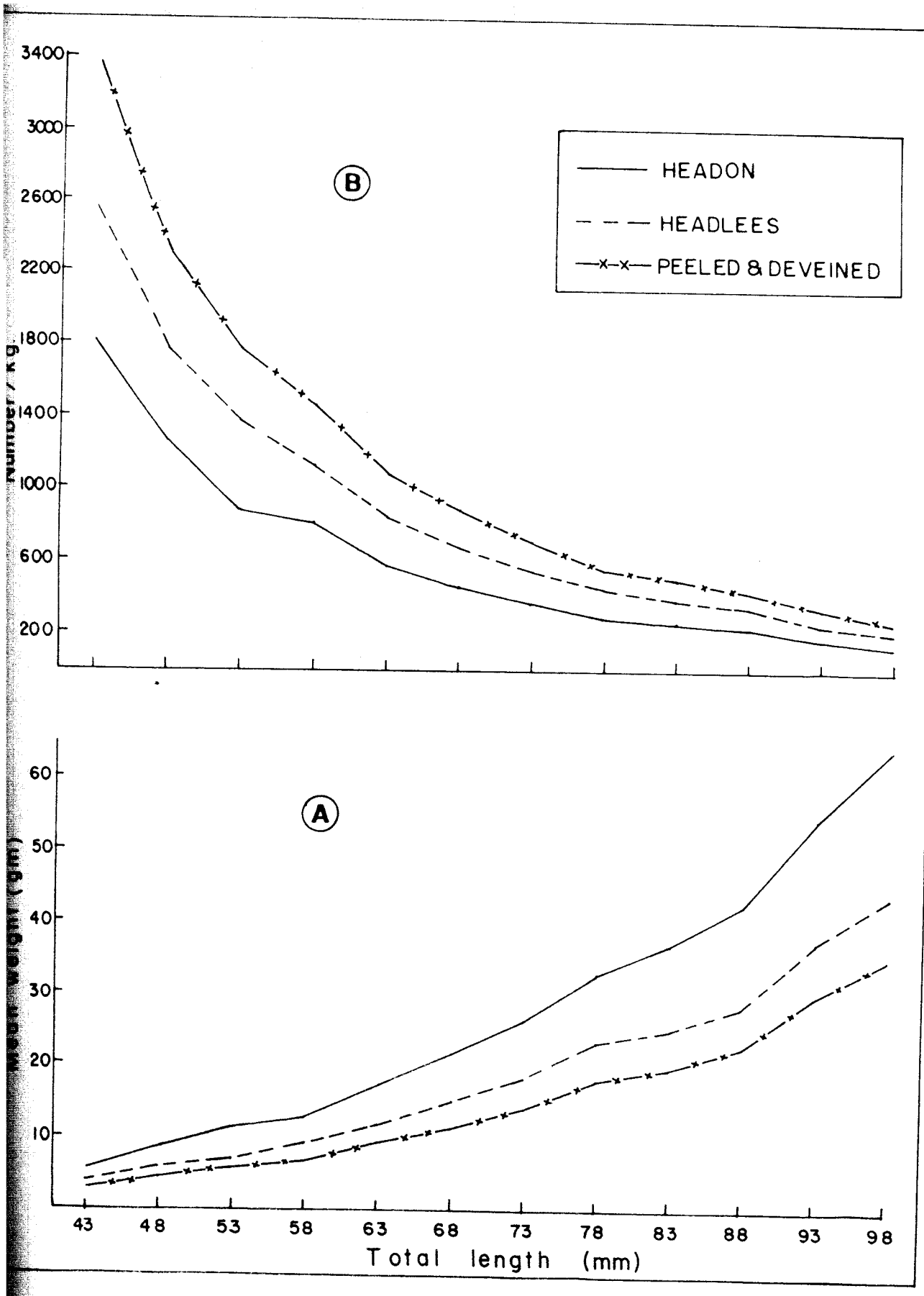


Fig.12: A - Relationship between length and weight of M. dobsoni headon and recovery in headless and peeled & deveined conditions.

B - Count per Kg. of M. dobsoni headon, headless and peeled & deveined.

As in the case of count per kg, the smaller size groups showed some inconsistencies in the mean weight for the identical size groups of the two sexes in headon, headless and peeled & deveined condition. In most of the size groups the males recorded comparatively higher pecentage of wet weight recovery in headless condition than in females for the corresponding sizes. The percentage recovery of headless prawn worked out to 70.7-75.6 for the smaller sizes below a mean length of 58.1 mm, while it was slightly low (68.7-71.0%) in larger sizes. The percentage of meat recovery remained more or less same in all the size groups at about 54.0-54.9 except a slight reduction (52.0-52.6%) in the size group 61-70 mm. In the case of females, the wet weight recovery of headless prawns showed a marginal decline from smaller to larger size groups. The percentage wet weight recovery in peeled & deveined condition remained more or less steady between 52.8 and 55 per cent for the different size group. The percentage of meat recovery in the two sexes is found to be more or less same for all the identical sizes grown in the culture system.

D I S C U S S I O N

Various authors have studied the recruitment, growth, distribution and emigration of M.dobsoni in the open brackishwater system of Cochin backwaters and have indicated that this species forms the most dominant one among all the estuary-dependent penaeid prawns of the area. According to Mohamed and Rao (1971) the species, after having recruited at late mysis or postlarval stages, stay in this environment for a minimum period of 5 months and return to the sea at a minimum size of 50 mm. During its stay in the backwater, the species migrates as far as the southern part of the Vembanad lake (South of Thanneermuckom bund), dispersing to more than 50 kms from the barmouth and withstanding very low salinity conditions near to freshwater (George & Suseelan, 1982). It is also reported by Mohamed and Rao (1971) that prawns of even 90 mm are encountered in this backwater, where they grow rapidly upto about 65 mm at an average growth rate of about 10 mm/month. Following the progression of modes in the size frequency distribution, these authors have recorded the highest growth rates of 10.5-11.0 mm/month for the sizes ranging about 23 to 65 mm during May-September when a considerable reduction in salinity occurs as a result of the onset of Southwest monsoon and the influx of freshwater. Taking into consideration the fast growth in early stages, they have also inferred that the emigration of the species from the ecosystem comencess in the prawns are about four months old, although they remain in the backwater for still longer period.

Growth in traditional prawn culture fields

A perusal of available literature on prawn culture in the traditional prawn culture systems would indicate that most of the earlier works dealt with the fishery and yield potential, while, only little has been recorded on the growth rates of the species. George et. al., (1968) while making observation on the paddy field prawn filtrton of Kerala, indicated that the prawns are entrapped in the culture system for about 5-6 weeks growth when species of Metapenaeus attained a growth increment of about 15 mm. These authors have also pointed out that culturing of juvenile prawns for about a month resulted in relatively better catches of large sized prawns than could be obtained by cultivation for longer periods. George (1974), studying the prawn fishery of the seasonal and perennial prawn culture fields of Vypeen island, observed dominance of M. dobsoni, which some times contributed as high as 80 per cent of the prawn catch. In the seasonal field, he recorded a size range of 36-70 mm with mode at 50-60 mm for the species. In the perennial fields, the species showed a size range of 16-110 mm with majority of the animals belonging to 45-85 mm size group. He has also noted an average growth rate of 10.0 mm/ month for the species in these fields, which is more or less similar to the growth rate arrived at (9.88 mm/month) by Mohamed and Rao (1971) from the open backwater. During the present study the size range of the species recorded in the two perennial prawn culture fields ranged from 23mm to 89 mm for males and 20 mm to 105 mm for females. The major size group recorded was 51-65 mm in males

size for this sex. In the case of females, a much faster growth is observed than in males. The prawns with an initial size of 20-22 mm, show the highest growth rates during the initial three months with the monthly growth increments ranging from 19.7 to 20.1 mm in the first month, 14.0 to 14.5 mm in the second month and 11.5 to 12.1 mm in the thrid month when they reach a harvestable size of about 66-69 mm. In the subsequent two months also a fairly good growth rate (6.7 - 9.0 mm) is observed in both the culture systems. At the end of the fifth month the prawn attains an average size of 84 mm.

According to Rao (1973) and Muthu et.al. (1978a), M. dobsoni takes 12 days to complete metamorphosis and 20-30 days to reach a size of about 20-25 mm. Taking into consideration the one month period that has elapsed before entry into the culture system, the male at a size of about 64 mm and the female of about 76 mm can be of five months old. Mohamed and Rao (1971) estimated the age of 50 mm size M.dobsoni grown in Cochin backwater as five months, when they start emigrating to the sea. The much higher growth rates observed during the present study would suggest that the age of the prawn when it commences the seaward migration from the backwater could be about three months. Kurup and Rao (1974), studying the inshore prawn fishery of Ambalapuzha, estimated the size of the species as 58.1 mm for males and 72.8 mm for females at the end of six months, 97 mm for males and 122 mm for females at the end of one year, and concluded that the bulk of the inshore fishery was constituted by 7 to 12 month old prawns. Achuthankutty and

Parulekar (1986c) obseved that males attain a size of about 86 mm and females 105 mm in the first year of their life in the inshore waters of Goa.

A perusal of Table 10 would reveal that the female M.dobsoni grown in Thoppilkettu has taken more than a year to attain a maximum estimated size of 102 mm, thereby showing a slightly slower growth when compared to the growth estimated by Kurup and Rao (1974) and Achuthankutty and Parulekar (1986 c). As the growth rates recorded in the initial five months during the present study were appreciably high as compared to the growth estimated by Kurup and Rao (1974), it may be presumed that the slower growth would have occurred in the higher size groups in comparison with the growth of the indentical size groups studied by these workers from the inshore sea. The only possible explanation to this apparent retardation of growth in the higher size groups could be the physiological stress caused by the prolonged stay of the animal in the culture ecosystem. The view expressed by George et. al. (1968) that culturing prawns for shorter period of about a month result in relatively better catch of large sized prawns holds good in the context of the present observation, and it may be inferred that trapping and growing M dobsoni for two to three months period in the perennial prawn culture fields would bring in better catch returns with relatively large sized prawns.

Growth and biomass production in coconut grove canal system

The experimental culture of M. dobsoni in the coconut grove canal system, with an initial size of 28.1 mm has yielded

a total length gain of 73.7 mm in males and 79.2 mm in females in 140 days. This growth increment is slightly higher than the growth observed in the perennial prawn culture systems for about the same period of culture. A close look at the monthly growth estimates (Table 13) made from the fortnightly growth increments would indicate a much faster growth (17.6 mm for males and 23.5 mm for females) than the growth in the perennial prawn culture fields (12.2-15.6 mm for males and 19.7 to 20.1 mm for females) during the first month of culture. However, in the second month, a drastic reduction is noticed in the growth rate in this system, whereas in the perennial prawn culture field such a steep fall in growth rate is observed after two or three months of growing period. The only possible reason that can be ascribed to this difference is perhaps the limited supply of natural food and restricted living space available for the prawns in the coconut grove canal as compared to the possibly better living conditions existing in the perennial prawn culture systems. The quick increase in size during the first month and a sudden fall in growth thereafter would suggest that the prawn utilizes fully the available natural food supply of the canal system resulting in a fast growth, but becomes unable to maintain the same probably due to the shortage of natural food in the absence of supplementary feeding during the second month. It is possible therefore that if adequate supplementary feeding is done during the culture period, a better and steady growth rate could be obtained in this system. By prolonging the period of growth through supplementary feeding during the

initial period of culture, it is also possible to increase the production rate to a much higher level than in the perennial prawn culture system.

The data on monthly weight gain during different months of culture period in the coconut grove canal system (Table 13) shows a consistant increase in weight gain till the animal attains a size of 56.8 mm in male and 61.3 mm in female towards the end of the second month of culture. This is followed by a sudden drop in weight gain which may be correlated with the physiological change in the animal's body associated with maturation. The weight gain picks up momentum in the subsequent month.

Lazarus and Nandakumaran (1990), during their fish/prawn culture experiments in polyethylene film-lined ponds on Calicut beach, noticed more or less similar pattern of growth for M.dobsoni. During their culture in the impoundment, where the salinity varied between 7.1 to 30.5 ppt, the eggs of M.dobsoni got accidentally pumped in and the larvae grew to about 64 mm during the first two months. In the subsequent five months, however, it has been observed that the prawns increased only 14mm more, thereby indicating a severe retardation of growth after the initial two months of very rapid growth. This faster growth may be attributed to the supplementary feeding done during the experiment.

A measure of biomass production, as suggested by New (1976), is a reliable indicator of biological productivity of

the candidate species since it takes into consideration the area, stocking density, survival and growth in the culture system. During the 140 days growing period a total estimated biomass production of 5.902 kg of M.dobsoni in the experimental area of 294 sq m and a per hectare production rate of 200 kg for the coconut grove canal system indicate a low productivity of the species. Higher stocking rates coupled with supplementary feeding appears to be essential for enhancing the production rate.

Effect of ecological factors on growth

The ecological parameters such as temperature, salinity, oxygen and pH recorded during the present study period showed a range of 26.3 to 33.1^{o}C, 2.45 to 22.60 ppt 3.78 to 7.55 mg/l and 7.35 to 8.19 resepctively in Kannuvilakettu and 28.4 to 33.0^{o}C, 3.64 to 19.01 ppt, 3.70 to 9.49 mg/l and 7.23 to 8.06 in Thoppilkettu, indicating almost a similar ecological condition for both the culture systems. These ecological parameters compare well with the observations of Qasim et. al (1969) Josanto (1971), Gopinathan et. al., (1974), Nair and Kutty (1975) and Sankaranarayanan and Qasim (1969) from Cochin backwaters and those of Gopinathan et al (1982) and Nair et. al. (1982) from the seasonal and perennial prawn culture fields, which are considered as good growth yielding ecosystems. A comparison of the nutrient levels during January to June 1991 in the two perennial prawn culture systems (Tables 3 and 4) with those recorded by Gopinathan et. al., (1982) for the neighbouring culturing fields in the Vypeen island would

indicate that the present culture systems can be rated as highly productive for better prawn growth. The standing crop of zooplankton (Fig. 2) studied for the corresponding period indicated a marginally higher productivity in Kannuvilakettu (45.28-68.10 ml/100 m^3) than in Thoppilkettu (31.85-56.60 ml/100 m^3). Although better growth of prawn was recorded in Kannuvilakettu during this period, the comparatively higher mean sizes noticed in Thoppilkettu durng 1990 does not permit correlation of the growth variation with any single environmental factor.

The coconut grove canal system also appears to have more or less similar productivity as observed in the two perennial prawn culture systems except for a comparatiely higher nitrate level (4.3-59.5 µg at/l). The sediment organic carbon (1.10-2.86 %) and organic matter (1.86-4.86%) were higher than those observed in the seasonal and perennial prawn culture systems. According to Banerjea (1967), organic carbon of 1.5 to 2.5 per cent is optimal and above 2.5 per cent is high for fish production ponds. A comparatively high zooplankton biomass of coconut grove canal system indicated a high rate of secondary production than in the perennial culture systems. No noticeable differences could be observed in temperature (28.0-33.0°C), salinity (2.87-18.62 ppt), oxygen (4.26-9.26 mg/l) and pH (7.27-8.65) in these two types of ecosystems. The higher secondary production in the coconut grove canal system would have been a reason for slightly better growth of prawns.

Effect of salinity on survival, growth and food utilization

It is seen from the laboratory experiments that salinity greatly influences the survival, growth, biomass production, food conversion, protein efficiency, moulting periodicity and biochemical composition of M. dobsoni during its juvenile phase. The influence of various water quality parameters on growth of prawn in the laboratory are also discussed.

A high survival rate of 80-90 per cent is associated with all the tested salinities (5,10,15,20 and 25 ppt) except 30 ppt salinity, in which the survival was very low. As the minimum salinity of the present study was 5 ppt, nothing can be said from this experiment as to the possibility of survival of the prawn in still lower salinity conditions. Published information on the distribution of M.dobsoni in the Vembanad lake and Cochin backwater (George, 1962; Rao, 1972; Mohamed and Rao, 1971; Kuttyamma, 1975; George and Suseelan, 1982; Suseelan and Kathirvel, 1982 a,b) reveal that postlarval and juvenile stages of the species occur in areas of very low salinities, sometimes almost in freshater condition, where other penaeids are rarely encountered . According to Kuttyamma (1982), the species prefers low salinity during postlarval period and some what higher salinities during the juvenile period in Cochin backwaters. Since the estuarine and backwater systems are always influenced by tide, it is likely that such a very low salinity condition may not be a prolonged situation to which the prawn is exposed. With the frequent variation in salinity

levels caused by the tidal influence, the animal may get physiologically adjusted to such low salinity conditions. In their salinity tolerance studies on P.monodon, Navas and Sebastian (1989) observed complete mortality of juveniles in less than 1 ppt salinity within two hours of transfer without pre-acclimation. When the salinity was gradually decreased, a survival rate of 53.34 per cent was recorded even in 0.5 ppt salinity, while still lower salinity proved to be lethal for juveniles. With these results the authors have demonstrated how the juvenile prawns adjust to the highly fluctuating salinity conditions of the estuaries and survive extreme low salinities during monsoon period. In the laboratory experiment, Rao (1973 a,b), observed that the postlarvae of M.dobsoni tolerated salinities upto 5.6 ppt, and when exposed to salinities below this value the animals became weak and died at 0.9 ppt. Raj and Raj (1982) experimentally proved that high survival rates in P.indicus occurred at low salinity levels of 5, 10 and 25 ppt and low survival rates in 35 and 45 ppt salinities.

The growth experiments carried out in the laboratory for 56 days have indicated recognisable variation in growth rates in different salinities. The growth rate in terms of length as well as weight proved to be maximum in salinities between 10 and 20 ppt. Within this range both length and weight increase have been found to be the highest in 15 ppt salinity. Through field studies as well as laboratory experiments many authors have pointed out that the salinity influences greatly the growth rate of penaeid prawns. Kuttyamma

(1982), carrying out a series of laboratory experiments extending for a month on the effect of salinity on growth of M dobsoni along with a few other species of penaeids, has arrived at the conclusion that good growth and survival of postlarvae of the species occur in 10 and 15 ppt salinities, while, juvenile prawns show best growth in 20 ppt salinities. This author has also found that postlarvae acclimated to 5 ppt salinity recorded maximum growth in 10 ppt and lowest growth in 35 ppt. The juveniles acclimated to 5 ppt salinity recorded maximum growth in 15 ppt and lowest in 35 ppt, while those acclimated in 30 ppt showed maximum growth in 25 ppt and lowest growth in 5 ppt salinities. Raj and Raj (1982) studied the effect of different salinities on the growth and suvival of P.indicus, P.mondon and P. semisulcatus and found that salinities of 15 and 25 ppt gave higher growth and survival rates in all the three species. They further observed that the growth and survival of P.indicus were adversely affected by high salinity levels of 35 and 45 ppt. In the present study, though the preferred salinities for better growth varied between 10 and 20 ppt. the growth and survival were adversely affected in 30 ppt. Nair and Kutty (1975) reported that the growth of P. indicus in the laboratory was significantly higher in a salinity of 10 ppt for postlarval stages and 30 ppt for juveniles. In related species P.monodon, on the otherhand, Navas and Sebastian (1989) obseved that even though very low salinities (less than 2 ppt) had a highly significant influence on the growth rate of juveniles, salinity ranging from 9-20 ppt did not influence growth rate

significantly. Zein-Eldin (1963) and Zein-Eldin and Aldrich (1965) reported that the growth of P.aztecus was not affected by salinity except under extreme temperature conditions. Venkataramaiah (1974) disagreed with these findings and put forward that the postlarvae of the species grew very fast in low saline waters. They have also stated that although the young shrimp can survive a wide salinity range, the best growth and survival rates were obtained in optimum salinities of 8.5 and 17 ppt. According to Kinne (1970), in most of the euryhaline invertebrates growth is restricted to a narrower range than survival is. Apart from salinity, other environmental factors like temperature either independently or in combination with salinity are known to influence growth and survival of prawns. Zein-Eldin and Aldrich (1965) have shown that combinations of low salinity and low temperature are detrimental to postlarvae of P. aztecus Williams (1960) has reported that the juveniles of P. aztecus. Williams (1960) has reported that the juveniles of P. aztecus and P.duorarum, although inhabit wide ranges of salinities, survive better in higher salinities at low temperature.

The compounded pelletized feed used for studying the growth of M.dobsoni in the present study was prepared in accordance with the requirements of protein, carbohydrate, fat, minerals and vitamins as shown by some of the penaeid prawns Colvin, 1976; Colvin and Brand, 1977; Sedgwick, 1979; Shannappa, 1977; Ali, 1982 a,b,; Andrews et. al., 1972; Sick and Andrews, 1973; Kanazawa and Teshima, 1977; Kanazawa et. al.,

1977, Deshimaru et. al., 1979; Kitabayashi et. al., 1971; Kanazawa et al., 1984; Kanazawa et. al., 1977 and Deshimaru and Kuroki, 1976, 1979). Generally in the laboratory experiments, the prawns are fed at 8-20 per cent of wet body weight of dry feed (Venkataramaiah et. al., 1974; Katre and Reddy, 1976; Royan et. al., 1987). Similar feeding regime was followed in the case of M.dobsoni in the present study. The prawns were first offered feed at the rate of 15 per cent of their body weight. It was gradually reduced to 7.5 per cent according to the consumption of feed by the prawns as observed from the left-over feed daily. However, it was ensured that the feed was available to the animals all through the day.

The results have shown that the feed conversion efficiency (FCE) gradually decreased with time, showing minor fluctuations. The FCE was found to be the best in the initial phase of growth (first fortnight) and gradually declines as the prawns grow. The investigations carried out in the present study on the impact of salinity on FCE gave interesting results. The FCE was highest in the prawns reared in 15 ppt salinity, even through the FCE recorded in 10 and 20 ppt salinities are not significantly different from the FCE recorded at 15 ppt salinity. This shows that M.dobsoni has the capacity to best utilize the feed under the salinity range of 10 to 20 ppt with a preferable salinity of 15 ppt. This has corroborated the result of growth studies (Table 19 & 20) carried out, in which the maximum growth of prawn was recorded in the salinity range of 10-20 ppt, again with best growth in 15 ppt salinity. The

results have also clearly indicated that salinities below 10 ppt and above 20 ppt are not favourable for proper utilization of feed for this prawn. Venkataramaih et al. (1974) while studying the effects of salinity on growth and FCE of P.aztecus, observed that the best FCE is recorded at salinities ranging from 8.5 to 17.0 ppt. This is in agreement with the results obtained in the present study in the case of M.dobsoni. Further, the growth studies conducted on different species of penaeid prawns indicate better growth in salinity range of 15 to 20 ppt (Nair and Kutty 1975; Kuttyamma, 1982; Raj and Raj, 1982). New (1976), while reviewing the studies on nutrition of shrimp and prawn indicated that most of the laboratory experiments with penaeid prawns are conducted in a salinity ranging from 15 to 25 ppt. The results of the present study with M. dobsoni are in full agreement with the observations made in the case of most of the penaeid prawns. Similar observations of best FCE have been made in finfish. Cyprinodon macularis shows a maximum FCE at the optimum salinity of 15 ppt (Kinne, 1960). Similarly, the mullet Liza parsia showed significantly better growth and FCE in the optimum salinity range of 15 to 25 ppt for the fish fry (Raj and Kiron, 1988). Corroborating these observations, M. dobsoni showed maximum FCE in the salinity range of 10 to 20 ppt, which is found to be the optimum range for this prawn.

The FCE is also influenced by the rate of feeding of the recipient animals. Royan et al(1987) recorded a FCR of 1.24-5.0 in P. indicus, 1.16-3.41 in M.dobsoni and 0.97-3.99 in M.monoceros at different feeding levels. The authors observed

better FCR at 15 per cent feeding rate. Sumitra Vijayaraghavan et al. (1982) also recorded maximum FCE in M.monoceros at 15 per cent feeding level. Similar observations were made on carridean prawns also. Katre and Reddy (1976) recorded maximum FCE at 10 per cent feeding level in Palaemon lamerrei and Ponnuchamy (1981) obtained highest FCE at 15 and 30 per cent feeding levels in Macrobrachium lanchesteri and Cardina weberi respectively. The feeding levels adopted for M.dobsoni (7.5-15 % of body weight) are also in the same range as adopted in the above studies. In the present study this species showed highest FCE at the feeding levels ranging from 7.5 to 15.0 per cent.

The protein efficiency ratio (PER) in M.dobsoni showed a similar trend as that of feed conversion efficiency (FCE). PER was found to be the highest in the first fortnight which coincided with period of maximum growth of prawns and it gradually decreased to the minimum in the fourth fortnight. In otherwords, the PER has decreased as the animal grew in size. This may be mainly due to the reduction in the intake of feed per unit weight of body of the animal coupled with increased metabolic needs as the size of the animal increases. Similar observations have been made by Lazarus et al. (1988) in P. indicus and Alava and Lim (1983) in P. monodon. In the present study high PER values are recorded at 10, 15 and 20 ppt salinity and the difference between PER's obtained at these three salinities is not significant, indicating once again that the prawn M.dobsoni has better dietary protein utilization for growth in salinity range of 10 to 20 ppt. Among the three

salinities at which the PER is determined, the animals reared in 20 ppt salinity showed marginally higher PER which may be due to higher survival of prawns at this salinity compared to that of 10 and 15 ppt salinities Once again the determination of PER at different salinities pointed to the optimum salinity range required by M. dobsoni as in the case of FCE and growth.

Studies on the effect of salinity on PER in prawns are meagre. Kalyanaraman (1983) recorded lowest PER at 5 ppt in postlarval and juvenile stages of P. indicus, which is attributed to enhanced catabolism of protein as being reflected by the elevated levels of ammonia. The maximum PER for postlarvae and juveniles were recorded in 20 and 25 ppt salinities respectively. Studying the effect of different protein levels on PER in P.monodon, Alava and Lim (1983) indicated that PER increased with increase in dietary protein upto 40 per cent but decreased when the protein level was further increased. The highest PER of 0.34 was noticed by Sedgwick (1979) in P.merguiensis, who found that PER increased as the protein level in the diet decreased, when the quantity of protein consumed by the prawn varied from 26.5 to 143.9 g. An inverse relation between PER and dietary protein was recorded by Colvin (1976) in P.indicus. Similar observations were also made by Ogino et.al.(1976) in carp and rainbow trout. This suggests that more protein is diverted to catabolic activities as the protein in the diet increases. When dietary protein becomes excessive more and more proteins may be wasted either unassimilated or through increased catabolic activity. Hajra et

al. (1988) also observed a steady increase in PER and growth concomitant with increase in total carbohydrate and gross energy in P.monodon which suggests that only optimum protein level should be used in the diet for obtaining best protein efficiency ratio.

From the above discussion, it may be concluded that the salinity of the medium in which the prawns are grown has marked impact on the FCE and PER as in the case of growth. It is also clear that M. dobsoni effectively utilizes the feed in the salinity ranging from 10 to 20 ppt.

Estimation of growth and biomass production of M.dobsoni in different salinity levels under laboratory conditions (Table 23) has shown a daily weight gain ranging from 6.00-10.41 mg with the highest value of 10.41 mg in 15 ppt, followed by 9.25 mg in 10 ppt and 8.34 mg in 20 ppt. The biomass production is also found to be maximum in 15 ppt (5.21 g/sq.m) salinity. Though the daily growth is found to be higher in 10 ppt than in 20 ppt, a reverse order is observed with regard to biomass production between these two salinities. This change is attributed to higher survival rate in 20 ppt (90 %) than in 10 ppt (80%) salinity.

In common with other members of crustacea, the prawns periodically cast away their exoskeleton in order to grow. The moulting is observed throughout their life and the periodicity of moulting depends upon a number of factors such as availability of food, temperature, salinity, size of prawns and the influence of hormones. Among all these factors salinity

appears to be an important one as it is the master factor involved in the process of osmoregulation (Gilles and Pequex, 1983), which inturn affects moulting and growth. Extremely limited information is on record regarding the effect of salinity or any other abiotic factors of the environment on moulting of penaeid prawns. Vijayan (1988) noticed that moulting and growth of P.indicuswere affected by the varying levels of salinity. The moulting occurred at a faster rate at 15 ppt with an accelerated growth when compared to all other tested salinities. This author also observed that prawns exposed to very low (5 ppt) and to very high(45 ppt) salinities showed signs of stress and muscle necrosis, as also indicated by Lakshmi et.al.(1978) in the brown shrimp P.aztecus.

Regarding the effect of other abiotic factors, Clark (1986) found that when P.semisulcatus was kept for 17 days at 2 ppm oxygen, it did not moult, instead a steady mortality was observed. When the oxygen level was increased to 5 ppm, the mortalities ceased and many prawns moulted. Studying the influence of some exogenous and endogenous factors on the intermoult cycle of Palaemon paucidens Kamiguchi (1971) concluded that in summer the intermoult period was shortest (20.2 days) while in winter it was the longest (56.1 days). In a certain range of high temperature, the prawns moulted more frequently, particularly the immature prawns.

The present study indicates a faster rate of moulting in 10 to 20 ppt salinities, with the highest moulting frequency

in 15 ppt salinity. The moulting rate has been found to be least in 30 ppt salinity in which the animal took as many as 50.5 days to complete five moultings in contrast to 38 days to complete six moultings in 15 ppt salinity.

Effect of salinity on biochemical composition

Although studies relating to the influence of salinity on body composition of prawns are meagre, many have reported the same in finfishes. Parker and Vanstone (1966) and Erlich (1972) showed that the body composition depends on quality and quantity of food, environmental factors such as salinity, temperature etc., size, age and reproductive phase. Considerable variation in muscle protein at the tested salinities was observed in Mugil cephalus by Perera and De Selva (1978) who recorded highest protein level in 20 ppt followed by 15 and 30 ppt salinities Kalyanaraman (1983), estimated highest protein levels in 20 and 25 ppt salinities in P. indicus. A low level of lipid content corresponding to decreased protein level in lower salinities (5-10 ppt) was also noticed by him in this species. Duchateau and Florkin (1961) have reported an enrichment of free amino acid content when the cray fish (Astecus astecus) were transferred from brackish water to sea water condition, the concentration of lysine was strikingly more. Larserre and Gilles (1971) observed immense decrease in muscle free amino acid content of euryhaline intertidal teleosts (Crenimugil labrosus and Paralichtyes lethostiama) upon transfer from 200 ppt seawater to freshwater.

Salinity is also known to affect the percentage of water content in prawns body. Kalyanaraman (1983) observed a higher moisture content in lower salinity levels (5 and 10 ppt) which gradually decreased in higher salinities. This trend of moisture content in different salinities may be due to an adaptation to maintain osmotic balance.

In the present study, analysis of biochemical constituents of prawns grown in different salinities has indicated an icnreasing trend in the values of protein in prawns of 5 to 20ppt, carbohydrates in prawns of 15-20 ppt and lipids in prawns of 5-20 ppt salinities. In the case of moisture and free amino acids, with maximum in 5 ppt salinity, the values showed a general declining trend with increase in salinity levels.

Effect of water quality parameters

The mean values of temperature (26.8-27.6^{o}C), oxygen(4.95 - 6.30 mg/l) and pH (7.37-7.53) indicate a narrow range of variation and are at optimal level for growth of prawns in the laboratory. Several environmental parameters, including feed are known to affect the survival and growth of prawns. The ammonia excreted is the principal end product of protein catabolism in crustaceans (Campbell 1973; Kinne, 1976). The unionsed ammonia (NH_3) is more toxic to aquatic organisms than onised ammonia (NH_4^+) which has little or no toxicity,

(Wuhrmann and Worker, 1948; Hemens, 1966; Brown, 1968). The ammonia concentration to certain extent depends on pH, temperature and salinity (Bower and Bidwell, 1978). In P. monodon maximum acceptable level of ammonia for larval growth has been estimated to be 100 ug/l by Chen et al. (1986) who suggested monitoring of ammonia and preventing increase of pH for shrimp culture. He has also stated that nitrite-nitrogen has more influence on growth and survival of penaeid prawn larvae. The conversion of hemoglobin to methemoglobin in the presence of nitrite-nitrogen and subsequent loss of oxygen binding capacities have been documented by Smith and Williams (1974) and Smith and Russo (1970). This may result in hypoxia and cyanosis (Kiese, 1974). Nitrite and nitrate are the products of nitrification and the release of hydrogen ions during nitrification lowers the pH in closed systems (Wickins, 1976 b; Sharma and Ahlert, 1977). Wickins (1977b) demonstrationed that the larvae of P. monodon were not affected by pH values as low as 6.45. Chen and Chin (1988) reported that the mixture of ammonia and nitrite exerted greater toxicity than higher concentration of either ammonia or nitrite alone. The result of the present study indicate a gradually increasing trend for both ammonia and nitrite with the growth of prawns (Fig 9). But for higher level of ammonia in 20 ppt and lower levels in 30 ppt, in all other salinities, weekly variations in ammonia accumulation between salinities showed narrow range. The higher levels of ammonia in 20 ppt may be due to the better survival of prawns, while the lower levels in 30 ppt due to low survival. Though the nitrite-nitrogen showed an increasing trend

(Fig.9) with increase in size of prawn in all the salinities excepting 30ppt, the extent of increase of nitrite at the end of the experiment was nominal. In 30 ppt no such trend was observed. The maximum level of ammonia recorded in all these test salinities indicate a range of 2.4 to 14.4 µg at/l while nitrite varied from 0.30 to 7.7 µg at/l while nitrite varied from 0 30 to 7.7 µg at/l, indicating that the concentration of ammonia and nitrite were well within the safe limits (Chen et al., 1986).

Length-weight relationship

A study of the length-weight relationship of M.dobsoni grown in different salinity regimes prevailing in the perennial prawn culture system have shown very little variations in the length-weight exponent (2.8319-2.9084) among males. In females, this is found to be significantly high(3.0691) in prawns grown in 10-15 ppt salinity as compared to the length-weight exponent (2.8347-2.8690) estimated in other salinity regimes. These results would indicate that the females, and also to some extent the males, follow isometric growth in 10-15 ppt salinities, while in other salinities the weight increase is at a slower rate than the cube of length. Nair et al. (1982) studying the legth-weight relationship of M.dobsoni under different levels of feeding, observed that the length-weight exponent was unaffected by the feeding levels and the consequent differences in growth rate. The regression coefficient was almost constant (2.9054-2.9179) although he found varying growth

rates under different feeding levels. Using specimens of M.dobsoni inthe size range 22 85 mm, collected from the perennial prawn culture system at Cochin, Lalithambika Devi et. al. (1983) obtained a regression coefficient of 2.822 for the species. While studying the growth of penaeid prawns in Goa water, Achuthankutty and Parulekar (1986c) have observed the length-weight exponent of M.dobsoni to be much lower than 3.0 in juveniles of 40 to 70 mm (2.77-2.88) and adult males of 50-120 mm (2.76), indicating a slower rate of increase in weight to the cube of length. These authors found the regresion coefficient to be above 3.0 for adult females (3.13), thus indicating a faster rate of weight increase to the cube of length. With limited samples from Singapore Straits, Hall (1962) estimated a length-weight exponent of 2.736 for this species. According to Kutty (1972), the estimation of the two constants in the length-weight relationship can be biased if the coverage is not adequate. In the present study a size range of 22 to 80 mm for males and 23 to 105 mm for females were used in sufficient numbers (242-426) in all the three salinity regimes for both the sexes. The size below 22 mm are not covered as they were not available in the harvest. Nevertheless, the regression coefficient estimated for the different salinity regimes can be taken as reliable and typical of natural populations.

Size, count and meat recovery relationship

The data on size, count and meat recovery relationship of the prawn shows a satisfactory level of count per kg and meat recovery from a size group of 66-70 mm onwards

which gave a count of 500 for males and 430 for females. The recovery of headless (69%) and peeled & deveined (52.53%) forms also appears to be profitable to the processing industry. Taking into consideration of all these facts, it is reasonable to fix the harvestable size of the prawns during brackishwater farming at about 66-70 mm, which is attained in 2 1/2 to 3 months of growing period with a stocking size of 20-25 mm total length.

CHAPTER V

REPRODUCTION

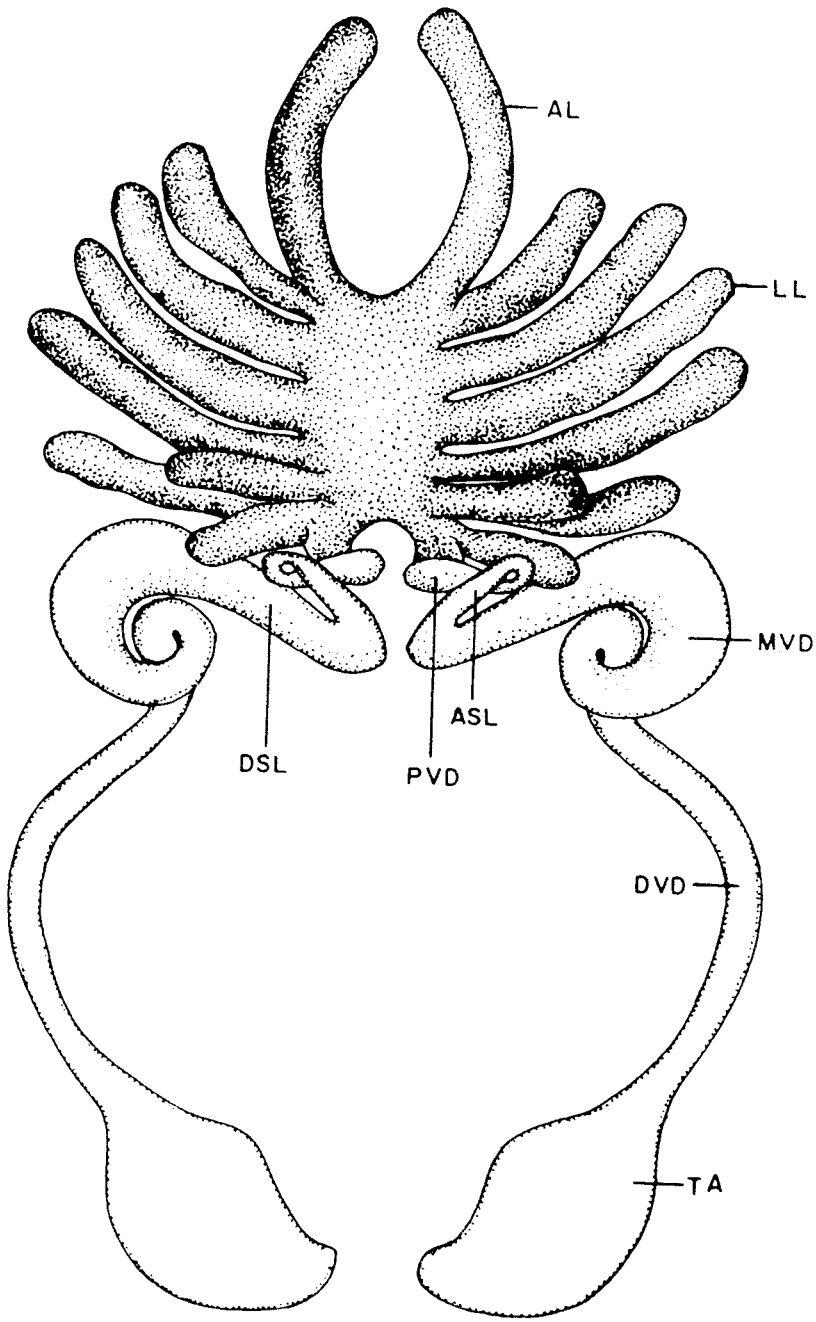
In the present study, two approaches have been adopted for investigating the possibility of maturation of the species and its spawining and early larval development in brackishwater. One, is by systematic survey of the natural population in the perennial prawn culture systems where the prawns attain comparatively larger size than in the open brackishwater system (Mohamed and Rao, 1971; George, 1974), and the other, by conducting a series of laboratory studies on these aspects, keeping the salinity as the variable environmental parameter. The monitoring of the natural population formed a part of regular studies carried out along with the growth investigations already described in the earlier chapter. The samples which were used for size frequency studies have been examined for the various aspects of reproduction of both the sexes. Along with the data on the incidence of animals in the reproductive phases, ecological data have also been monitored to correlate reproductive activities of the prawn with the environmental conditions. The study has yielded positive

results indicating that the male prawns readily mature passing through various maturity stages in the brackishwater conditions where the salinity was found to widely fluctuate. In the natural population a large proportion of animals were found attaining maturity with the production of functional spermatozoa stored in spermatophores. The seasonal abundance of the mature males have been studied in great detail. During the study, although not so pronounced as males, clear evidences could be collected to establish that the female prawns also attain maturity in waters of low salinity conditions prevailing in the prawn culture fields. The prawns in the reproductive phase passed through different well defined maturity stages as occurring in the marine environment.

The laboratory studies have yielded good confirmatory evidence to support the field observation as regard the possibility of M.dobsoni maturing in brackishwater conditions. The experiments have also thrown light on the possibility of propagation of the species through normal mating, spawning and fertilization of eggs and development of eggs to nomral protozoea stage in the brackishwater media itself. In the following section various aspects of reproduction, including structure of reproductive system, maturation, histological aspects, fecundity and bio-chemical composition of the species are described based on material collected from the brackishwater prawn culture systems as well as from those grown in the laboratory under brackishwater conditions are described.

Morphology of male reproductive system

The reproductive system of adult male consists of a pair of testes, a pair of vasa deferentia, a pair of terminal ampoullae and a petasma (Fig. 13). The testis and vasa deferentia overlie the hind part of hepatopancreas and are placed below the pericardinal sinus and heart. The mature testis is unpigmented and milky white in colour. Each testis has an anterior lobe and seven lateral lobes. The right and left halves of testis are fused together medially along their entire length, giving the appearance of a single flower-shaped mass to the organ. The bases of all the lobes are interconnected on either side and posteriorly opening into the respective vas deferens. Three distinct regions could be recognised in vas deferens, namely, the proximal vas deferens, medial vas-deferens and distal vas deferens as has been observed in Penaeus kerathums by Malek and Bawab (1974a). The proximal vas deferens is a small tubular structure hidden below the hind part of the testis. It has sparsely distributed dark pigments. The proximal vas deferens opens into the medial vas deferens after taking a twisted turn. The medial vas deferens, with its milky white colouration, is the most prominent part of the male reproductive system. The entire medial part has the shape of an inverted 'U' tube with gradually widening lumen. The anterior one third portion of the medial lobe may be termed as the ascending limb and the remaining portion running backwards as the descending limb. The hind part of the descending limb takes a full circular turn and opens into the distal vas deferens.



Structure of male reproductive system of M.dobsoni. AL - anterior lobe, LL - lateral lobe, MVD - medial vas deferens, ASL - Ascending limb of medial vas deferens, DSL- descending limb of medial vas deferens, DVD - Distal vas deferens. TA- terminal ampoule.

