Reproduction, Culture and Fishery of Metapenaeus dobsoni Miers

(CRUSTACEA : PENAEIDAE)

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CERTIFICATE

This is to certify that this thesis entitled, 'Reproduction, culture and Fishery of Metapenaeus dobsoni Miers (Crustacea: Penaeidae)' is the bonafide work done by Shri V. Thangaraj Subramanian as Research Scholar under my supervision at Zoological Survey of India, Marine Biological Station, Madras. This work has not been submitted for any award and degree.

(Dr. A. DANIEL)

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Preface

Prawn is the focus of marine fisheries in India in view of its export importance, besides being a substantial nutritional input to the nation's food requirements. The inshore and estuarine stocks of these valuable crustaceans have been traditionally exploited here by the artisanal fisheries over the centuries and since 1950s it has become an industrial fishery lucrated by highly profitable overseas markets. The impact of this recent development on the dismal coastal economy is appreciable and highly amazing in certain pockets, where the prawn industry is well established. Attracted by the creditable profits, huge capitals have been now invested by the enterpreuners and millions are employed in this profession along the coastal belts. Hence, it is imperative that both management and researchers explore measures to ensure the industry with sustainable yields and boost its tempo adding new avenues to step-up the productions.

Nature has augmented the coastal waters of India with rich resources of prawn stocks, which have their inherent 'burst' and 'fall', associated closely with ambient conditions at space and time. Fishing activity is an additional predator on the natural populations and, thus, the indiscriminate intensification of fishing would lead to over exploitation, the consequences of which could eventually endanger the very existence of the fishery, if adequate measures are not taken at the appropriate time. This necessitates regular investigations on the status of the stocks and biology of the component species, with special reference to the fluctuations of populations, due to commercial fishing.

Demands for prawns are global and insatiable, and hence, all over attract multi-project attempts to increase their production. Knowledge gathers under such pressing needs. One of the promising areas explored is prawn aquaculture in brackishwater farms and appreciable progress in this field of research has been widely made. However, commercially viable technology has not yet been well established.

Since most cultivable penaeids are dioecious, adults, the reproductive phase, being at sea, captive breeding,which could supply the large scale demands of seedlings, has been one of the major problems for prawn farming in brackishwater fields. This emphasises the need of extensive studies to understand and control reproductive processes. Ulterior motive of farming is, however, to obtain the highest yield at the cheapest cost and least efforts. Hence, knowledge about the on-growing phase of the species becomes essential, so that the most favourable conditions could be simulated to maximize growth and increase thereby the yield.

With major thrust upon these aspects, the present study is conducted on the species, *Metapenaeus dobsoni* Miers (Decapoda:Penaeidae), which is the most abundant, among the cultivable prawns of India and has also the added advantage of being traditionally cultured along Southwest coast, where the fishery activities are highly advanced. The subjects of present thesis are included in three chapters: one on Reproduction; another on Culture; and finally on Fishery, emphasising practical field orientations. Materials and Methods for these studies have been included, apart from introduction and summary and conclusion, as separate chapters.

The Chapter on Reproduction forms primarily the preamble of the thesis. It introduces sexual morphology and encompasses dynamics of sexual populations in their habitats. Aspects on process of maturation of ovary and movements of spawners in the habitat are the central problems of this chapter. Concentration of certain trace metals in relation to ovary maturation is also introduced and dealt with separately with more importance.

The Chapter on Culture comprises spawning and larval development and growth and habits of post-larvae and juveniles. The latter forms the focus and may also be considered a major contribution to the field of prawn aquaculture. Specifically, the presence of size heirarchy, among the siblings and possibility of enhancing the yield by pure culture of rapidly growing individuals are highlighted. Biotic and some environmental factors associated with growth have been analysed and few studies on natural habits added. In short, it deals comprehensively with the aspects aiming at increasing growth,while minimizing mortality during the on-growing phase, so that yield can be increased by appropriate implementations in culture in the field.

The Chapter on Fishery deals with the geographical distributions and status of fishery of this species in Indian waters. The importance of this species in Indian fishery and the contrast between west and east coast fishery are focused. The behaviour and pattern of local fishery at sea and estuary have been analysed with time and environmental changes. Dynamics of the populations entering Adyar Estuary along with the possibility of prawn farming around this area have been reported. Bathymetric movements of the brood stocks in relation to the environmental and biological parameters have also been traced.

Chapter 1

Introduction

Introduction

India ranks second only to United States in prawn production (Mohamed, 1973) and earns valuable foreign exchange from export of this crustacean to the tune of Rs.329.70 crores, which formed 85.8% of the total shipments of marine products in the year 1984-85 (Anon., 1985). Increasingly expanding demands for prawns at enviable profits in overseas markets, coupled with concurrent technological advances, have enormously increased the exploitation of natural stocks in recent years and raised the possibility or even probability of over-fishing, which may eventually lead to the total disaster of the fishery itself. It emphasises enforcement of rational fishing to ensure a long-term sustainable yield. In order to monitor the impact of increasingly intensified commercial fishing, the stock positions of prawns have, therefore, been periodically reviewed (Chopra, 1943; Panikkar and Menon, 1956; Bhimachar, 1963; Banerji, 1969; Jones, 1969; Mohamed, 1973; Silas et al., 1981). Since each species, that constitutes the fishery, has its characteristic behaviour, movements and habitat, a long-term fishing may have varying degree of impact on each one of them. This necessitates in-depth studies on individual species with regards to the resources available and exploited.

Among the 62 species of prawns of the family Penaeidae, which occur along the Indian coastal waters (Silas *et al*., 1981), a dozen belong to four genera, namely, *Penaeus*, *Metapenaeus*, *Parapenaeopsis* and *Solenocera*, form virtually the commercial catches, which was estimated at 1.70 lakh tonnes in 1980. Two other genera, *Trachypenaeus* and *Metapenaeopsis*, sporadically support minor fishery in certain noted pockets. The genus *Metapenaeus*, which contributes maximum to the fishery, is represented in Indian waters by *M. dobsoni*, *M. monoceros*, *M. affinis*, *M. brevicornis*, *M. kutchensis*, *M. ensis*, *M. moyebi*, *M. stebbengi*, *M. alcockii* and *M. lysianassa*, the first five species of which support major fisheries at geographically varying or overlapping regions.

Metapenaeus dobsoni, which topped the commercial prawns in India by quantity, sharing 18.9% (16072 t), as estimated for 1968 (Slips to second position during a few years later), is endemic to middle and southern latitudes of India supporting as fishery, though it has been recorded through Pakistan upto Gulf of Aden in the West and through Singapore upto Philippines in the East. The life-cycle of this species follows the general pattern of penaeids involving marine and estuarine ecosystems. Adults live in sea and discharge numerous eggs, which hatch out into planktonic larvae. After sequences of structural changes and growth in size, the larvae transform into post-larvae, while entering the estuarine nursery grounds, where they pass the on-growing juvenile phase and return to the sea at the onset of maturity.

Information on resources of M. dobsoni are available in fragments for different pockets along Indian coasts (Menon, 1955, 1957; George, 1961, 1967; Kuthalingam et al., 1966; George et al., 1967; Banerji, 1969; Muthu, 1973; Rao and Dorairaj, 1973; Kurup and Rao, 1974; Sudhakara Rao, 1975; Ramamoorthy et al., 1976; Silas et al., 1981). Since the penaeids migrate hundreds of miles along the coasts (Anderson, 1956; Silas et al., 1981) the resource studies stress to include wider areas for more reliable assessment of stocks. Hence, this study covers the entire coastal areas, selecting series of fishing centres within the geographical range of distributions," so as to focus a consolidated picture on fishery of the whole country and the difference in production between the West and East coasts is highlighted.

