BIOLOGY, POPULATION CHARACTERISTICS AND FISHERY OF THE SPECKLED SHRIMP *METAPENAEUS MONOCEROS* (FABRICIUS, 1798) ALONG THE KERALA COAST

THESIS SUBMITTED TO THE
COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

UNDER THE FACULTY OF MARINE SCIENCES

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This is to certify that the thesis entitled **Biology, population characteristics and fishery of the speckled shrimp *Metapenaeus monoceros* (Fabricius, 1798) along the Kerala coast** is an authentic record of research work carried out by **Shri. G. Nandakumar**, under my supervision and guidance in the Division of Marine Biology, Microbiology and Biochemistry, School of Marine Sciences, Cochin University of Science and Technology, in partial fulfilment of the requirements for the degree of Doctor of Philosophy of the Cochin University of Science and Technology and no part thereof has been presented before for the award of any other degree, diploma or associateship in any University.

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Prof. Dr. R. Damodaran

DECLARATION

I, Shri. G. Nandakumar, do hereby declare that this thesis entitled **Biology, population characteristics and fishery of the speckled shrimp *Metapenaeus monoceros* (Fabricius, 1798) along the Kerala coast** is a genuine record of research work done by me under the supervision and guidance of **Prof. Dr. R. Damodaran,** Division of Marine Biology, Microbiology and Biochemistry, School of Marine Sciences, Cochin University of Science and Technology, and has not been previously formed the basis of the award of any degree, diploma or associateship in any University.

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ACKNOWLEDGEMENT

I wish to express my deep sense of gratitude to Prof. Dr. R. Damodaran, Division of Marine Biology, Microbiology and Biochemistry, School of Marine Sciences, Cochin University of Science and Technology for his valuable guidance and constant encouragement.

I am thankful to Prof. Dr. N. R. Menon, Director, School of Marine Sciences for providing me the necessary facilities.

I am grateful to Dr. G. Sudhakara Rao, Head, Crustacean Fisheries Division and Dr. C. Suseelan, Senior Scientist, C.M.F.R.I. for their valuable suggestions and encouragements.

I would like to record my earnest thanks to Shri. K. N. Rajan, Senior Scientist, C.M.F.R.I. for his continuous help and valuable suggestions.

I thank Dr. N. G. Menon, Dr. M. Srinath and Shri. K. N. Kurup, Senior Scientists, C.M.F.R.I. for going through the thesis and offering valuable suggestions.

I am extremely thankful to my friend, Shri. K. Balachandran for his constant encouragements and helps throughout the course of this study.

I would like to place on record my sincere gratitude to the Indian Council of Agricultural Research, Government of India for granting me study leave to carry out the present research work.

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GENERAL INTRODUCTION

GENERAL INTRODUCTION

Crustaceans comprising numerous edible species of prawns, lobsters and crabs inhabiting different ecosystem form significant portion of the aquatic food resources of the world. India has ever remained one of the major contributors to the world production of marine crustaceans. The country's average annual production of 0.29 million tonnes (t) during 1984-1990 formed about 8% of the total crustacean landings of the world and 60 % of the Indian Ocean.

Among the crustaceans, prawns are the most commercially exploited group and hold premier rank by virtue of their importance as an esteemed food of gourmet and on account of their high export value. As in the case of most tropical region, the prawn fisheries of India is multispecies in nature. The common species supporting the prawn fishery in India belong to two major categories namely the penaeid prawns and caridean prawns. Among the penaeideans, 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

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There is no consistency in the usage of the term, "prawns" and "shrimps" to denote any particular group of Natantia (Holthuis, 1980). In the present work, these terms are used analogously.

prawns constitute the backbone of the sea food export industry of the country. Among the fishery products exported from India during 1994-95 shrimp was the principal commodity forming 33.01% in volume (101751 t) and 70.21 % in value (2510.94 crores) (Varghese, 1996). The penaeid prawns with an average annual landings of 1.84 lakh t constituted 8.20% of the total marine fish landings of India during 1991-93. Kerala with 53125 t of penaeid prawn catch during this period (1991-93) accounted for 28.81% of all India and 36.12% of west coast landings of penaeid prawns (CMFRI, 1995).

The wealth of informations that has been gathered on various aspects of the fishery and biology of commercially important species of prawns along the Indian coast have been consolidated and documented in a series of species synopsis published in the proceedings of World Scientific Conference on The biology and Culture of Shrimps and Prawns held at Mexico in 1967 (Mistakidis, Ed. 1968, 1969, 1970). Subsequent informations on prawn fisheries and biology of economically important prawns are available from a number of contributions. Some of the important works among them are, Rao (1972, 1986), Mohamed (1973), Subrahmanyam (1973), Mohamed and Suseelan (1973), Kurup and Rao (1974), Thomas (1974, 1975), Subrahmanyam and Ganapathi (1975), Kurian and Sebastian (1976), CMFRI (1978), Silas *et al.* (1984), Lalitha Devi (1987), Rao (1987,1988 a), George *et al.* (1988), Suseelan *et al.* (1989, 1992, 1993), Suseelan and Rajan (1993), Sriraman *et al.* (1989), Rao and Krishnamoorthi (1990), Sukumaran *et al.* (1993, 1993a) and Rao *et al.* (1993).

Metapenaeus monoceros (Fabricius, 1798) which is known as, '**Speckled shrimp**' (FAO name) and '**Brown shrimp**' (common name used in the industry) is one of the commercially important marine penaeid prawns of India. During 1995, *M. monoceros* catch constituted 7.5 % of the all India marine penaeid prawn landings. *M. monoceros* attains a maximum length of about 200 mm and has high export potential. In Kerala till recently fishery of this species was seasonal with average percentage composition of 2.1 in the annual prawn landings. However substantial increase in the catches of brown shrimp has been noticed along the Kerala coast from 1990 onwards, due to advent of multiday fishing and changes in the fishing pattern involving shrimp trawling in deeper grounds and introduction of night fishing etc. Practically there is no information on the fishery and biology of *M. monoceros* from this deeper fishing grounds off Kerala coast. The exported value of the speckled shrimp caught from Kerala during 1995 was about 16.86 crores. Thus realising the growing importance of *M. monoceros* in the capture fisheries, it was felt, that it would be ideal to carry out detailed study on this species for rational exploitation and management of its fishery.

Hence, the present work entitled, **"Biology, population characteristics and fishery of the speckled shrimp *Metapenaeus monoceros* (Fabricius, 1798) along Kerala coast"** was undertaken during 1991-93.

In the global fisheries scenario, the capture fisheries has been facing challenging problems of sustainable exploitation and management. Therefore, attempts were already made world over to culture candidate species in cinfined coastal / brackish water habitats with great success and prawns were the most dominant group among cultured organisms. The world marine fishery growth rate is 3.2 % per year whereas the aquaculture growth rate is 9.6 % per year. As many species of presently cultured prawns face problems of disease, intensive production often exceeding the carrying capacity of the species, monospecies culture related eco system hazards, it would be ideal to introduce new species of prawns into coastal aquaculture sector for multiple species / extensive culture activities as has been practised elsewhere in countries like Taiwan. One of the objectives of this investigation is to cater to the needs of aquaculturists by providing basic biological information during its estuarine phase as well as marine phase.

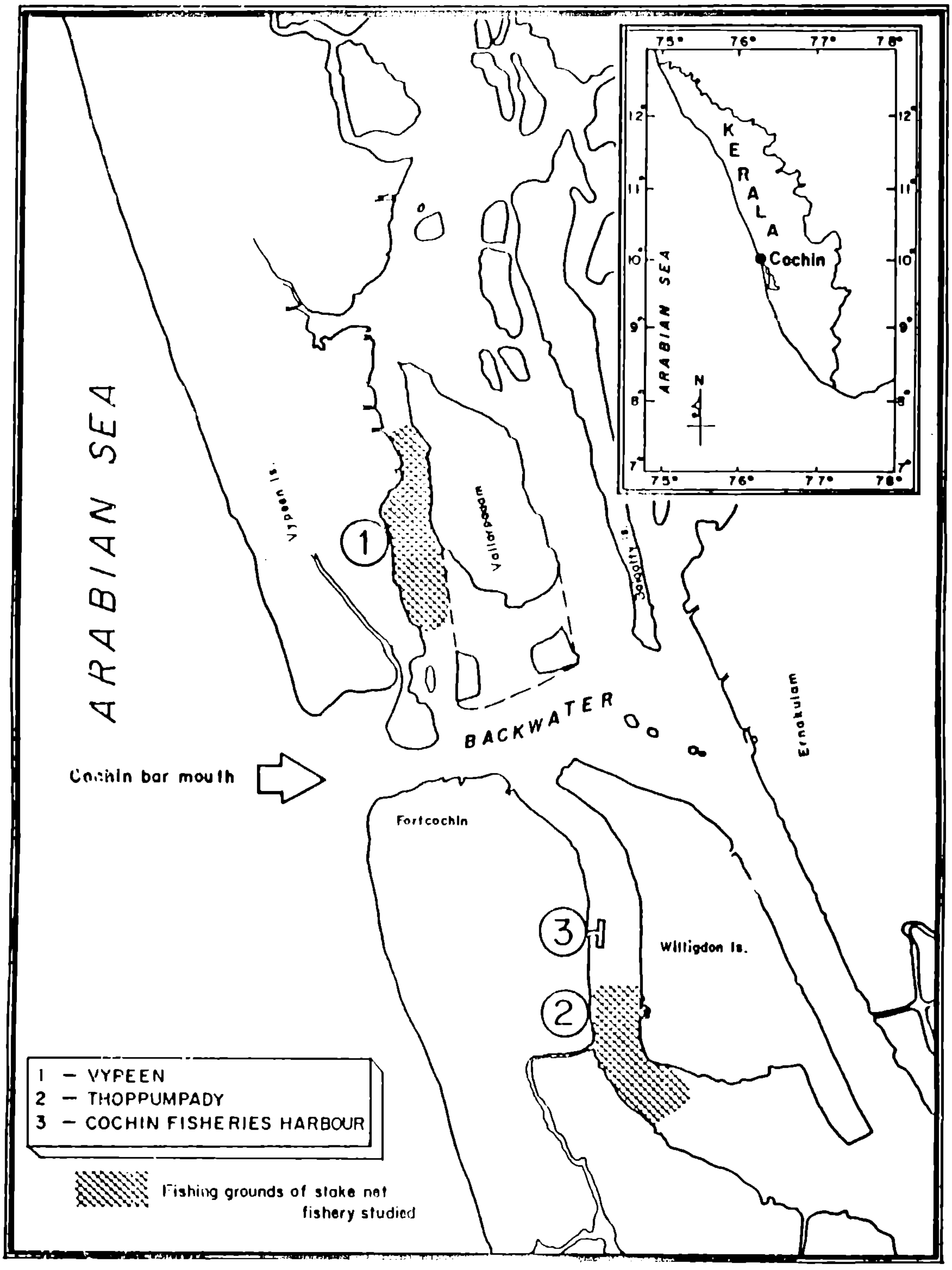


FIGURE 1. Locations of study centres

The available information on *M. monoceros* from Kerala coast is limited, based mostly on its estuarine phase and on a few samples collected from inshore fishery. (George, 1959, 1962, 1974; Menon and Raman, 1961; George and George, 1964; George *et al.*, 1963; Rao, 1972; Kuttyamma, 1974; Nalini, 1975, 1976; Kurup *et al*, 1993 and Kuttyamma and Antony 1975). Details on the study made by different research workers on *M. monoceros* are given in the relevant chapters of the present work.

Like other penaeid prawns *M. monoceros* spends its juvenile phase in estuaries and brackishwaters. Hence the biology and fishery of this species was studied from the inshore waters off Cochin as well as from Cochin Backwaters. Cochin Fisheries Harbour which is one of the major fish landing centres of Kerala coast was selected to collect the data on catch and effort and other biological aspects on the brown shrimp harvested from inshore regions. The details on the fisheries biology of juvenile *M. monoceros* from Cochin Backwaters were collected from Thoppumpady and Vypeen. The locations of the study centres are shown in Figure. 1.

The thesis is laid out in seven chapters comprising **TAXONOMY, FOOD AND FEEDING HABITS, AGE AND GROWTH, REPRODUCTION, LENGTH-WEIGHT RELATIONSHIP, FISHERY and POPULATION DYNAMICS.**

In the first chapter, the systematic status of ***Metapenaeus monoceros*** (Fabricius, 1798) with an objective to confirm the identity of the species and its general distribution are given. Each of the remaining chapters has been partitioned into various sections such as introduction, material and methods, results and discussion. Study of food and feeding habits and assimilation are of fundamental importance in understanding the rate of growth, population concentration, gonadial maturation and other metabolic activities. Hence the details on the food and feeding habits of *M. monoceros* from inshore regions and backwaters of Cochin were studied and given in the second chapter. In order to get a summary picture of frequency of occurrence as well as volume of various food items the method of Index of Preponderance' (Natarajan and Jhingaran, 1961) was used. Based on the Index, the importance of each individual food item was determined. Variations in food and feeding habits based on size and sex in estuarine and marine environments were studied and discussed. Seasonal and diurnal variation in feeding habits and intensity of feeding were also carried out.

Knowledge of age and growth is one of the basic requirements for the study of population dynamics of any resource which in turn helps to evolve suitable management policies. The age and growth of *M. monoceros* have been studied by using von Bertalanffy growth model (von Bertalanffy, 1938) and the results are given in Chapter 3. The model involves three parameters namely the asymptotic size, growth coefficient and age of individual at zero size. The first two parameters were estimated by modal progression and Ford-Walford method (Ford, 1933; Walford 1946) and the age at zero size by Gulland's method (1969). Alternatively, these parameters for the above model were also estimated by ELEFAN I method (Pauly and David, 1981).

In the next chapter on reproduction, the details on size at maturity of males and females of *M. monoceros*, the different stages of maturation in females along with ova diameter of the respective stages and fecundity are given. The particulars on the spawning season, spawning population in the fishery, spawning frequency and sex ratio are also included. The length-weight and other dimensional relationship of *M. monoceros* are given in the fifth chapter.

The Cochin Fisheries Harbour was visited regularly during 1991-93 and the details on prawn fishery carried out by shrimp trawlers were collected. In the sixth chapter on fishery, the following details are given: the general trend of prawn fishery of Kerala during 1991-93, the prawn fishery of Cochin, effort fluctuations, species composition of the prawn catch, the fishery of *M. monoceros* year-wise and for the total period of study

(1991-93), its fishery season, peak period of occurrence and seasonal movement etc. The details on the juvenile brown shrimp fishery from Cochin Backwaters was also included in this chapter.

In the final chapter on population dynamics, the instantaneous rate of total mortality (Z) natural mortality (M) and fishing mortality (F) of *M. monoceros* are given. Estimation of 'Z' was done using 1. Catch curve method of Pauly (1982), 2. Cumulative catch curve method of Jones and van Zalinge (1981), 3. Beverton and Holt method (1957) and 4. Wetherall *et al* method (1987). The natural mortality rate (M) was estimated by Rikhter and Efanov's formula (1976). Using the input from the length cohort analysis, the effect of fishing on yield was determined by following Thomson and Bell yield model (1934). Yield per recruitment model (Beverton and Holt, 1957) was used to study the effect of first capture and fishing mortality on the yield of *M. monoceros*. The present position of speckled shrimp stock in relation to fishing intensity is also explained in this chapter.

The salient features of the present study on fisheries biology and population characteristics of the speckled shrimp, *M. monoceros* are summarised followed by a list of reference cited in the text.

CHAPTER 1

TAXONOMY

CHAPTER 1

TAXONOMY

I.I. INTRODUCTION

The prawn fishery of Kerala coast is supported by penaeid prawns. Among them species belonging to genus ***Metapenaeus*** Wood-Mason and Alcock 1891, account for bulk of the prawn catches. In the revision of the genus Racek and Dall (1965) included 22 determinable species. Since then three more new species have been described from Indian waters raising the number to 25. Of these 11 species have been recorded to occur in Indian waters. They are *Metapenaeus dobsoni* (Miers), *M. monoceros* (Fabricius), *M. affinis* (H. Milne Edwards), *M. brevicornis* (H. Milne Edwards), *M. ensis* (De Haan), *M. lysianassa* (De Man), *M. moyebi* (Kishinouye), *M. stebbingi* (Nobili), *M. kutchensis* George *et al*, *M. alcocki* George & Rao and *M. krishnatrii* Silas & Muthu. The genus *Metapenaeus* has recently been reviewed in detail by Miquel (1982) including full descriptions and figures of the species. The genus *Metapenaeus* is represented along the Kerala coast mainly by *M. dobsoni*, *M. monoceros* and *M. affinis*. Other species that occur sporadically are *M. brevicornis* and *M. moyebi*.

1.2 MATERIAL AND METHODS

Metapenaeus monoceros samples were collected at random, from trawl landings at Cochin Fisheries Harbour during 1991. A total number of 75 males (size range 51 - 145 mm) and 101 females (size range 55 - 180 mm) were examined for systamatic studies following the methodology adopted by Dall(1957). The decriptions given by Alcock (1906), George (1969, 1970 a, b; 1979) and Miquel (1984) were followed for giving a detailed account on the genus and species.

1.3 DESCRIPTION OF GENUS

Genus *Metapenaeus* Wood-Mason and Alcock in Wood-Mason and Alcock, 1891, *Ann. Mag. nat. Hist.*, (6) 8: 271.

Rostrum dorsally toothed only; carapace without sutures; cervical sulcus well defined; hepatic sulcus not well defined behind level of hepatic spine, but pronounced in front with well defined postero-inferior border; antennal and hepatic spines pronounced; pterygostomial angle blunt. Telson with deep dorsomedian sulcus, without fixed subapical spines, and with movable dorsolateral spines which may be microscopic and very numerous. First antennular segment without spine on ventral distomedian border. Antennular flagella usually shorter than carapace. Maxillulary palp with 2 segments, distal small, basal with convex, foliaceous projections on inner and outer edges, and long spine on inner edge. First to 3rd pereopods with basial spines; 5th pereopod without exopod; ischium and merus often modified in adult male. Petasma tubular with thickned median lobes; lateral lobes thicker than median, forming distolateral spoutlike projections, each with dorsal lobule produced posteriorly into expanded, plate-like projection; median lobes with dorsal lobule produced into thin recurved plate-like or hood like structure. Appendix masculina with knob-like distal piece bearing deep posterodistal depression. Thelycum composed of anterior median plate, 2 posterior lateral plates more or less enclosing posterior end of median plate; posterior plates often continuous across sternite. Zygocardiac ossicle with two rows of teeth which get progressively smaller. Pluerobranchs on 3rd to 7th thoracic somites, rudimentary arthrobranch on 1st somite, anterior and posterior arthrobranchs on 2nd to 6th, vestigial anterior and fully developed posterior arthrobranchs on 7th somite; mastigobranchs on 1st, 2nd, 4th to 6th somites. Body usually with some dorsal setose depressed areas, remainder of body surface varying from completely glabrous to covered with close irregular setose depressed areas.

Distribution: Species belonging to genus *Metapenaeus* are distributed throughout the Indo-Pacific region.

1.4 DESCRIPTION OF SPECIES

Metapenaeus monoceros (Fabricius, 1798)

Penaeus monoceros Fabricius, 1798, *Suppl. Ent. Syst.*, 409

Penaeopsis monoceros De Man, 1911, *Siboga Exped.*, 39 a: 55

Metapenaeus monoceros George, 1970, *FAO Fish Rep.*, 57 (4): 1547

Body covered with stiff, very short tomentum. Rostrum nearly straight, uptilted, reaching nearly to , or a little beyond, tip of antennular peduncle; armed dorsally with 9 to 12 upper teeth. Postrostral crest continued to, or almost to, posterior border of carapace. Very small orbital tooth, postantennular spine strong, produced a ridge to base of small hepatic spine; ridge bounding well marked postantennular groove which meets cervical groove. Gastric region defined anteriorly by short oblique orbital groove. Branchial region defined anteriorly, by deep and narrow crescentic groove which embraces base of postantennular ridge and meets postantennular groove, superiorly, by sinuous ridge which runs from hepatic spine almost to posterior border of carapace(Plate).

Dorsal carina on first to sixth abdominal terga, blunt and inconspicuous on first to third, very sharp on 4th to 6th. Fifth abdominal somite about two-thirds length of 6th, 6th a little shorter than telson. Telson shorter than endopod of uropod, without marginal spines.

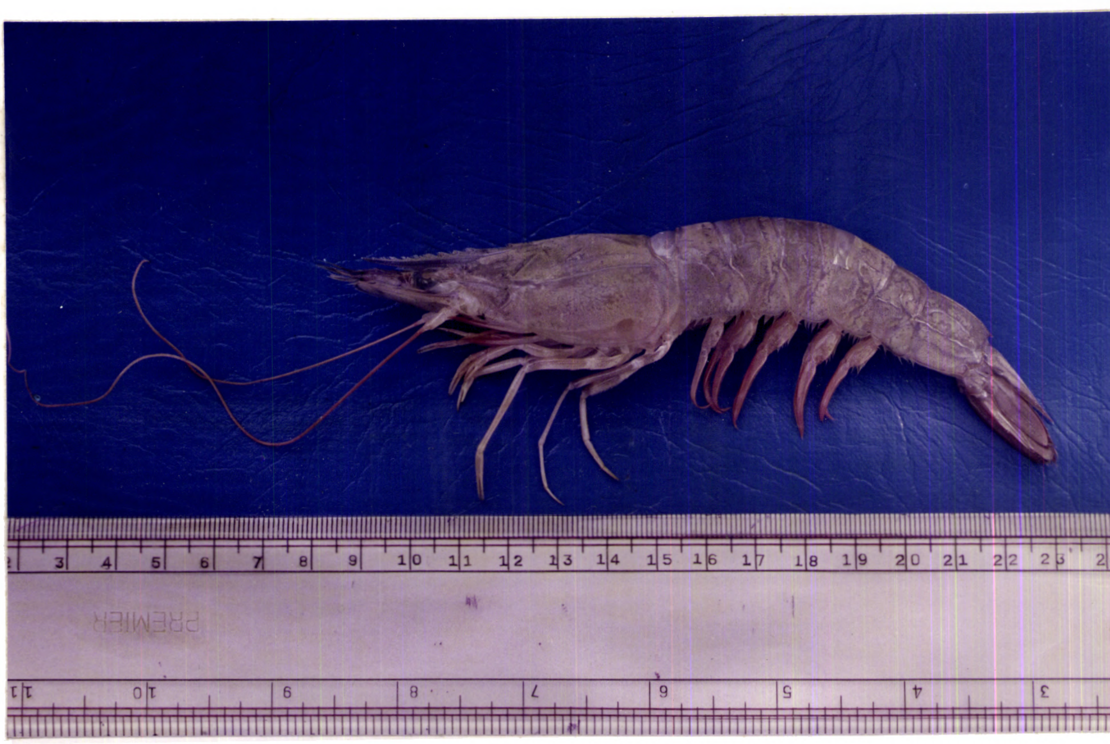


PLATE : <u>Metapenaeus</u> <u>monoceros</u> (Fabricius 1798)

Eyes very large, slightly surpassed by antennal scale. Outer (upper) antennular flagellum slightly longer than inner, not much more than half length of peduncle.

Third maxillipeds barely reach middle of antennal scale, dactylus in male not modified, consists of slender, setose, tapering joint, about four-fifths length of propodus. Strong anterior spine on basis of each cheliped. Fifth pereopod of adult male with proximal end of merus notched on outer side, notch deepened anteriorly by large hook-like spine, and posteriorly by subterminal lobule on posterior border of ischium. Edge of merus finely denticulate beyond spine. Three terminal joints of 5th legs slender in both sexes, the dactylus rarely reaches much beyond middle of antennal scale. No exopods on the 5th legs.

Petasma symmetrical, consists of 2 rigid segments tightly folded longitudinally, interlocked all along anterior margins, in close apposition along most of posterior margins, forming compressed tube; distomedian projection of petasma convoluted, greatly swollen, bulbiform, directed anterolaterally and concealing distolateral projections in ventral view.

Thelycum concave, bounded laterally by pair of ear-like lobes with free edge often incurved, bounded anteriorly by median projecting tongue embedded between 2 lobes of sternum corresponding with penultimate pair of pereopods.

Semitransparent, closely covered with small red chromatophores; dorsal carina of carapace, rostrum, bases of eyestalks, dorsal abdominal carinae of telson and uropods dull red; antennae bright red; first 2 pereopods colourless; last 3 pereopods with numerous red chromatophores; setae of uropods golden red; outer uropod bright red along external margin.

SYSTEMATC POSITION OF *METAPENAEUS MONOCEROS*

Phylum	:	Arthropoda
Class	:	Crustacea
Subclass	:	Malacostraca
Series	:	Eumalacostraca
Superorder	:	Eucarida
Order	:	Decapoda
Suborder	:	Dendrobranchiata
Infraorder	:	Penaeidea
Superfamily	:	Penaeoidea
Family	:	Penaeidae
Genus	:	*Metapenaeus* Wood-Mason and Alcock 1891
Species	:	*monoceros* (Fabricius,1798)

CHAPTER 2

FOOD AND FEEDING HABITS

CHAPTER 2

FOOD AND FEEDING HABITS

2.1 INTRODUCTION

Study of food and feeding and assimilation are of fundamental importance in understanding the rate of growth, population concentration, gonadial maturation and other metabolic activities. In general penaeid prawn have been described as "Omnivorous scavengers" or detritus feeders. It is unlikely, however, that under natural conditions in a densely populated shrimp ground, the proportion of larger food masses would be adequate for full nutrition of population. It has been assumed that this deficiency is made good by "detritus". The shrimp feeds by moving slowly over the surface methodically searching the surface with the three pairs of chelipeds. The tips of each chela meet precisely, so that quite small particles may be picked up and conveyed to the mouth. When relatively a larger food mass was found, it is held by the external maxillipeds and the mandibles are used to bite or tear off portions ; the maxillipeds are then used to push tough food away as it is grasped by mandibles. Young (1959) has published a description of the gut of *Penaeus setiferus*. The overall structure differs little in the shallow water penaeid except in details of the gastric mill (Dall, 1957) *Penaeus* spp. differs from the *Metapenaeus* spp only in the structure of posterior diverticulum of the midgut; it is compact in *Penaeus* species and longitudinal and simple structure in *Metapenaeus* spp.

The oesophagus is short and leads vertically into the anterior chamber of proventriculus ("stomach") which serves as a distensible crop, and posteriorly, as a gastric mill. In the flow of the anterior chamber is a system of grooves which enables secretions from the digestive gland to be passed forward and mixed with food. The posterior proventriculus is partly embedded in the digestive gland and is divided into dorsal channel which leads directly into the long simple midgut and a ventrical "filter press" which permits only the finest particles to pass into the digestive gland, like omnivorous Decapoda, penaeid shrimp appear to possess a full complement of enzymes i.e. proteinase, amylase and lipases. By the time the food particles have reached the digestive gland, digestion is well under way and is completed in the proximal half of the digestive gland tubules. The large indigestible particles pass through the dorsal part of the posterior proventriculus into the midgut. The midgut is a straight tube running from the cephalothorax dorsally through the abdomen through to the rectum. Since the rate of ingestion and digestion are more or less equal, the relatively small size of the "stomach" is not a major disadvantage.

Detailed studies have been made in India on food and feeding habits of *Metapenaeus dobsoni* (Menon 1951), *Penaeus indicus* (Gopalakrishnan, 1952), *P.monodon* (Thomas, 1972; Mohanty, 1975) and *P.semisulcatus* (Thomas, 1980). Panikkar (1952), Panikkar and Menon (1956), Kunju (1967) George (1959). Kuttyamma (1974) and Subramanyam and Ganapathi (1975) have mentioned the food of the penaeid prawns while studying their biology. The food and feeding habits of *M.monoceros* from Cochin backwaters and Godavari estuarine system were studied by George (1974) and Subrahmanyam (1973) respectively. Rao (1988c) made studies on the feeding biology of *M.monoceros* from Kakinada coast during 1974-75. Williams (1955) and Eldred *et al.* (1961) studied the food habits of North-American penaeid prawns i.e. *P.setiferus*, *P.aztecus* and *P.duorarum* while Hall (1962) and Dall (1968) investigated the food and feeding habits of Indo-West Pacific penaeid prawns and Australian penaeid shrimps respectively. Tiews *et al* (1968) studied the gut contents of some penaeid species from Manila and San Miguel Bays. The feeding habits and the seasonal variations in feeding habits of *P.monodon* were studied by Marte (1980, 1982) from Phillipine region.

2.2 MATERIAL AND METHODS

Regular samples of *M.monoceros* collected from trawl catches at Cochin Fisheries Harbour and stake net catches of Cochin backwaters during 1991 were analysed to study the food and feeding habits of this species. It is very difficult to identify the food items specieswise due to the nibbling action of mandibles on the food and mastigation of food inside the stomach by the action of gastric mill. The idenfification of food organisms were based mainly on broken shell remains, spines, setae etc. The gut contents were grouped as follows : polychaetes, prawns, fishes, molluscs, other crustaceans (consisting mostly, small crab bits, mysid bits and other unidentifiable crustacean bits) minor crustaceans (mainly amphipods and sometimes isopods and rarely tanaedaceans) and detritus (decomposed plant and animal matter and their remains mixed with mud).

Various methods are in prevalence in the studies of stomach analysis of fishes and these were critically discussed by Hynes (1950) and Pillay (1952). Since the quantity of food in the stomach of prawns is very little, instead of volumetric method the points (volumetric) method (Pillay, 1952) was utilised for studies on the food and feeding habits of *M.monoceros*. In order to get a summary picture of frequency of occurrence as well as volume of various items Natarajan and Jhingaran (1961) devised a method called `Index of Preponderance' for studying the food and feeding habits of fishes. This method was adopted here for studying the food and feeding habits of *M.monoceros*. This method is explained here briefly. If Vi and Oi are the volume and occurrence index of food item i, the combined Index (I) for food i may be presented as,

$$I_i = \frac{Vi\ Oi}{\text{Sum of } Vi\ Oi} \times 100$$

The sum of all items leads to 100. The Index designated as the Index of preponderance is in actuality, is a composite one based on volume and occurrence index. The Index of preponderance provides a definite and measurable basis for grading the various food elements as it gives a combined picture of frequency of occurrence as well as bulk. Food and feeding habits of *P.semisulcatus* in Palk Bay and Gulf of Mannar and of *M.monoceros* along the Kakinada coast were studied by utilising the method of Index of Preponderance by Thomas (1980) and Rao (1988 c) respectively.

In the present study 584 numbers of *M.monoceros* (ranging in size from 52 to 166 mm) collected from trawl grounds and 1293 juveniles size range : 56-106 mm) fetched from Cochin backwaters during January-December 1991 were subjected for gut content analysis. The intensity of feeding was determined by the degree of distension of the stomach due to the quantity of food inside the anterior and posterior chambers of the proventriculus. The condition of feed was expressed as full, 3/4 full, 1/2 full, 1/4 full, trace and empty and each one was assigned 100, 75, 50, 25, 10 and 0 points respectively. The stomach was cut open and the contents examined under a microscope. Percentages of occurrence of the various conditions of feeding were calculated from the conditions of individual prawn. Depending on the relative volume of each item, points were given for each food item and from these, volumes of each food item was calculated. The percentage volume was then computed for the individual items. The percentage occurrences of different food items were determined from the total number of occurrences of all items in each month. The indices of preponderance were then computed to indicate the food preference of the prawns. The Index of Preponderance for the year 1991 was also calculated taking the total number of prawns examined during the year. The degree of fullness of stomach in relation to size of prawns was noted to study the intensity of feeding in juveniles and adults in different months. From the total number of prawns examined in a month, the percentage occurrence of stomachs with different intensities of feeding was computed.

2.3 RESULTS

2.3.1 FOOD AND FEEDING HABITS OF M. MONOCEROS FROM SHRIMP GROUNDS OFF COCHIN

A critical study on the stomach contents and feeding habits of the brown shrimp from trawl catches landed at Cochin

Fisheries Harbour during January-December 1991 was carried out in detail. The particulars on the composition of food during different months, changes in food habits and intensity of feeding between juveniles and adults and changes in feeding habits between day and night time are given in the following few pages.

Composition of food: The food items noticed in the stomach in order of abundance were 1) polychaetes 2) detritus 3) fishes 4) prawns 5) sand 6) other crustaceans 7) minor crustaceans 8) molluscs and 9) foraminiferans. The month-wise details on Index of Preponderance (hereafter referred as Index), for each food item as well as the annual Index are given in Table 2. 1.

Polychaetes were the most predominant among the food items; and could be easily identified by the presence of setae, jaws and occassional body fragments in the proventriculus. They were present in the stomach throughout the year. The Index was above 50 in the months of February, March, July, October and November with the maximum during October-November period. Polychaetes ranked first among the food items for seven months (February, March, July, September-December) with Index between 39.76 and 84.99 and they also turned out to be the main food item during 1991 with an Index of 43.76.

Detritus ranked second among the food items with an Index of 16.36 in 1991. It ranked first in January and April with an

Index of 44.85 and 41.28 respectively and second in the months of February and March and occupied the third position in July and October-December duration.

Fishes constituted third important food item of the brown shrimp during 1991 with an Index of 14.86. They formed the most important food item in June with an Index of 48.09. Mostly very small juvenile fishes were found in the stomachs which were identified due to the presence of vertebrae, scales and spines. Fishes ranked second among the food items in May, August and September and third in January and April.

Prawns were observed in the stomach of the speckled prawn throughout the year and ranked 4th in importance among the food items encountered in 1991 with an Index of 13.16. The maximum Index of 53.02 for prawns in the stomach contents was noticed in May. Prawns occupied second position in June, October and December with Index between 7.97 and 26.51 and ranked third in the month of August. In many instances, penaeid prawns in semi-digested condition were found among which species of *Metapenaeopsis*, *Trachypenaeus* could be tentatively identified. *Acetes* species were rarelyseen in the stomach contents. From the nature of decapod remains in the stomach, it is likely that the *M.monoceros* may eat exuviae of juvenile prawns along with bottom mud.

Sand was found in the stomach in all months and had an Index of 7.65 in 1991, ranking 5th in abundance. This item was probably an accidental inclusion while the prawn was feeding at the bottom. It ranked first in the month of August, second in July and third in March and June and fourth during September-November period.

Other crustaceans consisting mostly small crab bits and other unidentifiable crustacean appendages ranked sixth in abundance with an index of 2.35 in 1991 and were noticed in the stomach throughout the year. In the monthly contributions, other crustaceans occuppied third position in December with an Index of 9.74.

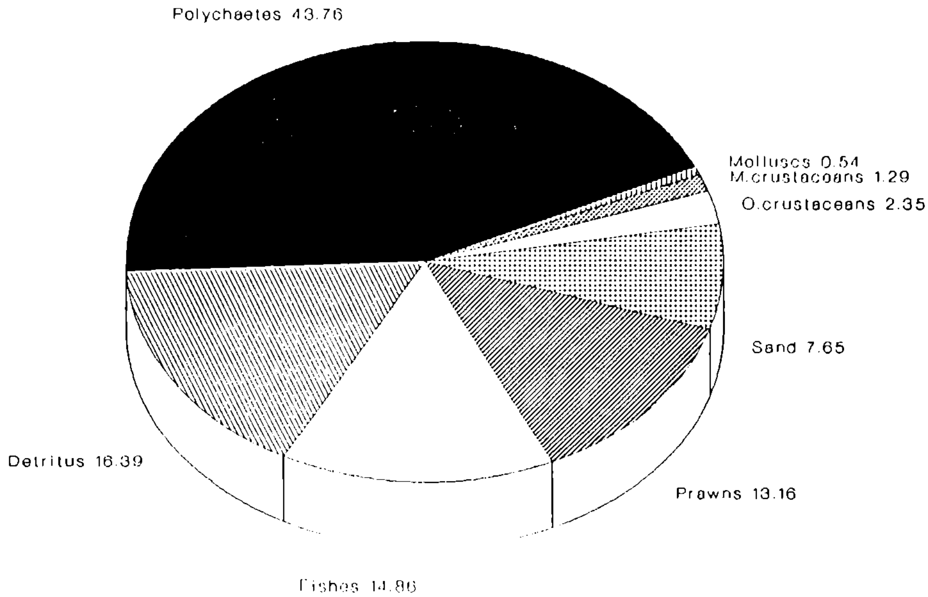
Minor crustaceans consisting mostly amphipods and rarely isopods were found in the stomach throughout the year with an exception of January and ranked seventh among the food items. This group ranked third in the month of September with an Index of 19.64.

Molluscs gained some importance as a food item of the brown shrimp in the months of January, May and December with an Index between 2.00 and 5.76. Their presence in the stomach was negligible during July-October and they were absent in other months. Although crushed shells of various forms of lamellibranch mollusc were noticed, the fresh appearance of the shells as well as partly digested flesh indicated that they were eaten alive. In a few instances calcareous outerbits of oyster shells were also encountered. During 1991, the molluscs ranked 8th among the food items.

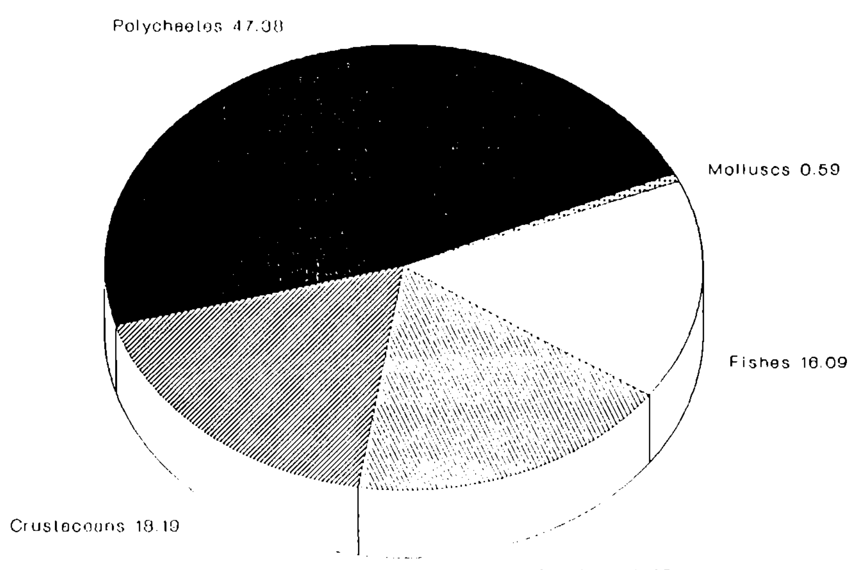
Foraminiferans were found in very small quantities during January-March and in the months of September and November with an Index between 0.03 and 0.14. They ranked last among the food items in these months as well as in 1991.

To find out the actual indices of relevant food items the Index of sand was deleted and that of foraminifera was included with detritus. Indices of prawns, other crustaceans and minor crustaceans were combined together as crustaceans. Thus the relative importance of polychaetes, fishes, crustaceans, molluscs and detritus was depicted in Figure 2.1. Polychaetes emerged as the most important food item of *M.monoceros* in the trawling grounds off Cochin, with an Index of 47.38, crustaceans (prawns : 78.35 %; other crustaceans : 13.96%; and minor crustaceans 7.69%) ranked second with an Index of 18.20. Detritus occupied third position with an Index of 17.75 among the other food items. The next in importance occupying fourth position were fishes and their food Index was 16.09. The mollusc were ranked last, the Index being 0.54 only.

Fig.2.1. Relative importance of food items in *M.monoceros* landed by trawlers at Cochin Fisheries Harbour



a. Entire food items



b. Important groups

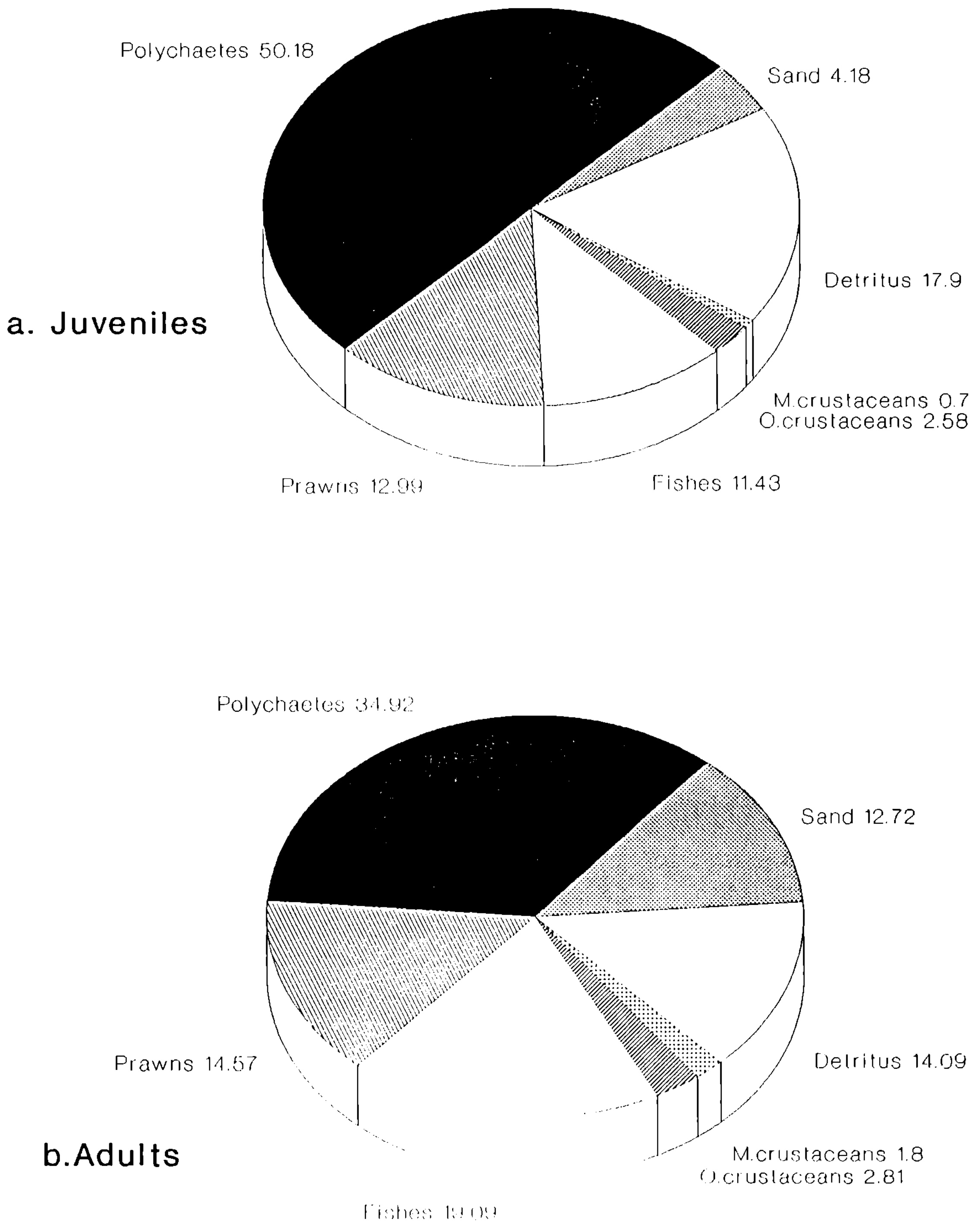
2.3.1.1 Food and feeding habits in relation to size

Samples of *M.monoceros* from trawl grounds were separated as juveniles and adults based on the minimum size at maturity to understand whether any differences existed in their food habits. The minimum size at maturity for males and females were 98 and 104 mm in total length respectively. Males measuring upto 98 mm and females upto 104 mm in total length were grouped as juveniles and beyond these sizes as per sex were considered as adults. The Indices of food items for juveniles and adults of *M.monoceros* from the inshore catches of Cochin, monthwise and annual are given in Table 2.2.

In juveniles polychaetes ranked first among the food items in October, second in March-April period and third in June. Detritus ranked first during March-April. Fishes ranked first in the food items of juveniles in the month of June. In adults polychaetes ranked first among the stomach content in March and October and third in April. Fishes ranked first in April and June. Detritus ranked second during March-April and in October. Sand particles ranked third among the food items in March, June and fourth in the month of April. When monthwise details alone were taken into account, polychaetes, detritus, fishes and prawns emerge as important food items but without regularity in their ranking in different months. However, when the Indices for the entire four month duration were taken into consideration, the following aspects in their food habits came to light. Polychaetes ranked first as the most important food for both juveniles and adults. However, the Index was more in juveniles (50.18) than in adults (34.92) showing higher preference of polychaetes by juveniles. Detritus, prawns and fishes with Indices of 17.93, 12.99 and 11.40 ranked second, third and fourth respectively in juveniles as food items. In adult speckled shrimps, fishes with an Index of 19.09 ranked second among food items followed by prawns and detritus with Indices of 14.57 and 14.09 respectively. Sand particles were present 3 times more in adults (Index:12.72) than in juveniles (Index:4.18). The other crustaceans were equally represented in the stomach contents of both juveniles and adults. Minor crustaceans were present more in the stomach contents of adults than in juveniles with Index of 1.81 and 0.71 respectively.

The relative importance of the food items in juveniles and adults of *M.monoceros* is shown in Fig.2.2. It is clearly seen that polychaetes were the most important food item of juveniles followed by detritus, prawns and fishes. In the case of adults, eventhough polychaetes were ranked high among the gut contents their importance came down due to lower percentage composition. The second important food item of adult prawn was fishes, followed by prawns and detritus.

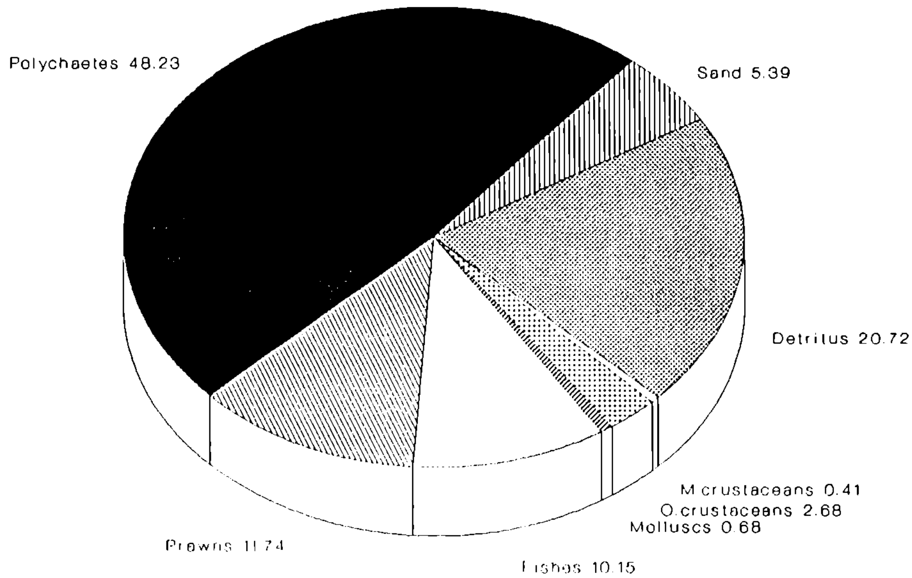
Fig.2.2. Relative importance of food items of *M.monoceros* from trawl landings at Cochin Fisheries Harbour



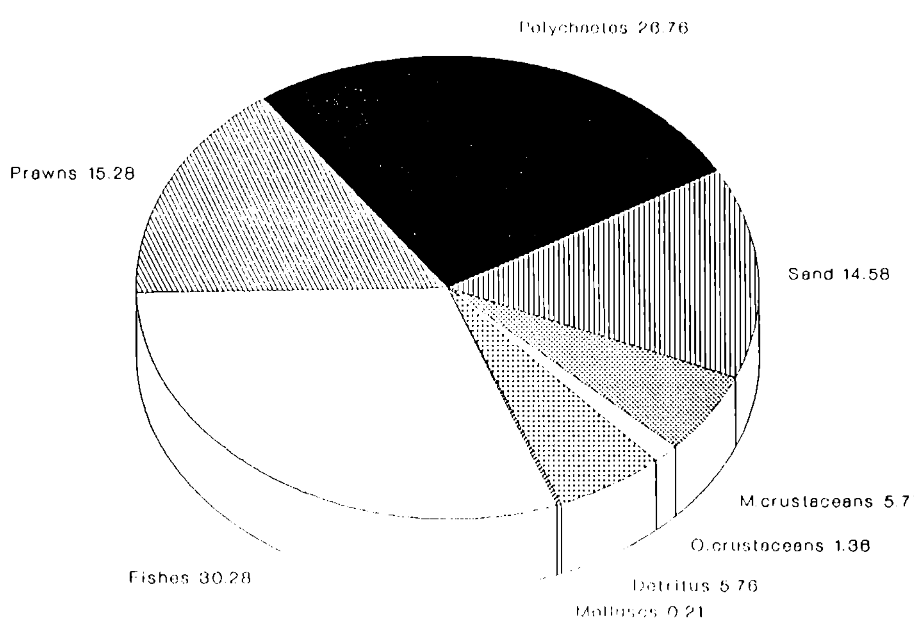
2.3.1.2. Food and feeding habits in relation to day and night fishing:

M.monoceros caught during day fishing from June to September 1991 and those from night fishery in other months were compared for studying diurnal variations in food habits (Tables 2. 1 and 2.2). Some important differences in selectivity of food items during day fishery from those of night fishing were observed. Hence data from these two fishery were treated separately and results were found out (Table 2. 3). In the night catches, polychaetes, detritus, prawns and fishes ranked first, second, third and fourth in importance followed by sand and other crustaceans. Polychaetes formed almost half (Index : 48.23) of the stomach content. The total Index of main constituents of stomach content viz. polychaetes, detritus, prawns and fishes amounted to 90.81. In day catches, the food preference was noticed to have changed, where, fishes ranked first, followed by polychaetes and prawns retained the third rank. Sand particles were found more in the stomach contents of day time caught prawns. Minor crustaceans ranked fifth and detritus, which occupied the second position in night catches, was pushed down to sixth position in day time caught *M.monoceros*. Thus fishes, polychaetes, prawns, detritus and minor crustaceans together contributed to an Index of 83.84 in day-fishery prawns. The relative importance of food items of prawns caught in day and night fishing has been shown in Fig. 2.3. Polychaetes

Fig.2.3. Relative importance of food items in *M.monoceros* in trawl landings at Cochin Fisheries Harbour



a. Night fishing



b. Day fishing

contributed almost half of the food requirements of *M.monoceros* caught at night-time and the other half being shared by detritus, prawns, fishes and other crustaceans. Whereas in day time caught prawns it was clearly seen that fishes contributed about one third of the food requirements; and polychaetes, prawns, minor crustaceans, detritus and sand particles contributed to the remaining two third of stomach contents.

2.3.1.3. The feeding intensity:

Details on the feeding intensity in numbers and percentages are given in Table 2. 4. Prawns with 'full', '3/4 full', '1/2 full' stomachs were considered as actively fed while '1/4 full', 'trace' and 'empty' stomachs were taken as poorly fed. The percentage of actively fed prawns from the trawling grounds off Cochin during 1991 was 53.42. The maximum numbers of actively fed prawns (77.59 %) were recorded in February'91 while the minimum numbers (8.62%) were noticed in the month of August. Feeding intensity in females (57.95 %) was more than males (48.58%) during 1991 (Table 2. 5). The maximum feeding intensity in both sexes was noticed in February which was 93.33 % for females and 60.71 % for males. The females fed actively for 7 months (January-April and October-December'91) while active feeding in males was observed for two months (February and December '91).

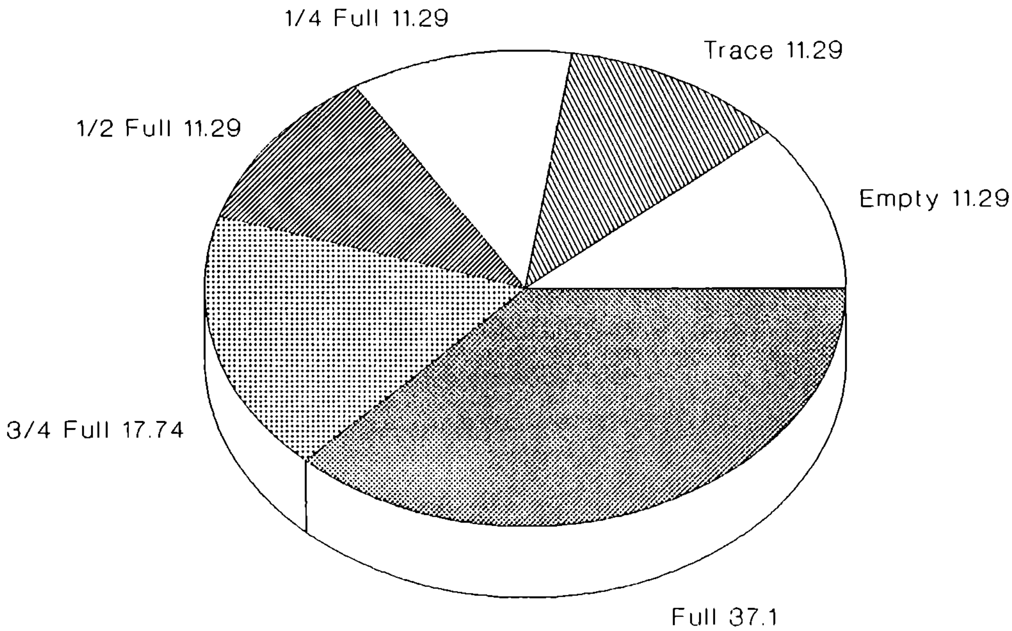
2.3.1.4 Feeding intensity in juveniles and adults:

Monthwise details on feeding intensity for juveniles and adults are given in Table 2. 6. The feeding intensity of juveniles varied between 53.33 % (June) and 79.99 % (April) with an average intensity of 66.13% for 1991. The adults showed the minimum feeding intensity in June (29.27 %) and the maximum in October (56.52 %) with an average intensity of 50.33 % during the period January-December'91. Fullness of stomach for juveniles and adults showing the feeding intensity has been shown in Fig. 2. 4. While 37.10 % of juveniles were noticed with full stomachs only 12.58 % of adults were seen in the same condition. . When about two third of juveniles fed intensively, about half of adults alone fed actively.

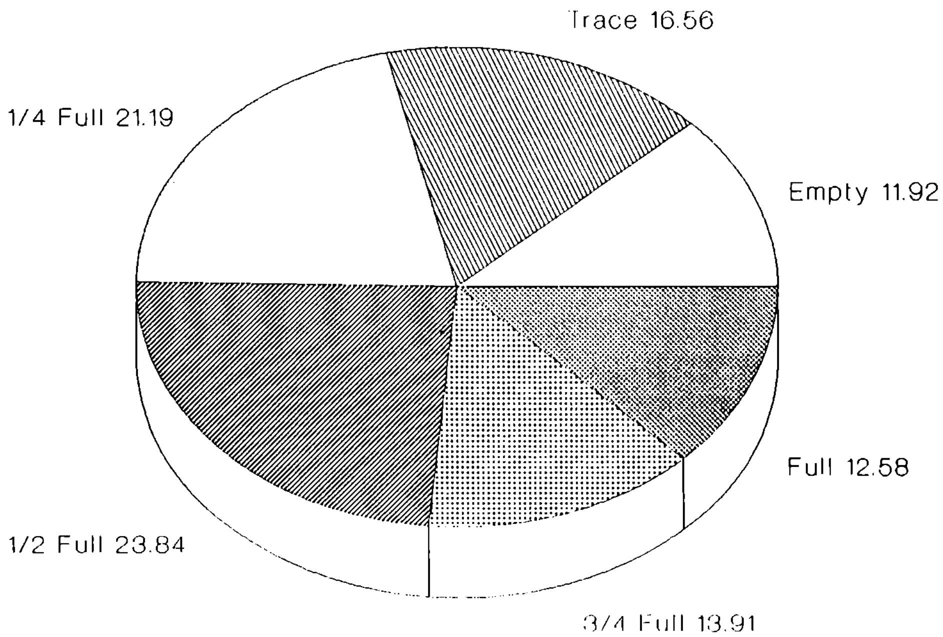
2.3.1.5. Feeding intensity in females with different stages of maturity:

An attempt was made to find out whether there exists any variation in the feeding activity in females with different maturity conditions. Feeding intensities (in numbers and percentages) of 199 female *M.monoceros* with stages of maturity are shown in Table 2. 7. *M.monoceros* in late maturing stage was found to feed very actively (81.48 %). Prawns in other maturity stages also fed actively with their percentages between 67.65 (mature) and 72.73 (early maturing). Spent females showed 70.91 %

Fig.2.4. Relative feeding intensity in *M.monoceros* from trawl landings at Cochin Fisheries Harbour



a. Juveniles



b. Adults

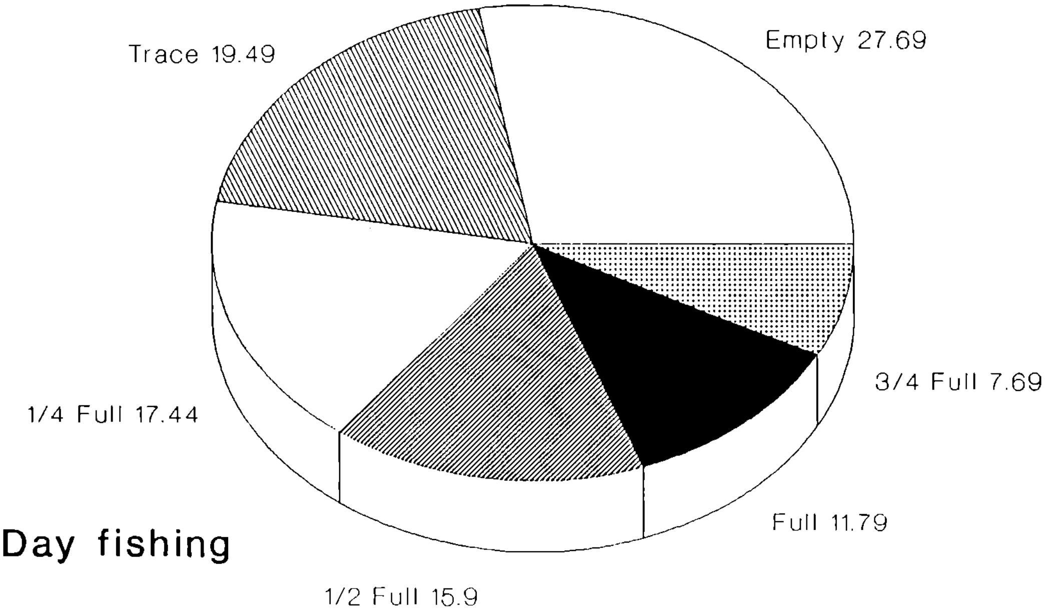
feeding intensity. The average feeding intensity of females of *M.monoceros* from early mature to mature condition was 73.49. Immature females showed a feeding intensity of only 54.10 %. Thus the onset of maturation increases the inclination of feeding in females.