The distal vas deferens is a narrow tubular structure running latero-ventrally in the thoracic region. The diameter of the distal vas deferens remains almost uniform throughout its length. This ultimately opens into the terminal ampoule, the most dialated part of the reproductive system. The terminal ampoule lies transversely inside the coxopodite of the 5th walking leg. The terminal ampoule is a sac-like structure with the wall consisting of circular and longitudinal muscular walls. The spermatophore produced by the vas deferens is stored in the terminal ampoule until mating. In fully mature males, the spermatophores are clearly visible through the exoskeleton as a patch of white mass at the base of the 5th walking leg. Some times,part of the spermatophore can be seen protruding outside the terminal ampoule near the gonopore on either side (Pl. 5).

Petasma, the external genital organ of the male prawn, is a modification of the endopodites of the first pair of pleopods. This secondary sexual organ takes its characteristic form and structure with the gonadal maturation of the animal. Each of the petasmal endopodites is formed by two lobes, the median and the lateral. The lateral lobe is composed of two foldings, the dorsal or anterior and the ventral or posterior lobules. The two halves are joined together in the median line on the dorsal side by a number of minute inter-locking hooks (cincinnuli) arranged in a zipper - like manner. On the ventral side, however the two halves are not united but only closely approximated. The distal part of the petasma is spout-like with the tip of the lateral lobes prolonged distolaterally ending in

an acute point. The distal end of median lobes are produced into a fleshy spout-like structure with corrugated surface provided with tubercles.

Another secondary sexual character, the appendix masculina, situated on the endopodite of the second pleopod is well developed in the adult prawn. It is more or less oval shaped and small in size.

Maturation process and maturity stages

The male prawns are generally smaller in size than females as in most other penaeid species. In the juvenile stages upto about 47 mm in total length, the endopodites of the first pair of pleopods remain as small independent structures. As the prawn grows, the endopodites of the right and left pleopods join together along the dorsomedian margin of the endopodites to form a single structure, the petasma. In the beginning of the petasmal formation, the union of endopodites is superfacial and the two halves easily separate even at gentle handling. The newly formed petasma is membranous and simple. Gradually it hardens as a rigid structure and assumes the specific shape.

Internally, the initiation of maturation process coincides with the petasmal fusion. As the hardening of petasma progresses, the gonad undergoes a series of structural and functional changes leading to the production of spermatozoa and the formation of spermatophores. Once the petasma has taken the final form and fully hardened, the spermatogenesis and

spermatophore formation are very active. Sometimes, two or three spermatophores in different stages of formation could be seen in the vas deferens and the terminal ampoule. When the animal is ready for mating, the spermatophore in the terminal ampoule get partially extruded into the coxopodite of the fifth pair of walking legs (Pl. 5a).

Based on the nature of petasma, structural changes of testis and vas deferens, presence of spermatophore in terminal ampoule and other macroscopical observations, the following four maturity stages have been distinguished in males.

Stage I - Immature: Testis rudimentary, lobes not properly differentiated; vas deferens more or less straight, transparent and not differentiated into various regions, terminal ampoule transparent and least swollen; endopodites of first pair of pleopods small and independent.

Stage II Early maturing: Entire system transparent; testes lobes fairly developed; vas deferens showing feeble differentiation into three regions, medial vas deferens moderately dialated; terminal ampoule slightly enlarged; endopodites of first pair of pleopods united forming petasma, interlocking of petasmal endopodites feeble and the whole structure membranous; no sign of spermatophores in any part of the reproductive system.

tage III - Late maturing: Testes lobes well developed and ransluscent; vas deferens clearly differentiated into proximal, edial and distal regions, each undergoing changes in shape, size nd placement in cephalothoracic cavity, terminal ampoule ialated into a bulbous structure; spermatophores seen in vas eferens and sometimes in terminal ampoule; petasma hardened and omplex in structure, left and right halves not easily separable.

tage IV - Mature or ripe: All conditions of previous stage ontinue, additionally, spermatophores lodged in and partially xtruded from terminal ampoule clearly visible through xoskeleton; petasma in typical adult form with spoutlike distal rojections with tubercles on them.

At the mature or ripe stage, the prawn is ready to ransfer the spermatophores on to the thelycum of the female. he animal remains in this stage, even after mating, as evidenced y the presence of spermatophore in the vas deferens and as such, here is no spent stage in males after attaining maturity.

ize at maturity:

The smallest prawn showing the endopodites of first air of pleopods in united condition measured 47 mm TL. In order o study the fusion of endopodites at 50 per cent level, the ercentage frequency of animals with endopodites in united ondition was worked out for 626 animals in the size range 45 to mm TL grouped into 2 mm class intervals. The results (Fig.) indicate that 50 per cent of prawns show fusion of petasmal

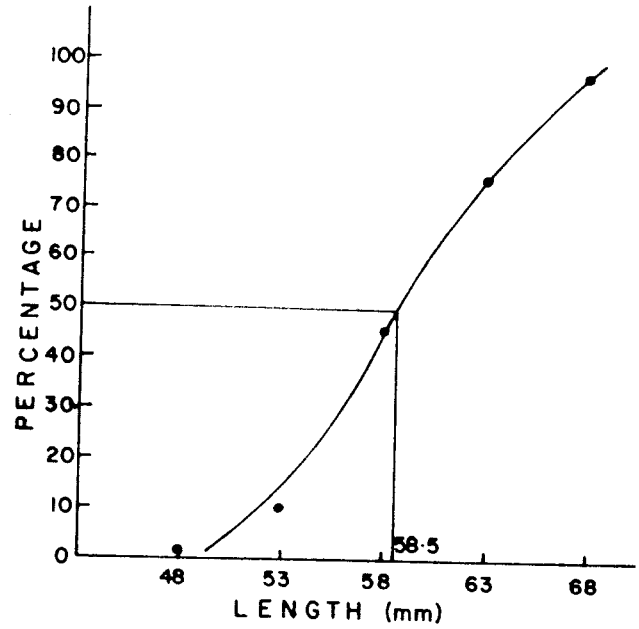
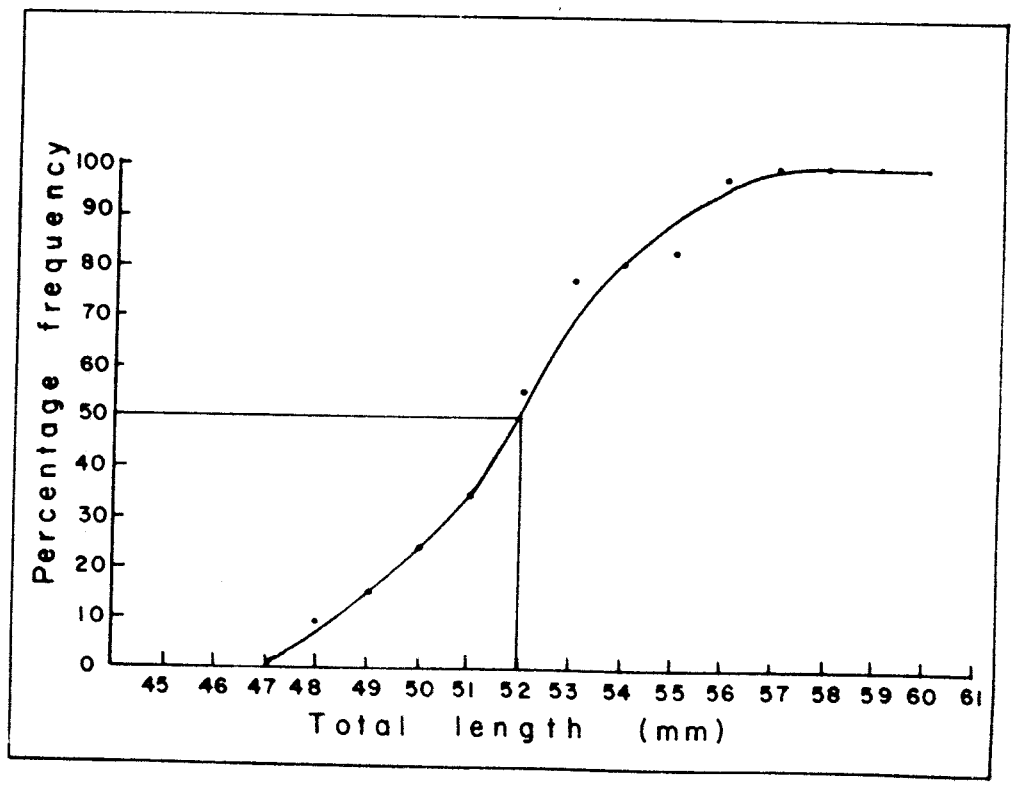


Fig.15: Size at maturity of M. dobsoni males.



.14: Size at fusion of petasmal endopodites in M. dobsoni.

The prawns in IIIrd and IVth maturity stages were pooled together and their percentage frequencies in 5 mm class intervals was determined for studying the size of maturity at 50 per cent level. A total of 1842 prawns were used for this sudy. The percentage frequencies were plotted against the mid-points of size groups and the size at 50 per cent maturity determined (Fig. 15). From this, the size at maturity at 50 per cent level was found to be 58.5 mm TL.

Spermatogenesis:

In prawns of less than 45 mm size, the testes are extremely delicate, small and transparent and remain so till the union of petasmal endopodites. The testis gradually increase in thickness and length and turn white opaque in larger males of 55 mm size and above. Each mature testis is surrounded by a thin wall or cortex. The cortex consists of two layers, an outer epithelial layer and an inner layer of connective tissue (Pl. 7a,b). No muscular tissue is present. The body of the testis is composed of a mass of very minute convoluted seminiferous tubules or acini (Pl. 7 c) in which the male reproductive cells or sperm cells are produced. The membranous wall of acini is also made of two layers (Pl. 7f), the outer tunica and the inner germinal epithelium. Spermatogenesis or formation of mature spermatozoea takes place in the lumen of the seminiferous tubule. In immature prawns, the seminiferous tubules are not clearly visible. The testis is filled with sparsely distributed primary spermatogonial cells (Pl. 7 a) having conspicuous nuclei. The nurse cells with distinct nuclei (Pl. 7 a-b) and a clear cytoplasmic boundary are

also seen. With the formation of petasma (stage II) the seminiferous tubules are clearly visible and the secondary spermatogonial cells greatly increase in size (Pl. 7c). These spermatogonial cells grew very rapidly as evident from the multiplication of nuclear and chromatin matter (Pl. 7 d), leading to formation of primary spermatocytes (Pl.7 e). The irregular, elongated multinucleated nurse cells are seen inbetween the spermatocytes and in the peripheral region of the seminiferous tubules (Pl. 7 d). The primary spermatocytes undergo meiotic division and result in two secondary spermatocytes (Pl. 7e). These divide again to produce four spermatids (Pl. 7f) which develop into spermatozoa.

Since spermatogenesis involves progressive reduction of cytoplasm and chromatin material with successive divisions, the spermatogonial cells are the largest, followed by spermatocytes and spermatids in their sizes. The spermatids gradually get enlarged and move out of their cell boundaries (Pl. 8a). The spermatids are seen in various stages of development (Pl. 8c). The cytoplasmic boundaries gradually disappear(Pl. 8b) and the lumel of the tubule gets filled up with spermatids. these spermatids grow in size and develop into spermatozoa (Pl. 8d). The fully developed spermatozoa occupy the entire portion of the seminiferous tubule (Pl. 8 e,f) and are seen in large numbers along with some nurse cells.

Once the prawn attain sexual maturity, the testis produces a continuous supply of sperm cells. In mature condition the tubule is filled with evenly distributed spermatozoa with a

small peripheral germinal zone consisting of spermatogonial cells and spermatocytes (Pl. 8f and 9a). The sperm of M.dobsoni has a typical 'tadpole' structure. It consists of a large spherical head portion which forms the main body and contains the well developed acrosomal complex anteriorly (Pl. 9b). The main body gradually tapers to form the tail. The spermatozoa tend to congregate at the centre of the tubule (Pl. 10a). This congregation of sperm mass is surrounded by sperm matrix (Pl. 10b).

Histology of vas deferens and Spermatophore formation

A detailed histological investigation was carried out to study the structure of the vas deferens and the role played by various regions of vas deferens in the process of formation of the spermotophores. Three successive stages can be readily recognised during the formation of the spermatophore in in M. dobsoni. All the three stages involve the participation of certain scretions yielded by appropriate glands which line the vas deferens throughout. In the first stage, the sperm cells, which are concentrated at the centre of the seminiferous tubule, are drained into the proximal vas deferens where they become a compact sperm mass. In the second stage, the sperm mass further gets compacted and the formation of the main layers of spermatophore and the partly independent accessory wing are noticed. In the third stage, the compact, convoluted spermatophore enters the terminal ampoule where it takes the final complete shape before extrusion.

The histology of the proximal vas deferens, medial vas deferens, distal vas deferens, terminal ampoule, and the formation of the spermatophore are described below.

Proximal vas deferens (PVD)

Judging by its slender appearance, the proximal vas deferens may be regarded as the conducting tube. The sperm mass concentrated in the seminiferous tubules is drained into the anterior proximal vas deferens (Pl. 10c, 11a). The proximal vas deferens consists of two layers; the outer thin layer of circular connective tissue and the inner thick wall of longitudinal muscle tissue (Pl. 10d, 11a). Some glandular cells are also seen with in the wall of proximal vas deferens, the secretion of which may be helpful in forming the sperm mass.

Medial vas deferens (MVD)

This consists of a short ascending limb followed by a gradually enlarging inverted 'U' shaped descending limb. The proximal vas deferens, after taking a twisted turn opens into the ascending limb of the medial vas deferens. The ascending limb also continues to have the same two layered wall as that of the proximal vas deferens. In addition, however three are three typhlosoles protruding from the wall into the sperm duct and a small wing duct situated inbetween the inner and outer layers of the wall. The wall of the ascending limb in the typhlosole area is narrow in the absence of longitudinal muscle tissue (Pl. 10e, 11b). The secretion of the glandular epithelial cells (Pl. 12a) which line the wing duct help in the formation of wing.

The spermatozoa are arranged compactly in the sperm duct where the sperm mass is partly covered by the first incomplete spermatophoric layer, secreted by the inner epethelial layer of the wall and typhlosoles. The secretory function of the typhlosoles in this region appears to be less active as evidenced by the large empty space between the typhlosoles and the sperm mass (Pl. 10e, 11b). The ascending limb opens into the descending limb of the medial vas deferens which gradually enlarges in size and opens into the distal vas deferens The narrow anterior part of the descending limb having the same number of typhlosoles appears more compact (Pl. 10f 12b). The wing duct has considerably reduced in size with in the muscular wall. The typhlosoles have become very active and their secretion fills most part of the lumen. The globular sticky secretion is clearly visible in this part (Pl 13a b, 14a). The structure of the wall remains almost the same as in ascending limb. The second layer encompassing the sperm mass over the first layer is clearly noticeable at this stage. The lumen of the descending limb gradaully expands and the longitudinal muscular tissue layer of the wall and the typhlosoles disappear (Pl.13d,14b). The wall is now consists of only a thin layer of circular connective tissue. The wing duct gets enlarged and develops a large wing from the secretions of the glandular epithelial septum and a typhlosole present in the outer wall (Pl. 13c, 14b). Three distinct spermatophoric layers are clearly seen (Pl. 13c, 15a). The first and the third layers are amorphous and non granular where as the second layer appears to

duct reduce greatly (Pl. 13f). The empty wing duct and the sperm duct (Pl. 16a) in the distal vas deferens could be noticed when the spermatophore is transferred to the terminal ampoule

Terminal ampoule

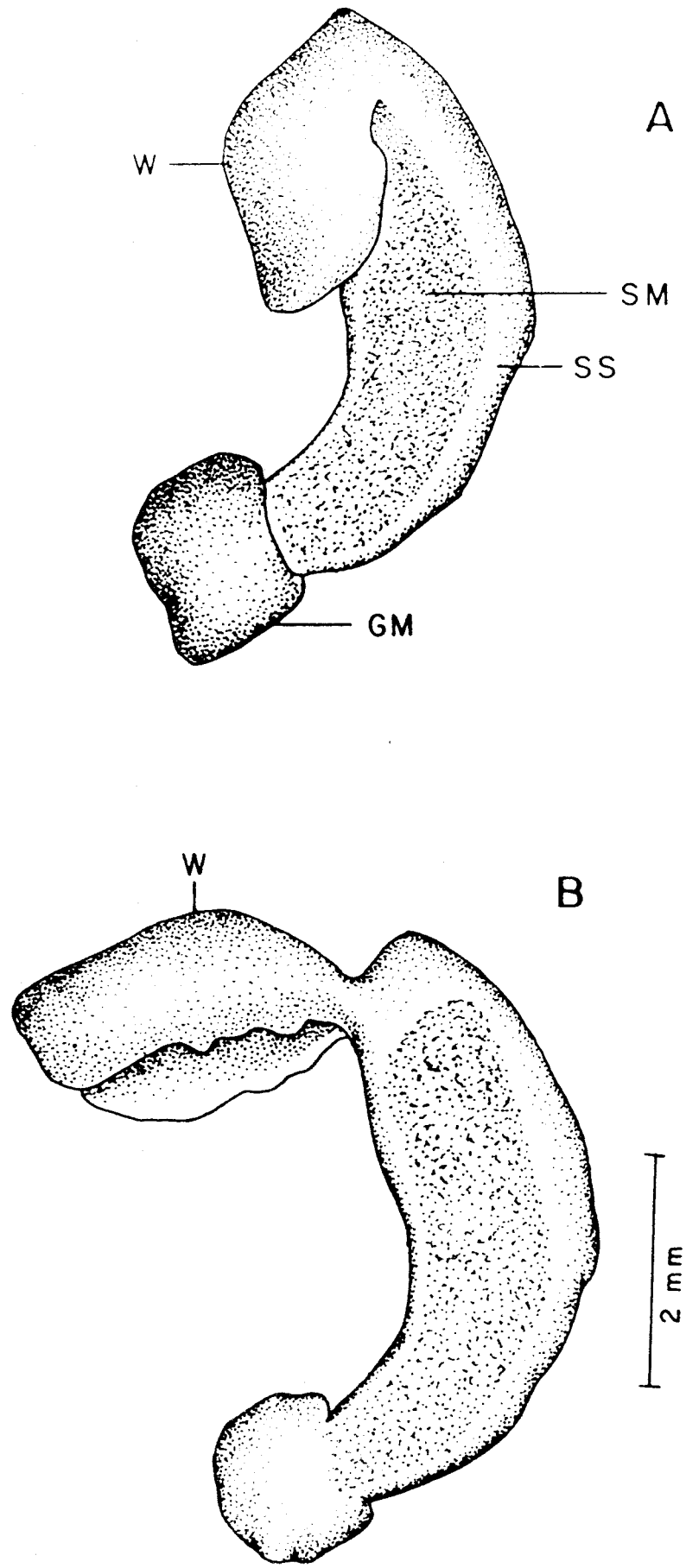
The distal vas deferens dialates to form the terminal ampoule or the ejaculatory duct. Terminal ampoule (Pl. 17b) is a highly muscular complex structure with thik circular muscle fibres forming the external wall followed by a well developed thick longitudinal muscle fibres (Pl. 16b, 18a). It also has layers of glandular epithelial cells originating from the external circular muscle wall and running into the lumen through the longitudinal muscle fibres (Pl.16c, 18a). The spermatophore received from the distal vas deferens undergoes final structural modifications before getting extruded during mating. A fifth layer of the spermatophore wall is formed (Pl. 16d, 18b) in the terminal ampoule and it surrounds the spermatophore giving a capsule like appearance. The multilayered portion of the spermatophore positions itself near the region of extrusion. The region of spermatophore extrusion is clearly differentiated by the absence of longitudinal muscle fibres (Pl.16d, 19a). The wing also undergoes some structural modifications. It further enlarges in size and become elongated with one end tapering like a tail (Pl. 17b). The tail like portion of the wing lies very close to the spermatophore while the other end remains as an independent structure. With the muscular contraction of the terminal ampoule, the spermatophore gets ejaculated along with

the wing. The adhesive material secreted by the glandular epithelial layer of terminal ampoule helps in cementing the two spermatophores released simultaneously from the right and left terminal ampoule. When extruded by mechanical force or through electrical stimulation the spermatophore was found to come out leaving the wing portion inside the terminal ampoule in most cases (Pl. 19b).

Structure of the spermatophore

The spermatophores of M.dobsoni extruded by electroejaculation were used to study structural details. It consists of a semicylindrical hardened sperm-sac enclosing a columnar sperm mass (spermatozoa with a viscous fluid) with a cap-like thick sheath of glutinous substance at one end (Fig. 16). The sac usually bears an anterolateral aliform process, the wing. The wing is like a flap covering about one-third portion of the spermatophore. The various accessories associated with the sperm sac presumably help to anchor the spermatophore to the thelycum of the female prawn.

During copulation, two closely united spermatophores (compound spermatophore) are transferred to the female's thelycum immediately after expulsion from the paired terminal ampoullae, each spermatophore joining its mate closely along the longitudinal axis dorsomedially. The tapering tail portion of the wing gets an entry into the thelycum along with the compound spermatophore and the free independent ends of the wing remain outside the thelycum covering the sternal plates as a 'pad'



16: Structure of spermatophore of M. dobsoni
A - Wing in normal position; B - Wing partly lifted.
W - wing, SM - sperm mass, SS - sperm Sac,
GM - glutinous material.

Histological study of the spermatophore also indicates the presence of wing which is feebly attached to the spermatophore and acts like a cover at one end. The sperm sac is surrounded by five spermatophoric layers (Pl. 16f). All the layers are not continuous The sperm sac wall opposite to the five layered wall is comparatively thin having two spermatophoric layers only. The thick sheath of glutinous material representing the cap-like structure can be clearly seen (Pl. 16e).

Biochemical compostion of immature and mature males

The concentration of biochemical components such as protein, carbohydrate and lipid were estimated for various body tissue, such as muscle, haemolymph and hepatopancreas of immature and mature prawns collected from the Kannuvilakettu prawn culture field. The testes of mature males only, were analysed for the above biochemical components. The term 'testes' refers to the whole male reproductive system consisting of testis vas deferens and terminal ampoule. The reproductive system of immature males could not be analysed due to its rudimentary nature. The analytical results of the study are presented in Table 30.

The total protein content in different body tissues of prawn in immature and mature males indicate that the protein content was highest in muscle tissue (46.81 mg/100 mg in immature prawn and 47.08 mg/100 mg in mature prawn) and lowest in hepatopancreas (3.98 - 4.06 mg/100 mg). Relatively higher

TABLE 30: Biochemical composition of various body tissues of immature and mature males of *M.dobsoni*

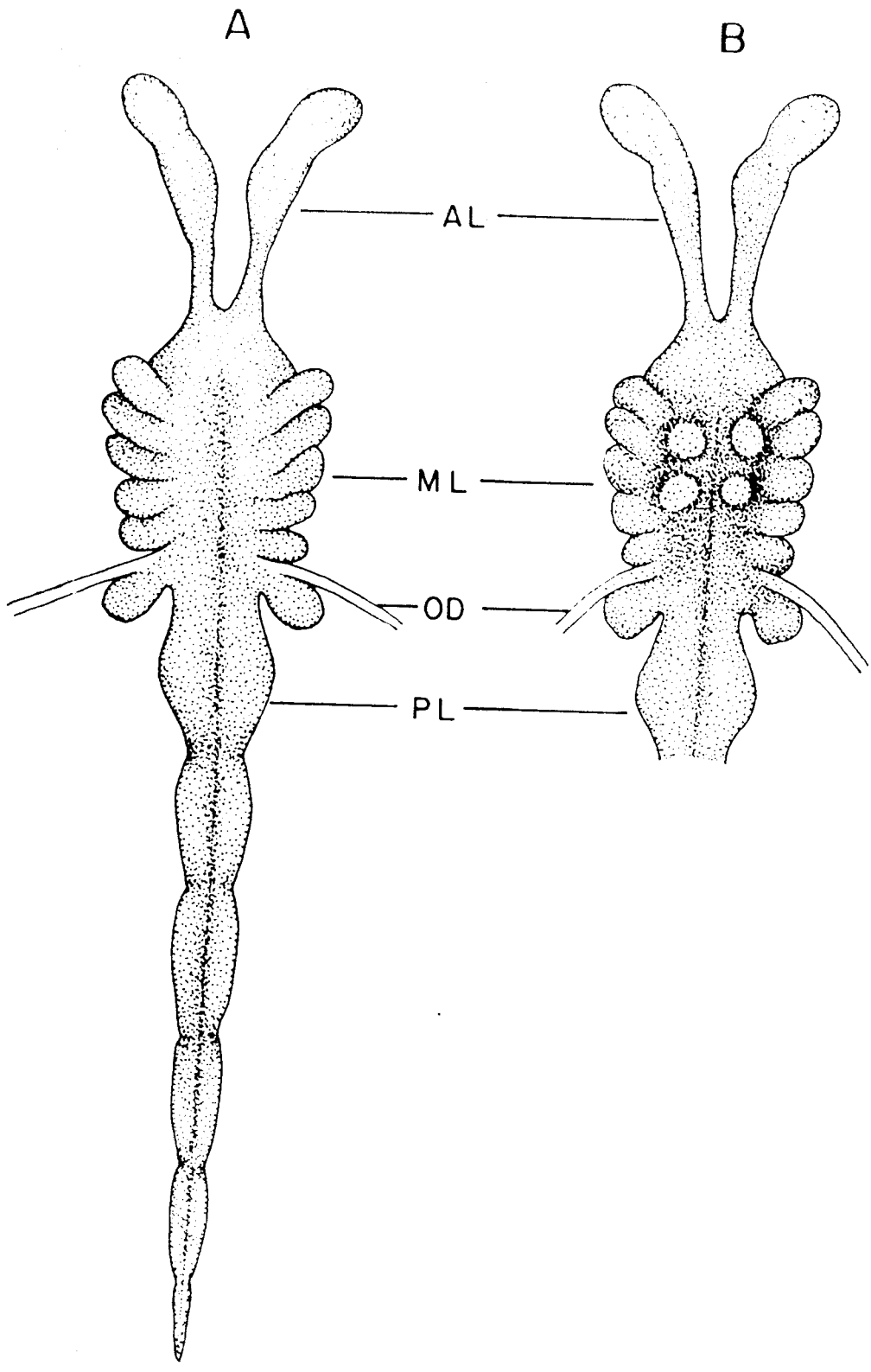
Biochemical component	Tissue	Immature	Mature
Protein	Muscle (mg/100 mg)	46.81 ±8.90	47.08 ±9.36
	Haemolymph (mg/ml)	69.48 ±11.41	71.18 ±14.64
	Hepatopancreas (mg/100 mg)	3.98 ±0.64	4.06 ±0.98
	Testes (mg/100 mg)	-	34.22 ±9.18
Carbohydrate	Muscle (mg/100 mg)	0.22 ±0.10	0.19 ±0.08
	Haemolymph (mg/ml)	0.29 ±0.64	0.34 ±0.76
	Hepatopancreas (mg/100 mg)	0.31 ±0.18	0.39 ±0.07
	Testes (mg/100 mg)	- -	0.49 ±0.20
Lipid	Muscle (mg/100 mg)	3.86 ±0.54	3.96 ±0.66
	Haemolymph (mg/ml)	2.98 ±0.33	4.08 ±0.32
	Hepatopancreas (mg/100 mg)	8.72 ±2.11	12.87 ±4.63
	Testes (mg/100 mg)	- -	9.64 ±3.81

level of protein concentration (60.48 - 71.18mg/ml) was also noticed in haemolymph The mean protein content of testes was 34.22 mg/100 mg.

The carbohydrate concentration in different tissues was generally low. The muscle tissue of immature male had comparatively higher level of carbohydrate (0.22 mg/100 mg) than that of mature prawn (0.19 mg/100 mg). The carbohydrate levels in haemolymph (0.34 mg/ ml) and hepatopancreas (0.39 mg/100 mg) of mature prawns was higher as compared to that in immature prawns (0.29 mg/ml, 0.31 mg/100 mg respectively). Among the different tissues studied, the carbohydrate concentration of testes (0.49 mg/100 mg) was the highest. Lipids formed one of the important biochemical components, next to protein. Lipid content of muscle and hepatopancreas showed a little increase, while that of hepatopancreas increased considerably from immature to mature condition. The lipid content of muscle tissue varied from 3.86 to 3.96 mg/100 mg, haemolymph 2.98 to 4.08 mg/ml and hepatopancreas 8.72 to 12.87 mg/100 mg. The lipid concentration of mature testes was also considerably high (9.64 mg/100 mg).

Morphology of female reproductive system

The female reproductive system consists of a pair of ovaries and a pair of oviducts internally (Fig. 17) and a thelycum externally. The mature ovaries extend from the base of the rostrum to the posterior end of the sixth abdominal segment. Each ovary can be divided into three parts, namely, the anterior



.17: Structure of female reproductive system of M. dobsoni. AL - anterior lobe, ML - middle lobe, OD - Oviduct, PL - posterior lobe.

lobe, the middle lobe and the posterior lobe. The right and left halves of ovary are closely approximated throughout their length and are fused together by commissures at two points, one at the base of the anterior lobes and the other at the posterior end of the ovary. The two anterior lobes are long, relatively more enlarged distally and extending beyond the position of esophagus The middle lobe consists of eight lateral lobules on either side of the ovary in the cephalothorax, of which the anterior five are dorso-laterally placed, one thumb like lobule placed at the posterior end of the middle lobe and the remaining two lobules directed towards the ventral side of the ovary. The whole middle lobe lies dorsal to the large hepatopancreas and underneath the cardiac chamber, occupying the entire space available in the cephalothorax. The paired oviducts originate from the base of the fifth lobules (from anterior most) of the middle lobe and runs downwards to the external genital openings at the base of the coxopodite of third pair of pareiopods on the inner side. The posterior lobe, which is the continuation of the middle lobe extends upto the last abdominal segment where the two halves fuse together and form a common structure. The anterior part of this lobe corresponding to the first abdominal segment is relatively more enlarged and takes more or less a diamond shape in the ripe condition.

Maturation Process and Maturity stages:

Generally prawns of about 70 mm in total length and above exhibit indication of ovarian maturation. These prawns

immediately after moulting, get impregnated with spermatophore by a mature male. With the spermatophore attached to the thelycum (impregnated condition, Pl. 5b), the strand-like ovary of immature female begins to mature under favourable eco-physiological conditions. However, all the impregnated females may not do so due to various reasons The commencement of maturation can be recognised by careful observation of the ovarian changes through the exoskleton of the thoracic region. With the initiation of maturation, the small transluscent anterior lobes and the lateral lobules of the middle lobe begin to enlarge in size and surge anteriorly. The anterior lobes grow almost up to the base of the rostral crest, while the lateral lobules embrace the hepatopancreas. The posterior lobe increase in thickness marginally though not clearly visible through the exoskeleton. Once the maturation is initiated, the subsequent process of maturation is rapid and the ovary becomes ripe in two to five days time. This transformation involves a series of changes in the size, shape and colouration of gonad.

The thelycum, which is the female secondary sexual organ is thoracic in origin and formed by the modification of sternal plates of somites xiii and xiv between the fourth and fifth legs. It is composed of a median or anterior plate and a pair of lateral or posterior plates. The anterior plate is long, grooved, tongue-like and partially ensheathed in a horse-shoe like process formed by the lateral plates.

Based on the size, shape and colour of the ovary, sizes and microscopic details of ova and gonado-somatic indices the following five maturity stages (pl.6) are recognised.

Stage I - Immature: Ovary thin, transluscent and strand-like, not visible through the exoskeleton; anterior and middle lobes confined to posterior half of cephalothorax; eggs spherical with conspicuous nucleus and clear cytoplasm; maximum size of ova 0.16 mm; gonado-somatic index varying 1.95-2.80.

Stage II - Early maturing: Ovary moderately enlarged, light yellowish green in colour; anterior and middle lobe faintly visible through exoskeleton, anterior lobe extending up to base of rostrum, lobules of middle lobe partly covering posterior region of hepatopancreas, abdominal lobe not clearly visible through exoskeleton; eggs oval or spherical, opaque, cytoplasm with sparsely distributed yolk granules and vacuolated, nucleoli 4 to 12 in number; ova measuring 0.91 to 0.32 mm; gonado-somatic index 3.68-4.41.

Stage III - Late maturing: Ovary fairly large, light green in colour and clearly visible through exoskeleton throughout its length; anterior lobe extending beyond base of rostrum, lobules of middle lobe further enlarged and covering the whole dorsal side of hepatopancreas, diamond-shaped enlargement of posterior lobe clearly visible through exoskeleton; eggs oval or spherical, opaque, cytoplasm embedded with yolk all over, nucleoli more than 30 in number; ova measuring 0.24 to 0.43 mm; gonado-somatic index 5.12-7.00.

Stage IV - Mature or Ripe: Ovary fully enlarged dark green in colour and clearly visible through exoskeleton; anterior lobe and middle lobe occupying the entire cephalothoracic region, diamond-shaped enlargement of posterior lobe in first abdominal segment clearly noticeable; egg fully embedded with yolk, nuclear material faintly visible; ova measuring 0.24 to 0.65 mm; gonado-somatic index varying 7.28-10.08.

Stage V - Spent/spent recovering: Ovary loose and flaccid, transluscent; anterior lobe slightly retracted , middle and posterior lobe not visible through exoskeleton; most of the ova small and spherical with clear cytoplasm and nucleus, residual eggs in early and late maturing stage seen at various stages of reabsorption; majority of ova measuring less than 0.16 mm in size, gonado-somatic index varying 1.22-2.35.

Oogenesis

Oogenesis has been studied by staining histological sections of different maturity stages. An examination of these histological sections revealed that the process of oogenesis is associatd with the oocyte development and yolk accumulation in a graded manner. Based on the ovarian change manifested in the cytoplasm and nucleus of oocyte, the process of oogenesis was classified into five different stages, namely, previtellogenic, early vitellognic, late vitellogenic, vitellogenic and spent oocyte stages. These phases of oocyte development correspond to the maturity stages I to V, classified on the basis of anatomical and morphological features of the ovary.

The ovary is a lobular organ with thin ovarian wall having two distinct layers of epithelial cells with a layer of connective tissue inbetween (Pl.20a). In hematoxylin-eosin stain the outer layer is found to be moderately basophilic, while the inner layer moderately eosinophilic. In prawns of size less than 60 mm, the ovarian lobe is occupied by primary and secondary oogonial cells with some of them getting transformed to formative stage of follicle cells (Pl.20a). The hollow surrounded by oogonial cells are clearly visible in the ovary. In prawns above 65 mm size, the germinal zone or germogen or germarium was observed in all sections and restricted to a small region of the inner most ovarian layer. This zone of proliferation was observed to be present in all stages of maturity. The oogonial cells originating from the zone of proliferation migrate towards the centre with a gradual increase in size (Pl. 20b). The very small primary oogonial cells appear as a thick mass in the proliferative zone without clear cytoplasmic boundaries. They show the presence of clear nucleus (Pl. 20c) with uniformly distributed cytoplasm. These primary oogonial cells undergo mitotic division to form relatively large secondary oogonial cells which are more centrally placed as compared to primary oogonial cells. These cells possess a faintly visible cytoplasmic boundary with clear cytoplasm and nucleus. The follicle cells with less differentiation in their cellular structure surround secondary oogonial cells. (Pl. 20c).

Pre-vitellogenic stage

This stage is characterised by the predominance of oogonia and primary oocytes (Pl.20c). The secondary oogonial cells undergo meiotic division to form primary oocytes. The primary oocytes in the chromatin nucleolus stage are larger than the secondary oogonial cells with clear cytoplasmic boundaries and unformly distributed chromatin network. Relatively larger perinucleolar oocyte having several nucleoli at the periphery of the nucleoplasm are also seen in this stage (Pl. 20 d,e). The nucleoli vary from 2-8 in number. Some oocytes with yolk nucleus in the peripheral region of cytoplasm are also noticed (Pl 20f). The cytoplasm in all these primary oocytes is deeply basophilic, homogenous and agranular. The follicle cells differentiate into cuboid or hypertrophoid in shape and start surrounding the slightly larger oocytes.

Early vitellogenic stage

The oocytes increase in size rapidly and assume a size range of 0 19-0.32 mm . The oocytes are almost spherical in shape, with the cytoplasm moderately basophilic and eosinophilic. The cytoplasm starts increasing in volume and becomes highly vaccuolated along the peripheral region (Pl. 21 a). The granular appearance is due to the presence of vesicular yolk. The nucleus also gets enlarged and 15-20 nucleoli are seen along the peripheral region of the nucleoplasm. The chromatin net work is uniformly distributed. The vacuolated cuboid shaped follicle cells form a conspicuous band around the

oocyte (Pl. 21a), leaving a lot of empty space between the oocyte wall and the inner follicular layer. Atretic cells are abundant from this stage onwards and are characterised by a reduction of the ooplasm through resorption by follicle cells which turn from cuboidal to spherical in shape and basophilic to partly eosinophilic in nature.

Late vitellogenic stage

The oocytes further increase in size and grow to 0.24 to 0.43 mm in diameter. The nucelus slightly becomes elongated. In this stage, the ovarian wall becomes thin (Pl. 21b) and the maturing oocytes are compactly arranged. The follicle cells become elongated and very closely surround the oocytes like a narrow band. A very clear shift is noticed from basophilic nature of cytoplasm to the eosinophilic nature with the cytoplasm becoming granular. The peripheral region of the cytoplasm continues to be slightly vacuolated in smaller oocytes. The yolk granules are seen concentrated around the nucleus with sparse distribution in the peripheral region. The nucleus is slightly elongated and has a large number of nucleoli arranged along the periopheral region of nucleoplasm (Pl. 21 c,d). Atretic cells are seen in this stage also with fully reabsorbed follicle cells. Proliferating oogonial cells get reduced in number and restrict to a small region in the ovary.

Vitellogenic stage

The ovaries in this stage are completely filled with vitellogenic oocytes and the oocytes of pre and early

vitellogenic stages become insignificant. The oocytes assume the largest size measuring 0.24-0.65 mm. They are oval in shape and characterised by the eosinophilic cytoplasm completely flooded with yolk granules (Pl. 21 e,f.). The nucleus gets elongatd like a narrow band with clearly visible nucleoli along its periphery. The striking feature of this stage is that the number of nucleoli get drastically reduced and the nuclear material in some cases gets dispersed in the cytoplasm (Pl. 21 f). The follicle cells are elongated and form a thin ring around the oocytes and some times appear like a loose thin ribbon around the oocytes (Pl. 22 a). Atretic oocytes are also seen. In some atretic oocytes, the contents are completely absorbed leaving a hollow space filled with some fluid material in the cavity (Pl. 22 b). The round, dispersed follicle cells are clearly seen around the cavity.

Spent oocytes

Structurally the oocytes of this stage are almost same as previtellogenic and early vitellogenic stage (Pl.22 c). The larger oocytes of early vitellogenic stage are seen in various stages of resorption with some completely resorbed. The empty rings of thick layer of follicle cells caused by the retraction of follicle cells from oocytes are also seen in large numbers. Proliferation of fresh batch of oocytes showing the characteristic of previtellognic oocytes, like nuclear halo, is also observed (Pl.22 c.). A few deeply stained irregular primary oocytes are also noticed. Atretic oocytes are generally seen in this stage.

Biochemical composition and its variation during maturation

Concentrations of varous metabolic components like protein, free amino acid, carbohydrate, lipid and moisture were estimated for various body tissues such as muscle, haemolymph, hepatopancreas and ovary. The prawns in different maturity stages, collected from Kannuvilakettu prawn culture field, were used for this study. The spent females were obtained from the successful laboratory maturation experiments. The analytical results of the study are summarised in Tables 31 to 35 and the trends in variation depicted in Figs. 18 to 22. The results obtained were analysed using ANOVA and the significance of F ratio tested.

Protein

Values of total protein concentration in different body tissues of the prawn at different maturity stages (Table 31 and Fig.18) indicate that the protein content of muscle tissue varies from 40.68 to 49.23 mg/100 mg. Low levels of protein were observed in stage I (41.52 mg/100 mg) and stage V (40.68 mg/100 mg. Relatively higher levels of protein were noticed (47.27-49.23 mg/100 mg) in stage II, III and IV with the maximum in stage II. The protein level in the haemolymph fluctuated widely in the different maturity stages. It ranged between 65.50 and 72.62 mg/ml. In hepatopancreas, the protein levels showed a clear trend depicting more or less a steady decline from stage I to stage V. The maximum value of 4.72 mg/100 mg was recorded in stage I which was followed by a gradual decrease in values in the subsequent stages of maturity,

TABLE 31: Total protein concentration in different maturity stages of *M. dobsoni*.