Although Madras (13.40'N : 80.17'E) supports considerable fishery of M. dobsoni, the earlier information is limited to only a technical report (Muthu, 1973). This scarcity has prompted an in-depth study on fishery of this species at this centre and several factors, biotic and abiotic, influencing the local productions have been discussed. Sediments of city's sewage dumped into the foregrounds, being the attractive feeding grounds to the moving populations from the adjoining nursery areas, has been focussed.

Population of penaeids is dynamic and their bathymetric movements are widely reported (Tuma, 1967; George et al., 1968; Isobel, 1969; Ruello, 1973: Silas et al., 1981; Crocos and Kerr, 1983). Each species has its own intrinsic depth range of distribution and commercial fishing can be expected to concentrate where more economic species are abundant. Such selectivity of fishing grounds may, thus, lead to biased estimates for relatively less valuable species, like *M. dobsoni*. This warrants more precise knowledge on the distribution and movements of population and their consequent relationship to the commercial fishery. Such informations gather greater importance in the context of legislation of fishing areas being demarcated for indegenous and modern mechanised crafts. A more realistic account on the bathymetric distribution of fishery of this species has been, thus, illustrated by sequences of experimental cruises off Cochin and the possible factors influencing downward movements of populations are also discussed.

The fishery of adults at sea and juveniles at brackish-water are sequential to each other and knowledge on both is, thus, essential for judicious management of resources. Hence, an extensive coverage of juvenile fishery is available for Indian brackishwaters (Menon, 1954; Gopinath, 1956; Menon and Raman, 1961; George, 1962, 1963; Raman and Menon, 1963; Subramanyam, 1964; Ganapathy and Subramanyam, 1966; George *et al.*, 1967; Rajyalakshimi, 1966; Subramanyam and Rao, 1968; Ramamoorthy, 1972; Sampson Manickam and Srinivasagam, 1972; George and Mohamed, 1972; Gopalakrishnan, 1973; Evangeline et al., 1974; Pillai and George, 1974; Kuttyamma, 1975; Kuttyamma and Antony, 1975; Sudhakara Rao, 1975; Suseelan, 1975; Paulinose et al. 1981; George and Suseelan, 1982; Suseelan and Kathirvel, 1982; Silas, 1984). Most of such studies pertaining to this coromandel coasts, where M. dobsoni forms a major component species (George and Suseelan, 1982), deal with only post-larval abundance. Information on juvenile population characteristics of M. dobsoni for the East coast are, however, very scanty (Suseelan, 1975). Sivalingam (1956) has reported this species as one of the major components of fishery at Balapatya lagoon in the neighbouring Ceylon waters. Records of larval abundance and dynamics of juvenile growth would also help analysis of the habitat and prediction of future fishery in the adjoining coastal grounds. Such detailed studies are, however, limited to larger backwaters of India, where the populations are often complex owing to the continuous breeding habits, fast juvenile growth and its short life span, misleading collectively to uncertain results. More reliable inferences on dynamics of juveniles may be drawn from populations of smaller and seasonal estuaries, where not more than a few broods manage to enter through the narrow bar-mouth enough to dominate the fishery keeping their identity in size distributions. Hence, this study includes the juvenile fishery and population characteristics of M. dobsoni for one season at Adyar estuary, which runs across the Madras metropolitan city and the possibility of prawn farming in this estuary, utilizing the urban sewage has been highlighted. The survey of fauna (Panikkar and Aiyar, 1937) and studies on breeding habits of varied groups of animals (Panikkar and Aiyar, 1939) are notable works earlier from this estuary. The report on natural breeding of a penaeid, M. monoceros, from this estuary based on the circumstantial evidence of small size specimens occurring after bar-mouth closure (Panikkar and Aiyar, 1939) has been internationally quoted in literature. Later, Nammalwar (1982) has monitored the penaeid larval abundance and recommended some management measures to be taken in the interest of fishery.

Exploitation of prawns at marine and estuarine systems is an exceptional nature. Man here harvests jointly what nature produces volunt~~ee~~arily. The insatiable global demands slowly ~~surmount~~ increase the pressure on the wild prawn stocks. Of the several possibilities to ease such swelling pressure on natural resources and augment the natural supply, perhaps, the most imaginative strategy is by means of aquaculture, the farming and husbandry in estuarine ecosystems. Unfortunately, the biological requirements of penaeids, the commercially valuable varieties, ~~meet~~ make this task more difficult than domestication and rearing of terrestrial animals. Husbandry of prawns, though a novelty to much of the world, has been in vogue through ages. In particular, it has the remote roots in Asian countries, where aquatic organisms form an important dietary component. The technique long been in practice is simple and crude, being nothing more than trapping the young prawns along with the tidal ingress in brackishwater inpoundments and confining them till harvestable size with or without feeding. The yield in this way is poor, but has potentially wide scope of improvements. According to world statistics collected by the FAO, 60,29,289 tonnes are estimated to have been produced through aquaculture in 1975. This is about 10% of the total aquatic production, of which, crustaceans form 0.3% during the same year. The development of aquaculture, both in terms of technical advancements and expanding production, has been very rapid and the FAO estimates a five fold increase in aquaculture production~~s~~ over the next thirty years. While devotees and sceptics argue its future significance, aquaculture continues to develop into an important industry in part of the world. National and international agencies like, ICAR, FAO, UNDP, AQUACOP and SEAFDEC are keen to evolve commercially feasible technology for cultivating marine organisms, of which, prawn finds a primary importance for its protein and economic values. Indeed the extent of interest is such that some 46 species of prawns have been experimentally cultured in over 40 countries (Wickens, 1982).

Prawn farming in India is old. It also extends in area, methods and technology in recent times. An area varying from 1.4-2.6 million ha. ~~are~~ is available in India for brackishwater culture, of which, about 5,117 ha. in Kerala and about 20,000 ha. in West Bengal are utilized for prawn/fish culture (Sexana, 1984). On a modest estimate, if 20,000 ha. can be brought under scientific culture operation to produce annually an average of 500 kg/ha, India can add another 1.0 million tonnes of fish and prawns (Jhingran, 1975). The method used here is a primitive one, trapping and holding till harvest, usually as a secondary crop in fields alternatively used for paddy cultivation and the production depends upon only the quantity of entrapped populations, which is uncertain until harvest. 'Aquaculture is regarded as man's attempt to improve the yield of aquatic organism by deliberate manipulation of their rates of growth, mortality and reproduction' (Reay, 1979). Major role of biologist is thus related with mass production of seed prawns of preferred species and maximizing the growth-rates, while minimizing the mortality at the growth-out phase, which forms the tenure of crop.