2.3.1.6. Diurnal variation in intensity of feeding

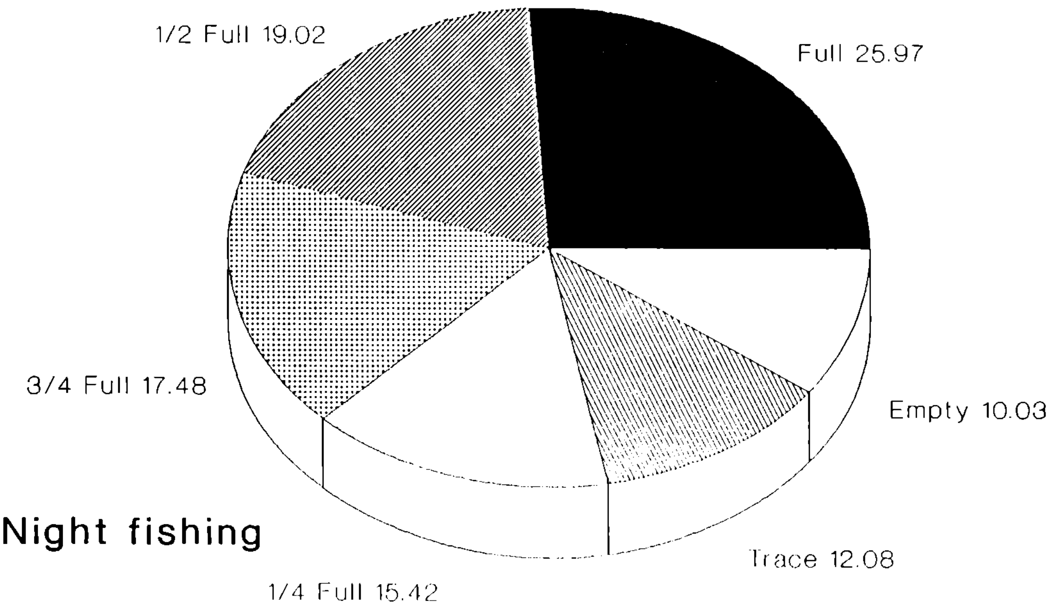
The monthwise details on intensity of feeding in numbers and percentages are given in Table 2. 4 and the same details for prawns caught during day and night times separately are given in Tables 2. 8 and 2. 9 respectively. Empty stomachs formed between 0.00 and 20.76 % in the night caught prawns while they were observed between 12.28 and 58.62 % in the prawns caught during day. The number of prawns with full stomach contents varied between 12.50 and 39.66 % in night catches whereas their maximum percentage was only 21.05 in the day time fishing. When the data for day fishing and night fishing for the whole year, were taken into consideration, the following details came to light.

Prawn with stomachs in 'empty' or 'trace' conditions constituted 47.18 and 22.11 % in the day and night fishery respectively. *M.monoceros* with full stomach content formed only 11.79 % in the day time fishery while they formed 25.97 % in the night fishery. The intensity of feeding in *M. monoceros* caught during day and night is shown separately in Fig. 2.5. Nearly two

Fig.2.5. Intensity of feeding in *M.monoceros* from trawl landings at Cochin Fisheries Harbour



a. Day fishing



b. Night fishing

third of the prawns caught during nights were actively fed while the same amount of prawns caught in day time were noticed to have fed very poorly. The above observations confirmed that the speckled shrimps feed actively during night time only.

2.3.2. FOOD AND FEEDING HABITS OF SPECKLED SHRIMPS FROM COCHIN BACKWATERS.

The food and feeding habits of 603 juvenile *M.monoceros* collected during 1991 from Cochin backwaters at Vypeen and 690 numbers at Thoppumpady fish landing centres were studied. The prawns were collected live from stake net catches.

2.3.2.1 Vypeen region:

The following food items in order of abundance were noticed in the stomach of brown shrimps of Vypeen region (between Cochin bar-mouth and Murukkumpadam) 1) *Acetes* spp. 2) prawns 3) other crustaceans 4) minor crustaceans (consisting mainly amphipods and rarely isopods) 5) polychaetes 6) detritus 7) fishes 8) copepods and 9) sand. The Index of Preponderance for individual food item for each month and for the whole year had been shown in Table 2. 10.

Acetes spp was an important food for juvenile *M.monoceros* for four months during January-March and the month of December ranking first among the stomach contents. The Index for *Acetes* spp was 90.47 in March and 72.81 in December indicating dependence of *M.monoceros* on *Acetes* spp alone to a greater extent as its food during these months. In January and February the food Index for *Acetes* spp. was 53.44 and 44.44 respectively. During peak monsoon months (June-August) *Acetes* spp were absent in the stomach contents. In other months the Index varied between 10.98 (September) and 20.24 (May). When the entire sample collected at Vypeen in 1991 were taken into account, the Index of *Acetes* spp was 43.08 ranking first among the stomach contents of juvenile *M.monoceros*.

Prawn group containing mainly post-larvae and mysis stages of penaeid prawns formed one of the main constituents in the stomach contents. They ranked first among the food items of *M.monoceros* at Vypeen backwaters in the month of April with an Index of 77.83 and second among the stomach contents in January, February and August with an Index of 42.80, 27.84 and 28.45 respectively. Prawns were absent in July and September and December and the Index for prawns during other months varied between 4.31 (November) and 17.72 (May). Prawns ranked second in importance as a food item with an Index of 21.30 for the year 1991.

Other crustaceans consisting mainly mysid type bits. small crab bits and unidentifiable crustacean bits ranked third in importance among the food items of *M.monoceros* at Vypeen during 1991 with an Index of 13.55. Other crustaceans were present in the stomach throughout the year. They constituted almost the entire food material in the month of June with an index of 91.05 and ranked first with an Index of 60.77 in May and 39.02 in August. They ranked third among the stomach contents in February and July. Their contribution as food was negligible in the months January, March and April (Table 2. 10). The Ponderal Index of other crustacens was between 2.19 (December) and 8.89 (September) during September-December period.

Minor crustaceans consisting mostly amphipod bits sometimes isopod shell bits and rarely fragments of Tanaidacean formed an important food item of *M.monoceros* during latter half of 1991. They ranked first among other food items in September and October with an Index of 35.10 and 35.91 respectively. They occupied the second position in stomach contents in July, November and December. For the period January-December, 1991 with an Index of 7.41, the other crustaceans ranked fourth in importance as a food item in spite of their presence only for 5 months in the later half of the year.

Polychaetes were identified by half digested flesh with setae embedded in it. Eventhough present in all months, polychaetes in appreciable quantities were noticed in the stomach contents only from July to November. They ranked first in the stomach contents in November with an Index of 53.14 and second in September and October with an Index of 15.19 and 31.08 respectively. For the year 1991, polychaete occupied fifth position among the stomach content of *M.monoceros* with a Index of 7.31.

Detritus ranked as sixth important food items in 1991. However, it formed the most important food item of *M.monoceros* with an index of 40.94 in the month of July. During other months, the food index of detritus varied between 1.75 (December) and 12.26 (August). The contribution of detritus as food item was almost insignificant in January, April, May and June.

Fishes identified mainly by scales and spines were present in the gut contents during most of the months in 1991. Appreciable quantities of them with an Index between 1.43 and 2.78 were noticed in January, July and September. Fishes ranked seventh among the stomach contents during 1991.

Copepods were noticed in good quantities in September alone and ranked third in the stomach contents with an Index of 11.29. For the year 1991 copepods ranked 8th among the food items.

Sand particles were encountered more in the month of September with an Index of 6.22 and in other months their occurrence was quite negligible.

The relative importance of food items of *M.monoceros* from stake net catches of Vypeen region is shown in Fig. 2. 6, *Acetes* spp, prawns, other crustaceans, minor crustaceans, polychaetes with food Indices of 43.08, 21.30, 13.55, 7.41 and 7.31 respectively were the important food items of juvenile *M.monoceros* in order of abundance. The relative importance of stomach contents as groups namely, polychaetes, crustaceans, fishes and detritus is shown in Fig. 2.7, for the year 1991. It is clearly seen from the figurative expression that crustacean group (*Acetes* spp : 50 %); prawns : 25 %, other crustaceans : 16 % and minor crustaceans : 9 % contributed to 85.73 % of the stomach contents, thus forming the most important food item of juvenile *M.monoceros* at Vypeen. Polychaetes ranked second with an Index of 7.31 followed by detritus (Index : 5.69). Fishes with an Index of 1.27, occupied the last position among the food items during 1991.

2.3.2.2. Thoppumpady region:

Food and feeding habits of 690 juvenile *M.monoceros* collected from stake net operations at Cochin backwater near Thoppumpady-Edacochi region were studied. The following food

Fig.2.6. Relative importance of food items of *M.monoceros* from Cochin Backwaters during 1991

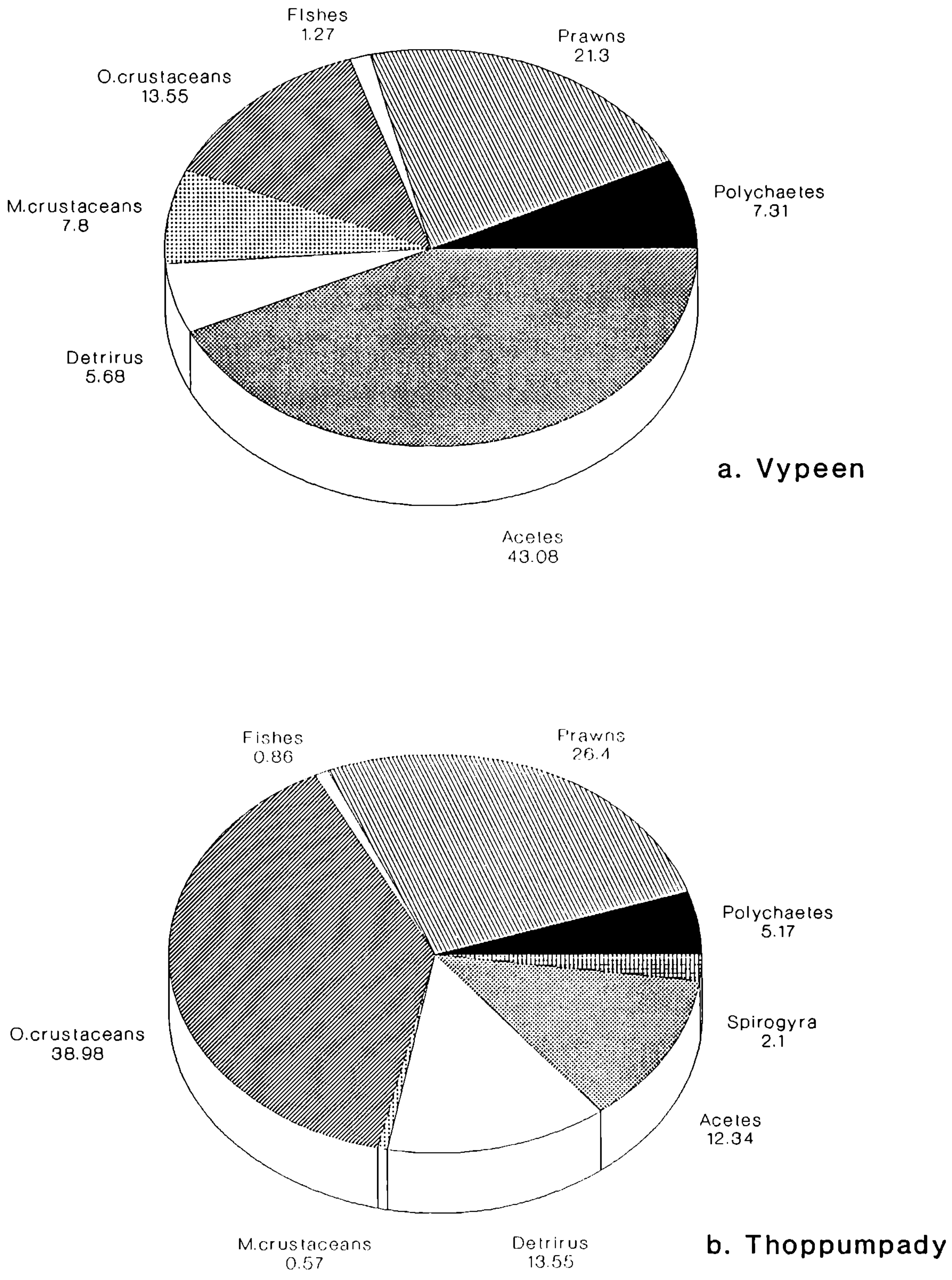
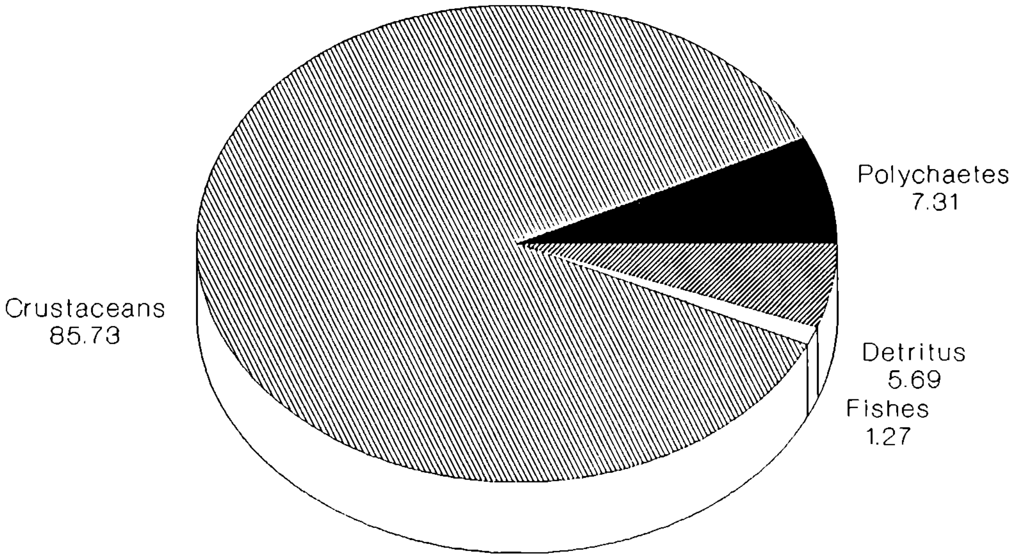
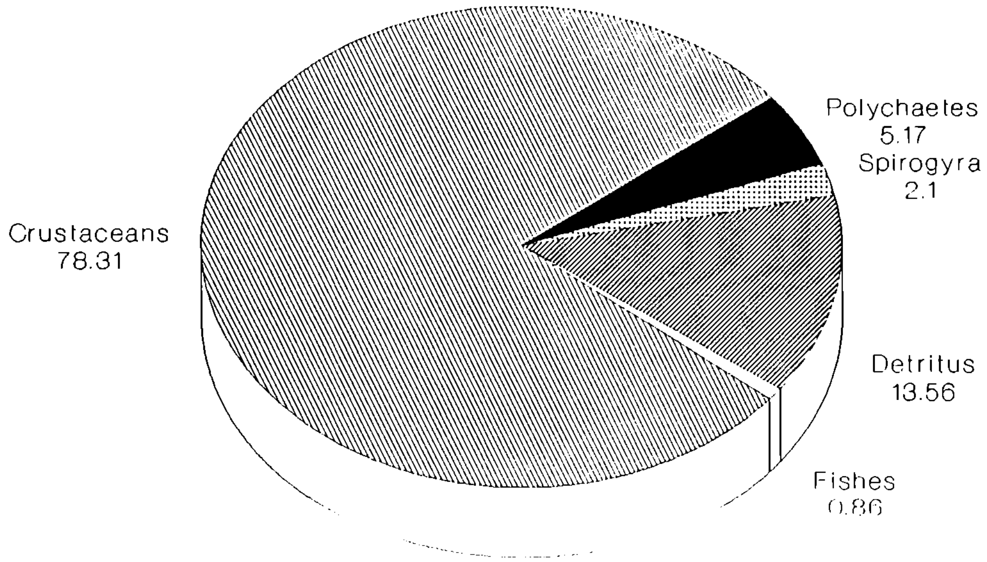


Fig.2.7. Relative importance of major food items of *M.monoceros* from cochin Backwaters during 1991



a. Vypeen



b. Thoppumpady

items were noticed in the stomach contents in order of abundance:1) other crustaceans 2) prawns (mainly mysis stages of penaeid groups, and juvenile *Metapenaeus* spp. and during monsoon season, fresh water prawns mostly, *Palaemon* spp.) 3) Detritus 4) *Acetes* spp. 5) Polychaetes 6) Blue green algae - mainly *Spirogyra* spp. 7) Fishes and 8) minor crustaceans (amphipods and rarely isopods). The detailed informations on Index of Preponderence, (monthwise and annual) for individual food items are given in Table 2. 11.

Other crustaceans were found in the stomach content of *M.monoceros* throughout the year as an important food item. They formed the main food during July-August with an Index of 71.43 in July and 68.44 in August and ranked first among other stomach contents during November-December with an Index of 38.37. They occupied the second position among the other food items in the months of January, March, September and October with Indices between 22.33 and 34.25. Their minimum contribution as food item was noticed in February'91 with an Index of 4.44. For the whole year, 1991, other crustaceans ranked first in the stomach content of *M.monoceros* collected from Thoppumpady region with an Index of 38.98.

Prawns are one among the main food items of juvenile brown shrimps occupying second position in importance for the year 1991 with an Index of 26.40. They were present in the stomach in all months. They turned out to be the most important food item in the month of April with an Index of 76.56. Prawns were ranked as second important food item in February. May, June, August, November and December with Indices between 12.18 in August and 30.23 in December (Table 2. 11). They became the third important food material in January, March and September.

Detritus was present in the stomach contents throughout the year but for the monsoon months (June-August). Detritus ranked first among the food items in September and October with Index of 30.27 and 33.19 respectively. It ranked third in importance in the months of February, May, November and December. Among the important food items of *M.monoceros* detritus occupied the third position during January-December 1991 with an Index of 13.55.

Acetes spp. became the most important food item of *M.monoceros* ranking first in the months of January, February, March and May with Indices of 52.08, 46.46, 36.19 and 45.51 respectively. During September-December '91 the Index ranged between 3.11 (October) and 12.85 (November). *Acetes* spp. were absent in the stomach during peak monsoon months. For the entire period of 1991*Acetes*spp. ranked fourth among the stomach contents with an Index of 12.34.

Polychaetes were present in the stomach in appreciable quantities during Fdbruary-May and July-November periods. They formed the third important food item in July and October with Index of 9.46 and 14.79 respectively and ranked fourth in February, August and September. However, during 1991, polychaetes ranked fifth (Index : 5.17) among the food items of *M. monoceros*.

Algae as a food for *M.monoceros* was observed only in the months of June and July. It was represented by the bluegreen filamentous algae - *Spirogyra*. During the peak monsoon in the month of June *Spirogyra* was observed to be the most important food for *M.monoceros*, ranking first with an Index of 72.65. However in July the dependance on *Spirogyra* as food had lessened and it ranked second with an Index of 10.02. *Spirogyra* ranked sixth among the food items during 1991 with an Index of 2.10.

Fishes mainly small juveniles were noticed in appreciable quantities in the stomach of brown shrimp in July, August and October. The maximum representation of fishes with an Index of 6.33 was recorded in July which led to their ranking to be fourth in the stomach contents. However for the year 1991, fishes ranked seventh as a food item.

Minor crustaceans consisting mainly amphipods and rarely isopods were seen in the stomach during August-November period only. They ranked eighth among the food items of *M.monoceros* in 1991.

A few numbers of copepods were encountered in the stomach during August-November and sand particles were rarely seen separately among the stomach contents.

The relative importance of main food items of juvenile *M.monoceros* of Cochin backwaters between ThoppumpadY and Edacochin region is shown in Fig. 2.6. Other crustaceans with an Index of 38.98 were the predominant food item followed by prawns with Index of 26.40 ; detritus formed the third important food item (Index : 13.55) and the fourth one was Acetes spp (Index 12.34). These four group viz. other crustaceans, prawns, detritus and *Acetes* spp with total Preponderal Index of 91.27 constituted the main food items of *M.monoceros* caught from ThoppumpadY-Edacochin region.

The food items were merged to form important groups to get a clear image on the food preference of these prawns (Fig.2.7). Crustacean (other crustaceans 50%, prawns 33%, *Acetes* spp. 16% and minor crustaceans 1%) turned out to be the most important food item of juvenile *M.monoceros* with an index of 78.31. The next important food was detritus with an Index of 13.56. Polychaetes with an index of 5.17 ranked third. Eventhough *Spirogyra* was consumed during June-July only, it was observed to be the fourth important food item. Fishes with an Index of 0.86 was ranked as fifth important food item of *M.monoceros*.]

2.3.2.3. Feeding intensity:

Vypeen: Actively fed prawns formed 75.51 % in January; 53.19% in April and 66.00 % in October. During the other periods the feeding intensity of the prawn was less than 50.00%. The intensity of feeding was least in November and August (19.00-20.00%). For the entire duration of January-December 1991 the actively fed prawns constituted only 34.93 %.

Thoppumpady Among the prawns collected from Thoppumpady-Edacochin region, the actively fed prawns formed 52.94 and 52.17% in the months of January and February respectively. The minimum percentage of actively fed prawns (18.89) was observed in August. During the year 1991, the average percentage of prawns with maximum inclination towards food was observed to be 37.65.

The results on the feeding intensity of prawns caught by stake nets, based on the fullness of the stomach did not give a real picture since the prawns remain alive for a few more hours (between 1-5 hours) after their capture in the stake net itself, till they were brought to the shore. This should be the main reason for the feeding activity of juvenile *M.monoceros* from Cochin backwaters to remain below 38% in Thoppumpady and Vypeen centres.

2.4 DISCUSSION

Menon (1951) recorded that food of *Metapenaeus dobsoni* mainly consisted of varying organic matter mixed with sand and mud. Gopalakrishnan (1952) observed that vegetable matter and crustaceans formed the bulk of the food consumed and presence of other animals indicated its omnivorous habit. Panikkar and Menon (1956) stated that food of prawns consisted of detritus both animal and plant that accumulate at the bottom of their habitat. Hall (1962) opined that Penaeidae in general cannot be considered detritus feeders and grouped several Malaysian species according to their food preferences. George (1974) stated that while sand grains, mud and detritus formed lesser in importance, there was a predominance of small crustaceans and their remains in the stomach of juvenile *M.monoceros* from Cochin backwateers. He concluded that *M.monoceros* is carnivorous and shows preference for small crustaceans such as amphipods, mysids, Tanaidacea, copepods and decopod larvae. Kuttyamma (1974) observed that *M.monoceros* (size range 30-128 mm) is omnivorous and fed more on vegetable matter than other penaeid species. Subramanyam (1967) concluded that *M.affinis* was carnivorous in habit . Thomas (1972), Kishinoye (1900), Ikematsu (1955), Kubo (1956) and Yasuda (1956) also reported the carnivorous habits of various penaeid prawn species studied by them. Thomas (1980) noticed that the diet of *P.semisulcatus* consisted of a variety of food items such as polychaetes, crustaceans, molluscs, diatoms eventhough detritus and sand formed bulk of the stomach contents. Commenting on the food of *P.monodon* from Chilka Lake, Mohanty (1975) stated that detritus, molluscs, plant matter and crustaceans form the major items of food in the order of abundance indicating its omnivorous feeding behaviour. Whereas Marte (1980) concluded that *P.monodon* in Philippine waters is less of a scavenger and more of a predator of slow moving benthic macro-invertebrates, mainly small crabs and molluscs.

Tiews *et al* (1968) drew a different picture regarding food and feeding habits of some Philippine shrimps (*P.semisulcatus*, *P.merguiensis*, *P.canaliculatus* and *M.monoceros*) where, they found that the main food of these species were benthic foraminiferans. They further suggested that the diet composition was related to the availability of food items within the selective feeding. The analysis of gut contents of *M.monoceros* from the estuarine and marine conditions by Subrahmanyam (1973) indicated that the most common food items of estuarine prawns were small crustaceans, algae, foraminifera, small molluscs and organic detritus; while the marine prawns subsisted mainly on small crustaceans. Based on detailed studies on the feeding biology of *M.monoceros* along the Kakinada coast during 1974-75 period, Rao (1988c) stated that the food of this species in the inshore waters comprised of mainly smaller crustaceans, polychaetes, prawns, detrius, fishes and algae and juvenile from backwaters depended on detritus, other crustaceans algae, copepods, polycheates, prawns and molluscs. He further stated that juvenile *M.monoceros* was omnivorous but it became carnivorous on attaining adulthood.

In the present study, the following food items were found in the stomach of *M.monoceros* from inshore waters of Cochin in the order of abundance: 1. Polychaetes, 2. detritus, 3.fishes, 4. prawns 5. sand 6. other crustaceans (consisting of crabs, mysids and unidentified crustaceans) 7. minor crustaceans (amphipods) 8. molluscs and 9. foraminiferans. The most important food item was polychaete with food Index of 43.76; and probably due to the browsing habit of the prawn species, detritus (Index: 16.36) had an edge over the other two important food item namely fishes (Index : 14.86) and prawns (Index : 13.16) Polychaetes, detritus, fishes and crustaceans (prawns, small crabs unidentified crustaceans and amphipods) constituted totally about 92.00% of the stomach contents of the speckled shrimp. Rao (1988c) stated that *M.monoceros* along the Kakinada coast feed on the water column, the pelagic forms such as sergestids and cephalopods. However, such habits were not exhibited by brown shrimps of Kerala coast in the present study. Actively fed prawns constituted 53.42% and the feeding intensity was higher in females of *M.monoceros* than the males. Females in different maturity stages were found to feed more vigorously than the immature ones; however when the total population is taken juveniles were observed to be active feeders thus indicating immature males feed more intensely than the adults. Significant differences in the food preferences were not noticed between the juveniles and adults which agrees well with the observations of Gopalakrishnan (1952) and Thomas (1980). Rao (1988c) stated that juvenile *M.monoceros* change their food habit from omnivorous to carnivorous on attaining adulthood. Eldred *et al* (1961) found *P.duorarum* which is also a burrowing species like *M.monoceros* to be mainly nocturnal feeder. Thomas (1980) observed that intensity of feeding in *P.semisulcatus* was better during darker hours of the day. Rao (1988c) also observed that feeding intensity in *M.monoceros* was more in the nights. The above said observation agree very well with the present studies in which *M.monoceros* was found to feed more intensely during night-time than the day hours. The order of preference of the food item differ between day and night caught prawns. The main food items of brown shrimps were polychaetes, detritus, prawns and fishes during night time while they were fishes, polychaetes, prawns, sand, amphipods and detritus in day caught *M.monoceros* in order of abundance.

M.monoceros in the Cochin backwaters differ in their food preferences from those from inshore shrimp grounds of Cochin. They fed mainly on crustaceans and the selectivity of food materials differ between places in the same environment. *M.monoceros* juveniles from Vypeen region which is in the proximity of the Cochin bar mouth, fed mainly on *Acetes* spp.

prawns, other crustaceans, amphipods, polychaetes and detritus in order of abundance during 1991. This prawn species from Thoppumpady-Edacochin region which is about two km from bar mouth preferred mainly other crustaceans, prawns, detritus and *Acetes* spp. The common feature of the observation was, in both centres *Acetes* spp. mostly dominated as food of *M.monoceros* during their peak occurrence in the stake net catches i.e. December-May period. The difference in stomach contents and food preference was mainly due to availability within the ambit of selectivity. This observation agrees with the statement of Tiews *et al* (1968). During peak monsoon months *M.monoceros* survived only on *Spirogyra* spp. at Thoppumpady region. This feeding habit of the species showed their adaptability in unfavourable conditions of nonavailability of other preferred food items. Results of the food and feeding studies of juvenile brown shrimps in the Cochin backwaters showed that they are carnivorous which agrees well with the observations of George (1974) in particular and with those made by Subrahmanyam (1967).

M.monoceros is one among the important penaeid species utilised for prawn culture practises (Chen, 1976). There is a very good scope for this species to be taken up for semi-intensive culture practises in India due to their larger size among the *Metapenaeus* group. In this context the result of the present studies may enable to select suitable food material for the brown shrimp for cultivable purposes. Experiments using different food materials such as detritus, mangroove leaves, compounded diets etc were carried out on *M.monoceros* by various research workers (Quasim and Easterson, 1974; Royan *et al*.1977; Alfred *et al*. 1978; Sumitra Vijayaraghavan *et al* 1978, Ramdhas and Sumitra Vijayaraghavan, 1979). Royan *et al* (1977) after testing food conversion efficiency of *M.monoceros* with different test diets stated that eventhough prawns could survive well on low protein and low caloric diet such as detritus, the conversion efficiency and relative growthrate were high in prawns fed with diets containing 60 % protein. *M.monoceros* gave best growth with a diet containing 55% Casein (Kanazawa *et al* 1981). These observations lead us to confirm that *M.monoceros* grow well with animal food or pelletised food material with more protein contents.

The present studies on food and feeding habits of the speckled shrimp made us to conclude that *M.monoceros* mainly depended on animal food items and were carnivorous, irrespective of the size and sex in both marine and estuarine conditions. Polychaetes given as food leads to better growth in *M.monoceros* has been confirmed by experiments conducted by Kaliperumal *et al*. (1993). In the present studies too, polychaetes were the predominant food item of *M.monoceros* in marine conditions. Hence results of the present studies enable us to conclude along with other studies that the most suitable food for *M.monoceros* for cultivable purposes should be a combination of crustaceans (*Acetes* spp. prawn, small crabs etc) fishes and annelids (mainly polychaetes) or pelletised feed consisting equal quantity of protein contents.

Table 2.1 Index of Preponderance of food items in the stomach contents of *M.monoceros* in the trawl landings at Cochin during 1991

Months	Polychaetes	Prawns	Fishes	Molluscs	Other Crustaceans	Minor crustaceans	Detritus	Foraminiferans	Sand	Feeding intensity	No.of prawns observed
January	21.15	4.30	19.53	4.87	0.74	-	44.85	0.03	4.53	69.77	43
February	62.91	4.09	4.30	-	0.60	0.17	24.36	0.11	3.46	77.59	56
March	52.34	3.30	3.71	-	3.52	0.45	26.92	0.09	9.67	57.14	50
April	15.56	12.43	15.46	-	3.92	3.49	41.28	-	7.86	50.00	51
May	8.42	53.02	28.40	2.00	3.41	0.13	3.31	-	1.31	54.00	47
June	7.10	26.51	48.09	-	1.25	2.06	2.40	-	12.59	52.63	50
July	58.71	6.81	0.06	0.28	0.03	1.34	13.28	-	19.49	42.86	22
August	9.65	23.47	24.31	0.40	1.53	0.46	6.83	-	33.35	8.62	24
September	40.33	2.65	26.61	0.25	1.90	19.64	4.13	0.11	4.38	42.31	45
October	83.07	7.97	2.05	0.19	0.81	0.02	3.19	-	2.70	61.36	37
November	84.99	0.85	5.34	-	0.80	0.51	3.85	0.14	3.52	58.62	24
December	39.76	21.51	4.39	5.76	9.74	0.30	1.06	-	7.48	69.81	42
Total	43.76	13.16	14.86	0.54	2.35	1.29	16.36	0.03	7.65		491

Table 2.2 Index of Preponderance of food items for juveniles and adults oof M.monoceros during 1991

Food Items	March		April		June		October		Total duration	
	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult
Polychaetes	32.88	57.71	10.77	15.19	8.98	6.27	87.28	73.50	50.18	34.92
Prawns	2.76	3.21	17.03	8.59	6.72	37.20	8.21	6.84	12.99	14.57
Fishes	3.92	3.56	0.13	29.12	67.72	38.52	1.45	2.85	11.43	19.09
Molluscs	-	-	-	-	-	-	-	0.93	-	0.04
Other crustaceans	10.93	2.19	2.18	4.30	2.29	0.85	0.11	2.48	2.58	2.81
Minor crustaceans	3.49	0.11	-	7.10	3.38	1.57	-	0.12	0.71	1.80
Detritus	45.07	21.93	69.72	21.27	1.76	1.93	0.28	10.60	17.93	14.09
Foraminiferans	-	0.14	-	-	-	-	-	-	-	0.02
Sand	0.95	11.15	0.17	14.43	9.15	13.66	2.67	2.68	4.18	12.72
Number of prawns observed	10	40	14	37	14	36	16	18	54	131

Table 2.3 Index of Preponderance of food items of *M.monoceros* in the day and night catches of trawlers at Cochin Fisheries Harbour during 1991

FOOD ITEMS	DAY CATCH		NIGHT CATCHES	
	Index	Rank	Index	Rank
POLYCHAETES	26.76	2	48.23	1
PRAWNS	15.28	3	11.74	3
FISHES	30.28	1	10.15	4
MOLLUSCS	0.21	8	0.68	7
OTHER CRUSTACEANS	1.36	7	2.68	6
MINOR CRUSTACEANS	5.77	5	0.41	8
DETRITUS	5.75	6	20.69	2
FORAMINIFERANS	0.01	9	0.03	9
SAND	14.58	4	5.39	5

Table 2.4 Intensity of feeding *M.monoceros* from inshore waters of Cochin during 1991 in numbers and percentages

Month	Empty	Trace	1/4 full	1/2 Full	3/4 Full	Full	Actively fed	Poorly Fed	Total No. of prawns observed
JANUARY									
Nos	-	6	7	14	6	10	30	13	43
%	-	13.95	16.28	32.56	13.95	23.26	69.77	30.23	
FEBRUARY									
Nos	2	3	8	7	15	23	45	13	58
%	3.45	5.17	13.79	12.07	25.86	39.66	77.59	22.41	
MARCH									
Nos	6	7	11	16	9	7	32	24	56
%	10.72	12.50	19.64	28.57	16.07	12.50	57.14	42.86	
APRIL									
Nos	5	9	14	7	13	8	28	28	56
%	8.93	16.07	25.00	12.50	23.21	14.29	50.00	50.00	
MAY									
Nos	3	9	11	11	3	13	27	23	50
%	6.00	18.00	22.00	22.00	6.00	26.00	54.00	46.00	
JUNE									
Nos	7	9	11	12	6	12	30	27	57
%	12.28	15.79	19.3	21.05	10.53	21.05	52.63	47.37	
JULY									
Nos	6	7	3	4	3	5	12	16	28
%	21.43	25.00	10.71	14.29	10.71	17.86	42.86	57.14	
AUGUST									
Nos	34	13	6	3	2	-	5	53	58
%	58.62	22.41	10.34	5.17	3.46	-	8.62	91.38	
SEPTEMBER									
Nos	7	9	14	12	4	6	22	30	52
%	13.46	17.31	26.92	23.08	7.69	11.54	42.31	57.69	
OCTOBER									
Nos	7	7	3	8	4	15	27	17	44
%	15.91	15.91	6.82	18.18	9.09	34.09	61.36	38.64	
NOVEMBER									
Nos	5	3	4	5	5	7	17	12	29
%	17.24	10.35	13.79	17.24	17.24	24.14	58.62	41.38	
DECEMBER									
Nos	11	3	2	6	13	18	37	16	53
%	20.76	5.66	3.77	11.32	24.53	33.96	69.81	30.19	
JAN-DEC'91									
Nos	93	85	94	105	83	124	312	272	584
%	15.92	14.56	16.10	17.98	14.21	21.23	53.42	46.58	

Table 2.5 Feeding intensity of females and males of *M.monoceros* from Cochin trawl grounds during 1991

Month	ACTIVELY FED		POORLY FED		COMBINED		Total No.of prawns observed
	Female	Male	Female	Male	Actively fed	Poorly fed	
JANUARY	82.61	55.00	17.39	45.00	69.77	30.23	43
FEBRUARY	93.33	60.71	6.67	39.29	77.59	22.41	58
MARCH	69.70	39.13	30.30	60.87	57.14	42.86	56
APRIL	60.71	39.29	39.29	60.71	50.00	50.00	56
MAY	53.33	54.29	46.67	45.71	54.00	46.00	50
JUNE	48.57	59.09	51.43	40.91	52.63	47.37	57
JULY	44.44	42.11	55.56	57.89	42.86	57.14	28
AUGUST	2.70	19.05	97.30	80.95	8.62	91.38	58
SEPTEMBER	46.15	38.46	53.85	61.54	42.31	57.69	52
OCTOBER	65.22	57.14	34.78	42.86	61.36	38.64	44
NOVEMBER	60.00	57.14	40.00	42.86	58.62	41.38	29
DECEMBER	78.57	60.00	21.43	40.00	69.81	30.19	53
ANNUAL %	57.95	48.58	42.05	51.42	53.42	46.58	584

Table 2.6 Intensity of feeding in percentage for juveniles and adults of _M. monoceros_ during 1991 in the trawl grounds of Cochin

Months	Juveniles			Adults		
	Actively Fed	Poorly Fed	Total No. observed	Actively Fed	Poorly Fed	Total No. observed
MARCH	63.64	36.36	11	55.55	44.45	45
APRIL	79.99	20.01	15	29.27	60.97	41
JUNE	53.33	46.67	15	52.38	47.62	42
OCTOBER	66.67	33.33	21	56.52	43.48	23
TOTAL	66.13	33.87	62	50.33	49.67	151

Table 2.7 Feeding intensity of female *M.monoceros* in different stages of maturity with percentages in parenthesis

Stages of Maturity	Empty	Trace	1/4 full	1/2 full	3/4 full	Full	Poorly fed	Actively fed	Total No. of Prawns
Immature	21 (34.42)	4 (6.56)	3 (4.92)	3 (4.92)	11 (18.03)	19 (31.15)	28 (45.90)	33 (54.10)	61
Early maturing	2 (9.09)	2 (9.09)	2 (9.09)	8 (36.37)	2 (9.09)	6 (27.27)	6 (27.27)	16 (72.73)	22
Late maturing	- -	- -	5 (18.52)	8 (29.62)	7 (25.93)	7 (25.93)	5 (18.52)	22 (81.48)	27
Mature	- -	- -	11 (32.35)	7 (20.59)	6 (17.65)	10 (29.41)	11 (32.35)	23 (67.65)	34
Spent	2 (3.64)	8 (14.54)	6 (10.91)	12 (21.82)	11 (20.00)	16 (29.09)	16 (29.09)	39 (70.91)	55

Table 2.8 Intensity of feeding in numbers and percentages during 1991- day fishing

Month	Empty	Trace	1/4 full	1/2 full	3/4 full	Full	Actively fed	Poorly fed	Total No. of Prawns observed
JUNE'91									
Nos	7	9	11	12	6	12	30	27	57
%	12.28	15.79	19.30	21.05	10.53	21.05	52.63	47.37	
JULY '91									
Nos	6	7	3	4	3	5	12	16	28
%	21.43	25.00	10.71	14.29	10.71	17.86	42.86	57.14	
AUGUST'91									
Nos	34	13	6	3	2	-	5	53	58
%	58.62	22.41	10.34	5.17	3.46	-	8.62	91.38	
SEPT.'91									
Nos	7	9	14	12	4	6	22	30	52
%	13.46	17.31	26.92	23.08	7.69	11.54	42.31	57.69	
TOTAL									
Nos	54	38	34	31	15	23	69	126	195
%	27.69	19.49	17.44	15.90	7.69	11.79	35.38	64.62	

Table 2.9 Intensity of feeding in numbers and percentage during 1991- night fihsing

Months	Empty	Trace	1/4 full	1/2 full	3/4 full	Full	Actively fed	Poorly fed	Total No. of Prawns observed
JANUARY'91									
Nos	-	6	7	14	6	10	30	13	43
%	-	13.95	16.28	32.56	13.95	23.26	69.77	30.23	
FEBRUARY									
Nos	2	3	8	7	15	23	45	13	58
%	3.45	5.17	13.79	12.07	25.86	39.66	77.59	22.41	
MARCH									
Nos	6	7	11	16	9	7	32	24	56
%	10.72	12.50	19.64	28.58	16.07	12.50	57.14	42.86	
APRIL									
Nos	5	9	14	7	13	8	28	28	56
%	8.93	16.07	25.00	12.50	23.21	14.29	50.00	50.00	
MAY									
Nos	3	9	11	11	3	13	27	23	50
%	6.00	18.00	22.00	22.00	6.00	26.00	54.00	46.00	
OCTOBER									
Nos	7	7	3	8	4	15	27	17	44
%	15.91	15.91	6.82	18.18	9.09	34.09	61.36	38.64	
NOVEMBER									
Nos	5	3	4	5	5	7	17	12	29
%	17.24	10.35	13.79	17.24	17.24	24.14	58.62	41.38	
DECEMBER									
Nos	11	3	2	6	13	18	37	16	53
%	20.76	5.66	3.77	11.32	24.53	33.96	69.81	30.19	
TOTAL									
Nos	39	47	60	74	68	101	243	146	389
%	10.03	12.08	15.42	19.02	17.48	25.97	62.47	37.53	

Table 2.10 Index of Preponderance of foode items in the stomach contents of *M.monoceros* from Cochin backwaters at Vypeen during the year 1991

Months	Polychaetes	Prawns	Fishes	Copepods	Other Crustaceans	Minor crustaceans	Detritus	Acetes spp	Spirogyra	Sand
January	0.26	42.80	2.78	-	0.34	0.01	0.34	53.44	-	0.03
February	0.04	27.84	0.07	0.19	20.42	-	7.00	44.44	-	-
March	0.84	5.31	0.48	0.01	0.54	-	1.91	90.47	-	0.44
April	0.46	77.83	0.66	-	0.71	-	0.09	20.10	-	0.14
May	0.38	17.72	0.76	-	60.77	-	0.13	20.24	-	-
June	1.77	6.65	0.44	-	91.05	-	0.09	-	-	-
July	12.74	-	1.43	-	20.52	22.66	40.94	-	-	1.71
August	16.42	28.45	0.12	0.49	39.02	-	12.26	-	2.87	0.37
September	15.19	-	2.29	11.29	8.89	35.10	10.04	10.98	-	6.22
October	31.08	7.11	0.79	1.07	6.31	35.91	6.40	11.33	-	-
November	53.14	4.31	-	-	3.90	13.94	10.34	13.89	-	0.48
December	0.36	0.09	0.39	0.05	2.19	22.36	1.75	72.81	-	-
Total	7.31	21.30	1.27	0.39	13.55	7.41	5.31	43.08	0.01	0.37

Table 2.11 Index of Preponderance of food items in stomach of *M.monoceros* from Cochin backwaters at Thoppumpady during the year 1991

Months	Polychaetes	Prawns	Fishes	Copopods	Other Crustaceans	Minor crustaceans	Detritus	Acetes spp	Spirogyra	Sand
January	0.02	17.99	-	0.07	26.01	-	3.81	52.08	-	0.02
February	8.27	23.33	-	-	4.44	-	17.50	46.46	-	-
March	3.01	21.62	-	-	34.25	-	4.93	36.19	-	-
April	3.52	76.56	-	-	8.37	-	6.90	4.58	-	0.07
May	2.00	21.79	0.16	-	11.51	-	18.61	45.51	-	0.42
June	-	14.40	-	-	12.10	-	0.85	-	72.65	-
July	9.46	2.46	6.33	-	71.43	-	0.30	-	10.02	-
August	4.65	12.18	11.17	0.12	68.44	1.53	1.91	-	-	-
September	15.54	15.84	0.39	0.03	22.33	5.97	30.27	9.63	-	-
October	14.79	6.23	3.18	0.02	24.57	4.89	33.19	3.11	-	0.02
November	9.03	24.18	0.15	0.10	38.38	1.52	13.78	12.85	-	0.01
December	0.64	30.23	0.28	-	38.37	-	20.16	10.32	-	-
Total	5.17	26.40	0.86	0.02	38.98	0.57	13.55	12.34	2.10	0.01

CHAPTER 3

AGE AND GROWTH

CHAPTER 3.

AGE AND GROWTH

3.1 INTRODUCTION

Studies on age and growth are of paramount importance in fishery biological investigations, since these are required both in assessing the changes in abundance of populations in relation to fluctuations in fishing pressure as well as in estimation of rates of mortality. Determination of age and growth of a species further helps in the study of biological characteristics such as, longivity, rate of growth, age at first maturity and age structure of the stock. The growth of penaeids, as in other crustaceans, varies with sex as well as other factors such as food quality, quantity, population density,light, temperature and salinity. The size attained by a crustacean at any age is determined by the number of moults and the increase in size at each moult. In practice, owing to difficulty in incorporating such phenomena in mathametical models growth is considered essentially a continuous process and it is measured as size at time or size at age directly. Hence all conclusions on growth presented by various authors represent overall increments in dimensions in a given period of time, which are summations of individual spurt of growth that has taken place at different moultings. Penaeids appear to conform with the typical crustacean growth pattern of a sigmoidal or 'S' shaped growth form (Dall *et al.* 1990).

The crustaceans do not have a bony structure which records an imprint of internal and environmental variations which would allow age to be read directly. Hence, reliance has perforce to be placed on methods of analysis of length frequency distributions in age determination (Bhimachar, 1965). The direct method of tagging and marking for studying the growth are unreliable operations in crustaceans owing to their discontinuous growth and occurrence of moultings (Garcia and Le Reste, 1981). Yano and Kobayashi (1969) stated that the number of lamellae in the endocuticle increase with size and thus may give some possibility of age determination. Sheehy (1990) suggested that morphological lipofuscin quantified by image analysis has significant potential as a means of age determination for crustaceans.

The studies on age and growth of penaeid prawns in India is mainly based on length frequency method. Some of the important works on age and growth of penaeid prawns along the Indian coasts are by Menon (1953), Rajyalakshmi (1961), George *et al* (1963), Banerji and George (1967), Ramamurthy (1967, 1980), Kurup and Rao (1974), Thomas (1975), Ramamurthy *et al* (1975, 1978), Lalitha Devi (1986, 1988) and Suseelan and Rajan (1989). The growth of *M. monoceros* from mysis to early juvenile stage was given by Rao (1973) based on rearing experiments. George (1959, 1975) and Menon and Raman (1961) studied the growth of juvenile brown shrimp based on the samples collected from Cochin Backwaters and nearby prawn farms. Subrahmanyam (1973) and Lalitha Devi (1988) observed the growth rate of *M. monoceros* in the Godavary estuarine system. The age and growth of *M. monoceros* along Kakinada coast was studied by Rao and Krishnamoorthi (1990) based on the trawl landings of 1974-1977.

Due to absence of regular catches of *M. monoceros* in appreciable quantities from the nearshore waters of Kerala, there has been no information on its age and growth from this state till now. From 1990 onwards, the trawlers extended their fishing trips from single day to 2-3 days, including shrimp trawling in deeper grounds during night. This multiday trawling has yielded better catches of brown shrimp. The situation thus facilitated to study the age and growth of *M. monoceros* along the Kerala coast based on data and samples collected during 1991-93. The present work gains importance as it is the first attempt to study the age and growth of *M. monoceros* along Kerala coast which is based on the brownshrimp catches fished from its natural habitat of 30-45 m deep shrimp grounds off Cochin coast and the details are given here.

3.2 MATERIAL AND METHODS

Data on length and weight of *M. monoceros* were collected from trawl landings at Cochin Fisheries Harbour. Length measurements were grouped into 5 mm class intervals (e.g. 81-85, 86-90, 91-95 etc, with mid points at 83, 88 and 93 mm). Length distribution was studied for males and females separately. The numbers in the length frequency distribution were raised to the total catch of the sampling day based on the sample weights. The data thus obtained for different sampling days in a month were pooled to get catch in numbers for all the sampling days which in turn, was raised to monthly catch. The monthly data so obtained during the three years period between 1991 and 1993 from Cochin Fisheries Harbour formed the basis for studies on length frequency analysis.

Putter (1920) developed a growth model which can be considered the base of most other models on growth including the one developed as a mathematical model for individual growth by von Bertalanffy (1938), and which has been shown to conform to the observed growth of most fish and prawn species. The theory behind various growth models is reviewed by Beverton and Holt (1957), Ursin (1968), Ricker (1975), Gulland (1969, 1983), Pauly (1984) and Pauly and Morgan (1987). A selection of methods for estimation of growth parameters applicable to tropical fisheries is given by Sparre *et al.* (1989). In the present work the age and growth of *M. monoceros* has been studied using von Bertalanffy growth model. The model involves 3 parameters L_{∞}, K, and t_0 and is given by

$$l_t = L_\infty \left[1-e^{-k(t-t_0)}\right]$$

where, l_t is the length at age, t; L_∞ the average asymptotic size to which the individual grows; k is the growth coefficient which determines how fast length of the fish approaches L_∞ ; and t_0 is the theoritical age of the individual fish at zero size.

The parameters for this growth equation were estimated in two different ways as described below:

I The first procedure involves the following :

a) Length frequency analysis to identify modes of different broods and study their progression over ages.

b) Ford-Walford method (Ford, 1933; Walford, 1946) for estimation of L_∞ and k.

c) Gulland method (1969) for estimation of t_0.

II. Alternatively, the parameters of the above model are estimated applying the ELEFAN I method (Electronic LEngth Frequency ANalysis) introduced by Pauly and David (1981).

Details and application of different methods are given while presenting results.

3.3 RESULTS

3.3.1 Fitting von Bertalanffy growth equation

3.3.1.1. Length frequency analysis

The method for the analysis of length frequency consists of two approaches, viz:- (1) "Peterson method" (sensu stricto) Peterson (1892) and (2) "the modal class progression analysis" (George and Banerji, 1964). The first approach involves attribution of relative ages to the distinct peaks of a single multi-peaked length frequency sample. Identifying the 'real' peaks representing different broods and attributing the proper relative age to them is the main problem in this method. In the "modal class progression analysis" method, individual peaks are followed through time series. The length frequency distribution of a number of samples, generally at monthly intervals, are studied to trace the progress of modes. The progression of modes from the first to those of subsequent months gives an idea of the growth of different broods in the population. This is the most commonly used method in the study of tropical fisheries because of its simplicity (Pauly and David, 1981).

In order to learn the age and growth of *M. monoceros* in the present study, "the modal progression analysis" method was used. The monthly size distribution of *M. monoceros* landed by shrimp trawlers at Cochin Fisheries Harbour during 1991-93 are given year-wise in Tables. 3.1 - 3.3 for females and 3.4 - 3.6 for males. Scatter diagrams of modal values for females and males of *M. monoceros* are shown in Figures 3.1 and 3.2 respectively. It was observed that most of the modes could be traced upto 3 months after which they lost their identity in the length frequency distribution. The modes traceable for 3 months are indicated in the scatter diagrams. These mode chains formed the basis for the estimation of the growth parameters, L_∞ and K.

3.3.1.2 Estimation of L_∞ and K

The Ford - Walford method which has been used to estimate these growth parameters is based on the following form of von Bertalanffy equation (Ford, 1933): $l_{t+1} = L_\infty (1-K) + K l_t$ where, l_{t+1} is length at time t+1, l_t is length at time t and K is <u>Fords growth coefficient</u> $(=e^k)$. Walford (1946) showed that when L_{t+1} is plotted against l_t and a straight line is adjusted to these points this line has a slope K and cuts the 45° diagonal at $L_t = L_\infty$. The modes selected for females and males of *M. monoceros* are given in Tables 3.7 and 3.8 respectively. The plot of l_{t+1} on l_t is shown in Figure 3.3 for females and in Figure 3.4 for males. In the case of females this line adjusted to the points intercepts the 45° line at 215 mm which is the estimate of

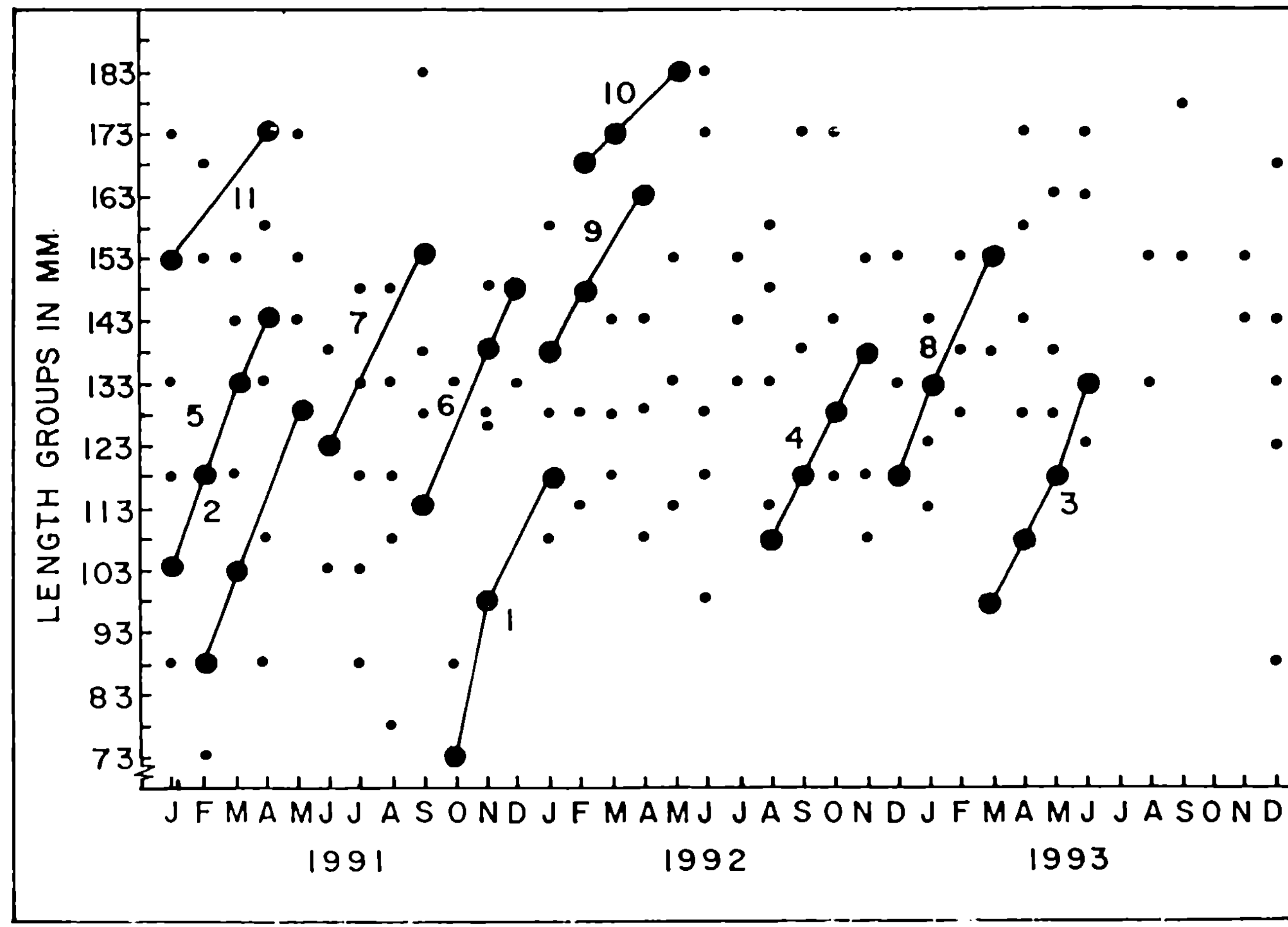


FIGURE 3.1. Scatter diagram of model values and mode-chains used for estimation of growth parameters of female *M. monoceros*.

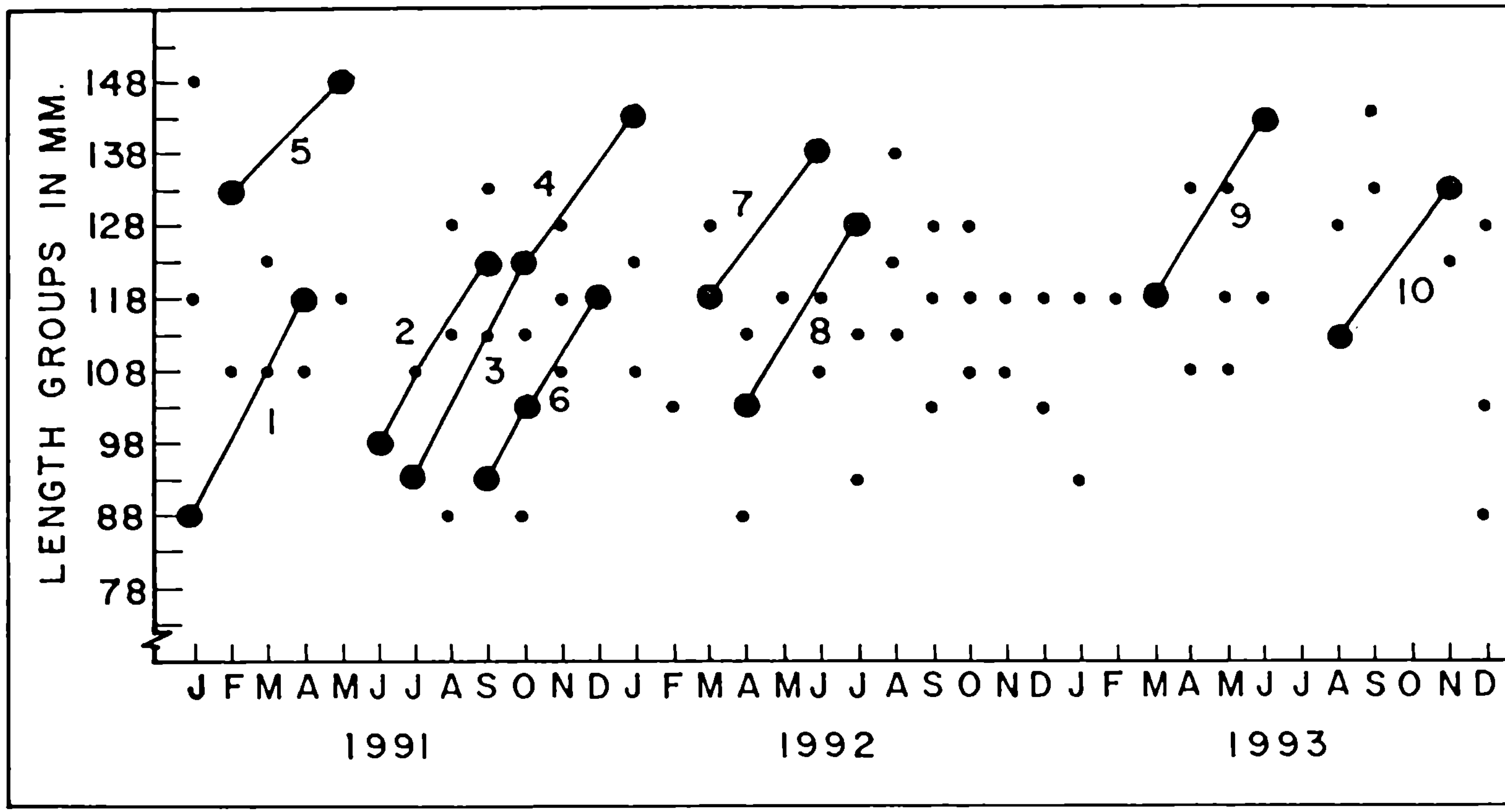


FIGURE 3.2. Scatter diagram of model values and mode-chains used for estimation of growth parameters of male *M. monoceros*.