Tissue	Maturity stages				
	I	II	III	IV	V
Muscle (mg/100 mg dw)	41.52 ±10.73	49.23 ±8.87	47.27 ±11.28	48.67 ±12.57	40.68 ±11.29
Haemolymph (mg/ml)	67.58 ±9.44	72.62 ±14.97	65.50 ±12.12	68.36 ±11.12	70.70 ±20.78
Hepatopancreas (mg/100 mg dw)	4.72 ±0.97	4.35 ±1.84	4.55 ±1.37	3.87 ±1.60	3.53 ±1.51
Ovary (mg/100 mg dw)	23.32 ±5.61	25.25 ±6.20	29.60 ±6.64	31.10 ±6.30	25.53 ±6.37

ANOVA

Tissue	Source	df	SS	MS	F ratio
Muscle	Treat	4	369.910	99.228	0.82
	Error	25	3029.074	121.163	
Haemolymph	Treat	4	183.688	45.922	0.27
	Error	25	4318.672	172.747	
Hepatopancreas	Treat	4	5.853	1.463	0.66
	Error	25	55.069	2.203	
Ovary	Treat	4	254.057	63.514	1.64
	Error	25	970.936	38.837	

P at 0.01)

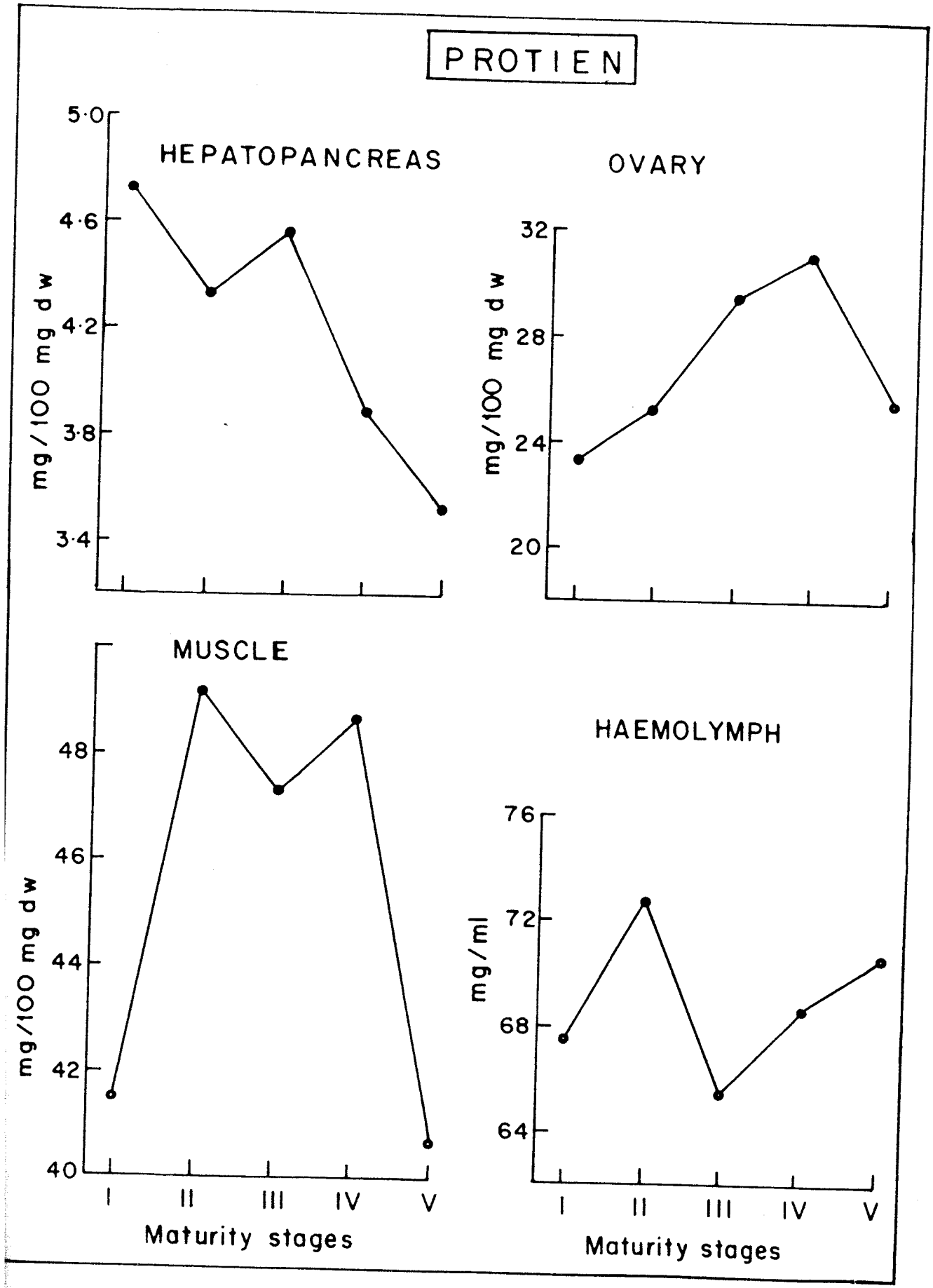


Fig.18: Total protein levels in various body tissues at different maturity stages of M. dobsoni.

except for a marginal increase in stage III. The minimum values of 3.53 mg/100 mg was recorded in stage V. The protein content of the ovary, varying from 23.32 to 31.10 mg/100 mg, showed a clear increasing trend from stage I to stage IV and thereafter suddenly dropped to 25.53 mg/100 mg in stage V reaching almost the same level as that of stage II.

Though the mean protein values obtained for different maturity stages show some trend in the muscle, hepatopancreas and ovary, the ANOVA indicated that the difference in concentration of protein is not statistically significant ($P>0.01$).

Free amino acid

Data on free amino acid (Table 32 and Fig.19) indicate that the concentration of the same in muscle tissue varied from 0.45 to 0.86 mg/100mg. Though the mean values remained very low in the first two stages, it shot up to the maximum level in stage III and thereafter declined in stages IV and V. The amino acid concentration varied from 0.13 to 0.30 mg/ml in haemolymph. It showed a clear increasing trend from stage I to stage IV when the maximum value was recorded. In stage V, the value decreased again to the minimum level of 0.13 mg/ml. Hepatopancreas, which showed the highest levels of free amino acid concentration among all the tissues studied, also exhibited a steady increasing trend in amino acid level from stage I (0.65 mg/100 mg) to stage IV (2.62 mg/100 mg). In stage V, a fall in its level was noticed.

ABLE 32: Total free amino acid concentration in different maturity stages of M. dobsoni.

issue	Maturity stages				
	I	II	III	IV	V
uscle mg/100 mg dw)	0.54 ±0.10	0.45 ±0.07	0.86 ±0.23	0.71 ±0.16	0.53 ±0.13
aemolymph mg/ml)	0.14 ±0.05	0.22 ±0.08	0.22 ±0.08	0.30 ±0.09	0.13 ±0.06
epatopancreas mg/100 mg dw)	0.65 ±0.15	0.96 ±0.28	1.76 ±0.47	2.62 ±0.59	0.88 ±0.35
vary mg/100 mg dw)	0.13 ±0.04	0.35 ±0.13	0.63 ±0.16	0.80 ±0.27	0.16 ±0.08

ANOVA

Tissue	Source	df	SS	MS	F ratio
scle	Treat	4	0.663	0.116	7.73 **
	Error	25	0.536	0.021	
emolymph	Treat	4	0.118	0.030	5.15 **
	Error	25	0.143	0.006	
patopancereas	Treat	4	15.751	3.938	25.32 **
	Error	25	3.889	0.156	
ary	Treat	4	2.095	0.524	21.33 **
	Error	25	0.614	0.025	

P at 0.01)

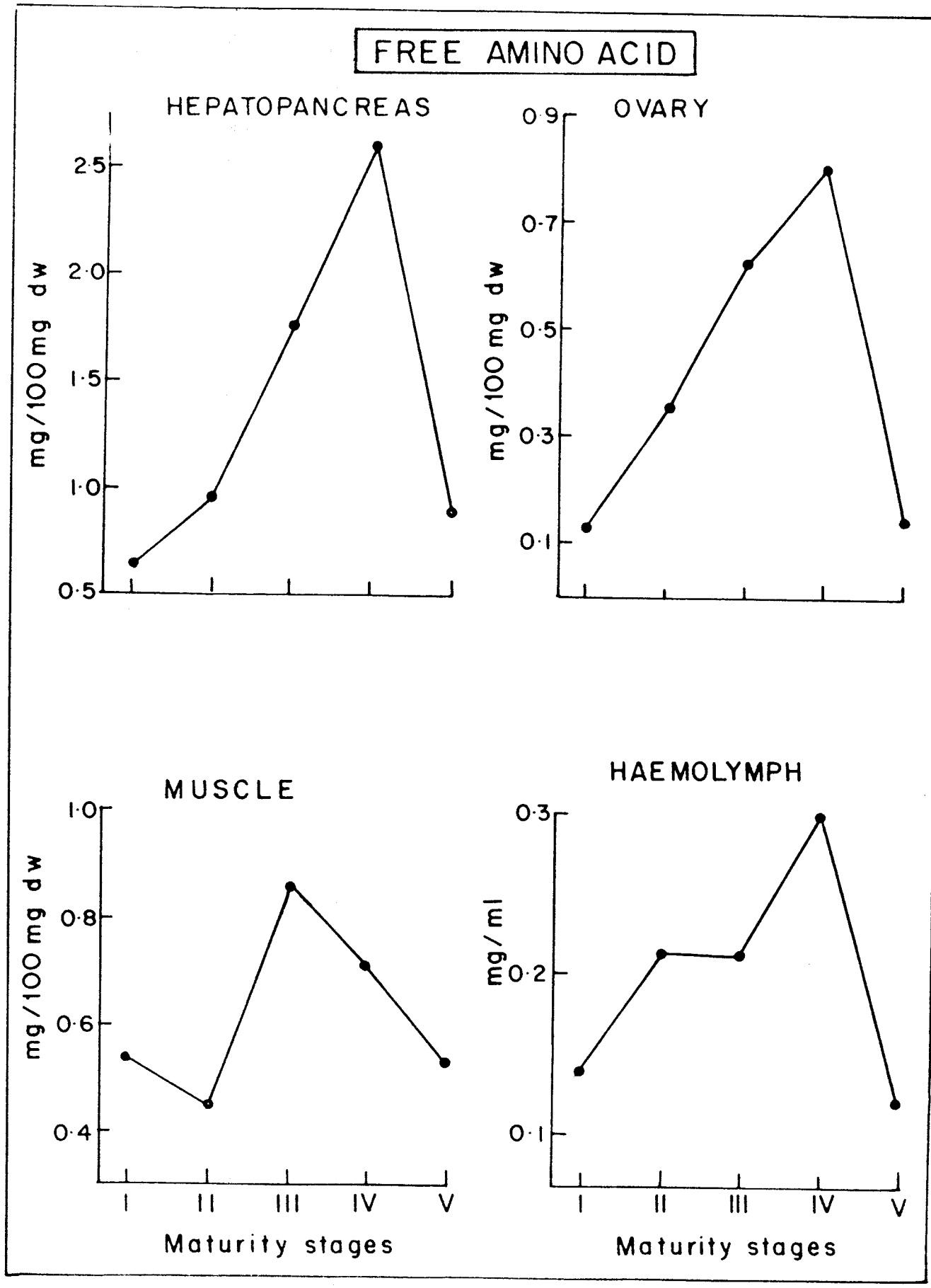


Fig.19: Total free amino acid levels in various body tissues at different maturity stages of M. dobsoni.

The ovary also showed more or less the same pattern of free amino acid values at different stages of maturation . The minimum values of 0.13 mg/100 mg was recorded in stage I and the maximum of 0.80 mg/100 mg in stage IV after passing through successive increases in stages II and III. The amino acid value suddenly dropped after stage IV, reaching to a very low level of 0.16 mg/100 mg in stage V.

From ANOVA it is seen that the variation in the concentration of free amino acid in different tissues, in different maturity stages is statistically significant ($P<.0.01$). The difference is higly significant in hepatopancreas and ovary.

Carbohydrate

As could be seen in Table 33 and Fig 20, the carbohydrate content was generally low in all the body tissues in different stages of maturity of the ovary. In muscle it varied from 0.21 to 0.45 mg/100 mg showing an increasing trend from stage I to stage IV though it marginlly decreased in stage III (0.29 mg/100 mg). In stage V, the carbohydrate concentration was the same as in stage I. Haemolymph showed a range of carbohydrate concentration from 0.38 to 1.11 mg/ml. It exhibited a clear increasing trend as the maturation progressed from stage I to stage IV. In stage V however, the carbohydrate level decreased considerably (0.56 mg/ml). In hepatopancreas, the carbohydrate level ranged from 0.37 to 0.58 mg/100 mg. The values were least in stages I and V, whereas in other stages of

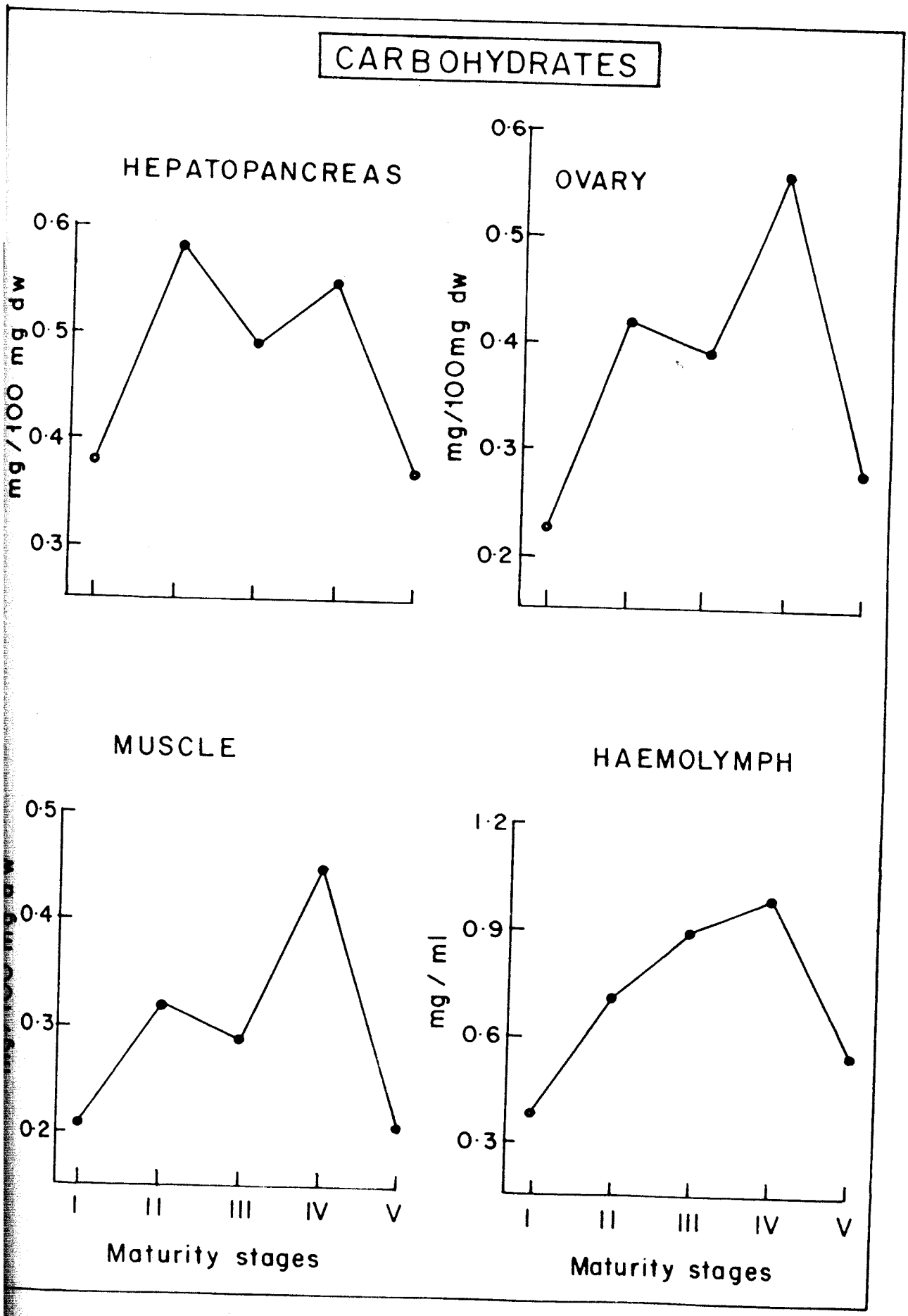
TABLE 33: Total carbohydrate concentration in different maturity stages of M. dobsoni.

Tissue	Maturity stages				
	I	II	III	IV	V
Muscle (mg/100 mg dw)	0.21 ±0.07	0.32 ±0.11	0.29 ±0.15	0.45 ±0.16	0.21 ±0.18
Haemolymph (mg/ml)	0.38 ±0.10	0.72 ±0.20	0.89 ±0.27	1.11 ±0.38	0.56 ±0.18
Hepatopancreas (mg/100 mg dw)	0.38 ±0.15	0.58 ±0.20	0.49 ±0.18	0.55 ±0.13	0.37 ±0.13
Ovary (mg/100 mg dw)	0.23 ±0.05	0.42 ±0.15	0.39 ±0.16	0.56 ±0.18	0.28 ±0.10

ANOVA

Tissue	Source	df	SS	MS	F ratio
Muscle	Treat	4	0.238	0.060	4.23
	Error	25	0.352	0.014	
Haemolymph	Treat	4	1.908	0.477	8.02 **
	Error	25	1.487	0.059	
Hepatopancereas	Treat	4	0.217	0.054	2.18
	Error	25	0.620	0.025	
Ovary	Treat	4	0.404	0.101	5.91 **
	Error	25	0.428	0.017	

P at 0.01%



ig.20: Total carbohydrate levels in various body tissues at different maturity stages of M. dobsoni.

maturation, it was relatively high (0.49 to 0.58 mg/100 mg) with the maximum in stage II. The carbohydrate concentration in ovary varied from 0.33 to 0.56 mg/100 mg and showed more or less the same trend as that in the muscle and haemolymph, showing maximum value in stage IV. The carbohydrate level showed a sudden decrease in stage V as in other tissues.

From ANOVA, it is seen that the quantitative variation of carbohydrate content in muscle, haemolymph and ovary in different maturity stages are statistically significant ($P<0.01$). The difference was however not statistically significant in hepatopancreas($P>0.01$).

Lipids

The pattern of lipid concentration in various body tissues with the advancement of maturation is evident from Table 34 and Fig.21 . As could be normally expected the mean lipid concentration in the various tissues is relatively high in all the maturity stages. It is clear from the figure that the values increased steadily from stage I to stage IV and thereafter they suddenly decreased to a very low level in all the four tissues studied. The values ranged between 3.19 and 1.59 mg/100 mg in muscle, 3.17 and 12.28 mg/ml in haemolymph, 1.39 and 19.43 mg/100mg in hepatopancreas and 9.01 and 18.56 mg/100 mg in ovary. The ANOVA reveals that the variation in lipid concentration in different tissues between different stages of maturation is highly significant statistically ($P<0.01$).

TABLE 34: Total lipid concentration in different maturity stages of *M. dobsoni*.

Tissue	Maturity stages				
	I	II	III	IV	V
Muscle (mg/100 mg dw)	3.19 ±1.11	5.68 ±2.13	7.30 ±1.63	8.59 ±2.15	3.90 ±0.89
Haemolymph (mg/ml)	3.17 ±0.59	6.29 ±2.13	9.35 ±1.63	12.28 ±2.15	5.59 ±0.99
Hepatopancreas (mg/100 mg dw)	9.39 ±3.11	14.34 ±2.18	18.52 ±2.91	19.43 ±4.59	10.13 ±3.38
Ovary (mg/100 mg dw)	9.26 ±2.93	12.41 ±2.22	16.73 ±1.99	18.56 ±2.14	9.01 ±2.02

ANOVA

Tissue	Source	df	SS	MS	F ratio
Muscle	Treat	4	122.817	30.704	10.94 **
	Error	25	70.153	2.806	
Haemoloymph	Treat	4	300.201	75.050	17.50 **
	Error	25	107.218	4.289	
Hepatopancreas	Treat	4	513.734	128.434	11.59 **
	Error	25	276.951	11.078	
Ovary	Treat	4	449.231	112.308	21.51 **
	Error	25	130.512	5.220	

(P at 0.01)

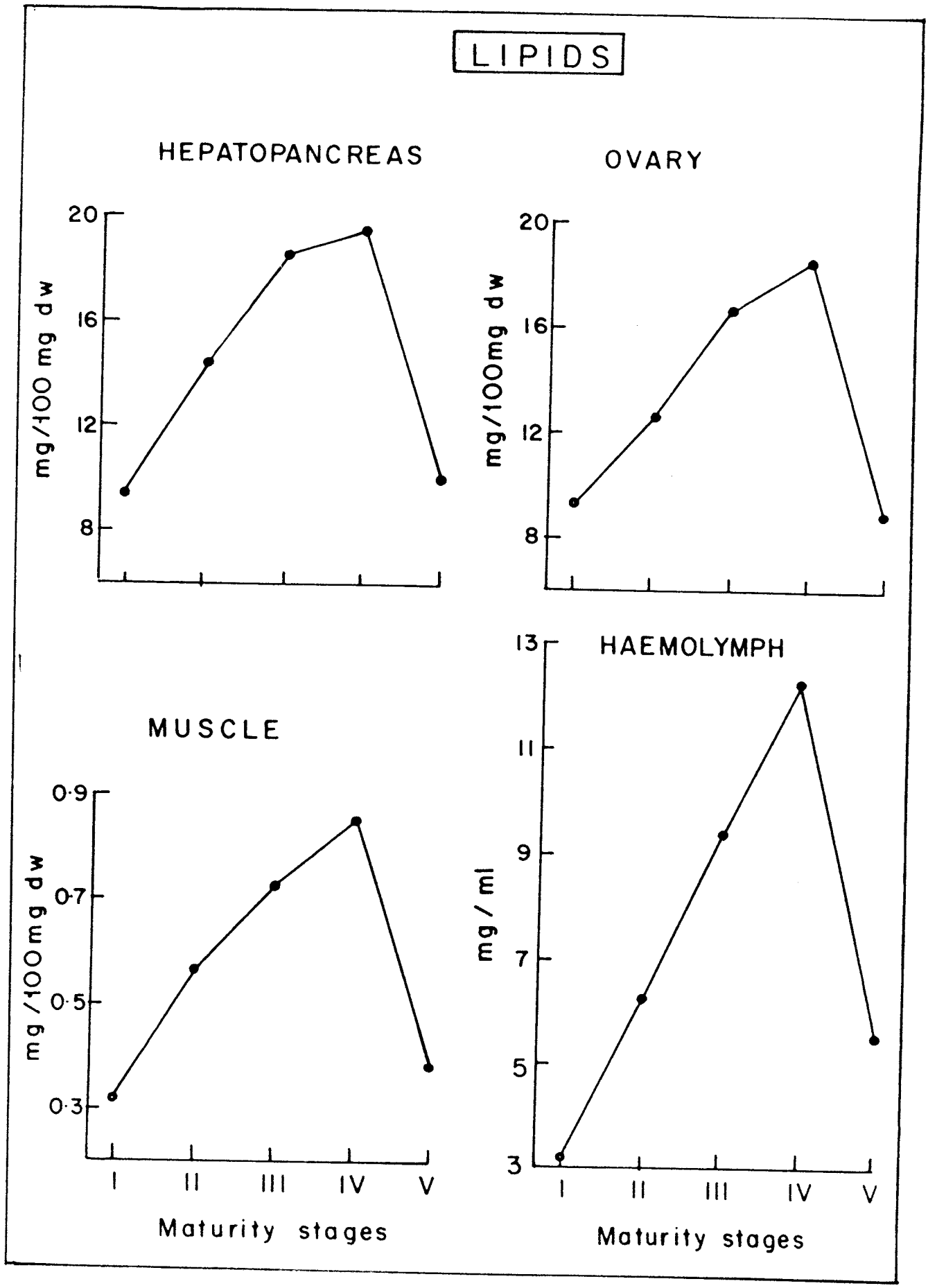


Fig.21: Total lipid levels in various body tissues at different maturity stages of M. dobsoni.

TABLE 35: Moisture levels in different maturity stages of M.dobsoni.

Tissue	Maturity stages				
	I	II	III	IV	V
Muscle (%)	71.67 ±1.50	71.17 ±1.90	72.82 ±0.75	74.00 ±0.75	73.00 ±0.89
Hepatopancreas (%)	69.67 ±1.87	60.50 ±1.87	54.17 ±1.72	54.00 ±1.41	70.17 ±1.47
Ovary (%)	72.00 ±1.27	70.83 ±1.72	70.33 ±1.37	68.50 ±1.64	75.33 ±1.50

ANOVA

Tissue	Source	df	SS	MS	F ratio
Muscle	Treat	4	30.469	7.617	4.05
	Error	25	47.000	1.880	
Hepatopancreas	Treat	4	1515.789	378.947	134.36 **
	Error	25	70.508	2.820	
Ovary	Treat	4	154.203	38.551	16.91 **
	Error	25	57.00	2.280	

(P at 0.01)

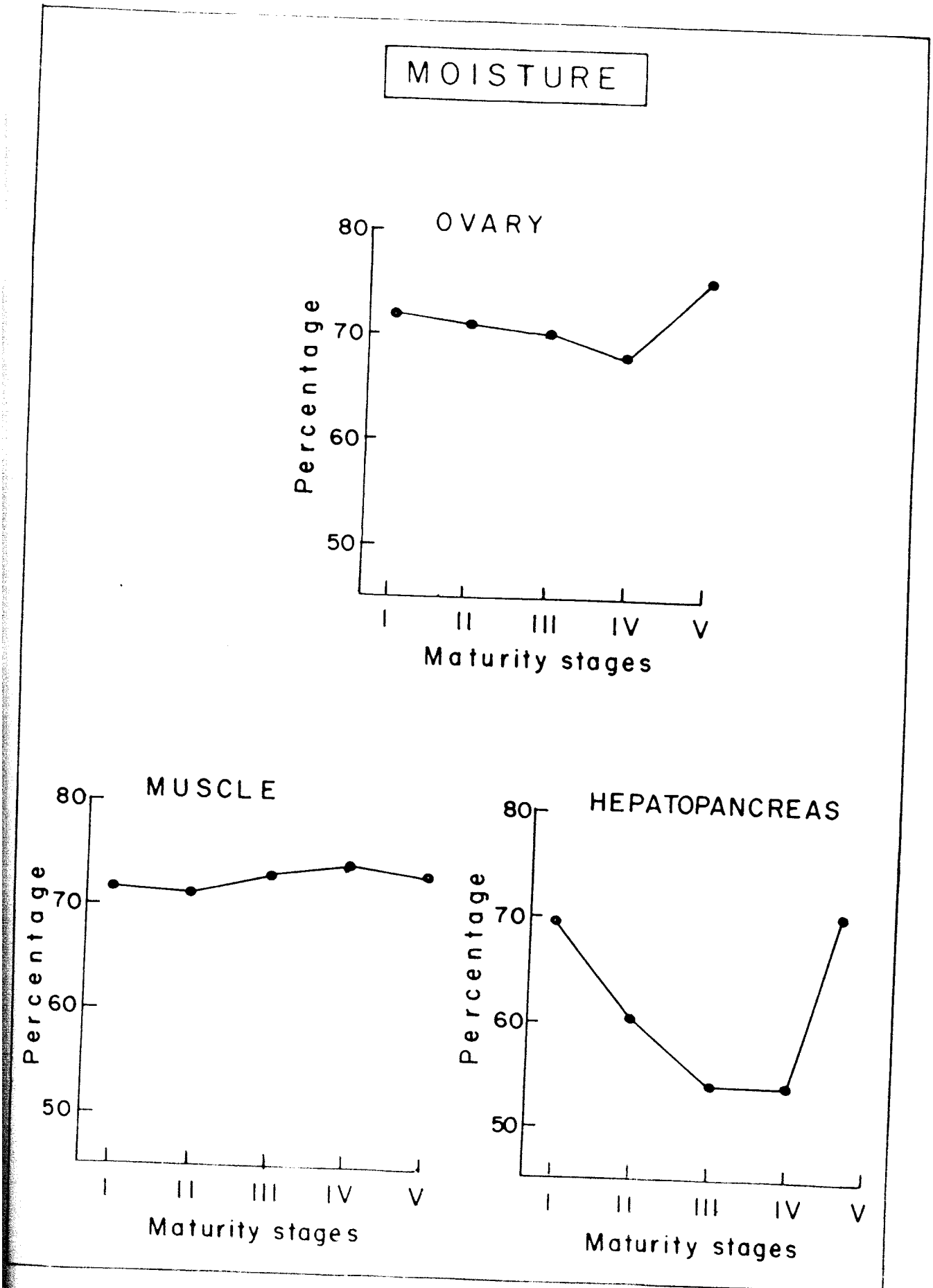


Fig.22: Moisture levels in various body tissues at different maturity stages of M.dobsoni.

Moisture

Analysis of moisture content in muscle, hepatopancreas and ovary (Table 35 and Fig.22) indicates that the moisture content is uniformly high in muscle tissue at all stages of maturity, with relatively less variation between the successive stages (Fig. 22). The values ranged between 71.17 in stage II and 74.00 in stage IV. In the case of hepatopancreas the values steadily dropped from 69.67 per cent in stage I to 54.17 per cent in stage III and after remaining more or less at the same level in stage IV (54.0%), it shot up to the maximum of 70.17 per cent in stage V. The moisture content of ovary ranged from 68.50 to 75.33 per cent. It showed a gradual decreasing trend from 72 per cent in stage I to 68.5 per cent in stage IV and thereafter suddenly increased to the maximum in stage V.

From the ANOVA, it is observed that the variation in moisture level of different body tissues, between different stages of maturation are statistically significant in all the three cases ($P<0.01$). The difference is found to be highly significant in hepatopancrea ($P<0.01$).

Distribution of reproductive stages in prawn culture fields

It is evident from the field studies on growth of M.dobsoni described in the preceeding chapter that the species attains fairly large size in the perennial prawn culture fields as compared to the growth recorded in the open backwater system

(Mohamed and Rao 1971). It is also observed that both the males and females attain full maturity in the culture fields and normal mating also takes place in the brackishwater conditions as revealed by the presence of impregnated females. Between the two sexes, it appears that, the attainment of maturation is quite common among males, where as in females the chances of maturation are relatively low since the number of animals in maturing or mature stage in the population is found to be relatively meagre. In order to study the seasonal and size wise distribution of various maturity stages of both the sexes, impregnated females and sex-ratios, the data collected over a period of 19 months from January 1990 to August 1991 and 10 months from August 1990 to May 1991 from Kannuvilakettu and Thoppilkettu respectively, have been analysed. No observation, however, could be made at Kannuvilakettu during November 1990 as there was no prawn filtration in that month. The maturity stages III and IV in the case of males and II, III and IV in the case of females were combined together and treated as 'mature' for the purpose of general comparison.

Seasonal distribution of maturity stages

Males

A total of 5903 prawns from Kannuvilakettu and 2111 prawns from Thoppilkettu were analysed. The percentage distribution of males in different maturity stages for Kannuvilakettu and Thoppilkettu are given in Tables 36 and 37. It can be seen from the Table 36, that prawns in immature and

TABLE 36: Monthly distribution of maturity stages of males of M.dobsoni in Kannuvilakettu.

Months	Total No. of prawns observed	Maturity stages							
		I		II		III		IV	
		No.	%	No.	%	No.	%	No.	%
Jan 1990	631	328	52.0	288	45.6	15	2.4	-	-
Feb	763	418	54.8	234	30.7	105	13.8	6	0.8
Mar	648	237	36.6	316	48.8	69	10.6	26	4.0
Apr	330	122	37.0	128	38.8	61	18.5	19	5.8
May	629	195	31.0	245	38.9	143	22.7	46	7.3
Jun	232	22	9.5	79	34.0	114	49.11	17	7.3
Jul	86	3	3.5	6	7.0	12	13.8	65	75.6
Aug	187	115	61.5	36	19.2	20	10.7	16	8.5
Sep	134	25	18.6	48	35.8	59	44.0	2	1.5
Oct	173	29	16.8	54	31.2	74	42.8	16	9.2
Dec	137	41	29.9	44	32.1	37	27.0	15	10.9
Jan 1991	374	149	39.8	74	19.8	73	19.5	78	20.9
Feb	381	273	71.6	96	25.2	10	2.6	2	0.5
Mar	161	23	14.3	121	75.2	16	9.9	1	0.6
Apr	164	25	15.2	15	9.1	19	11.6	105	64.0
May	368	89	24.2	136	37.0	71	19.3	72	19.6
Jun	192	8	4.2	63	32.8	84	43.7	37	19.2
Jul	107	4	3.7	17	15.9	58	54.2	28	26.2
Aug	206	10	4.8	33	16.0	98	47.6	65	31.6
Total/%	5903	2166	35.9	2033	34.4	1138	19.3	616	10.4

early maturing condition constituted about 70 per cent of the total prawns. The remaining 30 per cent was formed by mature males. The month-wise distribution indicates that the proportion of immature males was relatively low (3.5-9.5%) during June-July 1990 and June-August 1991. In the other months they formed about 14 to 72 per cent with peak occurrence in the months of February 54.8-71.6%). The early maturing males (stage II) were noticed in relatively high proportion almost throughout the study period except in July 1990 and April 1991, when it formed only less than 10 per cent. During the other months, the percentage ranged from about 16 to 75, the maximum (75.2%) being recorded in March 1991. The percentage of mature males was the least in January 1990 (2.4%) and February 1991 (3.1%). In the other months, it varied from 10 to 90 per cent with the highest value in July of both the years (89.5 & 80.4%).

The results presented in Table 37 for Thoppilkettu indicate that mature males accounted for about 50 per cent of the total prawns sampled. The immature males were of lower magnitude (15.7%) and as many as 34 per cent of the population was found to be constituted by early maturing males. The data on monthly distribution shows that immature males were absent from August to November 1990. During the rest of the months, their percentage varied from 12 to 34 with maximum during February 1991 (33.8%). Early maturing males were absent during August to October 1990 and thereafter their proportion varied between 13 and 49 per cent with the highest occurrence in December 1990. Mature males predominated the total male

TABLE 37: Monthly distribution of maturity stages of males of M.dobsoni in Thoppilkettu.

Months	Total No. of prawns observed	Maturity stages							
		I		II		III		IV	
		No.	%	No.	%	No.	%	No.	%
Aug 1990	104	-	-	-	-	-	-	104	100
Sep	47	-	-	-	-	-	-	47	100
Oct	145	-	-	-	-	-	-	145	100
Nov	152	-	-	20	13.2	23	15.1	109	71.7
Dec	385	63	16.4	189	49.1	95	34.7	38	9.9
Jan 1991	257	39	15.2	67	26.1	62	24.1	89	34.6
Feb	441	149	33.8	202	45.8	68	15.4	22	5.0
Mar	336	46	13.7	147	43.8	109	32.4	34	10.1
Apr	108	13	12.0	41	38.0	27	25.0	27	25.0
May	136	22	16.2	58	42.7	32	23.5	24	17.7
Total/%	2111	332	15.7	724	34.3	416	19.7	639	30.3

TABLE 38: Monthly distribution of maturity stages of females of M.dobsoni in Kannuvilakettu.

Months	Total No. of prawns observed	Maturity stages							
		I		II		III		IV	
		No.	%	No.	%	No.	%	No.	%
Jan 1990	664	664	100	-	-	-	-	-	-
Feb	713	713	100	-	-	-	-	-	-
Mar	661	661	100	-	-	-	-	-	-
Apr	459	459	100	-	-	-	-	-	-
May	723	723	100	-	-	-	-	-	-
Jun	290	290	100	-	-	-	-	-	-
Jul	87	87	100	-	-	-	-	-	-
Aug	226	226	100	-	-	-	-	-	-
Sep	14	14	100	-	-	-	-	-	-
Oct	300	300	100	-	-	-	-	-	-
Dec	173	173	100	-	-	-	-	-	-
Jan 1991	429	429	100	-	-	-	-	-	-
Feb	446	446	100	-	-	-	-	-	-
Mar	159	159	100	-	-	-	-	-	-
Apr	201	168	83.6	32	15.9	1	0.5	-	-
May	415	393	84.5	16	3.4	4	0.9	2	0.4
Jun	239	228	95.4	11	4.6	-	-	-	-
Jul	123	113	91.9	10	8.1	-	-	-	-
Aug	227	227	100	-	-	-	-	-	-
Total/%	6549	6473	98.8	69	1.1	5	0.1	2	0.03

population in all the months of observation. They accounted for 35 to 100 per cent of the total males except in February 1991 when the abundance of mature prawns was the minimum.

(b) Females

As the prawns in advanced maturity stages were noticed only in Kannuvilakettu, the study of seasonal abundance of different maturity stages was limited to only this system. Examination of a total of 6549 prawns indicated that prawns with maturing gonads occurred only for a short period of April to July 1991 (Table 38). During the rest of the months the prawns were all in immature condition. Mature prawns constituted only about 1 per cent of the total female population. Month-wise distribution of mature females indicated a range of 5 to 16 per cent with the maximum percentage in April 1991. In all, only 76 mature prawns could be recorded during the entire period of study.

Size-wise distribution of maturity stages

a) Males

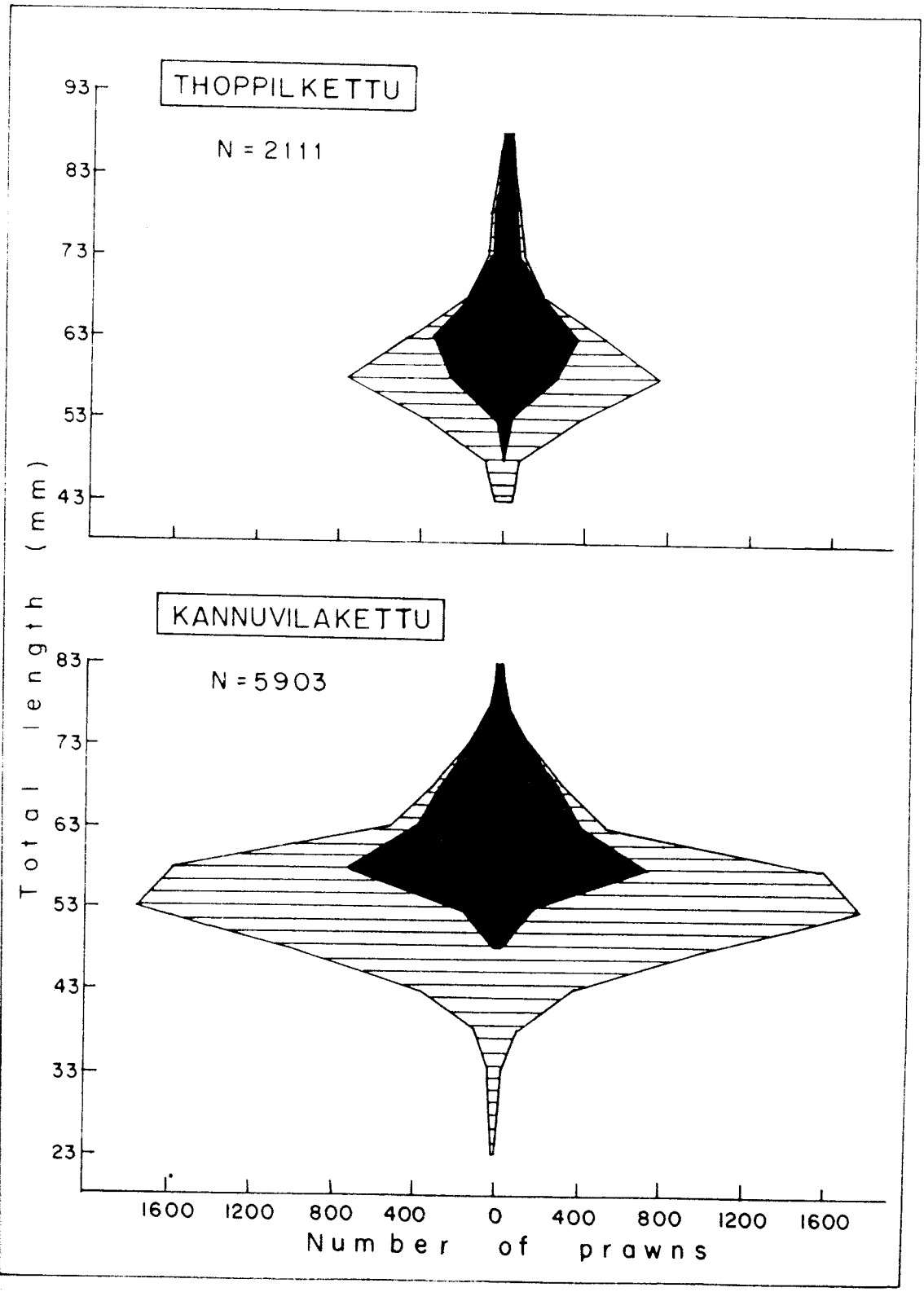
The relative abundance of mature males in total male population (Fig.23) indicate the predominance of mature males in sizes above 58 mm Prawns above 63 mm size were generally noticed in mature condition in both the culture systems.

b) Females

The results of size-wise analysis of the data (Table 39 and Fig. 24) showed that prawns above 70 mm only indicated

TABLE 39: Size-wise distribution of maturity stages of females of M.dobsoni in Kannuvilakettu.

Mid points of size groups (mm)	Total No. of prawns observed	Maturity stages							
		I		II		III		IV	
		No.	%	No.	%	No.	%	No.	%
23	2	2	100	-	-	-	-	-	-
28	17	17	100	-	-	-	-	-	-
33	24	24	100	-	-	-	-	-	-
38	89	89	100	-	-	-	-	-	-
43	289	289	100	-	-	-	-	-	-
48	825	825	100	-	-	-	-	-	-
53	1541	1541	100	-	-	-	-	-	-
58	1312	1312	100	-	-	-	-	-	-
63	958	958	100	-	-	-	-	-	-
68	623	623	100	-	-	-	-	-	-
73	390	384	98.5	6	1.5	-	-	-	-
78	245	224	91.5	21	8.6	-	-	-	-
83	160	128	80.0	29	18.1	3	1.9	-	-
88	65	51	78.5	10	15.4	2	3.1	2	3.1
93	8	5	62.5	3	37.5	-	-	-	-
98	1	1	100	-	-	-	-	-	-
otal/%	6549	6473	98.8	69	1.1	5	0.1	2	0.03



g.23: Relative abundance of mature males in total male population of M.dobsoni in the perennial prawn culture systems.

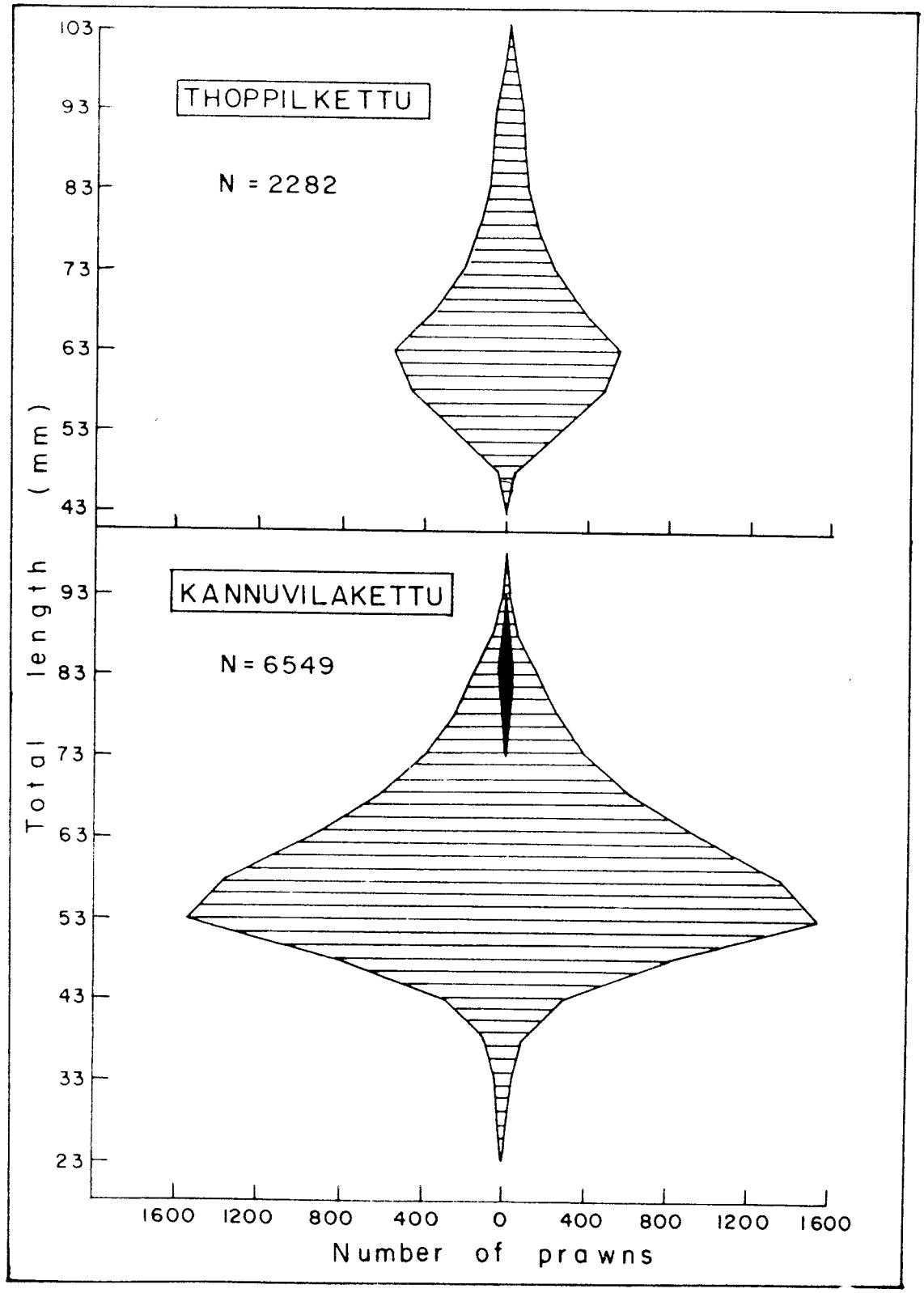


Fig.24: Relative abundance of mature females in total female population of M.dobsoni in the perennial prawn culture systems.

sign of maturation. In general, immature females dominated in all the size groups and their percentages ranged from 63 to 100. The mature females accounted for about 2 to 38 per cent in the higher size group (71-95 mm). In the category of mature females the proportion of early maturing (stage II), late maturing (stage III) and fully mature (stage IV) prawns was 1.1, 0.1 and 0.03 per cent respectively. Out of the 76 mature prawns recorded, the majority (46) belonged to the size group 81 to 90 mm which was represented by all the stages of ovarian development. The maturing and mature females were not encountered from Thoppilekttu.