Successful aquaculture is independent of natural stocks. Production of prawn seeds at will, which is essential to ensure year-round cultivation, stemmed from the pioneering works of Hudinaga (1942) on Penaeus japanicus and catalysed by his results, most of the suitable cultivable marine species scattered all over the world have now been able to be artificially propagated to stocking size: P. monodon (Delmendo and Rabanal, 1956; Liao and Huang, 1972; Silas et al., 1978; Motoh, 1979), P. semisulcatus (Devarajan et al., 1978; Hassan, 1982), P. indicus (Muthu et al., 1978), P. merguiensis

(Motoh and Buri, 1979), *P. esculentus* (Fielder *et al.*, 1975), *P. duorarum* (Cook, 1967), *P. setiferus* (Cook and Murphy, 1966), *P. califoriensis* (Kitani and Alvarado, 1982), *Metapenaeus dobsoni* (Rao and Kathirvel, 1973; Thomas *et al.*, 1974; Muthu *et al.*, 1978), *M. monoceros* (Raje and Ranade, 1972; Mohamed *et al.*, 1978), *M. affinis* (Thomas *et al.*, 1976; Muthu *et al.*, 1978; Hassan, 1980), *M. brevicornis* (Sudhakara Rao, 1978) and *Parapenaeopsis stylifera* (Muthu *et al.*, 1978). This list of literature includes most of the Indian species being successfully reared in the laboratory and, in addition, the larval history has been described for several of these species from the planktonic collections (Menon, 1937, 1951; Subramanyan, 1965; Rao, 1973; Paulinose, 1982).

Artificial propagation of penaeids mainly involves induced spawning and rearing of complex larval phase to stocking size under controlled conditions. Testing and perfection of spawning technique introduced by Hudinaga (1942) has been attempted in most part of the world with varying degree of success (Beard and Wickens, 1980; Primavera, 1979, 1980; Nagabushanam *et al.*, 1980; Joshi and Nagabhushanam, 1982). Though experimentally successful in a long list of species, application to large scale commercial farming, which is emerging in several nations, require still more studies. In this respect, it is absolutely indispensable to have a good knowledge on the reproductive biology of the cultivable species, so that, the animals be placed under the most favourable conditions in order to achieve maximum success of induced maturation and spawning.

A good body of literature on the fishery biology including reproduction of major commercial species of the world is now available and notable among them are on *Penaeus japonicus* (Hudinaga, 1942), *P. setiferus* (King, 1948; Anderson, 1956; Linder and Anderson, 1956), *P. duorarum* (Cummings, 1961; Ikusamiza, 1975), *P. latisulcatus* (Penn, 1980), *P. merguiensis* (Stephen, 1980), *P. keratheus* (Fubo, 1979), *P. plebejus* (Ruello, 1975), *P. stylirostris* (Brown *et al*., 1980), *Metapenaeus mastersii* (Dall, 1958), *M. macleayi* (Ruello, 1973) and *Crangon crangon* (Boddeke, 1975). Similar information on Indian penaeids has been briefly provided by Bhimachar (1962) and later consolidated with further information in the special bulletin 'Prawn fisheries of India' (Bull. 14, CMFRI, ICAR, 1969). The commercial species, barring *M. dobsoni*, which have been fairly studied are

P. indicus (Menon, 1957; Sheikhmahmed and Tambe, 1958; Subramanyam, 1963; George and Rao, 1967; Rao, 1968; Kurup and Rao, 1974), *P. semisulcatus* (Thomas, 1974), *M. monoceros* (George, 1963; George and Rao, 1967), *M. affinis* (Mohamed, 1965; George and Rao, 1967; Rao, 1968; Ramamoorthy *et al.*, 1975; Pillai and Nair, 1976), *M. brevicornis* (Rajyalakshimi, 1961; Bhimachar, 1964; Sudhakara Rao, 1979), *Parapenaeopsis stylifera* (Sheikmohmed and Tambe, 1958; Rao, 1968; Kurup and Rao, 1974) and *Solenocera crassicornicus* (Kunju, 1967).

Being the most abundant commercial prawn in India, the reproductive biology of *M. dobsoni* has been consistantly studied (Menon, 1951, 1955, 1957; George, 1961, 1962, 1963, 1967, 1969; Bhimachar, 1962; George and Rao, 1967; Banerji and George, 1967; George *et al.*, 1968; Rao, 1968; Ramamoorthy, 1972; Kurup and Rao, 1974; Ramamoorthy *et al.*, 1976). Most of these studies are based on commercial catches trawled from varying sites, where the populations of a species are characteristically different. Movements, behaviour and general habitat of various ages and sizes largely influence the actual representation of population. That is, the major problems are still associated with knowing definitely where the various age groups are distributed, since penaeids show different modes of behaviour and habit with age and size. Hence, the dynamics of age at size have been worked out for M. dobsoni as a pre-requisite of interpretation of age-dependant reproductive activities and earlier such estimates (Banerji and George, 1967; Kurup and Rao, 1974) have their own defects, such as, merging of both sexes in the former and too much of deviations from the actual values in the latter.

The view of inshore-offshore movements of penaeids for spawning purposes is generally upheld, though availability of spawners from near shore to the maximum limit of distribution raises the question whether the bathymetric migrations are indispensable for spawning. Hence, a detailed analysis of dynamics of spawners has been made by systematic sampling of spawners at different depths within the range of distribution on sequences of dates at a given site of a fertile region. This study specifically throws some light on maturation period required in nature and also the space utilization by different broods for spawning purposes.

Maturation in penaeids is a complex process, during which rapid and drastic histological and biochemical changes occur (King, 1948; Renfro and Brusher, 1963; Subramanyam, 1965; Tuma, 1967; Hignham and Hill, 1976; Crocos and Kerr, 1983; Teshima and Kanazawa, 1983). Induced maturation, an essential process in culture operations, is only restrictively successful under captive conditions by endocrine manipulation. However, wide scale commercial farming needs mass production of seeds, which would be possible only when the prawns naturally mature in farm conditions. To achieve this, attempts are mainly directed through environmental and dietary manipulations, the latter being paid lesser attention. Diet requirements of the animals to complete maturation may be better understood from the wide scope of knowledge on fluctuation of body constituents during maturation. Trace metals are generally focussed as health hazards in food organisms in view of wide spread industrial effluents (Bryan, 1968; Bishop, 1976; Boyden, 1977; Ireland and Woottan, 1977; Larsen, 1979) and similar investigations on prawns are also available (Nimmo <u>et</u> <u>al</u>., 1972; McKenny and Neff, 1979; Milner, 1979; Shiber, 1981; Sivalingam, 1980). However, a wide variation of body burden of metals in population raises whether the metals are delibrately accumulated in body tissues according to the physiological needs of the organism (Millington and Walker, 1983; Topping, 1973). This study envisages certain trace metal distributions in body tissues of females at varying degree of maturity and a correlation existing between the developing ovary and two metals, copper and zinc, is highlighted.

Aquaculturists are ultimately concerned with obtaining maximum yield with minimum efforts. Seed prawns of quality species with improved hatchery techniques could be now produced sufficiently to supply farming to some extent. But still a wide gap between stocking and harvest remains to be bridged to obtain the potential yield. In India, studies beyond larval developments of most cultivable species are negligible. Maximizing the growth-rates and minimizing the mortality of post larvae through juveniles, which form the crops, are the twin factors to achieve maximum yield. Most of the earlier studies on growth of Indian penaeids are based on size-frequency distributions of wild populations (Menon, 1951, 1955; George, 1959, 1967, 1974, 1975; George et al., 1967; Subramanyam and Rao, 1968; Mohamed and Rao, 1971; Suseelan, 1975; Nair and Kutty, 1980; Paulinose et al., 1981) and the inference drawn from them are sometimes widely varying. The present study attempts on dynamics of growth of post-larvae and juveniles reared from eggs over 5 months and the appropriate tenure of crop for this species is discussed from age-curve.