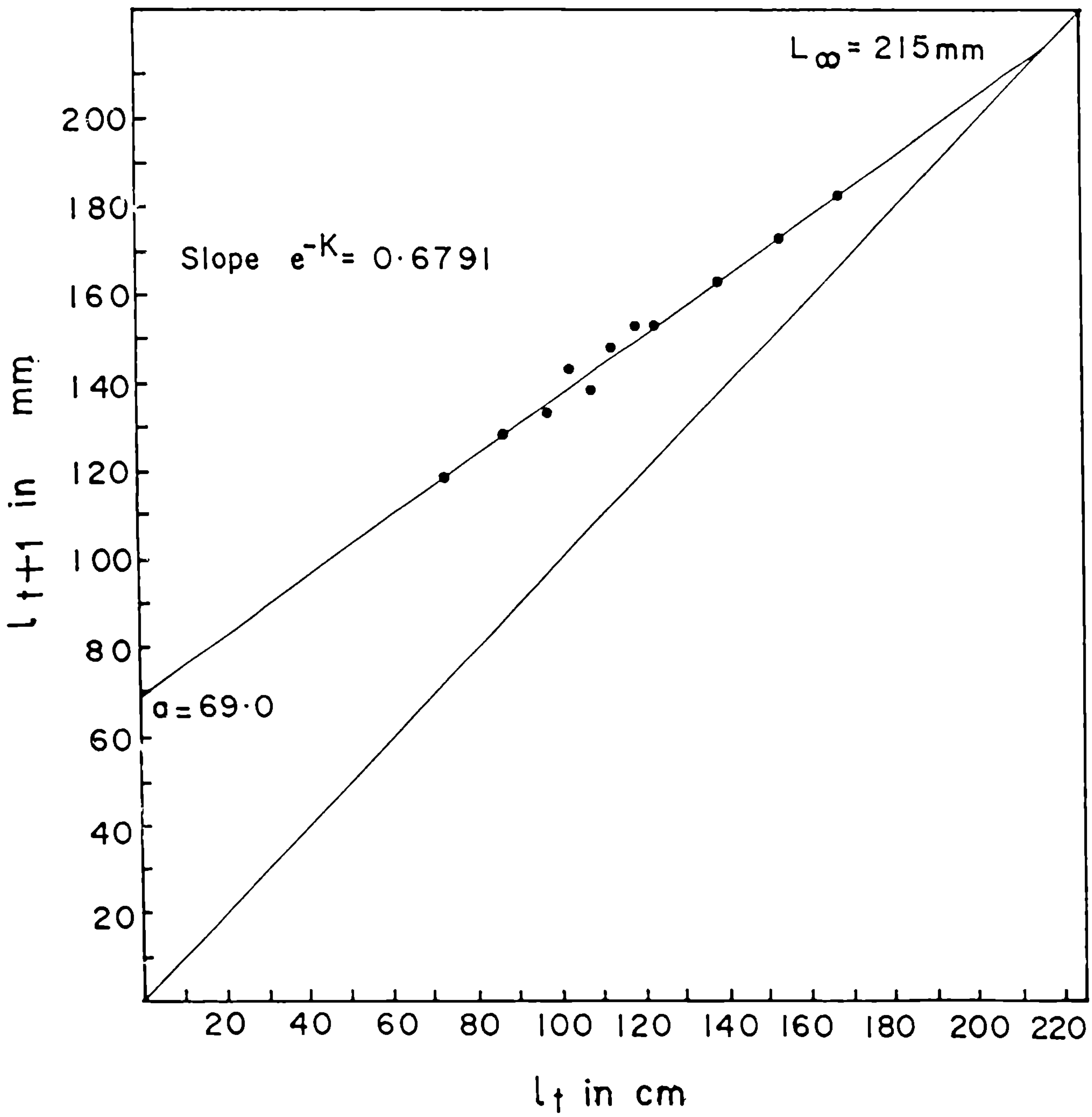


FIGURE 3.3 Graphical representation of estimation of growth parameters by Ford- Walford plot in females of *M. monoceros*.

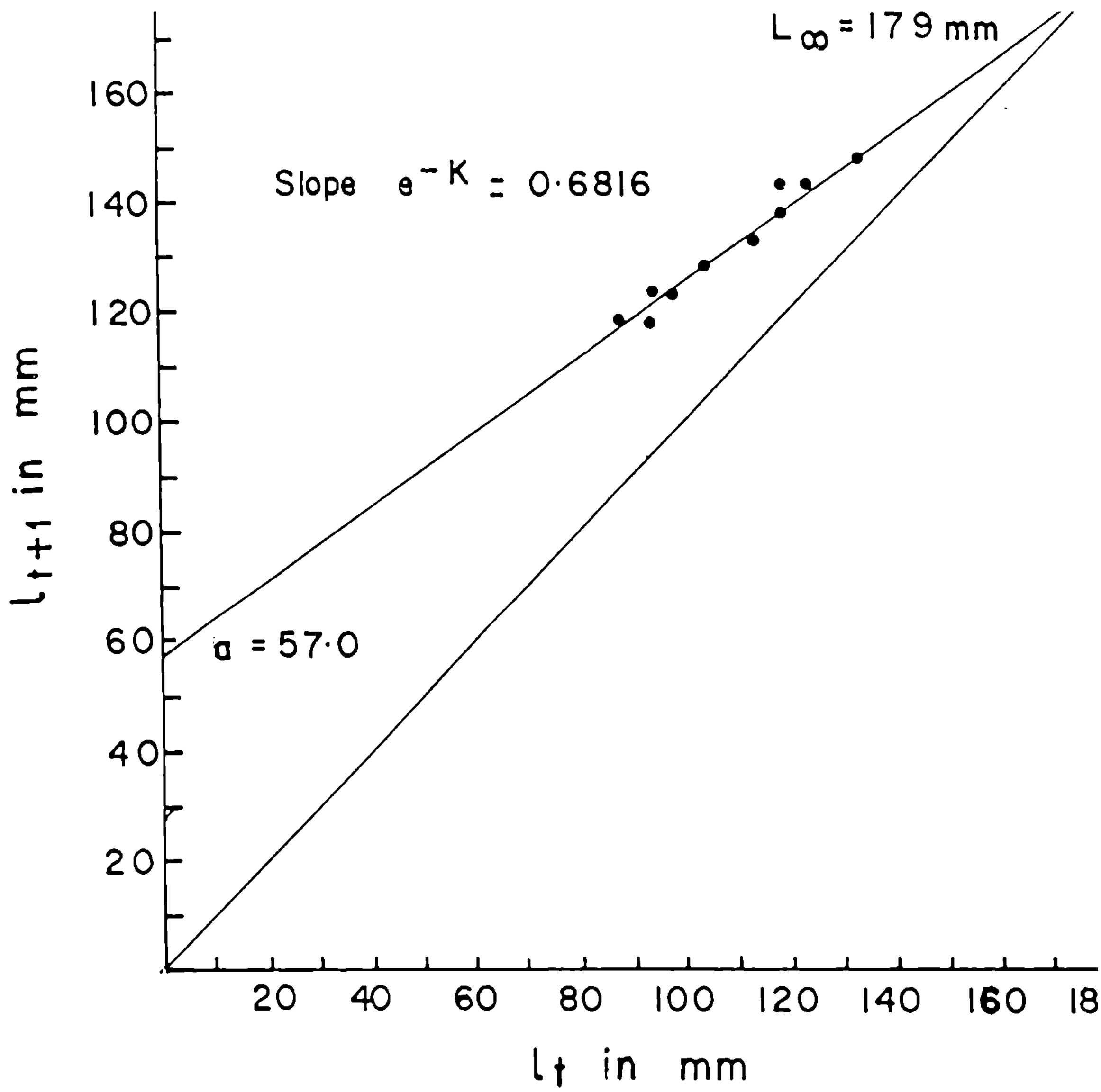


FIGURE 3.4 Graphical representation of estimation of growth parameters by Ford- Walford plot in males of *M. monoceros*.

L_∞ (asymptotic growth). The line at the other end cuts the Y axis at 69.0 giving the estimate constant 'a' of the regression describing the elevation of line. Slope of the line 'b' is related to K, the growth constant as $b = e^{-k}$ or $K = \log_e (1/b)$. Thus k was estimated as 0.38703 for 3 months and 1.5481 for an year (annual k). Similarly, the growth parameters for males were also estimated (Fig. 3.4) and the values of both sexes are as follows.

Sex	a	b	k (3 months)	k (annual)	L_∞
Females	69.0	0.67907	0.38703	1.5481	215 mm
Males	57.0	0.68156	0.38337	1.5335	179 mm

Provisional age - at length for *M. monoceros* was calculated with the help of these regression constants based on the relationship $Y = a + b x$ which formed the basis for estimation of t_0. The age at smallest length was fixed based on the studies on the growth of early juveniles of this species (George, 1959, 1975, Rao, 1973; Subrahmanyam 1973 and Lalitha Devi, 1988).

3.3.1.3 Estimation of t_0

The t_0 in the present study was estimated by the method of Gulland (1969) and obtained from the equation

$$Kt_0 - k\ t = \log_e (L_\infty - lt / L_\infty)$$

t_0 has been estimated by regression of $\log_e (L_\infty - l_t / L_\infty)$ on 't' which gives the values of constant 'a' and slope 'b'; t_0 is estimated by the relationship $t_0 = -a/b$. Details showing the estimation of t_0 for females and males of *M. monoceros* are given in Tables 3.9 and 3.10 respectively.

The graphical representation of t_0 estimation is shown in Figure 3.5. The slope is -k and intercepts K t_0 . The estimated t_0 (in months) are 0.7235 and 0.3106 for females and males of *M. monoceros* respectively. The t_0 (in years) amounted to 0.0603 for females and 0.0259 for males.

The growth parameters estimated by the methods, as explained earlier, are given below.

Sex	L_∞	k (annual)	t_0(in years)
Females	215 mm	1.5481	0.0603
Males	179 mm	1.5335	0.0259

The model most frequently used to get the best possible growth using a simple formula is that of von Bertalanffy (1938). The properties of von Bertalanffy model have been studied by a number of authors (Ricker, 1958, 1975; Gulland 1969; Silliman 1969 and Parrack 1979). Garcia and Le Reste (1981) and Ricker (1975) noted that the von Bertalanffy model most often agrees with what is observed and therefore can be applied as an empirical model.

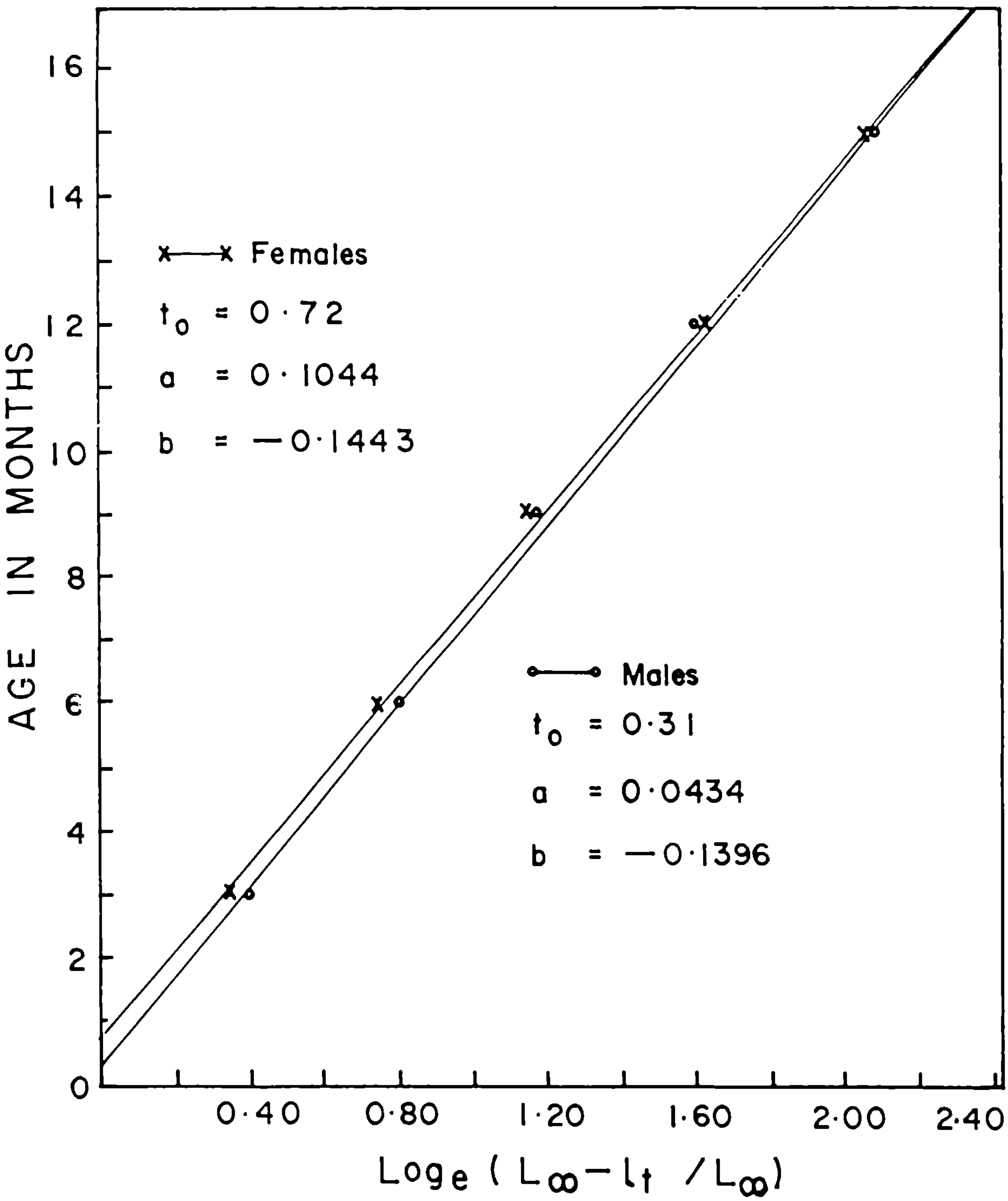


FIGURE 3.5 Estimation of t_0 in *M. monoceros*

Details indicating the fitting of von Bertalanffy equation to the growth data of females and males of *M. monoceros* are given in Tables. 3.11 and 3.12 respectively. The formulae thus derived are as follows:

$$\text{Females:} \quad l_t = 215 \left[1-e^{-1.5481\ (t-0.0603)}\right]$$

$$\text{Males:} \quad l_t = 179 \left[1-e^{-1.5335\ (t-0.0259)}\right]$$

The growth curves for females and males of *M. monoceros* based on these formulae are shown in Figure 3.6. The total length (in mm) at different age (in months) calculated for *M. monoceros* based on the application of von Bertalanffy growth equation in the present study are as follows.

Age (Months)	6	12	18
Length (mm)			
Females	106.15	164.81	191.85
Males	92.48	138.81	160.33

Thus the female *M. monoceros* grows to a size of 164.81 mm and 191.85 mm in total length at the end of 12 and 18 months respectively. Males are always found to be smaller than femals in the brown shrimp population. Accordingly, male *M. monoceros* measures 138.81 and 160.33 mm at the age of 12 and 18 months respectively.

The weight converted von Bertalanffy equation can be written as $W_t = W_\infty \left[1-e^{-k(t-t_o)}\right]^n$, where 'n' is the exponent of

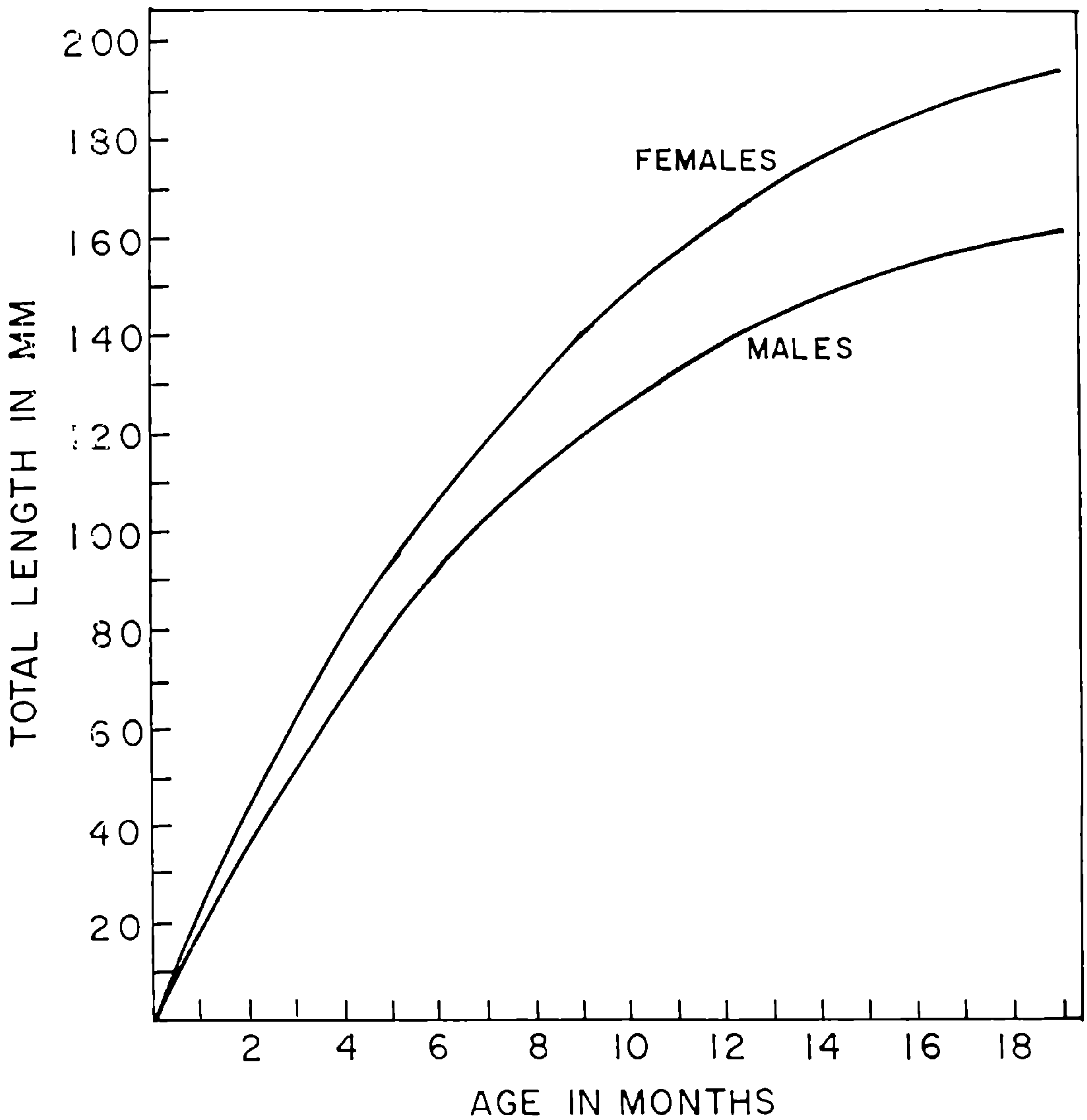


FIGURE 3.6 Growth curves of *M. monoceros* based on growth parameters estimated by modal progression, Ford - Walford and Gulland methods.

the length-weight relationship. Based on the length-weight relationships worked out in the present study, the weight converted von Bertalanffy equations fitted to data for *M. monoceros* are given below.

$$\text{Females: } W_t = 80.83 \left[1-e^{-1.5481(t-0.0603)}\right]^{3.1341}$$

$$\text{Males : } W_t = 37.63 \left[1-e^{-1.5335(t-0.0259)}\right]^{2.9004}$$

3.3.1.4. Application of ELEFAN I method

Gulland (1983) stated that the best procedure in practice is first to analyse length data by simple graphical method and to attempt to fit growth curves by well known methods; and if this produces sensible results, the ELEFAN or similar programmes can be used to extract the maximum amount of information from the data available. In the present study it has been learnt that the von Bertalanffy growth formula describes the mean growth of *M. monoceros* in the population and hence, the computer based length frequency analysis 'ELEFAN I method' was applied to study the age and growth of this species.

The "COMPLEAT ELEFAN" is a package of microcomputer programmes written in the language BASIC (Gayanilo *et al.*, 1988). It contains a number of programmes for fish stock assessment of which, "ELEFAN-I" deals with estimation of growth parameters using length frequency analysis (Pauly and David 1981, Pauly 1978). The 'ELEFAN-i method' consists of the following steps as given by Pauly *et al* (1984).

a. Identifying peaks and troughs, separate peaks in terms of deviations of each length class frequency from the corresponding running average frequency (peaks are positive, troughs negative deviations).

b. Attribute to each positive deviation a number of positive points, proportional to its deviations from the running average and attribute similarly, a certain number of negative points to each trough.

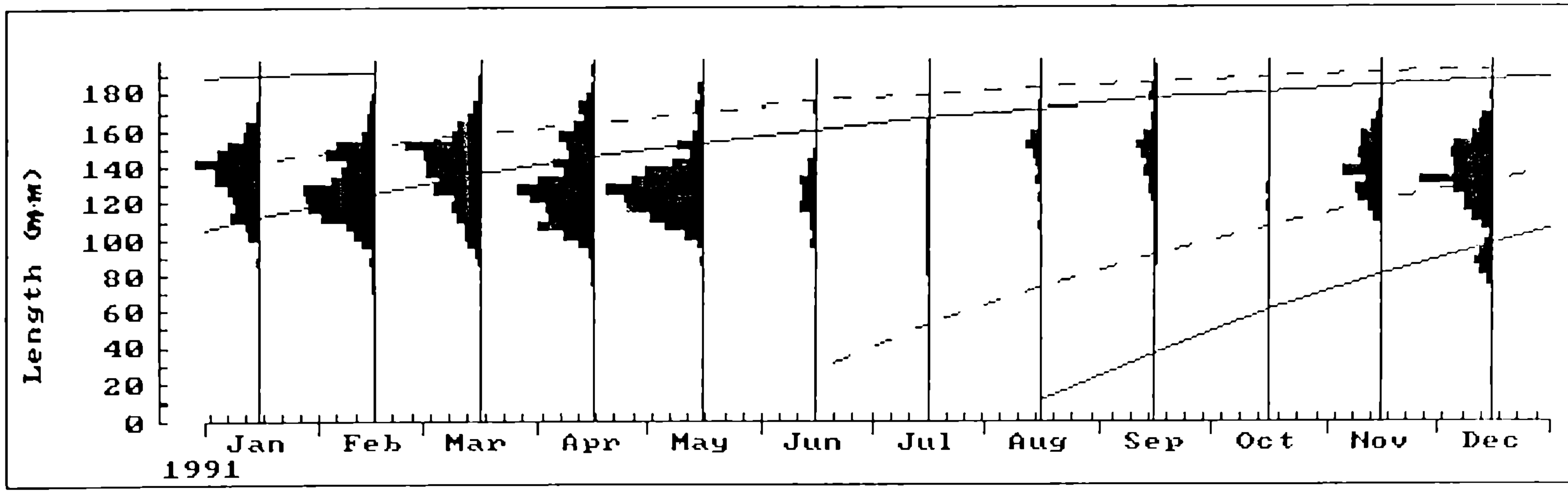
c. Identify the set of growth parameters, which, by generating a growth curve which passes through a maximum number of peaks and avoiding troughs as much as possible, accumulates the largest number of points termed, 'Explained Sum of Peaks' or ESP.

d. Divide the ESP by sum of points 'availble' in a set of length frquency samples i.e. by the 'Available Sum of Peaks' (ASP) to obtain an estimator of 'the goodness of fit; the ESP/ASP ratio, which generally ranges between 0 and 1, may be considered, analogous to a coefficient of determination (r).

The procedure for the estimation of best growth curve from the data set assumes that 1. the length frequency data are representative of the population; 2. the growth patterns are repeated from year to year; 3. the von Bertalanffy Growth Formula (VBGF) describes the mean growth in population and 4. all difference in size reflect difference in age. It is assumed in the ELEFAN I analysis that the value of the third parameter of von Bertalanffy growth function t_0 is zero (Pauly and David, 1981).

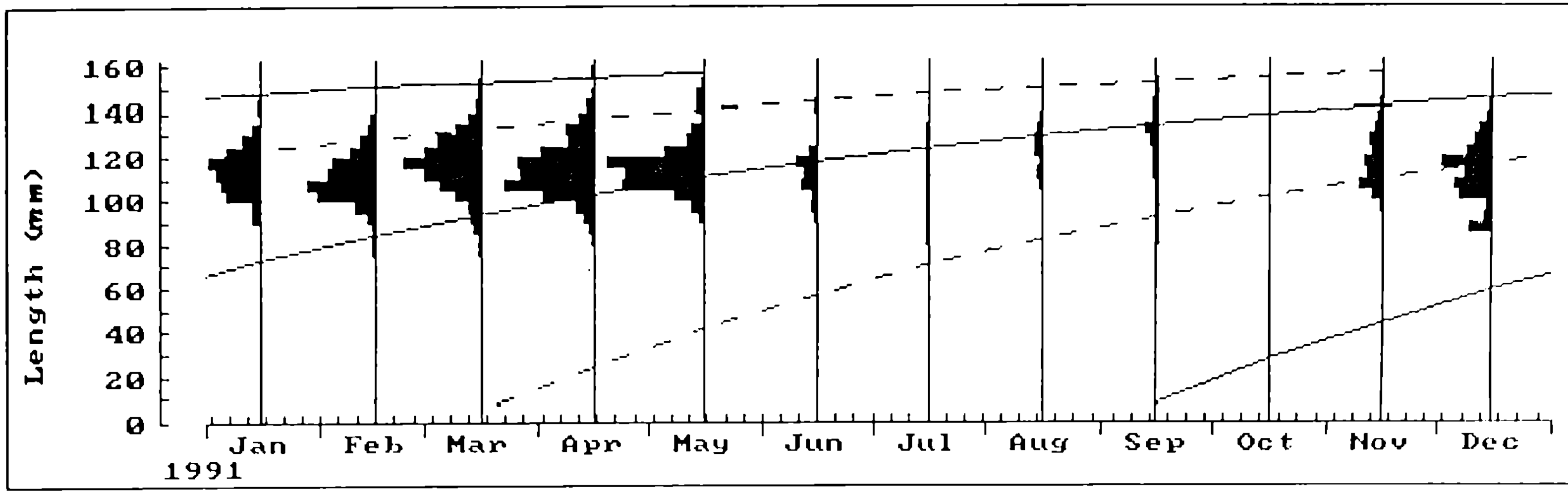
The L_∞ and K values of *M. monoceros* estimated by ELEFAN I method as per steps stated earlier are 204 mm and 1.8 for females; and 170 mm and 1.5 for males respectively. The growth curves derived by the ELEFAN I computer programme for females and males of the speckled shrimp are shown in Figures 3.7 and 3.8 respectively. The details on length at each month used by ELEFAN I programme to make the growth curves for *M. monoceros* are given in Table 3.13 for females and 3.14 for males.

It was observed that if a female *M. monoceros* was assumed to be born during August the expected length after 12 months (July) would be 166.53 mm (Table 3.13 and Figure 3.7). It will grow to 188.88 mm in January i.e. in 18 months (1 1/2 years old). In the same manner if a male was considered to be born in the month of September, the expected length it would reach at one year of age (Septmber-August) would be 129.12 mm (Table 3.14 and



Loo ▶	204.00	204.00
K ▶	1.800	1.800
C ▶	0.000	0.000
WP ▶	0.000	0.000
SS ▶	1	1
SL ▶	112.500	142.500
Rn ▶	0.132	0.111

FIGURE 3.7 Growth curves derived by the ELEFAN I computer programme for female *M. monoceros*



Loo	▸	170.00	170.00
K	▸	1.500	1.500
C	▸	0.000	0.000
WP	▸	0.000	0.000
SS	▸	4	9
SL	▸	102.500	92.500
Rn	▸	0.125	0.203

FIGURE 3.8 Growth curves derived by the ELEFAN I computer programme for male *M. monoceros*

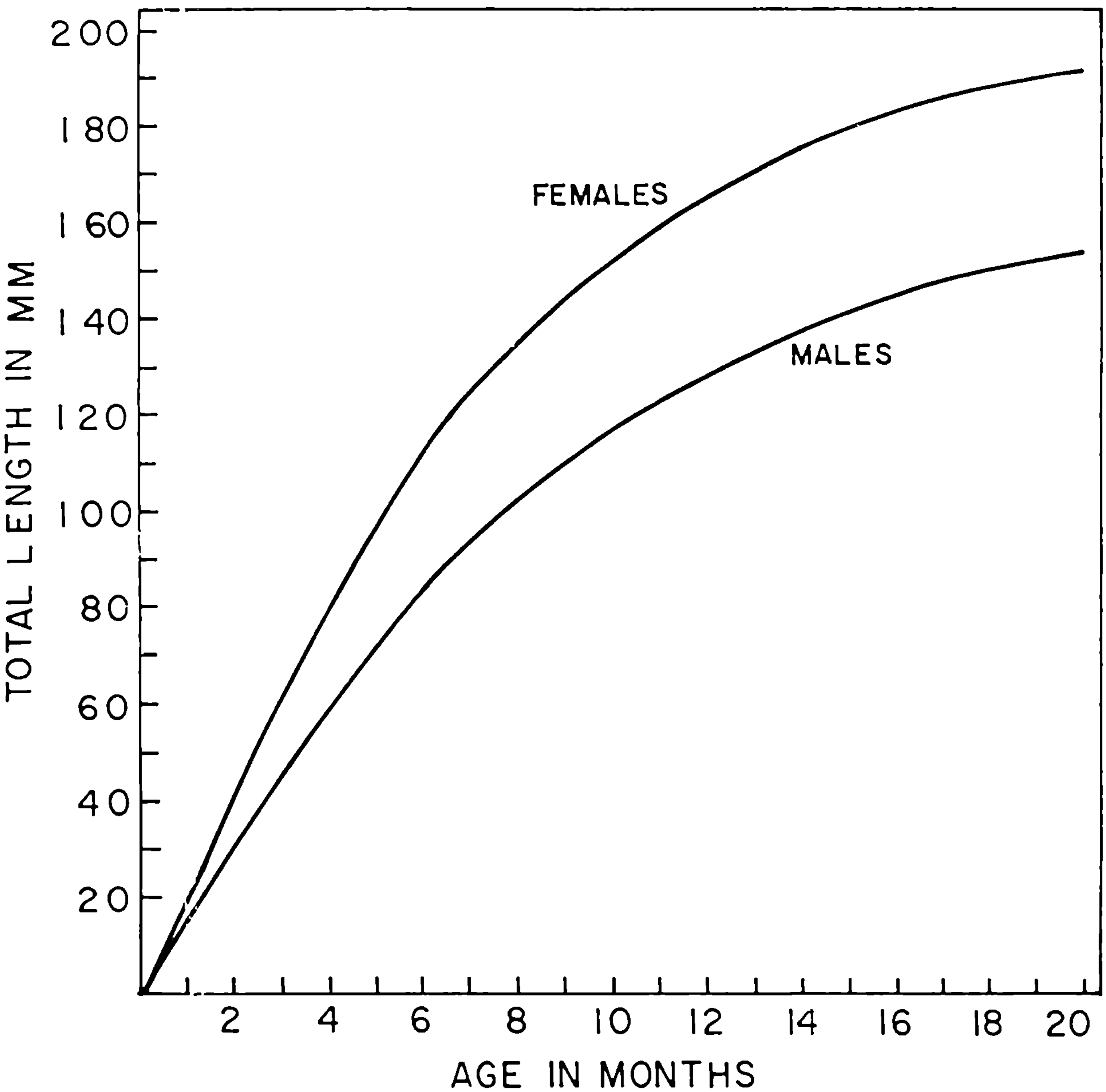


FIGURE 3.9 Growth curves depicting the age at length of *M. monoceros* based on growth parameters estimated by ELEFAN I programme.

Figure 3.8). In the month of February when the male brown shrimp is 1.5 years (18 months) old, it would measure 150.81 mm in total length. Based on the results thus obtained from the application of computer based length frequency analysis (ELEFAN I method) growth curves depicting age at length for *M. monoceros* are shown in Figure 3.9. The age of *M. monoceros* (in months) in relation to different length (in mm) as estimated by ELEFAN I method is given below:

Age (months)	6	12	18
Length (mm)			
Female	112.51	166.53	188.88
Males	83.98	129.12	150.81

3.4 DISCUSSION

Growth studies on wild population of penaeid prawns have been carried out by many Indian workers like Menon (1955),George *et al* (1963), Banerji and George (1967), Rao (1967), Kurup and Rao (1974), Thomas (1975), Ramamurthy *et al.* (1978), Lalitha Devi (1986), Sriraman *et al* (1989) Smitha and DevaraJ (1990), Rao *et al* (1993) and Sukumaran *et al.*,(1993 a), based on length frequency analysis. Most of the available studies on growth for *M. monoceros* are restricted to its juvenile phase. A monthly growth rate between 5.0 and 7.98 mm was recorded during the juvenile phase in the life history of brown shrimp from Cochin

Backwaters (George 1959; Menon and Raman 1961; and Mohamed and Rao, 1971). Rearing experiments of *M. monoceros* from mysis to early juvenile stage showed a growth rate of 0.32 mm per day (Rao, 1973). Subrahmanyam (1973) recorded monthly growth rate ranging from 15-25 mm for juveniles of the species from Adayar and Ennore Estuary when they remain closed. The species was observed to grow at the rate of 14.61 mm per month in the prawn culture fields around Cochin (George, 1975). Chen (1976) stated that *M. monoceros* reached a marketable size of about 15 gms in about 50 days in culture ponds in Taiwan. Lalitha Devi (1988) observed a monthly growth rate of 15.0-18.0 and 16.0-17.5 mm respectively for females and males of juvenile *M. monoceros* (size range 30-50 mm) in the Godavari Estuary.

The first account on the age and growth of *M. monoceros* from marine environment in India was given by George (1959). He stated that the clear modes at 108, 133 and 158 mm (males and females combined) seen in the length frequency distribution of *M. monoceros* caught by trawlers in 1957, represented I, II and III year classes respectively. However, results of the present study confirm that the dominant modes observed by George (1959) represented only the different broods of *M. monoceros* of the same year class. Based on the *M. monoceros* catches landed by shrimp tralwers during 1974-77 at Kakinada, Rao and Krishnamoorthi (1990) studied its age and growth by fitting von Bertalanffy growth equation. Their studies showed that the length attained by males and females of *M.monoceros* respectively are 142 mm and 162 mm at the end of 12 months; and 163 mm and 187 mm at the end of 18 months. The age and growth of *M. monoceros* was estimated by fitting the von Bertalanffy growth equation with parameters estimated by Ford - Walford method as well as by application of ELEFAN I method. Estimation of growth in the earlier procedure has enabled to compare the results obtained with those from other sources.

Fitting the von Bertalanffy growth equation based on the estimates obtained by Ford - Walford method (L_∞ and k) and Gulland method (t_0) showed that the length attained by females and males of *M. monoceros* respectively in the present study are 164.81 mm and 138.81 mm at the end of 12 months and 191.85 mm and 160.33 mm at the end of 18 months. These results agree with those observed for the same species along Kakinada coast (Rao and Krishnamoorthi 1990) up to 12 months and beyond which the growth rate showed slight variation in the two geographical locations Kakinada (East coast) and Cochin (West coast). At the end of 18 months female *M. monoceros* along Cochin coast showed a marginal increase in growth (4.84 mm in length; 2.52%) while males exhibited a slight decrease in length (2.5 mm; 1.56%) when compared with the growth of females and males of *M. monoceros* respectively from the Kakinada coast.

In the present study, the application of ELEFAN I method showed a length of 188.88 mm for females and 150.81 mm for males of brown shrimp after 18 months of life-span. When results on growth at the end of 18 months obtained by applying von Bartalanffy growth model by adopting these two procedures are compared, it has been observed that they are almost similar with a difference of only 1.55% in females and 5.94 % in males. In the first procedure the estimates of parameters of von Bertalanffy growth model are found to describe satisfactorily the growth of *M. monoceros* . However, in the modal progression analysis in identifying modes a little subjectivity is likely to creep in vitiating the reliablity of estimates. This subjectivity is minimum in the use of ELEFAN I programme which is based on a objective critaria. One of the main features of ELEFAN I method is that a number of different growth curves are tested in the process of finding the best fit curve. This method is rapid reliable and highly recommended objective method for studying single species dynamics in a multispecies context (Pauly, 1980, 1982). The L_{∞} values derived by the ELEFAN I method for *M. monoceros* (204 mm for females and 170 mm for males) in the present study was found to be reasonable not far away from the maximum length observed in the fishery (195 mm and 160 mm for females and males respectively). Hence the growth parameters and age at length estimated by ELEFAN I method in the present study are utilised for further investigations on population dynamics and stock assessment of *M. monoceros* along Kerala .

Table 3.1 Monthly size distribution of *M.monoceros* (females) landed by trawlers at Cochin fisheries harbour in 1991

Size group (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
68	-	3931	-	-	-	-	-	-	-	-	-	-	3931
73	96	15724	-	-	-	-	-	-	-	87	-	-	15907
78	96	11793	-	2497	-	-	-	130	-	-	-	-	14516
83	96	4721	-	4994	-	-	1170	50	-	43	277	5062	16413
88	325	20066	3028	5418	-	2208	3510	194	-	263	277	-	35289
93	144	11793	12354	3745	-	9365	2340	288	84	176	-	2233	42522
98	180	34160	30128	28087	9679	15770	2340	482	4102	352	6717	11154	143151
103	4343	54099	41740	45982	22041	19747	2400	1130	-	441	1108	12249	205280
108	2358	69646	29151	72853	52062	17492	1620	1654	4186	489	7270	34195	292976
113	20680	120813	61065	54590	61326	14094	1770	1038	12031	489	43125	53907	444928
118	20860	171044	78257	71816	156156	6890	2790	2176	8571	489	73095	82725	674869
123	16204	151775	54273	120523	189294	7376	2100	2088	19963	486	121872	90503	776457
128	20776	90035	58642	142465	234862	6890	990	1446	28068	528	147162	145169	877033
133	67440	49087	88850	150936	159273	2694	1080	2046	24088	530	78235	184042	808301
138	65636	38710	82052	72094	90807	5919	450	1728	51723	443	201505	84395	695462
143	74839	44474	88627	97651	102358	485	300	1208	19892	395	111541	47972	589742
148	76655	46345	66954	61502	18547	485	1470	1498	28132	354	120572	75701	498215
153	77341	68648	68944	30600	45760	485	-	1186	31509	87	108481	54422	487463
158	27453	16445	43204	70307	24308	-	-	352	4256	87	107970	51230	345612
163	18406	23517	38359	22212	12284	-	-	180	-	-	52157	22959	190074
168	2454	32409	28570	19021	17196	-	-	-	84	-	33072	11751	144557
173	13353	20894	19356	43419	28796	485	-	-	-	-	9819	1626	137748
178	5413	7862	7299	20074	7981	-	-	-	35	-	-	1626	50290
183	132	3242	-	11114	-	-	-	-	3900	-	6440	542	25370
188	60	-	3405	1616	4304	-	-	-	-	-	-	-	9385
193	-	-	-	-	3416	-	-	-	-	-	-	-	3416
Total	515340	1111233	904258	1153516	1240450	110385	24330	18874	240624	5739	1230695	973463	7528907

Table 3.2 Monthly size distribution of _M.monoceros_ (females) landed by trawlers at Cochin fisheries harbour in 1992

Size group (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
78	-	-	-	4321	-	-	-	-	-	-	-	-	4321
83	-	3666	-	4321	-	-	-	433	-	-	-	-	8420
88	9496	3666	3626	4321	6340	-	-	433	177	92	-	-	28151
93	-	3666	3863	12249	-	479	627	433	-	-	-	-	21317
98	3719	35771	10879	12964	6340	6257	-	433	177	373	-	6040	82953
103	20118	52006	40797	20177	45225	479	627	1298	355	324	959	3020	185385
108	40363	82539	49636	58951	86005	6257	209	2595	177	373	1439	15101	343645
113	32303	149444	56248	56608	132075	7216	627	2595	355	464	1016	22880	461831
118	64686	138100	60782	59616	100580	63054	418	1298	1419	1858	3837	41458	537106
123	53338	161405	50780	91277	184010	22126	627	1015	1064	972	1439	15101	583154
128	83399	221058	170285	109642	188850	52455	1255	1065	1064	1534	1439	88957	921003
133	40411	119661	49026	76402	193935	36557	1464	1930	887	880	1667	135174	657994
138	56881	43490	118025	46752	158035	15868	1046	1165	1419	1015	1782	73856	519334
143	55700	34721	135490	82901	28510	19730	1882	1115	710	1069	514	86394	448736
148	39844	118753	112501	47999	7390	1437	627	2263	-	281	457	100213	431765
153	12760	38702	80910	45722	96545	479	837	533	532	275	594	118791	396680
158	19902	8066	54431	22321	33595	-	627	865	355	184	228	43197	183771
163	16183	995	30304	35600	-	-	627	-	177	92	-	43197	127175
168	8962	2986	9915	11651	-	-	-	433	177	92	57	10799	45072
173	646	995	10649	3607	6340	479	-	-	532	275	-	-	23523
178	646	-	2662	4022	-	-	-	-	-	-	-	-	7330
183	-	-	-	-	20915	479	-	50	-	-	-	-	21444
Total	559357	1219690	1050809	811424	1294690	233352	11500	19952	9577	10153	15428	804178	6040110

Table 3.3 Monthly size distribution of *M.monoceros* (females) landed by trawlers at Cochin fisheries harbour in 1993

Size range	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
78	-	-	-	-	-	-		-	-		-	39963	39963
83	3843	-	-	-	-	-		-	-		-	79926	83769
88	8198	-	-	-	-	-		-	-		-	119889	128087
93	8198	-	6367	10949	-	-		-	-		-	79926	105440
98	8198	1380	19101	38426	14836	5076		-	-		-	39963	126980
103	31476	-	-	93349	44947	-		-	-		-	-	169772
108	34093	7305	-	170201	94187	5076		7855	1018		-	13840	333575
113	107842	17776	17079	132227	136566	15227	no catch	-	1018	no catch	-	53803	481538
118	46775	48769	32824	131775	229065	15227		-	1018		-	60204	565657
123	79697	60698	39578	137626	128980	50762		15709	2036		-	71622	586708
128	64617	75897	41901	170020	178456	20305		-	6802		-	13840	571838
133	134963	71410	106001	82642	96703	50762		23564	13605		1457	136670	717777
138	116333	101900	130437	38787	116119	25381		15709	14623		1457	95150	655896
143	219820	69402	100882	44126	59884	20305		23564	28922		2914	104146	673965
148	111630	94791	155259	27778	49036	20305		39274	53773		1457	84597	637900
153	86834	108342	311465	77634	22524	5076		78547	69416		11656	65913	837407
158	43737	39999	67972	93259	-	-		54983	53450		5828	43942	403170
163	39528	21170	56571	44186	23015	10152		15709	24156		2914	21971	259372
168	7759	11785	26070	22289	15326	5076		15709	22120		-	49651	175785
173	-	2760	10712	27778	7689	20305		7855	4767		-	-	81866
178	-	1380	-	11340	4090	10152		-	33366		-	13840	74168
183	-	1380	4345	5670	4090	-		-	10551		-	-	26036
188	3843	-	-	-	-	-		-	4767		-	-	8610
193	-	-	-	5670	-	-		-	4767		-	-	10437
Total	1157384	736144	1126564	1365732	1225513	279187		298478	350175		27683	1188856	7755716

Table 3.4 Monthly size distribution of _M.monoceros_ (males) landed by trawlers at Cochin fisheries harbour 1991

Size group (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
73	-	3931	-	-	-	-	-	-	-	43	-	-	3974
78	-	7862	7812	1245	-	-	-	-	-	43	-	6932	23894
83	289	12583	8837	7703	-	1237	1950	50	84	43	277	-	33053
88	5726	12583	23972	10837	-	1237	3120	202	35	217	277	7474	65680
93	5450	17304	27835	22856	5375	12058	4980	72	4067	176	10096	10612	120881
98	229	71435	27872	52991	15836	19920	3810	1188	356	-	24360	16406	234403
103	20535	140696	52524	64121	58797	17758	2880	1412	642	751	63041	49008	472165
108	28968	164547	119675	163135	194843	14047	3630	2044	12480	311	150776	121132	975588
113	39073	99913	106803	129312	236666	9897	2160	2080	24298	882	104462	136768	892314
118	64890	84347	115758	250977	287001	8613	1080	2052	16692	174	111818	179201	1122603
123	61269	68275	123792	147557	133595	3664	540	2276	24409	573	62253	74975	703178
128	56409	8273	72349	74427	54088	971	390	2400	12638	178	84675	39772	406570
133	41720	17443	53859	56573	47642	-	-	1556	27468	89	52157	35252	333759
138	7615	3931	19881	23272	13356	-	-	194	8051	43	29458	17355	123156
143	60	3931	2441	15961	37423	-	-	-	-	-	9819	7474	77109
148	5486	-	3405	7344	48530	-	-	-	-	-	9819	-	74584
153	5353	-	-		6909	-	-	-	-	-	-	-	12262
Total	343072	717054	766815	1028311	1140061	89402	24540	15526	131220	3523	713288	702361	5675173

Table 3.5 Monthly size distribution of *M.monoceros* (males) landed by trawlers at Cochin fisheries harbour 1992

Size group (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
83	9496	1833	-	-	-	-	-	-	-	140	-	-	11469
88	-	5498	-	12964	-	-	418	-	-	-	-	3020	21900
93	25600	29957	11352	8642	19020	6257	627	865	-	-	-	-	102320
98	47545	68240	23630	16686	19020	12515	-	865	355	324	-	3020	192200
103	86495	223602	95377	106002	79025	19730	209	1730	355	464	1439	22880	637308
108	90741	205289	128343	103925	177300	44281	837	2695	-	842	4796	21142	780191
113	65213	135825	191993	188953	187635	38982	1046	3178	177	653	765	30659	845079
118	40778	60119	227584	89482	241465	40419	837	2695	355	745	1645	186606	892730
123	43451	25557	87279	76735	137965	13952	1046	3178	-	140	822	97193	487318
128	29199	22468	100720	46253	73965	-	1673	1448	887	599	400	43197	320809
133	11467	6075	37084	21207	13525	-	627	533	177	232	114	21598	112639
138	646	5577	9915	14410	-	6737	-	865	-	-	114	21598	59862
143	4748	2489	10002	6781	7390	-	-	-	-	-	-	10799	42209
148	646	995	-	-	-	479	-	-	-	-	-	-	2120
Total	456025	793524	923279	692040	956310	183352	7320	18052	2306	4139	10095	461712	4508154

Table 3.6 Monthly size distribution of *M.monoceros* (males) landed by trawlers at Cochin fisheries harbour 1993

Size group (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul *	Aug	Sep	Oct *	Nov	Dec	Total
88	-	-	12734	-	-	-		-	-		-	159852	172586
93	28145	-	19101	32876	11237	-		-	-		-	53803	145162
98	15372	1380	26156	49404	49036	5076		-	-		-	21971	168395
103	117358	13832	32523	164681	95219	-		-	-		-	175249	598862
108	139117	72627	52312	318835	232677	40610		15709	1018		1457	149991	1024353
113	186825	81142	110346	165073	170716	45686		31419	1018		-	43942	836167
118	239803	143010	218972	154576	191278	96448		15709	-		4371	32524	1096691
123	127148	71070	197849	116120	26123	30457		39274	3054		5828	24393	641316
128	33654	67355	130351	44578	11237	10152		47128	25869		2914	52073	425311
133	12115	27972	92794	94133	26563	-		39274	46971		7285	35811	382918
138	-	15781	59282	49946	7689	-		23564	21102		2914	-	180278
143	12115	-	17767	28200	4090	20305		7855	24851		2914	8131	126228
148	-	-	4345	11340	4090	-		-	-		-	-	19775
153	-	-	4345	-	-	-		-	1018		-	-	5363
158	-	-	-	5670	-	-		7855	-		-	-	13525
Total	911652	494169	978877	1235432	829955	248734		227787	124901		27683	757740	5836930

* No catch

Table 3.7: Modes selected for growth estimation of females of *M. monoceros* by Ford-Walford Plot

S.No	Initial mode (lt)			Final mode (lt+1)		
	Modal length (mm)	Month	Year	Modal length (mm)	Month	Year
1	73	October	1991	118	January	1992
2	88	February	1991	128	May	1991
3	98	March	1993	133	June	1993
4	108	August	1992	138	November	1992
5	103	January	1991	143	April	1991
6	113	September	1991	148	December	1991
7	123	June	1991	153	September	1991
8	118	December	1992	153	March	1993
9	138	January	1992	163	April	1992
10	168	February	1992	183	May	1992
11	153	January	1991	173	April	1991

Table 3.8 : Modes selected for growth estimation of males of *M. monoceros* by Ford-Walford Plot

S.No	Initial mode (lt)			Final mode (lt+1)		
	Modal length (mm)	Month	Year	Modal length (mm)	Month	Year
1	88	January	1991	118	April	1991
2	98	June	1991	123	September	1991
3	93	July	1991	123	October	1991
4	123	October	1991	143	January	1992
5	133	February	1991	148	May	1992
6	93	September	1991	118	December	1991
7	118	March	1992	138	June	1992
8	103	April	1992	128	July	1992
9	118	March	1993	143	June	1993
10	113	August	1993	133	November	1993

Table 3.9: Details showing the estimation of t_0 for females of *M. monoceros*

L_∞ = 215 mm derived from Ford-Walford plot

t in months	l_t	$(L_\infty - l_t)$	$L_\infty - l_t / L$	$\log_e (L_\infty - L_t / L_\infty)$
3	64	151	0.7023	- 0.3534
6	113	102	0.4744	- 0.7457
9	148	67	0.3116	- 1.1660
12	173	42	0.1953	- 1.6332
15	188	27	0.1256	- 2.0747

Regression of $\log_e (L_\infty - l_t / L_\infty)$ on t gives the value of constants.

a = 0.1044 b = - 0.1443

$t_0 = -a/b$

= -0.1044/-0.1443 = 0.7235 month (or) 0.0603 year

Table 3.10: Details showing the estimation of t_o for males of *M. monoceros*

$L_{\infty} = 179$ derived from Ford-Walford Plot

t in months	l_t	$(L_{\infty} - l_t)$	$L_{\infty} - l_t / L_{\infty}$	$\log_e (L_{\infty} - L_t / L_{\infty})$
3	60	119	0.6648	- 0.4083
6	98	81	0.4525	- 0.7930
9	123	56	0.3128	- 1.1622
12	143	36	0.2011	- 1.6040
15	157	22	0.1229	- 2.0964

Regression of $\log_e (L_{\infty} - l_t / L_{\infty})$ on t gives the value of constants.

a = 0.04336 b = -0.1396

$t_o = -a/b$
$= -0.04336 / -0.1396$
$= 0.3106$ month (or) 0.0259 year

Table 3.11 Details indicating the fitting of von Bertalanffy equation to the growth data of female of *M. monoceros*

$L_{\infty} = 215$ $K = 11.5481$ $t_o = 0.0603$ year

t in years	t/t_o	$K(t-to)$	$e^{-k(t-to)}$	$1-e^{-k(t-to)}$	$l_t = L_{\infty}(1-e^{-k(t-to)})$
0.25	0.1897	0.2937	0.7455	0.2545	54.71
0.50	0.4397	0.6807	0.5063	0.4937	106.15
0.75	0.6897	1.0677	0.3438	0.6562	141.09
1.00	0.9397	1.4547	0.2335	0.7665	164.81
1.25	1.1897	1.8418	0.1585	0.8415	180.91
1.50	1.4397	2.2288	0.1077	0.8923	191.85
1.75	1.6897	2.6158	0.0731	0.9269	199.28

Table 3.12 Details indicating the fitting of von Bertalanffy equation to the growth data of males of *M. monoceros*

L_{∞} = 179 K = 1.5335 t_o = 0.0259 year

t in years	$t-t_o$	K(t-to)	$e^{-k(t-to)}$	$1-e^{-k(t-to)}$	$l_t=L_{\infty}(1-e^{-k(t-to)})$
0.25	0.2241	0.3437	0.7092	0.2908	52.06
0.50	0.4741	0.7270	0.4833	0.5167	92.48
0.75	0.7241	1.1104	0.3294	0.6706	120.03
1.00	0.9741	1.4938	0.2245	0.7755	138.81
1.25	1.2241	1.8772	0.1530	0.8470	151.61
1.50	1.4741	2.2605	0.1043	0.8957	160.33

Table 3.13 Details on length at each month derived by ELEFAN 1 method corresponding to its growth curves for female of *M.monoceros*

L_{∞} = 204 mm K = 1.8

Months	Total length in mm			
	I		II	
	S.L. 112.51 mm		S.L. 142.51 mm	
January	112.51	188.88	142.51	
February	125.48	191.02	151.22	
March	135.6		158.03	
April	145.3		164.55	
May	153.37		169.97	
June	160.55		27.32	174.80
July	166.53		51.62	178.82
August	9.42	171.84	73.22	182.39
September	37.01	176.40	91.76	185.45
October	59.97	180.20	107.20	188.00
November	80.39	183.57	120.92	190.27
December	97.39	186.38	132.35	192.16

S. L Starting length
Sequence of lengths to be followed first then the sequence of months

Table 3.14: Details on length at each month derived by ELEFAN I method corresponsing to its growth curves for males of *M.monoceros*

L_{∞} = 170 mm K = 1.5

Months	Total length in mm			
	I		II	
	S. L.	102.50 mm	S.L	92.50 mm
January	72.30	148.20	123.06	
February	83.98	150.81	128.68	
March	93.33	152.90	4.92	133.17
April	102.50	154.94	24.67	137.58
May	110.33	156.69	41.53	141.34
June	117.47		56.90	144.77
July	123.57		70.01	147.69
August	129.12		81.98	150.36
September	8.69	134.01	92.50	152.71
October	27.40	138.19	101.49	154.72
November	44.46	141.99	109.69	156.55
December	59.02	145.24	116.69	

S. L. Starting length

Sequence of lengths to be followed first then the sequence of months

CHAPTER 4

REPRODUCTION

CHAPTER 4

REPRODUCTION

4.1 INTRODUCTION

An understanding of the reproductive biology of any given species is an essential prerequisite for stock assessment in wild populations, sustainable exploitation and for culture in confined habitats. Different aspects on the reproductive biology of penaeid prawns have been studied by many research workers (Hudinaga (1942), King (1948), Menon (1951, 1953), Eldred (1958), Shaikhmahmud and Tembe (1958, 1960, 1961), Cummings (1961), Subrahmanyam (1963), Tuma (1967), Rao (1968) George and Rao (1968), Thomas (1974), Perez- Farfante (1975) Penn (1980) and Tan Fermin and Pudadera (1989). Wickins (1976) reviewed the results on studies carried out on reproduction and breeding of prawns. A detailed account on the morphology, composition and transfer of spermatophores in penaeid prawns was given by Subramoniam (1993).

Studies pertaining to reproduction of *M. Monoceros* are limited. George (1959) made some preliminary observations on the breeding of *M. Monoceros*. Based on the juvenile recruitment in the Cochin Backwaters, George (1962) discussed the spawning season of the brown shrimp in the inshore waters. George and George (1964) indicated a possible spawning ground off Cochin for *M. monoceros* based on the availability of larger spawners during experimental trawling. Nalini (1976) gave an account on stages of maturation and fecundity in female *M. monoceros* from Cochin region. Sasikala and Subramoniam (1987) described the composition of spermatophores in this species. Results of the studies on reproductive biology of the brown shrimp from Kakinada coast were given by Rao (1989).

A detailed account on the spawning season, periodicity of spawning, sex ratio, size at first maturity, process of maturation and fecundity of *M. monoceros* is given.

4.2. MATERIAL AND METHODS

Samples of *M. monoceros* for the studies on reproduction were collected from the trawl catch landed at Cochin Fisheries Harbour during 1991-93. Total length of *M. monoceros* was measured from tip of rostrum to tip of telson. The total weight was taken to the nearest milligram. The ovaries from females of *M. monoceros* were dissected out carefully and their nature, colour and size noted before they were preserved in 5% formalin The maturity stages could be differentiated from fresh specimens based on the colour and thickness of ovary. However, the different stages of maturity were confirmed later by microscopic examination. For the ova diameter studies, small portions of the ovary taken from different regions of the ovary were teased out on a glass slide and examined under the microscope. It was observed that the diameter of ova collected from different regions of ovary did not indicate any appreciable variation (Figure 4.1). Hence, for further studies on fecundity and ova diameter, a portion of ovary on the right side of first abdominal segment was removed and examined. The diameter of ova was measured by using an ocular micrometer, where one division equals 0.0145 mm. The ova were irregular in shape and measurement of each ovum was taken in the same parallel plane using mechanical stage of the microscope in order to avoid errors due to distortion and subjective bias. From each ovary 300 ova were measured.

For fecundity estimates the preserved ovary after four or five days was removed, washed and dried by placing it between blotting papers. The weight of ovary was taken to the nearest 0.001 gm, then a subsample of ovary segment was taken out and weighed to the nearest 0.0001 gm using an electronic balance. The mature ova present in the subsample were counted by using a counting slide. From the number of ova in the weighed subsample, total number of mature ova in the entire ovary was calculated based on total ovary weight. The relationships for fecundity on total length, total weight and ovary weight were found out by fitting regression on logarithms of observed values by least square method (Snedecor and Cochran, 1968).