Size-wise distribution of impregnated females

Mating and impregnation is an important aspect of reproduction for successful production of fertilized ova. In the present study, an attempt was made to understand the incidence of impregnation in females based on 6599 prawns from Kannuvilakettu and 2282 from Thoppilkettu and the results are presented in Table 40. In both the culture systems, impregnation was noticed in animals of 66 mm size and above. The number of impregnated females in the population gradually increased with increase in size. In the size-group 66 to 70 mm, the percentage of impregnated prawns was hardly 2, which steadily increased in the higher sizes and reached 100 in 96 to 100 mm size-group in Kannuvilakettu and 101 to 105 mm size group in Thoppilkettu. Over 50 per cent were impregnated in 76 to 80 mm size-group and above in Kannuvilakettu and 96 to 100mm size group and above in Thoppilkettu.

TABLE 40: Size-wise distribution of impregnated females of *M.dobsoni* in the prawn culture fields.

Size group	Kannuvilakettu			Thoppilkettu		
	Total No.of females	No. impregnated	% impregnated	Total No.of females	No. impregnated	% impregnated
21-25	2	-	-	-	-	-
26-30	17	-	-	-	-	-
31-35	24	-	-	-	-	-
36-40	89	-	-	1	-	-
41-45	289	-	-	1	-	-
46-50	825	-	-	40	-	-
51-55	1541	-	-	247	-	-
56-60	1362	-	-	473	-	-
61-65	958	-	-	541	-	-
66-70	623	11	1.8	365	6	1.7
71-75	390	116	29.7	217	49	22.6
76-80	245	173	70.6	143	38	26.6
81-85	160	129	80.6	91	39	42.9
86-90	65	56	86.2	78	34	43.6
91-95	8	7	87.5	67	26	38.8
96-100	1	1	100.0	17	14	82.6
101-105	-	-	-	1	1	100.0
Total/%	6599	493	7.5	2282	207	9.1

TABLE 41: Month-wise distribution of impregnated females of M.dobsoni (> 65 mm TL) in the prawn culture fields.

Months	Kannuvilakettu			Thoppilkettu		
	Total No.of females	No. impreg-nated	% impreg-nated	Total No.of females	No. impreg-nated	% impreg-nated
Jan 1990	31	-	-	-	-	-
Feb	56	3	5.4	-	-	-
Mar	36	5	13.9	-	-	-
Apr	23	3	13.0	-	-	-
May	44	8	18.2	-	-	-
Jun	59	7	11.9	-	-	-
Jul	95	44	46.3	-	-	-
Aug	3	2	66.7	140	52	37.1
Sep	4	-	-	96	32	33.3
Oct	189	29	15.3	140	43	30.7
Nov	-	-	-	183	41	22.4
Dec	27	2	7.4	29	2	6.9
Jan 1991	39	2	5.1	152	7	4.6
Feb	-	-	-	62	-	-
Mar	37	4	10.8	90	11	12.2
Apr	147	95	64.6	87	19	21.8
May	172	62	36.1	-	-	-
Jun	169	65	38.5	-	-	-
Jul	198	118	59.6	-	-	-
Aug	163	44	27.0	-	-	-
Total/%	1492	493	33.0	979	207	21.1

Seasonal distribution of impregnated females

For this study, prawns of 66 mm size and above were only considered as impregnation was not noticed in still smaller sizes. A total of 1492 prawns from Kannuvilakettu and 979 from Thoppilkettu were examined for the purpose and the results are presented in Table 41. It is observed that impregnated females in significant proportion were recorded during July and August 1990 (46.3-66.7%) and April to July 1991 (36.1-64.6%) in Kannuvilakettu. The percentage of impregnated females in Thoppilkettu ranged from 5 to 37, with relatively higher values during August to October 1990 (30.7-37.1 %). Comparing the incidence of impregnated animals in the two culture systems, it was observed that Kannuvilakettu had a higher proportion (33.0 %) than Thoppilkettu (21.1%).

Seasonal distribution of sex-ratios

Examination of a total of 12,502 prawns from Kannuvilakettu (Table 42) and 4393 prawns from Thoppilkettu (Table 43) showed a general dominance of females throughout the study period (50.3-63.4 %), in Kannuvilakettu except during February '90 (48.3%), September '90 (9.5 %) and March '91 (49.7 %). During September '90, males outnumbered females to the extent of over 90 per cent. In Thoppilkettu also the females (50.9-72.4 %) dominated over males almost throughout the study period except in December '90 (48.7%), February 91 (47.0 %) and March '91 (48.6%). A very high proportion of female prawns (72.4 %) was observed during September '90.

TABLE 42: Monthly distribution of sex-ratios of M. dobsoni in Kannuvilakettu.

Months	Total No. of prawns observed	Number		Percentage	
		Male	Female	Male	Female
Jan 1990	1295	631	664	48.7	51.3
Feb	1476	763	713	51.7	48.3
Mar	1309	648	661	49.5	50.5
Apr	789	330	459	41.8	58.2
May	1352	629	723	46.5	53.5
Jun	522	232	290	44.4	55.6
Jul	173	86	87	49.7	50.3
Aug	413	187	226	45.3	54.7
Sep	148	134	14	90.5	9.5
Oct	473	173	300	36.6	63.4
Dec	310	137	173	44.2	55.8
Jan 1991	803	374	429	46.6	53.4
Feb	827	381	446	46.1	53.9
Mar	320	161	159	50.3	49.7
Apr	365	164	201	44.9	55.1
May	833	368	465	44.2	55.8
Jun	431	192	239	44.6	55.4
Jul	230	107	123	46.5	53.5
Aug	433	206	227	47.6	52.4
Total/%	12502	5903	6599	47.2	52.8

TABLE 43: Monthly distribution of sex-ratios of M. dobsoni in Thoppilkettu

Months	Total No. of prawns observed	Number		Percentage	
		Male	Female	Male	Female
Aug 1990	240	104	136	43.3	56.7
Sep	170	47	123	27.6	72.4
Oct	295	145	150	49.1	50.9
Nov	361	152	209	41.1	57.9
Dec	750	385	365	51.3	48.7
Jan	565	257	308	45.5	54.5
Feb	832	441	391	53.0	47.0
Mar	653	336	317	51.4	48.6
Apr	231	108	123	46.8	53.2
May	296	136	160	45.9	54.1
Total/%	4393	2111	2282	48.1	51.9

Maturation and Spawning

The results obtained in different maturation experiments are summerised in Tables 44a-44i.

Experiment I (Table 44a)

This experiment was conducted in salinities 28 and 30 ppt, each in triplicate, during July-August 1990. Impregnated immature female prawns in the size range 80 to 93 mm were used. These animals were collected from coconut grove canal system where the water temperature recorded 28^{o}C, salinity 4.85 ppt, pH 7.54 and oxygen 4.64 mg/l. In each experimental tub, one female and a mature male were maintained. In 28 ppt salinity the prawns moulted on the third day, while in 30 ppt the moulting occurred in 3-8 days time from the beginning of the experiment. Though all the animals lost their spermatophore present on the thelycum during moulting, the experiment was continued. After 2-3 days of moulting, sign of gonadal development was noticed in prawns maintained in 28 ppt; though this was observed after 6-8 days in 30 ppt. Three days after initiation of maturation, the prawns spawned in 28 ppt whereas, it occured after 4-5 days in 30 ppt. Majority of ova released were unfertilized in both cases and the percentage of fertilization varied between 2.1 and 6.0. The number of eggs released varied from 23,000 to 33,400. During the experiment the temperature of water ranged 25.3-28.1^{o}C, pH 8.01-8.30, dissolved oxygen 5.08-6.24 mg/l, nitrite 2-16 µg at/l and ammonia 2-40 µg at/l.

TABLE 44a: Details of maturation experiments of M. dobsoni in different salinity conditions in the laboratory.

Expriment-I.

Particulars	Salinity ‰					
	28 ± 0.24			30 ± 0.15		
	Tank 1	Tank 2	Tank 3	Tank 1	Tank 2	Tank 3
1. Date of commencement	29.7.'90	29.7.90	29.7.90	29.7.90	29.7.90	29.7.90
2. Total length (mm)	90	90	80	88	87	93
3. Maturity stage	I	I	I	I	I	I
4. Physico chemical conditions of rearing media:						
i) Temperature (°C)	25.52-28.0	25.4-27.9	25.5-28.0	25.3-27.9	25.4-28.0	25.5-28.10
ii) pH	8.11-8.33	8.09-8.22	8.04-8.18	8.02-8.22	8.01-819	8.06-8.28
iii) Oxygen (mg/l)	5.08-6.20	5.48-6.15	5.01-6.10	5.40-6.30	5.08-6.24	5.65-6.18
iv) Nitrite (µg at/l)	4-16	4-14	8-16	2-12	2-16	4-10
v) Ammonia (µg at/l)	4-24	6-30	4-30	8-40	4-36	2-34
5. Time taken for initiation of maturation (in days)	5	5	5	6	8	no initiation
6. Progress of maturation: Time taken to reach the successive stage (in hrs)						
i) II to III stage	48	48	48	50	72	-
ii) III to IV stage	14	15	18	20	22	-
7. End result	Spawned	Spawned	Spawned	Spawned	Spwaned	-
8. No.of eggs spawned	33,400	29,600	23,600	30,600	23,000	-
9. Time taken for moulting after initiation of experiment (in days)	3	3	3	3	7	8

Experiment II (Table 44b)

This experiment was conducted in 27 ppt salinity with six replicates during August-September 1990. The impregnated immature female prawns in the size range of 80 to 93 mm used for the experiment were collected from coconut grove canal system where the water temperature recorded 28.2^0 C, salinity 3.7 ppt, pH 7.82 and dissolved oxygen 5.23 mg/l. The prawns moulted 5 to 8 days after commencement of the previous experiment. Though all the animals lost their spermatophores as in experiment (Table 44a), the rearing was continued. Only three of the six prawns (Tank 1,2 & 5) showed sign of gonadal development and it occurred with in two days after moulting. The maturation process progressed well in two prawns of size 90 mm (Tank 1) and 80 mm (Tank3) and the same spawned successfully on the third day. One of the prawns spawned at 0100 hrs and the other at 0300 hrs. Majority of ova were unfertilized in both the cases and rate of fertilization varied from 2.3 to 2.4 per cent. In the third, prawn of size 87 mm (Tank 5), the ovary attained late maturing stage on the third day after moulting, but the animal failed to spawn as the ovary was reabsorbed subsequently. The number of eggs spawned varied from 21,650-21,900 indicating only a marginal difference between the two. During the experimental period, the temperature of water ranged $26.8\text{-}28.3^oC$ pH 7.95-8.26, dissolved oxygen 4.68-6.50 mg/l, nitrite 2-18 µg at/l and ammonia 4-40 µg at/l.

BLE 44b: Details of maturation experiments of M.dobsoniin different salinity conditions in the laboratory.

Experiment II

Particulars	Salinity (‰)					
	27±0.21					
	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6
1. Date of commencement	21.8.'90	21.8.90	21.8.90	21.8.90	21.8.90	21.8.90
2. Total length (mm)	90	90	80	88	87	93
3. Maturity stage	I	I	I	I	I	I
4. Physico chemical conditions of rearing media:						
i) Temperature°(C)	26.8-28-2	26.8-28.2	26.8-28.3	26.8-28.3	26.8-28.2	26.8.28.3
ii) pH	7.95-8.31	7.95-8.26	8.00-8.26	8.00-8.24	8.08-8.24	8.08-8.20
iii) Oxygen (mg/l)	4.68-6.00	4.95-6.18	5.08-6.30	5.08-6.18	5.45-6.50	4.95-6.18
iv) Nitrite (µg at/l)	6-18	8-12	2-8	4-14	6-10	4-10
v) Ammonia (µg at/l)	4-22	4.36	6-38	6-38	6-42	6-40
5. Time taken for initiation of maturation (in days)	7	no initiation	8	no initiation	8	no initiation
6. Progress of maturation: Time taken to reach the successive stage (in hrs)						
i) II to III stage	48	--	44	--	72	--
ii) III to IV stage	18	--	16	--	--	--
7. End result	Spawned	--	Spawned	--	reabsorbed	
8. No.of eggs spawned	21,650	--	21,900	--	--	--
9. Time taken for moulting after initiation of experiment (in days)	5	8	6	6	6	7

Experiment III (Table 44c)

The experiment was conducted in salinities 24,26,28 and 30 ppt, each in duplicate, during May 1991. The immature impregnated females were collected from Kannuvilakettu where the water temperature recorded 28.3°C, salinity 18.2 ppt, pH 7.98, oxygen 6.25 mg/l, nitrite 4 µg at/l and ammonia 10 µg at/l. The size of females varied from 75 to 88 mm. In each tub two females were reared along with males. There was no sign of ovarian development at all in 24 ppt. In 26 and 28 ppt, only one prawn in each salinity, showed indication of gonadal development, while in 30 ppt salinity one prawn in each of the two tubs showed indication of maturation. The time taken for initiation of maturation was 4 days in both tanks of 26 and 28 ppt, while it was 2 and 5 days in the two tanks of 30 ppt salinity, from the beginning of the experiment. All prawns, after initiation of maturation attained stage III within 24 hours. However, further development of the ovary took place only in 28 and 30 ppt, in which the animal spawned on the third day. In 26 ppt salinity, the partly developed ovary was subsequently reabsorbed. All the three prawns spawned in the night between 0030 hrs and 0200 hrs. The number of eggs spawned varied from 19850 to 28350 in prawns maintained in 30 ppt (82 mm) and 28 ppt (88 mm) respectively. All the animals which had not shown any gonadal change moulted 10-12 days after commencement of the experiment. The temperature of the rearing media ranged 28.1-29.2°C, pH 8.02-8.34, oxygen 4.30-6.60 mg/l, nitrite 2-30 µg at/l and ammonia 8-32 µg at/l.

TABLE 44c: Details of maturation experiments of M. dobsoni in different salinity conditions in the laboratory.

Experiment III.

Particulars	Salinity ‰							
	24 ± 0.14		26 ± 0.36		28 ± 0.29		30 ± 0.18	
	Tank 1	Tank 2	Tank 1	Tank 2	Tank 1	Tank 2	Tank 1	Tank 2
Date of commencement	15.5.'91	15.5.91	15.5.91	15.5.91	15.5.91	15.5.91	15.5.91	15.5.91
Total length (mm)	86.84	85,76	98,82	86.75	88.75	81.83	86.73	85.82
Maturity stage	I	I	I	I	I	I	I	I
Physico chemical conditions of rearing media:								
i) Temperature (°C)	28.2-29.1	28.1-29.1	28.1-29.1	28.1-29.1	28.1-29.2	28.1-29.2	28.1-29.2	28.1-29.2
ii) pH	8.02-8.34	8.04-8.31	8.08-8.31	8.09-8.28	8.10-8.28	8.10-8.28	8.09-8.26	8.07-8.26
ii) Oxygen (mg/l)	4.68-6.60	4.45-6.30	4.30-6.40	4.58-6.05	5.05-6.20	5.05-6.40	4.68-6.30	5.08-6.30
iv) Nitrite (µg at/l)	4-16	4-16	2-30	4-14	2-24	2-18	6-18	4-16
v) Ammonia (µg at/l)	14-38	14-30	8-26	8-28	8-32	10-28	10-40	16-30
Time taken for initiation of maturation (in days)	no initiation	no initiation	4	no initiation	4	no initiation	2	5
Progress of maturation: Time taken to reach the successive stage (in hrs)								
i) II to III stage	-	-	24	-	24	-	22	24
ii) III to IV stage	-	-	-	-	10	-	10	12
End result	-	-	reabsorbed	-	spawned	-	spawned	spawned
No.of eggs spawned	-	-	-	-	28,350	-	26,450	19,850
Time taken for moulting after initiation of experiment (in days)	10	11	-	12	—	12	-	-

Experiment IV (Table 44d)

This experiment was also conducted in salinities 24, 26, 28 and 30 ppt in duplicate and it continued from the end of May to the middle of June 1991. Here also two female and 2 male prawns were maintained in each tub. The size of female prawns ranged from 81 to 94 mm. The animals were collected from Kannuvilakettu where the water temperature recorded 27.6°C, salinity 17.63 ppt, pH 8.0, oxygen 5.65 mg/l, nitrite 6 µg at/l and ammonia 9 µg at/l. The results on maturation indicated that only one prawn in each tub of salinities 26 and 28 ppt showed sign of gonadal development on the 4th and 5th days respectively after the commencement of the experiment. Within 24 hours of initiation of maturation, the ovaries reached the III stage of maturity in both the animals. Of the two prawns, however,the one maintained in 28 ppt only attained full maturity and spawned on the second day after initiation of maturation, releasing about 35,700 eggs, while the other in 26 ppt slowly resorbed the partly developed ovary. The spawning took place at 0215 hrs. In 24 and 30 ppt salinities, the animals did not show any sign of gonadal development. All animals which did not attain maturation moulted in about 10-13 days period after the commencement of the experiment. During the experiment the temperature of the rearing media ranged 27.7-28.9$_0$ C, pH 8.02-8.27, oxygen 4.68-6.20 mg/l nitrite 4-48 µg at/l and ammonia 6-95 µg at/l.

LE 44d: Details of maturation experiments of M. dobsoni in different salinity conditions in the laboratory.

Expriment-IV

Particulars	Salinity ‰							
	24 ± 0.24		26 ± 0.18		28 ± 0.16		30 ± 0.15	
	Tank 1	Tank 2	Tank 1	Tank 2	Tank 1	Tank 2	Tank 1	Tank 2
Date of commencement	28.5.'91	28.5.'91	28.5.'91	28.5.'91	28.5.'91	28.5.'91	28.5.'91	28.5.'91
Total length (mm)	84,91	82,83	90,86	90,84	94,85	88,83	88,83	88,81
Maturity stage	I	I	I	I	I	I	I	I
Physico chemical conditions of rearing media:								
i) Temperature (°C)	27.8-28.8	27.8-28.8	27.7-28.8	27.7-28.8	27.8-28.9	27.7-28.9	27.8-28.9	27.8-28.8
ii) pH	8.03-8.13	8.05-8.19	8.02-8.20	8.03-8.21	8.05-8.24	8.05-8.24	8.07-8.26	8.08-8.27
iii) Oxygen (mg/l)	5.03-6.10	4.78-5.90	5.03-5.98	4.78-6.10	4.98-6.20	5.03-6.20	5.03-5.98	4.68-6.10
iv) Nitrite (µg at/l)	16-36	14-42	14-40	10-32	4-44	8-48	14-38	12-46
v) Ammonia (µg at/l)	8-50	6-56	10-80	8-64	8-58	10-64	12-90	10-95
Time taken for initiation of maturation (in days)	no initiation	no initiation	4	no initiation	5	no initiation	no initiation	no initiation
Progress of maturation: Time taken to reach the successive stage (in hrs)								
i) II to III stage	—	—	24	—	24	—	—	—
ii) III to IV stage	—	—	—	—	10	—	—	—
End result	—	—	reabsorbed	—	Spawned	—	—	—
No.of eggs spawned	—	—	—	—	35,700	—	—	—
Time taken for moulting after initiation of experiment (in days)	11	12	13	12	-	13	10	12

Experiment V (Table 44e)

This experiment was conducted in the month of June 1991. Two impregnated females of the size 78 and 83 mm, with ovary in II stage of maturation, were used for the experiment. These animals were collected from Kannuvilakettu where the water temperature recorded 27.9°C, salinity 7.40 ppt, pH 8.08 and oxygen 4.28 mg/l. The prawn of 83 mm size was maintained in 20 ppt salinity and that of 78 mm size in 22 ppt salinity after 6 hours of gradual acclimation to the desired salinity. In the experimental tanks both the animals showed progress of ovarian development and attained III stage of maturity within 24 hours. The prawn maintained in 22 ppt showed rapid gonadal change and reached stage IV within 8 hours. It spawned in the same night at 2300 hrs releasing about 18,460 eggs. The prawn in 20 ppt salinity, on the other hand, abosrbed the gonad and reverted to the immature condition the next day. The temperature of the rearing media ranged 27-28.3°C, pH 8.12-8.16, dissolved oxygen 5.68-5.90 mg/l, nitrite 2-16 µg at/l and ammonia 4-80 µg at/l.

Experiment VI (Table 44f)

The experiment was conducted in salinities 26, 28 and 30 ppt, in duplicate, during July 1991, based on specimens collected from Kannuvilakettu where the water recorded a temperature of 27.5°C, salinity 5 ppt, pH 7.8, oxygen 6.35 mg/l, nitrite 6 ug at/l and ammonia 8 ug at/l. The female prawns used had a size range of 81-87 mm. Only one female and one male

TABLE 44e: Details of maturation experiments of M. dobsoni in different salinity conditions in the laboratory.

Particulars	Expriment-V. Salinity ‰ 20 ± 0.10 Tank 1	22 ± 0.18 Tank 1
1. Date of commencement	26.6.`91	26.6.`91
2. Total length (mm)	83	78
3. Maturity stage	II	II
4. Physico chemical conditions of rearing media:		
i) Temperature (°C)	27.0-27.3	27.0-27.3
ii) pH	8.12-8.16	8.12-8.15
iii) Oxygen (mg/l)	5.68-5.90	5.68-5.90
iv) Nitrite (µg at/l)	8-16	2-14
v) Ammonia (µg at/l)	4-68	4-80
5. Time taken for initiation of maturation (in days)	continued	continued
6. Progress of maturation: Time taken to reach the successive stage (in hrs)		
i) II to III stage	24	24
ii) III to IV stage	--	8
7. End result	reabsorbed	spawned
8. No.of eggs spawned	--	18,460
9. Time taken for moulting after initiation of experiment (in days)	not observed	not observed

LE 44f: Details of maturation experiments of M. dobsoni in different salinity conditions in the laboratory.

Expriment-VI

Particulars	Salinity ‰					
	26 ± 0.23		28 ± 0.10		30 ± 0.24	
	Tank 1	Tank 2	Tank 1	Tank 2	Tank 1	Tank 2
Date of commencement	15.7.'91	15.7.91	15.7.91	15.7.91	15.7.91	15.7.91
Total length (mm)	81	84	83	82	87	84
Maturity stage	I	I	I	I	I	I
Physico chemical conditions of rearing media:						
i) Temperature (°C)	26.1-27.9	26.0-27.8	26.1-28.0	26.1-27.8	26.1-26.9	26.0-27.8
ii) pH	8.11-8.21	8.09-8.19	8.08-8.20	8.10-8.21	8.06-8.22	8.08-8.23
ii) Oxygen (mg/l)	4.98-5.68	4.68-5.68	5.03-5.80	5.03-5.98	4.68-5.80	4.68-5.68
iv) Nitrite (µg at/l)	4-20	4-16	4-16	4-12	4-18	6-20
v) Ammonia (µg at/l)	6-48	6-42	6-56	6-38	6-48	6-44
Time taken for initiation of maturation (in days)	no initiation	no initiation	3	no initiation	no initiation	no initiation
Progress of maturation: Time taken to reach the successive stage (in hrs)						
i) II to III stage	-	-	24	-	-	-
ii) III to IV stage	-	-	10	-	-	-
End result	-	-	spawned	-	-	-
No.of eggs spawned	-	-	26,450	-	-	-
Time taken for moulting after initiation of experiment (in days)	9	11	-	11	12	10

prawn were maintained in each experimental tub. The outcome of the experiment was that, except for one prawn in 28 ppt, all the animals remained immature throughout the experimental period. The prawn (83 mm) which gave positive result in 28 ppt initiated gonadal maturation within 3 days of the commencement of the experiment and the prawn reached stage IV in another 36 hours. The prawn spawned in the same night at 0100 hrs releasing 26,450 eggs. The temperature of the experimental media ranged 26.0-28.0^{o}C, pH 8.09-8.23, oxygen 4.68-5.80 mg/l, nitrite 4-20 µg at/l and ammonia 6-56 µg at/l.

Experiment VII (Table 44g)

The experiment was conducted again in salinities 26, 28 and 30 ppt, in duplicate during August 1991. The prawns used were collected from Kannuvilakettu where the water recorded 27.8^{o}C, salinity 7.42 ppt, pH 8.22, oxygen 6.1 mg/l, nitrite 6 ug at/l and ammonia 8 ug at/l. In each maturation tub two female prawns and two mature males were maintained. The female prawns had a size range of 75 to 89 mm. Among the twelve animals tried only two prawns, one in 26 ppt and the other in 30 ppt, showed sign of ovarian maturation on the 5th day of the experiment. Within three days after initiation of maturation, the animals attained ripe stage and spawned in the night. The prawn in 30 ppt spawned at 0245 hrs while the other one in 26 ppt at 2345 hrs in the same night, releasing, 23750 eggs and 26450 eggs respectively. All the prawns which did not show any

TABLE 44g: Details of maturation experiments of M. dobsoni in different salinity conditions in the laboratory.

Expriment-VII

Particulars	Salinity ‰					
	26 ± 0.17		28 ± 0.10		30 ± 0.15	
	Tank 1	Tank 2	Tank 1	Tank 2	Tank 1	Tank 2
1. Date of commencement	1.8.91	1.8.91	1.8.91	1.8.91	1.8.91	1.8.91
2. Total length (mm)	86,87	89.81	77,83	86,82	75,82	82,84
3. Maturity stage	I	I	I	I	I	I
4. Physico chemical conditions of rearing media:						
i) Temperature (°C)	26.2-27.1	26.1-27.3	26.1-27.3	26.1-27.3	26.1-27.3	26.1-27.3
ii) pH	8.04-8.19	8.02-8.21	8.09-8.28	8.06-8.22	8.11-8.23	8.09-8.26
iii) Oxygen (mg/l)	4.58-5.60	4.58-5.64	5.03-6.10	5.03-6.30	4.68-5.98	4.70-6.10
iv) Nitrite (µg at/l)	2-6	2-8	2-10	2-8	4-12	4-14
v) Ammonia (µg at/l)	6-56	4-48	4-62	6-52	6-44	6-52
5. Time taken for initiation of maturation (in days)	no initiation	5	no initiation	no initiation	no initiation	5
6. Progress of maturation: Time taken to reach the successive stage (in hrs)						
i) II to III stage	-	24	-	-	-	24
ii) III to IV stage	-	10	-	-	-	9
7. End result	-	spawned	-	-	-	spawned
8. No.of eggs spawned	-	26,450	-	-	-	23,750
9. Time taken for moulting after initiation of experiment (in days)	12	-	11	10	12	-

sign of maturation moulted in 10-12 days after the beginning of the experiment. The temperature of the rearing media ranged 26.1-26.3°C, pH 8.02-8.28, oxygen 4.58-6.30 mg/l, nitrite 2-12 µg at/l and ammonia 4-62 µg at/l.

Experiment VIII (Table 44h)

This experiment was conducted in the month of August 1991 on the same line as that of experiment V. The single prawn used was collected from Kannuvilakettu, where the water temperature was 26.1°C, salinity 2.1 ppt, pH 8.00 and oxygen 5.84 mg/l. This prawn measured 76 mm TL and was in early maturing stage when brought to the laboratory. After gradual aclimation to higher salinities over a period of 20 hours, it was reared in 26 ppt salinity. During the acclimation period, the prawn did not show any change in the condition of ovary. In the experimental medium, the ovary developed further and attained the mature or ripe condition within 32 hours. The animal spawned on the same night at 2030 hrs releasing 17,200 viable eggs. The temperature of the rearing media ranged 25 1-26.7° C, pH 8.04-8.17, oxygen 5.64-6.12 mg/l, nitrite 4.16 µg at/l and ammonia 4-44 µg at/l.

Experiment IX (Table 44i)

This experiment was conducted in salinities 26, 28 and 30 ppt, in duplicate during September 1991. The female prawns used for the experiment were collected from Kannuvilakettu prawn culture field and ranged in size from 68 to 74 mm. In the prawn

TABLE 44h: Details of maturation experiments of M. dobsoni in different salinity conditions in the laboratory.

Particulars	Expriment-VIII. Salinity ‰ 26 ± 0.1 Tank 1
1. Date of commencement	13.8.91
2. Total length (mm)	76
3. Maturity stage	II
4. Physico chemical conditions of rearing media:	
i) Temperature (°C)	25.1-26.7
ii) pH	8.04-8.17
iii) Oxygen (mg/l)	5.64-6.12
iv) Nitrite (µg at/l)	4-16
v) Ammonia (µg at/l)	4-44
5. Time taken for initiation of maturation (in days)	already initiated and continued
6. Progress of maturation: Time taken to reach the successive stage (in hrs)	
i) II to III stage	24
ii) III to IV stage	8
7. End result	spawned
8. No.of eggs spawned	17,200
9. Time taken for moulting after initiation of experiment (in days)	not observed

44i: Details of maturation experiments of M. dobsoni in different salinity conditions in the laboratory.

Expriment-IX

ticulars	Salinity ‰					
	25.99 ± 0.15		27.87 ± 0.20		30.03 ± 0.08	
	Tank 1	Tank 2	Tank 1	Tank 2	Tank 1	Tank 2
te of commencement	10.9.91	10.9.91	10.9.91	10.9.91	10.9.91	10.9.91
tal length (mm)	73	74	68	71	70	71
turity stage	I	I	I	I	I	I
ysico chemical conditions of rearing media:						
Temperature (°C)	26.2-26.8	26.2-26.8	26.2-26.8	26.2-26.8	26.2-26.8	26.2-26.8
pH	8.11-8.22	8.09-8.22	8.10-8.23	8.07-8.12	8.12-8.24	8.11-8.30
Oxygen (mg/l)	4.89-5.61	4.68-5.98	5.03-6.10	5.03-6.20	4.85-5.98	5.03-5.98
Nitrite (µg at/l)	4-8	4-10	2-10	4-10	2-8	2-10
Ammonia (µg at/l)	8-20	10-22	6-16	12-22	6-22	8-18
ne taken for initiation maturation (in days)	no initiation	3	no initiation	5	no initiation	no initiation
ogress of maturation: ne taken to reach the ccessive stage (in hrs)						
II to III stage	-	14	-	12	-	-
III to IV stage	-	-	-	10	-	-
result	-	reabsorbed	-	spawned	-	-
of eggs spawned	-	-	-	3,850	-	-
e taken for moulting er initiation of eriment (in days)	10	11	11	-	9	11

culture field, the water temperature recorded 26.0°C, salinity 3.18 ppt, pH 7.89 and oxygen 4.96 mg/l. In each maturation tank one female prawn with a mature male was reared. Of the six prawns studied only two prawns, one in 26 ppt (73 mm) and the other in 28 ppt (71 mm) showed sign of gonadal development after 3 and 5 days of initiation of the experiment respectively. Within 24 hours of initiation of maturation, the prawn reached the ripe stage and spawned in the night at 0100 hrs in 28 ppt salinity, releasing 3850 viable eggs. In the case of the prawn in 26 ppt, ovarian development took place for about 10 hours and after attaining stage III, the ovary was reabsorbed. All the remaining prawns moulted 9-11 days after the initiation of the experiment. The temperature of the rearing media ranged 26.2-26.8°C, pH 8.09-8.30, oxygen 4.68-6.20 mg/l, nitrite 2-10 µg at/l and ammonia 6-12 µg at/l.

Experiments on rematuration

A knowledge on the rematuration of prawns is of vital significance for assessing its spawning frequency and the absolute reproductive potential which are essential pre-requisites for management of the natural population as well as hatchery development. The success achieved in the laboratory maturation experiments has enabled to make attempts for rematuration of the same prawn. The ten prawns which successfully matured and spawned during maturation experiments I, III, IV, VI and VII were used for this purpose. After each

spawning in the laboratory, the animal was transferred to a new tub having the same salinity media in which it had spawned. Usually one male prawn was also kept along with the experimental female. All the rematuration experiments were conducted in the months of August 1990 and June 1991. The result obtained are summerised in Table 45.

Experiment I:

The prawns (both 90 mm) which had spawned on 8.8.90 (Table 45) were reared in separate tubs having 28 ppt salinity media. Both the prawns showed signs of ovarian development within 4-5 days time after commencement of the experiment. The prawn maintained in Tank 2, showed steady progress of rematuration of ovary and reached stage IV within 74 hours. After attaining this stage, the animal spawned in the same night at 0115 hours, releasing 21,400 eggs. The eggs were unfertilized as the prawn had already moulted even before the first spawning and the thelycum had no spermatophores. In Tank 1, though the ovary developed for about 48 hours, passing through the first and second stages of maturity, it did not advance beyond stage III and got slowly reabsorbed. The temperature of the rearing media ranged 27.0-29.5^{o}C, pH 8.00-8.31, oxygen 4.68-6.13 mg/l, nitrite 4-10 µg at/l and ammonia 4-24 µg at/l

TABLE 45 : Details of rematuration experiments of M. dobsoni in brakishwater conditions.

Particulars	Expt 1		Expt 2	Expt 3	Expt 4
	Tank 1	Tank 2	Tank 1	Tank 1	Tank 1
1. Salinity, ‰.	28 ± 0.20	28 ± 0.16	30 ± 0.30	30 ± 0.21	28 ± 0.21
2. Expt. No. and date of previous spawning.	I 6.8.90	I 6.8.90	I 8.8.90	I 12.8.90	IV 3.6.91
3. Total length of animal(mm)	90	90	88	87	94
4. Salinity in which spawning took place. (‰.)	28.13	28.15	30.02	30.12	22.20
5. Date of commencement of experiment.	8.8.90	8.8.90	9.8.90	13.8.90	4.6.91
6. Physico chemical conditions of the rearing media:					
i) Temperature (°C)	27.0-29.5	27.0-29.5	27.2-29.5	27.4-29.5	26.9-27.8
ii) pH	8.00-8.31	8.11-8.28	8.08-8.25	8.16-8.27	8.12-8.22
iii) Oxygen (mg/l)	4.68-6.13	4.74-6.20	4.09-6.23	4.41-5.95	5.04-5.85
iv) Nitrite (µg at/l)	4-10	6-12	6-16	6-14	4-16
v) Ammonia (µg at/l)	4-24	6-28	4-32	6-36	6-30
7. Time taken for initiation of maturation (in days)	5	4	5	no initiation	2
8. Progress of maturation: Time taken to reach the successive stage (in hrs)					
i) II to III stage	48	48	48	—	24
ii) III to IV stage	—	26	28	—	10
9. End result	reabsorbed	spawned	spawned	—	spwaned
10. No.of eggs spawned	—	21,400	19,300	—	18,650

Experiment II

This experiment was conducted in 30 ppt salinity, using the animal (88 mm) spawned on 8.8.90 (Table 45). In this case also, the prawn showed sign of gonadal development on the 5th day after commencement of the experiment. The pattern of maturation was similar to that observed in Tank 2, of the rematuration experiment I. The prawn after reaching stage IV in 76 hours, spawned on the same night at 0040 hours releasing 19300 non-viable ova. The temperature of the rearing media ranged 27.2-29.5^{o}C, pH 8.08-8.25, oxygen 4.09-6.23 mg/l, nitrite 6-16 µg at/l and ammonia 4-32 µg at/l.

Experiment III

This experiment was conducted using the spent female (94 mm) which spawned on 3.6.91 in 22.2 ppt salinity at the end of the maturation experiment IV (Table 45). Unlike in the previous experiments, the salinity of this rematuration experiment was raised to 28 ppt when it was observed that the gonad rapidly changed into the different maturity stages. The ovary attained stage IV within 34 hours of commencement of the experiment which was the shortest duration noticed for rematuration of the ovary. The animal spawned successfully in the same night at 2350 hours, releasing 18,650 viable eggs. These eggs were further reared and the details of which are summerised in Table 47. The temperature of the rearing media ranged 26.9-27.8^{o}C, pH 8.12-8.22, oxygen 5.04-5.85 mg/l, nitrite 4-16 µg at/l and ammonia 6-30 µg at/l.

Embryonic and early larval development

Normal embryonic and larval development are the key features of successful reproduction in penaeid prawns. The experiments on maturation and spawning conducted during the present study indicated that the prawn attains maturation and successfully spawn in low saline conditions. In order to understand the capacity of the animal to complete it's embryonic and larval development in brackishwater condition in which it had spawned, the eggs released during the successful maturation experiments, were further reared in the same salinities in the laboratory. During the course of these experiments, the eggs hatched out in the normal manner releasing viable nauplii. These nauplii successfully underwent a series of moultings and transofmred into protozoea after passing through six well defined naupliar stages (Pl. 23 a-e) as was observed by Muthu et.al. (1978) during their laboratory experiments. Assuming normal development for the subsequent larval stages, the experiments were terminated after the protozoea I stage. The time taken for completion of embryonic development and the various naupliar stages were noted. The results of seven experiments in this line are presented in Tables 46a to 46c.

Experiment I (Table 46 a)

This experiment was the continuation of the maturation experiment III, in which the eggs released by three prawns in salinities 28 and 30 ppt were used. The percentage of fertilization varied from 91.6 to 98.05. The embryonic

BLE 46 a: Details of embryonic and early larval development of M.dobsoni in brackishwater conditions.

Particulars	salinities (‰)			
	28 ± 0.15	30 ± 0.09	30 ± 0.12	28 ± 0.25
. Date and time (hrs.) of spawning	21.5.91 0200	19.5.91 0100	22.5.91 0030	5.6.91 0215
. Fertilization (%)	91.6	97.4	98.05	94.0
. Duration of embryonic development (hrs.)	9-10	10-11	9-11	11-12
. Time taken to complete successive larval stage after hatching (hrs):				
i) Nauplius I to II	3-4	3-4	3-4	3-4
ii) Nauplius II to III	3-4	3-4	3-4	3-4
iii) Nauplius III to IV	3-4	3-4	3-4	3-4
iv) Nauplius IV to V	4-6	4-5	4-6	4-5
v) Nauplius V to VI	8-9	7-9	8-10	6-9
vi) Nauplius VI to Protozoea I	13-18	14-17	13-18	12-18
Physico-chemical conditions of the rearing media				
i) Temperature (°C)	28.2-28.4	28.2-28.4	28.4-29.6	26.8-27.2
ii) pH	8.0-8.12	8.08-8.18	8.09-8.10	8.08-8.14
iii) Oxygen (mg/lit)	5.61-5.85	5.32-5.61	5.27-5.43	5.45-5.79
iv) Nitrite (µg at/l)	2-14	3-18	2-16	3-18
v) Ammonia (µg at/l)	4-25	2-17	4-22	5-24

development was completed in 9 to 11 hours in all the three cases. The time taken for completion of naupliar development from nauplius I to nauplius III stages was same (9-12 hours) in all the three tubs. The time required for completion of naupliar stages IV to VI remained almost same for the larvae reared in 28 ppt and those reared in one of the tubs of 30 ppt salinity (25-34 hours). In the other tub of 30 ppt salinity, it took 4 to 5 hours for nauplius IV, 7 to 9 hours for nauplius V and 14 to 17 hours for nauplius VI stages whereby completing these stages in 25 to 31 hours. The total duration of naupliar development ranged from 34 to 46 hours. The temperature of the rearing media ranged 28.1-29.6^{o}C, pH 8.0-8.18, oxygen 5.27-5.85 mg/l, nitrite 2-18 µg at/l and ammonia 2-25 µg at/l.

Experiment II (Table 46 a)

The eggs liberated during maturation experiment IV (Table 44d) were used for this study. The rearing of eggs and larvae was carried out in 28 ppt salinity. The rate of fertilization was 94 per cent. The embryonic development lasted for a period of 11 to 12 hours. As in the earlier experiment, the naupliar development upto stage III took 9 to 12 hours. The nauplii took 4 to 5 hours for stage IV, 6 to 9 hours for stage V and 12 to 18 hours for stage VI before transforming into protozoea I. The total duration of naupliar development ranged from 31 to 44 hours. The temperature of the rearing media ranged 26.8 to 27.2^{o}C, pH 8.08-8.14, oxygen 5.45-5.79 mg/l, nitrite 3-18 µg at/l and ammonia 5-24 µg at/l.

Experiment III (Table 46 b)

The eggs released in 22 ppt salinity during maturation experiment V (Table 44 e) were used, which recorded a fertilization rate of 96.2 per cent. The embryos took 9 to 11 hours to hatchout into nauplius. As in previous experiments, the nauplii completed their development from stage I to stage III in 9 to 12 hours. Beyond this, they took 4 to 6 hours for nauplius VI, 8 to 10 hours for nauplius V and 11 to 15 hours for nauplius IV for developing into protozoea. The total duration of naupliar development ranged from 32 to 43 hours. The temperature of the rearing media varied 26.8-27.2^{o}C, pH 8.08-8.32, oxygen 5.15-5.40 mg/l, nitrite 4-21 µg at/l and ammonia 4-24 µg at/l.

Experiment IV (Table 46b)

In this experiment, the eggs released in 28 ppt during maturation experiment VI (Table 44 f) were reared for embryonic and early larval development. The rate of fertilization was 94.8 per cent. The embryo hatched out into nauplius (74%) in 10 to 11 hours.

As usual the nauplii took 9 to 12 hours to complete the first three stages, 5 to 7 hours to complete stage IV, 9 to 11 hours to complete stage V and 12 to 18 hours to complete stage VI before their transformation into protozoea I. The total time taken to complete the development from nauplius I to protozoea stage ranged from 35 to 45 hours. The temperature of

TABLE 46b: Details of embryonic and early larval development of M.dobsoni in brackishwater conditions.