The fact, that the penaeids have complex life cycles in the major bio-systems, makes it very unlikely that the growth of all life stages can be combined into a single curve - such as the logistic. This is evident that the size of juveniles under rearing conditions approaches the size ceiling and hence the popular von Bertalanffy growth equation for the juveniles has been estimated, from which, the optimum age of harvest in culture could be decided in the given system. In this penaeid, as generally in crustaceans, growth is closely related to moulting and the growth-rate of an individual is the product of size increment at each moult and the moulting frequency. Hence, the study on dynamics of growth initiates essentially with evaluation of these two factors.

Moulting has been reported in several species of crustaceans: Panulirus argus (Travis, 1954; Lipcius and Hernnkind, 1982), Palaemonetes varians (Jefferies, 1964), spiny lobster, *Jasus lalande* (Fielder, 1964), *Metapenaeus* sp. (Dall, 1965), *Penaeus durorum* (Bishop and Hernnkind, 1976), *P. monodon* (El Hag, 1984) and the dynamics of moulting have been discussed by Passano (1960) and Mauchline (1977). Little is known about moulting and growth in Indian penaeids and this study discusses the dynamics of moulting and growth of postlarvae through late juveniles.

Growth in size is an inevitable accompaniment of life. After the risky larval stages, the on-growing phase is set-in in penaeids and further acceleration of growth becomes an out-come of intrinsic potentialities in interactions with multitudes of extrinsic factors. Inheritance of growth is illustrated by focussing a size heirarchy developed among the siblings spawned together and reared under identical conditions in the laboratory. Improvement of the quality of the stock by monoculture of the rapidly growing individuals for aquaculture is highlighted. The stunted growth in stocked animals poses problems, besides poor yield, to fix the size at harvest. An investigation into this problem is approached by deliberately stunting the specimens and tracing the growth characteristics of them during rehabilitations. The result emphasises the necessity of regular feeding.

Environmental factors can be expected to influence more on the activities and growth of aquatic animals, as they are always submerged in the medium and several literature on this line are available as for penaeids (Linder and Anderson, 1956; Zein-Eldin, 1963; Gunter et al., 1964; Zein-Eldin and Aldrich, 1965; Zein-Eldin and Griffith, 1965; Dall, 1965; Nair and Kutty, 1975; Spaagran, 1980; Bordner and Conklin, 1981). Though salinity and raising summer temperature are the major confronted problems concerned with aquaculture of prawns in tropical waters, such studies are scantly available from India. The present study, thus, attempts growth pattern of young prawns of M. dobsoni in relation to those factors and also to that of endocrines and substrates. In all, a consolidated effort is made to increase the yield by improving the growth-rates with widely varying means of field applications.

Animals have evolved certain inbuilt habits and any disruptions to these habits are likely to distress the animal's life process. Hence, it is essential to acquire a good knowledge on these aspects to stimulate the most favourable conditions in aquafarming, so that, the best yield can be turned out. One of the proven cyclic habits in penaeids is the diurnal rhythm of burrowing behaviour (Williams, 1958; Dall, 1958; Fuss and Ogren, 1966; Hughs, 1968; Kutty and Murugapoopathy, 1968; Aziz and Greenwood, 1982; Wassenberg and Hill, 1984). Also, such studies are important in view of the fact that the interspecific differences in the composition of catches at different hours are related to the difference in diurnal rhythmic activities of the species. Earlier study in this respect in India is limited only to Kutty and Murugapoopathy (1968) on the penaeid, *P. semisulcatus*. Hence, for this scarcity of information and its relevance to aquaculture, this study includes burrowing behaviour of *M. dobsoni*. The biotic and abiotic factors controlling this habit and the consequential problems in culture operations are discussed.

Chapter 2

Materials and Methods

Reproduction

Materials for the study on reproductive biology of M. dobsoni were collected mainly from the commercial catches at Royapuram Fish Landing Centre, Madras, where hundreds of trawlers land their daily catches and supplementary samples were obtained from the catches of the research vessel 'CHOTA INVESTIGATOR' of Zoological Survey of India, Madras and 'CADALMIN' of Central Marine Fisheries Research Institute (ICAR), Cochin. Some of the post-larvae and juveniles reared in the laboratory and collected from Adyar estuary were also used for studies on genital morphology.

After assessment of catch and effort details, a random sample of M. dobsoni was collected from any one of the boats or merchant baskets during the weekly observation. On each day, 50 specimens of this species were sorted out for sexes, maturity stages of the females, based on the visual changes of the ovary in colour, size and texture, and the total lengths in mm of both sexes, measured from the tip of the rostrum till the end of telson. Few individuals of varying sizes of both sexes were weighed and similarly few ovaries of 'mature' individuals were dissected out and weighed before liberating the eggs in small bowls of water. The volume of water was made upto 500 ml, from which a sub-sample was separated, while stirring the suspended eggs to be dispersed uniformly in the water column, and the number of eggs enumerated. From these number of eggs in sub-samples, total number of eggs in the entire 500 ml, that is, fecundity of the specimen, was calculated.

Total length of individuals of either sex, which were measured to the nearest mm, were processed into 5 mm size-classes and plotted as monthly length frequency polygons. All the size frequencies were pooled for each month and the mean-length of respective months was calculated for each sex. Populations were found characterised by reflexes of new entrants, revealing seasonal spawning activities. Each brood, represented by a size mode could be traced through time sequences as mode-chains. The change of length with corresponding time lapse of each mode-chain was used for estimating the growth-rate of the particular brood at specific sizes. The growth-rates varied with the mean size of the respective mode-chains, larger animals increasingly reducing in growth-rate. Hence, the size against the age of the animals were also found to be fit into the popular von Bertalanffy growth equation, the details and calculation of which are given vide infra.

The sex-ratio was expressed in percentage numbers for each month and the size-wise sex proportions were illustrated by a slope of probability curve constructed, plotting mid-points of each size-class against the percentage male pooled in each of the respective length-class. Cumulative proportions of all the females with developing and spent ovary against length were plotted and the appropriate regression calculated as detailed vide infra to find out the minimum size at maturity.

A piece from the middle portion of the ovary was removed, fixed in neutral buffer and embedded in paraffin wax (m.p. 56°C). Sections were taken at 4-6 µm thickness and stained with Hematoxylin and Eosin for histology.

Two sets of pooled samples, each numbering 4-5 animals, of male and different maturity stages of females of M. dobsoni were collected from the same day's catch trawled from the same location and analysed for trace metals viz., copper, zinc, nickel, lead and cadmium, as follows:

The whole body of the animal~~s~~ ~~were~~ was washed with demineralised water and dried in an oven at 120°C for 24 hours. The dry material was digested with 6 N nitric acid, followed by concentrated nitric acid and then perchloric acid or hydrogen peroxide-nitric acid mixture until the matrix was clear. The digested matrix was then made up to the desired (25 ml) volume with 0.01 N nitric acid. This was directly aspirated into the AAS IL 457 and the concentration was read directly.

Breeding cycle was based on the frequency distributions of different maturity stages of females in commercial catches. Relative abundance of 'mature', supported by 'spent', females was basically considered for the breeding seasonality. Some of the fresh broods as young size modes were identified in catches and their breeding characteristics were traced through succeeding seasons to follow the spawning periodicity.

Information on bathymetric movements of different age-groups, sexes, spawners, maturation period and spawning characteristics of individual broods were based on data collected by experimental cruises systematically carried out off Cochin. The population at ≤ 10 M, 15 M and ≥ 20 M depths were analysed for sequences of changes and movements, which occurred in relevance to those aspects through succeeding periods.