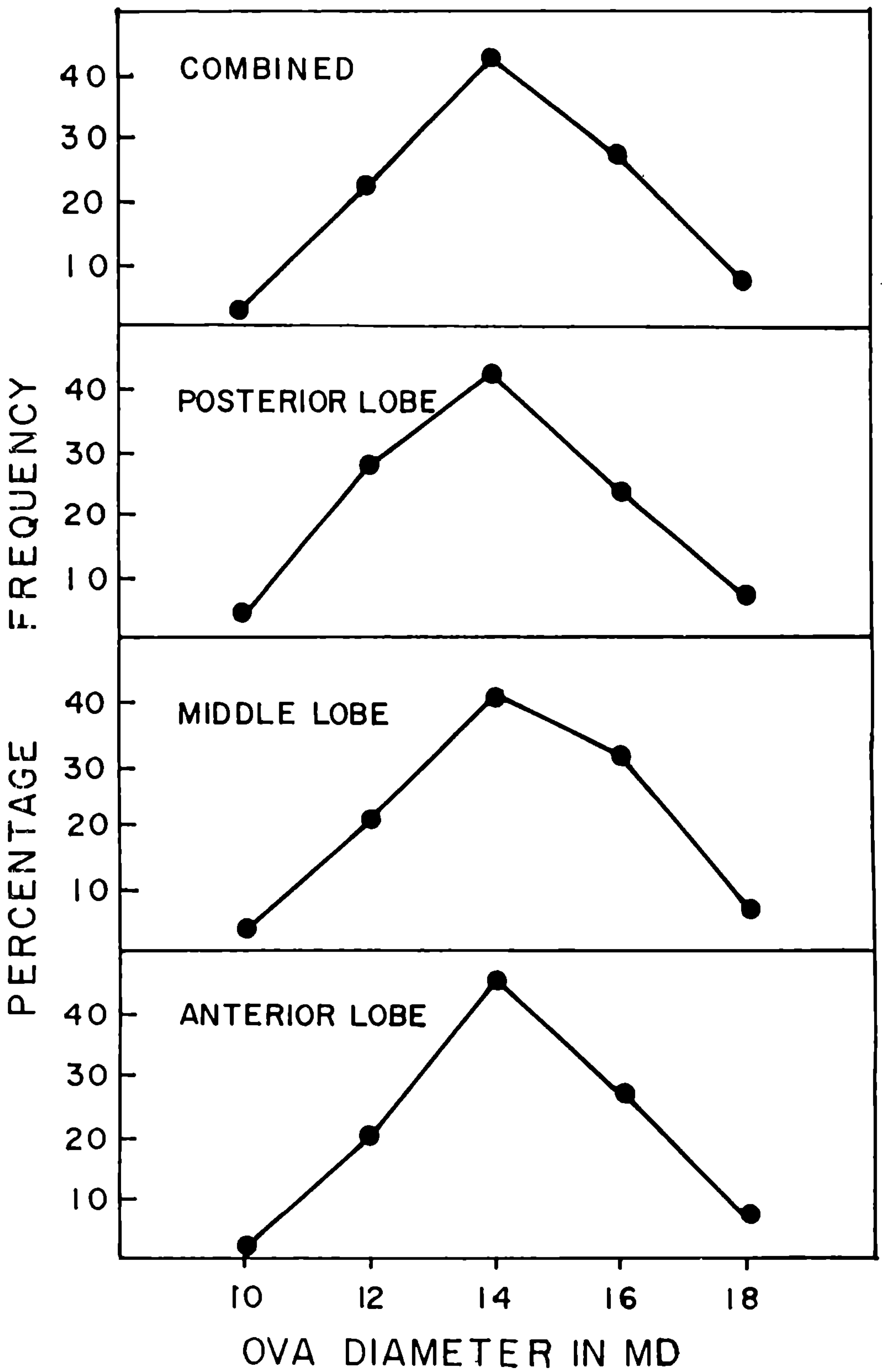


FIGURE 4.1 Ova diameter- frequency polygons showing the distribution of ova in mature ovary of *M. monoceros*

The sex ratio of *M. monoceros* was studied based on the monthly estimated numbers for the period 1991-93 as to get an actual representation of males and females in the population. Homogenity of the sex ratio (based on observed numbers) over months in different years has been tested using χ^2 test (Snedecor and Cochran, 1968). The χ^2 is computed as follows:

$$\chi^2 = \frac{\sum \left(\frac{x_i^2}{n_i} \right) - \frac{(\sum x_i)^2}{\sum n_i}}{pq}$$

Where, x_i is the number of females in the 'i'th month, n_i is the total number of observations in the 'i'th in month; $p = \sum x_i / \sum n_i$ and $q = 1-p$. Significant test at a probability level of p = 0.01 was carried out. Homogenity was tested for 1:1 ratio and for common ratios as observed from the data.

4.3. RESULTS

4.3.1 The Reproductive system

The structure of the reproductive system in males and females of *M. monoceros* in the present study agrees well with the descriptions given for *Penaeus setiferus* (King, 1948) and *Parapenaeopsis stylifera* (Shaikhmahmud and Tembe,1958), *M. dobsoni*, *M. affinis, and P. indicus* (Rao, 1968,1978). The male reproductive system consists of a pair of testes, vasa efferens and vasa defferens, a terminal ampoule and a petasma. The female reproductive system consists of a paired ovaries, oviducts and a single thelycum.

The mature ovaries are paired organs, situated dorsally extending from the base of rostrum to the last abdominal segment. They are bilaterally symmetrical and partly fused. Each half of the ovary consists of three lobes of which the slender anterior lobe occupies the cephalic region and lies in close proximity with the oesophagus and cardiac region of the stomach. The middle lobe has six finger-like lateral lobules which entirely fill the area between the epigastric tooth and the posterior border of the carapace. The lateral lobules are located dorsally to the large mass of hepatopancreas and ventrally to the pericardial chamber. The posterior lobes of the ovary extend the entire length of abdomen. The two halves of the ovary are united by two commissures, one at the base of the anterior lobe and other at the tip of the posterior lobe in the 6th abdominal segment. The thin oviducts start from the tip of the penultimate lobules of the middle lobe on either side and run downwards to the external gonophore on the 3rd pereopod.

4.3.2. Maturity stages of ovary

There is little consistency among various workers who have studied the maturation of ovaries in prawns as to the number of stages of maturity recognised. King (1948) recorded five stages in *P. setiferus* and Cummings (1961) described only four in *P. duorarum*. Shaikmahmud and Tembe (1961) differentiated between spent and regenerating *P. stylifera* to give five stages. Renfro and Brusher (1964) classified the developmental stages of *P. setiferus* into seven stages and Oka and Shirhata (1965) recognised eight maturity stages in *P. orientalis*. Rao (1968) differentiated the maturation of females of four species of Penaeidae into 5 stages which was followed by Nalini (1976) in her studies on *M. monoceros*. Eventhough Rao (1989) recorded 5 stages of maturity in *M. monoceros*, he differentiated the mature stage into two as mature and ripe. Based on the colouration and size of ovary and ova diameter variations five stages of maturity in females of speckled shrimp was recognised in the present work which agrees with the observations of Rao (1968). The maturity stages are as follows : 1. Immature. 2. Early maturing 3. Late maturing 4. Mature and 5. Spent-recovering. The size frequency distribution of maturing ova in different stages of maturity in females of *M. monoceros* is shown in Figure 4.2 and Table 4.1.

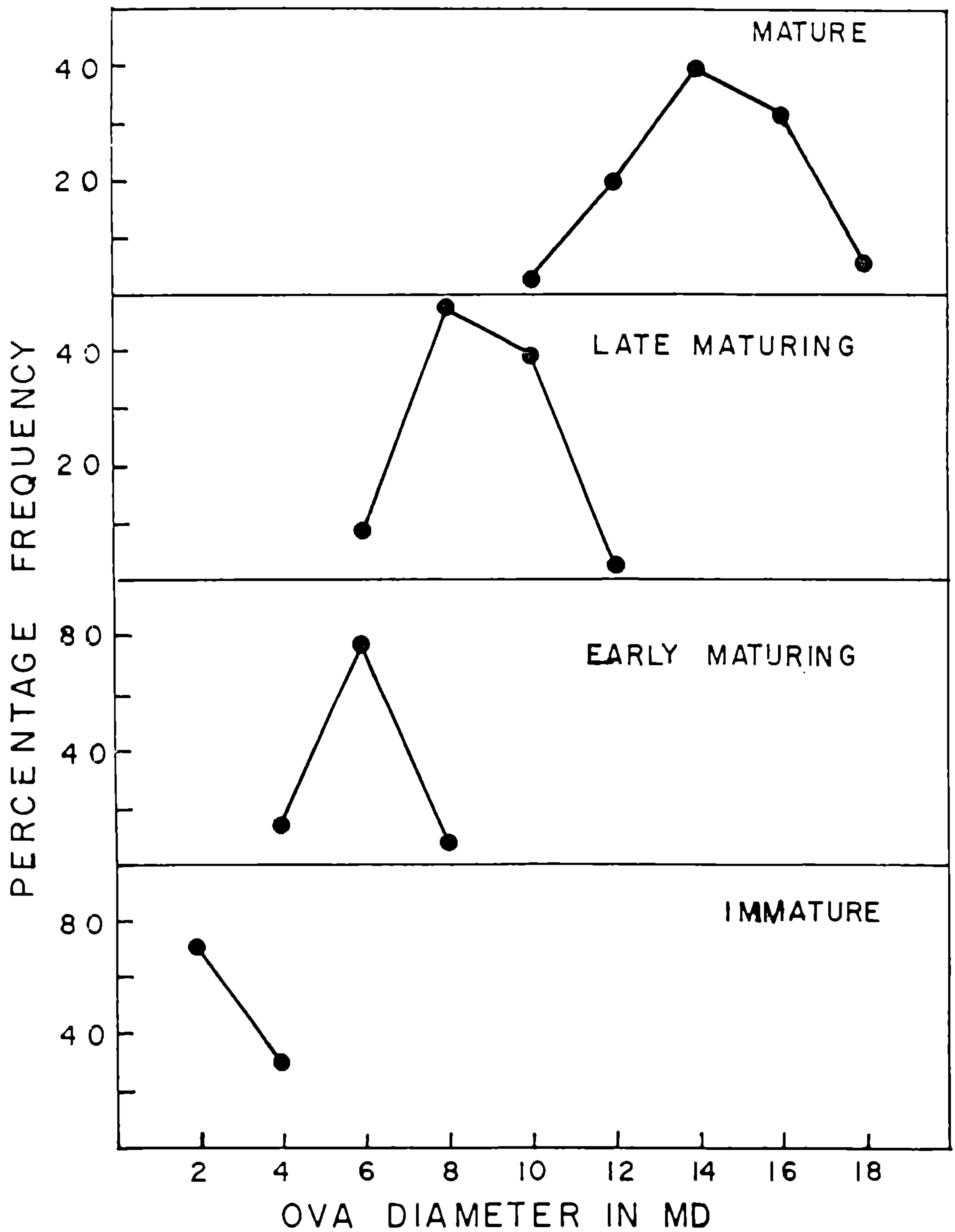


FIGURE 4.2 Diameter-frequency distribution of developing ova in different stages of ovarian maturity in *M. monoceros*

Immature stage: Ovary is thin, transluscent unpigmented and confined to posterior part of cephalothorax and the abdomen. The ovary contains ova which are not discernable to the naked eye. A microscopic examination of immature ovary revealed tiny ova with clear cytoplasm and conspicuous nuclei. The diameter of the ova varied between 1 and 4 microdivisions (0.0145 mm and 0.058 mm).

Early maturing stage: Size of ovary increases; anterior lobes further develop and extend forward in the cephalothorax; the middle lobes and the rudiments of their lobules develop. The posterior lobe increases in girth. The general colour of the ovary is yellowish. The ovary now contains two groups of ova, an immature group and developing ones. The developing ova are transluscent due to accumulation of yolk in the cytoplasm and measure between 4 and 8 microdivisions(0.058 and 0.116 mm) (Table 4.1).

Late maturing stage: The ovary develops further, the anterior, middle and posterior lobes are fully formed. However, the anterior and middle lobes do not fill the cephalothorax completely. The ovary is generally light green, sometimes brownish with branched brownish chromatophores distributed over the entire surface of ovary. Ovary is visible through the exoskeleton. The developing ovum is opaque and the nucleus becomes completely invisible due to accumulation of yolk. Size range of the developing ova was 6 to 12 microdivisions (0.087

mm to 0.174 mm) with majority of them distributed between 7 and 10 microdivisions (0.1015 and 0.1450 mm) (Fig. 4.2).

Mature stage: The ovary is very clearly visible through the exoskeleton, dark green mostly and in a few cases brownish green. The anterior and middle lobes are well developed. Due to fullness of the ovary, the lateral lobules of the middle lobe get folded and occupy the entire space available in the cephalothorax. The branched brownish pigments are densely distributed over the dorsal surface of the entire ovary. The ovary contains now immature and fully mature ova. The mature ova are opaque, fully yolked and measure between 10 and 18 microdivisions (0.1450 mm and 0.2610 mm), with majority of them in the range of 12 -16 microdivisions (0.1740 - 0.2320 mm) (Table 4.1 and Figure 4.2).

Spent recovering stage: After extrusion of ova,the gonad reverts almost immediately to immature condition. The ovarian lobes are flaccid and appear whitish. The ovary contains ova which are similar to those in immature stage. This stage is therefore distinguishable from that found in immature virgin females mainly based on the relative size of the prawn.

4.3.3 Size at first maturity

Male : The petasma in males is the modified endopods of the first pleopods. Joining of the endopods to form the petasma along with the presence of spermatophores in the terminal ampoule indicates the onset of maturity in male *M. monoceros*. The smallest male in fully mature condition with well developed petasma and having visible spermatophores in the terminal ampoules measured 90 mm in the present study. To determine the size at first maturity 150 numbers of males in the size range of 90-101 mm were examined and the details are given in Table 4.2. The frequency distribution of mature males of *M. monoceros* is shown in Figure. 4.3. It was noticed that 50% of the observed males attain maturity at 95 mm. All the males measuring 100 mm and above were fully mature. Hence the size at maturity in males of *M. monoceros* was fixed as 95 mm in total length. Thus males of brown shrimp measuring 95 mm and above are considered mature.

Female: During the course of this study, the smallest female having ovary in fully mature condition was observed to be 101 mm in total length. To decide the minimum size at maturity a total number of 408 females measuring between 101 mm and 121 mm in total length were considered (Table 4.2). The frequency distribution of the mature female is shown in Figure 4.3 which indicated that the minimum size at first maturity in females of *M. monoceros* was 114 mm (50 %) and all those measuring 120 mm

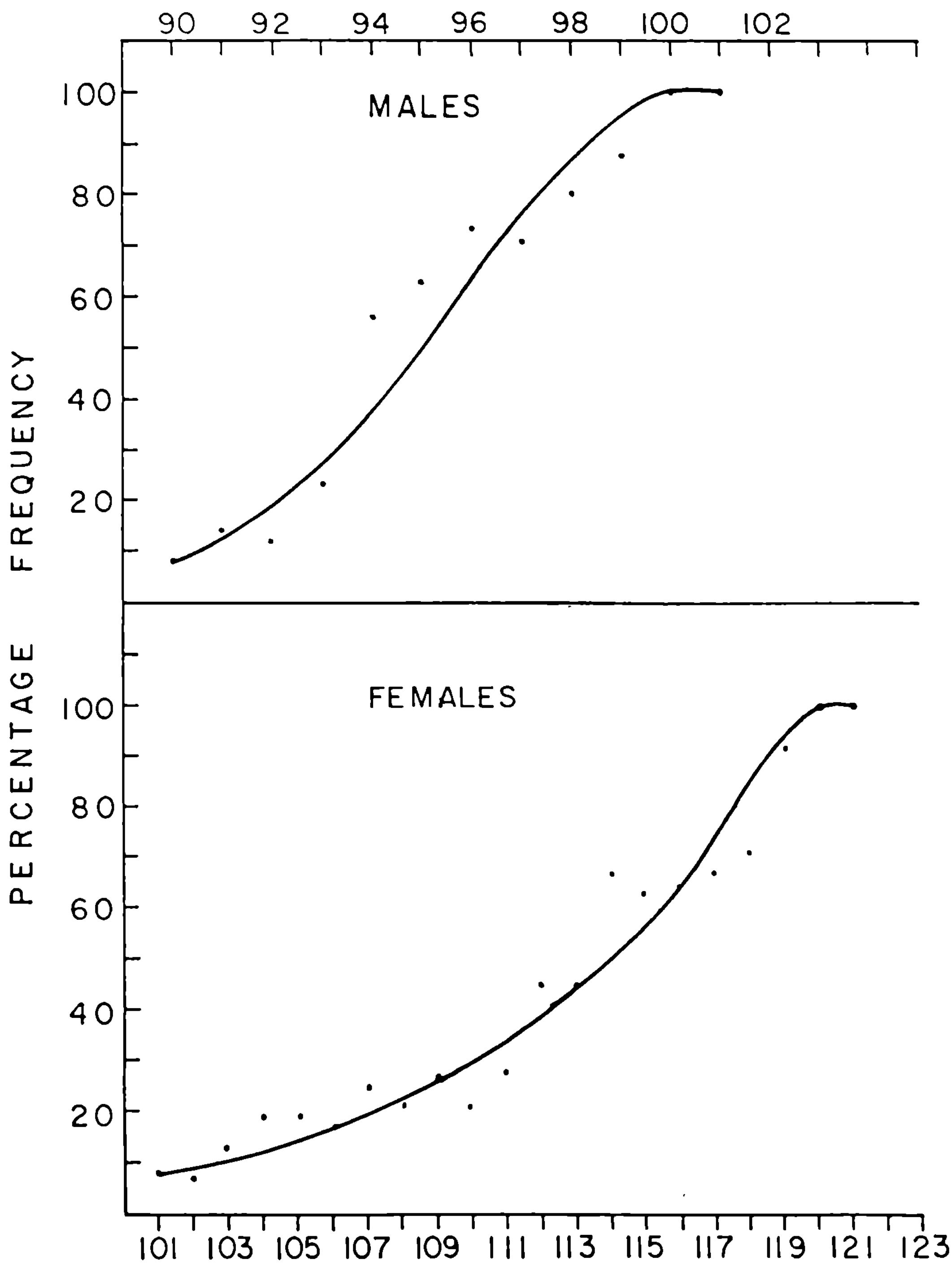


FIGURE 4.3 Determination of size at first maturity in *M. monoceros*

and above were completely (100%) mature. From the age data (vide Chapter 3) it is inferred that in females and males the age at first maturity is in the seventh and eighth month respectively of their life.

4.3.4. Spawning population

The details on the length wise distribution of females in the *M. monoceros* population in different stages of ovarian maturity are given in Tables 4.3, 4.4 and 4.5 for the years 1991, 1992 and 1993 respectively. Females of *M. monoceros* in the size range of 116-170 mm form the major spawning population of the fishery. They formed the main contributors to the brown shrimp fishery at Cochin probably owing to their behaviour of aggregation at the time of spawning.

4.3.5 Spawning frequency

Based on the informations on contribution of mature females of *M. monoceros* to each size group (Tables 4.3 - 4.5) the following inferences could be made. Mature females showed dominant modes at 163, 173 and 183 mm in 1991; at 138, 148 and 178 mm in 1992 and at 118, 138, 148 and 173 mm in the year, 1993. Taking into consideration of the entire size range and the modal groups of mature females during 1991-93, it may be inferred that an individual female matured and spawned when it measured 118, 138, 148, 163, 173 and 183 mm. Thus a female *M. monoceros* spawned at least six times between the age of 7 and 18 months. In the experimental studies on the allied species, *M. dobsoni*, successful rematuration after each spawning within 4-8 days interval was recorded (Vasudevappa, 1992). So it may be stated, that a female speckled shrimp spawns atleast six times in its life span after attaining the first maturity. Taking into consideration of age in months it may be assumed that female brown shrimp spawns bimonthly after attaining the size at first maturity.

4.3.6. Spawning season

The monthly percentage occurrence of different stages of maturity in females of *M. monoceros* are given in Table 4.6 for 1991 and 1992 and in Table 4.7 for 1993. The five stages of maturity were noticed in all months during 1991-93 indicating that *M. monoceros* is a continuous breeder. However based on the availability of mature females in the catches, suitable spawning season and peak spawning months could be arrived at. Mature females above the annual average of 20.88%, were noticed during January-April and in the month of December during the year 1991 and the peak months of spawning were observed to be January and April. In the following year (1992) the percentage composition of mature females in the catches was generally lesser than the percentage contribution of 1991 (Figure 4.4). The spawning periods for 1992 was noticed to be January, March - May and September - November based on the monthly occurrence of mature females above the annual average of 10.32%. The peak spawning months were May, January and March based on the order of abundance of mature females. In 1993, the females in advanced stage of maturity were observed during most of the months. Brown shrimp was absent in the trawl landings during July and October 1993. The percentage of mature females varied between 15.11 (May) and 54.43 (September) during 1993 and the peak months for spawning were observed to be August (31.58%) September (54.43%) and December (46.54%).

From the above details it is learnt that *M. monoceros* breeds throughout the year with peak spawning months varying between years. June-July duration which is heavy monsoon period and the month of October were observed to be the lean periods for spawning when mature females constituted less than 10 % . To obtain a better picture on the spawning period of the speckled shrimp, an attempt was made to combine the monthly availability of mature females for the entire period of study (1991-93),the details of which are shown in Table 4.8. It could be seen that there were two main spawning periods for *M. monoceros* i.e. December-April and August-September.

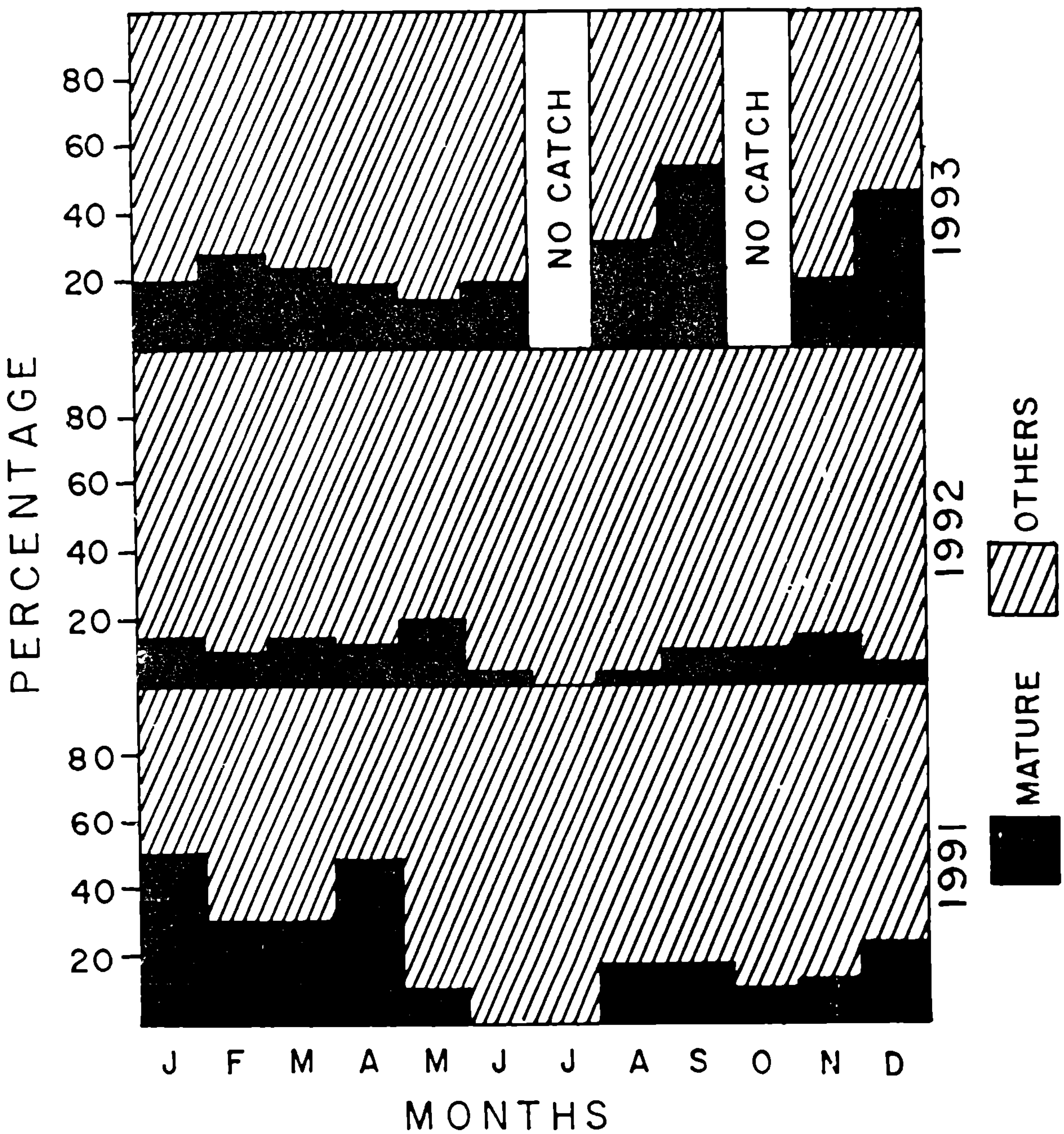


FIGURE 4.4. Month-wise percentage of females of *M. monoceros* in mature stage and other stages during the years 1991 -1993.

4.3.7. Fecundity

The number of ova present in the ovary of mature females of *M. monoceros* in the size range of 101-165 mm has been estimated in the present work. The details on the total length, total weight, ovary weight and the estimated number of ova are given in Table 4.9. It was observed that, as in the case of other penaeid prawns, *M. monoceros* also have high fecundity. The estimated number of ova in the mature ovary ranged from 47,930 in a female of 101 mm to 390708 in a female brown shrimp measuring 163 mm in total length. Fecundity increased generally with the increase in size. However, when fecundity was compared with total length, total weight and ovary weight, wide variations were noticed. In order to identify the factor which could be used as a good predictor of fecundity, statistical analysis was carried out on the data. The data were subjected to log transformation as the coefficient of variation was found uniform. The correlation coefficient between Fecundity and log Total length, log Total weight and log Ovary weight (all transformed variables) are as follows:

	r	r^2
log Total Length	0.9255	0.8565
log Total Weight	0.9241	0.8540
log Ovary weight	0.9309	0.8666

It could be observed that there were no significant difference in the coefficient of predictions (r^2) using these three variables namely log Total length, log Total weight and log Ovary weight. The multiple regression fitted on the three variables gave an r^2 of 88%, which again is not very much different from r^2 obtained from regression on log Ovary weight.

The correlation between log Total length and log Ovary weight and similarly between log Total weight and log Ovary weight was found to be 0.9546 and 0.9532 respectively. Because of this high correlation improvement in the coefficient of prediction, when these two variables (log Total length and log Total weight) are added in the regression equation is insignificant as they do not give additional information on fecundity which are not available from log Ovary weight.

Thus combining all the results obtained, it is inferred that ovary weight could be used as a single best predictor for fecundity of *M. monoceros* and the relation is given as:

$$\log \text{Fecundity} = 11.95298 + 0.87253 \log \text{Ovary weight}$$

or

$$\text{Fecundity} = 155280.5 \times \text{Ovary weight}^{0.87253}$$

4.3.8. Sex Ratio

The monthly percentage composition of females and males in the *M. monoceros* catches landed by shrimp trawlers at Cochin Fisheries Harbour during 1991-93 are given in Table 4.10 as well as shown in Figure. 4.5. Female outnumbered the males generally throughout the study period. The percentage composition of females in the catches ranged from 49.79 (July) to 64.71 (September) in 1991; between 52.51 (August) and 80.59 (September) during 1992 and from 50.00 (November) to 73.71 (September) in the year 1993. The maximum occurrence of females of brown shrimp in the month of September every year was probably due to aggregation of them during their annual inshore movement. The representation of males in the catches during 1991 varied from 35.29% to 50.21% ; between 19.41% and 47.49% in 1992 and from 26.29% to 50.00% in the year 1993. The maximum occurrence of male *M. monoceros* in the catches was noticed in July, August and November for the years 1991, 1992 and 1993 respectively. When the sex data of *M. monoceros* in the annual catch during 1991-93 was pooled, the sex ratio of F : M was 57.10 : 42.90 % . The X^2 test showed that the distribution of females and males in *M. monoceros* catches in various months was significantly different (Table 4.11).

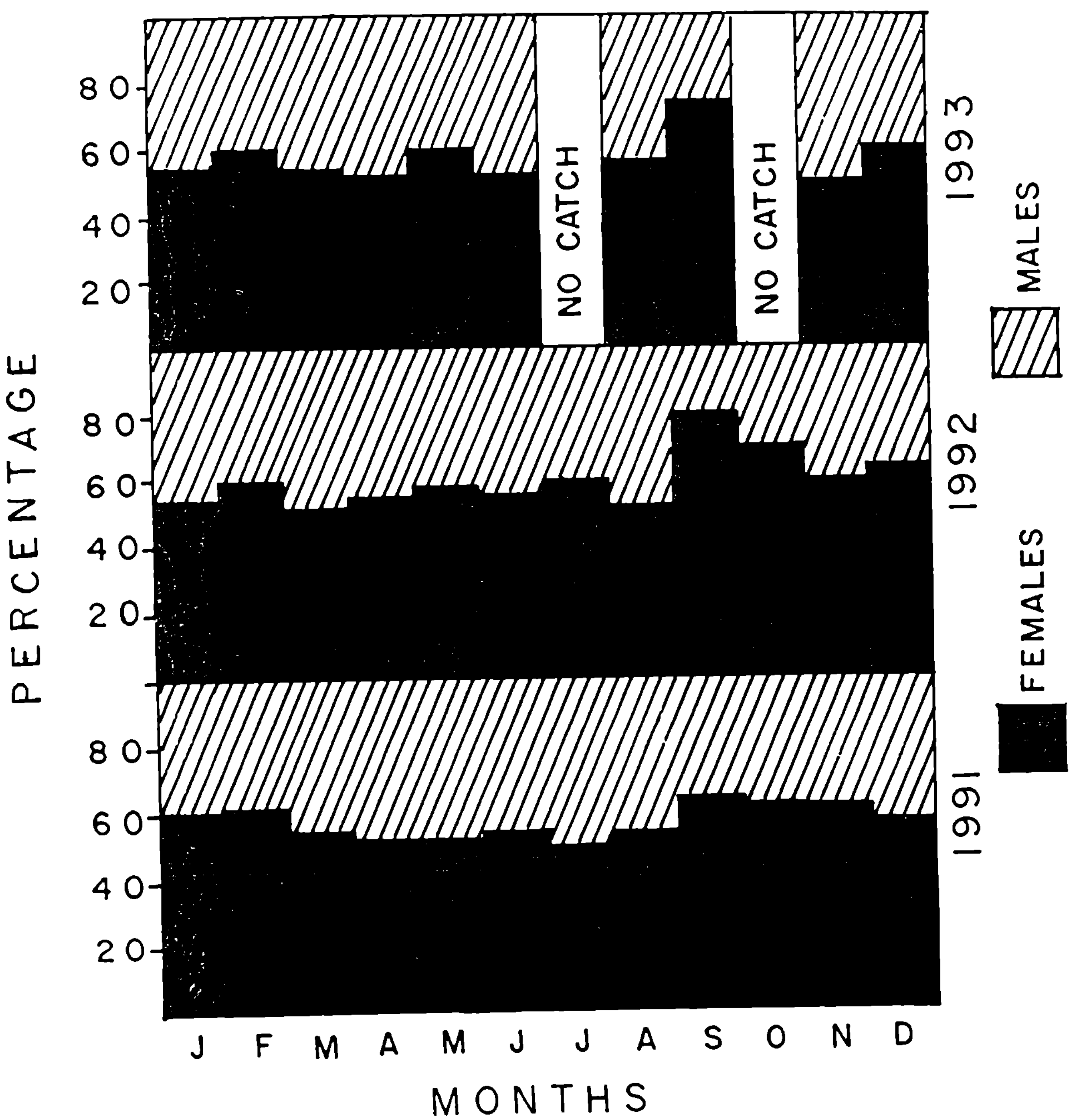


FIGURE 4.5 Monthly sex ratio of *M. monoceros* in trawler landings at Cochin Fisheries Harbour during the years 1991- 1993.

4.4. DISCUSSION

Five stages of maturity in females of *M. monoceros* i.e. immature, early maturing, late maturing, mature and spent recovery are recognised in the present studies. The mature ova are opaque, fully yolked with diameter, measuring between 0.145 and 0.261 mm. Majority of the ova in mature stage of ovary have diameter in the range of 0.174 and 0.232 mm. The largest ovum in mature ovary measuring 0.261 mm in the present studies agree with the observation made by Mohamed *et al* (1978) where, the viable eggs of *M. monoceros* obtained by artificial spawning measured 0.28 mm. Rao (1989) observed similar size range (0.11-0.27mm) and mode (0.17-0.23mm) for the ova in mature female of the same species from Kakinada region. However the size of the viable egg obtained by artificial spawning varied between 0.22 mm (Liao *et al*, 1969) and 0.35mm (Raje and Ranade, 1972). The observation by Gurney (1942) that size of the eggs of the same species occurring in different habitats and geographic localities varied considerably explains the variations in egg size of *M. monoceros* in different studies.

It was observed that the size at first maturity of *M. monoceros* at Cochin was 95mm in males and 114 mm in females, which is in close agreement with the studies of Rao (1989). He showed that *M. monoceros* attained first maturity at 96 mm and 116 mm for males and females respectively along the waters off

Kakinada . Slightly higher values as 120 and 118 mm were given as size at first maturity in females of *M. monoceros* by George (1959) and Nalini (1976) respectively. However George *et al* (1988) recorded the size at first maturity of *M. monoceros* at Karwar region as 135.5 mm inspite of recording the smallest prawn with fully mature ovary as 108 mm. The smallest mature female of this species measured 110 mm in Kakinada waters (Rao, 1989), whereas in the present study the smallest female with mature ovary measured 101 mm

The distribution of ova, in the ovaries of females in advanced stages of maturity showed only two groups of ova which are sharply separated from each other in size representing the immature and mature stages respectively. Since the mature ova are well differentiated from the immature, spawning is probably restricted to a short and definite period. As the ovaries of spent recovery stage contained only immature ova of less than 0.06 mm, it is possible that all the mature ova present in the ovary are liberated at a single spawning act within a short time. Fujinaga (1963) had observed that spawning takes place within 2-3 minutes in penaeid prawns. Spawning within a short period and completely releasing all the mature ova present in the ovary in the allied species were confirmed by the studies on *M. affinis* and *M. dobsoni* (Thomas *et al* 1974a,b respectively), *M. brevicornis* (Rao 1978) and *M. moyebi* (Nandakumar *et al*, 1989).

In the present study, it was observed that the main spawning season for *M. monoceros* extends from December to April which is followed by another short period viz. August-September. George (1959,1962) mentioned two peak breeding periods namely July-August and October-December for *M. monoceros* which do not compare well with the present work. Nalini (1976) and Srivatsa (1953) found October-April and February-April as the peak spawning periods for *M. monoceros* . Rao (1989) observed January-October as the spawning period for this species in Kakinada coast.

Based on the monthly distribution of mature females at each size group it is positively observed that female *M. monoceros* spawns about six times in its life span after attaining first maturity. Rao (1989) also mentioned five or more spawning for this species along the east-coast. Possibility of multiple spawning in a season for a single prawn has been mentioned by Lindner and Anderson (1956) in *P. setiferus* and Penn (1980) in *P. latisulcatus*. Rao (1968) stated that *M. dobsoni*, *P. indicus* and *P. stylifera* spawn atleast five times in their life after attaining the first sexual maturity. Vasudevappa (1992) observed successful rematuration and spawning of laboratory reared *M. dobsoni* in quick succession, probably many times during its life span. All these observations made by different research workers give supporting evidence for the present observation, on spawning frequency of *M. monoceros*.

Liao *et al* (1969) have observed that *M. monoceros* releases about 100000 eggs during artificial spawning. Rao (1968) recorded the fecundity of allied species, *M. affinis* and *M. dobsoni* ranging between 88,000 and 3,63,000 and between 34,500 and 1,60,000 respectively. Nalini (1976) estimated fecundity of *M. monoceros* in the size range of 146-175 mm as varying between 1,55,000 and 3,38,000. Rao (1989) estimated the fecundity of brown shrimp at Kakinada waters and observed linear relationships between fecundity and total length, total weight and ovary weight. In the present work the fecundity has ranged between 47,930 and 3,90,708 for *M. monoceros* measuring 101 mm and 163 mm respectively . The high fecundity observed in this species is in accordance with other penaeids which can release upto 1 million eggs at a single spawning (Hall 1962, Tuma 1967 and Martosubroto, 1974). Ovary weight has been observed to be a reliable indicator to estimate fecundity in *M. monoceros* and the relationship between them is logarithmic.

Females outnumbered males in the brown shrimp catches landed by trawlers at Cochin Fisheries Harbour during 1991-93 and formed 57% of annual catches of *M. monoceros*. Such differences in sex ratio of penaeid prawns has been reported by Menon (1957), George and Rao (1967), Ramamurthy *et al* (1978) an Rao (1989). They attributed the differences in sex ratio to the in-shore and offshore movements, breeding movement and sex segregation. It has been observed that *M. monoceros* along Kerala

Coast, irrespective of their size and sex undertake seasonal movement to deeper regions during monsoon months and return back to their natural habitat by September - October. (Vide Chapter 6). Hence it can be reasonably assumed that the preponderance of females in the speckled shrimp population observed in the present study, might be due to sizewise segregation and / or aggregation of females for spawning in the fishing grounds.

Table 4.1 Size -frequency distribution (in percentage) of maturing ova in different stages of maturity in females of *M. monoceros*.

Ova diameter in mm	Stages of Maturity				
	Immature	Early maturing	Late maturing	Mature	Spent
0.0145	54.73	-	-	-	62.19
0.0290	15.76	-	-	-	7.32
0.0435	25.40	-	-	-	20.73
0.0580	4.11	14.32	-	-	9.76
0.0725	-	32.15	-	-	-
0.0870	-	45.13	9.35	-	-
0.1015	-	6.39	24.46	-	-
0.1160	-	2.01	23.74	-	-
0.1305	-	-	18.71	-	-
0.1450	-	-	20.86	2.50	-
0.1595	-	-	1.44	7.50	-
0.1740	-	-	1.44	12.50	-
0.1885	-	-	-	26.25	-
0.2030	-	-	-	13.75	-
0.2175	-	-	-	25.25	-
0.2320	-	-	-	6.25	-
0.2465	-	-	-	5.18	-
0.2610	-	-	-	0.82	-

Table 4.2 Determination of size at first maturity in *M. monoceros*

	Total length in mm	Immature %	Mature %	Total No. of prawns observed
MALES	90	92.31	7.69	13
	91	85.71	14.29	7
	92	88.23	11.77	17
	93	76.92	23.08	13
	94	44.44	55.56	9
	95	37.50	62.50	8
	96	27.27	72.73	11
	97	29.41	70.59	17
	98	20.00	80.00	25
	99	12.50	87.50	8
	100	-	100.00	10
	101	-	100.00	12
FEMALES	101	91.67	8.33	12
	102	92.86	7.14	14
	103	86.67	13.33	15
	104	81.25	18.75	16
	105	81.25	18.75	16
	106	83.33	16.67	6
	107	75.00	25.00	24
	108	78.57	21.43	28
	109	72.73	27.27	11
	110	78.95	21.05	19
	111	72.00	28.00	25
	112	55.00	45.00	20
	113	55.00	45.00	20
	114	33.33	66.67	18
	115	36.84	63.16	19
	116	35.71	64.29	28
	117	33.33	66.67	30
	118	28.57	71.43	35
	119	8.23	91.67	12
	120	-	100.00	25
	121	-	100.00	15

Table 4.3 Percentage Occurrence of Females of *M. monoceros* in different stages of maturity in various size groups during the year 1991.

Size group in mm	Maturity stages					
	Immature	Early maturing	Late maturing	Mature	Spent	No. of prawns observed
68	100.00	-	-	-	-	1
73	100.00	-	-	-	-	8
78	100.00	-	-	-	-	5
83	100.00	-	-	-	-	11
88	100.00	-	-	-	-	37
93	100.00	-	-	-	-	38
98	100.00	-	-	-	-	85
103	83.33	7.14	3.98	4.76	0.79	126
108	65.24	19.51	9.76	4.88	0.61	164
113	39.90	27.09	19.21	8.87	4.93	203
118	9.85	29.20	22.26	9.49	29.20	274
123	-	25.91	25.91	17.16	31.02	274
128	-	25.08	23.00	23.00	28.92	287
133	-	20.00	28.52	26.67	24.81	270
138	-	18.30	27.23	29.91	24.56	224
143	-	20.46	26.70	34.09	18.75	176
148	-	11.32	25.79	38.99	23.90	159
153	-	9.74	26.62	45.46	18.18	154
158	-	12.87	24.76	48.51	13.86	101
163	-	7.14	22.86	60.00	10.00	70
168	-	5.36	17.86	44.64	32.14	56
173	-	2.17	21.74	65.22	10.87	46
178	-	-	27.59	55.17	17.24	29
183	-	-	14.29	64.28	21.43	14
188	-	-	40.00	40.00	20.00	5
193	-	-	-	100.00	-	1

Table 4.4 Percentage occurrence of females of *M. monoceros* in different stages of maturity in various size groups during the year 1992.

Size group in mm	Maturity stages					
	Immature	Early maturing	Late maturing	Mature	Spent	No. of prawns observed
78	100.00	-	-	-	-	1
83	100.00	-	-	-	-	4
88	100.00	-	-	-	-	9
93	100.00	-	-	-	-	11
98	100.00	-	-	-	-	20
103	84.44	6.67	8.89	-	-	45
108	66.27	19.28	10.84	3.61	-	83
113	38.14	37.11	19.59	1.03	4.12	97
118	12.40	33.33	22.48	7.75	24.03	129
123	-	31.82	25.76	8.33	34.09	132
128	-	19.79	31.02	13.37	35.83	187
133	-	19.21	21.85	16.56	42.38	151
138	-	21.12	21.12	16.67	40.91	132
143	-	15.63	39.06	13.28	32.03	128
148	-	8.49	44.34	19.81	27.36	106
153	-	17.58	26.37	18.68	37.36	91
158	-	13.21	28.30	16.98	41.51	53
163	-	13.33	30.00	13.33	43.33	30
168	-	15.79	31.58	21.05	31.58	19
173	-	10.53	15.79	31.58	10.53	13
178	-	-	-	100.00	-	2
183	-	-	-	50.00	50.00	2

Table 4.5 Percentage occurrence of females of *M. monoceros* in different stages of maturity in various size groups during the year 1993.

Size group in mm	Maturity stages					
	Immature	Early maturing	Late maturing	Mature	Spent	No. of prawns observed
78	100.00	-	-	-	-	1
83	100.00	-	-	-	-	3
88	100.00	-	-	-	-	4
93	100.00	-	-	-	-	5
98	100.00	-	-	-	-	13
103	75.00	10.00	15.00	-	-	20
108	54.00	10.00	30.00	6.00	-	50
113	41.46	29.27	15.85	9.76	3.66	82
118	6.06	20.20	21.21	18.18	26.26	99
123	-	17.70	37.17	8.85	36.28	113
128	-	11.83	36.56	22.58	29.03	93
133	-	14.91	26.32	28.07	30.70	114
138	-	11.30	22.61	31.30	34.78	115
143	-	7.63	24.58	27.12	40.68	118
148	-	10.68	22.33	39.81	27.18	103
153	-	4.23	23.94	33.10	38.73	142
158	-	2.99	17.91	40.30	38.81	67
163	-	-	19.61	43.14	37.25	51
168	-	-	8.82	50.00	41.18	34
173	-	12.50	-	75.00	12.50	16
178	-	-	21.43	50.00	28.57	14
183	-	-	33.33	33.33	33.33	6
188	-	-	-	50.00	50.00	2
193	-	-	-	100.00	-	1

Table 4.6 Monthly percentage occurrence of females of *M. monoceros* in different stages of maturity during 1991 - 92.

Year/ Month	Maturity stages					
	Immature	Early maturing	Late maturing	Mature	Spent	No. of prawns observed
1991						
January	2.51	2.96	12.86	50.37	31.30	294
February	24.38	6.35	19.00	30.82	19.45	378
March	15.64	12.55	16.83	29.37	25.62	364
April	13.22	10.86	15.30	47.47	13.15	299
May	9.09	39.81	22.28	10.25	18.57	270
June	70.15	3.80	3.32	0.44	22.29	119
July	62.89	1.23	2.47	0.62	32.80	53
August	22.35	18.99	16.34	17.62	24.70	237
September	3.54	24.72	37.95	18.68	15.11	186
October	27.67	31.42	13.10	9.24	18.58	88
November	1.29	42.91	35.83	11.66	8.31	195
December	4.12	11.73	35.79	24.03	24.33	266
1992						
January	11.92	24.14	31.18	15.47	17.29	219
February	10.58	30.76	26.69	9.69	22.27	230
March	8.26	13.66	24.76	15.61	37.71	216
April	19.22	17.10	28.09	12.60	22.98	182
May	16.87	13.95	19.38	20.25	29.55	148
June	19.59	21.23	23.92	3.91	31.34	77
July	21.82	12.73	5.45	-	60.00	55
August	45.76	22.04	9.47	4.36	18.37	70
September	7.41	29.63	27.78	11.11	24.07	54
October	9.28	30.10	30.58	11.11	18.93	37
November	3.11	31.68	47.82	13.55	3.85	63
December	3.65	18.02	22.10	6.21	50.03	104

Table 4.7 Monthly percentage occurrence of females of *M. monoceros* in different stages of maturity during 1993.

Year/ Month	Maturity stages					
	Immature	Early maturing	Late maturing	Mature	Spent	No. of prawns observed
1993						
January	12.57	15.32	24.25	20.02	28.30	220
February	1.00	12.77	30.31	28.07	27.85	226
March	2.68	15.24	32.74	24.49	24.85	135
April	18.11	17.69	28.95	19.44	15.81	191
May	12.58	15.76	24.37	15.11	32.18	192
June	5.45	18.18	38.18	20.00	18.18	55
July	-	No	Catch	-	-	-
August	2.63	-	10.53	31.58	55.26	38
September	0.58	-	11.47	54.43	33.52	112
October	-	NO	Catch	-	-	-
November	-	-	10.53	21.05	68.42	19
December	34.78	1.16	2.05	46.54	15.47	85

Table 4.8 **Monthly average percentage of females of *M. monoceros* in mature stage during 1991-93.**

Months	Percentage of mature females	Total No. of prawns observed
January	30.83	733
February	24.10	834
March	24.34	715
April	30.06	672
May	14.26	610
June	5.58	251
July	0.00	108
August	16.76	340
September	28.98	352
October	9.60	125
November	13.00	277
December	24.17	455

Table 4.9 Fecundity data of females of *M. monoceros*

Total length in mm	Total Weight in grams	Ovary Weight in grams	Fecundity (Number of Ova)
101	6.82	0.4262	47930
102	6.99	0.5031	125622
103	7.36	0.3106	49696
114	12.00	0.4815	110307
119	11.30	0.6918	115300
124	13.13	0.7659	81792
125	15.50	1.0040	171032
127	14.50	1.2150	154913
133	20.00	1.8293	208769
138	21.60	1.9760	250713
139	19.53	1.7787	319515
142	23.34	2.4517	296765
146	22.50	1.6100	263775
147	26.20	1.6143	296134
145	21.79	2.0544	278987
151	24.65	1.7605	315790
155	30.00	1.9485	382760
158	30.25	2.8655	299613
154	25.72	2.5265	467403
161	31.94	3.1860	395974
163	34.62	3.6230	390708

Table 4.10 Monthly sex ratio in percentage of *M.monoceros* (based on estimated numbers of the monthly catch)

Months	1991			1992			1993		
	No.of prawns	Females	Males	No. of prawns	Females	Males	No. of prawns	Females	Males
January	858412	60.03	39.97	1015383	55.09	44.91	2069036	55.94	44.06
February	1828287	60.78	39.22	2013213	60.58	39.42	1230311	59.83	40.17
March	1671073	54.10	45.90	1974086	53.23	46.77	2105441	53.51	46.49
April	2181825	52.86	47.13	1503462	53.97	46.03	2601163	52.50	47.50
May	2380511	52.11	47.89	2251000	57.52	42.48	2055467	59.62	40.38
June	199790	55.25	44.75	416705	56.00	44.00	527921	52.88	47.12
July	48870	49.79	50.21	18820	61.11	38.89	-	No Catch	-
August	34400	54.87	45.13	37998	52.57	47.49	526266	56.72	43.28
September	371847	64.71	35.29	11883	80.59	19.41	475065	73.71	26.29
October	9262	61.94	38.06	14291	71.04	28.96	-	No Catch	-
November	1943980	63.31	36.69	25523	60.45	39.55	55366	50.00	50.00
December	1675824	58.09	41.91	1265890	63.53	36.47	1946596	61.07	38.92
	13204081	57.02	42.98	10548254	57.26	42.74	13592632	57.06	42.94

Table 4.11 X^2 Values of sex ratios for *M. monoceros* for the period 1991 - 93

Year	1991		1992		1993	
Ratios tested F:M	1:1	57:43	1:1	57:43	1:1	57:43
Value of X^2	30.57	31.17	24.65	25.41	31.50	32.50
Degrees of freedom	11	11	11	11	9	9
p	<.01	<.01	<.01	<.01	<.01	<.01

Significant at 1% level.

CHAPTER 5

LENGTH - WEIGHT RELATIONSHIP

CHAPTER 5

LENGTH-WEIGHT RELATIONSHIP

5.1 INTRODUCTION

Growth is manifested as an increase in size of the prawn and as such is best measured in terms of its volume or weight. It has been mathematically proved that there is a fairly constant relationship between total length and weight of the individuals of the species. Therefore, when a knowledge of the growth in volume or weight is required, it is usually calculated from length-weight relationship. The length-weight relationship is also needed for studies on maturity and yield estimates by analytical models. As prawns are exported as 'headless' variety, to find out, the total length and total weight from tail weight alone, the relationship between total length and tail weight; and between total weight and tail weight are needed. For comparision of data from different sources the relationship existing between total length and carapace length is required. Based on the above observations, the present study on length-weight and other dimensional relationships of *M. monoceros* becomes meaningful.

George (1959) studied the length-weight relationship of juveniles of *M. monoceros* from Cochin backwaters. Hall (1962) gave the carapace length-weight relationship of some penaeid prawns while studying their biology. Rao (1967) and Thomas (1975) gave the length-weight relationship of *P monodon* and *P. indicus* from Chilka Lake and *P. semisulcatus* from Mandapam respectively. Rao (1992) gave this relationship in *P. indicus* from Visakhapatnam. The length-weight relationship in *M. monoceros* for males and females separately was compared between seasons in northern part of Egypt (Bishara, 1976). Length weight relationship in some common prawns from western Indian ocean *P. indicus*, *P. semisulcatus*, *P. latisulcatus* and *M. monoceros* were studied by Ivanov and Krylov (1980). Lalitha Devi (1987) and Rao (1988 d) studied the length- weight relationship of *M. monoceros* from Kakinada coast . Observations on length-weight relationship on *M. brevicornis* and *P. hardwickii* were made by Rajyalakshmi (1961) and Sukumaran and Rajan (1981) respectively. Relationship between total length and carapace length of three commercial species of penaeid prawns was observed by Ramamurthy and Manickaraja (1978) from Mangalore coast. Studies on the length-weight relationship and other dimensional relationships for males and females separately, covering the entire length range of *M. monoceros* along the west coast, is made for the first time and the details are given here.

5.2 MATERIAL AND METHODS

Samples of *M. monoceros* collected from trawl catches landed at Cochin Fisheries Harbour during 1991-1992 were utilised for the studies on length-weight relationship. The details on total length, carapace length, total weight, tail weight were collected from samples in fresh condition. Adhered moisture from the fresh specimens were removed and the weight of individual prawn was taken to the nearest 0.1 gm. After sex-wise sorting out, the total length from the tip of rostrum to tip of telson was measured to the nearest millimeter keeping the abdomen fully streched. The carapace length was measured from orbital notch to the posterior margin of carapace along the mid-dorsal line using vernier calipers. Data collected for the two year period (1991-92) were pooled to represent all available size groups in the trawl fishery.

Weight may be considered as a function of length. This relationship of length and weight follows approximately the cube law relationship expressed by the formula $K = W/L^3$, where W = weight and L = Length. As the prawn is continuously prone to change its bodily proportions during life, a simple cube law expression does not hold good throughout the life history and growth of the prawn (Kunju, 1978). Therefore a more satisfactory formula for the expression of the relationship is $W = aL^b$ where W = Weight, L = length, 'a' and 'b' are constants and expressed logarithmically as $\text{Log } W = a + b \text{ Log } L$. When the data for total length-total weight and total length-tail weight were plotted on a graph paper, an exponential relationship was observed between these parameters. Therefore logarithmic transformation was adopted for these relationships, as Log W = a + b log L. The relationships between total weight and tail weight as well as the total length and carapace length were found to be linear and they were calculated by the method of least squares on the basis of individual measurements. To learn whether the regression of different parameters are significantly different between males and females, analysis of covariance (Snedecor and Cocharan, 1968) was employed. The data analysed are given in Tables 5. 1-8.

5.3 RESULTS

5.3.1 Total length-total weight relationship

A total of 217 males ranging in total length from 56 to 152 mm and 260 females ranging in total length from 52 to 187 mm were measured to study the total length-total weight relationship of *M. monoceros*. When total length and total weight were plotted it was observed that a single equation would not fit the data for both males and females together. Therefore the estimates were made separately for males and females. However, it was noticed that a single equation would fit the data for entire length range of the same sex. The raw sums of squares and products of Log total length and Log total weight for males and females are shown in Table 5.1. The analysis of covariance showed that a significant difference existed between the regression coefficients of males and females (Table 5.2). Hence separate equation was formulated for each sex and given here.

Males: $\log W = -4.9587 + 2.9004 \log L$ (r=0.9956)

Females : $\log W = -5.4025 + 3.1341 \log L$ (r=0.9969)

The exponential form of equations are:

Males: $W = 0.000010998\ L^{2.9004}$

Females: $W = 0.000003958\ L^{3.1341}$

where 'W' is total weight and 'L' is total length. The calculated curves of total length and total weight for males and females are shown in Fig. 5.1 and 5.2 respectively.

5.3.2 Total length-tail weight relationship

A total of 157 males in the size range of 71-152 mm and 187 females in the size range of 52-168 mm of the brown shrimp were taken up for studies to find out the relationship between total length and tail weight. It was noticed again that a single equation would not fit the data for both sexes together and hence the estimates were made separately for males and females. A

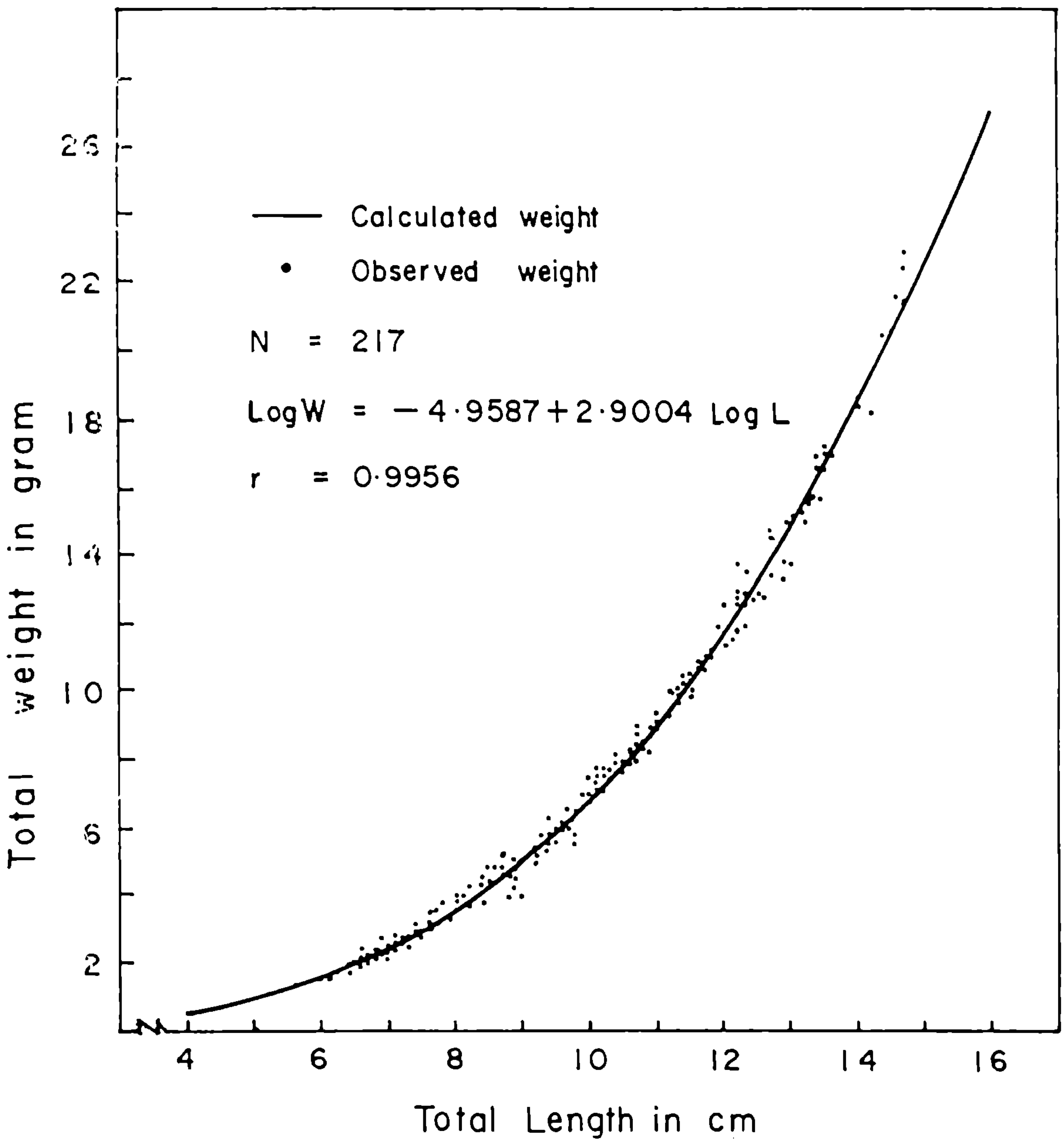


FIGURE 5.1 Relationship between total length and total weight in males of *M. monoceros*

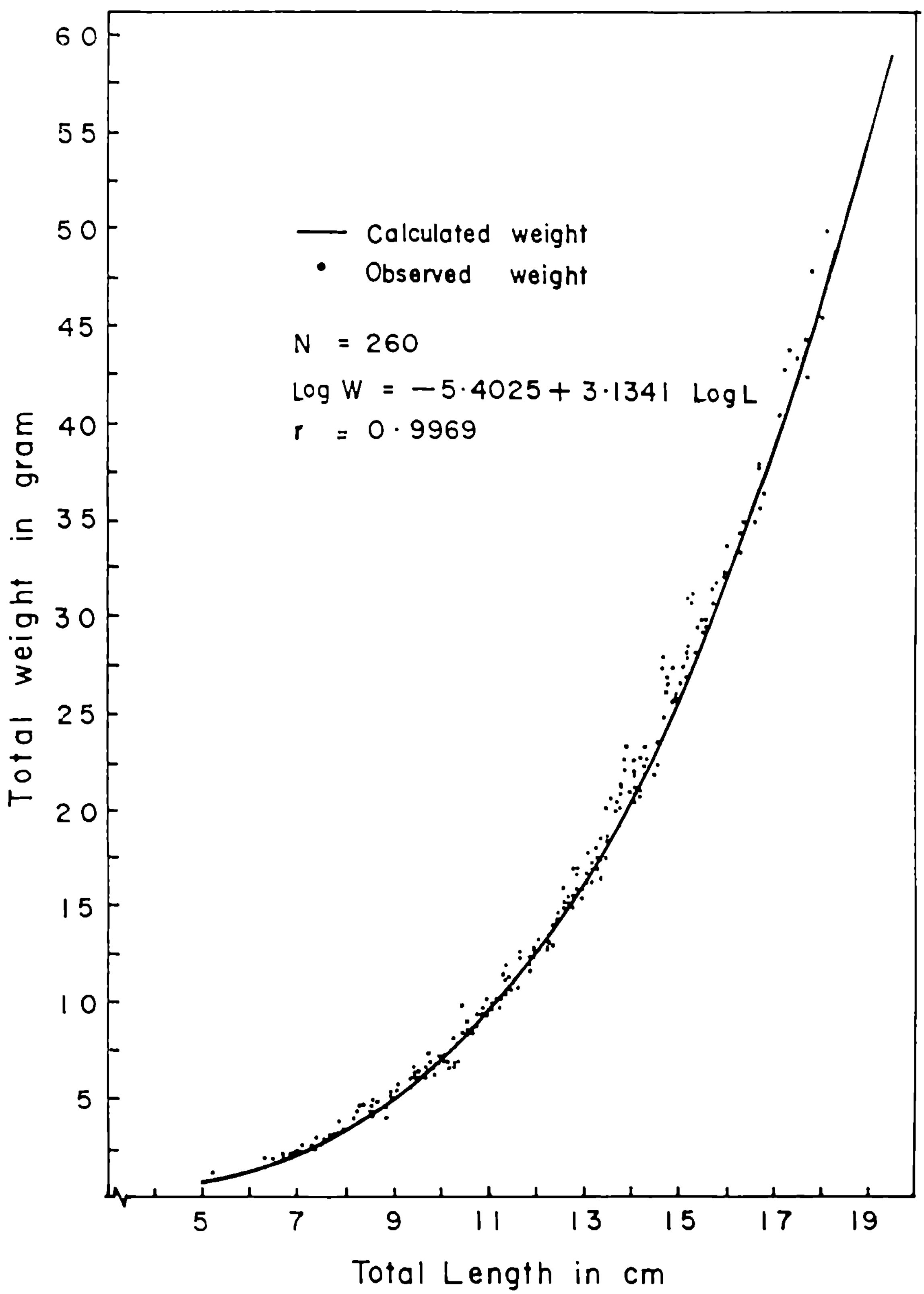


FIGURE 5.2 Relationship between total length and total weight in females of *M. monoceros*

single equation was observed to fit to data for the entire length range of the same sex. The raw sums of squares and products of Log total length and Log tail weight are given in Table 5.3. The analysis of covariance showed that significant differences existed between sexes and hence separate equation was given for males and females (Table 5.4). The equations for total length and tail weight relationship for *M. monoceros* landed at Cochin Fisheries Harbour during 1991-92 are as follows.