Particulars	salinities (‰)		
	22 ± 0.18	28 ± 0.30	26 ± 0.25
1. Date and time (hrs.) of spawning	27.6.91 2300	20.7.91 0100	8.8.91 2345
2. Fertilization (%)	96.2	94.8	91.1
3. Duration of embryonic development (hrs.)	9-11	10-11	9-10
4. Time taken to complete successive larval stage after hatching (hrs):			
i) Nauplius I to II	3-4	3-4	3-4
ii) Nauplius II to III	3-4	3-4	3-4
iii) Nauplius III to IV	3-4	3-4	3-4
iv) Nauplius IV to V	4-6	5-7	4-6
v) Nauplius V to VI	8-10	9-11	8-11
vi) Nauplius VI to Protozoea I	11-15	12-18	11-16
5. Physico-chemical conditions of the rearing media			
i) Temperature (°C)	26.8-27.2	26.3-26.5	26.0-26.4
ii) pH	8.05-8.29	8.05-8.27	8.08-8.32
iii) Oxygen (mg/lit)	5.12-5.74	5.89-6.12	5.15-5.40
iv) Nitrite (µg at/l)	4-21	4-24	4-23
v) Ammonia (µg at/l)	4-24	4-30	3-28

the rearing media ranged 26.3-26.5^0 C, pH 8.05-8.27, oxygen 5.89-6.12 mg/l nitrite 4-24 µg at/l and ammonia 4-30 µg at/l.

Experiment V (Table 46 b,c)

The eggs of two prawns which spawned on 8th August 1991 (maturation experiment VII, Table 44 g) in 26 ppt and 30 ppt salinities were further reared in the same salinities for embryonic and larval development. The rate of fertilization ranged from 91.1 to 93.65 per cent. The embryonic development was little faster in 26 ppt (9-10 hours) as compared to that in 30 ppt (11-13 hours) salinity. In both the cases the nauplii reached stage IV in 9-12 hours and completed stage IV and V in another 12-17 hours time. The nauplius of stage VI took 11-16 hours to moult into protozoea I in 26 ppt salinity and 12-18 hours in 30 ppt salinity. The total duration involved in completing naupliar development in the two salinities (26 and 30 ppt) varied from 32 to 45 hours and 33 to 47 hours respectively. The temperature of the rearing media varied 26-26.5^{o}C, pH 8.06-8.32, oxygen 4.98-5.40 mg/l, nitrite 2-23 µg at/l and ammonia 3-32 µg at/l.

Experiment VI (Table 46 c)

This experiment was conducted in the month of August 1991 using the eggs spawned during maturation experiment VIII (Table 44 h) in 26 ppt salinity. The fertilization was found to be 98.14 per cent. The embryonic development was completed in 9-10 hours. The nauplius I metamorphosed into nauplius IV in 9-12 hours. The subsequent stages were completed in 4-5 hours by

TABLE 46c: Details of embryonic and early larval development of M.dobsoni in brackishwater conditions.

Particulars	Salinities (‰)		
	30.2 ± 0.14	26 ± 0.1	28.03 ± 0.18
. Date and time (hrs.) of spawning	8.8.91 0245	15.8.91 0030	17.9.91 0100
. Fertilization (%)	93.65	98.14	96.14
. Duration of embryonic development (hrs.)	11-13	9-10	10-12
. Time taken to complete successive larval stage after hatching (hrs):			
i) Nauplius I to II	3-4	3-4	3-4
ii) Nauplius II to III	3-4	3-4	3-4
iii) Nauplius III to IV	3-4	3-4	3-4
iv) Nauplius IV to V	4-6	4-5	4-5
v) Nauplius V to VI	8-11	7-9	6-8
vi) Nauplius VI to Protozoea I	12-18	12-16	12-18
Physico-chemical conditions of the rearing media:			
i) Temperature (°C)	26.1-26.5	25.2-25.6	26.2-26.4
ii) pH	8.06-8.18	8.10-8.22	8.08-8.20
iii) Oxygen (mg/lit)	4-98-5.27	5.79-6.01	4.73-5.27
iv) Nitrite (µg at/l)	2-18	1-18	2-22
v) Ammonia (µg at/l)	6-32	5-32	5-22

nauplius IV, 7-9 hours by nauplius V and 12-16 hours bynauplius VI before moulting into protozoea I. The total time taken for the naupliar development upto protozpea I varied from 32 to 42 hours. The temperature of the rearing media ranged 25.2-25.6^0 C, pH 8.10-8.22, oxygen 5.79-6.01 mg/l, nitrite 1-18 µg at/l and ammonia 5-32 µg at/l.

Experiment VII (Table 46 c)

The eggs spawned in 28 ppt salinity during the maturation experiment IX in September 1991 (Table 44 i) were further reared. With a fertilization rate of 96.14 per cent the embryonic development was completed in 10-12 hours. The first three stages of nauplii took 3-4 hours each, nauplius IV took 4-5 hours, nauplius V 6-8 hours and nauplius VI 12-18 hours before metamorphosing into protozoea I. The total time taken to complete the naupliar development varied between 31 and 43 hours. The temperature of the rearing media ranged 26.2-26.4^{o}C, pH 8.08-8.20, oxygen 4.73-5.27 mg/l, nitrite 2-22 µg at/l and ammonia 5-22 µg at/l.

Embryonic and early larval development of eggs spawned after rematuration

The eggs spawned after rematuration of the prawn (94 mm) in 28 ppt salinity (Table 47) in June 1991 were further reared in the same slinity. The rate of fertilization was 91.3 per cent. The embryonic development took 10-11 hours and they hatched into nauplius with a hatching rate of 72.3 per cent.

TABLE 47: Details of embryonic and early larval development of *M.dobsoni* in brackishwater conditions after re-maturation

Particulars	salinity (‰)
	28 ± 0.21
1. Date and time (hrs.) of spawning	5.6.91 0215
2. Fertilization (%)	91.3
3. Duration of embryonic development (hrs.)	10-11
4. Time taken to complete successive larval stage after hatching (hrs):	
i) Nauplius I to II	3-4
ii) Nauplius II to III	3-4
iii) Nauplius III to IV	3-5
iv) Nauplius IV to V	5-7
v) Nauplius V to VI	8-10
vi) Nauplius VI to Protozoea I	12-15
5. Physico-chemical conditions of the rearing media:	
i) Temperature (°C)	27.0-27.8
ii) pH	8.10-8.24
iii) Oxygen (mg/lit)	5.11-5.88
iv) Nitrite (µg at/l)	2-12
v) Ammonia (µg at/l)	2-22

The first two stages of nauplius took 3-4 hours each, nauplius III took 3-5 hours, nauplius IV 5-7 hours, nauplius V 8-10 hours and nauplius VI 12-15 hours before metamorphosing into protozoea I. The total time taken to complete the naupliar development varied from 34-45 hours. These results clearly indicate the normal embryonic and naupliar development of ova spawned after rematuration. The temperature of the rearing media ranged 27.0-27.8^{o}C, pH 8.10 to 8.24, oxygen 5.11-5.88 mg/l nitrite 2-12 µg at/l and ammonia 2-22 µg at/al.

Effect of salinity on embryonic and ealry larval development

Having established that M.dobsoni can breed in brackishwater condition, it is felt desirable to understand the capability of the eggs/larval stages to survive in the low saline conditions since these stages are not generally encountered in brackishwater environment. The ability of the embryo and early larval stages to withstand the fluctuation in salinity and their survival has been studied by carrying out three experiments in the laboratory. The eggs spawned in 22, 26 and 28 ppt salinities were reared in 2 litre capacity glass beakers in lower as well as upper levels of salinities between 15 and 30 ppt, and their growth and survival monitored. Once the nauplii metamorphosed into protozoea stage I, the entire rearing medium was filtered using bolting silk and the protozoeae fixed in formaldehyde for estimation of their survival. The results are presented in Table 48 and depicted in Fig. 25.

Experiment I (Table 48 a)

The eggs spawned in 28 ppt salinity during maturation experiment IV (Table 44 d) were reared in 15, 20, 25 and 30 ppt salinities at a stocking density of 150-155 eggs/litre. The eggs hatched into nauplii within 9-12 hours in all salinity levels. The hatching rate, however, was only 15 per cent in 15 ppt salinity and all the nauplii died without showing further development. The average time taken for completing naupliar development in different salinities was 35 hours in 20 ppt, 39 hours in 25 ppt and 40.5 hours in 30 ppt thereby indicating a gradual increase in time taken for naupliar development with increase in salinity. The survival at protozoea stage varied from nil to 40.52 per cent. The survival rate was 22.1 per cent in 20 ppt while in 25 and 30 ppt salinities, it remained between 39.7 and 40.5 per cent. The temperature (26.5-26.6^{o}C), oxygen (5.71-5.94 mg/l) and pH (8.13-8.14) fluctuated narrowly while the concentration of ammonia (2-34 µg at/l) and nitrite (1-24 µg at/l) was well within the safe limits.

Experiment II (Table 48 b)

The eggs spawned in 22 ppt salinity during maturation experiment V (Table 44 e) were reared in 16, 18,20 and 22 ppt salinities at a stocking density of 173-176 eggs/litre. In 16 ppt salinity, only 18 per cent of the embryo hatched into nauplii I and all the nauplii died without further moulting. The embryonic development in all salinities was completed in 8-9 hours. All the six naupliar substages have been completed in different salinities but the total time taken for it varied from

TABLE 48 a: Details of embryonic and early larval development of M.dobsoni and survival rates in different salinities.

Experiment I

Particulars	salinities (‰)			
	15 ± 0.2	20 ± 0.15	25 ± 0.18	30 ± 0.17
1. Date and time (hrs.) of spawning	5.6.91 0215	5.6.91 0215	5.6.91 0215	5.6.91 0215
2. Fertilization (%)	94.0	94.0	94.0	94.0
3. No.of eggs stocked	308	306	310	300
4. Stocking rate/ litre	154	153	155	150
5. Physico-chemical conditions of the rearing media :				
i) Temperature (°C)	26.57±0.40	26.57±0.40	26.53±0.45	26.5±0.46
ii) pH	8.14±0.01	8.13±0.05	8.13±0.01	8.13±0.06
iii) Oxygen (mg/lit)	5.94±0.16	5.91±0.17	5.71±0.24	5.85±0.05
iv) Nitrite (µg at/l)	1-20	2-24	2-17	2-22
v) Ammonia (µg at/l)	2-30	3-34	4-28	3-29
6. Duration of embryonic development (hrs.)	9-10*	9-11	9-12	10-12
7. Time taken to complete successive larval stage after hatching (hrs):				
i) Nauplius I to II	All died	3-4	3-4	3-4
ii) Nauplius II to III	-	3-4	3-4	3-4
iii) Nauplius III to IV	-	3-4	3-4	3-4
iv) Nauplius IV to V	-	5-6	6-8	6-8
v) Nauplius V to VI	-	6-8	6-9	7-10
vi) Nauplius VI to Protozoea I	-	10-14	12-16	12-17
8. No. survived at protozoea stage	-	68	124	119
9. Survival %	-	22.08	40.52	39.67

*Only 15 per cent survived

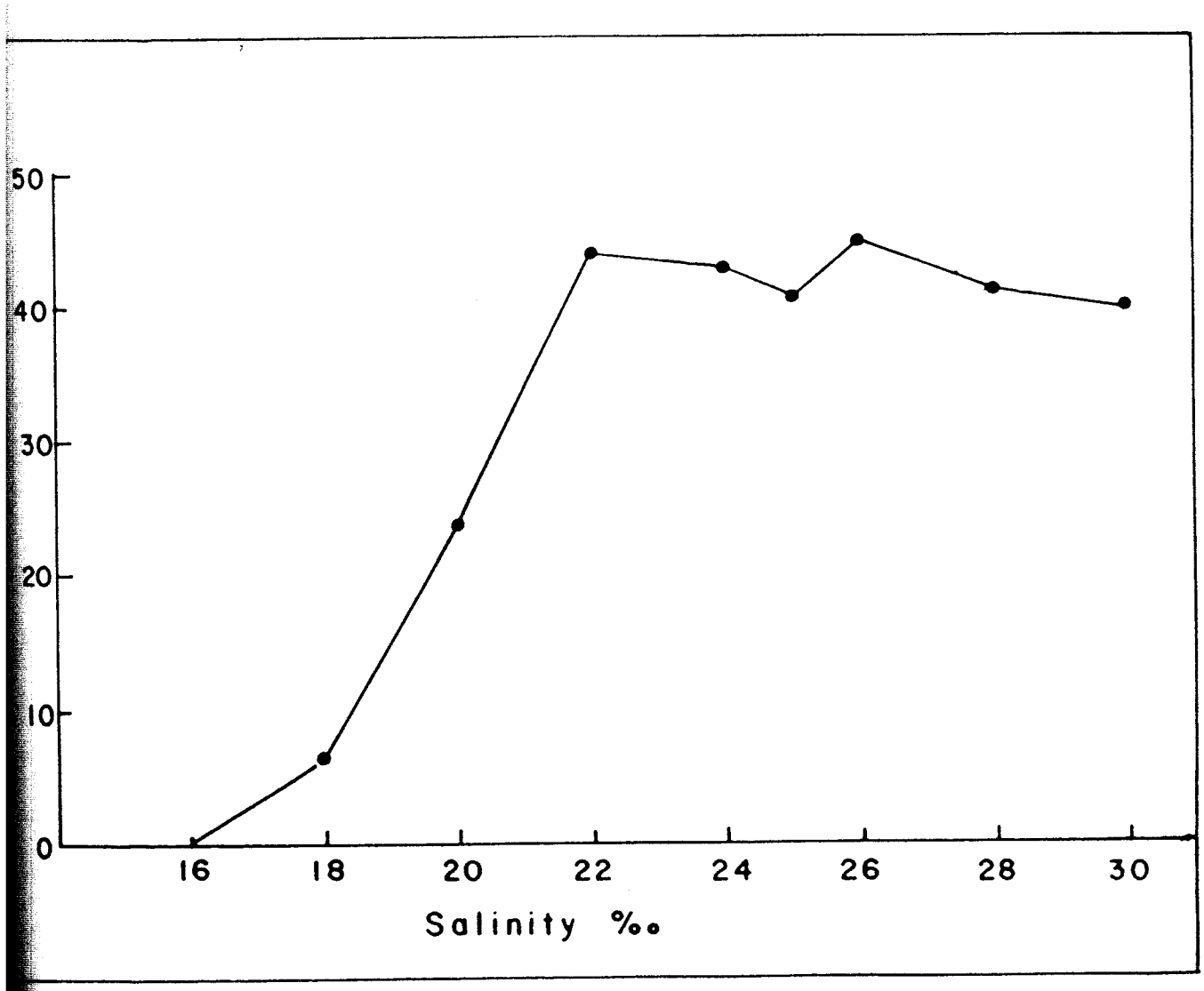
TABLE 48 b: Details of embryonic and early larval development of M.dobsoni and survival rates in different salinities.

Particulars	Experiment II			
	salinities (‰)			
	16 ± 0.18	18 ± 0.13	20 ± 0.21	22 ± 0.19
1. Date and time (hrs.) of spawning	27.6.91 2300	27.6.91 2300	27.6.91 2300	27.6.91 2300
2. Fertilization (%)	96.2	96.2	96.2	96.2
3. No.of eggs stocked	348	352	346	350
4. Stocking rate/ litre	174	176	173	175
5. Physico-chemical conditions of the rearing media:				
i) Temperature (°C)	26.9±0.20	26.9±0.21	26.9±0.21	26.9±0.21
ii) pH	8.16±0.08	8.12±0.09	8.17±0.06	8.15±0.10
iii) Oxygen (mg/lit)	5.64±0.21	5.58±0.22	5.31±0.18	5.78±0.15
iv) Nitrite (µg at/l)	1-14	1-22	1-22	1-18
v) Ammonia (µg at/l)	4-23	5-36	4-30	4-32
6. Duration of embryonic development (hrs.)	8-10	8-11	9-11	9-11
7. Time taken to complete successive larval stage after hatching (hrs):				
i) Nauplius I to II	all died	3-4	3-4	3-4
ii) Nauplius II to III	-	3-4	3-4	3-4
iii) Nauplius III to IV	-	3-4	3-4	3-4
iv) Nauplius IV to V	-	4-6	4-7	5-8
v) Nauplius V to VI	-	6-9	6-9	8-10
vi) Nauplius VI to Protozoea I	-	10-14	10-14	12-15
8. No. survived at protozoea stage	-	22	78	164
9. Survival %	-	6.25	22.54	46.86

E 48 c: Details of embryonic and early larval development of M.dobsoni and survival rates in different salinities.

Experiment III

Particulars	salinities (‰)				
	20 ± 0.10	22 ± 0.10	24 ± 0.15	26 ± 0.09	28 ± 0.13
ate and time (hrs.) of spawning	15.8.91 0030	15.8.91 0030	15.8.91 0030	15.8.91 0030	15.8.91 0030
ertilization (%)	98.14	98.14	98.14	98.14	98.14
o.of eggs stocked	336	342	333	331	340
tocking rate/ litre	168	171	166.5	165.5	170
hysico-chemical conditions of he rearing media :					
i) Temperature (°C)	26.3±0.28	26.3±0.28	26.3±0.28	26.3±0.28	26.3±0.28
ii) pH	8.17±0.02	8.17±0.05	8.16±0.01	8.21±0.05	8.13±0.04
iii) Oxygen (mg/lit)	5.52±0.17	5.54±0.20	5.64±0.06	5.54±0.20	5.55±0.35
iv) Nitrite (µg at/l)	3-15	3-12	3-15	3-18	2-14
v) Ammonia (µg at/l)	2-20	2-18	2-24	2-26	2-20
ration of embryonic development (hrs.)	9-10	9-10	9-10	9-11	9-12
e taken to complete successive rval stage after hatching (hrs):					
i) Nauplius I to II	3-4	3-4	3-4	3-4	3-4
ii) Nauplius II to III	3-4	3-4	3-4	3-4	3-4
iii) Nauplius III to IV	3-4	3-4	3-4	3-4	3-4
iv) Nauplius IV to V	4-6	5-7	6-8	6-9	6-8
v) Nauplius V to VI	7-9	8-10	8-10	8-10	8-10
vi) Nauplius VI to Protozoea I	10-12	10-14	12-14	12-13	12-16
survived at protozoea stage	85	139	142	148	139
rvival %	25.3	40.64	42.64	44.71	40.88



g.25: Survival rates of eggs and early larval stages of M. dobsoni in different experimental salinities.

29 to 41 hours in 18 ppt, 32-45 hours in 20 ppt and 33-45 hours in 22 ppt. The average time taken in different salinities was 35 hours in 18 ppt, 38.5 hours in 20 ppt and 39 hours in 22 ppt. The survival of the larvae at protozoea stage I was 6.3 per cent in 18 ppt, 22.5 per cent in 20 ppt and 46.9 per cent in 22 ppt. As in the previous experiment, temperature, oxygen, pH, ammonia and nitrite of the rearing media showed a little variation.

Experiment III (Table 48 c)

The eggs spawned in 26 ppt salinity during maturation experiment VIII (Table 44 h) were reared in 20, 22,24, 26 and 28 ppt salinities at a stocking density of 165-171 eggs/litre. The embryonic development was completed in 9-12 hours in all the salinities. In this experiment also the metamorphosis upto protozoea stage I was completed in all the salinities, taking an average growing period of 34.5 hours in 20 ppt, 37.5 hours in 22 ppt, 39.5 hours in 24 ppt and 40.5 hours in both 26 and 28 ppt salinities. The rate of survival at protozoea stage I varied between 25.3 per cent in 20 ppt and 44.71 per cent in 26 ppt salinities. The rate of survival varied narrowly between 40.6 and 44.7 per cent in all salinities except 20 ppt in which the survival was only about 25.3 per cent.

FECUNDITY

In egg laying animals, the fecundity or the total number of eggs released indicates its reproductive potential. In the present study, the fecundity has been estimated for prawns matured in Kannuvilakettu and compared the same with the

fecundity estimated based on the number of eggs released during the laboratory experiments on maturation and spawing (Table 44). The results are presented in Table 49.

The gonads of six prawns in stage III and IV of maturity in the size range 80-95 mm, collected from Kannuvilakettu were studied and fecundity estimated based on the number of maturing ova. Among the six prawns, two were in stage III and the remaining four in stage IV. The fecundity varied from 38,375 in 80 mm size to 80,600 in 95 mm size prawns, indicating that fecundity increased with the increase in size, as is the normal pattern in all the commercially important prawns of the southwest coast of India (Rao 1968). It is also observed that in prawns of stage IV maturity, the fecundity varied frommaturing ova. Among the six prawns, two were in stage III and the remaining four in stage IV. The fecundity varied from 38,375 in 80 mm size to 80,600 in 95 mm size prawns, indicating that fecundity increased with the increase in size, as is the normal pattern in all the commercially important prawns of the southwest coast of India (Rao 1968). It is also observed that in prawns of stage IV maturity, the fecundity varied from 42,800 to 80,600 and the corresponding weights of ovaries were 0.301 g and 0.576 g, respectively.

The fecundity estimated based on the number of eggs spawned in the laboratory maturation experiments (Table 44) ranged from 3900 to 35,700 egss in prawns of 71 to 94 mm sizes, respectively. Though the fecundity generally increased with increase in length of prawn, it often showed wide fluctuations.

TABLE 49 : Fecundity of M. dobsoni based on ovarian egg count.

Total length of prawn (mm)	Total weight of prawn (g)	Weight of ovary (g)	Maturity stage	Estimated fecundity
80	3.895	0.208	III	38,375
80	3.991	0.301	IV	42,800
82	4.186	0.310	IV	51,625
86	4.480	0.260	III	58,450
86	4.538	0.405	IV	62,875
95	5.958	0.576	IV	80,600

Size frequency of maturing ova

Information on the size profile of ova in different stages of development in the ovary is an important indicator of the animal's spawning habits. With this in view an attempt has been made to deleniate the various sizes of ova represented in the ovary at different maturity stages. The mean sizes of ova from five prawns in each stage of maturity and their frequency distribution are depicted in Fig.26.

In the immature stage, the developing ova had a size range of 0.054-0.081 mm. The ova of size 0.054 mm occupied the major part of the ovary forming over 92 per cent. This developing ova of more or less the same size range, were observed in all the subsequent maturity stages including the spent stage. In the early maturing ovary (stage II), a group of ova from the above developing ova further developed and formed a prominent mode at 0.108mm (46.38%) and the mean sizes of these ova ranged from 0.081 to 0.162 mm. In the third stage of maturity, the developing ova assumed a size range of 0.108-0.216 mm with a mode at 0.162 mm (40.42%). In the ripe (stage IV) condition, the ovary was found to be entirely filled withthe fully mature ova ranging in size 0.108-0.324 mm. Majority of these eggs had mean sizes of 0.189-0.216 mm (15.36-18.86%) with a mode at 0.216 mm (18.86%). Inthe spent stage the group of mature ova totally disappeared and majority of the existing ova had a size range of 0.054-0.081 mm. As in immature stage, most of the ova seem to be in the initial stage of development with the modal size at 0.054

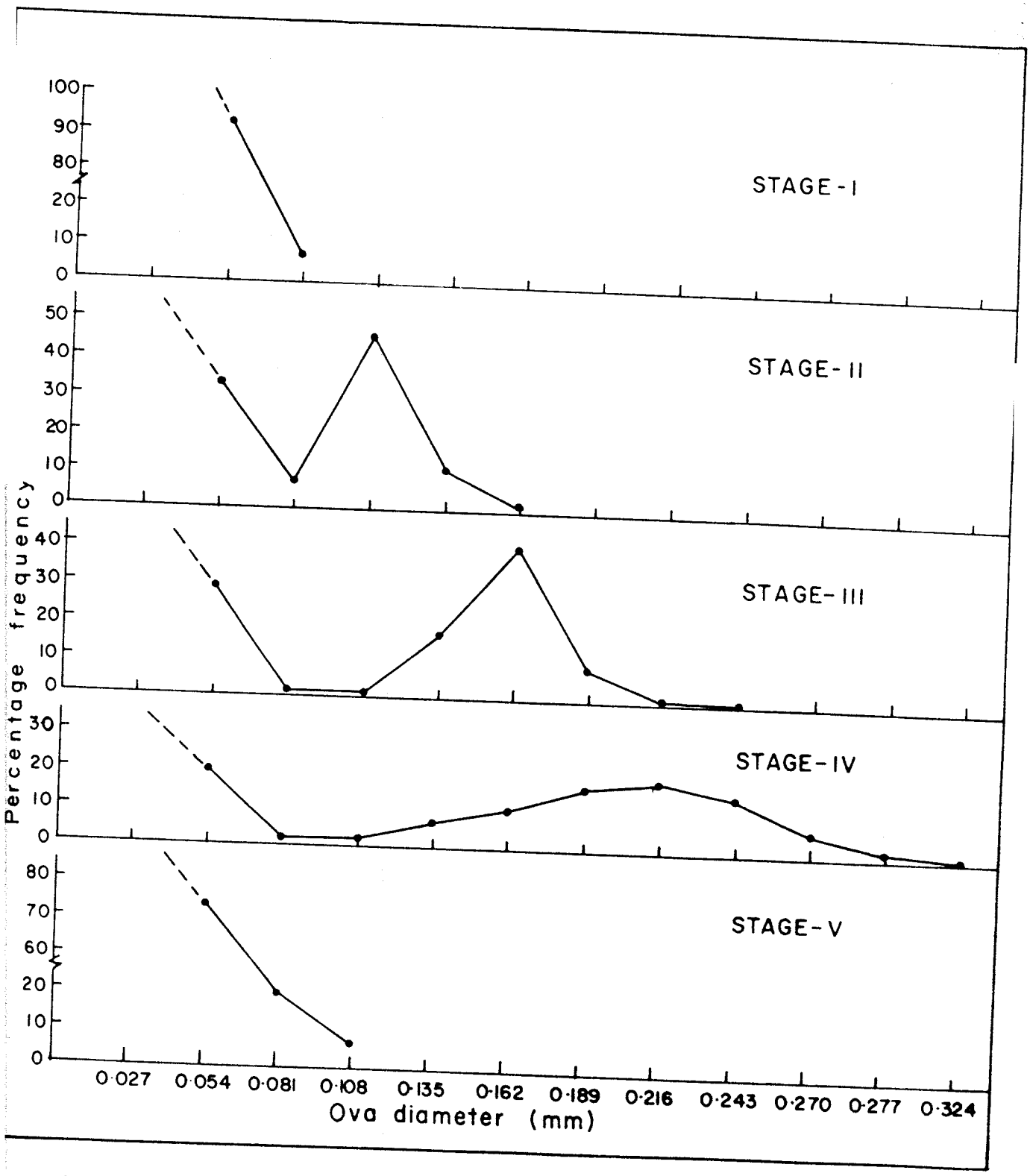


Fig.26: Size frequency distribution of maturing ova in M. dobsoni.

mm (73.5%). Some reabsorbing mature ova in the size range 0.108-0.115 mm were also noticed along with the developing ova.

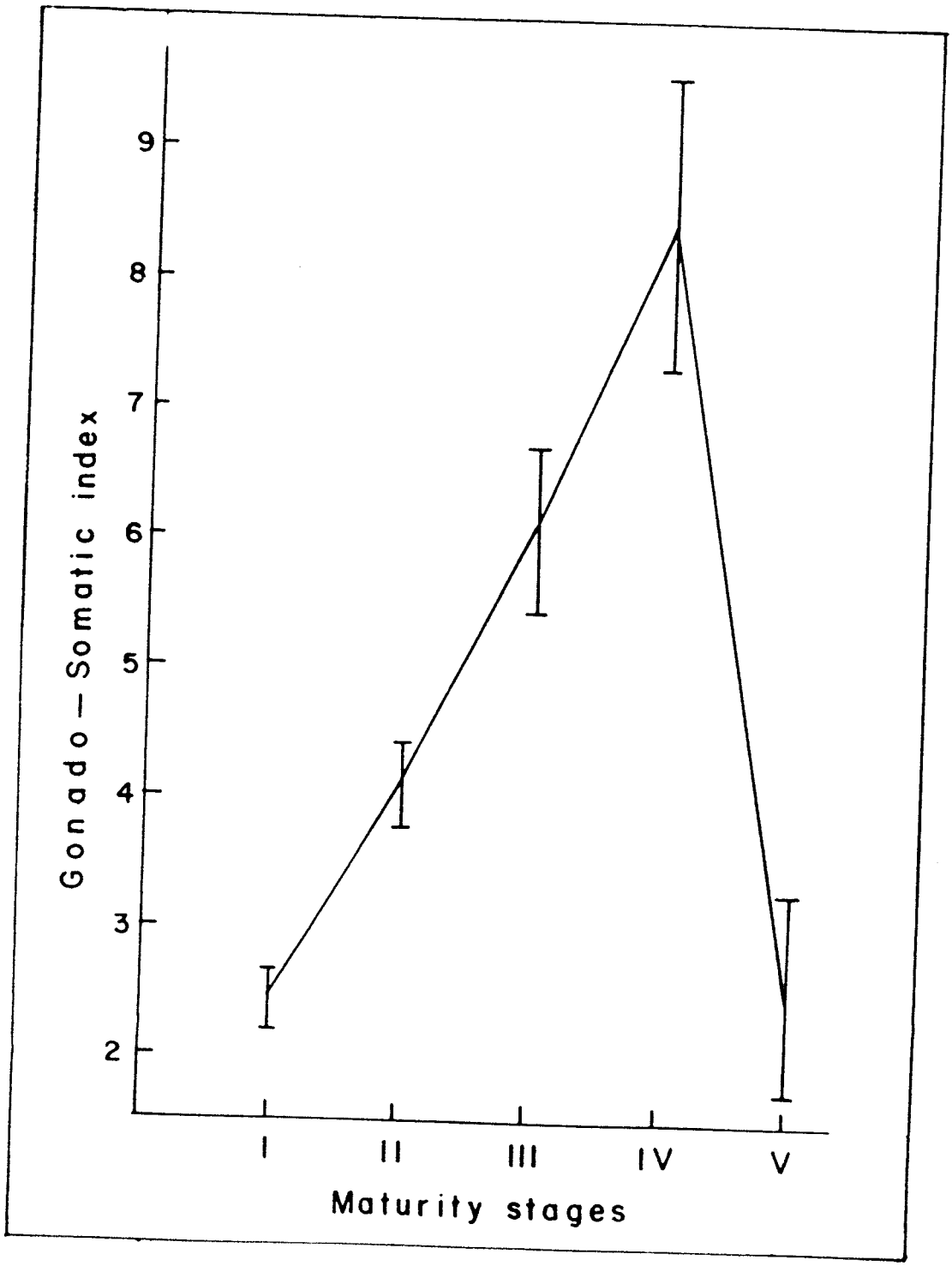
The different size groups of ova found in the five maturity stages of the ovary are as follows.

Stage of maturity	Diameter of ova (mm)
Immature	< 0.081
Early maturing	0.081-0.162
Late maturing	0.108-0.216
Mature	0.108-0.216
Spent	< 0.115

Gonado-somatic Index (GSI)

Study of changes in the ratio of gonad weight to body weight is considered as an alternate method of assessing gonadal development. In female prawn, the GSI can be closely correlated to the visual evaluation of maturity stages and it provides a quantitative measurement of gonadal development. The seasonal distribution of population gonad-indices is of great significance in understanding the spawning season of the animal. The present study, which pertains to females, was conducted using 13 immature (70-93 mm), 6 early maturing (78-91 mm), 8 late maturing (80-93 mm), 5 mature (80-94 mm) and 5 spent (71-88 mm) prawns. The distribution of mean values with standard deviations of GSI are depicted in Fig. 27.

The GSI of immature ovaries ranged from 1.95-2.80 with the mean at 2.42. It increased in the subsequent stage (Stage II), ranging from 3.68-4.36, with mean at 4.09. In the late



J.27: Gonado - somatic indices of M. dobsoni for different maturity stages.

maturing stage, the GSI further increased and varied from 5.12-7.00 with the mean at 6.06. In mature or ripe ovary, the GSI recorded the highest value of the entire maturation cycle and ranged from 7.28-10.08 with mean at 8.43. A steep decline in the value was observed in spent female, in which the GSI ranged from 1.22-3.25 with the mean at 2.51. This, however is slightly higher than the GSI level observed in the immature stage.

DISCUSSION

Morphology of reproductive systems

A perusal of available literature on the reproductive biology of penaeid prawns would reveal that no serious attempt has been made so far to study the structure of reproductive organs of species of Metapenaeus. The present study has indicated that the general morphology of the reproductive systems of this genus is closely similar to those of Penaeus and Parapenaeopsis described in detail by various workers (King, 1948; Subramanyam, 1965; Motoh, 1979; Shaikhmahmud and Tembe, 1958; Rao, 1969). In male M.dobsoni the structure of fully mature testis resembles that of P.setiferus in which each testis has an anterior lobe, six lateral lobes and a posterior lobe, with the main trunks of testis united for their entire length (King, 1948). Variations in the number of testis lobes and the nature of fusion of the two halves of testis have been reported in other species of the same genus (Subramanyam, 1965, Motoh, 1979; Mohamed, 1989). For instance, the testis of P.indicus is reported to have four lobes on either side (subramanayam, 1965) and P.monodon five (Motoh, 1979), the testis halves being fused together only anteriorly in both the species. In P.stylifera, the testis has three lobes on either side, the anterior lobe, the middle lobe and a small posterior lobe, with the anterior lobe fused in the middle with its fellow of the opposite side (Shaikhmahmud and Tembe 1958). The accessory gland noticed by Shaikhmahmud and Tembe (1958) and Rao (1969) in P.stylifera just below and behind the posterior lobe of testis is recognised

neither in M.dobsoni nor in species of the genus Penaeus. The three distinct regions of vas deferens namely, proximal,medial and distal vas deferens, are clearly visible in this species with the characteristic size and shape of each of the regions, as noticed in other penaeid species like P.monodon (Motoh, 1979), P.indicus (Subramanyam, 1965), P.kerathurus (Malek and Bawab, 1974 a) and P.stylifera (Shaikhmahmud and Tambe, 1958; Rao, 1969). Subramanyam (1965) mentioned a tubular portion with two distinct regions namely a generative portion and a lumen inbetween testis and vas deferens in the male reproductive organ of P.indicus, which according to Mohamed (1989) is analogous with the proximal and mid vas deferns. Ro et.al., (1990) studied the structure and function of vas deferens in the shrimp P.setiferus.

The structure of ovary has close resemblence to that of other penaeid prawns except for some minor variations. The middle lobe of the ovary carries eight lobules on either side in this species as against a lesser number (5 to 7) of lobules recorded in other penaeids. The oviduct in M.dobsoni originates from the base of fifth lobule of middle lobe anteriorly. It is a clear deviation from the pattern observed among other penaeids in which the oviduct originates from tip of one of the posterior lobules of the middle lobe (King, 1948; Motoh, 1979; Subramanyam, 1965).

Maturation

As a general rule, almost all the commercially important penaeid prawns of India are believed to breed in the sea, though some of the species utilize the brackishwater areas

as their nursery ground and develop all the adult characters including the secondary sexual characters in this environment. It is believed that the maturation of ovary and subsequent spawning takes place only in sea. According to Rao (1972), maturation and spawning are influenced by environmental factors such as higher salinity, temperature and pressure of the depth of water.

During the present study, it is observed that M.dobsoni matures in the brackishwater environment in a wide range of salinity conditions. Menon (1951) encountered mature males of this species in Cochin backwaters. The attainment of maturity in males is discernable externally from the nature of petasmal development. It is seen that the petasmal endopodites unite when the prawn is about 52 mm TL. George and Rao (1968) observed that fusion of petasmal endopodites in this species takes place at a size of 53.6 mm and the same is correlated with maturation of the animal. During the present study it is found that the fusion of petasmal endopodites signifies only the initiation of maturation process as evident from the histological study of the gonad. The endopodal halves after fusion remain thin and flexible for some time. It gradually hardens, and only after the process of hardening is completed, the testis is found to be in fully mature state. The attainment of maturation can also be judged externally from the presence of white mass of spermatophore at the base of the fifth pereiopod. The size at maturity of male at 50 per cent level is 58.5 mm as estimated based on the above mentioned externally visible characters.

During the maturation process of M. dobsoni males, four distinct stages of maturity, namely, immature, early maturing, late maturing and mature or ripe are recognised in the species. Rao (1977) has given a general classification of maturity stages in penaeid prawns with five maturity stages, while Castille and Lawrence (1991) recognised only three stages in P.duorarum. Based on variations in the tubular portion as well as the degree of development of testis with the age of prawn, Subramanyam (1965) identified five stages in P.indicus and categorised them by size.

Routine monitoring of prawn catch from the perennial prawn culture system has shown the occurrence of mature males almost throughout the year, with peak occurrence in July, when it formed as much as 90 per cent of the male prawns (Table 36). The minimum salinity recorded in the culture system during this study was 2.45 ppt, which was recorded in August 1991 (Table 1). The proportion of mature males in the population during this month was nearly 50 per cent. It is also seen that the percentage of mature males was least during the period January-February (2.4-3.1%) in Kannuvilakettu, when a relatively higher salinity of 15.30-16.33 ppt was recorded (Table 1). This would clearly indicate that maturation in male M.dobsoni is not influenced by salinity. The low percentage of mature males recorded during January-February was due to smaller sizes of the animal harvested during this period as evidenced by the low mean size of 50.61 to 52.71 mm (Table 6) as against fairly large mean sizes (Table 6)

recorded in other months. It may therefore be concluded that the maturation of males in brackishwater ecosystem is size dependent rather than being influenced by salinity or any other environmental factors.

M.dobsoni female prawns were found to mature in Kannuvilakettu in small numbers while none were found in maturing or mature stage in Thoppilkettu during the period of the present study. In Kannuvilakettu, the prawns showed maturation when salinity varied between 3.92 and 19.26 ppt during the premonsoon and early monsoon periods. The minimum observed size at maturity in this environment was found to be 84 mm total length, which is comparatively larger than the minimum size of mature females (64 mm) recorded by Rao (1968) from the marine environment. He also estimated statistically the minimum size at maturity as 64.1 mm. The maturation process and the number of maturity stages (five) observed during this study from the culture systems are similar to the pattern reported for the species in the inshore waters of Kerala coast by Menon (1953) and Rao (1968).

The size frequency distribution of maturing ova in the gonad of prawn matured in the perennial prawn culture system (Fig. 26) indicates that once the maturation begins, the group of maturing ova pass through the different maturity stages in quick succession and are released at a single stretch during spawning. The sizes of ova observed for different maturity stages are more or less similar to those recorded by Rao (1968) from the inshore waters.

Study of the Gonado-Somatic Index (GSI) for different maturity stages (Fig. 27) revealed a steady increase in GSI from immature stage (1.95-2.80) to fully mature stage (7.28-10.08) and then followed by a sharp fall in spent condition (1.22-2.35). A similar observation on GSI has been made in P.monodon by Dy-Penaflorida (1990).

The occurrence of impregnated females (Table 40 and 41) indicate successful mating in both the culture systems. Higher percentage of impregnated females during the period April to August in Kannuvilakettu coincides with the availability of larger and maturing prawns in this system. Prawns of size above 66 mm were found in impregnated condition in both the systems.

Seasonal distribution of maturity stages of females in Kannuvilakettu (Table 38, Fig. 24) revealed that 3-16 per cent of the prawns were in early maturing stage and less than 1 per cent in mature stage among the female population. Mature females were recorded only during April-May 1991 when the salinity ranged from 18.45 to 19.26 ppt. It is also noteworthy that in the subsequent two months (June-July 1991) about 5.8 per cent of the females were also found to be in early maturing stage when relatively low salinity conditions (3.92-10.61 ppt) prevailed. However, such maturing stages were not encountered in any other months of the study period. It would thus appear that the ovarian maturation in M.dobsoni would take place in the culture systems during the summer months when high salinity conditions prevail. Since no maturing or mature females were encountered

even in still higher salinity conditions (22.60 ppt) prevailed during summer months of the previous year (1990), it is possible that salinity alone may not be a contributing environmental factor to induce maturation in this species. Since the mean sizes of the prawns during this period (April-May 1990) (Table 6) were relatively low (53.8-54.2 mm), it can as well be presumed that the size is an important factor for initiation of maturation. This is proved to be so by the occurrence of early maturing females during June-July months when the mean size was fairly large (70.1-76.2 mm), even when the salinity was relatively low (3.92-10.61 ppt). Since advanced stages of maturity have not been encountered in the population during June-July period, it is possible that very low salinities are not condusive for maturation and the early maturing stages noticed would not have advanced further. A perusal of Table 39 would show that maturation in the culture system begins when the prawn is about 73 mm size; however, full maturity is noticed only in prawns above 80 mm, the smallest mature female observed being 84 mm size. Rao and Kathirvel (1973) noticed females of M.dobsoni measuring about 69 mm TL in mature condition in the open backwater when the salinity was about 30 ppt. George (1974) has come across mature females of the species in small numbers in the perennial culture fields of Vypeen island during the summer period of February-May. From this he inferred that the occurrence of relatively larger individuals (size not specified) of the species and mature specimens during summer months (salinity not mentioned) would indicate the possibility of its spawning in the culture ecosystem. The present observation

conforms to this view expressed by George (1974), with an empahsis on the point that both the size of the prawn and salinity are the two deciding factors for the maturation of M.dobsoni in the brackishwater environment. Silas et. al. (1982) could grow postlarvae of M.dobsoni in experimental ponds at Narakkal upto a size of 80-105 mm. During the summer months (March-April) when the salinity was 28.0-29.0 ppt, a number of females in the above size group developed dark green ripe ovaries and the same were subjected to spawning experiment in the laboratory.

Instances of maturation of other species of penaeid prawns in brackishwater conditions have been reported by many workers and pointed out the possibility of their spawning in such conditions. Among other species of the same genus, M.bennette and M.dalli are found to mature, breed and complete their lifecycle in the coastal lagoons, lakes and estuaries of Eastern Australia (Morris and Bennet, 1951; Racek, 1972 and Potter et. al.,1986). De Bruin (1965) has recorded mature females of M.elegans from the low saline lagoons of Srilanka, while Muthu and Manickam (1973) observed mature females and males of M.burkenroadi with fully developed ovaries and petasma in Pulicat lake. The latter authors have also indicated the possibility of breeding of this species inside the lake and the feasibility of utilizing it for culture in the lake. Jhingran(1974) observed M.brevicornis attaining maturity in experimental brackishwater ponds of Japara in Indonesia. A few species of genus Penaeus such as P.monodon (Anon, 1983) and

P.japonicus (Yano, 1984; Kathirvel and Selvaraj, 1989) have also been found to mature in culture ponds under brackishwater salinity conditions. Krishnamurthy and Ganapathi (1985) encountered P.indicus specimens with ovary in early maturing stage in brackishwater ponds having salinity of 18.9-21.5 ppt.

All the above observations point to the fact that penaeid prawns are able to mature in brackishwater conditions under favourable levels of salinity coupled with other factors like suitable size, as has been observed during the present study on M.dobsoni.