Culture

1. SPAWNING AND LARVAL DEVELOPMENT

Females in advanced stages of maturity (stage IV, 'mature') were collected at 20 M depth from the sea off Madras and kept in filtered sea water in plastic tank (1.5 x 0.5 x 0.4 M) under continuous aeration in the laboratory. The salinity was 32-34‰ and the temperature 25-31°C(+ 1°C). Spawning took place at night and large quantities of discharged eggs were transferred to glass and plastic troughs of 5 lt capacity of sea water and exposed to normal diurnal temperature fluctuations. Some eggs were also kept in thermostatic conditions (20°, 25°, 30° and 40°C) for hatching. The water in the rearing vessels were changed periodically to maintain better quality. Cultured diatom, *Skeletonema costatum* and rotifer, *Brachionus* sp. were fed to protozoaic and mysid larval stages respectively.

The larval samples were observed periodically for structural changes till no mysid stages were noticed. The chronology of each sub-stage (time at maximum occurrence) was recorded throughout. The total naupliar length was measured between the apical and caudal margins, excluding the furcal spines, in the middle line and width was measured across the greatest breadth. Total length of protozoea, mysids and post-larvae was taken from the tip of the rostrum to the end of telson. Spines of the telson were numbered and their morphometric changes of the appendages recorded. Figures to point out the salient features were hand drawn from binocular microscopic view.

2. GROWTH OF POST-LARVAE AND JUVENILES

a. Age and Growth

Studies on age and growth were carried out *in vitro* on post-larvae reared from a single spawning. Eggs through post-larvae were grown in larger aquaria tanks with about 50 lt seawater (32-34‰ salinity) as explained in Chapter 2.1. Twenty post-larvae were selected randomly and reared individually in a small tank with 3 lt diluted seawater (15-20‰ salinity) when they were 24 days old since the date of spawning. Such individual rearing continued for 4 months, during which moult-history was traced and the measurements, such as, pre-moult size, moult-increase and post-moult size, and the inter-moult periods were recorded. Water was partially changed and aerated for about 30 minutes daily. Also, the tanks were periodically cleaned thoroughly and the water changed completely. Water temperature ranged 26-32°C throughout. Feed consisted mainly of fresh prawn meat (just killed and fed) and occasionally fish flesh and earthworm. Feed was left in plenty overnight daily and the unconsumed feeds were collected along with fecal matters and moults every morning before changing water.

In addition, about 50 post-larvae were reared in the original stock tank with routine feeding daily and periodical change of diluted seawater (15-20‰ salinity). Periodically random samples of individuals in adequate numbers were measured for total length for 6 months. Measurements of length of post-larvae reared collectively and individually were pooled and plotted against age in months. The linear curve was in logistic form. That is, the growth-rate declined exponentially as the larva grew in size or became older. Since, the growth-rate was increasingly reduced to negligible levels beyond 6 month old, the age-curve of the larva through late juvenile reared continuously in estuarine conditions appeared to fit to the popular von Bertalanffy Growth Equation:

$$Lt = L\infty \ [1-e^{-k\ (t-t_\circ)}] \qquad \text{........} \ (2.1)$$

The details of the equation and the method of calculations are presented with result. The growth-rates at age were computed following Gulland and Holt (1969) Equation:

$$\frac{l_2-l_1}{t_2-t_1} = k\ (L\infty - \frac{l_1+l_2}{2}) \qquad \text{.........} (2.2)$$

where, Loc and k are the Bertalanffy growth parameters estimated by the Eq.(2.1) and l_1 and l_2 are the lengths at the age, t_1 and t_2 respectively, t_2 being later than t_1.

b. Moulting and Growth

As mentioned earlier, moult-history of 20 post-larvae were traced from 15 mm to 50 mm size (number reduced gradually). Data on pre-moult and post-moult size at every moulting was collected, so that the size increase at moulting could be calculated and the inter-moult period in days was also recorded. Size increase at moult was expressed as growth-factor, which was the percentage moult-increase upon pre-moult size calculated by the formula,

$$\text{Growth-factor} = \frac{\text{moult-increase}}{\text{pre-moult size}} \times 100 \quad \text{......(2.3)}$$

The inter-moult period and the growth-factor against pre-moult length revealed linear relationships in logarithmic forms and the appropriate regression equations were,

$$\text{Log. IP} = a + bL \quad \text{.............(2.4)}$$

$$\text{Log. GF} = a - bL \quad \text{.............(2.5)}$$

where, IP is the inter-moult period, GF, the growth-factor and L, the pre-moult length. Rearing conditions were identical to all individuals and same as in Chapter, 'Age and Growth'.

c. Inheritance of Growth

The eggs laid on a single spawning by a gravid female in the laboratory were reared to post-larvae appropriately as explained in earlier chapter. They were found to reach the first post-larval stage at the age varying between 12 and 18 days since spawning. Periodical measurements showed widening variations of size and hence 10 individuals of largest size (henceforth termed 'fast' group) and another 10 individuals of shorter size-ranges (henceforth termed 'slow' group) were separated and reared individually in small tanks of 3 lt diluted seawater (salinity 15-20‰ and temperature 26-32°C). Other rearing conditions were same as in Chapter 'Age and Growth' and all animals were subjected to similar treatments. Size measurements were taken periodically for six months and data of individuals for 'fast' and 'slow' groups pooled together into respective group. The size at age curves were separately estimated for 'fast' and 'slow' groups computing the von Bertalanffy growth equation (2.1) as in Chapter 'Age and Growth'. Similarly the growth-rates were also calculated by Eq. (2.2) substituting with the respective values of von Bertalanffy growth parameters.

Moult-history was traced for individuals of 'fast' and 'slow' groups and the data on moult-interval and moult-increase for respective groups were pooled. The regressions of moult-interval and moult-increase against pre-moult length were computed as in for Eq. (2.4) and (2.5). These computed values, such as age for size, growth-rates, inter-moult period, growth-factor and daily growth-rates for 'fast' and 'slow' groups are compared to illustrate the disparity and thereby emphasising the inheritance of growth being existed among the siblings of the same mother and spawn.

d. Starvation and Growth

The short-time and long-term effects of starvation on growth of post-larvae were separately experimented. In the first set, two post-larvae of M. dobsoni, spawndd and reared in vitro, were used in two separate experiments, Experiment I and Experiment II. Rearing conditions were the same as in Chapter 'Age and Growth', except deliberate starvation as specified in results.

In both Experiment I and II, 9 moults were traced recording the informations on moult-intervals, pre- and post-moult sizes and moult increase. Animals were completely starved during 5th inter-moult periods. Details of three 'pre-starvation', 'starvation' and three 'post-starvation' moults were selected for calculations and comparisons. The 'pre-starvation' moults selected were contiguous to 'starvation' moults. The mean size, intermoult periods and moult-increases were estimated for all these three durations. The mean growth-rate is then computed by simple division of moult increase by inter-moult periods. These growth-rates specific to the mean size were compared with control values of growth-rates for the same size estimated by Eq. (2.2) substituting the values computed from Eq. (2.1) in Chapter 'Age and Growth'.

e. Stunted Growth and Rehabilitation

Post-larvae of M. dobsoni, collected from the local Adyar Estuary and conditioned for two days, were divided into two groups, Group I and II, each numbering 10 with the mean-size of 22.5 mm at the beginning. Rearing conditions were the same (salinity 15-20‰ and temperature 26-32°C) for both groups during the entire 71 days of observations and food had been mostly prawn meat and occasionally fish flesh and earthworm. Group I was fed ad libetum daily throughout; whereas, Group II was deprived of food during the first 19 days and fed later daily as similarly to Group I. Mortality was negligible during the first 40 days and 6 individuals in Group I and 5 in Group II were present when the experiments were terminated after 71 days.