Males: $\text{Log } y = -5.6076 + 3.1391 \text{ Log } x$ $(r = 0.9900)$

Females: $\text{Log } y = -5.7240 + 3.2090 \text{ Log } x$ $(r = 0.9962)$

The exponential form of equations are

Males : $y = 0.000002468 \; x^{3.1391}$

Females : $y = 0.000001888 \; x^{3.2090}$

where \`y' is tail weight and \`x' is total length.

5.3.3. Total weight-tail weight relationship

A total number of 157 males (size range 71-152 mm) ranging in total weight from 1.4 to 23.0 gm and 187 females (size range 52-168 mm) ranging in weight from 1.2-36.5 gm were taken for this study on total weight- tail weight relationship. A preliminary plot of the data for males and females separately showed a linear relationship. The raw sums of squares and products of total weight and tail wdight are presented in Table 5.5. The analysis of covariance indicated that significant differences existed between the regression lines of males and females (Table 5.6). The equations for the relationship between total weight and tail weight for males and females are as follows:

Males : $Y = -0.2093 + 0.7181\ X \quad (r=0.9956)$

Females : $Y = 0.0499 + 0.6891\ X \quad (r = 0.9959)$

where 'Y' is the tail weight and 'X' is the total weight.

5.3.4. Total length - carapace length relationship

A total of 152 males ranging in total length between 56 and 152 mm and 260 females in the size range of 52-187 mm were analysed to find out the relationship between total length and carapace length of *M. monoceros*. A preliminary plot of the total length and carapace length indicated that separate estimates were needed for males and females. Similar analysis within the same sex showed that a single equation would fit the data for the entire length range.

Raw sums of squares and products of total length and carapace length are given in Table 5.7. Analysis of covariance showed the existance of significant differences between regression coefficients of males and females (Table 5.8). The equations for total length-carapace length relationship for males and females are as follows:

Males : CL = -0.9888 + 0.2330 TL (r=0.9910)

Females : CL = -5.5291 + 0.2866 TL (r=0.9889)

Where 'CL' is carapace length and 'TL' is total length.

5.4. DISCUSSION

The earliest study on length-weight relationship of *M. monoceros* in India was by George (1959). Based on the length and weight of 175 juveniles of *M. monoceros* (size range 25-105 mm) collected mainly from Cochin Backwaters he derived a common equation for both sexes as $W = 0.01989\ L^{2.7603}$. However it was observed in the present studies that males and females require different equations for length-weight relationship. Bishara (1976) provided data on males and females separately as well as by seasons while studying this relationship in *M. monoceros* from northern Egypt and observed seasonal changes in condition of *M.monoceros*. Ivanov and Krylov (1980) based on the collection of *M. monoceros* from Zambezi delta in western Indian Ocean at depth range around 25 m gave the equation for length and weight relationship for males and females separately as well as combined for both sexes. Rao (1988d) gave length-weight relationship and other dimentional relationships on *M. monoceros* collected from trawl catch at Kakinada during 1974 and observed that male was heavier than female upto 77mm after which female became heavier than males due to maturation process. The present study also revealed the same trend and females in general becomes heavier than males from 80 mm onwards due to maturation processes in the ovary. Further *M. monoceros* (both males and females) from Kerala coast was found to weigh more than their counterparts of corresponding length from Kakinada coast.

Rao (1988 d)comparing the total length and carapace length of this species stressed separate relationship for juveniles and adults for both sexes based on the inflection in linear relationship at 100 mm in males and 110 mm in females. However such prominent inflection based on size was not noticed in the present study when comparing the total length and carapace length of males and females of *M. monoceros* and hence one common equation each for males and females was calculated. Ivanov and Krylov (1980) gave only a single equation each for males and females of *M. monoceros* for comparing total length and carapce length. Ramamurthy and Manickaraja (1978) did not observe any differences between juveniles and adults in the carapace length and total length relationship in *P. stylifera*, *M. dobsoni* and *M. affinis* and hence gave one regression equation alone for each sex for the above said species. Sukumaran and Rajan (1981) also gave one common equation each for the entire size range for males and females of *P. hardwickii*.

Table 5.1. Raw sums of squares and products for total length total weight relationship of *M. monoceros*

Sex	N	S X	S Y	S XY	S X2	S Y2
Male	217	431.8700	176.5502	357.1872	861.5074	160.6689
Female	260	534.0243	269.0380	562.5526	1100.0332	309.8153

S = Summation

Table 5.2 Comparison of the regression lines of the tottal length - total weight relattionship of *M. monoceros*

Source	Corrected sums of squares and products				Regression coefficient	Deviation from regression		
	d.f.	S x2	S xy	S y2		d.f.	S.S.	M.S.
Males	216	2.0065	5.8197	17.0285	2.9004	215	0.148905	0.000693
Females	259	3.1795	9.9648	31.4251	3.1341	258	0.194643	0.000754
Pooled (within)						473	0.343548	0.000726
combined	475	5.1860	15.7845	48.4536	3.0437	474	0.410708	0.000866
Between slopes						1	0.067160	0.067160
Between sexes	1	0.4808	1.6678	5.7856				
Total	476	5.6668	17.4523	54.2392	-	475	0.490563	-
Between adjusted means						1	0.079855	0.079855

Comparison of slopes : F = 92.51 (d.f.= 1,473) significant at 1% level

Comparison of elevations: F = 92.21 (d.f. = 1,474) significant at 1% level

Table 5.3. Raw sums of squares and products for total length tail weight relationship of *M. monoceros*

Sex	N	S X	S Y	S XY	S X2	S Y2
Male	157	319.1951	121.4367	249.2705	649.7101	101.5470
Female	187	384.8944	164.6472	344.6169	793.9980	163.4957

S = Summation

Table 5.4 Comparison of the regression lines of the total length tail weight relationship of *M. monoceros*

Source	Corrected sums of squares and products				Regression coefficient	Deviation from regression		
	d.f.	S x2	S xy	S y2		d.f.	S.S.	M.S.
Males	156	0.7578	2.3788	7.6179	3.1391	155	0.150640	0.000972
Females	186	1.7857	5.7303	18.5294	3.2090	185	0.140904	0.000762
Pooled (within)						340	0.291544	0.000857
combined	342	2.5435	8.1091	26.1473	3.1882	341	0.294144	0.000863
Between slopes						1	0.002600	0.002600
Between sexes	1	0.0541	0.2298	0.9768				
Total	343	2.5976	8.3389	27.1241	-	342	0.354292	
Between adjusted means						1	0.060148	0.060148

Comparison of slopes : F = 3.03 (d.f. = 1,340) not significant at 1% level
Comparison of elevation : F= 69.70 (d.f. = 1,341) significant at 1 % level

Table 5.5. Raw sums of squares and products for total weight tail weight relationship of *M. monoceros*

Sex	N	S X	S Y	S XY	S X2	S Y2
Male	157	1509.70	1051.30	12297.64	17564.57	8625.29
Female	187	2550.80	1767.10	32439.00	46889.38	22489.63

S = Summation

Table 5.6. Comparison of the regression lines of the total weight - tail weight relationship of *M. monoceros*

Source	Corrected sums of squares and products				Regression coefficient	Deviation from regression		
	d.f.	S x2	S xy	S y2		d.f.	S.S.	M.S.
Males	156	3047.41	2188.42	1585.60	0.7181	155	14.041825	0.090592
Females	186	12094.83	8334.62	5791.01	0.6891	185	47.573300	0.257153
Pooled (within)						340	61.615125	0.181221
combined	342	15142.24	10523.04	7376.61	0.6949	341	63.664832	0.186700
Between slopes						1	2.049707	2.049707
Between sexes	1	1382.46	945.83	647.09				
Total	343	16524.70	11468.87	8023.70	-	342	63.798817	-
Between adjusted means						1	0.133985	0.133985

Comparison of slopes : F = 11.31 (d.f. 1,340) significant at 1 % level
Comparison of elevations : F = 0.72 (d.f. 1,341) not significant at 1 % level.

Table 5.7. Raw sums of squares and products for total length carapace length relationship of _M. monoceros_

Sex	N	S X	S Y	S XY	S X2	S Y2
Male	236	22908	5106	524358	2346864	117210
Female	259	30244	7236	901956	3730544	218692

S = Summation

Table 5.8. Comparison of the regression lines of the total length - carapace length relationship of _M. monoceros_

Source	Corrected sums of squares and products				Regression coefficient	Deviation from regression		
	d.f.	S x2	S xy	S y2		d.f.	S.S.	M.S.
Males	235	123234.9155	28729.8305	6738.6610	0.2331	234	40.858225	0.174608
Females	258	198885.5599	56992.3552	16531.0116	0.2866	257	199.365612	0.775742
Pooled (within)						491	240.223837	0.489254
combined	493	322120.4754	85722.1857	23269.6726	0.2661	492	457.421639	0.929719
Between slopes						1	217.197802	217.19780
Between sexes	1	47843.8806	15335.2804	4905.1274				
Total	494	369964.3560	101057.4661	28174.8000	-	493	570.488155	-
Between adjusted means						1	113.066516	113.06651

Comparison of slopw = F = 443.94 (1,491) Significant at 1% level.

Comparison of elevation = F = 121.61 (1,492) significant at 1% level.

CHAPTER 6

FISHERY

CHAPTER 6

FISHERY

6.1 INTRODUCTION

Prawn fishery of India have been studied by many research workers and information on the biology and fishery characteristics of important species from different states along both coasts of our country are available . Jones (1969) gave an account on the prawn fishery and species composition on both the coasts along with export details of the country. Ramamurthy and Muthu (1969) made a detailed account on the fishing methods practised in India to exploit prawn resources. A general account on the prawn fisheries of India, fishing methods and prawn culture practises were given by Kurian and Sebastian (1976). George (1988) reviewed shrimp resources around the Asian countries with special reference to India. A descriptive account on the present status of prawn fishery of India along with a review on the investigations carried out so far on the biology of commercially important prawns was given by Rao (1986). An overview of crustacean fishery resources of India was made by Suseelan and Pillai (1993).

Kerala has an unique feature of continuous chain of thirty identifiable backwaters running parallel to the sea coast and receiving waters from forty one west-flowing rivers that originate from the Western Ghats. These backwaters are locally called 'kayals'. The backwater fishery resources of Kerala are indeed of high magnitude. They support a rich fishery. The resources survey made in 1991 by Agency for Development of Aquaculture Kerala (ADAK) showed that the total area of backwaters in Kerala as per revenue records amounted to 44000 hectares. The landings of commercially important fish and prawns from the backwaters are about 15-21 thousand tonnes per annum with an average of 18 t (Sanjeevaghosh, 1993). The fishery wealth is composed of several species of fishes, crustaceans and molluscs belonging predominantly to the marine habit. The extensive estuarine systems combined with backwaters serve as nursery grounds for commercially important prawns. Postlarvae of most penaeid prawns occurring along the Kerala coast enter into these estuaries and backwaters to spend their juvenile phase. The muddy bottom containing large amounts of animal and plant detritus provide optimum conditions for growth. The juvenile prawns then emigrate to the sea for further growth, maturation and spawning. *M. monoceros* also follow this pattern of life cycle.

Though there is an extensive backwaters system rich in prawn fishery in Kerala, attempt to study this biological resources is scanty and available informations are summarised below. An account of seasonal occurrence of penaeid post larvae in Korapuzha estuary was given by Koumudi Menon (1980). Kurup *et al.*,(1993) studied the prawn fishery of Korapuzha Estuary during 1983-87 and stated that on an average annually 6508 units operated fetching a total catch of 96.6 t of prawns. Suseelan and Kathirvel (1982) gave an account on the availability of penaeid prawns based on the expermental prawn fishing in Ashtamudi Backwaters.

Shetty (1965) made detailed observations on the fish and fisheries of Vembanad Backwaters. George and Suseelan (1982) gave an account on the distribution of prawns in Vembanad Estuary in relation to salinity. Kurup *et al* (1993) conducted monthly surveys during 1988-89 in the Vembanad lake and estimated the annual yield of fishes and crustaceans as 7202 t. A detailed account on the prawn fishery of Cochin Backwaters with special reference to the stake net catches was given by Menon and Raman (1961). George (1962), Mohamed and Rao (1971) described the recruitment level of post-larvae of penaeid prawns and their estuarine phase in the Cochin Backwaters. Kurian (1972) made detailed studies on the benthos of Cochin Backwaters. Kuttyamma and Antony (1975) observed the relative abundance and size variation of penaeid prawns in the Cochin Backwaters. At present there is a lacunae in our knowledge on the recent developments of prawn fishery in the Cochin Backwaters. Hence observations on prawn fishery in general and fisheries biology of *M. monoceros* in particular from Cochin Backwaters were made and given here in detail.

Following the encouraging results of exploratory cum commercial trawling operations of the Indo-Norwegian Project which started off the Kerala coast in 1953, an organised commercial fishery by mechanised vessels began at Cochin in 1958. The average annual marine fish landings in India during 1991-93 was 2.25 million tonnes which showed an increase of 23 % over the average annual landings of 1985-86 duration i.e. 1.83 million tonnes (CMFRI, 1995). The penaeid prawns with an average annual catch of 1.84 lakh tonnes, constituted 8.20 % of the all India marine landings for the period 1991-93. West coast of India contributed to 79.76 % of the penaeid prawn landings of the country. Kerala with 53125 t of prawn catch accounted for 28.81 % of all India and 36.12 % of west coast landings of penaeid prawns. Important landing centres along the Kerala coast for trawl catches are shown in Fig. 6.1. A total number of 2525 mechanised trawlers operate in the inshore waters of Kerala. Sakthikulangara and Cochin are the two major fishing harbours of Kerala, where maximum number of trawlers land their catches.

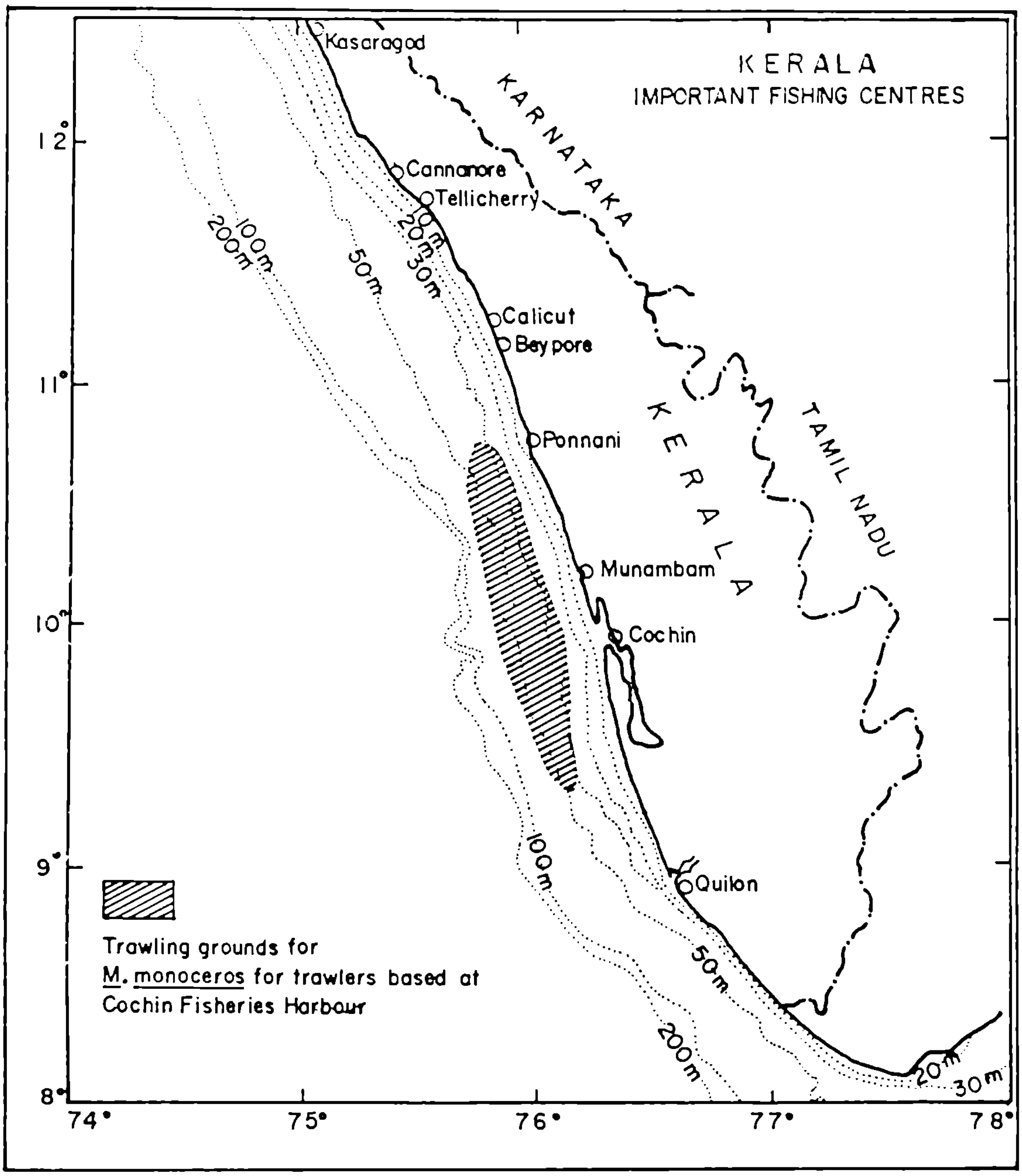


FIGURE 6.1 Important landing centres for trawler catchesalong the Kerala coast.

Other important trawl landing centres of Kerala are Munambam, Ponnani, Beypore, Pudyappa/Calicut, Tellicheri, Cannanore and Kasargod.

The prawn catch landed by trawlers for Kerala state, Sakthikulangara, Cochin Harbour -Murikkampadam and other centres for the period 1985-93 (Source: NMLRDC, CMFRI) are given in Table 6.1. During 1985-90 period, the average annual prawn catch of Kerala amounted to 35861 t which increased to 44271 t in 1991, in spite of reduction of 0.84 % in effort. In comparison with the previous year, in 1992, the prawn catch (39782 t) and CPUE (73.37 kg) decreased in accordance with reduction in effort (542240). The prawn catch further decreased by 11.9 % in 1993 (35046 t) eventhough the effort was increased by 11.71 % (605727 units). The average annual prawn landing by trawlers in Kerala during 1991-93 was 39670 t with CPUE of 69.94 kg with an average effort of 567202 shrimp trawlers. In Sakthikulangara, the average annual prawn landings during 1985-90 amounted to 8755 t with CPUE of 65.59 kg. The annual prawn catch and CPUE respectively showed a steady progress in 1991 (14147 t; 90.72 kg), 1992 (15433 t; 87.48 kg) and 1993 (17138 t; 96.28 kg). The contribution of Sakthikulangara to the prawn landings of Kerala increased from 31.95 % in 1991 to 48.90 % in 1993. The prawn landings at Cochin harbour-Murikkampadam which was 4374 t (CPUE 79.01 kg) during 1985-90, showed initially, about three fold increase in 1991 (12155 t) and the effort increased to 108911 units with CPUE of 111.60 kg (Table.6.1). However, the prawn catch declined to 5761 t (CPUE: 62.06 kg) in 1992. The prawn landings in 1993 increased to 7130 t along with modest increase in effort (102565) and CPUE (69.52 kg). The prawn catch of Cochin-Murikkampadam during 1991-93 constituted between 14.48 % (1992) and 27.46 % (1991) in the all Kerala prawn landings by shrimp trawlers. The percentage composition of prawn catch of other centres, in all Kerala prawn landings by trawlers, showed a decreasing trend between 1991 (40.59) and 1993 (30.75).

6.2 MATERIAL AND METHODS

Two important fish landing centres viz. Thoppumpady which is about 2 km from bar mouth on the southern side and Vypeen (about 500m from bar mouth on the northern side) were selected for observation of stake net fishery of Cochin Backwaters. Stake nets were selected for observation of prawn fishery, as bulk of the prawn catches from this backwaters are landed by these nets and they are operated regularly. The catches are landed at selected centres alone, which enables one, to get the catch details accurately as well as to collect the prawn samples for biological studies regularly. The details on catch and effort were collected by visiting these two centres twice in a fortnight and random sample of about 1 kg of *M. monoceros* was collected every fortnight for biological studies. The collected sample of

M. monoceros was separated sexwise and total length (from the tip of the rostrum to the tip of telson), carapace length, total weight and tail weight were taken for males and females separately.

Cochin Fisheries Harbour was selected for collecting the details on the fisheries biology of brown shrimp from inshore waters. The fish landing centre was visited twice a week and data on shrimp catch, effort expended, species composition by weight were estimated based on sampling 10-20 % of the trawlers operated. Alagaraja (1984) gave a detailed account on the maintenance of proformae for recording the length frequency data from sampling days to annual level. Using the raising factor N/n where 'N' is the number of units landed on the day and 'n' is the units observed, total weight of resource on the sampling day is estimated on the basis of sampling units. The monthly estimates are obtained by raising the estimated resource on the observation day to the number of fishing days in the month. In the similar way the total monthly fishing effort in terms of fishing hours was also estimated. The raising factor is also used to raise each length frequency of the sampled totals to the days total. The monthly length frequency estimates are made by raising the number recorded for observation days catch to month's catch. The annual estimate is the sum of monthly length frequencies. Percentages of length frequencies for each month are to be taken from this and graphed for monthly progression of modes. The number of vessels (trawlers) went for fishing for the day is taken as boat-days. The commercial trawlers at Cochin do not maintain any record on the fishing ground and catches etc. Hence the details on area of operation, depth of operation, fishing hours and number of hauls were collected on enquiry from the crew members.

The Cochin Backwaters forming the northern extension of the Vembanad Lake, support a very good juvenile prawn fishery during the greater part of the year. The fishing gears operated to exploit the fishes and crustaceans in this backwaters mainly consisted of stake nets (Oonni or Kutti vala), dip nets (cheena vala or kampa vala), gill nets and cast nets. As stake nets are operated mainly to catch prawns in the Cochin backwaters, fishery of these nets alone, were monitored for the present studies. The description of a stake net and mode of operation was given by Menon and Raman (1961) and Kurian and Sebastian (1976). The design of the stake net in detail along with economics of stake nets operation in the backwaters of Kerala are given by Hridayanathan and Pauly (1993). The stake net is a long tapering bag, 15 m in length with mouth about 18 m in circumference. Mesh size at the mouth region ranged between 195 mm and 210 mm and at the cod end between 10 and 12 mm, as per the design of the net. Floats or sinkers are not used in this operation of the net. The time of operation is generally from evening to early morning during the low tides. Usually the stake nets are operated four days prior to new moon and full moon and continued till the fifth day after the moon's phase. During other days the receding force of the ebb tide is not sufficient for operation of the stake net. However, depending on the availability of the catches and favourable tides the nets are operated both in the evening and early morning of the same day.

The otter trawling is very effective for capturing bottom dwelling marine species like prawns. The mechanised trawlers based at Cochin Fisheries Harbour and operating off Cochin for shrimp fishery, varied in size between 9 and 17 m and powered by 25 to 90 BHP engines. Shrimp trawl nets of varying sizes and designs depending on the size of the mechanised vessels are used for exploitation of prawns along the Kerala coast. The gear being used by the mechanised vessels are mainly four seam or two seam shrimp trawl nets of 12-33 m head-rope length. During eightees the cod end mesh size measured between 20 and 25 mm. However in recent times there is a tendency to reduce the cod end mesh size regularly by the trawl operators to enhance the catches and currently the mesh size of the shrimp trawl cod end is in the range of 15-20 mm .

6.3 RESULTS

6.3.1. PRAWN FISHERY OF COCHIN BACKWATERS

6.3.1.1 Prawn fishery at Thoppumpady

The total prawn catch landed by stake nets at Thoppumpady during 1991 amounted to 61.26 t with cpue of 3.24 kg. The details on the catch and effort and species composition of prawns are shown in Table 6.2. The total number of stake nets operated in this centre in 1991 was 18902. January-May was found to be the peak fishing season for prawns when more than three fourth of the catch (47070 kg; 76.84%) was caught and the average catch per unit effort during these five months was 4.28 kg. During January-February the nets were operated twice a day, in the evening and early morning. Heavy rains from first week of June '91 resulted in strong outflow of water from the backwaters to the sea. During this period the stake nets were operated in the early mornings without depending on the ebb tides. From second half of June, till November '91 only a few nets were operated and that too for restricted days due to decrease in the catch of prawns as well as fishes. From September '91, the prawn catch started improving in the stake net operation. In the month of December, the prawn catch increased to 5947 kg with CPUE of 3.78 kg. The maximum prawn catch (14126 kg) and CPUE (6.62 kg) were recorded in the month of February'91. The prawn catch was very poor during July-August which coincided with peak monsoon. During fishing season between 50 and 125 stake nets per day land their catches at Thoppumpady. The prawn catch in 1991 mainly consisted of the following three species viz. *Metapenaeus dobsoni*, *Penaeus indicus* and *M. monoceros* in the order of abundance with percentage composition of 86.58, 9.33 and 3.95 respectively *P. semisulcatus* and *M. affinis* were encountered sporadically in the catch during February-April and August-October respectively.

6.3.1.2. *M. monoceros* fishery at Thoppumpady

The estimated catch of *M. monoceros* landed by stake nets at Thoppumpady for the year 1991 was 2418 kg with CPUE of 0.13 kg. The peak season of fishery for this species was January-June when 88.63 % (2143 kg) of the annual catch was harvested with CPUE of 0.17 kg (Fig.6.2 and Table.6.2). The monsoon settled down from second of June and catch of the brown shrimp dwindled and very poor fishery for this species was noticed during July-December '91. Thus *M. monoceros* was one of the main contributors to the backwaters fishery at Thoppumpady region, forming third in importance among the constituent species.

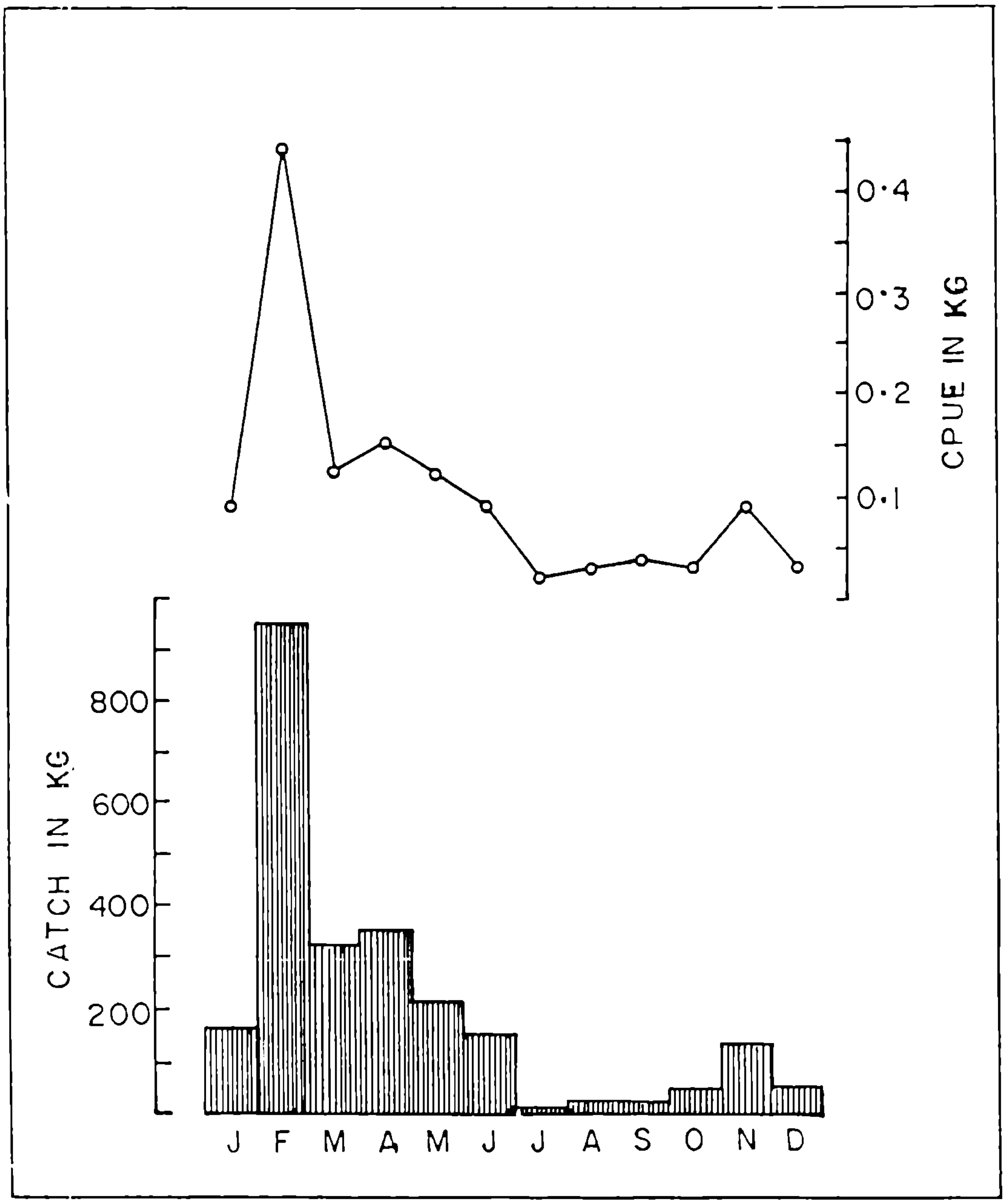


FIGURE 6.2 The monthly catch (kg), CPUE (kg) of *M. monoceros* in the stake net fishery at Thoppumpady during the year 1991.

6.3.1.3 Prawn fishery at Vypeen.

Between 250 and 300 stake nets operate regularly at Cochin Backwaters region near the bar mouth and land their catches at Vypeen centre. The number of days of net operation is always more at Vypeen centre due to better outflow of water during low tides when compared with other fishing centres of Cochin Backwaters. It was observed further, that when juvenile fishes constitute the main catch the stake nets are operated even during high tides. During January-February 1991, the stake nets were operated during ebb tide in the morning as well as in the evening. In the month of June due to heavy rains there was a good outflow of water from estuary and the nets were operated twice a day. The details on the stake net fishery at Vypeen are given in Table.6.3. The estimated prawn landings by stake nets at Vypeen amounted to 222 t in 1991 with average annual CPUE of 2.84 kg. The peak season of the prawn fishery at this centre was January-May '91 when 68.55 % (152.25 t) of the annual catch was landed with catch rate of 4.13 kg. The maximum prawn catch (53.16 t) and CPUE (7.64 kg) were recorded in the month of February. During the monsoon (June-August) the prawn catch went down to 15.69 t constituting 7.06 % of the annual catch with CPUE of 0.79 kg. There was an increase in the prawn landings during September-October period when 39.69 t of prawns were caught with CPUE of 4.17 kg forming about 17.87% of the annual prawn catch.

In the November-December duration a reduction in the catches was noticed when 14.47 t of prawns were caught (6.5 % of annual prawn catch) with CPUE of 1.21 kg. Thus there were two important seasons i.e. January-May and September-October in 1991 for the prawn fishery in general. The peak fishery seasons were same in the case of *M. dobsoni* which was the most dominant species of the stake net prawn catches constituting 75.35 % (167.34 t) of the annual prawn catch with CPUE of 2.14 kg. *P. indicus* (12.67%) and *M. monoceros* (11.92 %) were the other important contributors to the prawn fishery at Vypeen. The annual landings of *P. indicus* was 28.15 t with CPUE of 0.36 kg. January-July duration was the peak fishing season for this species when 95.27% (26.82 t) of the annual catch was landed. The maximum catch (6.12 t) and catch rate (0.88 kg) were recorded in February '91.

6.3.1.4 *M. monoceros* fishery at Vypeen

The total catch of *M. monoceros* during 1991 was 26.47 t with CPUE of 0.34 kg. The peak fishing season for this species was January-April, when 76.13 % (20.15 t) of annual landings was recorded with average cpue of 0.68 kg (Fig.6.3 and Table.6.3). The catches were moderate during October-November '91 when 3.67 t of *M. monoceros* was caught which amounted to 13.87 % of annual

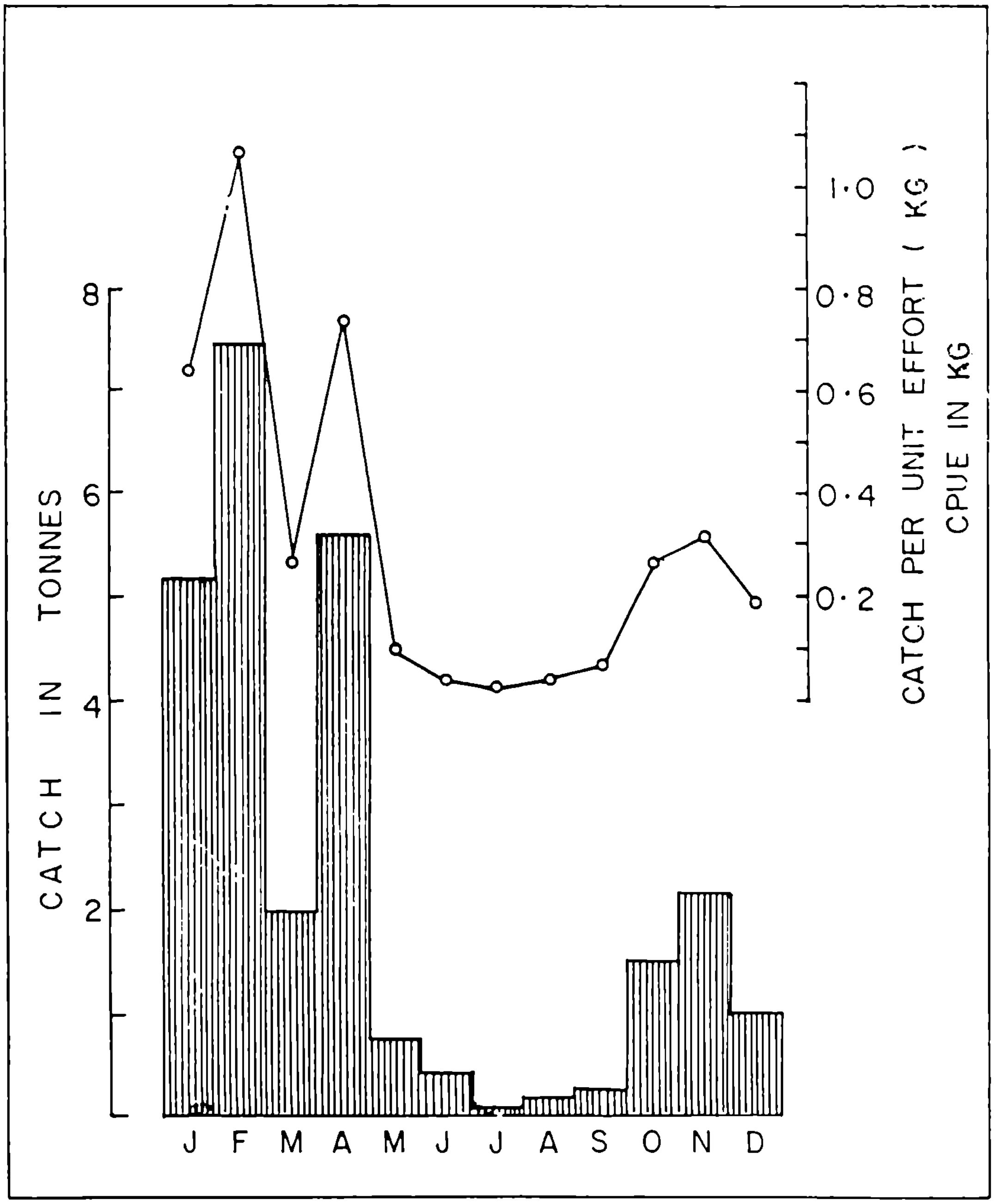


FIGURE 6.3 The monthly catch (t), CPUE (kg) of *M. monoceros* in the stake net fishery at Vypeen during the year 1991.

catch. The catch of *M. monoceros* was very poor during monsoon period (June-September'91) and amounted to 924 kg, with the CPUE of 0.04 kg. The maximum catch of *M. monoceros* (7.44 t) and CPUE (1.07 kg) were recorded in the month of February '91. Appreciable catches of this species above 5 t were recorded in January and April with CPUE of 0.64 and 0.74 kg respectively.

6.3.1.5. Lunar-periodicity .

A relationship between the prawn catch and the phases of moon was generally observed during 1991. Hence an attempt was made to learn whether any differences exist between the newmoon and full moon phases in the emigration of juvenile *M. monoceros* to sea from Cochin backwaters, which can be deduced from the variations in catch rates during these phases. As the peak fishing season for this species in the stake nets fishery of Cochin Backwaters was during January-May '91, continuous observations were made on the landings of six stake net units at Thoppumpady during full and new moon phases of April and May'91 and the catch details were showh in Table 6.4.

During the darker nights of new moon phase in the month of April '91, the juvenile brown shrimps emigrated to the sea from the Cochin Backwaters in greater numbers which was indicated by the higher catch rate of 1.21 kg. In the full moon phase during the brighter nights in the same month, the CPUE of *M. monoceros* reduced by 43 % to 0.69 kg. However, in May'91, the same affinity towards emigration during darker nights to the sea by juvenile *M. monoceros* was not so significant as in April(CPUE of 0.67 kg in new moon phase, and 0.59 kg during full moon phase). The above observations showed the preference of darkness by *M. monoceros* for emigration towards the sea for further growth and maturation. The maximum catch was noticed on different days in the new and full moon phases and there was no relationship between catch rate and any particular day in the new moon or full moon phase.

6.3.1.6. Length composition of *M. monoceros* catch

As Thoppumpady region represents an ideal backwater system the population characteristics of the brown shrimp in the stake net fishery from this centre were studied. The monthly length distribution (at 5 mm intervals) in percentage frequency for females and males of *M. monoceros* in the stake net fishery at Thoppumpady is presented in Tables 6.5 and 6.6 respectively. The monthwise size range in total length for females and males of *M. monoceros* and sex ratio (in percentage) in the catches during 1991 are furnished in Table 6.7. Size distribution in most of the months was multimodal which indicate post-larval recruitment to the Cochin Backwaters at intervals as a result of different peak spawning durations of the adults in the sea.

Females of 56-120 mm and males of 56-115 mm in total length represented *M. monoceros* catches in the stake nets in Cochin Backwaters in 1991. Bulk of the speckled shrimp catches (96.60%) was contributed by *M. monoceros* measuring between 61 and 95 mm in total length. The dominant group within the above said length range was 66-90 mm in females (85.66%) and 71-90 mm in the case of males (80.20%). There were two dominant modal groups in 66-70 and 76-80 mm for females and one predominant group in 76-80 mm for males in the stake net fishery in 1991. The number of monthly modes varied between one and three for both sexes. The lowest size group of the population at 56-65 mm occurred more during February-March and October-November periods. Larger prawns in the stake net fishery measuring between 96 and 120 mm in total length were encountered mainly during peak summer months (April - May) as well as during the first fortnight of June when good outflow from backwaters resulted due to heavy monsoon rains. Female *M. monoceros* outnumbered the males in the stake net catches during January-July period and in November and formed 53.83 % in the annual catch (Table 6.7).

6.3.2. PRAWN FISHERY OF INSHORE WATERS OF COCHIN

6.3.2.1. Fishing grounds, fishing seasons and fishery

The shrimp trawling ground, off Cochin lies mainly between latitudes 9°50'N and 10°10'N covering a distance of about 35 km along the coast. The bottom is muddy and facilitates easy operation of the trawl net. Whenever the prawn catches were poor in the usual grounds, the trawlers operated upto Ponnani in the north and Ambalapuzha in the south (Fig.6.1).

In general, trawling season along the west coast commences by about September and lasts till the end of May, the operation being suspended during monsoon period. However shrimp trawling is most active during southwest monsoon season at Cochin and Sakthikulangara. At Cochin, the trawl fishing during non-monsoon period is mainly restricted to the coastal waters upto about 25m depth. These vessels make single day cruises starting from the base early in the morning and returning in the afternoon after taking 3 or 4 hauls. From the middle of seventees, the vessels started operating during monsoon and the catch rate of prawns proved to be much higher than other seasons. The Government of Kerala, imposed a ban on trawling during monsoon from 1988 onwards. During the southwest monsoon period (June-August) the vessels gradually move out to deeper waters and operate between 30 and 60 m (Suseelan *et al*, 1992, 1993). However from 1990 onwards, a change in fishing pattern was observed in the trawl fishery operation off Cochin. To meet the demands of developing market for cuttlefishes and squids for export purposes, some of the trawlers diversified their activities and started going for fishing in deeper waters upto 60m to catch mainly cuttlefishes. To minimise the fuel consumption as well as to avoid long distance travelling to the fishing ground daily, each fishing trip was extended from the regular single day to 2-3 days. Fish trawls are operated during day to catch cuttlefishes and squids and shrimp trawls during night for netting prawns mostly in 30-60 m depth range. By 1991-92, most of the vessels went for 2-3 day fishing trips and fished for prawns, cuttlefishes and squids. When prawn catch in the shallow waters of 15-20 m was good, the trawlers combined fishing of this depth range along with earlier mentioned fishing. Thus, during the period of study (1991-93), the commercial trawlers at Cochin operated in the inshore regions between 15-60 m as per the availability of shellfish resources in general, depending on seasonal variations. On an average about 200 trawlers operate from Cochin Fisheries Harbour every day.

6.3.2.2. Effort fluctuations

The monthwise details on prawn landings, effort (boat trips), prawn catch per unit effort per day (CPUE) of Cochin Fisheries Harbour during 1991-93 are given in Table 6.8. The total effort (boat trips) for 1991 was estimated as 59640, with an average monthly effort of 4970 boat trips. The maximum number of effort was noticed in May (6853). The minimum effort was recorded in July (1878) mainly due to trawling ban imposed between 15th July and 6th August '91. In October due to poor fishery, the effort was reduced to 3284. The effort was above the monthly average of 4970 boat trips during January-June, and in the months of September and November '91. During the year 1992, the number of trawlers operated came down to 52099 showing a decrease of 12.64 % (7541) in comparison with 1991. The average effort per month was 4342 boat trips and the maximum (7070) and minimum effort (1463) were recorded in the months of May and July respectively. During January-June and in the month of October, the trawler units operated exceeded the monthly average. The effort expended during 1993 when compared with 1992, further went down to 45509, which showed a reduction of 12.64 %. The average monthly effort in 1993 was 3792 and the level of effort above this limit was seen during February-May and in August. The maximum effort was observed in May (6790) and the minimum in September (2534). The maximum effort for prawn fishing in the inshore waters of Cochin was made in 1991 and the level of effort showed a declining trend in the next two years. In general, trawlers in appreciable numbers operated for shrimp fishery from January to May during 1991-93. Maximum number of vessels were operated in the month of May in all three years. When the effort as an average during 1991-93 was taken into account, the number of boat trips between January and May hovered around 5000 per month showing an increasing trend from January onwards till May (Fig. 6.4 and Table 6.8). The minimum effort expended was in July, mainly due to the trawling ban implemented in the state. The average monthly effort during August-December (1991-93) was 3755 boat trips.

6.3.2.3. Trends in prawn landings

The prawn catch landed by trawlers in 1991 at Cochin Fisheries Harbour amounted to 5471 t with an average monthly landings of 456 t. (Table 6.8). August-September was observed to be peak duration for the prawn fishery with landings of 1016 t in August and 947 t in September. The lowest eatch (359 t) was recorded in October '91. During monsoon months (June-September) 51.01 % of annual prawn catch was caught. The maximum CPUE (269.54 kg) was noticed in the month of August and during other monsoon months it varied between 110 kg (June) and 188 kg (September). The minimum CPUE was recorded in January (38.55 kg). The average CPUE for the year was 91.74 kg. In 1992, eventhough, the effort in comparison with 1991 decreased only by 12.64%, the prawn catch went down by 45.40 % to 2987 t. The average monthly prawn landings amounted to 249 t. The maximum (612 t) and minimum catches (4 t) were recorded in the months of Sepember and July respectively. The average annual CPUE also decreased from 91.74 kg in 1991 to 57.34 kg in 1992. The CPUE was found to be at its maximum (159.54 kg) in September and minimum (2.99 kg) in July. The prawn landing during monsoon season (June-September) was 1028 t forming only 34.49 % of the total prawn catch of 1992. January-May period was found to be more productive, contributing to 56.71 % (169.40 t) of the annual prawn catch. In spite of further reduction of fishing effort to the extent of 12.65 % in 1993, the annual prawn landings (3136 t) showed an increase of 148 t (4.96 %) with an average monthly landings of 261 t. The maximum prawn catch of 610 t was recorded in May followed by March (414 t) and July (400 t) and the minimum landings of prawns (3 t) was observed in the month of October. January-May duration was found to be more productive with a contribution of 62.14 % of annual catch. The highest CPUE of 142.27 kg was seen in July and the lowest (0.95 kg) in October. The monsoon fishery in 1993 also, yielded very moderate catches (847 t) forming 27 % of the annual prawn catch.

The average catch, effort and CPUE for 1991-93 period were shown in Fig.6.4 and Table 6.8. During this period prawn landings of the monsoon season (June-September), contributed to 40.26 % of average annual prawn catch. The months of October and November were found to be lean period of prawn fishery, with 6.32 % contribution to the total prawn catch. The prawn fishery got momentum again from December and its yield showed an upward trend till the month of May. The percentage composition of prawn catch for these 6 months (December-May) in the average annual prawn landings of 1991-93 amounted to 53.42 %. Eventhough annual

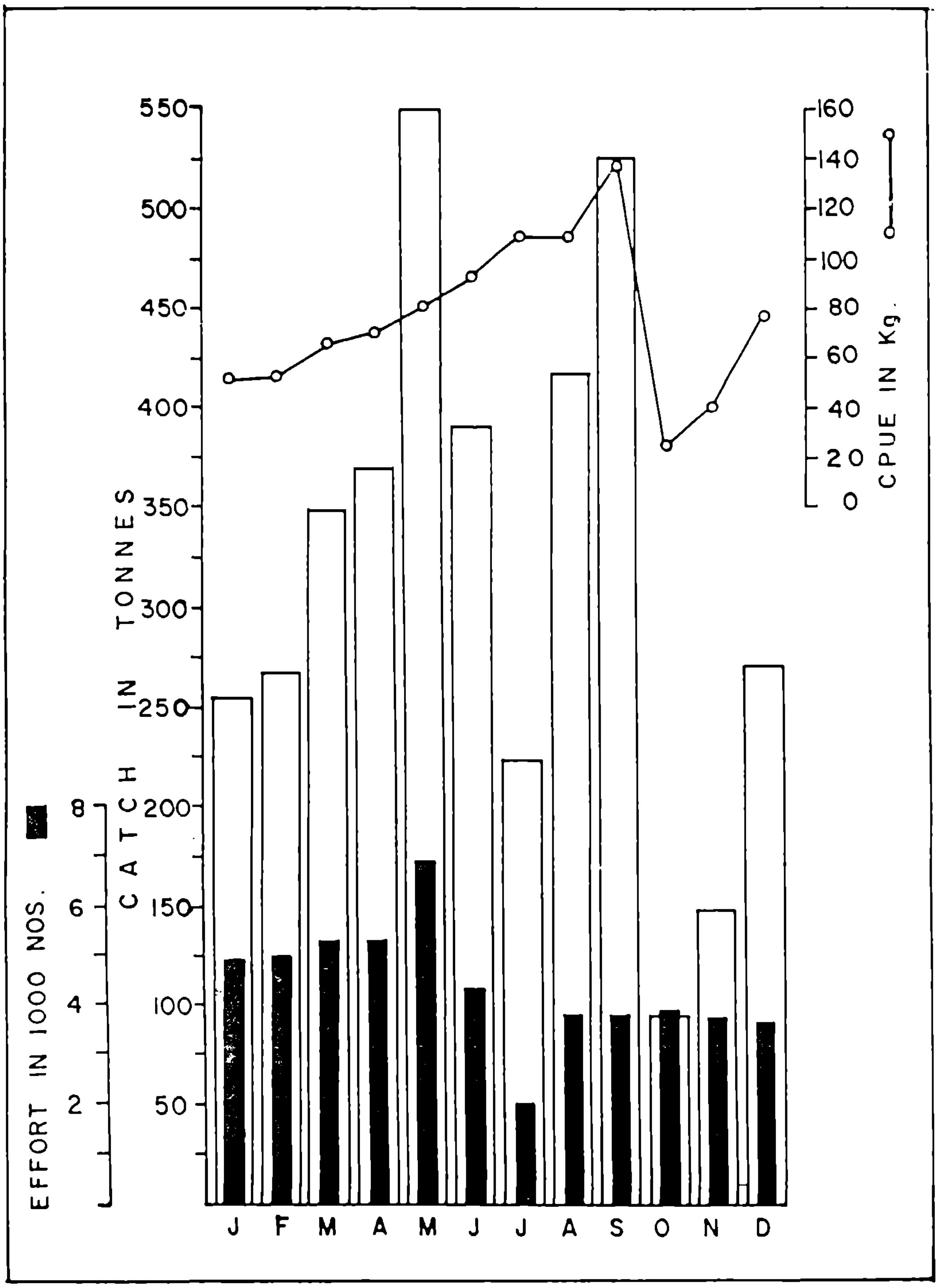


FIGURE 6.4 The average month-wise prawn catch (t), CPUE (kg) and effort (in boat trips) in trawler operation at Cochin Fisheries Harbour during the years 1991-1993

variations are noticed in the shrimp fishery at Cochin, success of the monsoon fishery determines the total yield of the respective years.

6.3.2.4. Species composition

The prawn fishery of Cochin was exclusively constituted by penaeid prawns. The monthwise details on the species composition of prawn catch in trawl landings at Cochin Fisheries Harbour for the years 1991, '92 and '93 are given in Tables 6.9; 6.10 and 6.11. respectively. The species composition of the prawn catches in the trawl fishery for the entire three years study period are shown in Table 6.12. The prawn landings at Cochin Fisheries Harbour during 1991-93 consisted of the following penaeid species i.e. *P. stylifera* (51.28 %), *M. dobsoni* (36.43%), *M. monoceros* (4.98 %), *P. indicus* (4.95 %), *Trachypenaeus* sp. (1.47 %), *P. semisulcatus* (0.34 %), *P. canaliculatus* (0.25 %), *M. affinis* (0. 25 %) and *P. monodon* (0.05 %). Thus the speckled shrimp *M. monoceros* was one of the important contributors to the prawn fishery of Cochin and occupied third position in abundance during 1991-93. *P. stylifera* with 61.89 % contribution (3386 t) to the fishery predominated the prawn catch in 1991 and it formed 50.33 % (1504 t) of the catches in 1992. However *M. dobsoni* which was second important constituent in the prawn fishery in 1991 (27.45 %) and 1992 (36.08 %) increased its presence in 1993 by forming 52.43 % (1644 t) of total prawn catch. Peak fishery season for *P. stylifera* during 1990-93 was the monsoon period (June-September) and it was generally between November and May for *M. dobsoni*. The most important commercial species, *P. indicus* contributed 4.81, 5.96 and 4.24 % of the total prawn catch in the above three years respectively. The percentage composition of *M. monoceros* in the prawn landings at Cochin was 3.76 in 1991, 5.18 in 1992 and 6.91 in 1993.

6.3.2.5. Fishery of *M. monoceros*

1991: The details on monthwise catch, catch composition in total prawns and CPUE of *M. monoceros* during 1991 are shown in Table 6.13 and Fig. 6.5. In 1991, the total catch of *M. monoceros* landed at Cochin Fisheries Harbour amounted to 205.78 t with monthly average catch of 17.15 t. The fishery was good in the months of April (33.50 t), May (35.46 t) and November (34.66 t) with peak fishery in May. The catch was about 25 t in the months of February, March and December. Thus *M. monoceros* fishery which started with a catch of 15.99 t in January, showed an increasing trend till May when maximum monthly catch of the year was recorded. Once the rains started in June, the brown shrimp catch decreased to 1.89 t which further went below 0.50 t during July-August. Further, the fishing was not carried out by trawlers along the Kerala coast due to trawling ban implemented

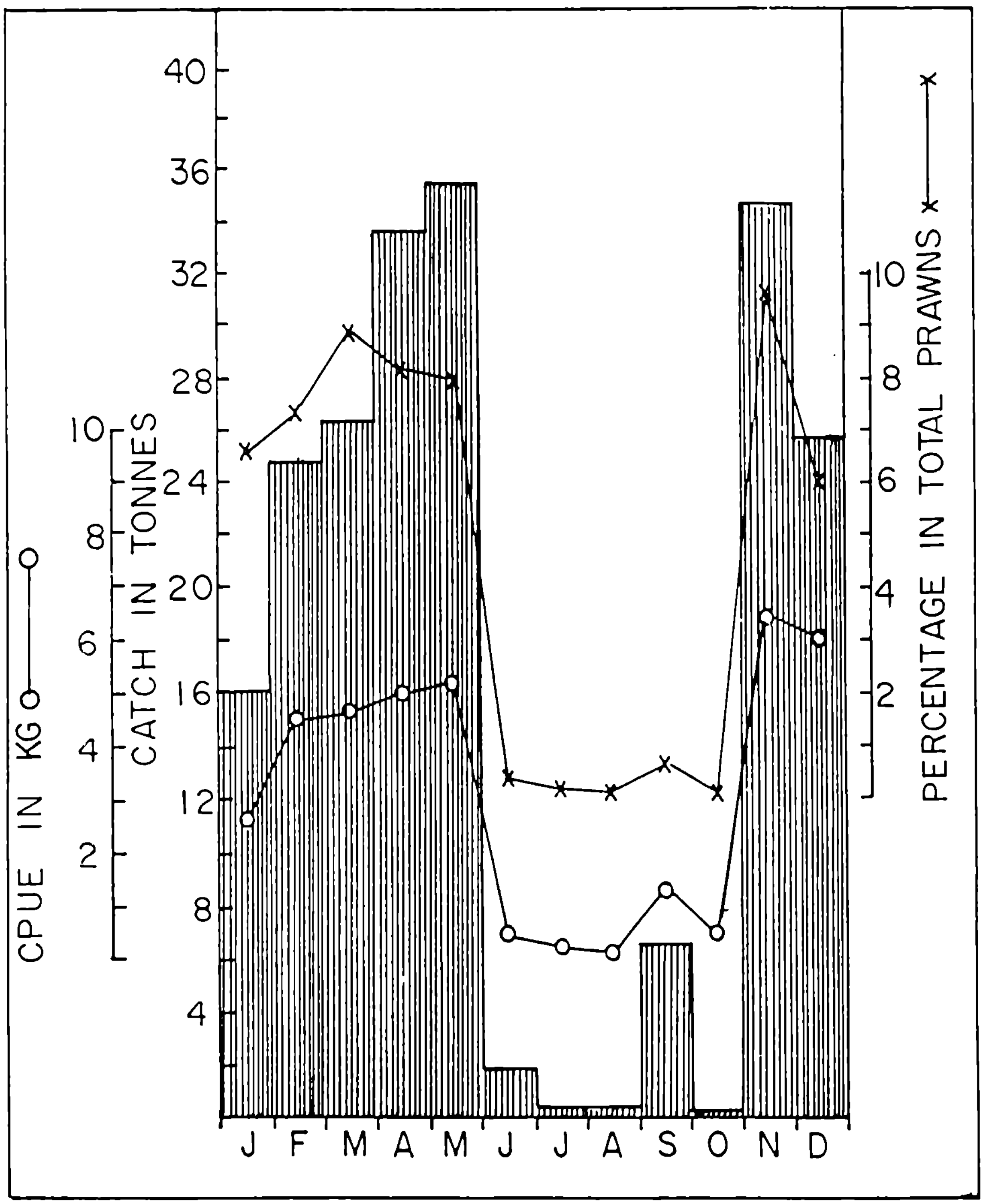


FIGURE 6.5 The month -wise catch (t), catch per unit effort (kg) and percentage composition in total prawns of *M. monoceros* landed by trawlers at Cochin Fisheries Harbour during the year 1991.

by the Government between 15th July and 6th August. There was a slight revival in the fishery in September when the catch went up to 6.49 t but it tumbled down to the lowest level in October with a catch of 114 kg. From November onwards, the trawl fishery yielded good catches of *M. monoceros* which amounted to 34.66t in November and 25.71 t in December. The shrimp trawling was carried out in nights, mostly in the depth range of 35-45 m during January-May and November-December periods which should be the main reasons for better catches of the speckled shrimps in the above said periods.

The average annual percentage composition of *M. monoceros* in total prawn catch was 3.76 %. The maximum contribution of the brown shrimp to the prawn fishery (9.66 %) was noticed in the month of November. The monthly percentage composition varied between 6.63 and 8.90 during January-May (Table 6.13 and Fig. 6.5. However between June and October contribution of this species to prawn catches of trawl landings, decreased below 1.00 %, mainly due to change of shrimp trawling from night to day time in a single day trip mainly targeting *P. stylifera* (Table 6.9). When the trawlers resumed operations at nights in the usual grounds of *M. monoceros* from November, catch composition of this species increased in the total prawn landings.

The average annual CPUE of *M. monoceros* in 1991 was 3.45 kg. The CPUE varied between 2.56 kg (January) and 5.17 kg (May) during January-May duration. The maximum catch rate (6.64 kg) was noticed in November followed by 5.93 kg in December. The fishery was least productive from June to October.