Spermatogenesis, Spermatophore formation and oogenesis

The process of spermatogenesis observed in M. dobsoni appears to be similar to that reported in other crstaceans (Pochon-Masson, 1983). A general feature of the process is that the spermatogonial cells after passing through a period of quick growth transform into primary spermatocytes and then undergo reduction division to become secondary spermatocytes and then spermatids. The spermatids further increase in size and move out of their cell boundaries to become spermatozoa and later fully developed sperm. The shape of the sperm is contrastingly different from that observed in other penaeids. Shaikhmahmud and Tembe (1958) described the sperm of P.stylifera to be short and cylindrical with a small head and very short tail. Subramanyam (1965) observed the shape of the spermatozoa of P. indicus to be oval. Mohamed (1989), giving the fine structure of the sperm of

P.indicus reported a spherical main body partially encompassed by a morphologically diverse cap region containing the acrosomal complex. From the main body, a single short spike arises. More or less similar structure has also been reported for the sperm of Sicyonia ingentis by Kleve et. al. (1980) and that of P. setiferus by Lu et. al. (1973). Pochon-Masson (1983) distinguished the flagellate and nonflagellate sperms in crustaceans. According to King (1948), the spermatozoa of P. setiferus is composed of three typical parts, namely a head, middle piece and a tail. The head is large and almost circular in outline, the middle piece is short and considerably more slender while the tail is relatively thick and short. In the present study, the sperm is like a typical 'tadpole' in shape with a well differentiated head having acrosomal complex and a comparatively long tapering tail (Pl. 8e, 9b). The sperm appears to be motile as could be judged from the shape and size of the tail (Pl.9b). Opinions however differ as to motility of the sperms in crustaceans. King (1948), based on the structure of the sperm, has logically assumed that the spermatozoan in P. setiferus is capable of movement. However, Malek and Bawab (1974 a) expressed doubt about the motility of the sperms aided by any nourishing fluid in the seminiferous tubule in crustaceans. They opined that "in crustaceans the sperm cells lack discrete vibratile oranelles, and their conduction along channels free from secretion is still possible even though these channels may further be devoid of muscles". In lobsters and hermit crabs Mathews (1954, 1957) believed that the passive motility of sperms along similar channels (seminiferous tubules)

is effected by the pushing action of a continuous flow of the developing new sperms. The vas deferens of decapod crustaceans conveys sperms from the testis to the exterior in the form of a spermatophore (Dudenhausen and Talbot, 1983). As regards the functions of the three different regions of vas deferens viz., Proximal, medial and distal vas deferens, in moulding the spermatophore and formation of it's wing, the present observation agrees with that of Malek and Bawab (1974 b) in P.kerathurus, Chow et al. (1982) in Macrobrachium rosenbergii, Subramoniam (1984) in anamuran crabs A. symnista and E. asiatica, Mohamed (1989) in P. indicus and Radha and Subramoniam (1985) in P.homarus, Chow et. al. (1989) in P. setiferus and P. vannamei and Ro et. al (1990) in P. setiferus. Chow et .al (1989) studied the medial vas deferens, distal vas-deferens and terminal ampoule by light and elctron microscopy to assess their roles in spermatophore formation. Ro et. al. (1990) studied the functional morphology of the first three regions of vas deferens at ultrastructure level. The presence of three conspicuous typhlosoles in the sperm duct and one small typhlosole in the wing duct in the medial vas deferens appears to be characteristic of M.dobsoni. In all other penaeids studied, usually one typhlosole in each of the sperm duct and wing duct is reported (Malek and Bawab, 1974 b; Mohamed, 1989). The three typhlosoles of the sperm duct developed in the ascending limb of the medial vas deferens disappear in the posterior part of the descending limb of MVD. However, the typhlosoles of the wing duct continued to occur throughout the length of vas deferens. The presence of rich blood supply to the typhlosoles and their active secretions (Pl. 13a;

14a) indicate the high metabolic rate of these cells. Similar typhlosoles have also been observed in the vasa deferentia of the spiny lobster P. homarus (Berry and Hydorn, 1970; Radha and Subramoniam, 1985).

The process in which the different layers of spermatophore wall are laid also appears to be characteristically different in M.dobsoni than in other species. The first three incomplete layers secreted by the sperm duct are encompassed by the fourth layer secreted by the wing duct, which completely surrounds the sperm mass. The fifth and final layer which also surrounds the spermatophore, is formed in the terminal ampoule. Malek and Bawab (1974 b) have described the five successive stages involved in the formation of the complete spermatophoric layer in P. kerathurus. They have also indicated the presence of two complete layers for the spermatophore wall. In P. indicus, Mohamed (1989) also noticed two complete layers for spermatophore, however the formation of which has not been described by him. Kooda-Cisco and Talbot (1982) observed three complete layers in H. americanus. The morphological and histological structure of the wing also shows some variation as compared to the same in species of Penaeus. Malek and Bawab (1974 b) reported a two layered wing in P. kerathurus while Mohamed (1989) has observed an amorphous wing in P. indicus. The wing in M.dobsoni is a single layered amorphous structure with a round disc shape at one end, a wide middle portion followed by a typical tail like process (PL. 17b).

Most workers have investigated spermatophores of crustaceans by using material teased out from the distal vas deferens (Malek and Bawab 1974 a & b; Chow et. al. 1982; Subramoniam, 1984 and Radha and Subramoniam, 1985). Dudenhausen and Talbot (1983) made an ultrastructural comparison of soft and hardened spermatophores from the cray fish Pacifastacus leniusculus. The fully formed spermatophore extruded using the technique of electro-ejaculation (Kooda-Cisco and Talbot, 1982) in M. dobsoni is a semicylindrical, hardened peanut shaped sperm sac with a flap like wing covering one end and a cap like glutinous structure at the other end. Though the structure resembles to some extent that of the American species of Penaeus (Perez Farante, 1975), the spermatophore of M.dobsoni appears to be comparatively simple (Fig. 16). The parachute like wing noticed in P.indicus (Mohamed, 1989) is represented by a flap, covering the spermatophore at one end in M. dobsoni.

The ovary of M.dobsoni is found to be encompassed by a three layered wall consisting of an inner and an outer layer of epithelial cells and a connective tissue layer inbetween. This is similar to the condition observed in P. setiferus by King (1948) and in P. indicus by Subramanyam (1965). The presence of small blood vessels seen on the inner wall of the ovary might help in transportation of the nutrients to ovary (King, 1948; Mohamed, 1989). A wide variation in the placement of germinal zone in the ovary of crustaceans has been reported by Adiyodi and Subramoniam (1983). In the present study, it was found that the germinal epithelium on the inner ovarian wall producing a continuous crop of oogonia, is confined to a certain well defined area which has

been referred to as the zone of proliferation (Gutsell, 1936). Similar observations have also been made by King (1948) in P. setiferus, Subramanyam (1965) and Mohamed (1989) in P. indicus, Shaikhmahmud and Tembe (1958) in P. stylifera and Aiyer (1953) in Palaemon idae. The gradual movement of oogonia towards the centre of the lumen of the ovary during their transformation into primary and secondary oocytes is clearly demonstrated in this species. Similar observations have been made by King (1948) in P. setiferus. Shaikhmahmud and Tembe (1958) report that in P.stylifera young or immature ova present in the centre of the lumen move towards the periphery as they grow and become mature. As in other crustaceans, the process of oogenesis in M.dobsoni is completed in two phases. First is the proliferative phase in which the primary oogonial cells undergo mitotic division forming secondary oogonial cells, which after meiotic division give rise to primary oocytes. The second phase is the differentiative phase wherein the immature ova accumulate yolk and develop into mature oocytes. More or less similar observations have been reported in many other decapod crustaceans (Adiyodi and Subramonium, 1983; Yano, 1988). The process of oogenesis in M. dobsoni closely resembles that of M. ensis (Yano, 1985) and P. stylifera (Shaikhmahmud and Tembe, 1958). The mature ova of M.dobsoni shows significant structural variations from those of genus Penaeus. The striking difference is the absence of cortical rods (Duronslet et. al., 1975) or peripheral bodies. These cortical rods are the characteristic of mature ova of Penaeus and are indicators of imminent spawning (Anderson et. al., 1984). The absence of cortical rods is also noticed in M.ensis (Yano, 1985) and P.

stylifera (Shaikhmahmud and Tembe, 1958). Clark et. al. (1980) demonstrated that in P.aztecus the cortical bodies are responsible for the jelly layer which surrounds the eggs during early development. In the present species, the absence of such jelly like substance surrounding the eggs can be attributed to the absence of cortical bodies. The basophilic reaction of cytoplasm of ova of pre and early vitellogenic stages and the gradual shift to acidophilic nature in late vitellogenic and vitellogenic oocytes noticed in this species is similar to that noticed in P. setiferus (King, 1948), P. monodon (Tan Fermin and Pudadera, 1989) and P. indicus (Mohamed, 1989). During the process of oogenesis in M. dobsoni, the number of nucleoli gradually get reduced and finally in the vitellogenic stage, the entire nuclear material gets dispersed in the cytoplasm (Pl. 21 e). This process is very clearly noticed in this species than in other prawns of the genus Penaeus reported by many workers.

Folliculogenesis in M.dobsoni is observed to begin in previtellogenic stage and complete in early vitellogenic stage. In previtellogenic stage, the round follicle cells (Pl. 20c) surround a large number of secondary oogonial cells and in the later stages with increase in volume of oocyte, the follicle cells encircle the oocytes individually (Pl. 21 a). The round follicle cells gradually elongate and form a thin ribbon like covering to the ovum in late vitellogenic and vitellogenic stages (Pl. 21b,e). According to Charniaux-Cotton (1975), follicle cells facilitate vitellogenic activity by aiding in uptake of yolk protein from external sources.

Biochemical changes during maturation

The biochemical composition of various tissues and haemolymph during the process of maturation showed cyclic changes in M.dobsoni depicting some trend in mobilisation of organic reserves.

Protein, undoubtedly, is the most dominant biochemical constituent of muscle tissue of penaeid prawns (Shaikhmahmud and Magar, 1961; Dabrowskii et .al., 1969; Pillay and Nair, 1973; Sriraman and Reddy, 1977; Achuthankutty and Parulekar, 1984, Ashokan, 1984) and so is in M. dobsoni. Though the variation in protein content is not statistically significant, low levels of protein in immature and spent females and relatively higher levels in early maturing to mature animals indicate the increase in muscle protein during vitellogenesis. Mohamed and Diwan (1992) did not find any trend in muscle protein levels during maturation in P. indicus Claybrook (1983) reported that muscle protein are mainly involved in process of tissue growth and metabolism in crustaceans. Contrary to the present observation, Achuthankutty and Parulekar (1984) reported higher levels of protein in young prawns than in sexually mature specimens of M. affinis, M.dobsoni, P. merguiensis and P. stylifera. The high levels of protein noticed in haemolymph did not show any trend from immature to spent condition during the present study, while it showed an increasing trend according to Dall (1974) in Panulirus longipes, Gilles (1977) in Carinus

meanas, Barlow and Ridgway (1969) in H. americanus and Mohamed and Diwan (1992) in P. indicus. The clear increasing trend in the protein content of the ovary with advancement of maturation and its sudden drop in spent ovary in the present study, clearly indicate the gradual increase in protein content during active vitellogenesis. Pillay and Nair (1971) correlated the increase in percentage of both lipid and protein in the ovaries of M. affinis with increase in gonad indices from months of minimal reproductive activity to months of peak activity. Diwan and Nagabhushanam (1974) observed highest percentage of protein when the gonads were in developing condition and least during spawning period in the freshwater crab Barytelphusa cunicularis. A similar trend was noticed in P. aztecus and P. setiferus by Castille and Lawrence (1989) and in P. monodon by Dy-Penaflorida (1990). In the present study, the protein level was generally low in hepatopancreas and it showed a decreasing trend as maturation advanced, indicating considerable mobilisation of protein during vitellogenesis. The reason for low level of protein in hepatopancreas during spent stage could not be explained. Similar trends in the protein content of the hepatopancreas have been reported in P. monodon by Dy-Penaflorida (1990) and in P. indicus by Mohamed and Diwan (1992). Adiyodi (1969) reported that in Paratelphusa hydrodromous the hepatopancreas was not the major source of vitellogenic proteins but could well be the source of vitellogenic precursor.

Free amino acids, the simplest form of protein, though recorded in very low proportion, showed significant variations between the various maturity stages in different tissues. But for a widely fluctuating levels in muscle, in other tissues such as hepatopancreas, ovary and haemolymph, it showed a clear increasing trend from a low level in the immature stage to highest level in fully mature stage, before declining sharply in spent condition. The increase was steady in hepatopancreas and ovary. The increasing trend noticed in hepatopancreas is inverse to the pattern noticed for total protein. This clearly indicates the gradual storage and mobilization of simpler forms of protein in the hepatopancreas. A steadily increasing trend of free amino acid noticed in the ovary and haemolymph also indicated mobilization of free amino acid as well as storage and utilization of the same during various stages of vitellogenesis.

The carbohydrate level in various tissues appeared to be quite low as compared to that noticed by Mohamed and Diwan (1992) in P. indicus. In all the tissues excepting hepatopancreas, the variations in carbohydrate levels between different stages of maturation were found to be statistically significant ($P<0.01$). The carbohydrate content of haemolymph showed a three fold increase during maturation. Similarly, in P. hardwickii, Nagabhushanam and Kulkarni (1980) reported an incessant hike in haemolymph glucose levels during ovarian development. Mohamed and Diwan (1992) observed a four fold

increase in carbohydrate content during fully mature condition in P. indicus and the same decreased drastically in spent female. A doubling of haemolymph glucose level was observed by Dean and Vernberg (1965) in Callinectes sepidus and by Telford (1968) in Cancer borealis in ovigerous crabs. Adiyodi and Adiyodi (1970 b) reported that in P. hydrodromous, the sugars present in the hepatopancreas and haemolymph were also found in some abundance in the ovary during early stage of vitellogenesis, but disappear progressively as the proteins in the ovary became conjugated in the course of yolk formation. The trend of haemolymph and hepatic carbohydrate content observed in the present study indicates translocation of these substances to ovary for utilization in the synthesis of yolk and perhaps also as energy during the vitellogenic process. Truijillo and Luna (1981) have clearly demonstrated the mobilizatin of glycogen from hepatopancreas to gonads during ovarian development in the prawn P. notalis. A similar pattern of variation in carbohydrate content of hepatopancreas and ovary was noticed in M. dobsoni with relatively higher levels in early-vitellogenic, late vitellogenic and vitellogenic stages.

The present observation shows that lipid forms an important biochemical component, which undergoes significant variations in all the body tissues of the prawn during maturation and spawning. The lipid levels are quite low in muscle and haemolymph as compared to hepatopancreas and ovary. In all the tissues studied, the lipid content gradually

increased with advancement of maturation and reached peak level when the animal was fully mature. This is followed by a sharp decline in spent condition which would indicate mobilization of organic reserve during vitellogenesis,. Due to mobilization of stored lipid for gonad development, wide fluctuation in lipid composition have been reported to occur both in hepatopancreas and gonads of prawns (George and Patel, 1956; Morris, 1973; Pillay and Nair, 1973; Gopakumar and Nair, 1975). Shaikhmahmud and Magar (1957) recorded higher lipid content in various body tissues in females of P. stylifera. Teshima et. al. (1989), studying the lipid metabolism during maturation in P. japonicus, indicated that triglycerides, phosphatidylcholine and phosphat idylethanolamine are the major lipid classes responsible for the increase in quantities of ovarian total lipids. Similar observations have been made on wild prawns of P. japonicus, by Teshmima and Kanazawa (1983). Polyun saturated fatty acids have been reported to be involved in the reproductive process of the prawns such as P. setiferus (Brown et. al. 1979; Lawrence et .al. 1980 and Middleditch et . al. 1979). In P. duorarum ,Gehring (1974) reported that the total lipid of the ovary increased between the developing and nearly ripe stages. However, in contrast to the present observation, he also reported a decrease in the total lipid of the ovaries between the nearly ripe and ripe stages. Ashokan (1984) in P. indicus, Castille and Lawrence (1989) in P. aztecus and P. setiferus reported the gradual build up in ovarian lipid concentration during maturation and sharp fall in spent ovaries. Similar

observations have been reported by Mohamed and Diwan (1992) for P. indicus and they noticed an inverse relationship between ovarian and hepatic lipid contents. Gopakumar and Nair (1975) and Achuthankutty and Parulekar (1984) did not find any regularity or consistency to suggest that maturity condition influences the lipid composition of muscle tissue in different species of penaeid prawns studied by them. Hepatopancreas has been identified as the principal storage site for lipids in crustaceans (Chang and O'Connor, 1983). Apparently, large amounts of this stored lipids are mobilized to ovary from hepatopancreas as indicated by the higher levels of lipids in hepatopancreas than other tissues in different stages of maturity.

Moisture, the major component of the wet body tissue, showed highly significant variation ($P<0.01$) in hepatopancreas. The moisture content of the ovary also showed a signifcant variation with maturation while the moisture content of muscle fluctuated narrowly without any trend. In both hepatopancreas and ovary, the moisture content showed a clear decreasing trend with progression of maturation and minimum levels were noticed in fully ripe prawns and maximum in spent females, which would indicate an inverse relationship between water content and gonad development. Similar inverse relationship has been recorded by Pillay and Nair (1971) in M. affinis and P. pelagicus and by Mohamed and Diwan (1992) in P. indicus. It is possible that the

continued deposition of organic materials in ovarian and hepatic tissues results in loss of water content.

In males, the generally high levels of protein, carbohydrate and lipids in mature condition in all the tissues studied when compared to the same in immature stage indicate synthesis, storage and mobilization of organic reserves. The mature testes are rich in protein (34.22 mg/100 mg) followed by relatively high levels of lipids (9.64mg/100 mg). Carbohydrate content is generally low (0.49 mg/100 mg). Castille and Lawrence (1989) have reported that protein is the most abundant biochemical constituent of the male reproductive organ. They have also noticed low levels of carbohydrates in males of P. aztecus and P. stylirostris. Diwan and Nagabhushanam (1974) noticed highest protein, carbohydrates and lipid values in testes of the freshwater crabs P. cunicularis when the animal was in peak reproductive phase. Pillay and Nair (1971, 1973) concluded that in Uca annulepis and M. affinis change in the biochemical constituents were less pronounced in the testes than in the ovaries. The present study conforms to this observation.

Maturation and spawning under controlled conditions

Though several studies have been reported in recent years on maturation and spawning of penaeid prawns in captivity with varying success (Primavera, 1984), all these studies are carried out in seawater conditions. It has been almost

established beyond doubt that penaeid prawns mature and spawn easily in confinement and this has paved the way for development of hatchery techniques for cultivable species in many parts of the world. The maturation in confinement has also been made easy through eyestalk ablation technique. However, attempts on maturation of penaeid prawns in captivity under brackishwater conditions are rarely reported, although species such as Metapeneus bennette and M. dalli are believed to complete their life cycle in lagoons and estuaries (Morris and Bennet, 1951; Potter et. al., 1986). Though many authors have reported maturation of penaeid prawns in brackishwater environment, direct evidence on maturation and spawning in this environment is reported only by SEAFDEC in P. monodon (Anon, 1983). In India, Rao and Kathirvel (1973) and Silas et. al., (1982) reported to have succeeded in breeding M. dobsoni in brackishwater medium. These authors have collected mature females of the species from brackishwater areas/ponds having salinities 28.0-30.2 ppt and got the prawn spawned in laboratory in the same media. In the experiments of Rao and Kathirvel (1973), although spawning took place in 30.2 ppt salinity, the eggs did not develop beyond the first nauplius stage. When these nauplii were transferred to seawater, they developed into abnormal protozoea and then died. The authors attributed this mortality to a combination of various environmental factors of which lesser salinity was considered to be one. In the experiments of Silas et. al. (1982), the prawn spawned in the initial salinities of 28.72-30.1 ppt. When reared in the same

medium, the eggs hatched and metamorphosed to postlarvae in 20-32 days of rearing. During rearing, the salinity increased gradually to a maximum of 34.85 ppt. In the light of the results, these authors concluded that M. dobsoni can spawn successfully and complete its life history in brackishwater.

The results of the nine successful experiments (Table 44) carried out on maturation and spawning of M. dobsoni during the present investigation indicate that success of maturation and spawning largely depends on the salinity and size of the prawn, as noticed in the perennial prawn culture systems. The prawns for this study were collected from the coconut grove canal system during July-August 1990 for experiment I and II, while those for the remaining seven experiments (Experiments III to IX) were collected from Kannuvilakettu during different months from May to September 1991. The salinity of water in the coconut grove canal system at the time of collection of these animals ranged from 3.70 to 4.85 ppt, while the same in Kannuvilakettu varied between 2.10 and 18.20 ppt. Immature impregnated females and mature males were utilized for all the maturation experiments except experiments V and VIII in which early maturing prawns collected from Kannuvilakettu during June and August 1991 were reared for studying the possibilities of further gonadal development, full maturation and spawning in captivity under brackishwater salinity. All the maturation and spawning experiments were conducted in higher salinities (15-30

ppt) than those prevailed in the culture systems. The fact that even prawns collected from very low salinity conditions that prevailed during the monsoon months (June-September) matured and spawned successfully in the laboratory at higher salinity levels, indicates that salinity of the environment from which the animals were drawn does not have any significance on maturation. The variation in temperature (25.1-28.9^{o}C) and oxygen (4.30-6.50 mg/l) recorded in the experimental media were almost same as in the culture systems (Temp. 26.0-28.3^{o}C; oxygen 4.28-6.25 mg/l). It would appear therefore that these parameters are within the normal range needed for growth and reproduction of the prawn. The pH of the maturation tubs was maintained above 8.0 using sodium carbonate, as pH below 8.0 is reported to have adverse effect on prawn maturation (Muthu and Laxminarayana,. 1984). The pH of the pond water from where the prawns were collected generally remained below 8.0. Ammonia and nitrite of the rearing medium varied from 4 to 50 ug at/l and 2-30 ug at/l respectively, in most cases. However, in some experiments, they have gone up to 40-48 ug at/l and 62-95 ug at/l, which are within the permissible limit according to Chen et. al., (1986) observed for postlarvae of P. monodon.

Effect of salinity on maturation

Contrary to published information (Rao and Kathirvel, 1973; Silas et. al., 1982) on the maturation and spawning of M.dobsoni in brackishwater, the present investigation reveals

that the species has the potentiality to mature in conisderably low saline conditions. The range of salinity in which the animal has been observed to successfully mature and spawn is 22 to 30 ppt. In experiment V when the early maturing prawns were gradually acclimated to 20 and 22 ppt salinities, the prawn in 22 ppt spawned successfully while that in 20 ppt reabsorbed the gonad. A similar experiment conducted in 26 ppt (Experiment VIII) indicated successful spawning. When immature prawns were used for the experiments, in 26 ppt, four prawns showed indication of maturation of which two spawned successfully and the remaining two reabsorbed the gonads, indicating 50 per cent success in spawning after induction of maturation. In 27 ppt salinity, among three prawns in which maturation was initiated two spawned and the remaining animal reabsorbed the gonads, showing 66.67 per cent success. In 28 ppt, the induction of maturation was noticed in seven prawns and all of them spawned successfully, indicating 100 per cent spawning success. Similarly, in 30 ppt, five prawns matured and spawned successfully. These results clearly indicate that M. dobsoni matures and spawns successfully in salinities as low as 22 ppt. Silas et. al., (1982) encountered fully mature females of M. dobsoni in 28 ppt salinity and got it successfully spawned in the laboratory at a minimum salinity of 28.72 ppt.

Effect of size of prawn on maturtion

During the maturation experiments, size of the prawn also appeared to be an important factor for obtaining positive

results. The sizes at which the prawns matured ranged from 71-96 mm. When tried with still smaller sizes on many occasions the prawns did not show any sign of gonadal change, indicating that 71 mm could be the lower limit of size for maturation. During the maturation experiments, attempts were also made to find out the size/salinity relationship for maturation of the female by carrying out a number of experiments using different size and salinity combinations. It was observed that sign of maturation occurred only when prawns of 71 mm and above were used and in salinities above 22 ppt. It is also interesting to note that there was absolutely no gonadal change in prawns less than 71 mm size when they were experimented in higher levels of salinities ranging 22-32 ppt. These observations clearly show that the maturation of M. dobsoni in less saline water is size dependent. Out of the 22 prawns that have matured during the maturation experiments, 10 were in the size group 86-90 mm, 5 in 81-85 mm, 4 in 76-80 mm and one each in 71-75 and 91-95 mm. Thus, it is clear that prawns in the size range of 86-90 mm mature readily in the brackishwater salinities. The results further indicate that prawns above 76 mm can be induced to mature and spawn in the laboratory by providing higher salinities, preferably above 26 ppt. The size of the prawn observed in maturing or mature state in the prawn culture system was always above 71 mm (Table-39) which corroborates with the findings from the laboratory experiments. Rao and Kathirvel (1973) collected mature specimens of the size 69 mm from the open backwater when the salinity was relatively high (30.2 ppt). Silas et. al. (1982) observed maturation of M. dobsoni taking

place in size ranging from 74 to 104 mm in the brackishwater ponds at a minimum salinity of 28 ppt. The relatively smaller size for the mature prawn recorded by Rao and Kathirvel (1973) may be due to the fact that the maturation took place in the open backwater in the vicinity of the bar mouth where normally marine conditions prevail during the summer months.

The present studies have also revealed that considerable variations exist for the time taken for completion of the maturation process, spawning time and the number of eggs produced during each spawning in the brackishwater. Once the maturation is initiated (Stage II), the time taken for attainment of full maturation (Stage IV) varied from one to four days (22-94 hours). In as many as 10 out of 17 prawns spawned, the time required for full maturation ranged from 32 to 36 hours or in otherwords less than 1 1/2 days. This indicates that the maturation process is very fast in this species.

In all the 17 cases, spawning took place only at night and majority of the spawnings took place between 2330 and 0130 hours in the midnight as observed by Silas et. al. (1982) and Muthu and Laxminarayana (1977).

The number of eggs released by the laboratory matured prawns varied widely, the minimum and maximum being 3850 and 35,700, respectively. In most of the cases (13) the total number of eggs varied between 18,000 and 30,000 for sizes ranging from 76 to 90 mm. The fecundity of prawns matured in

the perennial prawn culture system varied between 38,400 and 80,600 for size ranging 80 to 95 mm respectively. This shows that the fecundity is comparatively higher for prawns matured in the field than those induced to mature in the laboratory. Rao (1968) observed a fecundity ranging from 34,500 at 70 mm size to 1,60,000 at 120 mm size for the species in the sea. Since the sizes of the prawns for which fecundity estimates have been made by Rao (1968) and in the present study are not identical, it is not possible to draw any comparison between these two observations. According to Rao (1968), the fecundity increases approximately as the cube of total length in M. dobsoni, while Rao (1989) reports that fecundity in the related species M. monoceros increases in direct proportion to total length.

Rematuration

Many workers have reported that ovarian development in penaeid prawns occurs again after spawning (King, 1948; Cummings, 1961; Eldred et. al. 1961; Martosubroto, 1974; O'Connor, 1979). The eyestalk ablation resulting in shortening of maturation period led to an increase in number of spawnings per moult cycle. Browdy and Samocha (1985) noticed repeated spawning within one moult cycle in eye ablated as well as non ablated P. semisulcatus. They observed a maximum of four spawnings between moults with 95-100 per cent fertilization rate. The eggs developed normally and metamorphosed into

protozoea I. However, the number of eggs released was found to decrease with repeated maturation and this has been attributed to the increased bioenergetic demand after ablation and apparent decrease in growth as well. Emmerson (1983) also observed four spawnings in eyestalk ablated females of P. monodon, while in non ablated females it was only three times. They also observed a slightly higher intermoult period (28 days) for unablated females while in ablated females, it was about 26 days. Rematuration or respawning is found to occur in captivity in several penaeid prawns (Arnstein and Beard, 1975; AQUACOP, 1977; Beard and Wickins, 1980; Kelemec and Smith, 1980; Chamberlain and Lawrence, 1981). Yano (1984b) reported rematuration of spent Kuruma prawn P.japonicus in culture tanks. He has indicated that the process of rematuration a little after spawning proceeds through the following three steps: (1) absorption of unspawned ripe eggs and repair of ovaries; (2) appearance of oil globule I oocytes and increase in number and rapid increase in size of follicle cells (biosynthesis of vitellogenin) and (3) extensive accumulation of yolk granules in cytoplasm of oocytes. Primavera and Borlongan (1977) also observed ovarian rematuration of ablated sugpo prawn P.monodon in concrete tanks. The authors observed that 10 per cent of the animals had a second spawning, 1.4 per cent third spawning with 10-22 days period inbetween. Mohamed et. al., (1981) also observed rematuration in P.indicus under controlled conditions.

Joshi and Nagabhushanam (1982) indicated multiple spawning in P.stylifera. All the above observations were made in seawater. However, rematuration of prawn in brackishwater has not been reported so far. In the present study, three cases of successful rematuration of M.dobsoni have been noticed (Table 45). The time taken for initiation of rematuration after first spawning varied from 2 to 5 days and the interval between successive spawnings varied from 4 to 8 days. The actual process of ovarian rematuration has been found to be completed in 34 to 76 hours. In the case of rematuration that occurred in unmoulted prawn, the time taken (34 hours) for completion of maturation process for the second time was more or less similar to the time taken in the first maturation of the same animal (32 hours), as well as other animals (32-36 hours) which gave positive results. The eggs spawned after rematuration of the prawn were viable and showed a fertilization rate of 91.3 per cent. In those prawns which had undergone moulting prior to spawning, a considerable delay has been noticed in completion of the maturation process in the first maturation (63-70 hours) as well as rematuration (74-76 hours). The eggs released by these prawns on both the occasions were unfertilized, evidently due to the absence of spermatophore in reserve, at the time of spawning. The number of eggs released after rematuration varied from 18,650 to 21,400, which is much less than the number of eggs produced during the first spawning (29,600-35,700).

The present finding on rematuration of M. dobsoni has given a direct evidence to the fact that the animal is able to spawn in quick succession and possibly many times in it's life time. The interval between successive spawnings in its natural environment such as the inshore sea could be much shorter than what has been observed during the present investigation (4-8 days). Rao (1968), studying the maturation and spawning of M.dobsoni in the coastal waters of southwest coast of India arrived at the conclusion that the species spawns 5 times in its life time and the interval between successive spawnings is about 2 months. The present observation clearly shows that these estimates are very conservative and what is happening in nature may be different. More studies are warranted to establish the present finding as regards the number of spawnings during the life time of the species and the exact period between successive spawnings.

Embryonic and early larval development

The fact that hatching of eggs and larval development are accomplished in the marine environment is an accepted principle in the life history of penaeid prawns except in the case of M. bennette and M. dalli, which are believed to complete the life cycle in coastal lakes and estuaries (Morris and Bennet, 1951; Potter et. al., 1986). In the latter case also the embryonic and larval development are completed in high salinity conditions which are comparable to those existing in the inshore waters. In most of the penaeid prawns studied in

India, the egg hatching and larval development is reported to occur in seawater conditions (Raje and Ranade, 1972 a,b; Thomas et. al., 1974, Silas et .al., 1978, Muthu et. al., 1978). Though Silas et al. (1982) succeeded in spawning M. dobsoni in brackishwater conditions, the larval development as observed by them, cannot be considered as successful in brackishwater in the real sense as the minimum salinity they tried was 30.1 ppt which gradually increased with the progress of larval development. The salinity reached a maximum of 37.31 ppt by the time the larval metamorphosis was completed.

During the present study, it has been observed that the percentage of fertilization of the eggs (91.1-98.14%) remained relatively high in all the experiments. The embryonic development is also found to be normal. However, in the pond culture experiments, Silas et. al. (1982) noticed that some of the eggs spawned had very narrow perivitelline space instead of the characteristic wide perivitelline space in this species (Muthu et. al., 1978). According to these authors, even such eggs with narrow perivitelline space developed normally and produced active nauplii. In the present study, no such abnormality was noticed in any of the salinities in which spawning had taken place. The eggs were quite normal and the larvae hatched out were also normal and active. The embryo hatched into nauplius in all the salinities above 22 ppt. A total of six substages of nauplius have been observed in all the experiments, as recorded by Muthu et.al., (1978) in seawater salinity. Rao and Kathirvel (1973) noticed embryonic

development leading to abnormal nauplii in 30.2 ppt salinity. In the present study, the time taken for completion of the naupliar development ranged from 31 to 48 hours, which is comparatively shorter than the time taken for the naupliar development (40-56 hours) in the seawater salinity (Muthu et.al., (1978). The average time taken for completing the naupliar development worked out to 37.5 hours in 22 ppt, 37.75 hours in 26 ppt, 39 hours in 28 ppt and 39.5 hours in 30 ppt, indicating a gradual increase in the time taken for naupliar development as the salinity increased from 22 ppt to 30 ppt. However, only a narrow range of variation is noticed between salinities. In all the salinities above 22 ppt, the protozoea, after completing the naupliar stages, remained to be healthy till the termination of the experiment. Thus it can be inferred that complete larval development of M.dobsoni is possible in the brackishwater environment when the salinity is above 22 ppt.

The occurrence of mature females of M.dobsoni in perennial prawn culture system coincided with period of high salinity (19.26 ppt) in 1991. The absence of eggs or larvae of the species in the plankton samples taken from the culture system during this period may be due to the fact that salinity lower than 22 ppt would not have been condusive for spawning.

Effect of salinity on embryonic and early larval development

In the present study (Tables 48 a,b,c), the perusal of the results clearly indicate that normal embryonic

development with successful hatching is possible in salinities above 18 ppt. Though successful hatching is noticed in 15 and 16 ppt salinities, the nauplii hatched, died immediately, indicating that salinities below 18 ppt are unsuitable for normal embryonic development and hatching. The period of embryonic development remained relatively same (9-12 hours in all salinities). The observations on the average duration of naupliar development clearly indicate that at low salinities a shorter period is required (35 hours in 18 ppt) than in higher salinity conditions (40.5 hours in 30 ppt) for completing the naupliar development. The low survival at protozoea I stage, (6.25 % in 18 ppt and 22.08-25.3 % in 20 ppt) noticed in 18 and 20 ppt salinities clearly demonstrates that these salinities are not suitable for the naupliar metamorphosis. The little fluctuation in survival at protozoea I stage noticed in salinities 22 to 30 ppt (39.67 - 46.86%) clearly indicates that salinities above 22 ppt are suitable for the normal naupliar development.

In conclusion, it may be mentioned that breeding of M.dobsoni in brackishwater environment is possible beyond doubt. George (1974) based on the incidence of mature females during the summer months (February-May) and also based on the occurrence of early juvenile prawns of the size 16-35 mm in the perennial prawn culture system, inferred that M.dobsoni could spawn and complete its life cycle in this environment. These assumptions were later proved partly correct by the studies of

Silas et .al., (1982). These authors also state that M.dobsoni which are prevented from migrating back to the sea by getting trapped in the perennial prawn culture fields may mature and spawn there during the summer months when the salinity is high (28-30 ppt) and the resulting larvae also may grow into juveniles and contribute to the backwater fishery. The present study, which was inspired by the above findings of Silas etal.(1982), has conclusively proved that M.dobsoni is able to mature, spawn and complete its life cycle in brackishwater of salinity as low as 22 ppt, since the critical larval stage of protozoea could tolerate this salinity and undergo moulting and survive further.

S U M M A R Y

1. Metapenaeus dobsoni (Miers), one of the most important penaeid prawns of the southwest coast of India, has been studied for its growth and reproductive capability in brackishwater environment through field and laboratory investigations. The field studies were carried out based on samples drawn from two selected perennial prawn culture systems, namely, Kannuvilakettu and Thoppilkettu, during January 1990 to August '91 and by conducting a short term experimental culture in a coconut grove canal system during January to June '91 in the Vypeen island, Cochin.

2. The ecological parameters such as temperature, salinity, oxygen and pH recorded in the perennial culture systems ranged from 26.3 to 33.1^0 C, 2.45 to 22.60 ppt, 3.78 to 7.55 mg/l and 7.35 to 8.19, respectively, in Kannuvilakettu and 28.4 to 33.0^0 C, 3.64 to 19.01 ppt, 3.70 to 9.49 mg/l and 7.23 to 8.06 in Thoppilkettu, indicating almost a similar ecological condition existing in both the systems. Salinity showed wide fluctuations, while the other parameters varied in moderate levels.

3. A comparison of the nutrient parameters such as nitrate, phosphate and silicate recorded in the two perennial prawn culture systems with those recorded in the neighbouring culture fields by other workers indicated that Kannuvilakettu and Thoppilkettu are highly productive.

4. The water quality parameters recorded in coconut grove canal system were more or less similar except for a comparatively higher level of nitrate in the initial period of culture. A comparatively higher zooplankton biomass indicated a better secondary production in this ecosystem than in the perennial prawn culture fields.

5. The size of the species in the two perennial culture fields ranged from 23 mm to 89 mm for males and 20 mm to 105 mm for females with majority belonging to the size group 51-65 mm for males and 51-75 mm for females. The monthly mean sizes were invariably larger in females than in males in both the culture systems. Larger prawns of above 70 mm were observed during April to September in Kannuvilakettu and August to November in Thoppilkettu.

6. Differential growth rate was noticed between sexes, the females registering faster growth than males. In the first two months, a maximum growth rate of 10.2 to 15.6 mm/month was recorded in males and 14.0 to 20.1 mm/month in females. The females exhibited fairly high growth rate of 11-12 mm/month during the third month also. From the growth pattern observed, it is inferred that, with an intial stocking size of about 25 mm, the male attains a harvestable size of about 53 to 62 mm and females about 65 to 70 mm in three months growing period. The study has also indicated that trapping and growing M. dobsoni for two to three months period in the perennial prawn culture fields would bring in better catch returns with relatively large sized prawns.

7. In the coconut grove canal system, without supplementary feeding M.dobsoni showed a much faster growth rate of 17.6 mm in males and 23.5 mm in females during the first month as compared to the growth recorded in the perennial culture systems. A sharp decline in growth rate observed in the succeeding month is attributed to shortage of food in the limited space. It is presumed that the rapid growth noted in the first month of culture could be prolonged further and large sized prawns obtained by resorting to supplementary feeding. The harvestable size of 65 mm has been recorded in 2 1/2 to 3 months period with a stocking size of about 28 mm and a stocking density of 10.2 prawns/sq.m.

8. Taking into account the fast growth rate of M.dobsoni observed during the experimental culture in the coconut grove canal system, it is recommended that the extensive coconut grove canal net works can be better utilized for culturing this species and add substantially to the production through brackishwater farming.

9. The reduction in growth increment after attainment of a size of about 56.8 mm in males and 61.3 mm in females in the brackishwater environment is attributed to the possible physiological change occurring in the animal with the approach of size at maturity.

10. The rate of biomass production during the experimental culture in coconut grove canal system is estimated

at 200 kg/ha/140 days. It is inferred that this level of production could be considerably enhanced by increasing the stocking density and providing supplementary feeding.

11. The growth experiments conducted in different salinity levels for 56 days in the laboratory indicated recognisable variation in survival, growth rate, food utilization, biomass production and moulting periodicity in different salinities. A high survival rate of 80-90 per cent was observed in salinities between 5 and 25 ppt. The maximum growth rate in terms of length and weight was recorded in 10 to 20 ppt salinities of which 15 ppt proved to be the best.

12. The variation in food utilization indices such as Feed Conversion Efficiency (FCE) and Protein Efficiency Ratio (PER) indicated maximum conversion of feed into body tissue during the initial phase of growth (first fortnight) which gradually declined as the prawn increased in size. The FCE and PER were relatively high in 10 to 20 ppt salinities, with the maximum food utilization in 15 ppt salinity.

13. A comparison of the biomass production of prawns in different salinity levels in the laboratory also indicated maximum biomass production in 15 ppt (5.21 g/sq.m). The relatively higher biomass production in 20 ppt than in 10 ppt, inspite of higher daily growth in the latter salinity, is attributed to higher survival rate in 20 ppt than in 10 ppt.

14. A faster moulting rate for M.dobsoni was observed in 10-20 ppt salinities with the maximum moulting frequency in 15 ppt. The moulting rate was least in 30 ppt in which the animal took as many as 50.5 days to complete five moultings as against 38 days to complete six moultings in 15 ppt salinity thereby indicating a shorter intermoult period in 15 ppt salinity.

15. The biochemical composition of the muscle tissue of prawn grown in different salinities indicated an increasing trend for protein and lipid levels with increasing of salinity from 5 to 20 ppt. Higher carbohydrate levels were recorded in 15-20 ppt salinities.

16. The temperature (26.8-27.6^{0} C), oxygen (3.58-6.41 mg/l) and pH (6.85-7.92) of the experimental tanks varied within the optimal levels.

17. The weekly accumulation of ammonia and nitrite, the two important metabolites in the experimental media, showed an increasing trend with the progress of experiment. The increase in ammonia content was higher than that noticed for nitrite. Besides the differential growth associated with salinity, the survival in different salinity levels also influenced the accumulation of these metabolites.

18. A comparison of the length-weight relationship of the species in three salinity regimes namely 0-5 ppt, 10-15 ppt and 20-25 ppt showed a significantly higher length-weight

exponent (3.0691) for females in 10-15 ppt salinity regime as compared to the same in other salinity regimes (2.8347-2.8690). The prawns showed isometric growth (b = 2.9084 for males and 3.0691 for females) in 10-15 ppt salinity, whereas in other salinities they showed a lower weight gain than the cube of length.

19. The size, count and meat recovery relationship indicated a count per kg of 500 for males and 430 for females headon at 66-70 mm size, which gave a recovery of 69 per cent for headless and 52-53 per cent for peeled & deveined prawns.

20. The field observations and laboratory experiments conducted have clearly shown that M.dobsoni attains maturity and breeds in brackishwater.

21. The morphology and anatomy of male and female reproductive systems have been described. The testis is characterised by the fusion of the right and left halves for their entire length, and by the presence of eight lobes on either side. The ovary bears a pair of anterior lobe, a middle lobe with eight lobules on either side and a posterior lobe extending up to the sixth abdominal segment. The oviduct originates characteristically from the base of the fifth lobule of the middle lobe.

22. Based on externally visible sexual characters and the gonadal development, four maturity stages have been distinguished in males and five in females. In males, the fusion of petasmal endopodites signifies only the initiation of

maturation process. The mature condition of testis can be judged externally from the fully hardened petasma in its typical form. The size at maturity of male at 50 per cent level is found to be 58.5 mm. The observed minimum size at maturity in female is 84mm.

23. The spermatogenesis and spermatophore formation have been studied based on histological examination of testes and vasa deferentia of immature, maturing and mature male prawns. The sperm has a well differentiated head having acrosomal complex and a long tapering tail and it resembles a typical 'tadpole'. The spermatophore is a semicylindrical, hardened, peanut-shaped sperm sac with a flap-like covering at one end and a cap-like glutinous structure at the other end.

24. In oogenesis, the germinal zone or the zone of proliferation is confined to a certain well defined area on the inner ovarian wall. In mature ova, cortical rods are not noticed. Folliculogenesis is observed to begin in previtellogenic stage and complete in early vitellogenic stage.

25. Studies on the biochemical variations of free amino acids, carbohydrates and lipids in muscle, haemolymph hepatopancreas and ovary of female prawn during different stages of maturation indicated cyclic changes showing an increasing trend till attainment of full maturation and a sudden fall after spawning. Protein levels showed erratic variation in these tissues exept in ovary. Moisture content of hepatopancreas and

ovary decreased as maturation progressed and showed a steep increase after spawning.