The length measurements of all the available animals were recorded and the mean-size was estimated periodically. Growth-rate for each interval of observation days was calculated as follows:

$$\text{Growth-rate } [G] = \frac{l_2 - l_1}{t_2 - t_1} \qquad \text{.........} \ (2.6)$$

where, l_1 and l_2 are the mean-size on the experimental days t_1 and t_2 respectively, t_2 being later than t_1. The growth-rate [G] against t_2 and the same against the mean of l_1 and l_2 for the successive observation intervals were calculated to obtain age and size-specific growth-rates respectively. The growth-rates between control and experimental groups (Gr. I and II) were compared to illustrate stuntedness owing to long-term starvation and the after effects on growth characteristics of starved animals while refed.

f. Eyestalk-ablation and Growth

Two individual post-larvae, spawned and reared in the laboratory itself, were traced for 7 moults separately in two experiments, Experiment I and II, which extended 32 and 31 days respectively. Left eye-stalk in the former and right eye-stalk in the latter were removed at the beginning of the 4th inter-moult (next morning of moult-night) and thus, 3 'pre-ablation' moults', 1 'ablation-moult' and 3 'post-ablation moults' were involved during the course of this experiment. Rearing conditions were with 15-20‰ salinity and 26-32°C temperature and feedings daily ad libetum comprised mostly prawn meat and on few other occasions fish flesh and earthworm.

Inter-moult periods and moult-increments in size were recorded throughout and their values for 'pre-ablation', 'ablation' and 'post-ablation' durations were compared to measure the differences, before and after the ablation. The mean-size at these three durations were calculated and the growth rates to the corresponding sizes were computed as control using the equation (2.2), substituting the values of Eq. (2.1) and compared with experimental values. The daily growth-rates for the control and observed were also compared to measure the deviations of growth owing to eye-stalk ablations.

g. Salinity, Substrate and Growth

Post-larvae and juveniles netted from Adyar Estuary were used in these experiments and initial sizes were chosen to be in closer ranges (24-28 mm) to avoid size influence on growth-rates. Most of the animals belonged to the same stock. The rearing vessels used in experiments were the mud pots, being otherwise used in gardening. The salinity of the fresh sea water was estimated and appropriately made upto 6 gradients viz., 5, 10, 17, 23, 28 and 33 (± 1-1.5‰), to fill up each pot with about 3 lt. All gradients had duplicate pots and thus there were 12 pots for 6 gradients. All these 12 pots were not provided with sand substratum. In addition to these pots, two pots were provided with sand substratum and filled up with 17‰ salinity. After few days of conditioning, the animals were introduced into each pot measuring the length and further details of rearing and feeding were as usual in other experiments. Periodical measurements were recorded for each individual and those missed and died were replaced by similar sizes. One of the animals grown in each gradient was chosen for calculations, considering the maximum survival time and the mean-size, if both had survived longer periods. From the length increments and the corresponding time lapse, the daily growth-rates of them were calculated and compared.

Meantime, two animals were reared in glass trough with 5‰ salinity and sand substratum kept near the window, unlike the other mud pots, which were kept in the centre of the shed leaving a minimum distance of about 10 ft on any side, so that a difference of 2-3°C in temperature was invariably recorded between the trough near the window and the pots at the centre. The growth-rate of these animals reared in trough were compared to those reared in pots to elucidate effects of temperature on growth.

3. BURROWING HABITS OF JUVENILES

Juveniles of M. dobsoni (25-50 mm length) netted from Adyar Estuary and stocked in aquarium tanks with

50‰ seawater were used in experiments as and when required. Two aquarium glass tanks, with 50 lt of 50‰ seawater giving a water column of 20 cm depth and 6-8 cm of beach-sand substratum and another larger tank with 200 lt similar seawater, without any substratum, were the main experimental vessels. One of the smaller tanks with substratum and the other larger one without substratum were housed in a thatched shed with low roof and enclosure of bamboo-meshes, while another smaller tank was kept in the verandah, where one side was wide open exposing the aquarium tank to the glaring sky light at an acute angle. Hence, the intensity of light was slightly different between these tanks. Besides, still smaller glass tanks and troughs with substratum were used for certain specific experiments as explained vide infra. Twenty five animals from the stock tank were randomly collected and introduced into each tank and the sea water (salinity 50‰) was aerated throughout. Animals deburrowed were counted periodically for 24 hrs from the following day of introduction into the tank. Animals were not fed during experiment and repetition of experiments were carried out after a few days interval on new animals from the stock tank. Mean values were used.

Fishery

1. FISHERY OF *METAPENAEUS DOBSONI* MIERS OFF MADRAS

Fishery data of M. dobsoni pertain to trawler catches landed at Royapuram, the main fish landing centre in Madras city for the period of two calender years, 1981-82. On every weekly observation day, 8-10 boats were randomly noted for their total prawn catches and the proportion of M. dobsoni therein by visual assessment with the knowledge of predetermined weight of a basket of prawns. The total weights so noted and the efforts in trawling hours involved were added up and the catch per unit effort (CPUE) in kg/hr was calculated by simple arithmetic division. The CPUE for different observed days were summed up and the average value of it for the month was estimated. These calculated mean values formed the basic units reflecting the abundance of both total penaeids and M. dobsoni during the respective months. The percentage composition of M. dobsoni in penaeids was worked out from the mean monthly CPUE values.

Environmental parameters, such as rainfall, salinity and temperature were collected. Monthly rainfall data were collected from the concerned departments. Mean value of salinity, which was estimated by the Winkler's titration method, for weekly samplings of surface waters off Santhome beach was taken as monthly value. Two temperature readings at 8.30 A.M. and 5.30 P.M. were noted for most of the days and the average value for the month was appropriately calculated. The fluctuation in percentage composition of 'mature', supported by 'spent', individuals among females in random samples of M. dobsoni, analysed on each day of observation, was the basis of evaluating breeding seasonality.

2. BATHYMETRIC DISTRIBUTION OF *METAPENAEUS DOBSONI* MIERS

This part of this thesis was based on data collected during the experimental cruises by the ICAR Research Vessel, 'CADALMIN' off Cochin, the most flourishing centre of fishery for this species on the West Coast, over a period of 3 years with intermittent breaks. Considering the magnitude of fishery during a few days of trial fishing at the beginning, three depth zones viz., ≤10 M, 15 M and ≥20 M, were arbitrarily fixed for periodical sampling of trawl-net operations. Trawling was invariably between 0800 and 1300 hours for a fixed time of one hour at each depth horizontal to the shore-line opposite to the New Light-House in Vypeen Island near bar-mouth. After hauling, the catch of M. dobsoni was assessed for weight on deck and the random samples were analysed, in addition, for other biological studies, such as, sex, size, maturity stages of females, as required for Chapter III.

Three or four days of sampling were made on most of the months and the catch for all the sample days was averaged to obtain catch in kg per hour of hauling (CPUE) for the month for each depth zone separately. Considering the requirements for the present studies, only data pertaining to six months representing a cross section through the entire fishery season were used.