1992: The estimated landings of *M. monoceros* by trawlers at Cochin Fisheries Harbour in 1992 amounted to 154.63 t which showed a reduction of 33.08 % (51.15 t) when compared with the landings of last year (205.78 t). The catch details of the speckled shrimp for 1992 are shown in Fig. 6.6 and Table 6.13. The average montly catch was 12.89 t during 1992. *M. monoceros* catch which was 14.18 t in January, slowly increased in the following months till May. The peak month of fishery was May when 32.05 t of this species was caught by shrimp trawlers. In March, landings of the speckled shrimp amounted to 30.71 t. Monthly catch in the range of 21-26 t was observed in February (25.92 t), April (21.75 t) and December (23.04 t). In the first fortnight of June, before the onset of heavy rains, 5.42 t of *M. monoceros* was landed by shrimp trawlers. The trawling ban by Government of Kerala was imposed on 21st June and continued for 21 days till 12th July '92. In the five months duration from July to November, the shrimp trawling did not yield any appreciable quantity of *M. monoceros* and the catch ranged between the lowest level of 0.21 t in September and 0.51 t in August. The single day shrimp trawling for *P. stylifera* during day time was the main reason for the negligible catch of the brown shrimp during August-September. During October-November, the day

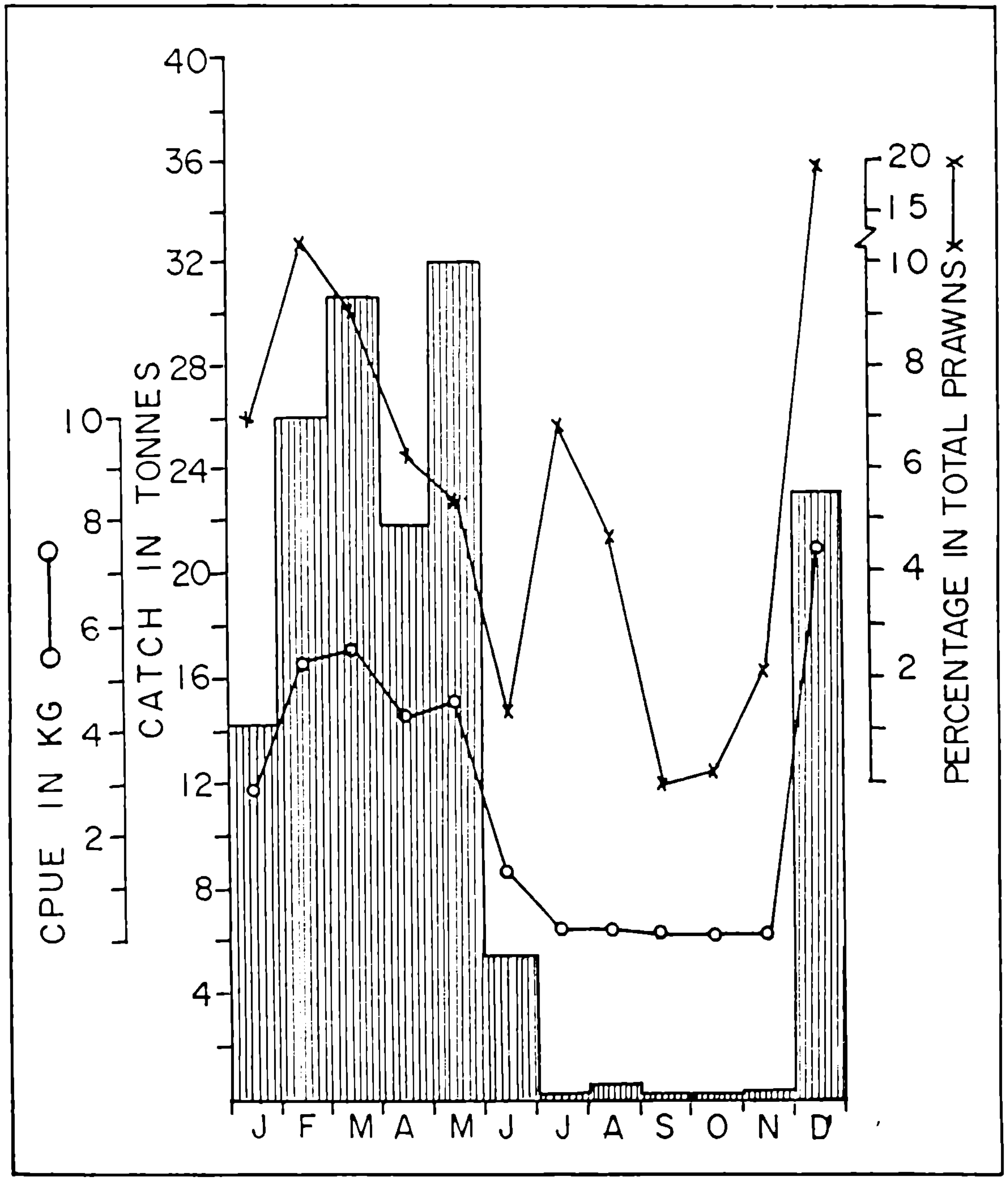


FIGURE 6.6 The month -wise catch (t), catch per unit effort (kg) and percentage composition in total prawns of *M. monoceros* landed by trawlers at Cochin Fisheries Harbour during the year 1992

fishing conducted for fishes and cephalopods in deeper depths resulted in meagre landings of brown shrimp (0.22 and 0.33 t in October and November respectively). *M. monoceros* landings started showing improvement in the month of December, due to shrimp trawling in nights in the 30-40 m depth range, and 23.04 t of this species was caught in this month.

The percentage composition of *M. monoceros* in total prawn landings in 1992, increased to 5.18 from 3.76 of 1991, in spite of lesser annual catch of this species. This was mainly due to the reduction of prawn catches in general, in the trawl fishery during this year. The maximum percentage contribution of this species (19.55 %) to prawn fishery was observed in the month of December and the lowest contribution (0.03 %) was recorded in September. During January-May, the percentage composition of *M. monoceros* in total prawn catch varied between 5.40 % (May) and 12.21 % (February). In the peak monsoon months of July and August, the contribution of brown shrimp to prawn fishery of Cochin amounted to 6.91 and 4.66 % respectively. Such higher percentage composition resulted mainly due to drastic reduction in the catches of *P. stylifera* during these months (Table 6.10 and Fig.6.6).

The average CPUE of 1992 for *M. monoceros* was 2.97 kg, which showed a decline of 14 % in comparison with the CPUE of previous year (3.45 kg) in spite of reduction in effort by 12.64

% (Tables.6.8 and 6.13). The maximum CPUE was observed in the month of December (7.36 kg). During February-May, the monthly CPUE exceeded the annual average of 2.97 kg and ranged between 4.17 kg (April) and 5.48 kg (March). As observed in the trend of *M. monoceros* landings during this year, the CPUE also showed the lowest level during July-November '91, which ranged between 0.04 kg (October) and 0.21 kg (July).

1993: In 1993, the catch of *M. monoceros* landed by trawlers at Cochin Fisheries Harbour was estimated to be 216.75 t (Table 6.13 and Fig. 6.7). The boat trips in 1993, decreased by 12.65 % (6590) in comparison with 1992 (Table 6.8). In spite of this reduction in number of vessels, the annual catch of speckled shrimp in 1993 showed an increase of 40.17 % over the *M. monoceros* landings in 1992. The average monthly catch of this species was 18.06 t during this year and the maximum quantity (39 t) was caught in the month of March. Fishery for this species was good in January and April with landings of 32.15 and 37.25 t respectively. Appreciable catches of *M. monoceros* were observed in February (21.61 t), May (26.29 t) and December (26.18 t). During the first fortnight of June, the catch of speckled shrimp amounted to 8.67 t and the trawling ban was implemented from 15th June which lasted till 15th July. A few numbers of *M. monoceros* were caught in the fish trawls in deeper depths during July and the catch amounted to 0.25 t which was the lowest monthly catch for this year. The boats which regularly go in

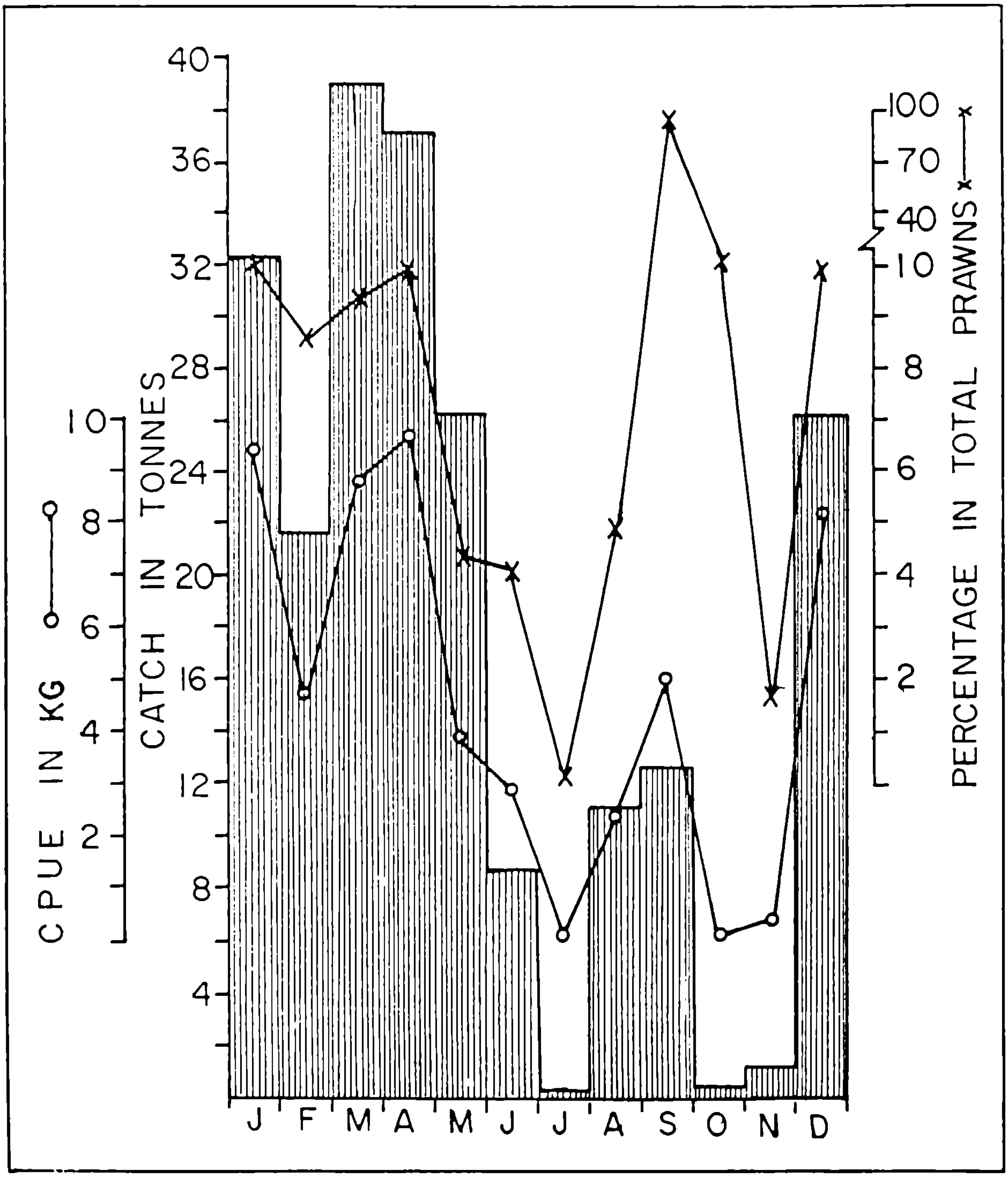


FIGURE 6.7 The month -wise catch (t), catch per unit effort (kg) and percentage composition in total prawns of *M. monoceros* landed by trawlers at Cochin Fisheries Harbour during the year 1993

deeper grounds during August for fish trawling, operated shrimp trawls in nights on certain days which yielded 11.05 t of *M. monoceros*. Shrimp trawling during nights, off Alleppey coast during first week of September resulted in netting of 12.71 t of *M. monoceros*. In the months of October and November only sporadic catches of speckled shrimp (0.42 and 1.16 t respectively) were obtained from day fishing carried out for cuttlefishes. When the shrimp trawling during nights was resumed in December, *M. monoceros* catch improved significantly and resulted in the landings of 26.18 t of this species at Cochin Fisheries Harbour.

The average percentage composition of brown shrimp in total prawns in 1993 was 6.91. The maximum contribution of *M. monoceros* (97.78 %) in September as well as its high percentage in prawn catches in October (13.27) were due to absence of other penaeid prawns in appreciable quantities in the trawl catches (Table 6.11) *M. monoceros* constituted between 8.58 and 10.59 % in the total monthly prawn landings of January-April duration and in December.

The average catch of *M. monoceros* per boat trip for this year was 4.76 kg which was 60.27 % more than the catch rate of 1992 (2.97 kg). The maximum CPUE of 9.67 kg was recorded in the month of April (Fig. 6.7 and Table 6.13). The monthly catch rate exceeded the annual averge in January (9.43 kg), March

(8.78 kg) April (9.67 kg) September (5.02 kg) and December (8.14 kg). The CPUE was very low in the months of July (0.09 kg), October (0.13 kg) and November (0.39 kg).

<u>1991-93</u>: The annual landings of *M. monoceros* which was 205.78 t in 1991 went down to 154.63 t in 1992, but made a good recovery in 1993 with landings of 216.75 t (Table 6.13). The general declining trend in total prawn catch during 1992 was reflected in the landings of *M. monoceros* also. The CPUE also reduced from 3.45 kg in 1991 to 2.97 kg in 1992. Eventhough, reduction in boat trips persisted in 1993 which was 12.65 % in comparision with 1992, the catch (216.75 t) and catch rate (4.76 kg) of speckled shrimp showed an increase of 40.17 % and 60.27 % respectively. When fishery for the entire study period (1991-93) was considered, catch of the speckled shrimp increased by 5.33 % (10.97 t) and catch rate by an impressive 37.97 % (1.31 kg). The month of peak fishery when maximum catch of *M. monoceros* was recorded at Cochin Fisheries Harbour remained as May in 1991 and '92, but changed to March in 1993. The percentage composition of speckled shrimp varied between months as well as between years, depending on the success of its fishery in comparison with the availability of other penaeid prawns in the trawl fishery. As *M. monoceros* is nocturnal, success of its fishery depends on shrimp trawling during night time alone in proper fishing grounds in the depth range of 30-45 m. The fishing season for the brown shrimp was December-May in all the

three years of study period. During 1991, in addition to the regular fishing season,good quantities of *M. monoceros* (34.66 t) were caught in the month of November. The lean period of fishery for this species was observed to be Jume - November during 1991 - 1993 (Table .6.13). This was mainly due to the operation of tralwers, during day time for fishing *P. stylifera* and fishes in the monsoon season (June-September); and for cuttlefishes and squids in October-November period. However in 1993, appreciable quantities of *M. monoceros* were caught during August (11.05 t) and September (12.71 t) due to shrimp trawling in nights on certin days. During 1991-93, minimum catch of this species was observed in the months of July and November.

The details on *M. monoceros* fishery collected during 1991-'93 from Cochin Fisheries Harbour when considered altogether the following conclusions could be made. General trend of the fishery during this period is shown in Figure 6.8. The average annual catch of *M. monoceros* was 192.39 t with CPUE of 3.67 kg (Table 6.13). The average monthly landings of this species amounted to 16 t. Generally, the fishery for the speckled shrimp started after regular monsoon period, from November/December and the fishing season extended till May. The month of December with an average catch of 24.98 t (12.98 % of average annual catch) gave the real start to the speckled shrimp fishery in the inshore waters of Cochin. The fishing season continued with a moderate dip in January but gained further momentum with increase in

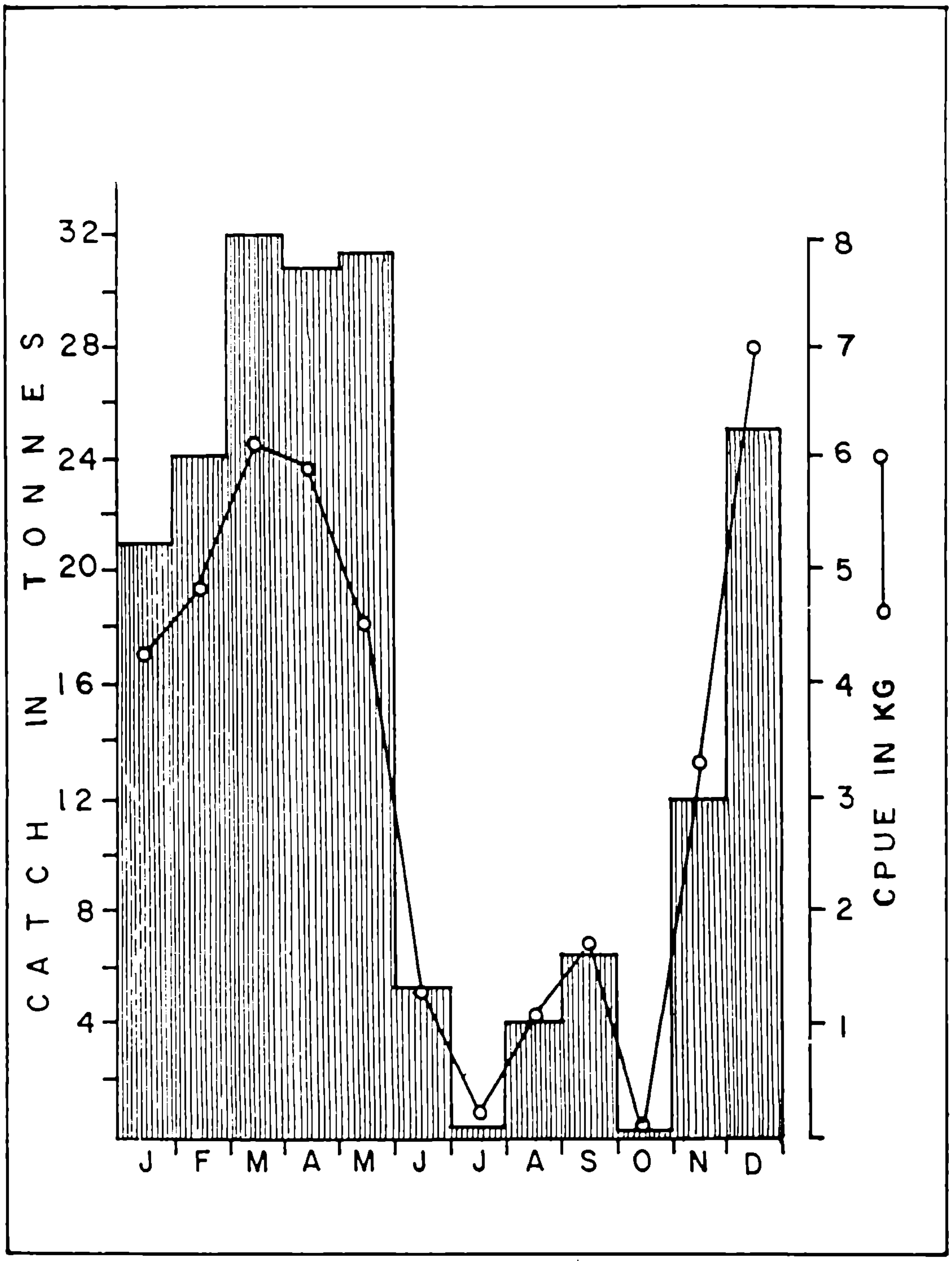


FIGURE 6.8 The average month-wise landings (t) and catch per unit effort (kg) of *M. monoceros* landed by trawlers at Cochin Fisheries Harbour during 1991- 1993.

landings from February to reach an average monthly catch exceeding 30 t in the next three months till May. The peak season of the *M. monoceros* fishery was March-May when 48.92 % of average annual landings of this species was caught by shrimp trawling. The declining trend in the fishery started from June, when only moderate catch of the brown shrimp was fished out, mainly during the first fortnight of the month just before the actual monsoon effect was felt with heavy rainfall and turbulent sea. The fishery of *M. monoceros* was generally poor during June-October period and the minimum catch was recorded in the months of July and October. The catch rate of *M. monoceros*, more than the annual average (3.67 kg) was observed during January-May and in the month of December.

6.3.2.6. Seasonal movement of *M. monoceros*

Movement of *M. monoceros* to deeper grounds during the peak monsoon months (July-August) was observed every year during the present study period of 1991-93. The monthwise details on the availability of the speckled shrimps in different depths during 1991-93 along with the size distribution of the species are shown in Table 6.14. Once the rains started in the second fortnight of June '91, the trawlers operated for 'karikkadi' fishery in 30-40 m depth, which was the usual fishing grounds for *M. monoceros* during non-monsoon months. These operations did not yield any catch of the brown shrimp, which in turn showed a possible movement of this species to deeper grounds. A few numbers of *M. monoceros* per boat were available in fish catches landed by trawlers which operated in 54-70 m depths in day time during July-August '91. However in September, this species was not observed in trawl catches from this depth. Instead they were caught in appreciable quantities (6.49 t) in 40-42 m depths during night time (Table 6.13). This indicated a possible movement of the species in the month of September towards their usual grounds. From November/December *M. monoceros* was caught in good quantities from their usual grounds in the depth range of 30-45 m.

In 1992, *M. monoceros* was observed in the fish catches landed by trawlers, which operated during day time in 64-70 m depths in July and 73-80 m in August. During July '93, as in previous years, the vessels went for single day trip and operated trawl nets in day time alone in deeper fishing grounds of 70-75 m depth range which fetched only 0.26 t of *M. monoceros*. The trawlers which went for fish trawling in the month of August '93, unusually operated shrimp trawls on certain days in 80-90 m deep grounds in night time, which resulted in the landings of 11.05 t of *M. monoceros*. During September, some units carried out shrimp trawling off Alleppey coast in 40-50m deep fishing ground during nights and landed 12.71 t of the speckled shrimp.

Thus the present study on *M. monoceros* fishery in the inshore waters of Cochin during 1991-93 showed that this species usually moved out every year during peak monsoon period from their normal grounds in the depth range of 30-45 m to deeper regions of 54-75 m in July and continued to do so, still further upto 90 m depth in August. The speckled shrimp started moving back to their usual grounds in September which was proved by their occurrence in 40-50 m in appreciable quantities during this month. In these three years period of observations, size range of *M. monoceros* during November-June, July-August and September-October was 66-195, 76-185 and 71-195 mm respectively (Table 6.14). Significant variations in size distribution of this species in different depths were not observed. Thus the above said observations revealed the existance of seasonal movement of *M. monoceros* belonging to all size groups in the fishing grounds off Cochin every year.

The details collected on board the Research Vessel 'Skipjack', regarding distribution of *M. monoceros* during 1986-1988 are given here to corroborate the conclusions made on the seasonal movement of this species and its natural habitat. The details collected on the availability of *M. monoceros* at different depths along with sexwise size distribution are given in Table 6.15. *M. monoceros* in the size range of 66-175 mm were caught regularly in the experimental trawling in depths between 25 and 35 m during January-May and October-December periods. In the course of peak monsoon months of August and September brown shrimps in the size range of 61-170 mm were available rarely in 45 m depth but they were common in 55 m grounds. Thus the experimental trawling in the shrimp grounds off Cochin in different depths brought to light the following facts. The shrimp trawling grounds of 25-40 m depth range off Cochin, are natural habitat for *M. monoceros* and the bottom condition of this ground is muddy. Availability of speckled shrimp was better when trawling was carried out after sun set in comparison with day time operations. During the peak monsoon, *M. monoceros* was commonly found in 55 m depth and above, showing a seasonal movement to deeper grounds. *M . monoceros* showed a shoreward movement and returned back to their regular habitat by October.

6.3.2.7. Structure of exploited population and biological features

Size distribution of M. monoceros in trawl catches.

The length range of females and males of *M. monceros* for the entire period of this studies (1991-93) was 66-195 and 71-160 mm respectively. The monthly size distribution in estimated numbers for 1991-93 for females of *M. monoceros* are shown in Tables 3. 1-3 and for males in Tables. 3. 4-6 in the Chapter 3.

Based on the size at maturity at 50 % level, females measuring upto 110 mm and males upto 95 mm were considered as juveniles and those *M. monoceros* crossing these lengths of respective sexes were treated as adults. The month-wise length range of females and males and percentage contribution of juveniles and adults to the brown shrimp fishery for the years, 1991, '92 and '93 are given in Tables 6.16; 6.17 and 6.18 respectively.

The size range of females and males in the fishery during 1991 was 66-195 and 71-155 mm respectively. The length distribution, showed wide variations between months. Juveniles were represented in the catches throughout the year. For the year, 1991, the contribution of juveniles to the fishery was 10.22 and 4.36 % in the case of females and males respectively. Adult females and males of *M. monoceros* predominated the trawl catches landed at Cochin Fisheries Harbour and their annual contribution to the fishery of speckled shrimp was 89.78 and 95.64 % respectively. There were four peak months of occurrence for juveniles i.e. February, April, June and October for females and three in the case of males (March, July and October).

The size range of females and males which represented the trawl catches at Cochin Fisheries Harbour in the year 1992 was 76-185 and 81-150 mm respectively. Wide variations in the monthly size distribution were observed (Table.6.17). The percentage composition of juveniles in the catches was 11.16 for females and 3.01 for males. The brown shrimp catch was dominated by adults (88.84 % in females and 96.99 % in males). Females in juvenile stage constituted higher percentages of 14.86, 14.46, 28.20 and 15.55 % in the months of February, April, August and November respectively and immature males contributed to 7.61, 3.12 and 14.28 % of the catches in the months of January, April and July respectively thus showing the peak months of recruitment to the fishery.

Females of 76-195 mm and males of 86-160 mm represented the catches of speckled shrimp in 1993 with wide variations in size range between months. As in the previous years, adults dominated *M. monoceros* catches. contributing to 87.26 % in females and 94.55 % in males (Table 6.18). The juveniles constituted 12.74 and 5.45 % of females and males respectively in the brown shrimp catches, showing a higher contribution in comparison with 1992. There were three months of peak occurrence of juveniles in case of females (January, April and December) and males (January, March and December).

The average annual contribution of adults and juveniles (not differentiating them as males and females) to the fishery was 92.18 and 7.82 % respectively during the period 1991-93.

Adults predominated *M. monoceros* catch throughout the three years duration of 1991-93. However, dominance of them came down from 92.71 to 90.91 % between 1991 and 1993. There were three or four peak months of occurrence of juveniles (combining females and males) annually indicating the recruitment period. They were February, July and October in 1991; January, April, August and November in 1992 and January, April and December in 1993 (Table 6.19).

6.3.2.8 Age composition of the catches

The following age groups were identified based on growth parameters of *M. monoceros* by using suitable methods as explained in Chapter 3.

Age in months	Mean total length (mm)	
	Females	Males
6 months old	112.51	83.98
12 months old	166.53	129.12
18 months old	188.88	150.81

The percentage composition of the above said age classes in the *M. monoceros* catches landed at Cochin Fisheries Harbour during 1991-93 is given below.

Years	Age classes							
	Females				Males			
	Nos	0.5	1.0	1.5	Nos	0.5	1.0	1.5
1991	7528907	16.14	80.85	3.01	5675173	1.07	87.99	10.94
1992	6040110	18.81	80.33	0.86	4508154	0.25	94.94	4.81
1993	7755716	18.95	78.45	2.60	5836930	-	87.53	12.47

Seven to twelve months old *M. monoceros* dominated the trawl fishery forming between 78.45 and 80.85% in females and between 87.53 and 94.94 % in males during 1991-93.

6.3.2.9 Relationship of inshore fishery to the backwaters fishery

An attempt was made to study the quantum of contribution made by the emigrating juvenile *M. monoceros* from Cochin backwaters to the existing marine fishery of this species. The period of maximum intensity of emigration of juveniles of this species was observed to be January-June in 1991 as well as in 1992 which was arrived at based on the stake net catches landed at Thoppumpady and Vypeen. During other months *M. monoceros* catch in stake net fishery was very less. The fishing season for the speckled shrimp in the inshore waters was generally between December and May during 1991-93. Hence a comparison was made between stake net catches of brown shrimp during January-June period of 1991 and 1992 to the annual landings of *M. monoceros* from inshore waters of Cochin in 1992 and 1993 respectively to find out any existing relationship. The catch details of *M. monoceros* from Thoppumpady and Vypeen centres during January-June 1991 and 1992 and landings of this species at Cochin Fisheries Harbour in 1992 and 1993 are given in Table 6.20.

The catch per stake net for juvenile *M. monoceros* in 1991 was 0.169 and 0.454 kg at Thoppumpady and Vypeen respectively with an average CPUE of 0.393 kg for both these centres. There was a drastic reduction of catch and CPUE of *M. monoceros* juveniles in 1992 in Cochin Backwaters for both centres combined. The catch of juvenile *M. monoceros* went down by 80.17% at Thoppumpady, 61.59% at Vypeen and showed a reduction of 63.28% for both centres together in 1992 in comparison with 1991 landings. The CPUE also showed a reduction of 79.28 and 58.59% for Thoppumpady and Vypeen centres respectively and when both the centres were combined, the decrease in *M. monoceros* catch per stake net was 60.56%. The landings of inshore catches of speckled shrimp at Cochin Fisheries Harbour in 1992 was 154.63 t with CPUE of 2.968 kg. The catch and catch rate of *M. monoceros* from inshore waters in 1993 was 216.75t and 4.763 kg which showed an increase of 40.17 and 60.48 % respectively in comparision with corresponding values of 1992. Thus the present studies showed that a direct correlation between backwaters fishery and marine fishery is lacking at Cochin region. Dependence of marine fishery of this species at Cochin to the backwater juvenile stock of other nursery grounds in other places cannot be ruled out. However to conclude concretely, the contribution of emigrant *M. monoceros* from Cochin Backwaters to the inshore fishery of the species at Cochin, tagging studies in a systematic way has to be carried out.

6.4 DISCUSSION

The peak fishing season for *M. monoceros* in the Cochin Backwaters was noticed to be January-June, which agrees well with the observations on this species made by George (1974) and George and Suseelan (1982) in the same backwater system; and by Koumudi Menon (1980) and Kurup *et al.* (1993) in the Korapuzha Estuary. *M. monoceros* was one of the important contributors to the prawn fishery of Cochin Backwaters forming third in abundance in the stake net fishery. This observation coincided with the earlier studies on the distribution and abundance of prawn seeds in Cochin backwater system which showed that *M. monoceros* was third in abundance with density of $6/m^2$ (Sosamma Easo and Mathew, 1989). The annual landings of speckled shrimp in the stake net fishery at Vypeen was better than the landings at Thoppumpady centre. This can be attributed to the proximity of Vypeen to harbour mouth, stronger tidal outflow and operation of more number of stake nets. The percentage composition of this species in the total prawn landings of the stake net fishery was 11.92 at Vypeen and 3.95% at Thoppumpady. Menon and Raman (1961) based on their observations on the stake net fishery in Cochin Backwaters stated that the prawn catches at Azhikal situated nearer to Cochin harbour was better than Thevara (which is six miles away from harbour) and attributed this trend to nearness of Azhikal to harbour entrance and greater strength of tidal currents. Similar observation on the prawn fishery of Cochin backwaters was made by Kuttyamma and Antony (1975).

Catch of *M. monoceros* was found to be better during the darker nights of new moon phase which indicated positively the nocturnal nature of the brown shrimp and its preference of darkness for emigraton to the sea. Subrahmanyam (1965) also stated that *M. monoceros* was nocturnal in movement and the number of emigrants was generally higher during new moon period than during full moon in the Godavari estuarine system. However Menon and Raman (1961) noticed highest catch of prawns in the stake net fishery of Cochin backwaters on new or full moon day or on the following two days and concluded that brighter and darker fortnights did not influence the catches. Juveniles of *M. monoceros* in the size range of 56-120 mm contributed to the brown shrimp catches in the stake net fishery. Predominance of females over the males in the *M. monoceros* catch was noticed during the period of observation.

Prawn fishery along the Kerala coast has been studied by various research workers and most of the studies so far carried out have been from Cochin and neighbouring areas. George (1959, 1961), George *et al.*, (1963) observed that *M. monoceros* was available in stray numbers in the nearshore commercial catches of indigenous gears as well as in the landings of trawl nets operated off Cochin. The details on the prawn landings of trawl fishery of Ambalapuzha-Purakkad region in 10-35 m depths were reported by Kurup and Rao (1974) and Kurup (1986) and their studies showed no significant catches of the speckled shrimp in the landings. The non-availability of this species in the inshore waters of Cochin and Ambalapuzha regions in the earlier years was due to the operation of nets in day time mostly in lesser depths. Shrimp trawling which was done during day time alone in the earlier years was carried out during nights also in 30-45 m depths off Cochin, from 1990 onwards. Eventhough, several species of prawns were encountered, *P. stylifera*, *M. dobsoni*, *M. monoceros* and *P. indicus* formed the main contributors in order of abundance and they together formed 97.64 % of the prawn catch landed at Cochin Fisheries Harbour during 1991-93 which agrees well with the earlier studies on prawn fisheries of Kerala by Suseelan *et. al* (1989, 1992, 1993). The present studies has shown that *M. monoceros* was one of the important contributors to the prawn fishery of Cochin occupying third position. The average annual landings of the speckled shrimp at Cochin Fisheries Harbour was 192 t with CPUE of 3.67 kg and the slight reduction in the catches in 1992 was in accordance with the general trend of the regular prawn fishery. Between 1991 and '93 the catch and catch rate of the speckled shrimp landed at Cochin Fisheries Harbour increased by 5.33 and 37.97% respectively.

As *M. monoceros* is nocturnal, success of its fishery depends on the shrimp trawling during nights in their normal habitat of 30-45 m grounds. The fishing season was generally observed between December and May with the peak availability during March-May period when about half of the annual landings of speckled shrimp was recorded. The trawling ban during June-August for a limited duration, did not affect the annual landings of this species since the catch of *M.monoceros* during this period was generally found to be negligible due to day fishing. Changes in bottom hydrography brought about by upwelling during monsoon have significant effect on the demersal fisheries of the West coast of India (Banse, 1959; Damodaran,1973). The present studies have revealed the existence of annual movement of *M. monoceros* during peak monsoon months (July-August) from their normal habitat of 30-45 m, to deeper grounds of 55-90 m and again during the post monsoon months (September-October) in the reverse direction, back to the usual grounds along the Kerala coast. These movements of speckled shrimp occur possibly due to upwelling. The movement of *M. monoceros* to deeper grounds during monsoon months was correlated by the availability of this species in 55-60 m grounds off Ratnagiri during July 88 and in 60 m depth in the month of August '90 off Calicut in the experimental trawling carried out by FORV Sagar Sampada (Suseelan *et al*, 1990, 1994).

In the present studies, the inshore catch of *M. monoceros* at Cochin did not show any positive relationship with the juvenile fishery of this species in Cochin Backwaters. Ramamurthy *et al* (1978) stated that there was no relationship between juvenile fishery of *M. dobsoni* in the estuary and its inshore fishery along South Kanara coast. However, Rao (1993) stated that the inshore fishery of *M. monoceros* along the Kakinada coast was influenced by the abundance of juveniles of this species in Godavari estuary after a time lag of 5-6 months. Females of 66-195 mm and males of 71-160 mm in total length contributed to the *M. monoceros* catches landed by shrimp trawlers at Cochin Fisheries Harbour during 1991-93. Adults predominated the catch throughout the study period with average annual contribution of 92.18%. The trawl landings of *M. monoceros* at Cochin Fisheries Harbour was predominated by 7-12 months old speckled shrimp during the present period of observations.

Table 6.1. Prawn landings (t) fishing effort (boat trips) and CPUE (kg) of shrimp trawlers operated in the inshore waters of Kerala during 1985-1993

	1985-90			1991			1992			1993		
	Catch	Effort	CPUE	Catch	Effort	CPUE	Catch	Effort	CPUE	Catch	Effort	CPUE
Kerala	35861	558305	64.23	44271	553638	79.96	39782	542240	73.37	35046	605727	57.86
Sakthikulangara & Neendakara	8755	133476	65.59	14147	155939	90.72	15433	176413	87.48	17138	178009	96.28
%	24.41	23.91	-	31.95	28.16	-	38.79	32.53	-	48.90	29.39	-
Cochin FHarbour & Murikkumpadam	4374	55357	79.01	12155	108911	111.60	5761	92829	62.06	7130	102565	69.52
%	12.20	9.91	-	27.46	19.68	-	14.48	17.12	-	20.35	16.93	-
Other centres	22732	369472	61.52	17969	288788	62.22	18588	272998	68.09	10778	325153	33.15
%	63.39	66.18	-	40.59	52.16	-	46.73	50.35	-	30.75	53.68	-

Table 6.2 Monthwise details on catch, CPUE (kg), Effort and Species composition of prawns in stakenet fishery for the year 1991 at Thoppumpadi centre

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	All months
Total Units	1871	2134	2790	2400	1800	1720	240	600	543	1710	1519	1575	18902
Total prawn catch	8341	14126	9882	6708	8013	2586	101	539	1447	1872	1697	5947	61259
CPUE	4.46	6.62	3.54	2.80	4.45	1.50	0.42	0.90	2.66	1.10	1.12	3.78	3.24
M. monoceros	165	947	324	348	207	152	5	16	22	45	133	54	2418
CPUE	0.09	0.44	0.12	0.15	0.12	0.09	0.02	0.03	0.04	0.03	0.09	0.03	0.13
%	1.98	6.70	3.28	5.19	2.58	5.88	4.95	2.97	1.52	2.40	7.84	0.91	3.95
M. dobsoni	7523	12346	8892	5704	5922	1668	36	488	1421	1773	1402	5866	53041
CPUE	4.02	5.79	3.18	2.38	3.29	0.97	0.15	0.81	2.62	1.04	0.92	3.73	2.81
%	90.19	87.41	89.98	85.03	73.90	64.50	35.64	90.54	98.29	94.72	82.62	98.64	86.58
P. indicus	653	820	639	652	1884	766	60	32	2	18	162	27	5715
CPUE	0.35	0.38	0.23	0.27	1.05	0.44	0.25	0.05	-	0.01	0.11	0.02	0.30
%	7.83	5.80	6.47	9.72	23.51	29.62	59.41	5.94	0.14	0.96	9.54	0.45	9.33
M. affinis	-	-	-	-	-	-	-	3	24	36	-	-	41
CPUE	-	-	-	-	-	-	-	0.01	-	0.02	-	-	-
%	-	-	-	-	-	-	-	0.56	0.14	1.92	-	-	0.07
P. semisulcatus	-	13	27	4	-	-	-	-	-	-	-	-	44
CPUE	-	0.01	0.01	-	-	-	-	-	-	-	-	-	-
%	-	0.09	0.27	0.06	-	-	-	-	-	-	-	-	0.07

Table 6.3 Monthwise details on catch, CPUE (kg), effort and species composition on the stake net prawn fishery at Vypeen Centre for the year 1991

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	All months
Total Units	8004	6960	7200	7544	7200	10000	5400	4322	3915	5594	6780	5220	78139
Total Prawn Catch(kg)	29815	53160	15840	34627	18804	9280	3162	3247	10827	28861	5601	8866	222090
CPUE	3.72	7.64	2.20	4.59	2.61	0.93	0.59	0.75	2.77	5.16	0.83	1.7	2.84
M. monoceros	5149	7440	1980	5582	744	420	87	168	249	1510	2157	984	26470
CPUE	0.64	1.07	0.27	0.74	0.10	0.04	0.02	0.04	0.07	0.27	0.32	0.19	0.34
%	17.27	14.00	12.50	16.12	3.96	4.53	2.75	5.17	2.30	5.23	38.51	11.10	11.92
M. dobsoni	22678	39480	12240	25650	13428	2750	108	2470	10337	27095	3263	7838	167337
CPUE	2.83	5.67	1.70	3.40	1.87	0.28	0.02	0.57	2.64	4.84	0.48	1.50	2.14
%	76.06	74.27	77.27	74.08	71.41	29.63	3.42	76.07	95.47	93.88	58.26	88.40	75.35
P. indicus	1988	6120	1620	3395	4632	6110	2952	609	241	256	181	44	28148
CPUE	0.25	0.88	0.23	0.45	0.64	0.61	0.55	0.14	0.06	0.05	0.03	0.01	0.36
%	6.67	11.51	10.23	9.80	24.63	65.84	93.36	18.76	2.23	0.89	3.23	0.50	12.67
M. affinis	-	-	-	-	-	-	15	-	-	-	-	-	15
CPUE	-	-	-	-	-	-		-	-	-	-	-	
%	-	-	-	-	-	-	0.47	-	-	-	-	-	0.01
P. semisulcatus	-	120	-	-	-	-	-	-	-	-	-	-	120
CPUE	-	0.02	-	-	-	-	-	-	-	-	-	-	-
%	-	0.22	-	-	-	-	-	-	-	-	-	-	0.05

Table 6.4. Catch per unit effort (kg) of *M. monoceros* in stake net fishery at Thoppumpadi during different phases of moon with CPUE of total prawns (kg) in parenthesis

Months	Newmoon phase	Fullmoon phase	Number of units observed	Number of total days observed
April'91	1.21 (20.01)	0.69 (16.11)	6	15
May'91	0.67 (24.18)	0.59 (13.76)	6	14

Table 6.5 Length frequency details in percentage on *M. monoceros* (females) from Thoppumpadi region of Cochin backwaters in 1991

Size group	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	All months
56-60	-	1.67	-	0.77	-	-	-	-	-	-	3.48	-	0.98
61-65	-	7.54	8.14	0.77	-	-	-	-	0.62	7.02	7.91	2.06	5.01
66-70	20.83	28.33	5.41	4.54	0.95	2.56	-	-	-	10.52	13.29	1.03	15.32
71-75	11.42	16.68	7.03	8.25	0.95	0.62	3.17	-	1.23	19.30	24.05	12.92	11.91
76-80	30.86	24.15	27.64	20.53	9.71	10.95	-	132	20.58	12.28	15.51	19.18	22.10
81-85	22.84	19.12	18.43	27.06	16.34	22.62	11.11	368	20.58	26.32	24.37	31.89	21.10
86-90	10.03	2.51	32.81	24.63	35.88	14.84	15.88	612	32.72	8.77	9.49	15.80	15.23
91-95	2.01	-	0.54	8.58	24.82	21.29	34.92	236	23.05	8.77	0.95	14.78	5.01
96-100	2.01	-	-	2.16	8.03	16.17	26.98	128	1.23	-	0.95	2.34	2.05
101-105	-	-	-	1.55	2.13	6.45	7.94	68	-	-	-	-	0.71
106-110	-	-	-	-	1.18	1.94	-	-	-	7.02	-	-	0.30
111-115	-	-	-	1.16	-	1.94	-	-	-	-	-	-	0.25
116-120	-	-	-	-	-	0.62	-	-	-	-	-	-	0.03
Total	28304	123238	53532	41561	23153	16609	504	1544	1944	5472	22752	7275	325888

Table 6.6 Length frequency details in percentage on *M. monoceros* (Males) from Thoppumpadi region of Cochin backwaters in 1991

Size group	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	All months
56-60	2.69	1.88	-	-	-	-	-	-	-	-	1.06	1.02	1.05
61-65	-	10.33	5.98	4.38	-	-	-	-	-	5.06	4.93	1.02	5.94
66-70	5.38	9.39	2.77	6.38	1.02	-	9.26	-	0.49	1.27	17.60	8.46	6.94
71-75	30.64	33.65	12.31	16.27	13.15	-	-	1.67	0.98	16.46	29.93	20.26	23.50
76-80	40.58	33.57	33.88	24.53	5.80	22.35	18.52	18.20	0.49	37.97	32.04	32.68	29.81
81-85	15.32	11.18	25.92	21.34	19.90	24.62	16.67	32.64	16.83	24.05	13.38	30.90	17.30
86-90	5.39	-	12.76	12.96	42.50	27.65	22.22	37.24	32.68	13.92	1.06	5.66	9.59
91-95	-	-	6.38	5.94	15.31	22.22	11.11	8.58	40.85	1.27	-	-	4.35
96-100	-	-	-	4.63	1.00	3.16	12.96	1.67	7.68	-	-	-	0.94
101-105	-	-	-	2.44	1.25	-	9.26	-	-	-	-	-	0.43
106-110	-	-	-	-	-	-	-	-	-	-	-	-	-
111-115	-	-	-	1.13	-	-	-	-	-	-	-	-	0.15
116-120	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	21096	109908	36396	36754	21749	13464	432	1912	2448	7584	20448	7330	279521

Table 6.7. Length range (mm) and percentage composition of females and males in stake net catch at Thoppumpadi in 1991

Month	Length range		Percentage composition	
	Females	Males	Females	Males
January	66-100	56-90	57.30	42.70
February	56-90	56-85	52.86	47.14
March	61-95	61-95	59.53	40.47
April	56-115	61-115	53.07	46.93
May	66-110	66-105	51.56	48.44
June	66-120	76-100	55.28	44.77
July	71-105	66-105	53.85	46.15
August	76-105	71-100	44.68	55.32
September	61-100	66-100	44.26	55.74
October	61-110	61-95	41.91	58.09
November	56-100	56-90	52.67	47.33
December	61-100	56-90	49.81	50.19
All months	56-120	56-115	53.83	46.17

Table 6.8. Prawn landings (kg) fishing effort (boat trips) and prawn catch per unit effort (CPUE) by shrimp trawlers for 1991-93 duration (monthwise) at Cochin Fisheries Harbour

Year	Particulars	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1991	Effort	6254	5445	5717	6745	6853	5109	1878	3770	5033	3284	5218	4334	59640
	Catch	241121	337134	295753	414812	449723	562641	264882	1016166	946899	153892	358695	429544	5471262
	CPUE	38.55	61.92	51.73	61.50	65.62	110.13	141.04	269.54	188.13	46.86	68.74	99.11	91.74
1992	Effort	4998	5021	5605	5216	7070	4660	1463	3190	3836	5106	2803	3131	52099
	Catch	204547	212236	336720	347470	593058	403139	4372	10993	611990	130084	14972	117841	2987422
	CPUE	40.93	42.27	60.07	66.62	83.88	86.51	2.99	3.45	159.54	25.48	5.34	37.64	57.34
1993	Effort	3408	4560	4441	3852	6790	3019	2813	4534	2534	3346	2996	3216	45509
	Catch	320415	252034	414207	351760	609918	209580	400194	223947	13002	3194	71898	265474	3135623
	CPUE	94.02	55.27	93.27	91.32	89.83	69.42	142.27	49.39	5.13	0.95	24.00	82.55	68.90
1991-93 (Average)	Effort	4887	5009	5254	5271	6904	4263	2051	3831	3801	3912	3672	3560	52416
	Catch	255361	267135	348893	371347	550900	391787	223149	417035	523964	95723	148522	270953	3864769
	CPUE	52.26	53.33	66.40	70.45	79.79	91.91	108.78	108.85	137.85	24.47	40.44	76.10	73.73

Table 6.9. MOnthwise details on prawn landings (kg) and species composition of prawns (catch and percentage) in trawler landings at Cochin Fisheries Harbour in 1991

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Prawn catch	241121	337134	295753	414812	449723	562641	264882	1016166	946899	153892	358695	429544	5471262
M. monoceros	15987	24734	26320	33501	35460	1895	432	482	6485	114	34660	25713	205783
%	6.63	7.34	8.90	8.08	7.88	0.34	0.16	0.05	0.68	0.07	9.66	5.99	3.76
M. dobsoni	162870	191023	125300	171262	217293	62037	-	-	-	32325	227703	312082	1501895
%	67.55	56.66	42.37	41.29	48.32	11.03				21.00	63.48	72.65	27.45
M. affinis	-	5	181	442	696	1036	888	176	-	120	-	2168	5712
%	-	-	0.06	0.10	0.15	0.18	0.34	0.01		0.08		0.50	0.10
P. indicus	22665	30417	29966	65301	73641	22150	96	-	-	307	5457	12909	262909
%	9.40	9.02	10.13	15.74	16.37	3.94	0.04			0.20	1.52	3.01	4.81
P. monodon	-	-	-	156	556	-	-	-	-	-	213	-	925
%				0.04	0.12						0.06		0.02
P. canaliculatus	148	168	1355	1537	1520	99	60	-	63	-	1674	2903	9527
%	0.06	0.05	0.46	0.37	0.34	0.02	0.02		0.01		0.47	0.68	0.17
P. semisulcatus	378	4063	7525	3558	2712	10	-	-	-	-	445	313	19004
%	0.16	1.21	2.54	0.86	0.60						0.12	0.07	0.35
Trachypenaeus Sp.	-	120	16331	38499	24565	-	-	-	-	-	-	-	79515
%	-	0.04	5.52	9.28	5.46								1.45
P. stylifera	39073	86604	88775	100556	93280	475414	263406	1015508	940351	121026	88543	73456	3385992
%	16.20	25.69	30.02	24.24	20.74	84.50	99.94	99.94	99.31	78.64	24.68	17.10	61.89

Table 6.10. Monthwise details on prawn landings (Kg). and species composition of prawns (catch and percentage) in trawler landings at Cochin Fisheries Harbour in 1992

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Prawn catch	204547	212236	336720	347470	593058	403139	4372	10993	611990	130084	14972	117841	2987422
M. monoceros	14178	25921	30706	21750	32050	5420	302	512	206	216	331	23042	154634
%	6.93	12.21	9.12	6.26	5.40	1.34	6.91	4.66	0.03	0.17	2.21	19.55	5.18
M. dobsoni	109510	112615	139596	167132	306309	185512	-	-	-	292	2360	54462	1077788
%	53.54	53.06	41.46	48.10	51.65	46.02	-	-	-	0.22	15.76	46.22	36.08
M. affinis	1735	-	241	2922	6394	3782	-	-	-	-	81	-	15155
%	0.85	-	0.07	0.84	1.08	0.94	-	-	-	-	0.54		0.51
P. indicus	10520	16040	18806	24554	83095	21438	-	-	-	162	954	2495	178064
%	5.14	7.56	5.59	7.07	14.01	5.32				0.12	6.37	2.12	5.96
P. monodon	-	-	-	80	955	-	-	-	-	49	47	1336	2467
%	-	-	-	0.02	0.16	-	-	-	-	0.04	0.31	1.13	0.08
P. canaliculatus	817	477	3749	1190	3788	513	25	-	-	-	3	2346	12908
%	0.40	0.22	1.11	0.34	0.64	0.13	0.57	-	-	-	0.02	1.99	0.43
P. semisulcatus	535	1973	4020	2097	2462	61	17	-	-	-	4	100	11269
%	0.26	0.93	1.19	0.60	0.42	0.02	0.39	-	-	-	0.03	0.08	0.38
Trachypenaeus Sp.	8645	2752	453	9128	10577	-	-	-	-	-	-	-	31555
%	4.23	1.30	0.13	2.63	1.78	-	-	-	-	-	-	-	1.06
P. stylifera	58607	52458	139149	118617	147428	186413	4028	10481	611784	129365	11192	34060	1503582
%	28.65	24.72	41.32	34.14	24.86	46.24	92.13	95.34	99.94	99.45	74.75	28.90	50.33

Table 6.11. Monthwise details on prawn landings (kg) and species composition of prawns (catchpercentage) in trawler landings at Cochin Fisheries Harbour in 1993

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Prawn catch	320415	252034	414207	351760	609918	209580	400194	223947	13002	3194	71898	265474	3135623
M. monoceros	32150	21617	39005	37248	26292	8666	246	11046	12714	424	1162	26176	216746
%	10.03	8.58	9.42	10.59	4.31	4.14	0.06	4.93	97.78	13.27	1.62	9.86	6.91
M. dobsoni	274493	161621	248859	204970	500940	68501	-	-	-	761	34668	149318	1644131
%	85.67	64.13	60.08	58.27	82.13	32.69				23.83	48.22	56.25	52.43
M. affinis	32	404	1612	169	458	1546	-	-	-	-	-	4266	8487
%	0.01	0.16	0.39	0.05	0.08	0.74						1.61	0.27
P. indicus	3688	8376	12291	44036	15406	7615	-	-	-	4	4182	37454	133052
%	1.15	3.32	2.97	12.52	2.53	3.63				0.13	5.82	14.11	4.24
P. monodon	487	216	83	371	98	-	-	-	-	-	10	618	1883
%	0.15	0.09	0.02	0.11	0.02						0.01	0.23	0.06
P. canaliculatus	815	545	1102	2524	1680	506	-	-	-	7	-	-	7179
%	0.25	0.22	0.27	0.72	0.28	0.24				0.22			0.23
P. semisulcatus	363	1440	1394	1406	3382	888	-	-	-	7	26	248	9154
%	0.11	0.57	0.34	0.40	0.55	0.42				0.22	0.04	0.09	0.29
Trachypenaeus Sp.	1462	5060	10416	22160	16034	-	-	-	-	-	-	3928	59060
%	0.46	2.01	2.51	6.30	2.63							1.48	1.88
P. stylifera	6925	52755	99445	38876	45628	121858	399948	212901	288	1991	31850	43466	1055931
%	2.16	20.93	24.01	11.05	7.48	58.14	99.94	95.07	2.22	62.34	44.30	16.37	33.68

Table 6.12. Species composition of prawns (kg) with percentages in parentheis in trawl landings at Cochin Fisheries Harbour during 1991-93

Year	1991	1992	1993	1991-93
Total prawns	5471262	2987422	3135623	11594307
M. monoceros	205783 (3.76)	154634 (5.18)	216746 (6.91)	577163 (4.98)
M. dobsoni	1501895 (27.45)	1077788 (36.08)	1644131 (52.43)	4223814 (36.43)
M. affinis	5712 (0.10)	15155 (0.51)	8487 (0.27)	29354 (0.25)
P. indicus	262909 (4.81)	178064 (5.96)	133052 (4.24)	574025 (4.95)
P. monodon	925 (0.02)	2467 (0.08)	1883 (0.06)	5275 (0.05)
P. canaliculatus	9527 (0.17)	12908 (0.43)	7179 (0.23)	29614 (0.25)
P. semisulcatus	19004 (0.35)	11269 (0.38)	9154 (0.29)	39427 (0.34)
Trachypenaeus Sp.	79515 (1.45)	31555 (1.05)	59060 (1.89)	170130 (1.47)
P. stylifera	3385992 (61.89)	1503582 (50.33)	1055931 (33.68)	5945505 (51.28)

Table 6.13. Monthwise catch, catch per unit effort (in kg) and percentage composition in total prawns of *M.monoceros* in trawler catches at Cochin Fisheries Harbour during 1991-93

Months		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1991														
	Catch	15987	24734	26320	33501	35460	1895	432	482	6485	114	34660	25713	205783
	%	6.63	7.34	8.90	8.08	7.88	0.34	0.16	0.05	0.68	0.07	9.66	5.99	3.76
	CPUE	2.36	4.54	4.60	4.97	5.17	0.37	0.23	0.13	1.29	0.35	6.64	5.93	3.45
1992														
	Catch	14178	25921	30706	21750	32050	5420	302	512	206	216	331	23042	154634
	%	6.93	12.21	9.12	6.26	5.40	1.34	6.91	4.66	0.03	0.17	2.21	19.55	5.18
	CPUE	2.84	5.16	5.48	4.17	4.53	1.16	0.21	0.16	0.05	0.04	0.12	7.36	2.97
1993														
	Catch	32150	21617	39005	37248	26292	8666	246	11046	12714	424	1162	26176	216746
	%	10.03	8.58	9.42	10.59	4.31	4.14	0.06	4.93	97.78	13.27	1.62	9.86	6.91
	CPUE	9.43	4.74	8.78	9.67	3.87	2.87	0.09	2.44	5.02	0.13	0.39	8.14	4.76
1991-93														
Average Catch		20772	24091	32010	30833	31267	5327	327	4013	6468	251	12051	24977	192388
Average CPUE		4.25	4.81	6.09	5.85	4.53	1.25	0.16	1.05	1.70	0.06	3.28	7.02	3.67

Table 6.14. Depthwise distribution of *M. monoceros* in the shrimp grounds off Cochin

Year	Particulars	Jan-Jun	Jul	Aug	Sep-Oct	Nov-Dec
1991	Depth (m)	30-42	54-63	55-70	40-42	30-45
	Size range (mm)	66-195	81-150	76-165	71-185	76-185
1992	Depth (m)	30-45	64-70	73-80	40-50	33-40
	Size range (mm)	76-185	86-165	81-185	81-175	86-170
1993	DEPTH (m)	30-42	70-75	80-90	40-50	30-40
	Size range (mm)	81-195	81-165	106-175	106-195	76-185

Table 6.15. Depthwise distribution and size range of _M. monoceros_ based on experimental trawling conducted off Cochin

Particulars	Depth in Meters						
	5	15	25	35	45	55	65
Availatility	Rare	Rare	Common	Common	Rare	Common	Very rare
Period of availability	Jan, Apr & Dec	Jan- May & Dec	Jan- May & Oct- Dec	Feb- May & Nov- Dec	Aug- Sep	Aug- Sep	Sep
Size range(mm) Females	46-102	56-133	66-163	116-175	68-156	61-170	158
Size range (mm) Males	62-100	61-115	66-145	101-145	110-127	76-140	-
Percentage of mature females	-	13.19	39.45	18.24	-	2.78	-

Table 6.16. Monthwise details on the length range (mm) and percentage composition of juveniles and adults of *M. monoceros* in trawl catches in 1991

Month	Length range		Percentage composition			
	Females	Males	Females		Males	
			Juveniles	Adults	Juveniles	Adults
January	71-190	81-155	1.48	98.52	3.34	96.66
February	66-185	71-145	20.33	79.67	7.56	92.44
March	86-190	76-150	12.87	87.13	8.63	91.37
April	76-190	76-150	14.18	85.12	4.14	95.86
May	96-195	91-155	6.76	93.24	0.47	99.53
June	86-175	81-130	57.51	41.49	16.25	83.75
July	81-150	81-130	55.00	45.00	40.95	59.05
August	76-165	81-140	20.81	79.19	2.08	97.92
September	91-185	81-140	3.47	96.53	3.19	96.81
October	71-160	71-140	32.25	67.75	14.82	85.18
November	81-185	81-150	1.27	98.73	1.50	98.50
December	81-185	76-145	6.67	93.33	3.56	96.44
January-December	66-195	71-155	10.22	89.78	4.36	95.64

Table 6.17. Monthwise details on the length range (mm) and percentage composition of juveniles and adults of <u>*M.monoceros*</u> in trawl catches in 1992

Month	Length range		Percentage composition			
	Females	Males	Females		Males	
			Juveniles	Adults	Juveniles	Adults
January	86-180	81-150	13.18	86.82	7.61	92.39
February	81-175	81-150	14.86	85.14	4.70	95.30
March	86-180	91-145	10.36	89.64	1.23	98.77
April	76-180	86-145	14.46	85.54	3.12	96.88
May	86-185	91-145	11.11	88.89	1.99	98.01
June	91-185	91-150	5.78	94.22	3.41	96.59
July	91-165	86-135	12.72	87.28	14.28	85.72
August	81-185	91-140	28.2	71.80	4.79	95.21
September	86-175	96-135	9.26	90.74	-	100.00
October	86-175	81-135	11.44	88.56	3.38	96.62
November	101-170	101-140	15.55	84.45	-	100.00
December	96-170	86-145	3.01	96.99	0.65	99.35
January-December	76-185	81-150	11.16	88.84	3.01	96.99

Table 6.18. Monthwise details on the length range (mm) and percentage composition of juveniles and adults of *M.monoceros* in trawl catches in 1993

Month	Length range		Percentage composition			
	Females	Males	Females		Males	
			Juveniles	Adults	Juveniles	Adults
January	81-190	91-145	8.13	91.87	3.09	96.91
February	96-185	96-140	1.18	98.82	-	100.00
March	91-185	86-155	2.27	97.73	3.25	96.75
April	91-195	91-160	22.91	77.09	2.66	97.34
May	96-185	91-150	12.57	87.43	1.35	98.65
June	96-180	96-145	3.64	96.36	-	100.00
July		NO CATCH		---------		
August	106-175	106-160	2.64	97.36	-	100.00
September	106-195	106-155	0.29	99.71	-	100.00
October		---------				NO CATCH
November	131-165	106-145	-	100.00	-	100.00
December	76-180	86-145	31.40	68.60	28.20	71.80
January-December	76-195	86-160	12.74	87.26	5.45	94.55

Table 6.19. Monthly percentage composition of juvenile (females and males) *M. monoceros* in the trawl catches during 1991-93

Months	1991	1992	1993
January	2.41	10.39	5.61
February	13.50	9.78	0.59
March	10.75	5.80	2.76
April	9.16	8.79	12.79
May	3.62	6.55	6.96
June	37.38	4.60	1.82
July	47.98	13.50	NO CATCH
August	11.45	16.50	1.32
September	3.33	4.63	0.15
October	23.54	7.41	NO CATCH
November	1.39	7.78	0.00
December	5.12	1.83	29.80

Table 6.20. Catch details on *M. monoceros* from Cochin Backwaters and inshore regions of Cochin during 1991-93

Particulars	1991				1992			1993
	Backwaters			Sea	Backwaters			Sea
	Thoppumpadi	Vypeen	Total	Cochin	Thoppumpadi	Vypeen	Total	Cochin
Units	12715	46908	59623	52099	12216	43525	55651	45509
Catch (kg)	2143	21315	23458	154634	425	8188	8613	216746
CPUE (kg)	0.169	0.454	0.393	2.968	0.035	0.188	0.155	4.763

CHAPTER 7

POPULATION DYNAMICS

CHAPTER 7

POPULATION DYNAMICS

7.1 INTRODUCTION

Fisheries are based on stocks of wild animals living in their natural environment and the success of fisheries depends critically on the state of fish stocks. Conventionally, fish stock assessment involves collection or estimation of information on age, rate of growth and other factors which cause variations in the stocks. Information on mortality is extremely critical to the study of population dynamics and estimation of mortality rates is a basic requirement for fish stock assessment. The rate at which the numbers of the population are decreasing is the mortality (Here , the rates are instantaneous rates). Usually in an exploited stock, we are dealing with two sources of mortality - the natural mortality (M) and the fishing mortality (F). Thus we have, $Z = F + M$. Z is called the " instantaneous rate of total mortality", the " total mortality coefficient" or simply the "total mortality rate". An essential characteristic of a stock is that its population parameters remain constant throughout its area of distribution. (Gulland, 1983). The easiest way to describe the change in fish stock is often to follow the fate of a cohort. A "Cohort" is a batch of prawns, all of approximately the same age and belonging to the same stock (Sparre *et al.*, 1989).