26. A comparison of the biochemical composition of muscle, haemolymph and hepatopancreas of immature and mature males indicated that protein, carbohydrate and lipids are generally higher in mature prawns than in immature ones. The biochemical composition of mature testes indicated high levels of protein followed by lipids and carbohydrates.

27. Monthly distribution of mature prawns in the perennial prawn culture systems indicated that male matures throughout the year irrespective of the prevailing salinity. The maturation is largely size dependent rather than being influenced by salinity or any other environmental factor.

28. Mature and maturing females were observed only during April to July when relatively larger females were available in the culture system. The maturation of female gonad in the brackishwater is found to be combinedly influenced by size and salinity. Laboratory maturation experiments further revealed that salinities above 22 ppt and sizes above 70 mm are essential for maturation of female in the brackishwater.

29. In the laboratory, the optimum time taken for initiation of maturation in brackishwater varied from 4 to 5 days. Once maturation is initiated, the ovarian development is very rapid and completed in 32 to 36 hours.

30. The prawns matured in the perennial prawn culture system showed a fecundity ranging from 38,400 to 80,600 for prawns of 80-95 mm size. However, those induced to mature in the laboratory by salinity change recorded a lower fecundity rate of 3850 to 37,700 for more or less the same size.

31. Successful rematuration and spawning of the spent ovary immediately after the first spawning was observed in 28 ppt and 30 ppt salinities with a time interval of 4 to 8 days between successive spawnings. This gives a direct evidence to the fact that M. dobsoni is able to spawn in quick succession and possibly many times in its life time. The number of eggs released after rematuration was much less than the number released during the first spawning.

32. A high rate of fertilization of egg (91-98%) was noticed in the laboratory matured prawns, which underwent normal embryonic and early larval development in the brackishwater above 22 ppt salinity. The time taken for embryonic (9-12 hours) and naupliar (31-48 hours) development in brackishwater is comparatively shorter than the time taken in the seawater.

REFERENCES

ACHUTHANKUTTY, C.T. M.J. GEORGE AND S.C. GOSWAMI 1977. Larval ingression of penaeid prawns in the estuaries of Goa. Proc. Symp. Warm Water Zooplankton, Spl. Publ. NIO UNESCO: 412-421.

ACHUTHANKUTTY, C.T. AND S.R.S. NAIR 1982. Penaeid prawn population and fry resources in a mangrove swamp of Goa. Proc. Symp. Coastal Aquaculture, Part I: 190-195.

ACHUTHANKUTTY, C.T. AND S.R.S.NAIR 1983. Larval migration and growth of marine prawns in the estuarine habitat. Mahasagar, 16(2): 243-250

ACHUTHANKUTTY C.T. AND A.H. PARULEKAR 1984. Biochemical composition of muscle tissue of penaeid prawns. Mahasagar, 17 (4): 239-242.

ACHUTHANKUTTY, C.T. AND A.H. PARULEKAR 1986a. Biology of commercially important penaeid prawns of Goa waters. Indian J. Mar. Sci.,4:5-10

ACHUTHANKUTTY, C.T. AND A.H. PARULEKAR 1986b. Distribution of penaeid larvae in the coastal waters of Goa. Indian J.Mar. Sci., 15: 171-173.

ATHUTHANKUTTY, C.T. AND A.H. PARULEKAR 1986c. Growth of penaeid prawns in Goa waters. Indian J. Mar.Sci., 15 (2): 117-120.

ACHUTHANKUTTY, C.T. 1987. Commercially important penaeid shrimp larvae in the estuaries of Goa. Mahasagar, 20(4):217-224

ACHUTHANKUTTY, C.T. 1988. Nursery life of the marine prawn, Metapenaeus dobsoni (Miers) in the Mandavi Estuary along Goa coast, India. Indian J. Mar. Sci., 17(4): 313-316.

ADIYODI, K.G. AND R.G. ADIYODI 1970. Endocrine control of reproduction in decapod crustacea. Biol. Rev. Cambridge Philos. Soc., 45: 121-165.

ADIYODI, R.G. 1968. Protein metabolism in relation to reproduction and moulting in the crab Paratelphusa hydrodromous (Herbst). Part I. Electrophoretic studies on the mode of utilization of soluble proteins during vitellogenesis. Indian J. Exp. Biol., 6:144-147.

ADIYODI, R.G. 1969. On the storage and mobilization of organic resources in the hepatopancreas of a crab (Paratelphusa hydrodromous). Experimentia, 25: 43-44.

ADIYODI, R.G. AND K.G. ADIYODI 1970 a. Lipid metabolism in relation to reproduction and moulting in the crab Paratelphusa hydrodromous (Herbst). Part I. phospholipid and reproduction. Indian J. Exp. Biol., 8(3): 222-223.

ADIYODI, R.G. AND K.G. ADIYODI 1970b. Free sugar in Paratelphusa hydrodromous (Herbst) in relation to reproduction and moulting. Physiol. Zool., 43(1): 71-77.

ADIYODI, R.G. AND T. SUBRAMONIAM 1983. Arthropoda - Crustacea. In " Reproductive Biology of Invertebrates. Vol.I. 'Oogenesis oosorption'. K.G. Adiyodi and R.G. Adiyodi (Eds.). Wieley, Chichester England. pp. 443-495.

ADIYODI, R.G. 1985. Reproduction and its control. In: The biology of Crustacea, D.E. Bliss and L.H. Manter (Eds.), Academic Press, New York.

AIKEN .E. 1978. Moulting and growth in decapod crustaceans with particular reference to the lobster Homarus americanus. Work h Lobster and Rock Lobster Ecology and Physiology, CSIRO Circular, No.7: 41-47.

AIKEN, D.E. 1980. Moulting and growth. In: Biology and management of lobsters, Vol. , Academic press. pp. 91-163.

AIYER, R.P. 1953. On the female reproductive system of Palaemon ideae Heller. J. zool. Soc. India, 5(2): 227-234.

ALAGARJA, K., M.J. GEORGE, K. NARAYANA KURUP AND C. SUSEELAN 1984. Yield-per recruit on Parapenaeopsis stylifera and Metapenaeus dobsoni from Kerala state, India. J. Appl. Ichthyol., : 1-11.

ALAGARSWAMI, K. 1988. Research needs for brackishwater aquaculture in India by 2000 AD. Paper presented at the International Symposium on Aquaculture Research Needs for the year 2000, FERRO/OICD/USDA/ICAR, 15-18 November, 1988.

ALAVA, V.R. AND C. LIM 1983. Quantitative dietary protein requirements of Penaeus monodon juveniles in a controlled environment. Aquaculture, 30: 53-61.

ALI, S.A. 1982 a. Relative efficiencies of pelletized feeds compounded with different animal proteins and the effect of protein level on the growth of the prawn Penaeus indicus. Proc. Symp. Coastal Aquaculture, Part I: 321-328.

ALI, S.A. 1982 b. Effect of carbohydrate (starch) level in purified diets on the growth of Penaeus indicus. Indian J. Fish.,19(1&2): 201-208.

ALIKUNHI, K.H., A. POERNOMO, S.ADISUKERESNO, M.BUDIONO AND S. BUSMAN 1975. Preliminary observations on induction of maturity and spawning in Penaeus monodon Fabricius and Penaeus merguiensis de Man by eyestalk extirpation. Bull. Shrimp Cult. Res. Cent., 1: 1-11.

AMATO, G.D. AND G. PAYEN 1978. Mise in evidence du controle des differentes etapes de la spermatogenesis duz l Ecrenisse Pontastacus leptodactylus Eshscholtz 1823, (Crustacea, Decapoda Reptantia), Gen. Comp. Endocr., 36: 487-496.

ANDERSON, S.L., E.S. CHANG AND W.H. CLARK Jr. 1984. Timing of post-vitellogenic ovarian changes in the ridgeback prawn Sicyonia ingentis (Penaeidae) determined by ovarian biopsy. Aquaculture, 42: 257-271.

ANDREWS, J.W., L.V. SICK AND G.J. BAPTIST 1972. The influence of dietary protein and energy levels on growth and survival of penaeid shrimp. Aquaculture, 1: 341-347.

ANIL, A.C. 1985. Prawn seed resources and its farming potentialities in Sunkeri backwaters (Kali estuary-Karwar). J. Indian Fish. Ass., 12 & 13: 13-20.

ANONYMOUS 1983. Annual report of SEAFDEC, pp. 24-25.

ANONYMOUS 1986. Further success in controlled breeding of penaeid prawns. CMFRI Newsletter No. 33, pp. 56.

ANONYMOUS 1988. Research Highlights of Central Marine Fisheries Research Institute, Cochin. N.G.K. Pillai (Ed.), P.6.

ANONYMOUS 1991a. World Trade in Fishery commodities by major countries. Prime. A Publication of the Marine Products Development Authority, Kochi, 05.05. 1991.

ANONYMOUS, 1991 b. Marine products export review 1990-91. The Marine Products Export Development Authority, Cochin, P 5.

ANONYMOUS 1991c. World shrimp Farming 1991. Published by Aquaculture Digest, November 1, 1991, pp: 1-31.

ANONYMOUS 1991d. Fish Farming International 18(2): P 1

ANONYMOUS 1991e. Manual of methods in aquatic environment research. FAO Fish. Tech. Paper, 137: 1-238.

ANONYMOUS 1992. Research highlights of Central Marine Fisheries Research Institute, Cochin. N.G.K. Pillai (ed.), pp. 13.

AOAC 1965. Official methods of analysis of the Association of Official Agricultural Chemists 1965. 10th Edition, Publ. by the Association of Official Agricultural Chemists, Washington D.C.

AQUACOP 1977. Reproduction in captivity and growth of Penaeus mondon, Fabricius in Polynesia. Peoc. 8th Annu. Meet. World Maricult. Soc., pp. 927-945.

AQUACOP 1979. Penaeid reared broodstock : Closing the cycle of Penaeus mondon. P. stylirostris and P. vannamei. Proc. World Maricul. Soc., 10: 445-452.

ARMSTRONG, D.A., M.L. STEPHENSON AND A.W. KNIGHT 1976. Acute toxicity of nitrite to larvae of the giant Malayan prawn. Macrobrachium rosenbergii. Aquaculture, 9: 39-46.

ARNSTEIN, D.R. AND T.W. BEARD 1975. Induced maturation and spawning of Penaeus orientalis Kishinouye in the laboratory by means of eyestalk removal. Aquaculture, 5: 411-412.

ASHOKAN, P.K. 1984. Comparative studies on protein, carbohydrates and fat content during maturation and induced maturation experiments. M.Sc Thesis, Cochin University of Science and Technology, Cochin.

BALASUBRAMANIAN, T., C.B.LALITHAMBIKA DEVI AND H.KRISHNANKUTTY 1979. Feeding behaviour and preying efficiency of Metapenaeus dobsoni. Indian J.Mar.Sci., 8(3): 197-199.

BALAZS, G.H., E. ROSS AND C.C. BROOKS 1973. Preliminary studies on the preparation and feeding of crustacean diets. Aquaculture, 2: 369-377.

BANARJEA, S.M. 1967. Water quality and soil condition of fish ponds in some states of India in relation to fish production. Indian J.Fish., 14: 115-144.

BANERJI, S.K. 1965. A note on the production trend of marine shrimps in India. Fish.Tech., 2 (1): 43-47.

BANERJI, S.K. AND M.J. GEORGE 1967. Size distribution and growth of Metapenaeus dobsoni (Miers) and their effect on the trawler catches off Kerala. Proc. Symp..Crustacea, Mar. Biol. Ass. India, Part II : 634-648.

BARLOW, J. AND G.T.RIDGWAY 1969. Changes in serum protein during the moulting and reproductive cycle of the American lobster (Homarus americanus). J.Fish.Res.Bd.Canada, 26(8) : 2101-2109.

BARNES, H. AND J. BLACKSTOCK 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.

BEARD, T.W., J.F. WICKINS AND D.R.ARNSTEIN 1977. The breeding and growth of Penaeus merguiensie de Man in laboratory recirculation systems. Aquaculture, 10 : 275-289.

BEARD, T.W. AND J.F. WICKINS 1980. Breeding of Penaeus monodon in laboratory recirculation systems. Aquaculture, 20: 79-89.

BERRY, P.F. AND A.E.F. HEYDORON 1970. A comparison of the spermatophoric masses and mechanisms of fertilization in Southern African spiny lobsters (Palinuridae). Oceanogr.Res.Inst.(Durban),Invest.Ewp., 25 : 1-18.

BHASKAR, T.I.C.J. AND S.A. ALI 1984. Studies on the protein requirement of postlarvae of the penaeid prawn Penaeus indicus H. Milne Edwards, using purified diets, Indian J. SFish., 31 (1) : 74-81.

BOOKHOUT, G.G. 1972. The effect of salinity on moulting and larval development of Pagurus alatus reared in the laboratory. In: Vth European Marine Biology Symp, pp. 173-187.

BOWER, C.E. AND J.P.BIDWELL 1978. Ionization of ammonia in seawater. Effects of temperature, pH and salinity. J. Fish. Res. Bd.Canada, 35 (7) : 1012-1016.

BROWDY, C.L. AND T.M. SAMOCHA, 1985. The effect of eyestalk ablation on spawning, moulting and mating of Penaeus semisulcatus de Haan. Aquaculture, 49 : 19-29.

BROWN, A. Jr., J.P. Mc. VEY, B.S.MIDDLEDITCH AND A.L.LAWRENCE 1979. Maturation of the white shrimp (Penaeus setiferus) in captivity. Proc.Wor Maricult. Soc., 10: 435-444.

BROWN, V.M. 1968. The calculation of the acute toxicity of mixtures of pesticides to rainbow trout. Water Res., 2: 723-733.

CAILLOUET, A.C., Jr. 1972. Ovarian maturation induced by eyestalk ablation in pink shrimp, Penaeus duorarum Burkenroad. Proc. World Maricul. Soc., 3: 205-225.

CAMPBELL, J.W. 1973. Nitrogen excretion. In : Comparative animal physiology, C.L. Prosser (Ed.) W.B. Saunders, Philadelphia.

CASTILLE, F.L. AND A.L. LAWRENCE 1989. Relationship between maturation and biochemical composition of the gonad and digestive glands of the shrimps Penaeus aztecus and Penaeus setiferus (L). J.Crust. Biol., 9 (2) : 202-211.

CASTILLE, F.L. AND A.L. LAWRENCE 1991. Reproductive studies concerning natural shrimp populations. A description of changes in the size and biochemical composition of the gonads and digestive glands in penaeid shrimp. In: Frontiers in Shrimp Research, W.S. Dougherty and M.A. Davidson (Eds.), Elsevier Science Publishers, pp 17-31.

CHAKRABORTI, R.K., D.D. HALDER, N.K.DAS, S.K. MANDAL AND M.L. BHOWMICK 1986. Growth of Penaeus monodon Fabricius under different environmental conditions. Aquaculture, 51 : 189-194.

CHAMBERLAIN, G.W. AND A.L. LAWRENCE 1981a. Maturation, reproduction and growth of Penaeus vannamei and Penaeus stylirostris fed on natural diets. Proc.World Maricult. Soc., 12 : 209-244.

CHAMBERLAIN, G.W. AND A.L. LAWRENCE 1981b. Effect of light intensity and male eyestalk ablation on reproduction of Penaeus stylifostris and Penaeus vannamei. proc. 12th Annu. Meet.World.Maricult.Soc., (2) : 357-372.

CHANDRAN, M.R. 1968. Studies on the marine crab, Charybdis variegata. I Reproductive and nutritional cycle in relation to breeding periodicities. Proc.Indian Acad.Sci., 67 : 215-223.

CHANG, E.S. AND J.D.O'CONNOR 1983. Metabolism and transport of carbohydrates and lipids. In: Biology of Crustacea, Academic Press, Vol. V: 263-281.

*
CHARNIAUX-COTTON . 1975. Control hormonale de la differenciation sexuella et de le activite genitale chez les crustace's Malocastrace's. Publ. Stz. Zool. Napoli, 39: 480-509.

CHEN, J.C., T.S. CHEN AND C.K. LEE 1986. Effects of ammonia and nitrite on larval development of the shrimp, Penaeus monodon. In: The First Asian Fisheries Forum, J.L. Maclean, L.B.Dizon and L.V. Hosillos (Eds.), Asian Fisheries Society, Manila, Philippines pp 657-662.

CHEN, J.C. AND T.S. CHIN 1988. Joint action of ammonia and nitrite on tiger prawn Penaeus monodon postlarvae. J. World Aquacult.Soc., 19 (3) : 43-48.

*
CHEN, T.P. 1976. Aquaculture practices in Taiwan. Fishing News Books Ltd.

CHOW, S., Y.OGASAWARA AND Y.TAKI 1982. Male reproductive system and fertilization of the palaemonid shrimp, Macrobrachium resenbergii. Bull. Jap. Soc. Sci. Fish., 48 (2) : 177-183.

CHOW, S., M.M. DOUGHERTY, W.J. DOUGHERTY AND P.A. SANDIFER 1991. Spermatophore formation in the white shrimps Penaeus setiferus and P.vannamei. J.Crust.Biol., 11(2) : 201-216.

CHOY, S.C. 1987. Growth and reproduction of eyestalk ablated Penaeus canaliculatus (Olivier, 1811) (Crustacea: Penaeidae). J. Exp. Mar. Biol. Ecol., 112: 93-107.

CLARK, J.V. 1986. Inhibition of moulting in Penaeus semisulcatus (De Haan) by long-term hypo Aquaculture, 52 (4) : 253-254.

CLARK, W.H. Jr., P.TALBOT, R.A. NEAL, C.R. MOCK AND B.R. SALSER. 1973. In-vitro fertilization with non-motile spermatozoa of the brown shrimp Penaeus aztecus. Mar. Biol., 22: 353-354.

CLARKE, A. 1982. Lipid synthesis and reproduction in the polar shrimp Chorismus antarcticus. - Marine Ecology Progress Series, 9 : 81-90.

CLAYBROOK, D.L. 1983. Nitrogen metabolism. In : Biology of crustacea, Academic Press, Vol.5, pp. 163-202.

COLVIN, P.M. 1976a. Nutritional studies on penaeid prawns: Protein requirements in compounded diets for juvenile Penaeus indicus (Milne Edwards). Aquaculture, 7 : 315-326.

COLVIN, P.M. 1976 b. Effect of selected seed oils on the fatty acid composition and growth of Penaeus monodon. Aquaculture, 8:81-89.

COLVIN, P.M. AND C.W. BRAND 1977. Protein requirement of penaeid shrimp at various life cycle stages in controlled environment systems. Proc. World Maricult. Soc., 8: 821-840.

CONAN .Y. 1965. Periodicity and phasing of moulting. In: Crustacean Issues, III, A.M. Wenner (Ed), pp. 73-99.

COTT, J.E. AND D.A. ARMSTRONG 1981. Nitrogen toxicity to crustacean, fish and molluscs. In: Proc. of the bioengineering Symposium for fish culture. Fish culture section of the American Fisheries Society and the Northwest Society of Conservation Engineering. L.J. Allen and E.C.Kinney (Eds). Bethesda, Maryland. pp. 34-37.

CUMMINGS, W.C. 1961. Maturation and spawning of the pink shrimp Penaeus duorarum Burkenroad. Trans. Am. Fish. Soc., 90 (4) : 462-468.

CROCOS, P.J. AND J.D. KERR. 1983. Maturation and spawning of the banana prawn Penaeus merguiensis de Man (Crustacea: Penaeidae) in the Gulf of Carpentaria, Australian J. Exp. Mar. Biol. Ecol., 69 : 37-59.

DABROWSKII, T., F. KOLAKOWSKI AND B. KARNIKA 1969. Chemical composition of shrimp flesh (Parapenaeus spp.) and its nutritive value. J. Fish. Res. Bd. Canada, 26: 2969-2974.

DALL, W. 1974. Indices of nutritional state in the Western rock lobster Panulirus longipes. J. Exp. Mar. Biol., Ecol. 30: 199-208.

DEAN, J.M. AND F.J. VERNBERG 1965. Variation in the blood glucose level of Crustacea. Comp. Biochem. Physiol., 14: 29-34.

*
DE BRUIN, G.H.P. 1965. Penaeid prawns of Ceylon (Crustacea, Decapoda, Penaeidae). Zool. Meded., 41(4): 73-104

DESHIMARU, O. AND K. SHIGENO 1972. Introduction to the artificial diet for prawn (Penaeus japonicus). Aquaculture, 1: 115-133.

DESHIMARU, O. AND K. KUROKI 1976. Studies on the purified diet for prawn, VII. Adequate dietary levels of ascorbic acid and inositol. Bull. Japan. Soc. Sci. Fish., 42(5): 571-576.

DESHIMARU, O. AND K. KUROKI 1979. Requirement of prawn for dietary thiamine, pryridoxine and choline chloride. Bull. Japan. Soc. Sci. Fish., 43(3): 363-367.

DESHIMARU, O., K. KUROKI AND Y. YONE 1979. The composition and the level of dietary lipid appropriate for growth of prawn. Bull. Japan. Soc. Sci. Fish., 45(5): 591-594.

DEVARAJAN, K., J. SUNNY NAYAGAM, V. SELVARAJ AND N.N. PILLAI 1978. Larval development - Penaeus laltisulcatus de Haan. In: Larval development of Indian penaid prawns. CMFRI Bulletin, 28: 22-30.

*
DIETZ, R.A. 1982. Eyestalk histology and the effect of eyestalk ablation on the gonads of the shrimp Macrobrachium rosenbergii (De Man). Ph.D. Thesis, Texas A & M Univ. 98 p.

DIWAN, A.D. AND R. NAGABHUSHNAM 1974. Reproductive cycle and biochemical changes in the gonads of the freshwater crab Barytelphusa cunicularis (WestWood 1836). Indian J. Fish., 21 (1): 164-187.

DUBOIS, M., K.A. GILLES, J.K. HAMILTON, P.A. REBERS AND F. SMITH 1956. Colorimetric method for determination of sugar and related substances. Anal. Chem., 28: P 350

DUCHATEAU-BOSSON, Gh., AND H. FLORKIN 1961. Changes in intracellular concentration of free amino acids as a factor of euryhalinity in cray fish Astecus astecus. Comp. Biochem. Physiol., 3: 245-249.

DEDENHAUSEN, E. AND P.T. TALBOT 1983. An ultra structural comparison of soft and hardened spermatophore from the cray fish Pacifastacus leniusculus Dana. Canadian J. Zool., 61: 182-194.

DURONSLET, M.J., A.I. YUDIN, R.S. WHEELER AND W.H. CLARK Jr. 1975. Light and fine structural studies of natural and artificially induced egg growth of penaeid shrimp. Proc. World. Maricult. Soc., 6: 105-122.

DY-PENAFLORIDA, V. AND O.M. MILLAMENA 1990. Variation in the biochemical composition of Penaeus monodon tissues during the reproductive cycle. The Israeli J. Aquacult. Bamidgeh, 42(3): 84-90.

*
ELDRED, B., R.M. INGLE, K.D. WOODBURN, R.F. HUTTON AND H. JONES 1961. Biological observations on the commercial shrimp Penaeus duorarum Burkenroad in Florida waters. Florida State Bd. Consen. Mar. Lab., Prof. Pap., Ser.3, 139 pp.

EMMERSON, W.D. 1980. Induced maturation of prawn Penaeus indicus. Mar. Ecol. Prog. Ser. 2: 121-131.

EMMERSON, W.D. 1983 Maturation and growth of ablated and unablated Penaeus monodon Fabricius. Aquaculture, 32: 235-241.

*ERLICH, K.F. 1972. Morphological, behavioural and chemical changes during growth and starvation of herring and plaice larvae. Ph.D. Thesis, University of Stirling, Scotland. 122 p.

GALOIS, R.G. 1984. Changes in the tissue lipid composition during vitellogenesis in the prawn Penaeus indicus. J. Exp. Mar. Biol. Ecol., 84(2): 155-166.

GANAPATI, P.N. AND M. SUBRAMANYAM 1966. The prawn fishery in Godavari estuary. J. Zool. Soc. India, 16 (1&2): 11-20.

GEHRING, W.R. 1974. Maturational changes in the ovarian lipid spectrum of the pink shrimp, Penaeus duorarum Burkenroad. Comp. Biochem. Physoil., 49A: 511-524.

GEORGE, J.C. AND B.S. PATEL 1956. The seasonal variation in the fat content of the liver and gonads in a marine and freshwater decapod. J. anim. morph. physiol., 3: 49-55.

GEORGE, K.V. 1974. Some aspects of prawn culture in the seasonal and perennial fields of Vypeen island. Indian J. Fish., 21(1): 1-19.

GEORGE, M.J. 1961. Studies on the prawn fishery of Cochin and Alleppy coast. Indian J. Fish., 8(1): 75-95.

GEORGE, M.J. 1962. On the breeding of penaeids and the recruitment of their postlarvae into the backwaters of Cochin. Indian J. Fish., 9(1): 101-106.

GOERGE, M.J. 1967a. Postlarval abundance as a possible index of fishing success in the prawn Metapenaeus dobsoni (Miers). Indian J. Fish., 10A(1): 135-139.

GEORGE, M.J. 1967b. A synopsis of biological data on penaeid prawn Metapenaeus dobsoni (Miers). FAO Fish. Rep., (57) Vol 4: 1335-1358.

GEORGE, M.J. AND K.H. MOHAMED 1967. Utilization of brackishwater areas for prawn culture. Proc. Symp. Sci. and India's Food Problem, ICAR, New Delhi, 1972, pp. 114-120.

GEORGE, M.J. AND P.V. RAO 1967. Distribution of sex-ratios of penaeid prawns in the trawl fishery of Cochin. Proc. Symp. Crustacea, Part II: 698-700.

GEORGE, M.J. 1968. The influence of backwaters and estuaries on marine prawn resources. Proc. Sympsoium on Living Resources of the Seas around India, ICAR, CMFRI, Dec. 1968, pp 563-569.

GEORGE, M.J., S.K. BANERJI AND K.H. MOHAMED 1968. Size distribution and movement of the commercial prawns of the southwest coast of India. FAO Fish. Rep., (57), Vol.2: 265-284.

GEORGE, M.J., K.H. MOHAMED AND N.N. PILLAI 1968. Observations on the paddy field prawn filtration of Kerala, India. FAO Fish. Rep., (57) Vol.2: 427-442.

GEORGE, M.J. AND P.V.RAO 1968. Observations on the development of external genitalia in some Indian penaeid prawns. J. mar. biol. Ass. India, 10(1): 52-70.

GEORGE, M.J. 1975. Observations on the growth in certain penaeid prawns studied in prawn culture experiments in paddy field. Bull Dept. Mar. Sci. Univ. Cochin, 7(1): 41-53.

GEORGE, M.J. AND S.C. GOSWAMI 1977. Observation on the larvae of penaeid prawns of commercial importance in the coastal waters of Goa. Publication by NIO, Goa, 1977, pp. 146-154.

GEORGE, M.J. AND C. SUSEEIAN 1982. Distribution of species of prawns in the backwaters and estuaries of India with special reference to coastal aquaculture. Proc. Symp. Coastal Aquaculture, Mar. Biol. Ass. India, Part I: 272-284.

GEORGE, M.J., K. ALAGARAJA, K.K. SUKUMARAN, G. NANDAKUMAR AND K.Y. TELANG 1988. The present status of shrimp trawling and its impact on shrimp stock of Karanataka Coast. Proc. Sem. Problems and Prospects of marine fishing and fish processing in Karnataka, Forum of Fishery Professionals, Mangalore. pp. 1-14.

GIESE, A.C. AND J.S. PEARSE 1974. Introduction. In: Reproduction of Marine Invertebrates', Acad. Press. New York/London Vol. 1: 1-49.

* GILLES, R. 1979. Mechanism of osmoregulation in animals. Publ. John Wiley & Sons, New Yrok.

GILLES, R. AND A. PEQUEX 1983. Interaction of chemical and osmoregulation with environment. In: Biology of Crustacea, 8: 109-165.

GOPAKUMAR, K. AND M.R. NAIR 1975. Lipid composition of five species of Indian prawns. Journal of the Society of Food and Agriculture, 26 : 319-32.

GOPALAKRISHNAN, P., V.K. RAJU, K.M. PILLAI AND S.R. THAKAR 1985. Some observations on spawning and larval rearing of the ginger prawn. Metapenaeus kutchensis, George and Rao. Sea Food Export J., 17(5): 5-8.

GOPINATH, K. 1956. Prawn culture in the rice-fields of Travancore-Cochin, India. Proc. Indo-Pacif. Fish. Counc., 6(3): 419-424.

GOPINATHAN, C.P., P.V.R. NAIR AND A.K.K. NAIR 1974. Studies on the phytoplankton of Cochin. Indian J. Fish., 21(2): 501-513.

GOPINATHAN, C.P., P.V.R. NAIR, V.K. PILLAI, P.P. PILLAI, M. VIJAYAKUMARAN AND V.K. BALACHANDRAN 1982. Environmental characteristics of the seasonal and perennial prawn culture fields in the estuarine system of Cochin. Proc. Symp. Coastal Aquaculture, Part I: 369-382.

GORNALL, A.G., C.J. BARDAWILL AND M.M. DAVID 1949. Determination of total serum protein by means of biuret reaction. J. Biol. Chem., 177: 751-766.

GOSWAMI, U. AND S.C. GOSWAMI 1982. Formulation of cheap prawn diets and their biological evaluation on some penaeid prawns. Symp. Coastal Aquaculture, Mar. Biol. Ass. India, Part I: 211-214.

GRACER, D. AND B. NEAL 1972. Growth of hatchery reared Penaeus aztecus on experimental diets. Proc. World Maricult. Soc., 3: 461-470.

GUNTER GORDON 1950. Seasonal population changes and distributions as related to salinity of certain invertebrates of Texas coast including the commercial shrimp. Publications of the Institute of Marine Science, Univ. Texas, 1(2):7-51.

GUNTER GORDEON 1961. Some relation of estuarine organisms to salinity. Limnol. Oceanogr., 6: 182-190.

*GUTSELL, JAMES, S. 1936. A study of the ovaries of the common shrimp Penaeus setiferus (Linn.) with reference to the life history. Unpublished manuscript in the files of the gulf investigations, U.S. Fish and Wildlife Service, New Orleans, Lousiana.

HAJRA, A., A. GHOSH AND S.K. MANDAL 1988. Biochemical studies on the determination of optimum dietary protein to energy ratio for tiger prawn, Penaeus monodon (Fab.) juveniles. Aquaculture, 71: 71-79.

HALDER, D.D. 1978. Induced maturation and breeding of Penaeus monodon under brackishwater pond conditions by eyestalk ablation. Aquaculture, 15: 171-174.

HALLL, D.N.F. 1962. Observations on the taxonomy and biology of some Indo-West Pacific penaeidae, Fishery Publications, 17: Her Majestry's Stationery Office, London : 229 pp.

HEMENS, J. 1966. The toxicity of ammonia solutions to the mosquito fish (Gambusia affinis Baird and Girad). J. Proc. Inst. Sewage Purif., 3: 265-271.

HUDINAGA, M. 1942. Reproduction, development and rearing of Penaeus japonicus. Japan J. Zool., 10: 305-342.

HUNER, J.V. AND L.B. COLVIN 1979. Observations on the moult cycles of two species of juvenile shrimp Penaeus californiensis and Penaeus stylirostris (Decapoda, Crustacea). Proc. Nat. Shellfish. Assoc., Vol69. pp. 77-84.

JAMES, P.S.B.R. 1992. Scope for increasing sea food production through sea farming in India. Souvenir, 9th Indian Sea Food Trade Fair, Cochin, 7-9 February 1992.

JHINGRAN, V.G. 1974. (Ed.), Fish and Fisheries of India. Hindustan Publishing Corporation (India), New Delhi. P. 548.

JOHNSON, M.C. AND J.H. FIELDING 1956. Propogation of white shrimp Penaeus setiferus (Linn.) in captivity. Tulane Studies in Zoology, 4: 175-190.

JONES, S. AND K.H. SUJANASINGANI 1954. Fish and Fisheries of the Chilka lake with statistics of fish catches for the years 1948-1950. Indian J. Fish., 1: 256-344.

JONES, S., 1967. The crustacean fishery resources of India. Proc. Symp. Crustacea, Mar. Biol. Ass. India, Part IV: 1328-1340.

JOSANTO, V. 1971. The bottom salinity characteristics and factors that influence the salt water penetration in the Vembanad lake. Bull. Dept. Mar. Biol. Oceanogr., 5:1-16.

JOSHI, P.K. AND R. NAGABHUSHANAM 1982. Multiple spawning in penaeid prawn, Parapenaeopsis stylifera in captivity. Mahasagar, 15(2): 135-137.

JOSHI, P.K., R. NAGABHUSHANAM AND G.K. KULKARNI 1982. Gametogenesis in a marine penaeid prawn Parapenaeopsis stylifera (H. Milne Edwards). In:Progress in Invertebrate Reproduction and Aquaculture. Subramonian, T. and S. Varadarajan (Eds.), Publ. Indian Soc. Invertebrate Reproduction, Univ. Madras (India), pp. 25-30.

KAGWADE, P.V. 1980. Maturity size of female populations of certain commercial prawns from Bombay. Indian J. Mar. Sci.,9(4): 294-295.

KALYANARAMAN, M. 1983. Effect of salinity on food intake, growth, conversion efficiency and proximate composition of juvenile Penaeus indicus H. Milne Edwards. M.Sc. Thesis, Cochin Univ. Sci. Tech. Cochin.

KAMIGUCHI, Y. 1971. Studies on the moulting in the freshwater prawn Palaemon paucidens. II. Effects of eyestalk removal in relation to the state of ovarian growth. J. Fac. Sci., Hokkaido Univ. (Zool.), 18(1): 24-31.

KANAZAWA, A., M. TANIKA, S. TESHIMA AND K. KASHIWADA 1971. Nutritional requirements of prawn II. Requirements for sterols. Bull. Jap. Soc. Sci. Fish., 37: 211-215.

KANAZAWA, A. AND S. TESHIMA 1977. Bio-synthesis of fatty acids from acetate in prawn, Penaeus japonicus. Mem. Fac. Fish. Kagoshima, Univ., 26: 49-53.

KANAZAWA, A., S. TESHIMA, M. KAYAMA AND M. HIRAJA 1977. Essential fatty acids in the diet of prawn. I. Effects of linoleic and linolenic acids on growth. Bull. Japan Soc. Sci. Fish., 43(9): 1111-1114.

* KANAZAWA, A., S. TESHIMA AND M. SASAKI 1984. Requirements of potassium, copper, manganese and iron. Mem. Fac. Fish. Kagoshima Univ., 33(1): 63-71.

KANAZAWA, A. 1985. Nutrition of penaeid prawns and shrimps. Proc. First Int. Conf. on culture of penaeid prawns/shrimps. Iloilo city, Philippines, 1984, pp. 123-130.

KATHIRVEL, M. AND V. SELVARAJ 1987. On an experimental seed collection and field culture of King prawn Penaeus latisulcatus. Indian J. Fish., 34(4): 365-373.

KATHIRVEL, M. AND V. SELVARAJ 1989. Attainment of maturity in pond reared Kuruma prawn Penaeus japonicus Bate. J. mar. biol. Ass. India, 31 (1 & 2): 110-116.

KATRE, S. AND S.R. REDDY 1976. Effects of different feeding levels on moulting, growth and conversion efficiency of Palaemon lamerri. Hydrobiologia, 50: 239-243.

KELMEC, J.A. AND I.R. SMITH 1980. Induced ovarian development and spawning of Penaeus pelbejus in a recirculating laboratory tank after unilateral eyestalk ablation. Aquaculture, 21: 55-62.

KHANNAPPA, A. 1977. Effect of various protein levels on growth and survival rates of Penaeus monodon. Q. Res. Rep. SEAFDEC. Aquaculture Dept., 1(1): 24-28.

KHANNAPPA, A. 1979. The effects of various protein levels on the growth and survival of Penaeus mondon. Thai. Fish. Gazette, 31: 51-60.

*
KIESE, M. 1974. Methemoglobinemia, a comprehensive Treatise C R C Press. Clevela.

KING, J.E. 1948. A study of the reproductive organs of the common marine shrimp, Penaeus setiferus (Linnaeus). Biol. Bull., 94: 244-262.

KINNE, O. 1960. Growth, food intake and food conversion in a euryhaline fish exposed to different temperatures and salinities. Physiol. Zool., 33: 288-317.

KINNE, O. 1970. Salinity. In: Marine Ecology, O. Kinne (Ed.), Willley-Interscience, London, New York, Sydney, Toronto, 1 (2): 821-995.

KINNE, O. 1976. Cultivable marine organisms. Water quality management technology. In: Marine Ecology, O. Kinne (Ed.), Vol. III, Part I, Wiley Interscience, New York. pp. 79-300.

KITABAYASHI, K., H. KURATA, K. SHUDO, K. NAKAMURA AND S. ISHIKAWA 1971. Studies on formula feed for Kuruma prawn - I. On the relationship among glucosamine, Phosphorous and Calcium. Bull. Tokai. Reg. Fish. Res. Lab., (65): 91-107.

KLEVE, M.G., A.I. AUDIN AND W.H. CLARK 1980. Fine structure of the unistellate sperm of the shrimp. Sicyonia ingentis (Natantia). Tissues and Cells, 12: 29-45.

KRISHNAMURTHY, V. AND R. GANAPATHY 1985. On the occurrence of maturing Penaeus indicus in brackishwater environment. Sea Food Export J., 17(5): 13-14.

KODA-CISCO, M.J. AND P. TALBOT 1982. A structural analysis of the freshly extruded spermatophore from the lobster, Homarus americanus. J. Morph., 172: 193-207.

KON, T. AND Y. HONMA 1970. Studies on the maturity of the gonad in some marine invertebrates. III. Seasonal changes in the ovary of the Tanner crab. Bull. Japan Soc. Sci. Fish., 36: 1021-1027.

KULKARNI, G.K. AND R. NAGABHUSHANAM 1979. Mobilization of organic reserves during ovarian development in a marine penaeid prawn Parapenaeopsis hardwickii. Aquaculture, 18: 373-378

KULKARNI, G.K., R. NAGABHUSHANAM AND P.K. JOSHI 1979. Effect of progresterone on ovarian maturation in a marine penaeid prawn Parapenaeopsis hardwickii (Miers). Indian J. Exp. Biol., 17: 986-987

KULKARNI, G.K., R. NAGABHUSHANAM AND P.K. JOSHI 1980. Electrophoretic seperation of protein pattern in different tissues of four marine penaeid prawns in relation to sex. Hydrobiologia, 69(1-2): 25-28

KURUP, N.S. AND P.V. RAO 1974. Population characteristics and exploitation of the important marine prawns of Ambalapuzha, Kerala. Indian J. Fish., 21(1): 183-210.

KUTTY, M.K. 1972. Allometric growth formula and yield estimation in fish population. Indian J. Mar. Sci., 1: 74-78.

KUTTYAMMA, V.J. 1973. Observations on the food and feeding of some penaeid prawns of Cochin area. J. mar. biol. Asso.India, 15(1): 189-194.

KUTTYAMMA, V.J. 1975. Studies on relative abundance and seasonal variation in the occurrence of the postlarvae of three species of penaeid prawns in the Cochin backwaters. Bull. Dept. Mar. Sci. Univ. Cochin, 7(1): 213-219.

KUTTYAMMA, V.J. AND A. ANTONY 1975. Observations on the relative abundance, size variation and sex difference on the penaeid prawns in the Cochin backwaters. Bull. Dept. Mar. Sci. Univ. Cochin, 7(3): 503-510.

KUTTYAMMA, V.J. 1982. The effect of salinity on the growth of some penaeid prawns. Bull. Dept. Mar. Sci. Univ. Cochin, 8: 1-34.

LAKSHMI, G.J., A. VENKATARAMAIAH AND H.D. HOSE 1983. Effect of salinitiy and temperature change on spontaneous muscle necrosis in Penaeus aztecus. Aquaculture, 13: 35-43.

LALITHADEVI, S. 1987. Growth and population dynamics of three penaeid prawns in the trawling grounds off Kakinada. Indian J. Fish., 34(3): 245-264.

LALITHAMBIKA DEVI, C.B., K.K.C. NAIR, T. BALASUBRAMANIAN, T.C. GOPALAKRISHNAN, P.N. ARAVINDAKSHAN AND M. KRISHNANKUTTY 1983. Length-weight relation and condition factor of Penaeus indicus and Metapenaeus dobsoni in the Cochin backwater. Mahasagar, 16(3): 399-402.

LARSERRE AND R. GILLES 1971. Modification of the amino acid pool in the parietal muscle of two euryhaline teleosts during osmotic adjustment. Experimentia, 27: 1434.

LAWRENCE, A.L., D. WARD, S. MISSLER, A. BROWN, J. McVEY AND B.S. MIDDIEDITCH 1979. Organ indices and biochemical levels of ova from penaeid shrimp maintained in captivity versus those captured in the wild. Proc. World Maricult. Soc., 10: 453-463.

LAWRENCE, A.L., Y. AKAMINE, B.S. MIDDLEDITCH, G. CHAMERLAIN AND D. HUTCHINS 1980. Maturation and reproduction of Penaeus setiferus in captivity. Proc. World Maricult. Soc.,11: 481-487.

LAZARUS, S., M.S. MUTHU, K. NANDAKUMARAN AND S.A. ALI 1988. Experimental field culture of white prawn Penaeus indicus in the polyethlene film-lined ponds, using pelletized feed. Indian J. Fish., 35(3): 171-177.

LAZARUS, S. AND K. NANDAKUMARAN 1990. Observations on the growth of Metapenaeus dobsoni(Miers) in the polyethylene film-lined ponds at Calicut beach. Indian J. Fish., 37(1): 31-36.

LECAL, J. 1958. Influence of salinity factor on the serum proteins of Blennius pavo. C.R. Seanc. Soc. Biol., 152: 1492-1494.

LEUNG-TRUJILLOD, J.R. AND A.L. LAWARENCE 1991. Spermatophore generation times in P. setiferus, P. vannamei and P. stylirostris. J. World Maricult. Soc., 22(4): 244-251.

LIAO, I.C. 1977. A culture study on grass prawn, Penaeus monodon, in Taiwan - the patterns, the problems and the prospects. J. Fish. Soc. Taiwan, 5(2): 11-29.

LICHATOWICH, T., T. SMALLEY AND F.D. MATE 1978. The natural reproduction of Penaeus merguiensis (de Man, 1888) in an earthern pond in Fiji. Aquaculture, 15: 377-378.

LU, C.C., W.H. CLARK AND L.E. FRANKLIN 1973. Spermatogenesis of the decapod Penaeus setiferus. J. Cell Biol., 59: P. 202.

LUMARE, F. 1981. Artificial reproduction of Penaeus japonicus Bate as a basis for the mass production of eggs and larvae. Proc. World Maricult. Soc., 12: 335-344.