3. JUVENILE FISHERY OF *METAPENAEUS DOBSONI* MIERS IN ADYAR ESTUARY OFF MADRAS

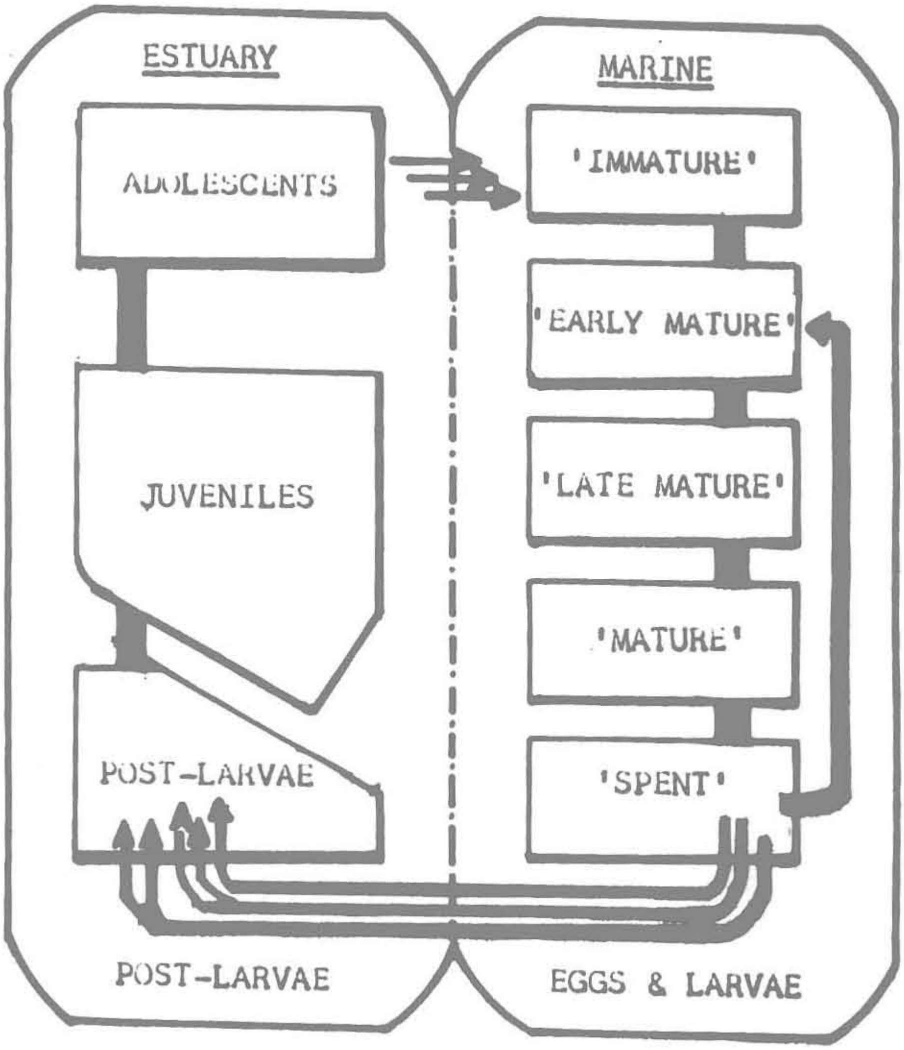
The fishery data pertain to cast-net fishing during the annual season from October 1983 through June 1984, when the bar-mouth was open, ensuring tidal flows and thereby the exchange of life between the sea and the estuary. In each month 2-3 observations were made and on each observation day 5-6 cast-catches were assessed for the total weight and therein the proportion of prawns and in turn of M. dobsoni. From the average weights of each item separately for the sampled units, the day's catches were estimated by simple arithmetical multiplication. Likewise, from the mean values for the observation days in the month, the monthly total landings were calculated by multiplying with number of days in the month.

Random samples of M. dobsoni were collected from one or two units on each observation day and analysed for sex and total length in mm. The sex-ratio is expressed in percentage from the actual number in the sample analysed during the month. The length of either sex was distributed separately into 3 mm size-classes and therein the prominent length modes, which represented major broods in populations, were identified and their progression through successive months traced as mode-chain. The growth-rate of each brood was estimated from size increase of that mode-chain and the corresponding time lapse. The average growth-rate per day and then per month was calculated independently for each sex.

Length-modes of smaller individuals, whose sexes could not be sorted out for certainity, were taken as common to both sexes.

Chapter 3

Reproduction



Schematic sketch of breeding cycle of *M. dobsoni*

Results

1. SEXUAL DIMORPHISM

a. Sexual Morphology

Metapenaeus dobsoni is heterosexual with prominent external genitalia, petasma in male and thelycum in female (Fig. 1). The petasma is the modified endopodites of the first pair of pleopods and thelycum is the specialised sternal surface of the last two thoracic segments. In addition, the second pair of pleopods in male is slightly modified into appendix masculina and the genital pores of this sex are positioned one each at the coxa of the 3rd pereopods. The adult females may be recognised by the developing ovary seen through the transparent cuticle and the genital pores are at the coxa of the 5th pereopods. Females are also larger in a given population compared to males.

In adult males, petasma is a complex structure, with many folds and protrusions, and it functions as the copulatory organ enabling deposition of spermatophore upon the surface of thelycum. It looks like a compressed tube distally ending on each side with a