Most of the earliest attempts to calculate mortality rates in prawns were based on tagging experiments (Lindner and Anderson, 1956, Klima, 1964, Kutkunn, 1966, Costello and Allen, 1968). Neal (1968), Berry (1970), Garcia (1977), Jones and van Zalinge (1981), Ye Chang Cheng (1984), Pauly *et al* (1984) and others have used catch composition to estimate mortality rates. Banerji and George (1967), Kurup and Rao (1974) and Ramamurty (1980) estimated the mortality rates of some of the penaeid prawns in India. Very few studies (Lalitha Devi, 1986, 1987, Rao 1988 a, b; and Rao *et al* (1993) have been carried out on population dynamics of *Penaeus* spp along the Indian coast. Silas *et al* (1984) and Rao (1988 a) used surplus yield model to assess the stocks of prawns. Stock assessment of *M. dobsoni* was studied by Ramamurthy *et al* (1978), Alagaraja *et al* (1986), George *et al* (1988), Smitha and Devaraj (1990) and Sukumaran *et al* (1993a). Stock assessment of *P. stylifera* along the west coast had been carried out by Ramamurthy (1980), Alagaraja *et al.*, (1986) Suseelan and Rajan (1989) and George *et al* (1988). There are only limited works on the population dynamics of *M. monoceros*. George *et al* (1988) made some preliminary observations on the impact of trawling on the stocks of *M. monoceros* in the Karwar Coast. Lalitha Devi (1987) and Rao (1994) gave the result on their study on mortality and stock assessment of this species from Kakinada Coast. Based on the data collected from Bomaby, Varaval and Visakhapatnam coasts, Sukumaran *et al* (1993) made general studies on the stock of this species. The present work gains prominance, as it is the first attempt on the population dynamics of *M. monoceros* along the Kerala coast.

7.2 MATERIAL AND METHODS

Catch and effort and the length distribution data of *M. monoceros* landed by shrimp trawlers at Cochin Fisheries Harbour during 1991-93 formed the data base for the present study. The landing centre was visited twice a week and the data on effort, catch and length composition of *M. monoceros* collected on each observation day were weighted following Alagaraja (1984) to get monthly estimates which were pooled to get the annual estimates. The details on the collection of data on the fisheries biology of this species and further estimation are given in Chapters 3 and 6. The growth parameters (K and L_{∞}) and the relative age estimated by ELEFAN I method (Pauly and David, 1981) for *M. monoceros* have been used for the present study.

The length frequency data used for age and growth study in Chapter 3 were pooled into annual length frequency distribution on calender year basis. Direct estimation of instantaneous rate of fishing mortality (F) poses a number of problems because of uneven distribution of the species identified in the fishing grounds and difficulty in quantification of effective effort directed at this species. Hence total mortality coefficient (Z) and natural mortality coefficient (M) are estimated first and the fishing mortality coefficient (F) is obtained by deducting natural mortality from the total mortality. A number of methods is available to estimate the total mortality rate among which, the following four methods are used in the present studies:

1. Catch-curve method of Pauly (1982)
2. Cumulative catch-curve method of Jones and van Zalinge (1981)
3. Bevertion and Holt method (1957) and
4. Wetherall, Polovina and Ralston method (1987)

The estimation of natural mortality coefficient (M) was made based on the Rikhter and Efanov's formula (1976).

The following four methods were used for assessment of *M. monoceros* stock:

1. Jones' length based Cohort analysis (Jones, 1974, Jones and van Zalinge, 1981)
2. Length based Thomson and Bell analysis (Sparre, 1985)
3. Yield per recruitment model (Beverton and Holt, 1957) and
4. Baranov's catch equation (Baranov, 1918)

The details on the methods used in the present study and the results obtained are given in the respective section.

7.3 RESULTS

7.3.1 Estimation of total mortality coefficient (Z)

Due to mortality (fishing or natural causes) there is a continuous decrease in the number of survivors. At birth, the cohort has age zero and from this age to Tr, (the minimum age at recruitment), it is in the pre-recruitment phase. The rate of change in numbers per year $\Delta N/\Delta t$ depends on the number of survivors, N:

$$\frac{\Delta N(t)}{\Delta t} = -Z(t)$$

The unit of Z is "per year" or in general, "per time unit". If Z remains constant throughout the life of a cohort, the earlier equation is mathematically equivalent to

$$N(t) = N(Tr) \exp(-Z(t-Tr))$$

which is called the "exponential decay model" and together with the growth equation is a corner-stone of the theory of exploited fish stocks. An assumption is made that Tr = Tc (Tc is age at first capture and marks the beginning of exploited phase). The fraction surviving after one year is called the "Survival rate" (Ricker, 1975):

$$\exp(-Z) = \frac{N(tr+1)}{N(tr)}$$

There are several methods available to estimate Z (Heincke, 1913; Beverton and Holt, 1957; Chapman, 1961; Robson and Chapman, 1961; Pope, 1972; Ssentongo and Larkin, 1973; Ricker, 1975; Jones and van Zalinge, 1981; Pauly, 1982; Wetherall *et al* 1987). Among these, four methods were used for estimation of total mortality rate of *M. monoceros*.

7.3.1.1. Catch-curve method of Pauly (1982)

One of the methods of estimating total mortality rate is to construct catch-curves i.e., plots of the natural logarithm of fish numbers against their age, where Z is the slope, with sign changed, of the "descending" part of the curve (Ricker, 1975). There are three steps for this method, to derive catch-curves from length frequency data. The first step is to smooth out the recruitment pulses by pooling data obtained at regular intervals, after converting them to percentage length frequency sample. This is followed by construction of catch-curve proper where, the number of fish in each size group is divided by the time it takes the fish to grow through a size group (Δ t). The catch curve equation thus becomes,

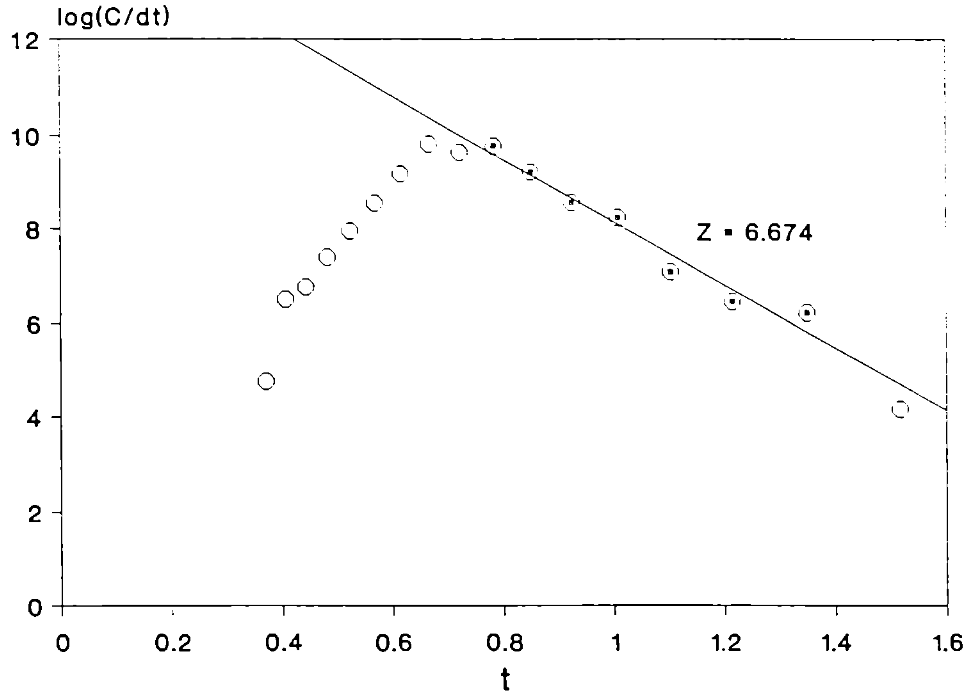
$$\log_e (N/\Delta t) = a + b\ t$$

where, t is the age corresponding to midlength of each length class, b = −Z, N = the number of fish in each length class and Δt = the time needed for the fish to grow through a length class. The third step is the identification of biased data points. The conversion of length frequency samples to catch-curve by means of growth parameter values can involve fishes, the individual lengths of which, are very close to L_∞, in which cases unrealistically high "ages" are generated. Thus, it is imperative that a scattergram be drawn of the points to use for the computation of Z, in order to select for points really belonging to the descending part of the curve, and contained within a reasonable age-span.

The same set of data on length frequency used for ELEFAN I method were analysed using the ELEFAN II method (Pauly *et al* 1981) for estimation of Z of *M. monoceros* by the catch-curve method. The construction of catch-curves for estimation of Z is shown in Table 7.1 - 7.3 for females and Tables 7.4 to 7.6 for males of *M. monoceros*. The estimation of Z by catch-curve method for males and females separately is shown in Figures 7.1, 7.2 and 7.3 for the years 1991, 1992 and 1993 respectively. It was observed that the length range considered for females and males of *M. monoceros* in the calculation during 1991-93 varied from 125 to 185 mm and between 115 and 150 mm respectively. The

Figure . 7·1

Catch curve of *M.monoceros* (Males)-1991



Catch curve of *M.monoceros*(Females)-1991

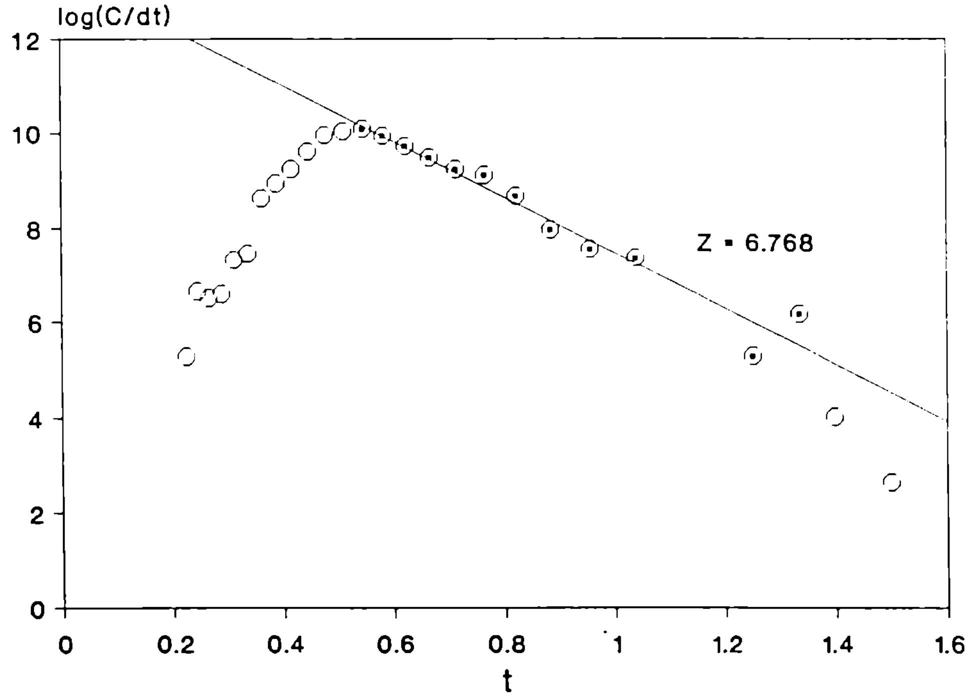
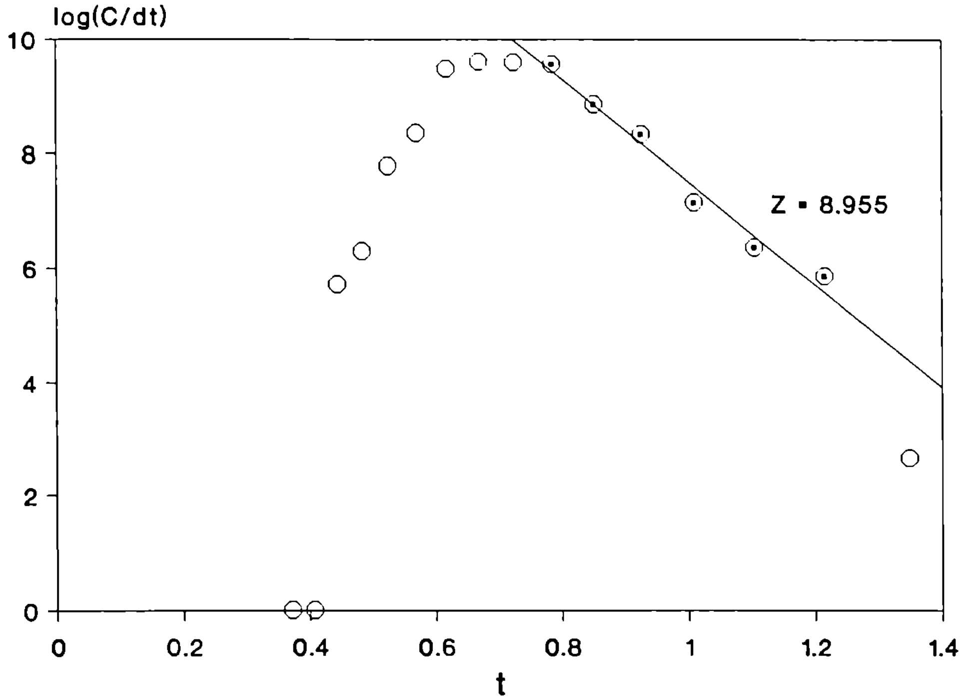


Figure . 7·2

Catch curve of *M.monoceros*(Males)-1992



Catch curve of *M.monoceros*(Females)-1992

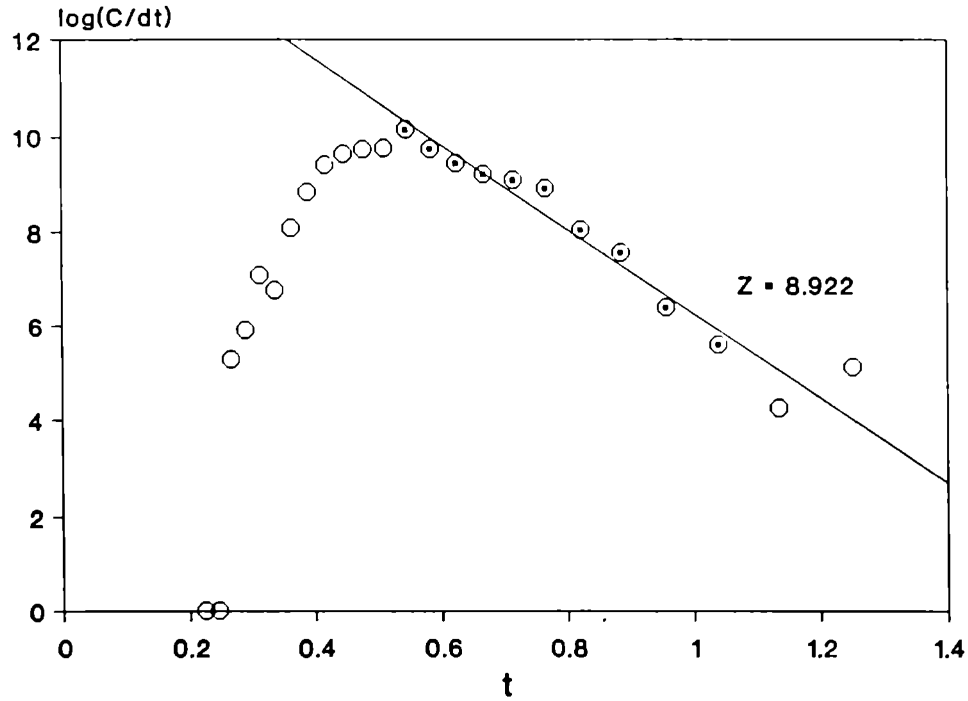
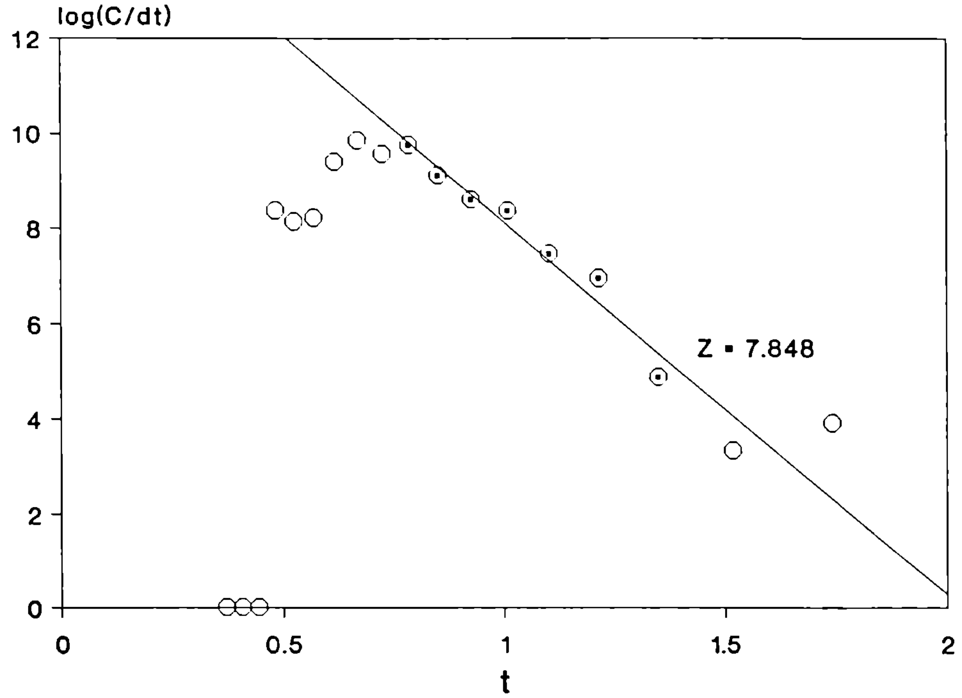
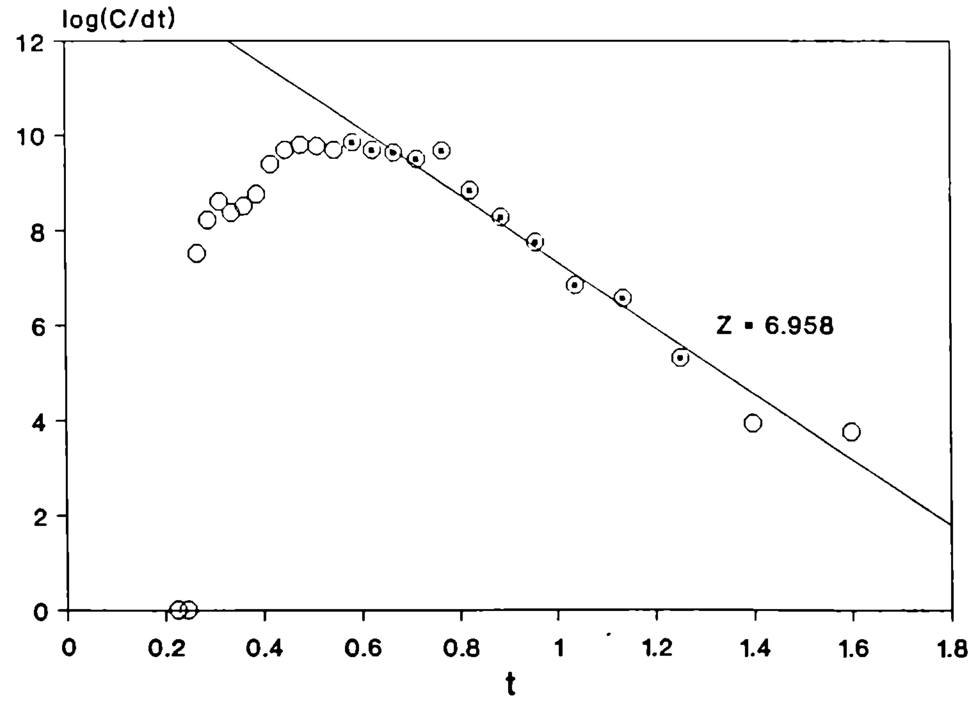


Figure. 7·3

Catch curve of *M.monoceros*(Males)-1993



Catch curve of *M.monoceros*(Females)-1993



Z values estimated for *M. monoceros* by this method are as follows:

Years	Total mortality coefficient (Z) Females	Males
1991	6.768	6.674
1992	8.922	8.955
1993	6.958	7.848

7.3.1.2 Cumulative catch-curve method

Jones and van Zalinge (1981) showed that,

$$\log_e \Sigma_L N = Z/K \log_e (L_\infty - L) + \log_e C$$

where $\Sigma_L N$ is the accumulated number above a certain size L and C is a complex term independent of L. Plotting $\log_e \Sigma_L N$ on $\log_e (L_\infty - L)$ thus gives a line with a slope equal to Z/K, Z being assumed as constant. If linearity is not maintained over the whole range of sizes examined, only the linear section can be used for regression. The usable interval must however represent a sufficient proportion of the life span to allow a certain significance to be attached to the calculated values of Z

In the present studies on *M. monoceros* the linearity is maintained in the size range between 125 and 185 mm in females and 115 and 150 mm in males for the three year duration of 1991-93. The construction of cumulative catch-curve for the speckled shrimp are given in Tables 7.7 - 7.9 for females and 7.10 - 7.12 for males. The estimation of Z by cumulative catel-curve method is shown for males and females of *M. monoceros* in FIgures 7.4, 7.5 and 7.6 for the years 1991, 1992 and 1993 respectively. The total mortality rates of *M. monoceros* estimated by the cumulative catch-curve method are as follows:

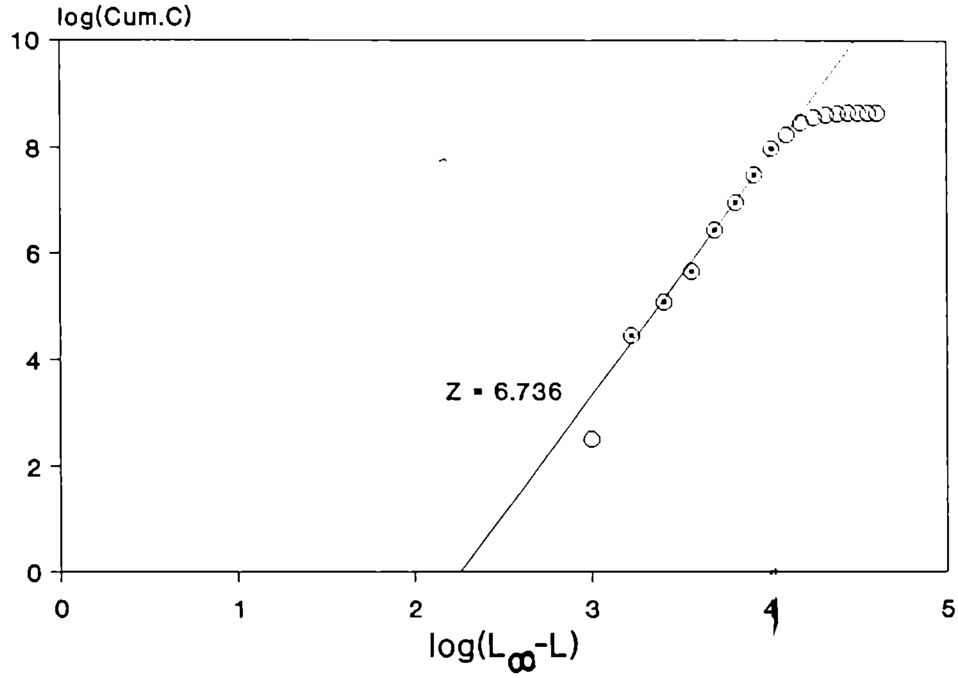
Years	Total mortality coefficient (Z)	
	Females	Males
1991	7.279	6.736
1992	9.364	9.426
1993	7.409	7.896

7.3.1.3 Beverton and Holt method

One of the simplest method to assess the total mortality rate is to estimate Z from the mean size in the catch as suggested by Beverton and Holt (1957). They showed that the functional relationship between Z and L is

Figure. 7·4

Cumulativre catch curve of
M.monoceros (Males)- 1991



Cumulative catch curve of
M.monoceros (Females) - 1991

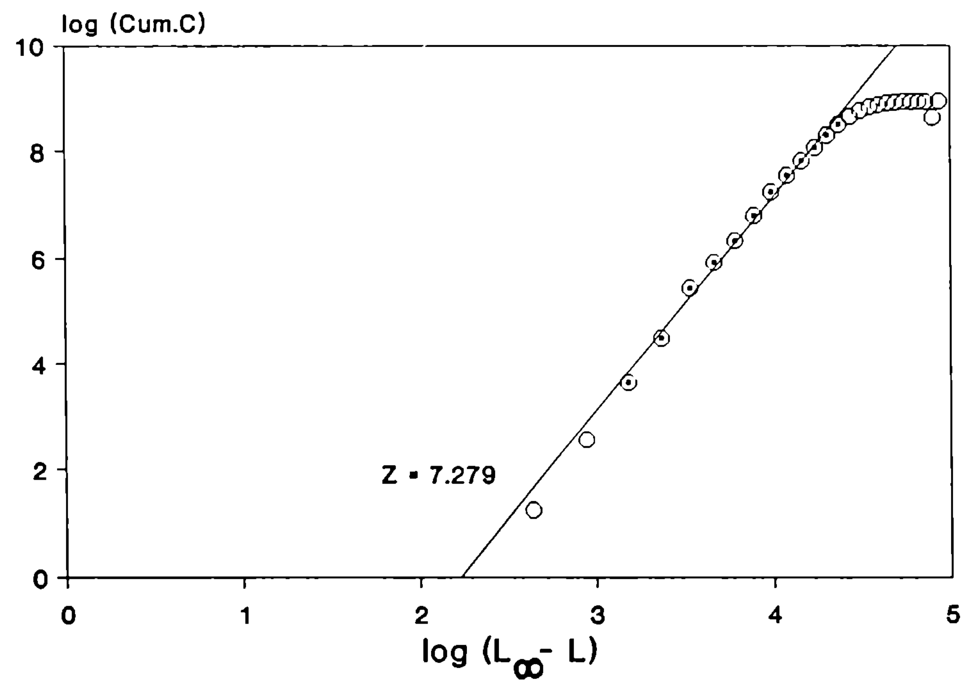
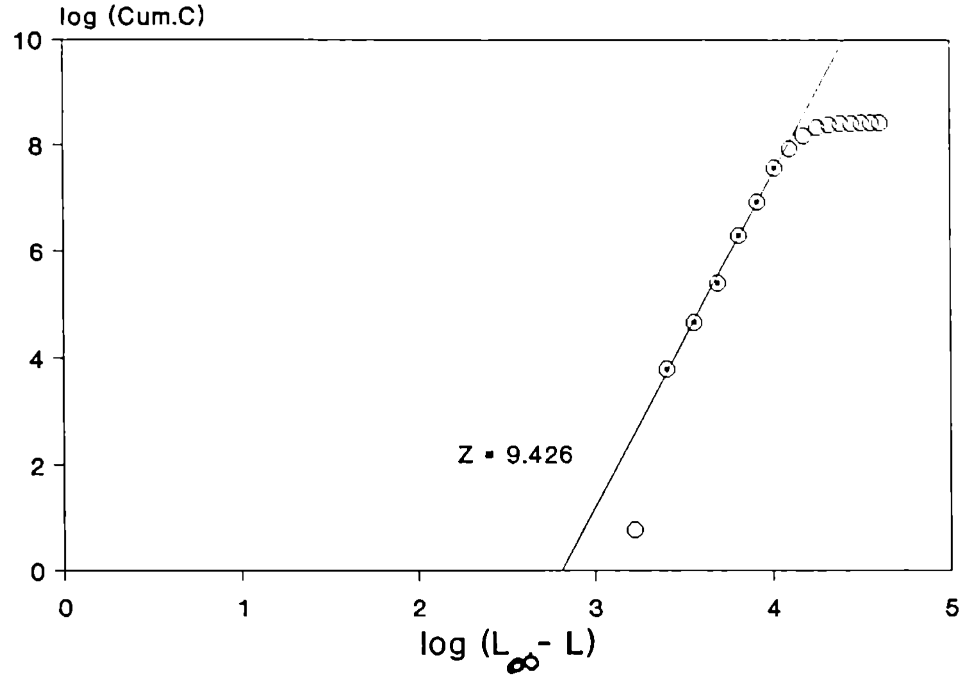


Figure. 7·5

Cumulative catch curve of
M.monoceros(Males) - 1992



Cumulative catch curve of
M.monoceros (Females) - 1992

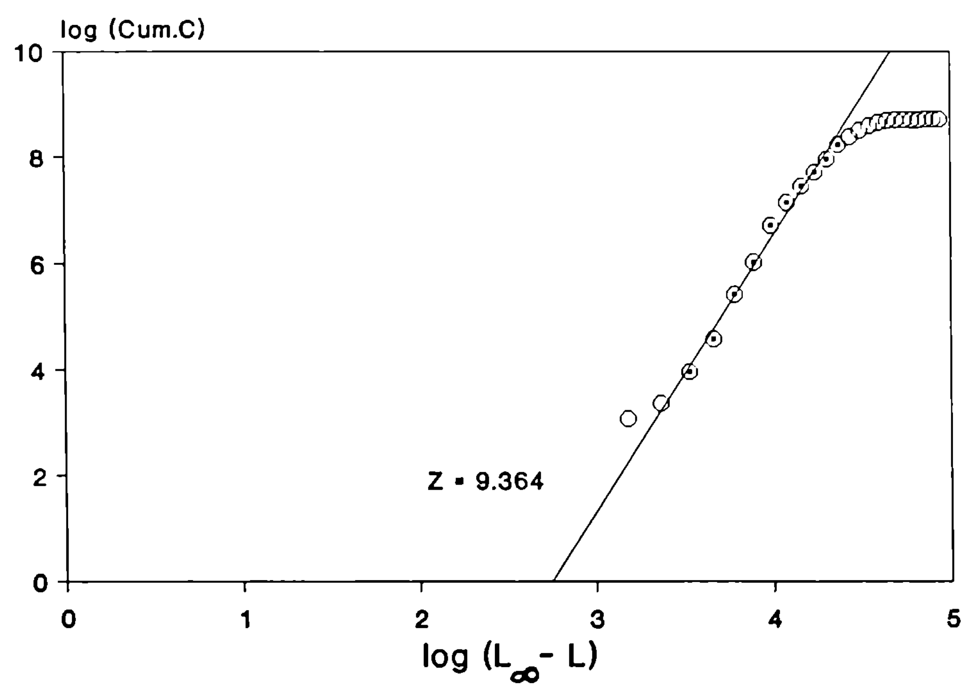
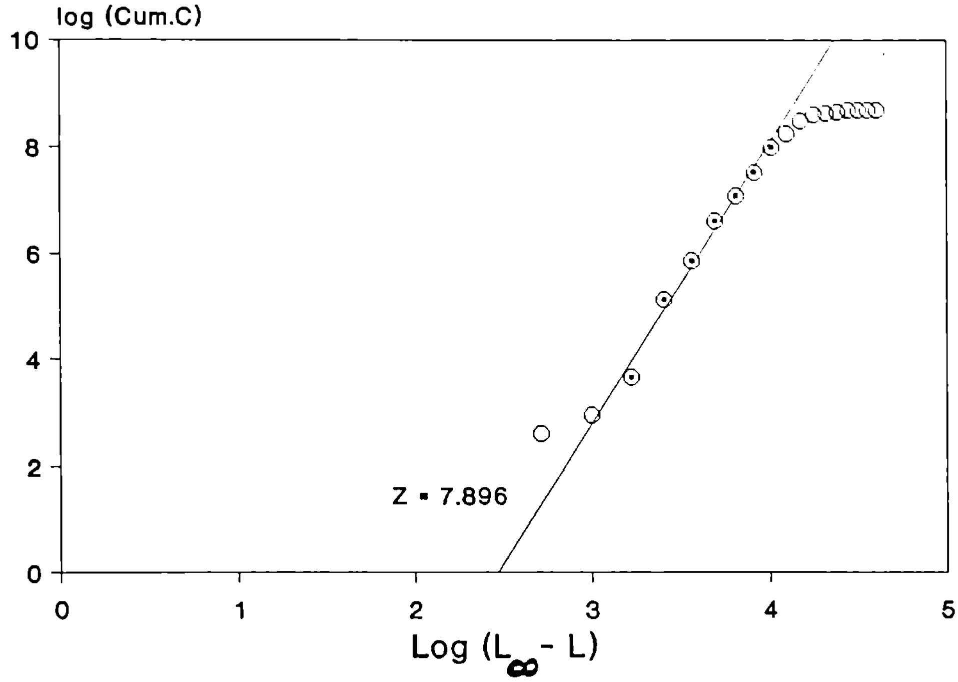
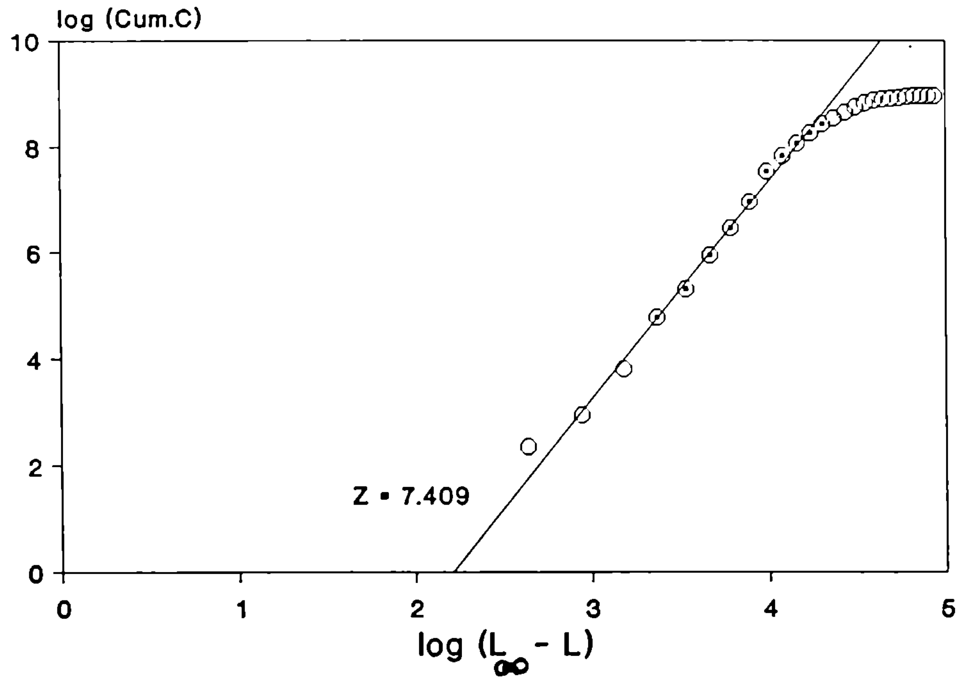


Figure. 7·6

Cumulative catch curve of
M.monoceros(Males) - 1993



Cumulative catch curve of
M.monoceros (Females) - 1993



$$Z = K \frac{L_{\infty} - \bar{L}}{\bar{L} - L'}$$

where $\bar{L}$ is the mean length of the prawn of L' and longer, while L' is " some length for which all prawns of that length and above are under full exploitation". L' is usually the lower limit of the corresponding length interval. K and L_{∞} are constants of the growth equations. In the present studies the L_{∞} and K respectively are 204 mm and 1.8 for females and 170 mm and 1.5 for males of *M. monoceros*. L' is taken as 71 mm for both sexes based on their size distribution in trawl catches at Cochin Fisheries Harbour during the entire study period.

The total mortality rates of the speckled shrimp estimated by Beverton and Holt method are as follows:

Years	Total mortality coefficient (Z) Females	Males
1991	6.070	7.290
1992	7.542	9.452
1993	5.724	6.865

7.3.1.4 The Wetherall, Polovina and Ralston method (1987)

Wetherall *et al* (1987) suggested special application of the Beverton and Holt equation by which L_{∞} and Z/K can be estimated. As L' can take any value equal to and above the smallest length under full exploitation, the said equation can give a series of estimates of Z, namely one for each choice of L'. This makes it possible to turn the Beverton and Holt equation based on length data into a regression analysis with L' as the independent variable. A series of algebric manipulations show that

$$\bar{L} - L' = a + b \times L'$$

Where $Z/K = -(1+b)/b$ and $L_\infty = -a/b$ OR

$$b = - K/(Z+K) \text{ and } a = -b \times L_\infty$$

Thus plotting $\bar{L} - L'$ against L' gives a linear regression from which 'a' and 'b' can be estimated and hence L_∞ and Z/K.

The total mortality rates estimated by this method for *M. monoceros* during 1991-93 period are as follows:

Years	Total Mortality coefficient (Z)	
	Females	Males
1991	5.517	6.348
1992	7.596	7.116
1993	5.588	8.415

The Beverton and Holt method and Wetherall *et al* method for estimation of 'Z' for *M. monoceros* in the present study were executed by the programme "BHZWET" in the LFSA package of microcomputer programmmes (Sparre, 1987).

The annual estimated Z for each sex was obtained by pooling the estimate of Z derived from the different methods cited above. Ideally, the pooled estimate could be obtained by taking into consideration the standard errors of the estimates derived from each method. Since the standard errors of some of the methods (e.g., Beverton and Holt method) could not be obtained, the pooled estimate was computed by a simple average of the respective estimates of Z. The average estimates of total mortality coefficients for *M. monoceros* in the present study are as follows:

Years	Average estimate of Z by different methods	
	Females	Males
1991	6.4085	6.7620
1992	8.3560	8.7373
1993	6.4200	7.7560
1991-1993	7.0615	7.7518

Thus, in the present study the annual average total mortality rate of *M. monoceros* was estimated to be 7.0615 for females and 7.7518 for males assessing steady state during 1991-1993.

7.3.2 Estimation of natural mortality coefficient

Natural mortality is the mortality created by all other causes other than fishing e.g. predation including cannibalism, diseases, spawning stress, starvation and old age. The same species may have different natural mortality rate in different areas depending on the density of predators and competitors, whose abundance is influenced by fishing activities. As direct measurement of M are often impossible to obtain, it has been attempted to identify quantities which can be assumed proportional to M and which are easier to measure. As a rough generalization, fish species with a high K value have a high M value. Beveraton and Holt (1959) found that values of the ratio, M/K mostly lie in the range of 1.5 to 2.5. Pauly's empirical formula (Pauly, 1980 a) was not used in the present study as it is based on data for fish stocks only, which predicts M from known growth parameters of a stock and its mean environmental temperature. It could not be used for crustaceans, molluscs or any other non fish animals as the formula does not cover these groups (Sparre *et al*, 1989).

The natural mortality coefficient of *M. monoceros* in the present work was estimated by using Rikhter and Efanov's formula. Holt (1962) noted that the ratio of Lm/L_{∞} (where Lm is the length at first spawning was about 0.66. Continuing these investigations in comparative dynamics for fish stocks, Rikhter and Efanov (1976) showed a close association between M and T_{m50}, the age when 50% of the population is mature.

$$M = 1.521/(T_{m50}^{0.720}) - 0.155 \text{ per year}$$

The age at which 50% of female *M. monoceros* mature was estimated as 0.5 years. Using this, natural mortality coefficient (M) was estimated as 2.35 based on the formula, and was assumed to be the same for both sexes. The natural mortality coefficient (2.35) estimated for *M. monoceros* was found to agree well with the observations of Beverton and Holt (1959).

7.3.3 Estimation of fishing mortality coefficient(F)

As the total mortality rate (Z) is the sum of natural mortality rate and fishing mortality rate, (Z = M + F), the fishing mortality coefficient (F) was estimated by the substraction of M from Z. The fishing mortality rates computed for different years are given below:

Years	Fishing mortality coefficient (F)	
	Females	Males
1991	4.0585	4.4120
1992	6.0060	6.3873
1993	4.0700	5.4060
Average (1991-93)	4.7115	5.4018

The mortality due to fishing activities (F) as estimated in the present work, 4.7115 for females and 5.4018 for males of *M. monoceros* during 1991-93) far exceeds the natural mortality (2.35) which indicates heavy exploitation of speckled shrimp resources along the Kerala coast.

7.3.4 Stock assessment

It is easier to identify a stock for a demersal species such as prawns than for highly migratory species such as tunas. Assessment of the stock of the any particular fishery resource throws more light on its maximum sustainable yield (MSY) which in turn helps to estimate the optimum level of effort.

7.3.4.1. Jones' length based cohort analysis (Jones, 1974; Jones and van Zalinge, 1981).

Several methods are brought under the cohort analysis which deal with a method of sequential computation of fishing mortality and of population size for which Ricker (1975) gives the background. Pope (1972) proposed a simplified cohort analysis method which was later on modified by Jones (1974) to enable direct applications to catch data by size classes (annual catch by size class). Jones and van Zalinge (1981) used this method to estimate population size of *P. semisulcatus* in the Kuwait waters. Population biomass can be obtained by simple multiplications of the average weight of the animals in the size group with the number of individuals in the size group. In this method an assumption is made that the picture presented by all size (or age) classes caught during one year reflects that of a cohort during its life span. This length based cohort analysis is written as:

$$N(L_1) = [N(L_2) \; X \; (L_1, L_2) + C(L_1 \; L_2)] \; X \; (L_1, L_2)$$

Where $N(L_1)$ = The number of fish that attains length L_1

$N(L_2)$ = The number of fish that attains length L_2

$C(L_1, L_2)$ = The number of fish caught of lengths between L_1 and L_2

$$X(L_1, L_2) = \left[\frac{L_\infty - L_1}{L_\infty - L_2}\right]^{M/2K}$$

The average length composition of *M. monoceros* for 1991-93 at 5 mm intervals were used for this studies. Stepwise computation details for the Jones "length cohort analysis" are shown in Tables. 7.13 for females and in Table 7.14 for males of the speckled shrimp. "L COHOR" programme in the LFSA package of microcomputer programme (Sparre, 1987) was used for this analysis. Based on this analysis, the standing stock of female *M. monoceros* was determined as 52t while in the case of males the standing stock was observed to be 27t (Tables 7.13 and 7.14). The average fishing mortality rate for females from L $\geqslant$ 125mm was estimated to be 4.0845; and for males from L $\geqslant$ 115 mm the average F was determined as 5.1554 which agrees well with the average F values estimated earlier in the present studies for the females (4.7115) and males (5.4018) respectively.

7.3.4.2. Length based Thomson and Bell analysis

Thomson and Bell model (1934) is an age-structured model for prediction of catch and stock size for a given fishing pattern. The "length based Thomson and Bell Model" used here (Sparre, 1985) is the "forwards" version of length based cohort analysis. It is used to predict catches and stock sizes under given assumptions on future exploitation levels and mesh sizes. The analysis takes the fishing mortalities by length group as input and calculates the numbers caught as well as the stock numbers. The natural mortality must be the same as for the cohort analysis which provides also an estimate of the numbers in the first length group.

In the Jones "length cohart analysis" equation, $C(L_1, L_2)$ is rewritten as $(F/Z)*(N(L_1) - N(L_2))$ and given as

$N(L_1) = (N(L_2)\ X\ (L_1, L_2) + (F/Z)(N(L_1)-N(L_2))x(L_1, L_2)$

Solving this equation with respect to $N(L_2)$ gives

$$N(L_2) = N(L_1)* \ (1/X\ (L_1, L_2) - F/Z)/(X(L_1, L_2)-F/Z)$$

in which

$$X(L_1, L_2) = [(L_\infty - L_1)/(L_\infty-L_2)]^{M/2K} \quad \text{as before.}$$

* = multiplication sign.

In its simplest form, the length converted Thomson and Bell analysis used the F-array estimated in cohort analysis as the reference F - array and assesses the effect of raising (reducing) all F's by a certain factor. In general case where all F-values are raised (or reduced) by the factor XX the general step becomes:

$$N(l_{i+1}) = N(l_i) * (1/X\ (L_i, L_{i+1})-E(L_i,L_{i+1}) \ / \ (X(L_i,L_{i+1}) - E(L_i, L_{i+1}))$$

where

$E(L_i, L_{i+1}) = XX * F(L_i, L_{i+1}) / Z(L_i, L_{i+1})$

$Z(L_i, L_{i+1}) = XX * F(L_i, L_{i+1}) + M$

$C(L_i, L_{i+1}) = XX * F(L_i, L_{i+1}) * (N(L_i) - N(L_{i+1}))/Z(L_i, L_{i+1})$

The yield (catch in weight) in length group i is:

$YIELD(L_i, L_{i+1}) = C(L_i+L_{i+1}) * W(L_i, L_{i+1})$ where $W(L_i, L_{i+1})$ is the mean weight of fish of lengths between L_i and L_{i+1}. It may be calculated from;

$W(L_i, L_{i+1}) = a * (L_i{}^b + L_{i+1}{}^b)/2$

where 'a' and 'b' are the parameters in the length - weight relationship.

The mean number of survivors in length group i is:

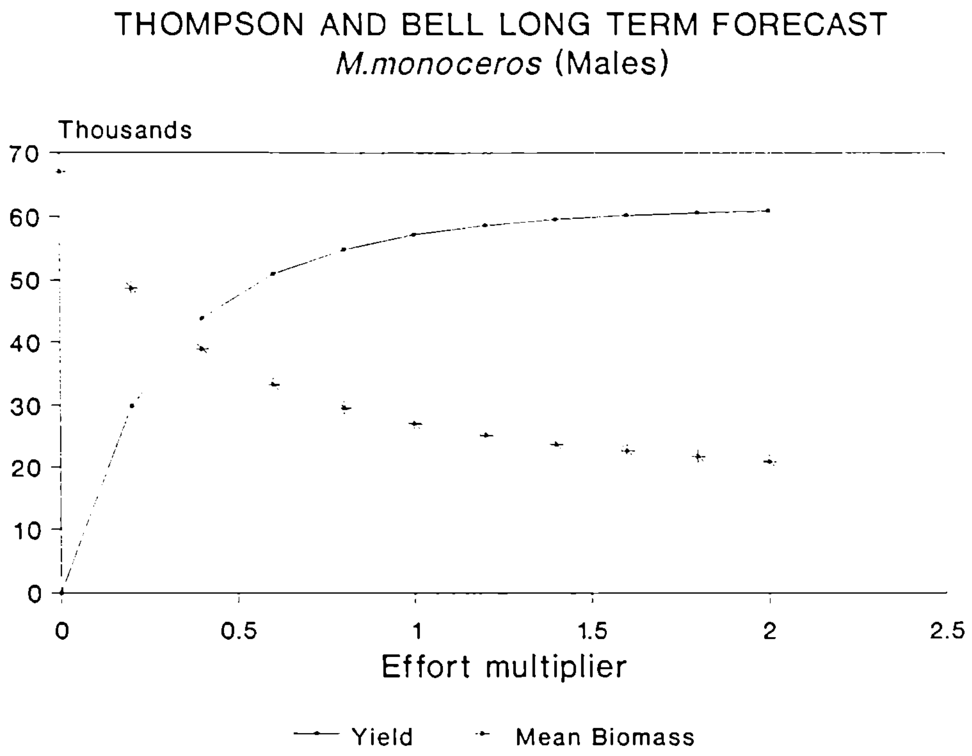
$NMEAN(L_i, L_{i+1}) = (N(L_i) - N(L_{i+1})/Z(L_I, L_{i+1})$ and the corresponding mean biomass is

$BIOM(L_i, L_{i+1}) = NMEAN(L_i, L_{i+1} * W(L_i, L_{i+1})$

The prediction made by the length converted Thomson and Bell analysis is a prediction of the average long term catches, assuming recruitment to remain constant.

The input from the length cohort analysis was used for the length based Thomson and Bell analysis in the present studies. "MIXFISH" programme of the LFSA package (Sparre, 1987) was used for yield analysis of *M. monoceros* (sexes combined). The summary results for 11 different F-factors based on this analysis are shown in Tables - 7.15, 7.16 and 7.17 respectively for females, males and for both sexes combined. The estimations of yield and biomass of *M. monoceros* are shown in Figure 7.7 for females and males separately and in Figure 7.8 for both sexes combined. The maximum sustainable yields (MSY) of *M. monoceros*, estimated by the length based Thomson and Bell analysis were 136.7 t for females, 61.6t for males and 196.7 t for total *M. monoceros* (sexes combined). Although the MSYs are not additive as a first approximate the term of the MSYs of males and females is taken as the estimate MSY of the speckled shrimp stock from this area. Results of the analysis indicated that to increase the yield of female speckled shrimp from the present 135.2t to MSY level the increase in effort required is 41.25%. The additional catch amounts to only 1.5 t (i.e., 1.1% increase). In the same manner, for males, the effort has to be increased 400% to get a further yield of 4.5 t (to reach MSY level) which is only 7.9% increase in the catch. The "MIXFISH" analysis showed that the present effort has to be enhanced by 60% to get an additional yield of 2.3% (4.4 t) of *M. monoceros*. Thus the yield model showed some scope for increasing the fishing effort to obtain maximum sustainable yield. However, it was observed that the average annual catch of *M. monoceros* (both sexes combined) amounted to 192.3 t which was very close to MSY (196.7t). Thus, it appears there does not exist any scope for increasing the fishing effort to result in higher yield, as the analysis

Figure. 7·7


THOMPSON AND BELL LONG TERM FORECAST
M.monoceros (Males)
Thousands
70
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
Effort multiplier
Yield
Mean Biomass

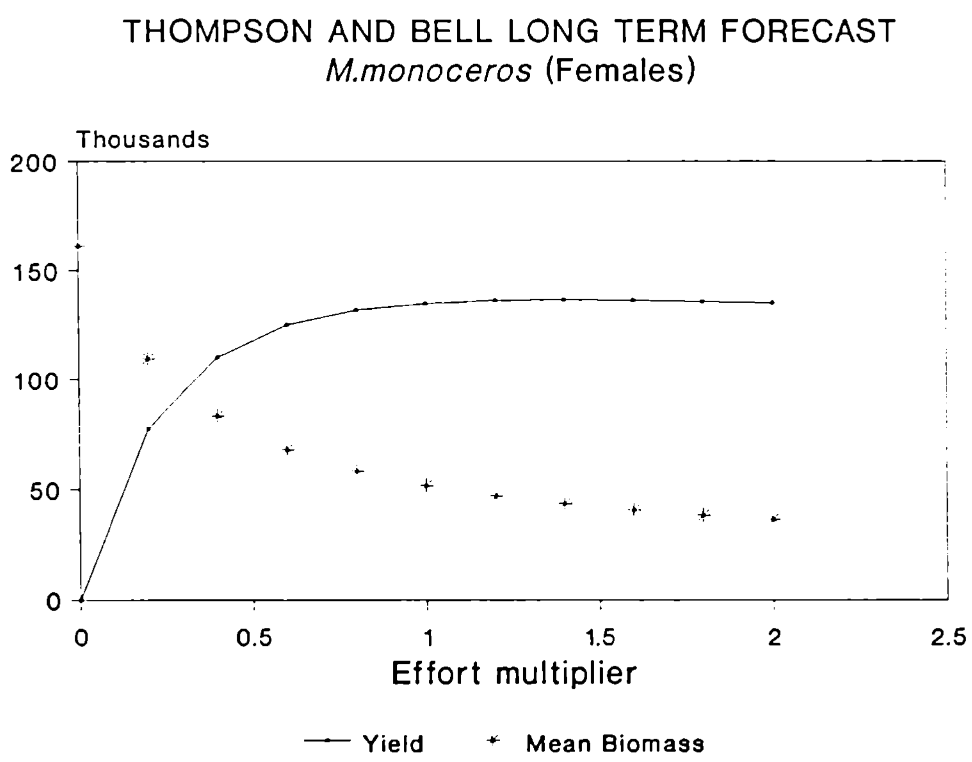
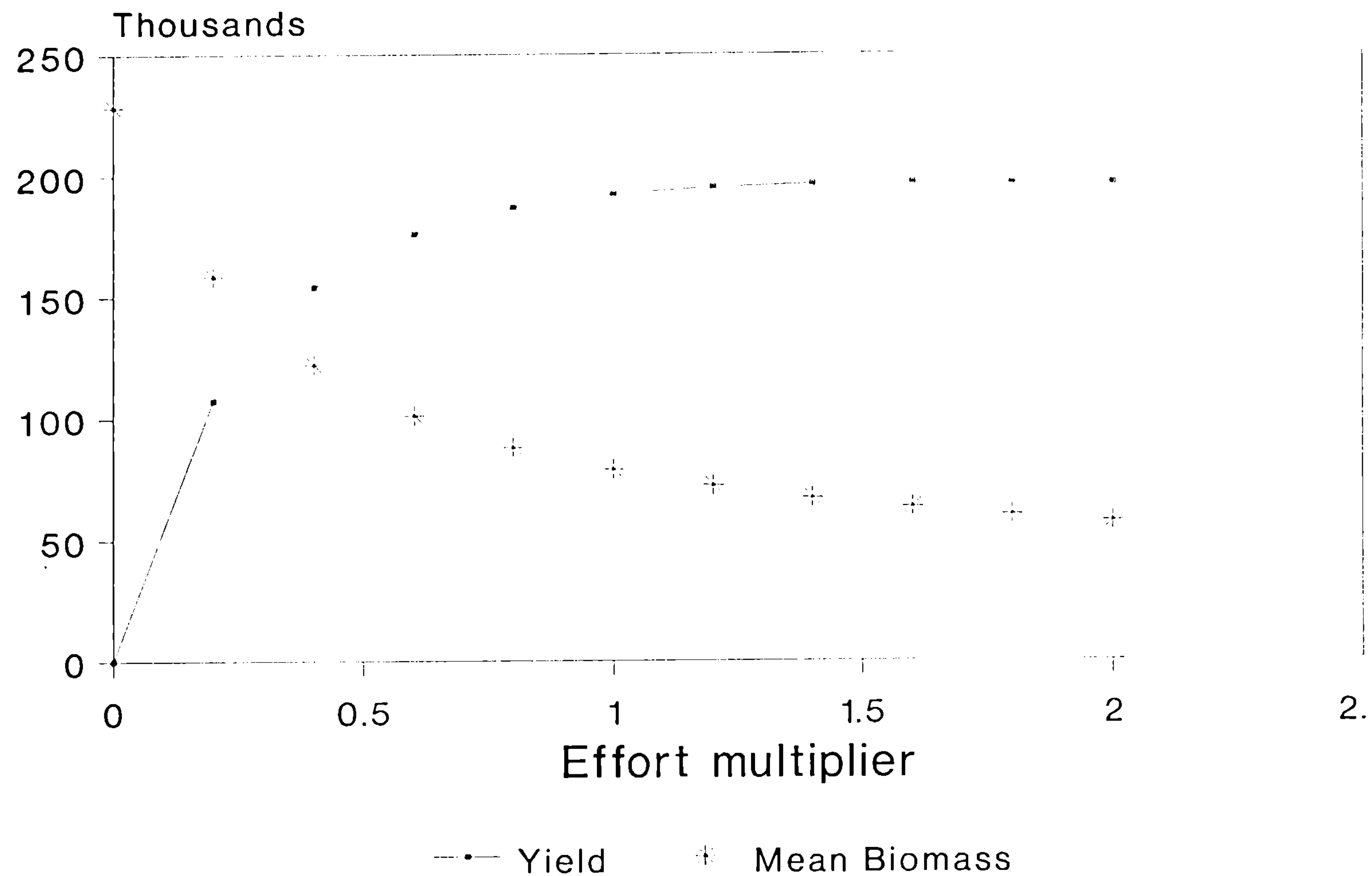

THOMPSON AND BELL LONG TERM FORECAST
M.monoceros (Females)
Thousands
200
150
100
50
0
0
0.5
1
1.5
2
2.5
Effort multiplier
Yield
Mean Biomass

Figure. 7·8
THOMPSON AND BELL LONG TERM FORECAST
M.monoceros (Mixfish analysis)



suggests that the fishery is already operating almost near the biologically optimal level.