MALEK, S.R.A. AND F.M. BAWAB 1974a. The formation of spermatophore in Penaeus kerathurus (Forskal, 1775) (Decapoda, Penaeidae). 1. The initial formation of sperm mass. Crustaceana, 26: 273-285.

MALEK, S.R.A. AND F.M. BAWAB 1974 b. The formation of spermatophore in Penaeus kerathurus (Forskal, 1775) (Decapoda, Penaeidae). II. The deposition of the main

layers of the body of the wings. Crustaceana, 27: 73-83.

MANICKAM, P.E.S. AND S. SRINIVASAGAM 1972. Prawn fishery of Pulicat lake. Proc. Seminar on Mariculture and Mechanised fishing. Madras, 28th and 29th November 1972. pp 57-59.

MARTOSUBROTO, P. 1974. Fecundity of pink shrimp Penaeus duorarum Burkenroad. Mar. Biol., 24(3): 606-627.

MATHEWS, D.C. 1951. The origin, development and nature of the spermatophoric mass of the spiny lobster Panulirus penicillatus (Olivier). Pacif. Sci., 5(5): 359-371.

MATHEWS,D.C. 1954. The development of the spermatophoric mass of the rock lobster, Parribacus antarcticus (Lund). Pacif. Sci., 8(1): 28-34.

MATHEWS, D.C. 1957. Further evidences of Anomuran non-pedunculate spermatophores. Pacif.Sci., 11 (4): 380-385.

MENON, K.K. 1980. Observations on the occurrence of penaeid postlarvae in Korapuzha estuary. Indian J. Fish., 27(1&2): 236-243.

MENON, M.K. 1952. The life history and binomics of an Indian penaeid prawn Metapenaeus dobsoni (Miers). Proc. Indo-Pacif. Fish. Coun., 3(2): 80-93.

MENON, M.K. 1954. On the paddy field prawn fishery of Travancore-Cochin and an experiment in prawn culture. Proc. Indo-Pacif. Fish. Coun., 5th meet, Sec., 2:1-5.

MENON, M.K. 1955. Notes on the binomics and fishery of the prawn Metapenaeus dobsoni (Miers) on the south west coast of India. Indian J. Fish., 2(1): 41-56.

MENON, M.K. 1956. Indentification of marine and inshore prawns of commercial value in India. Proc. Indo-Pacif. Fish. Coun., 6(3): 345-346.

MENON, M.K. 1957. Contribution to the biology of penaeid prawns of the southwest coast of India. 1. Sex ratio and movements. Indian. J. Fish., 4(1): 162-174.

MENON, M.K. AND K. RAMAN 1961. Observations on the prawn fishery of the Cochin backwaters with special reference to stake net catches. Indian J. Fish., 8(1): 1-23.

MENON, M.K. 1965. Life history of prawns - A review of recent studies with special reference to Indian species. Fish. Technol., 2(1): 12-18.

MIDDLEDITCH, B.S., S.R.. MISSLEH, D.R. WARD, J.P. Mc. VEY. A. BROWN AND A.L. LAWRENCE 1979. Maturation of penaeid shrimp: Dietary fatty acids. Proc. World Maricult. Soc., 10: 472-476.

MIDDLEDITCH, B.S., S.R.MISSLER, H.B. HINES, D.C. WARD AND A.L. LAWRENCE 1980. Metabolic profiles of penaeid shrimp: dietary lipids and ovarian maturation. J. Chromatogr., 195: 359-368.

MISTAKIDIS, M.N. (Ed.) 1968. Proceedings of the world scientific conference on the Biology and Culture of shrimps and prawns. Mexico city. FAO Fish. Rep., (57) Vol.2: 77-587.

MISTAKIDIS, M.N. (Ed.) 1969. Proceedings of the world scientific conference on the Biology and Culture of shrimps and prawns. Mexico city. FAO Fish. Rep., (57) Vol.3: 589-1165,

MISTAKIDIS, M.N. (Ed.) 1970. Proceedings of the world scientific conference on the Biology and Culture of shrimps and prawns. Mexico city. FAO Fish. Rep., (57) Vol.4: 1167-1627.

MOHAMED, K.H., M.J. GEORGE AND N.N. PILLAI 1968. Observations on the paddy field prawn filtration of Kerala, India. FAO. Fish. Rep., (57) Vol. 2 : 1-16.

MOHAMED, K.H., P.V. RAO AND M.J. GEORGE 1968. Postlarvae of penaeid prawns of southwest coast of India with a key to their identification. FAO Fish. Rep., (57) Vol.2: 487-503.

MOHAMED, K.H. AND P.V. RAO 1971. Estuarine phase in the life history of the commercial prawns of the West coast of India. J. mar. biol. Ass. India, 13(2): 149-161.

MOHAMED, K.H., M.S.MUTHU, N.N. PILLAI AND K.V. GEORGE 1978. Larval development - Metapenaeus monoceros (Fabricius). In: Larval development of Indian penaeid prawns. CMFRI Bulletin, 28: 50-59.

MOHAMED, K.H., M.S. MUTHU AND C. LAXMINARAYANA 1981. Rematuration of penaeid prawns after spawning in controlled system. Paper presented in Indo-Pacific Symposium on Invertebrate reproduction held at Aurangabad, 27-29 November 1981. (Abstract).

MOHAMED, K.S. 1989. Studies on the reproductive endocrinology of the penaeid prawn, Penaeus indicus H. Milne Edwards. Ph.D Thesis. Cochin University of Science and Technology. 250 pp.

MOHAMED, K.S. AND A.D. DIWAN 1992. Biochemical changes in different tissues during yolk synthesis inmarine prawn Penaeus indicus H. Milne Edwards. Indian J. mar. Sci., 21: 30-34.

MORRIS, M.C. AND I.BENNET 1951. The life history of a penaeid prawn (Metapenaeus) breeding in a coastal lake (Tuggerah, NSW). Proc. Linn. Soc. N.S.W., 76(5-6): 164-182.

MORRIS, R.J. 1973. Relationships between sex and degree of maturity of marine crustaceans and their lipid compositions. J. mar. biol. Ass. U.K., 53: 27-37.

MOTOH, H. 1978. Preliminary histological study of the ovarian development of the giant tiger prawn, Penaeus monodon. - Quarterly Research Reports, 2: 4-6.

MOTOH, H. 1979. Preliminary study on the internal genital organ of the giant tiger prawn, Penaeus monodon. Research Report of SEAFDEC, 3(1): 15-18.

MURPHY, J. AND J.P. RILEY 1962. A modified single solution method for determination of phosphate in natural waters. Anal. Chim. Acta., 27: 31-36.

MOHAMED, K.H. AND P.V. RAO 1971. Estuarine phase in the life history of the commercial prawns of the West coast of India. J. mar. biol. Ass. India, 13(2): 149-161.

MOHAMED, K.H., M.S.MUTHU, N.N. PILLAI AND K.V. GEORGE 1978. Larval development - Metapenaeus monoceros (Fabricius). In: Larval development of Indian penaeid prawns. CMFRI Bulletin, 28: 50-59.

MOHAMED, K.H., M.S. MUTHU AND C. LAXMINARAYANA 1981. Rematuration of penaeid prawns after spawning in controlled system. Paper presented in Indo-Pacific Symposium on Invertebrate reproduction held at Aurangabad, 27-29 November 1981. (Abstract).

MOHAMED, K.S. 1989. Studies on the reproductive endocrinology of the penaeid prawn, Penaeus indicus H. Milne Edwards. Ph.D Thesis. Cochin University of Science and Technology. 250 pp.

MOHAMED, K.S. AND A.D. DIWAN 1992. Biochemical changes in different tissues during yolk synthesis inmarine prawn Penaeus indicus H. Milne Edwards. Indian J. mar. Sci., 21: 30-34.

MORRIS, M.C. AND I.BENNET 1951. The life history of a penaeid prawn (Metapenaeus) breeding in a coastal lake (Tuggerah, NSW). Proc. Linn. Soc. N.S.W., 76(5-6): 164-182.

MORRIS, R.J. 1973. Relationships between sex and degree of maturity of marine crustaceans and their lipid compositions. J. mar. biol. Ass. U.K., 53: 27-37.

MOTOH, H. 1978. Preliminary histological study of the ovarian development of the giant tiger prawn, Penaeus monodon. - Quarterly Research Reports, 2: 4-6.

MOTOH, H. 1979. Preliminary study on the internal genital organ of the giant tiger prawn, Penaeus monodon. Research Report of SEAFDEC, 3(1): 15-18.

MURPHY, J. AND J.P. RILEY 1962. A modified single solution method for determination of phosphate in natural waters. Anal. Chim. Acta., 27: 31-36.

MUTHU, M.S. AND P.E.S. MANICKAM 1973. On the occurrence of mature specimen of Metapenaeus burkenroadi Kubo. in Pulicat Lake. Indian J. Fish., 20: 214-215.

MUTHU, M.S., N.N. PILLLAI AND K.V. GEORGE 1974. On the spawning and rearing of Penaeus indicus in the laboratory with a note on the eggs and larvae. Indian J. Fish., 21(2): 571-574.

MUTHU, M.S. AND A. LAXMINARAYANA 1977. Induced maturation and spawning of Indian penaeid prawns. Indian J. Fish., 24: 172-180.

MUTHU, M.S., N.N. PILLAI AND K.V. GEORGE 1978a. Larval development - Metapenaeus dobsoni (Miers). In: Larval development of Indian penaeid prawns. CMFRI Bulletin, 28: 30-40.

MUTHU, M.S., N.N. PILLAI AND K.V. GEORGE 1978b. Larval development - Metapenaeus affinis (H. Milne Edwards). In: Larval development of Indian penaeid prawns. CMFRI Bulletin, 28: 40-50.

MUTHU, M.S., M. KATHIRVEL, P.V. RAO AND N.N. PILLAI 1982. Research progress in the culture of penaeid prawns along the coast of Indian Ocean and Indo-Pacifc. Proc. Symp. Coastal Aquaculture, Part I: 1-11.

MUTHU, M.S. AND A. LAXMINARAYANA 1982. Induced maturation of penaeid prawns - a review. Proc. Symp. Coastal Aquaculture, Part-I: 16-27.

MUTHU, M.S. 1983. Penaeid brood stock development and management. Symp. Shrimp Seed Production and Hatchery Management, MPEDA, Cochin.

MUTHU, M.S. AND A. LAXMINARAYANA 1984. Artificial insemination of Penaeus monodon. Curr. Sci., 53: 1075-1077.

MUTHU, M.S., A. LAXMINARAYANA AND K.H. MOHAMED 1984. pH as a factor influencing maturation of Penaeus indicus in captivity. Indian J. Fish., 31: 217-222.

MUTHU, M.S.,A. LAXMINARAYANA AND K.H. MOHAMED 1986. Induced maturation and spawning of Penaeus Indicus without eyestalk ablation. Indian J. Fish., 33: 246-250.

NAGABHUSHANAM, R. AND G.K. KULKARNI 1980. Blood glucose in marine penaeid prawns. 3. Variation in relation to ovarian grwoth in Parapenaeopsis hardwickii (Crustacea, Decapoda, Penaeidae). Hydrobiologia, 70(1-2): 29-30.

NAGABHUSHANAM, R., G.K. KULKARNI AND R. SAROJINI 1980. Reproductive endocrinology of decapod Crustacea. Proc. Natl. Acad. Sci. Golden Jub. Comm. Vol. pp. 709-746.

NAGABHUSHANAM, R. AND G.K. KULKARNI 1982. Reproductive biology of the female of a penaeid prawn Parapenaeopsis hardwickii (Miers). Indian . Fish., 29(1 & 2): 151-159.

NAGARAJ, M. AND B. NEELAKANTAN 1982. Prawn culture in paddy fields of Uttara Kannada District, Karanataka. Proc. Symp. Coastal Aquaculture, Mar. Biol. Ass. India, Part I: 392-393.

NAIR, P.V.R., N.N. PILLAI, V.K. PILLAI, P.P. PILLAI, K.J. MATHEW, C.P. GOPINATHAN, N.K. BALACHANDRAN AND D. VINCENT 1982. Brackishwater prawn farming in the Ashtamudi lake area (S-W coast of India) - its prospects and problems. Proc. Symp. Coastal Aquaculture, Part I: 285-294.

NAIR, S.R.S. AND M. KRISHNAANKUTTY 1975. Notes on the varying effects of salinity on the growth of the juveniles of Peneaus indicusfrom the Cochin backwaters. Bull. Dept. Mar. Sci. Univ., Cochin. 7(1): 181-184.

NAIR, S.R.S., H.K. IYER, C.B. LALITHAMBIKA DEVI AND M. KRISHNANKUTTY 1982. Studies on the growth of penaeid prawns; 1. Length-weight relation and condition factor under different levels of feeding. Mahasagar, 15(2): 95-104.

NAIR, S.R.S., K.K.C. NAIR, T.C.GOPALAKRISHNAN AND M. KRISHNANKUTTY 1983. Studies on the growth of penaeid prawns; 3 Growth pattern of Penaeus indicus and Metapenaeus dobsoni. Mahasagar, 16(1): 34-46.

NAIR, S.R.S. 1987. In-vitro fertilization of banana prawn Penaeus merguiensis De Man. Mahasagar, 20(3): 187-190.

NAIR, S.R.S., T. BALASUBRAMANAIN, P.N. ARAVINDAKSHAN AND M. KRISHNANKUTTY 1987. Studies on the growth of penaeid prawns; 4. Growth of Metapenaeus dobsoni under different levels of feeding. Mahasagar, 20(1): 23-33.

NANDAKUMAR, G., N.N. PILLAI, K.Y. TELANG AND K. BALACHANDRAN 1989. Larval development of Metapenaeus moyebi (Kishinouye) reared in the laboratory. J. mar. biol. Ass. India, 31 (1 & 2): 86-102.

NAVAS, K.A. AND M.J. SEBASTIAN 1989. Effect of low salinities on the survival and growth of Penaeus monodon (Fabricius). Indian J. Fish., 36(3): 257-261.

NEW, N.B. 1976. A review of dietary studies with shrimp and prawns. Aquaculture, 9: 101-144.

NORREVANG, A. 1968. Electron microscopic morphology of oogenesis. Int. Rev. Cytol., 23: 113-186.

O'CONNOR, C. 1979. Reproductive periodicity of a Penaeus esculentus population near Low Islets, Queensland, Australia. Aquaculture, 16: 153-162.

OGINO, C., J.Y. CHIOU AND T. TAKEUCHI 1976. Protein nutrition in fish. VI. Effects of dietary energy sources on the utilization of proteins by rainbow trout and carp. Bull. Jap. Soc. Sci. Fish., 42: 213-218.

PAI, M.V., V.S. SOMAVANSHI AND K.Y. TELANG 1982. A case study of economics of a traditional prawn culture from the North Kanara District, Karnataka, India. Proc. Symp. Coastal Aquaculture, Part I: 123-128.

PANIKKAR, N.K. AND M.K. MENON 1956. Prawn fisheries of India. Proc. Indo-pacif. Fish. Coun., 6 (3): 328-344.

PAPATHANASSIOU, E. AND P.E. KING 1984a. Ultra structural studies on gametogenesis of the prawn Palaeomon serratus (Pannant). 1. Oogenesis. Acta. Zool. (Stockh), 65(1): 17-31.

PAPATHANASSIOU, E. AND P.E. KING 1984b. Ultra structural studies on gametogenesis of the prawn Palaeomon serratus (Pannant). 2. Spermatogenesis. Acta. Zool. (Stockh), 65(1): 33-40.

PARKER, R. AND W.E. VANSTONE 1966. Changes in chemical composition of central Columbia pink salmon during early sea life. J. Fish. Res. Bd. Canada, 23: 1353-1384.

PASSANO, L.M. 1960. Moulting and its control. In: Physioloy of Crustacea, T.H. Waterman (Ed), Acad. Press., New York, Vol.I: 473-536.

PAULY, D. AND N. DAVID 1981. ELEFAN I, a Basic program for the objective extraction of growth parameters from length frequency data. Meereshforch, 28(4): 205-211.

PEARSE,A.S. AND G. GUNTER 1957. Salinity. In: Treatise on Marine Ecology and Paleoecology, J.W. Hedgpeth (Ed.), Vol.1. Memoirs of the Geographical Society of America, 67: 129-157.

*

PENN, J.W. 1977. Trawl caught fish and crustascens from Cockburn Sound. Fish. Rep. West. Aust., No.20.

PERERA, P.A.B. AND S.S. DE SELVA 1978. Studies on the chemical biology of the young grey mullet, Mugil cephalus (L). J. Fish. Biol., 13: 297-304.

PEREZ FARFANTE 1975. Spermatophores and thelyca of the American white shrimps of genus Penaeus, Sub-genus Litopenaeus. U.S. Fish. Bull., 73 (3): 463-486.

PILLAY, K.K. 1971. The reproductive cycle of three decapod crustaceans from the southwest coast of India. Curr. Sci., 40(7): 161-167.

PILLAY, K.K. AND N.B. NAIR 1971. The annual reproductive cycles of Uca annulepis, Portunus pelagicus and Metapenaeus affinis (Decapoda: Crustacea) from the Southwest coast of India. Mar. Biol., 11: 152-166.

PILLAY, K.K. AND N.B. NAIR 1973. Observations on the biochemical changes in gonads and other organs of Uca annulepis, Portunus pelagicus and Metapenaeus affinis (Decapoda-Crustacea) during reproductive cycle. Mar. Biol., 18: 167-198.

PILLLAY, N.N. AND M.S. MUTHU 1988. observations on the stake net fishery at Thoppumpadi in Cochin backwater. Symposium on Tropical Marine Living Resources. Cochin, India, 12-16 January 1988, Abstract No.146, P 74.

PILLAI, R.S. 1960. Studies on the shrimp Cardina laevis (Heller). II The reproductive system. J. mar. biol. Ass.India, 2: 226-236.

PILLAY, T.V.R. 1954. The ecology of a brackishwater Bheri with special reference to the fish cultural practices and the biotic interaction. Proc. Nat. Inst. Sci. India, 20 (4): 399-427.

PILLAY, T.V.R. 1982. State of Aquaculture 1981. World Conference on Aquaculture and International trade show. 21-25 Sept. 1981. Venice, Itlay.

POCHON-MASSON, J. 1983. Arthropoda-Crustacea. In: Reproductive Biology of Invertebrates, Spermatogenesis and sperms function. Adiyodi K.G. and R.G. Adiyodi (Eds.) Wiley, Chichester, England, pp 407-449.

PONNUCHAMY, R. 1981. Studies on the bioenergitics of feeding and behaviour of a few freshwater prawns. Ph.D Thesis, Bangalore University.

POTTER, I.C., J.W. PENN AND K.S. BROOKER 1986. Life cycle of the western school prawn, Metapenaeus dalli Racek, in a western Australian estuary. Aust. J. Mar. Freshw. Res., 37:95-103.

PRIMAVERA, J.H. AND BORLONGAN, E. 1977. Notes on ovarian rematuration of ablated sugpo (prawn) Penaeus monodon Fabricius. Q. Rep. SEAFDEC Aquacult. Dep., 3: 5-8.

PRIMAVERA, J.H. 1978. Induced maturation and spawning in five month-old Penaeus mondon Fabricius by eyestalk ablation. Aquaculture, 13: 355-359.

PRIMAVERA, J.H. AND W.G. YAP 1979. Status and problems of brood stock and hatchery management of Sugpo (Penaeus monodon) and other penaeids. PCARR Symposium Workshop on Fish Hatchery/Nursery Development and Manageent, Metro Manila, 27-29, Sept.

PRIMAVERA, J.H., T. YOUNG AND C.D.DE LOSREYES 1982. Survival, maturation, fecundity and hatching rate of unablated and ablated Penaeus indicus H.M. Edwards from brackishwater ponds. Proc. Symp. Coastal Aquaculture, 1: 48-54.

PRIMAVERA, J.H. 1984. Maturation and reproduction in closed thelycum penaeids. In: proceedings of First International Conference on the culture of Penaeid prawns/ shrimps. December 1984, Ilialo, Philippines, 47-64.

QASIM, S.Z., S. WELLERSHAUS, P.M.A. BHATTACHARI AND S.A.H. ABIDI 1969. Organic production in tropical estuary. Proc. Indian Acad. Sci., 69(2): 51-94.

QASIM, S.Z. AND D.C.V. EASTERSON 1974. Energy conversion in the shrimp, Metapenaeus monoceros (Fabricius) fed on detritus, Indian J. Mar. Sci., 3: 131-134.

QUACKENBUSH, L.S. 1989a. Vitellogenesis in the shrimp, Penaeus vannamei: In-vitro studies of the isolated hepatopancreas and ovary. Comp. Biochem. Physiol., 94 B(2): 253-261.

QUACKENBUSH, L.S. 1989b. Yolk protein production in the marine shrimp Penaeus vannamei. J. Crust. Biol., 9(4): 509-516.

RACEK, A.A. 1972. Indo-West Pacific penaeid prawns of commercial importance. In: T.V.R. Pillay (ed), Coastal Aquaculture in the Indo-Pacific Region: Fishing News (Book) Ltd., London, pp. 152-172.

RADHA, T. AND T. SUBRAMONIAM 1985. Origin and nature of the spermatophoric mass of the spiny lobster Panulirus homarus. Mar. Biol., 86: 13-19.

RADHAKRISHNAN, N. 1982. On the prawn resource of Karwar region. Proc. Symp. Crustacea, Mar. Biol. Ass. India, Part IV: 1421-1423.

RAHAMAN, 1967. Reproductive and nutritional cycle of the crab Portunus pelagicus of Madras coast. Proc. Indian Acad. Sci., 65: 76-82.

RAJ, R.P. 1976. Studies on the penaeid prawns of Pulicat lake, South India. Ph.D., Thesis, Unviersity of Madras (unpublished) 241 pp, 33 plates.

RAJ, R.P. AND P.J.S. RAJ 1982. Effect of salinity on growth and survival of three species of penaeid prawns. Proc. Symp. coastal Aquaculture, Part I: : 236-243.

RAJ, R.P. AND V. KORON 1988. Influence of salinity on the growth and feed utilization in Liza parsia fry. In: The First Indian Fisheries Forum Proceedings. M. Mohan Joseph (Ed.). Asian Fisheries Society, Indian Branch, Mangalore, pp. 61-63.

RAJALAKSHMI, T. 1961. Studies on maturation and breeding in some estuarine palaemonid prawns. Proc. Nat. Inst. Sci. India, 27B (4): 179-188.

RAJALAKSHMI, T. 1964. The prawn fishery of Hoogly estuarine system. Symp. Prawn Fisheries in India, Soc. Fish. Technol. (India), Cochin. P. 18.

RAJE, P.C. AND M.R. RANADE 1972a. Larval development of Indian penaeid shrimps - I. Penaeus merguiensis De Man. J. Indian Fish. Ass., 2(1 & 2): 1-16.

RAJE, P.C. AND M.R. RANADE 1972b. Larval development of Indian penaeid shrimps-II. Metapenaeus monoceros (Fabricius). J. Indian Fish. Ass., 2(1 & 2): 30-46.

RAMAKRISHNAIAH, M. 1979. Observations on the postlarval incursions and fishery of penaeid prawns in Chilka lake. J. Inland Fish. Soc. India, 11(2):

RAMAMURTHY, S., G.G. ANNIGERI AND N.S. KURUP 1978. Resource assessment of the penaeid prawn Metepenaeus dobsoni (Miers) along the Mangalore coast. Indian J. Fish., 25(1-2): 52-66.

RAMAN, K. AND M.K. MENON 1963. A preliminary note on an experiment in paddy field prawn fishing. Indian J. Fish., 10 A(1): 33-39.

RAO, G.S. 1978. Larval development - Metapenaeus brevicornis (H. Milne Edwards). In: Larval development of Indian penaeid prawns, CMFRI Bulletin, 28: 60-64.

RAO, G.S. 1979. Observations on the marine prawn fishery by shore seines at Kakinada. Indian J. Fish., 26(1&2): 52-64.

RAO, G.S. 1989. Studies on the reproductive biology of the brown prawn Metapenaeus monoceros (Fabricius 1789) along the kakinada coast. Indian J. Fish., 36(2) : 107-123.

RAO, P.V. 1968. Maturation and spawning of the penaeid prawns of the southwest coast of India. FAO Fish. Rep., (57) Vol 2: 285-302.

RAO, P.V. 1969. Genus Parapenaeopsis Alcock 1901. CMFRI Bulletin No.14: 127-158.

RAO, P.V. 1972. The influence of salinity and temperature on the breeding and development of some cultivable marine penaeid prawns. Proc. Seminar on mariculture and mechanised fishing, 28 - 29th November 1972, Madras, pp. 67-69.

RAO, P.V. 1973a. Studies on the larval development of the commercially important penaeid prawns of India. J. mar. biol. Ass. India, 15(1): 95-124.

RAO, P.V. 1973b. Some observations on the larval growth of the commercially important penaeid prawns of southwest coast of India. Indian J. Fish., 20(2): 308-317.

RAO, P.V. AND M. KATHIRVEL 1973. On the breeding of a penaeid prawn Metapenaeus dobsoni in the brackishwater medium. Indian J. Fish., 20(1): 228-230.

RAO, P.V. 1978. Maturation and spawning of cultivable marine penaeid prawns. Proc. Summer Inst: Breeding and rearing of marine prawns, 3: 56-67.

RAO, R.M. 1965. Breeding behaviour in Macrobrachium rosenbergii (de Man). Fish. Technol., 2: 19-25.

RAVEN, C.P. 1961. Oogenesis. The storage of developmental information. Pergamen Press, New York, 274 pp

READ, G.H.L. AND M.S. CAULTON 1980. Changes in mass and chemical composition during the moult Cycle and ovarian development in immature and mature Penaeus indicus H.Milne Edwards. Comp. Biochem. Physiol., 66A(3): 431-437.

RICHARD, P. AND H.J. CECEALDI 1974. Variation in free amino acid in the muscle and hepatopancreas of Penaeus kerathurus (Forskal) in relation to diluted seawater. 9th European Mar. Biol. Symp. Oban, U.K.

RO, S., P. TALBOT, J.L. TRUJILLO AND A.L. LAWRENCE 1990. Structure and function of the vas deferens in the shrimp Penaeus setiferus Segments 1-3. J. Crust. Biol., 10(3): 455-468.

RODRIGUEZ, A. 1981. Growth and sexual maturation of Penaeus kerathurus (Forskal) and Palaemon serratus (Pennant) in salt ponds. Aquaculture, 24: 257-266.

ROTHILSBERG, P.C. 1979. Combined effect of salinity and temperature on the survival and growth of larvae of Pandalus jordani. Mar. Biol., 54: 125-134.

ROYAN, J.P., SUMITRA VIJAYARAGHAVAN AND M.V.M. WAFAR 1977. Food conversion efficiency in the shrimp Metapenaeus monoceros fed on different foods. Indian J. Mar. Sci.,6: 100-104.

ROYAN, J.P.,SUMITRA VIJAYARAGHAVAN AND L. KRISHNAKUMARI 1987. Adult Artemia as food for juvenile prawns. Mahasagar, 20(2): 109-113.

RYAN, E.P. 1967. Structure and function of the reproductive system of the crab Portunus sanguinolentus (Herbst) (Brachyura: Portunidae), II. The female system. Proc. Symp. Crustacea, Part 2: 522-527.

RYTHER, J. 1979. Aquaculture in China. Oceans, 22(1): 21 pp.

SANDIFER, P.A., A.L. LAWRENCE, A.S.G. HARRIS, G.W. CHAMBERLAIN, A.D. STOKES AND W.A. BRAY 1984. Electrical stimulation of spermatophore expulsion in marine shrimp, Penaeus spp. Aquculture, 41 (2): 181-187.

SANKARALINGAM,S. 1989. Instance of heavy catches of Metapenaeus dobsoni along Madras coast. Mar. Fish. Infor. Serv. T & E Ser., No.95: P 8.

SANKARANARAYANAN, V.N. AND S.Z. QASIM 1969. Nutrients of the Cochin Backwater in relation to environmental characteristics Mar. Biol., 2(3): 236-247.

SANTIAGO, Jr. A.C. 1977. Successful spawning of cultured Penaeus monodon Fabricius after eyestalk ablation. Aquaculture, 11: 185-196.

SEDGWICK, R.W. 1979. Influence of dietary protein and energy on growth, food consumption and food conversion efficiency in Penaeus merguiensis de Man. Aquaculture, 16: 7-30.

SELVAKUMAR, R.A., M.J. GEORGE, C.T. ACHUTHANKUTTY AND S.C. GOSWAMI 1977. Penaeid prawn larval abundance in the Mandovi estuary, Goa. Indian J. Mar. Sci.,6: 160-162.

SHAIKHMAHMUD, F.S. AND V.B. TEMBE 1958. Study of Bombay prawns. The reproductive organs of Parapenaeopsis stylifera (M. Edwards). J. Univ. Bombay, 27(3): 99-100.

SHAIKHMAHMUD, F.S. 1961. A brief account of the changes in the developing ovary of (Penaeid prawns) Parapenaeopsis stylifera (M. Edw.) in relation to maturation and spawning cycle. J. Univ. Bombay, 29(3-5): 62-77.

SHAIKHMAHMUD, F.S. AND N.G. MAGAR 1961. Studies on nutritive value of Bombay prawns. Part II. Chemical composition and nutritional constituents of penaeid prawns. J. Sci. Indust. Res., 20D: 157-158.

SHARMA, B. AND R.C. AHLERT 1977. Nitrification and nitrogen removal. Water Res., 11: 897-925.

*

SHOKITA, S. 1970. A note on the development of egg and larvae of Penaeus latisulcatus Kishinouye reared in an aquarium. Biol. Mag. Okinawa, 6(8): 34-36 (In Japanese).

SICK, L.V. AND J.W. ANDREWS 1973. The effect of selected dietary lipids, carbohydrates and proteins on the growth, survival and body composition of Penaeus duorarum. Proc. World Maricult. Soc., 4: 263-276.

SILAS, E.G., M.S. MUTHU, N.N. PILLAI AND K.V. GEORGE 1978. Larval development - Penaeus monodon Fabricius. In: Larval development of Indian penaeid prawns. CMFRI Bulletin, 28: 2-11.

SILAS, E.G., M.S. MUTHU, N.N. PILLAI AND K.V. GEORGE 1982. Breeding of the marine parawn Metapenaeus dobsoni in brackishwater ponds. J. mar. biol. Ass. India, 24(1): 147-149.

SMITH, C. AND R.C. RUSSO 1970. Nitrite induced methemoglobinemia in rainbow trout. Prog. Fish. Cult., 37(3): 150-152.

SMITH, C.E. AND W.G. WILLIAMS 1974. Experimental nitrite toxicity in rainbow trout and Chinook salmon, Trans. Aus. Fish. Soc., 103:389-390.

SMITA, P. AND M. DEVARAJ 1990. Population dynamics of the prawn Metapenaeus dobsoni (Miers) exploited in the trawl fishery along the southwest coast of India. Fish. Res., 8: 381-395.

SNEDCOR, W.G. AND G.W. COCHRAN 1967. Statistical methods - Oxford and IBH publishing Co., New Delhi, 593 pp.

SOLORZANO, L. 1969 Determination of ammonia in natural waters by the phenol-hypochlorite method. Limnol. oceanogr., 14: 799-801.

SOLYOM, P. AND S. CARLBERG 1975. Determination of nitrite. FAO Fish. Tech. Paper, 137: 156-160.

SRIRAMAN, K. AND P.S. REDDY 1977. Biochemical studies in planktonic juveniles and adults of Penaeus indicus and Penaeus monodon. Proc. Symp. Warm Water Zoopl. Spl. Publ. NIO-UNESCO, pp.693-699.

STRICKLAND, J.D.H. AND T.R. PARSONS 1968. A practical handbook of seawater analysis. Bull. Fish. Res. Bd. Canada, 310 pp.

STRITS, H.M. AND R.L. TURNER 1981. Effect of salinity on survival and moulting of larval Emirita talpodia. Comp. Biochem. Physiol., 69A:$_1$125-127.

SUBRAMANYAM, C.B. 1963. A note on the annual reproductive cycle of the prawn Penaeus indicus (M.Edw). of Madras coast. Curr. Sci., 32(4): 165-166.

SUBRAMANYAM, C.B. 1965. On the reproductive cycle of Penaeus indicus (M.Edw.). J. mar. biol. Ass. India, 7: 284-290.

SUBRAMANYAM, C.B. 1973. Experimental studies on growth in Penaeus monodon Fabricius. Proc. Seminar on Mariculture and Mechanised Fishing, Madras, India, pp 70-73.

SUBRAMANYAM, M. 1965. Lunar, diurnal and tidal periodicity in relation to the prawn abundance and migration in the Godavari estuarine systems. Fishery Technol. Ernakulam, 2(1): 26-33.

SUBRAMANYAM, M. 1968. Preliminary observations on the age and growth in Penaeus indicus M. Edw. from Ennur and Adyar estuaries. Indian J. Vety. Sci., 38(4): 764-767.

SUBRAMONIAM, T. 1984. Spermatophore formation in two intertidal crabs Albunea symnista and Emerita asiatica (Decapoda, Anomura). Biol. Bull., 166: 78-95.

SUKUMARAN, K.K. 1983. Prawn fishery of South Kanara coast with emphasis on the unusual catch of Metapenaeus dobsoni by purse seines and trawls during the first half of September 1983. Mar. Fish. Inf. Serv. T & E. Seri., No. 65, 1985.

SUKUMARAN, K.K. 1987. Monsoon prawn fishery by indigenous gears along the Mangalore coast. Mar. Fish. Infor. Serv. T & E. Ser., No. 76: 1-4.

SUKUMARAN, K.K., ALI, C. GUPTA, UMA, S. BHAT, D. NAGARAJA, H. RAMACHANDRA, O. THIPPESWAMI AND Y. MUNIYAPPA 1988. Monsoon prawn fishery by Matabala along the Mangalore coast - A critical study. Mar. Fish. Infor. Serv. T & E Ser., No. 82: 23-28.

SUMITRA VIJAYARAGHAVAN AND M. VIJAYAKUMARAN 1976. Caloric content of Metapenaeus dobsoni. Indian J. Fish., 23 (1&2): 120-126.

SUMITRA VIJAYARAGHAVAN, M.V.M. WAFAR AND J.P. ROYAN 1978. Feeding experiments with the shrimp Metapenaeus monoceros (Fabricius). Indian. J. Mar. Sci., 7: 195-197.

SUMITRA VIJAYARAGHAVAN, J.P. ROYAN AND T.S.S. RAO 1982. Effect of different feeding levels on moulting, growth and food conversion efficiency and biochemical composition of the prawn, Metapenaus monoceros (Fabricius). Indian J. Mar. Sci., 11: 347-349.

SUSEELAN, C. 1977. The environmental requirements for culture of marine prawns. CMFRI Spl. Publ., No.3.

SUSEELAN,C. AND M. KATHIRVEL 1982a. Prawn seed calendars of Cochin backwates. Proc. Symp. Coastal Aquaculture, Mar. Biol. Ass. India, Part I: 173-182.

SUSEELAN, C. AND M. KATHIRVEL 1982b. A study of the prawns of Ashtamudi backwaters in Kerala with special reference to penaeids. Indian J. Fish., 29(1&2): 71-78.

SUSEELAN, C., G. NANDAKUMAR, N.S. KURUP, V.D. DESHMUKH, K.N. RAJAN, M. ARAVINDAKSHAN AND P.T.SARADA 1992. Present status of exploitation of fish and shellfish resources - Prawns. (MS in press).

TAN FERMIN, AND R.A. PUDADERA. 1989. Ovarian maturation stages of the wild giant tiger prawn, Penaeus monodon Fabricius. Aquaculture, 77: 229-242.

TELFORD, M. 1968. The identification and measurement of sugars in the blood of three species of Atlantic crab. Biol. Bull. (Woods Hole), 135: 574-584.

TESHIMA, S. AND A. KANAZAWA 1983. Variation in lipid compositions during the ovarian maturation of the prawn. Bull. Jap. Soc. Sci. Fish., 49(6): 957-962.

TESHIMA, S., A. KANAZAWA, S. KOSHIO AND K. HORINOUCHI 1989. Lipid metabolism of the prawn Penaeus setiferus during maturation: Variation in lipid profiles of the ovary and hepatopancreas. Comp. Biochem. Physiol., 92B(1): 45-49.

THARAKAN, A.J. 1991. Shrimp production in India. Sea Food Export J., 23: 5-14.

THOMAS, M.M 1974. Reproduction, fecundity and sex-ratio of the tiger prawn, Penaeus semisulcatus. Indian J. Fish., 21(1): 152-163.

THOMAS, M.M., K.V. GEORGE AND M. KATHIRVEL 1974. On the spawning and early development of the marine prawn, Parapenaeopsis stylifera (H. Milne Edwards) in the laboratory. Indian J. Fish., 21(1): 266-271.

THOMAS, M.M., M. KATHIRVEL AND N.N. PILLAI 1974a: Laboratory spawning and early development of Parapenaeopsis acclivirostris (Alcock) (Decapoda: Penaeidae) J. mar. biol. Ass. India, 16(3): 731-740.

THOMAS, M.M., M. KATHIRVEL AND N.N. PILLAI 1974b. Spawning and rearing of the penaeid prawn, Metapenaeus affinis (H. Milne Edwards) in the laboratory. Indian J. Fish., 21(2): 543-556.

THOMAS, M.M., M. KATHIRVEL AND N.N. PILLAI 1974c. Observations on the spawning and rearing of Metapenaeus dobsoni under laboratory conditions. Indian J. Fish., 21(2): 575-579.

THOMAS, M.M., D.C.V. EASTERSON AND M. KATHIRVEL 1984. Energy coversion in the prawn Metapenaeus dobsoni (Miers) fed on artificial feed. Indian J. Fish., 31(2): 309-312.

TRUIJILLO, R.L. AND I.F. LUNA 1981. Variations in the glucidic metabolism during the reproductive cycle of Penaeus notalis Perez Farfante, 1967. Rev. Invest. Mar., 2(2): 141-156.

TUMA, D.J. 1967. A description of the development of primary and secondary sexual characters in the banana prawn, Penaeus merguiensis de Man (Crustacea: Decapoda: Penaeidae). - Aust, J. Mar. Freshw. Res., 18: 73-88.

UMA, K. AND T.SUBRAMONIAM 1979. Histological characteristics of spermatophore layers of Scylla serrata (Forskal) (Decapoda Portunidae). Int. J. Invertebr. Reproduction, 1(1): 31-40.

VARADARAJAN, S. AND T. SUBRAMONIAM 1982. Biochemical changes during vitellogenesis in a hermit crab Clibanarius clibanarius. In: Progress in Invertebrate Reproduction and Aquaculture S. Varadarajan and T. Subramonium (Eds.) pp 7-14.

VENKATARAMAIAH, A., G.J. LAKSHMI AND G. GUNTER 1972. The effects of salinity and feeding levels on the growth rates and food conversion efficiency of the shrimp P. aztecus. In: Proc. 3rd Workshop, World Maricult. Soc., pp 267-283.

VENKATARAMAIAH, A. 1974. Studies on the effects of salinity and temperature on the commercial shrimp Penaeus aztecus Ives, with special regard to survial limits, growth, oxygen consumption and ionic regulation. Contract Report, H. 74-2, US Army Engineers Waterways Experiment station, Mississippi 134 pp.

VENKATARAMAIAH, A. 1975. A review of the effects of some environmental and nutritional factors on brown shrimp, P. aztecus Ives in laboratory cultures. 10th European Symposium on Marine Biology, Ostend, Belgium, Sept 17-23 1975, 1: 523-547.

VIJAYAN, K.K. 1988. Studies on the physiology of moulting in the penaeid prawn Penaeus indicus. Ph.D. thesis, Cochin Univ. Sci. Technol. Cochin.

VIJAYARAGHAVAN, S. AND V. RAMDHAR 1982. Food conversion in shrimp Meta penaeus monoceros (Fabricius) fed on mangrove leaves. Symp. Coastal Aquaculture, Part I: P. 423.

VON BERTALANFFY. L. 1938. A quantitative theory of organic growth. Human Biol., Vol.10; 181-213.

WALKEY, A. AND T.A.BLACK 1934. Determination of organic carbon. Soil Sci., 37: P 29.

WEAR, R.G. AND A. SANTIAGO, Jr. 1976. Induction of maturity and spawning in Penaeus mondon Fabricius 1798, by unilateral eyestalk ablation. Crustaceana, 31 (2): 218-220.

WICKINS, J.F. 1976a. Prawn biology and culture. Oceanogr. Mar.Biol., 14: 435-507.

WICKINS, J.F. 1976b. The tolerance of warm water prawns to recirculated water. Aquaculture, 9(1): 19-37.

WILLIAMS, A.B. 1960. The influence of temperature on osmotic regulation in two species of estuarine shrimps (Penaeus). Biol. Bull., Mar. Biol. Lab., Woods Hole, 119(3): 560-571.

WUHRMANN, K. AND H. WORKER 1948. Experimentella untersuchunger uber de amnonia and blausaurevergifturg. Schueiz Z. Hydro/Rov. Suisse Hydrol/Swiss J. Hydrol. 11(1&2): 210-244.

YANO, I. 1984a: Maturation of Kuruma prawn (Penaeus japonicus) cultured in earthernponds. Proc. Symp. U.S. Japan Aquaculture Panel on Reproduction, maturation and seed production of cultured species. U.S. Rep. Commer. NOAA, Tech. Rep.NMFS.

YANO, I. 1984b. Rematuration of spent Kuruma prawn Penaeus japonicus. Aquaculture, 42: 179-183

YANO, I. 1985. Induced ovarian maturation and spawning in Greasyback shrimp, Metapenaeus ensis by progesterone. Aquaculture, 47: 223-229.

YANO, I. AND Y. CHINZEI 1987. Ovary is the site of vitellogenin synthesis in Kuruma prawn, Penaeus japonicus. Comp. Biochem. Physiol., 86 B: 213-218.

YANO, I. 1988. Oocyte development in the kuruma prawn Penaeus japonicus. Comp. Biochem. Physiol., 86: 213-218.

YEMM, E.W. AND E.C. COOCKING 1955. The determination of amino acids with ninhydrin. Analyst., 80: 209-213.

ZEIN-ELDIN, Z.P. 1960. Effect of salinity on growth of post-larval penaeid shrimp. Biol. Bull., Mar. Biol. Lab., WoodsHole, 119 (3): 560-571.

ZEIN-ELDIN, Z.P. 1963. Effect of salinity on growth of postlarval penaeid shrimp. Biol. Bull., Mar.Biol. Lab., Woods-Hole, 125 (1): 188-196.

ZEIN ELDIN, Z.P. AND D.V. ALDRICH 1965. Growth and survival of postalarval Penaeus aztecus under controlled conditions of temperature and salinity. Biol. Bull., Mar. Biol. Lab., Woods Hole. 129(1): 199-226.

ZEIN-ELDIN, Z.P. AND G.W. GRIFFITH 1969. An appraisal of the effects of salinity and temperature on growth and survival of postlarval penaeids. FAO Fish. Rep., (57) Vol 3: 1015-1026.

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* Not referred to in original.