7.3.4.3. **Yield-per-recruit model** (Beverton and Holt, 1957)

Once reasonable estimates of growth and natural mortality are attained, then the task of calculating the yield from a given recruiting year-class is straight forward, requiring no further assumption. Calculation of yield from a given recruitment usually expressed as yield-per-recruit is a basic element in the assessment of any fish stock for which the data allow the calculations to be made. The yield-per-recruitment model (Beverton and Holt, 1957) is in principle a steady state model, i.e. a model describing the state of the stock and the yield in a situation when the fishing pattern has been the same for such a long time, that all fish alive have been exposed to it since they recruited. There are some rigorous assumptions underlying the Beverton and Holt approach. They are as follows:

1. Recruitment is constant yet not specified
2. All fish of a cohort are hatched on the same date.
3. Recruitment and selection are 'knife-edge'.
4. The instantaneous rates of fishing and natural mortality are constant from the entry to the exploited phase.
5. There is a complete mixing within the stock.

Beverton and Holt express yield as "per recruit basic" i.e., relative to the recruitment. Following is the "Beverton and Holt yield per recruitment model" (1957) written in the form suggested by Gulland (1969).

$$Y/R = F \exp[-M(T_c-T_r)]W_\infty \left[\frac{1}{Z} - \frac{3S}{Z+K} + \frac{3S^2}{Z+2K} - \frac{S^3}{Z+3K}\right]$$

where: $S = \exp[-K(T_c - t_o)]$; K = curvature parameter; t_o = point in time when length is zero, T_c = age at first capture; T_r = age at recruitment; W_∞ = asymptotic body weight; F = fishing mortality; M = natural mortality and Z = F+M, total mortality. The two parameter F and T_c are those which can be controlled by fishery managers, because, 1) F is proportional to effort and 2) T_c is a function of gear selectivity. Therefore Y/R is considered a function of F and T_c and usually Y/R are plotted against F. A detailed explanation and methodology of the model is given by Sparre *et al* (1989).

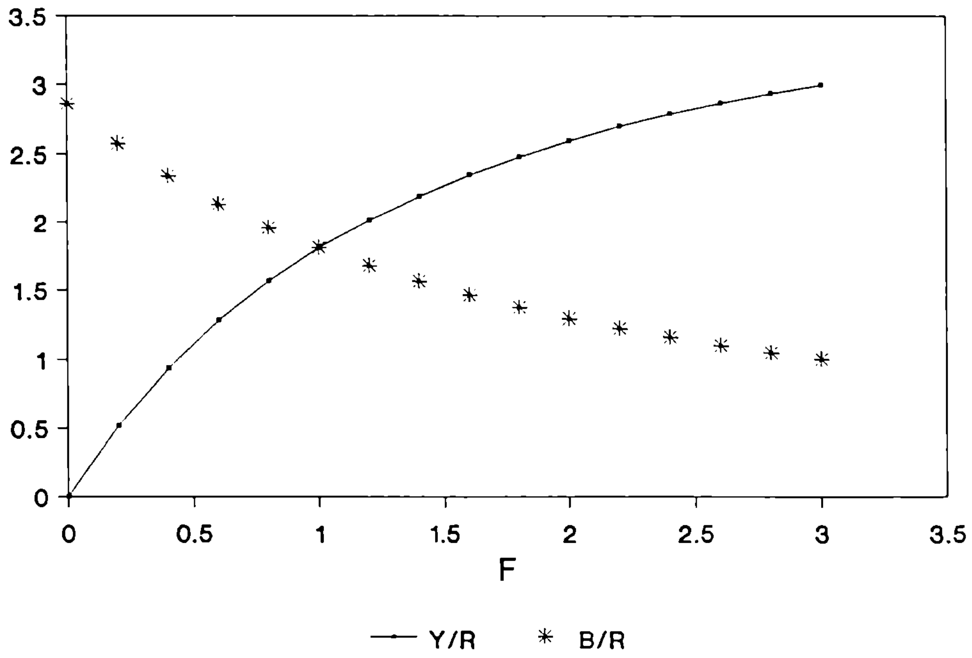
By finding the Y/R at different F a graphical representation can be made where, the most suitable 'F' which gives the maximum value of Y\R, "the Maximum Sustainable Yield per Recruit" (MSY/R). The details on the different Y/R values obtained against respective F for females and males of *M. monoceros* in the present studies are given in Table 7.18 and 7.19

respectively. The Y/R curves are shown in Figure 7.9 separately for females and males. It is seen that the MSY/R can be obtained, only by increasing the F from the present level of 4.7115 for females and 5.4018 for males, atleast, by 3 or 4 times of the present level of exploitation. The increase of F in females by 100% (2.0 in the Table 7.18) will increase the Y/R by 40 % only i.e. from 4.47 to 6.25. The same trend was noticed in the case of males of *M. monoceros* where the two fold increase of F (in turn the effort) will enhance the Y/R by 43.35% only (from the present Y/R of 1.806 to 2.589). Thus it was observed that there shall not be any significant improvement in the yield with the increase in fishing mortality (increase in effort).

The yield isopleth plots for females and males of *M. monoceros* are shown in Figures 7.10 and 7.11 respectively. When lines of equal yields are drawn these are termed yield isopleths. These lines are used to find the combination of fishing effort and age at which the cohort becomes vulnerable to fishing (age at first capture) that gives *equal yield levels*. Age at first capture is a management option achieved by regulating mesh size of nets or retention size. The parameters on F, T_c and Y/R(gm) are given as yield per recruit (three dimensional) pictures for females and males of *M. monoceros* in figures 7.12 and 7.13. It is observed that the increase in the current level of age at first capture (0.53 year for females and 0.75 year for males) as well as the enhancement of present F will not effect any

Figure . 7·9

BEVERTON AND HOLT YIELD PER RECRUIT
M.monoceros (Males)



BEVERTON AND HOLT YIELD PER RECRUIT
M.monoceros (Females)

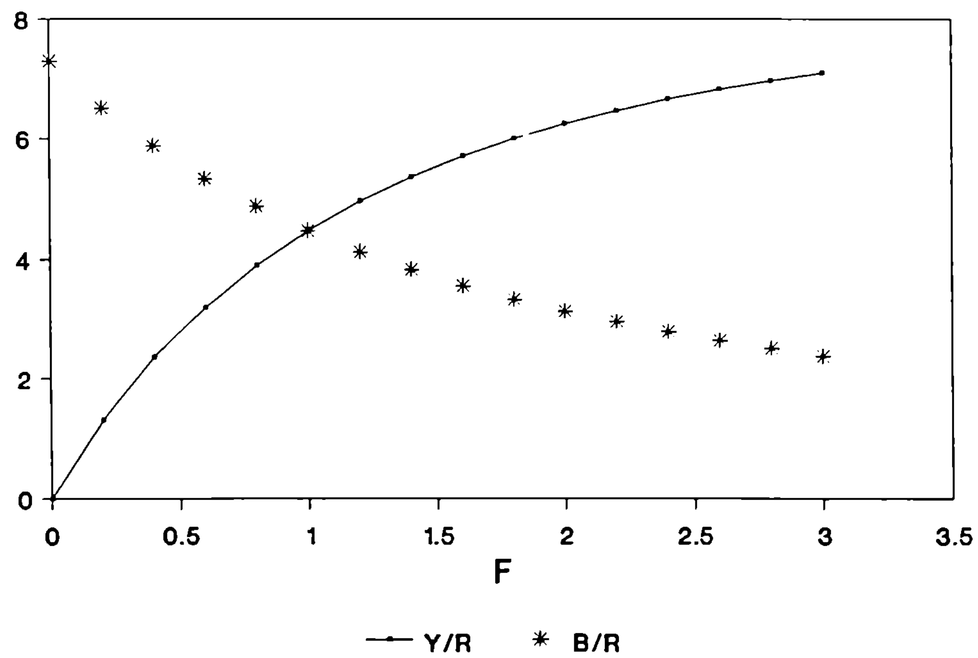


Figure. 7·10
Yield Isopleths
M. monoceros (Females)

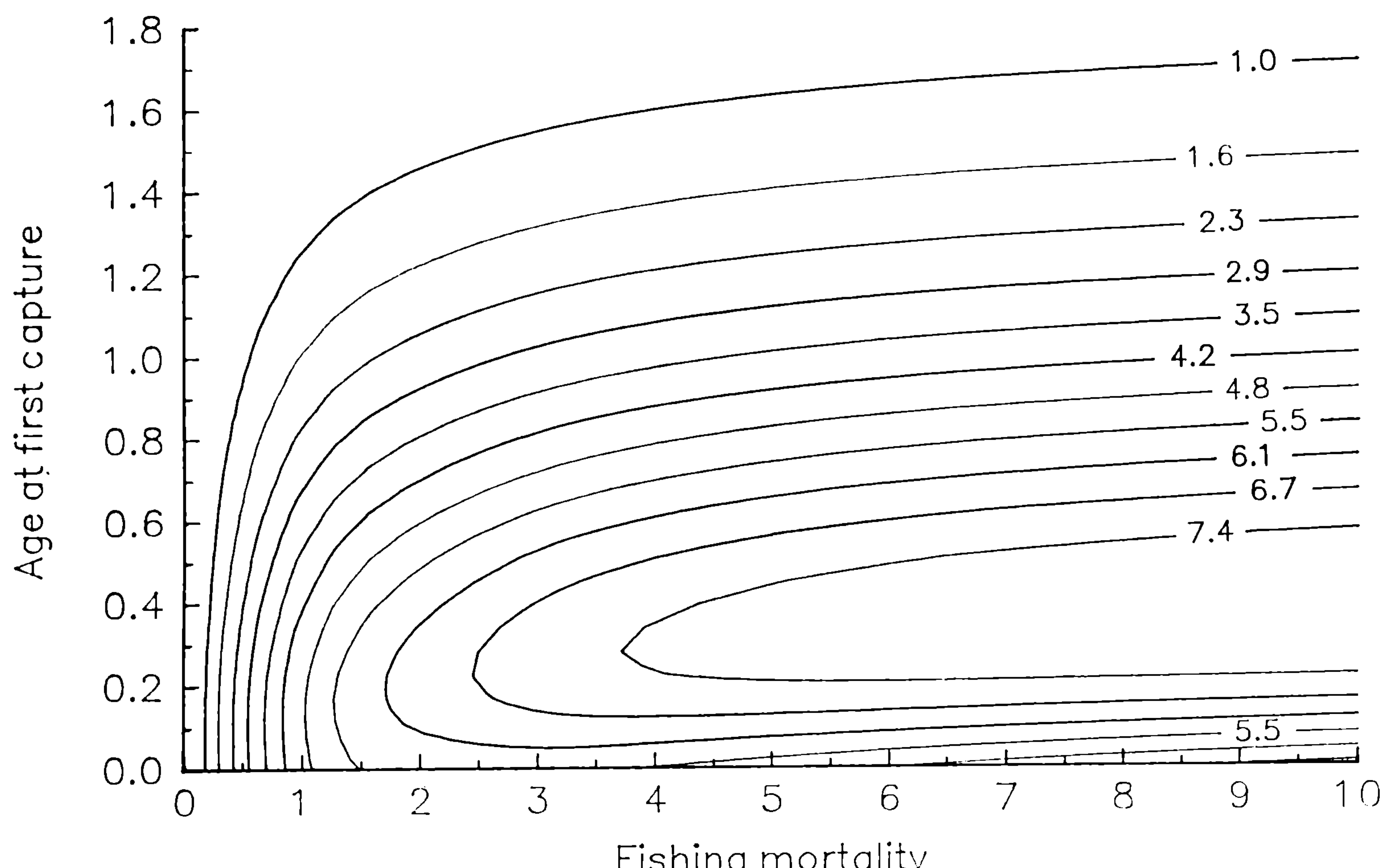


Figure . 7·11

Yield Isopleths

M. monoceros (Males)

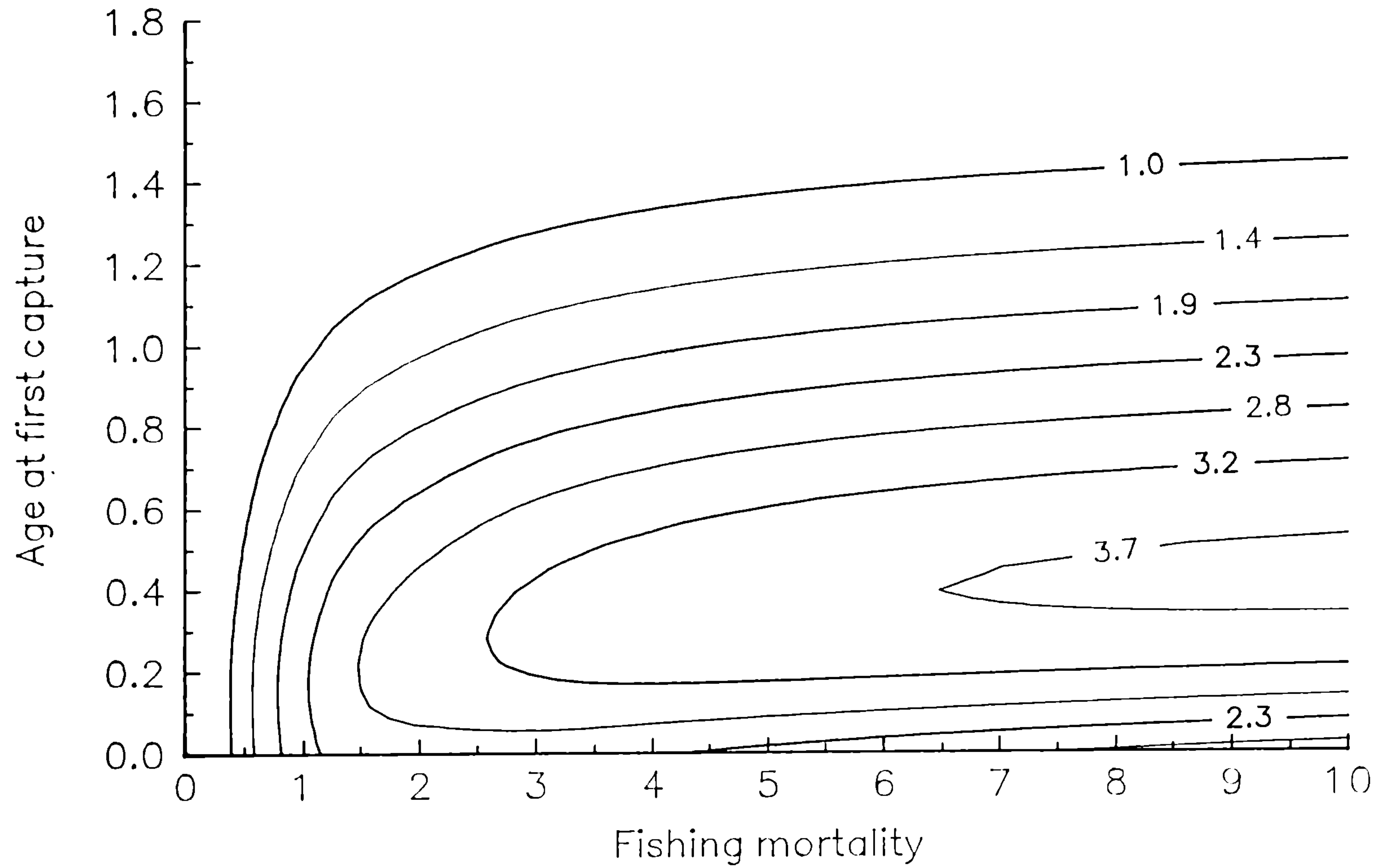


Figure . 7·12

Yield per recruit – _M._ _monoceros_ (Females)

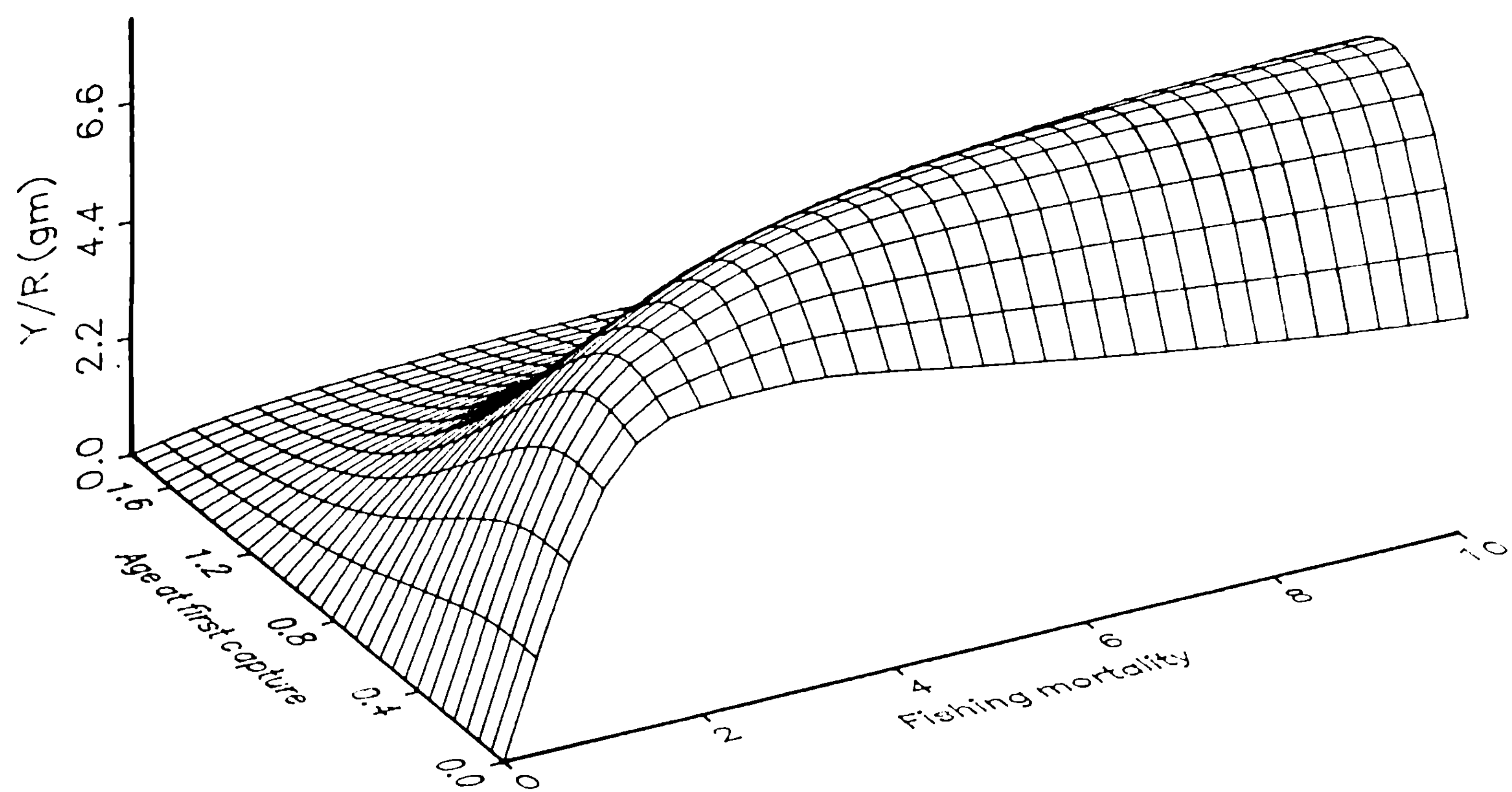
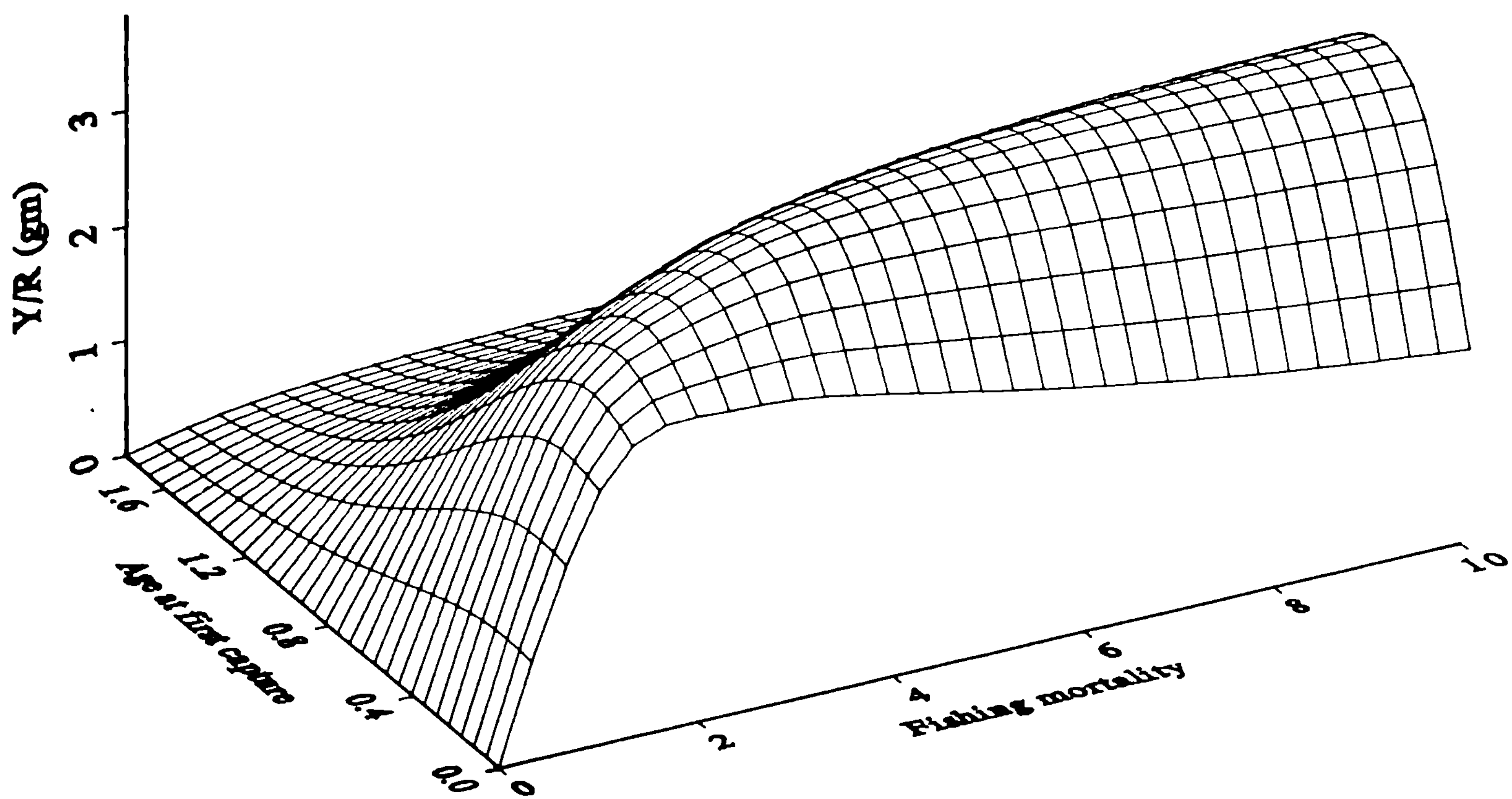


Figure. 7·13

Yield per recruit - M. monoceros (Males)



significant improvement in the yield of *M. monoceros* along the Kerala coast. Thus the yield-per-recruitment analysis has indicated that the present pattern of exploitation of the speckled shrimp resources from Kerala waters seems to be nearer to optimum yield.

7.3.4.4. Baranov's Catch equation

The general principle of the method is that the population size depends on the birth and death in a population and if all other factors are assumed constant, fishing mortality determines the size of population. Based on Baranov's catch equation (1918), Widrig (1954) proposed a method to calculate population size. The exploitation rate, 'U' gives the magnitude of the stock, provided the annual catch removed from the stock is known. The exponential rate 'U' can be obtained by the relationship.

$$U = F/Z\ (1 - e^{-Z})$$

Where, F and Z are instantaneous rates of fishing and total mortality. The average annual standing stock (AASS) and the average standing stock (ASS) can be obtained by the formula,

$$AASS = C/U \text{ and } ASS = C/F$$

Where C is the average annual catch. The details on the estimates of AASS and ASS are given in Table 7.20 for females and males of *M. monoceros* for the period 1991-93. Based on the estimates on yield, Z, M and F, the exploitation rate U for females and males of *M. monoceros* were estimated as 0.67 and 0.70 for 1991-93 duration. From the values Y, F and U, the average annual standing stock and the average standing stock were estimated as 202.51 t and 28.65 t for females; and 81.83 t and 10.55 t for males of *M. monoceros* respectively.

7.4. DISCUSSION

In the present study, analytical models which are "age structured models" working with concepts such as mortality rates and individual growth rates have been used to get reliable assessment of *M. monoceros* stocks. Average Z values of speckled shrimp in the present work was estimated to be 7.06 and 7.75 for females and males respectively. The total mortality rate of male was found to be more than females for the brown shrimp which agrees well with the earlier observations made on different penaeid species (Berry, 1970, Kurup and Rao, 1974 ; Ramamurthy ***et al*** ., 1975; Ramamurthy ,1980; Pauly ***et al.***, 1984 ; Lalitha Devi, 1987; Suseelan and Rajan , 1989; George ***et al.***, 1988; Sukumaran ***et al.***, 1993 and Rao ,1994). Sukumaram ***et al.***,

(1993) recorded the average Z values for females and males of *M. monoceros* as 5.10 and 6.10. Lalitha Devi (1987) estimated Z value of 5.49 for females and 7.98 for males of *M. monoceros* from Kakinada coast. However, Rao (1994) observed lower estimates of Z for this species from the same coast (3.664 for females and 4.364 for males). The lowest total mortality rate of *M. monoceros* was recorded from Karwar by George *et al.*, (1988) (1.06 and 3.16 for females and males respectively).

The natural mortality rate (M) for both sexes was estimated as 2.35 which agrees with observation of Rao (1994) for the same species (2.32 for females and 2.42 for males). The estimated fishing mortality rate (F) was 5.40 for males and 4.71 for females of brown shrimp. The higher F value for male *M. monoceros* may probably due to differential growth in sexes and sex-wise segregation etc.

The standing stock of *M. monoceros* was estimated as 52 t and 27 t for females and males respectively. The maximum sustainable yield (MSY) for the speckled shrimp was estimated to be 196.7 t. The present effort has to be enhanced by 60.0% to get the MSY which actually is an additional yield of mere, 2.3%. The estimated average exploitation rate was 0.67 and 0.70 for females and males respectively. The average annual yield of 192.3 t of *M. monoceros* being harvested at present is very close to the MSY estimated in the present studies. The Yield-per-recruit analysis further confirm that there may not be any significant improvement in the yield with increase in fishing effort as well as in the level of age at first capture. Hence, the present level of exploitation appears to be biologically optimal.

Table 7.1Details on construction of catch-curve from length distribution of *M.monoceros* (Females) for the year 1991

Lower limit (mm)	C	dt	t	log(C/dt)	
65	3.93	0.0203	0.2232	5.2634	
70	15.90	0.0211	0.2439	6.6240	
75	14.51	0.0219	0.2654	6.4937	
80	16.41	0.0228	0.2879	6.5762	
85	35.29	0.0238	0.3112	7.2996	
90	42.52	0.0249	0.3356	7.4422	
95	143.15	0.0260	0.3611	8.6102	
100	205.28	0.0273	0.3878	8.9225	
105	292.97	0.0288	0.4158	9.2277	
110	444.92	0.0303	0.4454	9.5923	
115	674.87	0.0321	0.4766	9.9527	
120	776.45	0.0341	0.5097	10.0333	
125	877.03	0.0363	0.5449	10.0918	
130	808.30	0.0388	0.5824	9.9425	
135	695.46	0.0418	0.6227	9.7196	S
140	589.74	0.0452	0.6661	9.4765	E
145	498.21	0.0492	0.7132	9.2229	L
150	487.46	0.0539	0.7647	9.1083	E
155	345.61	0.0598	0.8214	8.6621	C
160	190.07	0.0670	0.8846	7.9502	T
165	144.55	0.0762	0.9560	7.5477	E
170	137.74	0.0883	1.0378	7.3516	D
175	50.29	0.1051	1.1338	6.1703	
180	25.37	0.1297	1.2500	5.2754	
185	9.38	0.1696	1.3970	4.0131	
190	3.41	0.2454	1.5976	2.6330	

Table 7.2 Details on construction of catch-curve from length distribution of *M.monoceros* (Females) for the year 1992

Lower limit (mm)	C	dt	t	log(C/dt)	
65	0.00	0.0203	0.2232	0.0000	
70	0.00	0.0211	0.2439	0.0000	
75	4.32	0.0219	0.2654	5.2819	
80	8.42	0.0228	0.2879	5.9087	
85	28.15	0.0238	0.3112	7.0736	
90	21.31	0.0249	0.3356	6.7517	
95	82.95	0.0260	0.3611	8.0645	
100	185.38	0.0273	0.3878	8.8206	
105	343.64	0.0288	0.4158	9.3872	
110	461.83	0.0303	0.4454	9.6296	
115	531.10	0.0321	0.4766	9.7244	
120	583.15	0.0341	0.5097	9.7470	
125	921.00	0.0363	0.5449	10.1407	
130	657.99	0.0388	0.5824	9.7368	S
135	519.33	0.0418	0.6227	9.4276	E
140	448.73	0.0452	0.6661	9.2032	L
145	431.76	0.0492	0.7132	9.0798	E
150	396.68	0.0539	0.7647	8.9022	C
155	183.77	0.0598	0.8214	8.0305	T
160	127.17	0.0670	0.8846	7.5484	E
165	45.07	0.0762	0.9560	6.3823	D
170	23.52	0.0883	1.0378	5.5842	
175	7.33	0.1051	1.1338	4.2445	
180	21.44	0.1297	1.2500	5.1073	

Table 7.3Details on construction of catch-curve from length distribution of *M.monoceros* (Females) for the year 1993

Lower limit (mm)	C	dt	t	log(C/dt)	
65	0.00	0.0203	0.2232	0.0000	
70	0.00	0.0211	0.2439	0.0000	
75	39.96	0.0219	0.2654	7.5064	
80	83.77	0.0228	0.2879	8.2061	
85	128.08	0.0238	0.3112	8.5888	
90	105.44	0.0249	0.3356	8.3505	
95	126.98	0.0260	0.3611	8.4903	
100	169.77	0.0273	0.3878	8.7326	
105	333.57	0.0288	0.4158	9.3575	
110	481.53	0.0303	0.4454	9.6714	
115	565.65	0.0321	0.4766	9.7762	
120	586.00	0.0341	0.5097	9.7531	
125	571.83	0.0363	0.5449	9.6641	
130	717.77	0.0388	0.5824	9.8238	S
135	655.89	0.0418	0.6227	9.6610	E
140	673.96	0.0452	0.6661	9.6100	L
145	637.90	0.0492	0.7132	6.4700	E
150	837.40	0.0539	0.7647	9.6494	C
155	403.17	0.0598	0.8214	8.8162	T
160	259.37	0.0670	0.8846	8.2611	E
165	175.78	0.0762	0.9560	7.7433	D
170	81.86	0.0883	1.0378	6.8313	
175	74.16	0.1051	1.1338	6.5588	
180	26.03	0.1297	1.2500	5.3013	
185	8.61	0.1696	1.3970	3.9269	
190	10.43	0.2454	1.5976	3.7499	

Table 7.4 Details on construction of catch-curve from length distribution of *M. monoceros* (Males) for the year 1991

Lower limit (mm)	C	dt	t	log(C/dt)	
70	3.97	0.0342	0.3706	4.7554	
75	23.89	0.0360	0.4057	6.4966	
80	33.05	0.0381	0.4427	6.7655	
85	65.68	0.0404	0.4820	7.3933	
90	120.88	0.0430	0.5236	7.9407	
95	234.40	0.0460	0.5681	8.5362	
100	472.16	0.0494	0.6157	9.1650	
105	975.58	0.0533	0.6670	9.8137	
110	892.31	0.0580	0.7226	9.6410	
115	1122.60	0.0635	0.7833	9.7795	S
120	703.17	0.0702	0.8500	9.2114	E
125	406.57	0.0785	0.9242	8.5521	L
130	333.76	0.0890	1.0076	8.2293	E
135	123.15	0.1027	1.1030	7.0887	C
140	77.11	0.1215	1.2144	6.4526	T
145	74.58	0.1487	1.3481	6.2173	E
150	12.26	0.1917	1.5157	4.1578	D

Table 7.5 Details on construction of catch-curve from length distribution of *M. monoceros* (Males) for the year 1992

Lower limit (mm)	C	dt	t	log(C/dt)
70	0.00	0.0342	0.3706	0.0000
75	0.00	0.0360	0.4057	0.0000
80	11.46	0.0381	0.4427	5.7070
85	21.90	0.0404	0.4820	6.2950
90	102.32	0.0430	0.5236	7.7740
95	192.20	0.0460	0.5681	8.3377
100	637.30	0.0494	0.6157	9.4649
105	780.19	0.0533	0.6670	9.5902
110	845.08	0.0580	0.7226	9.5866
115	892.73	0.0635	0.7833	9.5503
120	487.31	0.0702	0.8500	8.8447
125	320.80	0.0785	0.9242	8.3152 *
130	112.63	0.0890	1.0076	7.1430
135	59.86	0.1027	1.1030	6.3673
140	42.20	0.1215	1.2144	5.8500
145	2.12	0.1487	1.3481	2.6568

* SELECTED

Table 7.6 Details on construction of catch-curve from length distribution of _M.monoceros_ (Males) for the year 1993

Lower limit (mm)	C	dt	t	log(C/dt)
70	0.00	0.0342	0.3706	0.0000
75	0.00	0.0360	0.4057	0.0000
80	0.00	0.0381	0.4427	0.0000
85	172.58	0.0404	0.4820	8.3594
90	145.16	0.0430	0.5236	8.1238
95	168.39	0.0460	0.5681	8.2055
100	598.86	0.0494	0.6157	9.4027
105	1024.35	0.0533	0.6670	9.8624
110	836.16	0.0580	0.7226	9.5760
115	1096.69	0.6350	0.7833	9.7561
120	641.31	0.0702	0.8500	9.1193
125	425.31	0.0785	0.9242	8.5972
130	382.91	0.0890	1.0076	8.3667 *
135	180.27	0.1027	1.1030	7.4698
140	126.22	0.1215	1.2144	6.9455
145	19.77	0.1487	1.3481	4.8898
150	5.36	0.1917	1.5157	3.3308
155	13.52	0.2703	1.7400	3.9127

* SELECTED

Table 7.7 Details showing the construction of cumulative catch-curve from length distribution of M.monoceros (Female) for the year 1991

Lower limit (mm)	C	Cum.C	log(LG-L)	log(Cum.C)	Z	Conf.	Interval	
65	3.93	7528.90	4.9344	8.9265				
70	15.90	7524.97	4.8978	8.9259				
75	14.51	7509.07	4.8598	8.9238				
80	16.41	7494.55	4.8202	8.9219				
85	35.29	7478.14	4.7791	8.9197				
90	42.52	7442.85	4.7362	8.9150				
95	143.15	7400.33	4.6913	8.9092				
100	205.28	7257.17	4.6444	8.8897				
105	292.97	7051.89	4.5951	8.8610				
110	444.92	6758.92	4.5433	8.8186				
115	674.87	6313.99	4.4886	8.7505				
120	776.45	5639.12	4.4308	8.6374				
125	877.03	4862.66	4.3694	8.4893	7.279	6.872	7.686	S
130	808.30	3985.63	4.3040	8.2904	7.398	6.910	7.885	E
135	695.46	3177.33	4.2341	8.0638	7.521	7.077	7.965	L
140	589.74	2481.87	4.1588	7.8167	7.654	7.177	8.130	E
145	498.21	1892.13	4.0775	7.5454	7.790	7.257	8.323	C
150	487.46	1393.91	3.9889	7.2398	7.941	7.261	8.567	T
155	345.61	906.45	3.8918	6.8095	7.991	7.069	8.914	E
160	190.07	560.84	3.7841	6.3294	8.171	7.761	9.581	D
165	144.55	370.76	3.6635	5.9155	8.659	6.558	10.759	
170	137.74	226.21	3.5263	5.4214				
175	50.29	88.46	3.3673	4.4825				
180	25.37	38.17	3.1780	3.6420				
185	9.38	12.80	2.9444	2.5495				
190	3.41	3.41	2.6390	1.2284				

Table 7.8 Details showing the construction of cumulative catch-curve from length distribution of M.monoceros (Female) for the year 1992

Lower limit (mm)	C	Cum.C	log(L8-L)	log(Cum.C)	Z	Conf.	Interval	
65	0.00	6040.11	4.9344	8.7061				
70	0.00	6040.11	4.8978	8.7061				
75	4.32	6040.11	4.8598	8.7061				
80	8.42	6035.79	4.8202	8.7054				
85	28.15	6027.37	4.7791	8.7040				
90	21.31	5999.21	4.7362	8.6993				
95	82.95	5977.90	4.6913	8.6958				
100	185.38	5894.94	4.6444	8.6818				
105	343.64	5709.56	4.5951	8.6499				
110	461.83	5365.91	4.5433	8.5878				
115	537.10	4904.08	4.4886	8.4978				
120	583.15	4366.98	4.4308	8.3818				
125	921.00	3783.82	4.3694	8.2385	9.364	8.565	10.162	S
130	657.00	2862.82	4.3040	7.9595	9.620	7.767	10.473	E
135	519.33	2204.83	4.2341	7.6984	9.955	9.102	10.807	L
140	448.73	1685.49	4.1588	7.4298	10.326	9.518	11.133	E
145	431.76	1236.76	4.0775	7.1202	10.647	7.778	11.517	t
150	396.68	804.99	3.9889	6.6908	10.728	9.303	12.154	T
155	183.77	408.31	3.8918	6.0120	10.326	7.747	12.905	E
160	127.17	224.54	3.7841	5.4140				D
165	45.07	97.37	3.6635	4.5785				
170	23.52	52.29	3.5263	3.9569				
175	7.33	28.77	3.3673	3.3594				
180	21.44	21.44	3.1780	3.0654				

Table 7.9 Details showing the construction of cumulative catch-curve from length distribution of M.monoceros (Female) for the year 1993

Lower limit (mm)	C	Cum.C	log(L8-L)	log(Cum.C)	Z	Conf.	Interval	
65	0.00	7755.71	4.9344	8.9561				
70	0.00	7755.71	4.8978	8.9561				
75	39.96	7755.71	4.8598	8.9561				
80	83.77	7715.75	4.8202	8.9510				
85	128.08	7631.98	4.7791	8.9401				
90	105.44	7503.89	4.7362	8.9231				
95	126.98	7398.45	4.6913	8.9090				
100	169.77	7271.47	4.6444	8.8917				
105	333.57	7101.70	4.5951	8.8681				
110	481.53	6768.13	4.5433	8.8199				
115	565.65	6286.59	4.4886	8.7461				
120	586.70	5720.93	4.4308	8.6518				
125	571.83	5134.22	4.3694	8.5436				
130	717.77	4562.39	4.3040	8.4256	4.409	6.844	7.974	S
135	655.89	3844.61	4.2341	8.2544	4.634	7.095	8.173	E
140	673.96	3188.71	4.1588	8.0673	4.843	7.308	8.377	L
145	637.90	2514.75	4.0775	7.8299	7.975	7.321	8.629	E
150	837.40	1876.85	3.9889	7.5373	7.945	6.997	8.892	C
155	403.17	1039.44	3.8918	6.9464	7.519	6.641	8.397	T
160	259.37	636.27	3.7841	6.4556	7.300	5.643	8.956	E
165	175.78	376.90	3.6635	5.9319				D
170	81.86	201.11	3.5263	5.3038				
175	74.16	119.25	3.3673	4.7812				
180	26.03	45.08	3.178	3.8085				
185	8.61	19.04	2.9444	2.9469				
190	10.43	10.43	2.639	2.3453				

Table 7.10 Details showing the construction of cumulative catch-curve from length distribution of M.monoceros (Male) for the year 1991

Lower limit (mm)	C	Cum.C	log(L8-L)	log(Cum.C)	Z	Conf.	Interval	
70	3.97	5675.17	4.6051	8.6438				
75	23.89	5671.20	4.5538	8.6431				
80	33.05	5647.30	4.4998	8.6389				
85	65.68	5614.25	4.4426	8.6330				
90	120.88	5548.57	4.3820	8.6213				
95	234.40	5427.69	4.3174	8.5992				
100	472.16	5193.28	4.2485	8.5551				
105	975.58	4721.12	4.1743	8.4598				
110	892.31	3745.53	4.0943	8.2283				
115	1122.60	2853.22	4.0073	7.9562	6.736	6.117	7.355	
120	703.17	1730.61	3.9120	7.4562	6.568	5.780	7.356	
125	406.57	1027.44	3.8066	6.9348	6.384	5.217	7.551	*
130	333.76	620.87	3.6886	6.4311	6.147	3.836	8.458	
135	123.15	287.11	3.5553	5.6598				
140	77.11	163.95	3.4012	5.0996				
145	74.58	86.84	3.2188	4.4641				
150	12.26	12.26	2.9957	2.5065				

* SELECTED

Table 7.11 Details showing the construction of cumulative catch-curve from length distribution of *M.monoceros* (Males) for the year 1992

Lower limit (mm)	C	Cum.C	log(L8-L)	log(Cum.C)	Z	Conf.	Interval
70	0.00	4508.15	4.6051	8.4136			
75	0.00	4508.15	4.5538	8.4136			
80	11.46	4508.15	4.4998	8.4136			
85	21.90	4496.68	4.4426	8.4111			
90	102.32	4474.78	4.3820	8.4062			
95	192.20	4372.46	4.3174	8.3830			
100	637.30	4180.26	4.2485	8.3381			
105	780.19	3542.95	4.1743	8.1727			
110	845.08	2762.76	4.0943	7.9239			
115	892.73	1917.68	4.0073	4.5588	9.426	8.718	10.134
120	487.31	1024.95	3.9120	6.9324	9.299	8.192	10.407
125	320.80	537.63	3.8066	6.2871	9.093	6.836	11.350 *
130	112.63	216.83	3.6888	5.3791			
135	59.86	104.19	3.5553	4.6462			
140	42.20	44.32	3.4012	3.7916			
145	2.12	2.12	3.2188	0.7514			

* SELECTED

Table 7.12 Details showing the construction of cumulative catch-curve from length distribution of *M.monoceros* (Males) for the year 1993

Lower limit (mm)	C	Cum.C	log(L8-L)	log(Cum.C)	Z	Conf.	Interval
70	0.00	5836.93	4.6051	8.6719			
75	0.00	5836.93	4.5538	8.6719			
80	0.00	5836.93	4.4998	8.6719			
85	172.58	5836.93	4.4426	8.6719			
90	145.16	5664.34	4.3820	8.6419			
95	168.39	5519.18	4.3174	8.6159			
100	598.86	5350.78	4.2485	8.5850			
105	1024.35	4751.92	4.1743	8.4663			
110	836.16	3727.57	4.0943	8.2235			
115	1096.69	2891.40	4.0073	7.9695	7.896	6.792	8.000
120	641.31	1794.71	3.9120	7.4926	8.126	6.639	9.612
125	425.31	1153.39	3.8066	7.0504	8.571	6.545	10.597 *
130	382.91	728.08	3.6886	6.5904	9.217	5.934	12.500
135	180.27	345.17	3.5553	5.8440			
140	126.22	164.89	3.4012	5.1052			
145	19.77	38.66	3.2188	3.6548			
150	5.36	18.88	2.9957	2.9385			
155	13.52	13.52	2.708	2.6045			

* SELECTED

Table 7.13 The calculation procedure for the estimation yield and average biomass of *M.monoceros* (Females) for the period 1991-93 in Jone's length based cohort analysis

Lower limit mm	number caught (000') C	Number of survivors (000') N	F/Z	F	Z	mean N*)	mean N*W	C*W
65	3.931	58187.46	0.0014	0.0034	2.3534	1156.3309	837.0971	2.8458
70	15.907	55466.15	0.0059	0.0139	2.3639	1143.0166	1034.5385	14.3973
75	58.800	52764.15	0.0217	0.0521	2.4021	1128.7488	1258.4958	65.5589
80	108.602	50052.79	0.0399	0.0976	2.4476	1113.0551	1509.0092	147.2357
85	191.527	47328.51	0.0693	0.1749	2.5249	1095.3593	1785.1428	312.1378
90	169.279	44562.89	0.0627	0.1573	2.5073	1076.4105	2087.4082	328.2711
95	353.084	41864.05	0.1247	0.3347	2.6847	1054.7748	2411.7832	807.3402
100	560.437	39032.24	0.1884	0.5456	2.8956	1027.2327	2746.7986	1498.5969
105	970.196	36057.81	0.2943	0.9799	3.3299	990.0895	3073.1338	3011.3867
110	1388.297	32760.90	0.3861	1.4778	3.8278	939.4398	3361.9243	4968.2261
115	1777.632	29164.92	0.4639	2.0331	4.3831	874.3314	3585.2878	7289.3662
120	1946.319	25332.61	0.5095	2.4406	4.7906	797.4698	3725.8989	9093.4941
125	2369.874	21512.24	0.5879	3.3527	5.7027	706.8472	3743.2410	12550.1094
130	2184.072	17481.27	0.6046	3.5932	5.9432	607.8330	3630.9705	13046.8408
135	1870.692	13868.79	0.6077	3.6402	5.9902	513.8914	3447.3918	12549.3584
140	1712.443	10790.46	0.6316	4.0297	6.3797	424.9563	3188.2114	12847.5098
145	1567.880	8079.37	0.6638	4.6403	6.9903	337.8854	2824.1167	13104.6680
150	1721.550	5717.46	0.7495	7.0315	9.3815	244.8327	2271.5930	12972.7920
155	932.553	3420.55	0.7077	5.6902	8.0402	163.8869	1682.2566	9572.4150
160	576.621	2102.86	0.6870	5.1573	7.5073	111.8078	1265.7177	6527.6260
165	365.414	1263.49	0.6750	4.8817	7.2317	74.8533	931.7610	4548.6113
170	243.137	722.17	0.6857	5.1270	7.4770	47.4233	647.2950	3318.6511
175	131.788	367.59	0.6692	4.7533	7.1033	27.7255	413.8706	1967.2562
180	72.850	170.65	0.6783	4.9543	7.3043	14.7044	239.4570	1185.3460
185	17.995	63.24	0.5064	2.4106	4.7606	7.3611	130.4662	318.9397
190	13.853	27.71	0.5000	2.3500	4.7000	5.8949	113.3953	266.4790
Total		598162.30				51946.2656	135316.4530	

*) meanN(i) = (N(i)-N(i+1))/Z(i). Mean F(L >= 125) : 4.0845 (Weighted by stock number)

These results were obtained using the parameters :

L8 (L-infinity)	204	Terminal exploitation rate	0.5
K (curvature parameter)	1.8	M/2K	0.652
M (natural mortality)	2.35	q in W = q L^b (grammes,cm)	3.958E-06
		b in W = q L^b	3.1341

Table 7.14 The calculation procedure for the estimation yield and average biomass of *M.monoceros* (Males) for the period 1991-'93 in Jone's length based cohort analysis

Lower limit mm	Number caught (000') C	Number of survivors (000') N	F/Z	F	Z	mean N*)	mean N*W	C*W
70	3.974	45621.42	0.0011	0.0027	2.3527	1498.9440	1385.8839	3.6743
75	23.894	42094.93	0.0069	0.0164	2.3664	1454.3936	1630.9961	26.7954
80	44.522	38653.21	0.0133	0.0136	2.3816	1408.0542	1892.3301	59.8346
85	260.166	35299.76	0.0755	0.1919	2.5419	1355.8953	2160.7202	414.5939
90	368.363	31853.24	0.1079	0.2843	2.6343	1295.7698	2425.4641	689.5139
95	594.998	28439.82	0.1711	0.4851	2.8351	1226.5583	2674.1138	1297.2009
100	1708.335	24962.41	0.3929	1.5207	3.8707	1123.3756	2830.9775	4305.1123
105	2780.132	20614.14	0.5515	2.8902	5.2402	961.9331	2782.8215	8042.7754
110	2573.560	15573.46	0.5864	3.3321	5.6821	772.3535	2548.9792	8493.4570
115	3112.024	11184.87	0.7010	5.5089	7.8589	564.9044	2114.7107	11649.8125
120	1831.812	6745.32	0.6752	4.8848	7.2348	375.0056	1584.0264	7737.5869
125	1152.690	4032.25	0.6661	4.6878	7.0378	245.8936	1166.3397	5467.5205
130	829.316	2301.71	0.7020	5.5347	7.8847	149.8390	794.5511	4397.6133
135	363.296	1120.27	0.6461	4.2894	6.6394	84.6955	500.0177	2144.7930
140	245.546	557.94	0.6986	5.4463	7.7963	45.0848	295.2018	1607.7631
145	96.479	206.45	0.6798	4.9902	7.3402	19.3336	139.8996	698.1318
150	17.625	64.53	0.4702	2.0858	4.4358	8.3346	66.4291	140.4762
155	13.525	27.05	0.5000	2.3500	4.7000	5.7553	50.3336	118.2839
Total		309352.8				27043.7969	57294.9375	

*) meanN(i) = (N(i)-N(i+1))/Z(i). Mean F (L >= 115) : 5.1554 (weighted by stock number)

These results were obtained using the parameters :

L8 (L-infinity)	170	Terminal exploitation rate	0.5
K (curvature parameter)	1.5	M/2K	0.783
M (natural mortality)	2.35	q in W = q L^b (grammes,cm)	1.0998E-05
		b in W = q L^b	2.9004

Table 7.15 Yield table derived from the length based Thomson and Bell analysis for *M. monoceros* (Females)

X	Yield	Mean biomass
0.0	0.00	161497.01
0.2	77495.11	109788.89
0.4	110439.93	83202.99
0.6	125237.43	67971.73
0.8	132067.68	58386.70
1.0	135164.81	51863.62
1.2	136411.14	47136.01
1.4	136696.03	43536.21
1.6	136463.78	40687.80
1.8	135947.81	38365.32
2.0	135276.50	36426.32

MSY = 136689 x = 1.4125 Biom.msy = 42991.32

Table 7.16 Yield table derived from the length based Thomson and Bell analysis for *M. monoceros* (Males)

X	Yield	Mean biomass
0.0	0.00	66956.40
0.2	29748.92	48645.58
0.4	43728.08	38904.87
0.6	50881.09	33175.34
0.8	54829.82	29500.52
1.0	57159.48	26967.12
1.2	58613.18	25115.63
1.4	59562.22	23698.47
1.6	60203.67	22573.53
1.8	60648.29	21654.41
2.0	60961.57	20885.87

MSY = 61609.37 X = 4.015625 Biom.msy = 16777.11

Table 7.17 Yield table derived from the length based Thompson and Bell analysis for *M. monoceros* (Females &Males combined)

X	Yield	Mean biomass
0.0	0.00	228453.42
0.2	107244.03	158434.46
0.4	154168.01	122107.86
0.6	176118.53	101147.07
0.8	186897.50	87887.22
0.0	192324.29	78830.75
1.2	195024.32	72251.64
1.4	196258.25	67234.69
1.6	196667.43	63261.33
1.8	196596.09	60019.73
2.0	196238.09	57312.19

Table 7.18Beverton and Holt's yield-per-recruit analysis for *M.monoceros* (Females)

X F	y Y/R	y B/R
0.0	0.000	7.290
0.2	1.302	6.513
0.4	2.347	5.868
0.6	3.195	5.326
0.8	3.892	4.865
1.0	4.469	4.469
1.2	4.952	4.126
1.4	5.358	3.827
1.6	5.703	3.564
1.8	5.998	3.332
2.0	6.250	3.125
2.2	6.468	2.940
2.4	6.657	2.774
2.6	6.822	2.623
2.8	6.965	2.487
3.0	7.091	2.364

F max = 12.8739 MSY /R = 8.136826
F0.1 = 2.677415 Y/R for F = F0.1 = 6.879958

Parameters

W8	68.562	tr	0.23
K	1.8	L8	203.999
to	0	Q	3.958E-06
M	2.35	d	3.1341
tc	0.5270428	Lc	125

Tablee 7.19Beverton and Holt's yield-per-recruit analysis for *M. monoceros* (Males)

X F	y Y/R	y B/R
0.0	0.000	2.859
0.2	0.514	2.571
0.4	0.932	2.331
0.6	1.277	2.128
0.8	1.564	1.955
1.0	1.806	1.806
1.2	2.012	1.676
1.4	2.188	1.563
1.6	2.341	1.463
1.8	2.473	1.374
2.0	2.589	1.294
2.2	2.691	1.223
2.4	2.781	1.159
2.6	2.862	1.100
2.8	2.933	1.047
3.0	2.997	0.999

The curve has no maximum
F0.1 = 3.11889 Y/R for F =F0.1 = 3.032922

Parameters

W8	32.397	tr	0.35
K	1.5	L8	169.999
to	0	Q	1.0998E-05
M	2.35	d	2.9004
tc	0.7523135	Lc	115

Table 7.20 Estimates of average annual stock and standing stock of *M.momoceros* for the period 1991-93

Year	Y	F	M	Z	E	U	Av.An. St Y/U	Sta.sto Y/F
Males								
1991	62	4.41	2.35	6.76	0.65	0.65	95.13	14.05
1992	46	6.39	2.35	8.74	0.73	0.73	62.94	7.2
1993	63	5.41	2.35	7.76	0.7	0.7	90.42	11.65
Average	57	5.4	2.35	7.75	0.7	0.7	81.83	10.55
Females								
1991	144	4.06	2.35	6.408	0.63	0.63	227.77	35.49
1992	108	6.01	2.35	8.356	0.72	0.72	150.29	17.98
1993	153	4.07	2.35	6.42	0.63	0.63	241.74	37.59
Average	135	4.71	2.35	7.06	0.67	0.67	202.51	28.65

SUMMARY

SUMMARY

The salient findings of the present investigation are as follows:

1. A complete description and geographical distribution of the genus and species of *Metapenaeus monoceros* (Fabricius, 1798) is given in order to confirm its identity. Systematic status of *Metapenaeus monoceros* is also included along with the synonyms.

2. *M. monoceros* is carnivorous, mainly depends on animal food items irrespective of size and sex in both marine and estuarine conditions.

3. The important food items encountered in its stomach from inshore waters are polychaetes, detritus, fishes and prawns in the order of abundance. Polychaete is the most preferred food item with an Index of 43.76.

4. Juveniles in Cochin Backwaters feed mainly on crustaceans (*Acetes* spp., other crustaceans, prawns and amphipods) and the selectivity of food materials differ between places in the same environment.

5. Diurnal variation in the feeding intensity is noticed where it feeds more in nights than during day time.

6. Growth has been estimated by following von Bertalanffy growth model. Restructuring of length frequencies and fitting of the growth curves have been done by using the computer programme ELEFAN I.

7. Female grows to a size of 166.53 and 188.88 mm in total length in 12 and 18 months respectively, whereas the male measures 129.12 and 150.81 mm at the end of 12 and 18 months respectively.

8. The size at first maturity is 114 mm in total length in females and 95mm in males. Although *M. monoceros* is a continuous breeder it has two major spawning periods in December-April and August-September.

9. From the monthly distribution data of mature females it is learnt that female spawns about six times during its life span of about 2 years.

10. The mature ova are fully yolked, opaque and measure between 0.145 and 0.261 mm and the most dominant size group range from 0.174 to 0.232 mm.

11. The fecundity of the species increases generally with size, but the variations are wide. However, the ovary weight has been observed to be a possible indicator to estimate fecundity and the

relationship between fecundity and ovary weight is as follows:

$$\log F = 11.95298 + 0.87253 \log O\,W$$

12. The total length-total weight relationship has been estimated separately for females and males. The relationship is as follows:

Females: $\text{Log } W = -5.4025 + 3.1341 \text{ Log } L \quad (r = 0.9969)$

or

$$W = 0.000003958\,L^{3.1341}$$

Males : $\text{Log } W = -4.9587 + 2.9004 \text{ Log } L \quad (r=0.9956)$

or

$$W = 0.000010998\,L^{2.9004}$$

13. The relationship between total length and carapace length is linear and is given as:

Females: $CL = -5.5291 + 0.2866\,TL \quad (r= 0.9889)$

Males : $CL = -0.9888 + 0.2330\,TL \quad (r=0.9910)$

14. The Cochin Backwater fishery composed mainly of juvenile *M. monoceros* and it has formed third in abundance in the stake net fishery.

15. Better catch rate has been observed in stake net fishery at Vypeen than at Thoppumpady owing to proximity of the earlier centre to harbour mouth and strong tidal influence.

16. The preference of darkness for emigration towards the sea and its nocturnal nature is evident from the high catch rates during new moon phase.

17. The inshore prawn fishery of Cochin is exclusively constituted by penaeid prawns, of which *M. monoceros* forms 4.98 %.

18. The average annual catch of speckled shrimp landed by the trawlers at Cochin Fisheries Harbour was 192.3 t with CPUE of 3.67 kg. Its average monthly landing amounted to 16 t. During 1991 - 1993 period the annual catch and catch rate increased by 5.3 % and 37.9 % respectively.

19. As *M. monoceros* is nocturnal, success of its fishery depends on shrimp trawling during nights in their normal habitat, off Cochin (shrimp grounds in the depth range of 30-45 m).

20. The fishing season is between December and May with peak availability during March-May and this three months period has yielded about 49 % of the annual speckled shrimp landings.

21. It has been observed that this species exhibits movement to deeper grounds upto 90 m during peak monsoon months (July-August) and in the reverse direction back to its normal habitat (30-45 m) during postmonsoon months (September-October).

22. Its size in trawl catches has ranged from 66-195 mm in females and 71-160 mm in males during 1991- 1993.

23. *M. monoceros* of 7-12 months is the major contributor to the inshore water speckled shrimp fishery of Cochin.

24. The annual average total mortality rate (Z) for *M. monoceros* was estimated to be 7.06 (females) and 7.75 (males) assessing steady state during 1991-1993.

25. The natural mortality rate (M) has been estimated as 2.35 and assumed to be the same for both sexes of this species.

26. The annual average fishing mortality rate (F) of speckled shrimp was estimated as 4.71 and 5.40 for females and males respectively.

27. The standing stock of *M. monoceros* at Cochin has been estimated to be 52 t for females and 27 t for males.

28. The maximum sustainable yield (MSY) for *M. monoceros* amounts to 196.7 t at Cochin.

29. It is observed that the average annual catch of speckled shrimp (192.3 t) is very close to the MSY(196.7 t). The effort has to be increased by 60% from the present level to harvest the MSY, which amounts to a marginal increase of 2.3% in catch (4.4t). Thus the Thomson and Bell analysis suggests that there is not much scope of getting higher yields by increasing the effort.

30. It is learnt from the Yield per recruitment analysis that increase in current level of age at first capture of *M. monoceros* (0.53 year for females and 0.75 year for males), as well as enhancement of present 'F' will not effect any significant improvement in the yield thus indicating that the present pattern of exploitation of this species seems to be nearer to sustainable yield.

31. Eventhough the multiday shrimp trawling (nights) is a recent development from 1990 onwards, which in turn increased the yield of *M. monoceros* to the present level, the study on its stock assessment at Cochin shows that the level of exploitation as existing now is biologically optimal.

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