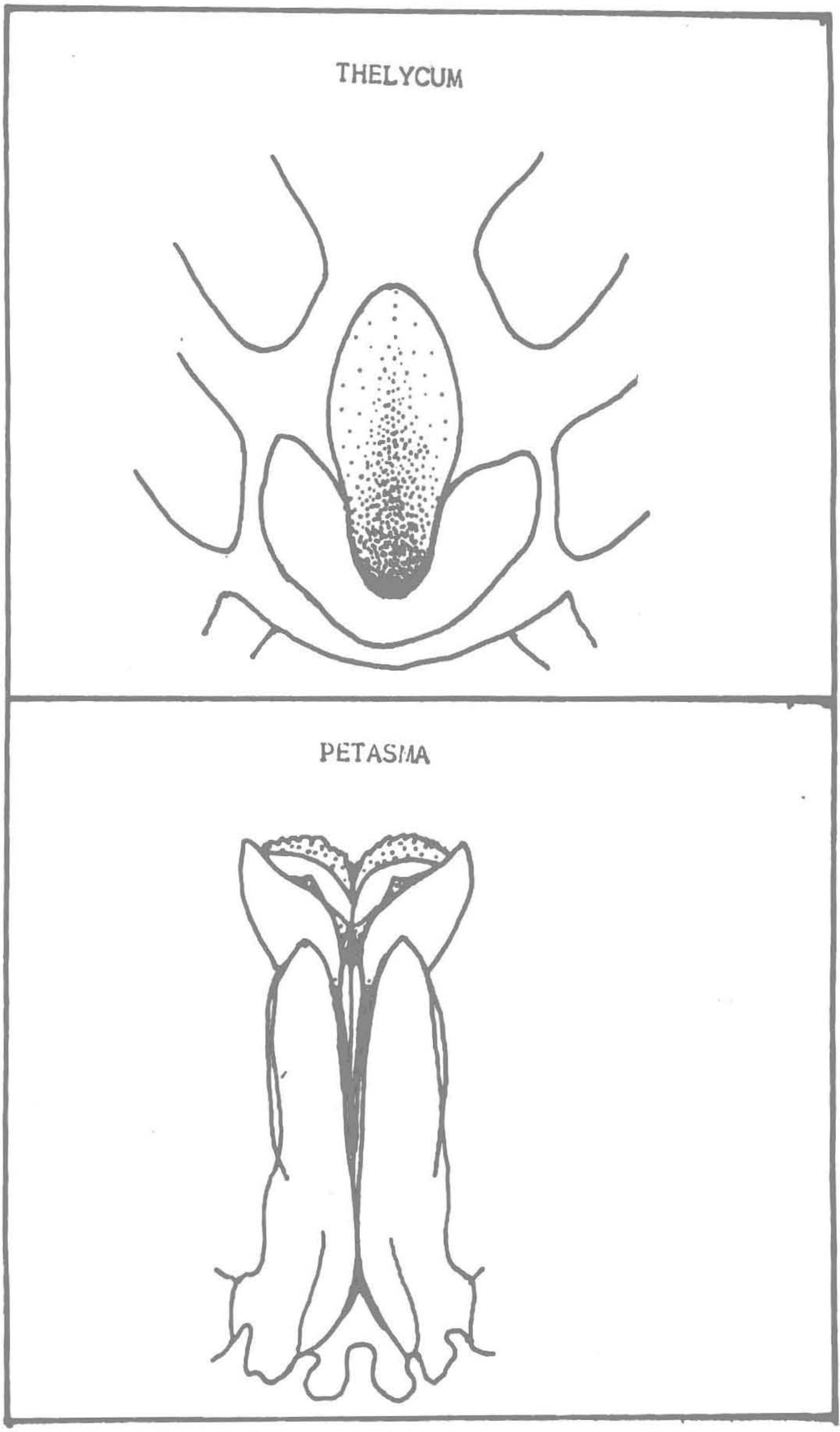


Fig. 1. External genitalia of M. dobsoni (adults).

rounded spout-shaped with corrugated edges and two blunt and stout filaments are present at the origin of each spout. Thelycum is the complicated sternal structure with troughs and ridges and its main components are the median tongue-like plate with a concave surface on the exposure side and the horse-shoe shaped transverse plate, which ensheaths the median plate antero-laterally from behind. The posterior depression in the concave surface of the median plate and the crevices between median and transverse plates are usually the spots, where the spermatophores are anchored in impregnated females.

The development of petasma can be traced from animals shortest by 15 mm length, when the structure is a foliaceous process at the middle of protopodite of the first pair of pleopods. Development and modifications follow the animals' growth in size. Adult features are attained usually around the size of 50-55 mm, and these animals normally migrate to the sea after one or two moults and the corresponding size increase.

Sequences of changes, that occur during the development of this species have been adequately

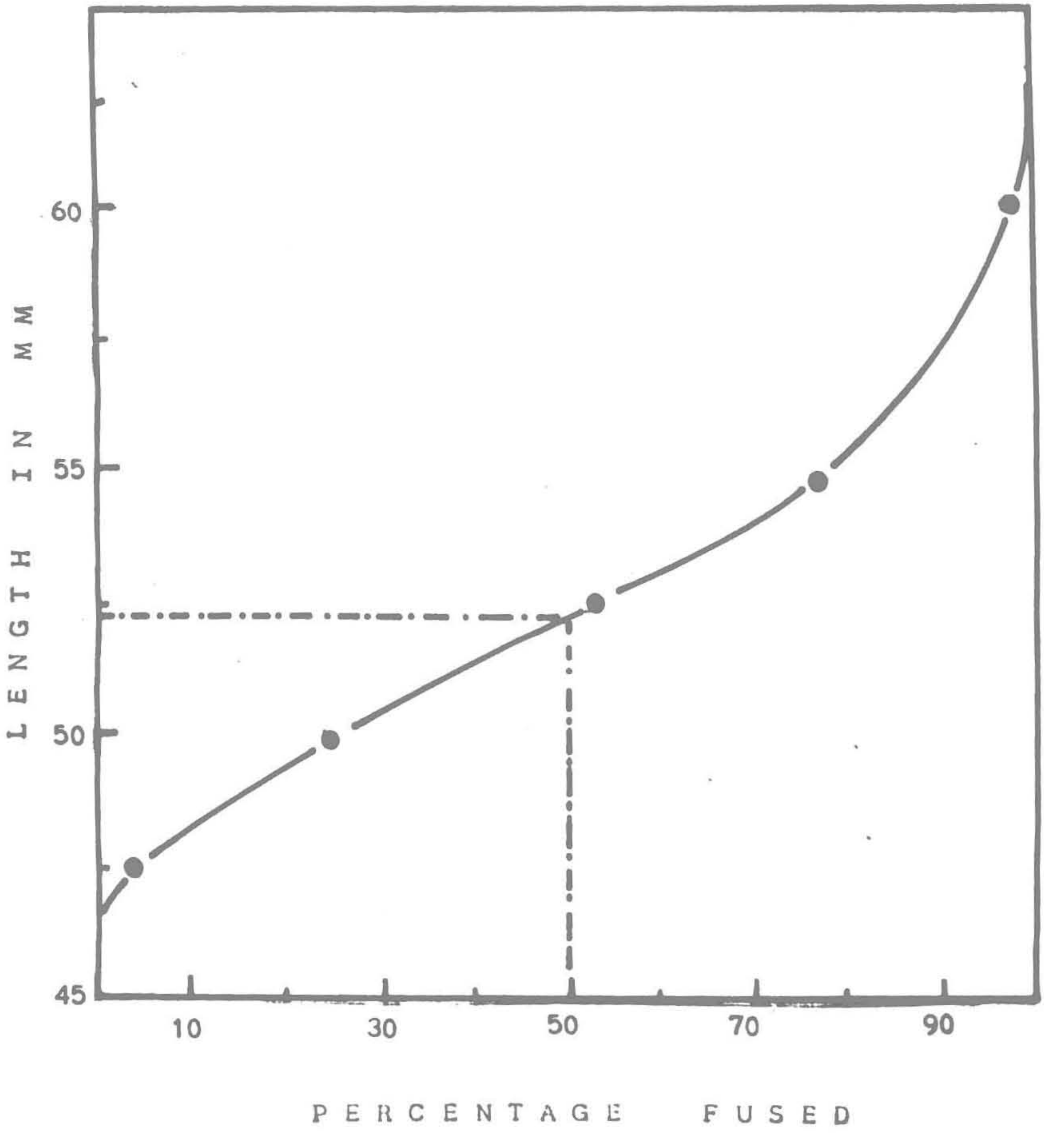


Fig. 2. Size at fusion of petasma in males.

described by Menon (1951) and George and Rao (1968). Development in size of the lateral lobes, formation of longitudinal folds and ridges of them and convergence of them towards each other are the major changes occurring while the animal grows from 25 to 45 mm sizes and interlocking of lateral lobes, distal modifications into spouts and growth of filaments follow at size between 40-45 mm and 50-55 mm. Further changes are only enlargement in overall structures and hardening to more rigidity at every successive moult.

The development of thelycum may be traced from 20 mm length, when the median plate appears as an elongated ridge and later, a transverse groove and ridge follow to form behind the median ridge. At the size of 40-45 mm the median ridge has slowly expanded antero-posteriorly while the transverse ridge has increased antero-laterally on either side of the median plate. And at 50-55 mm size the median plate has developed the concavity, while the posterior transverse plate has taken the shape of a horse-shoe, expanding slightly at the distal ends. Further growth is only the enlargements with the size increase of the animal.

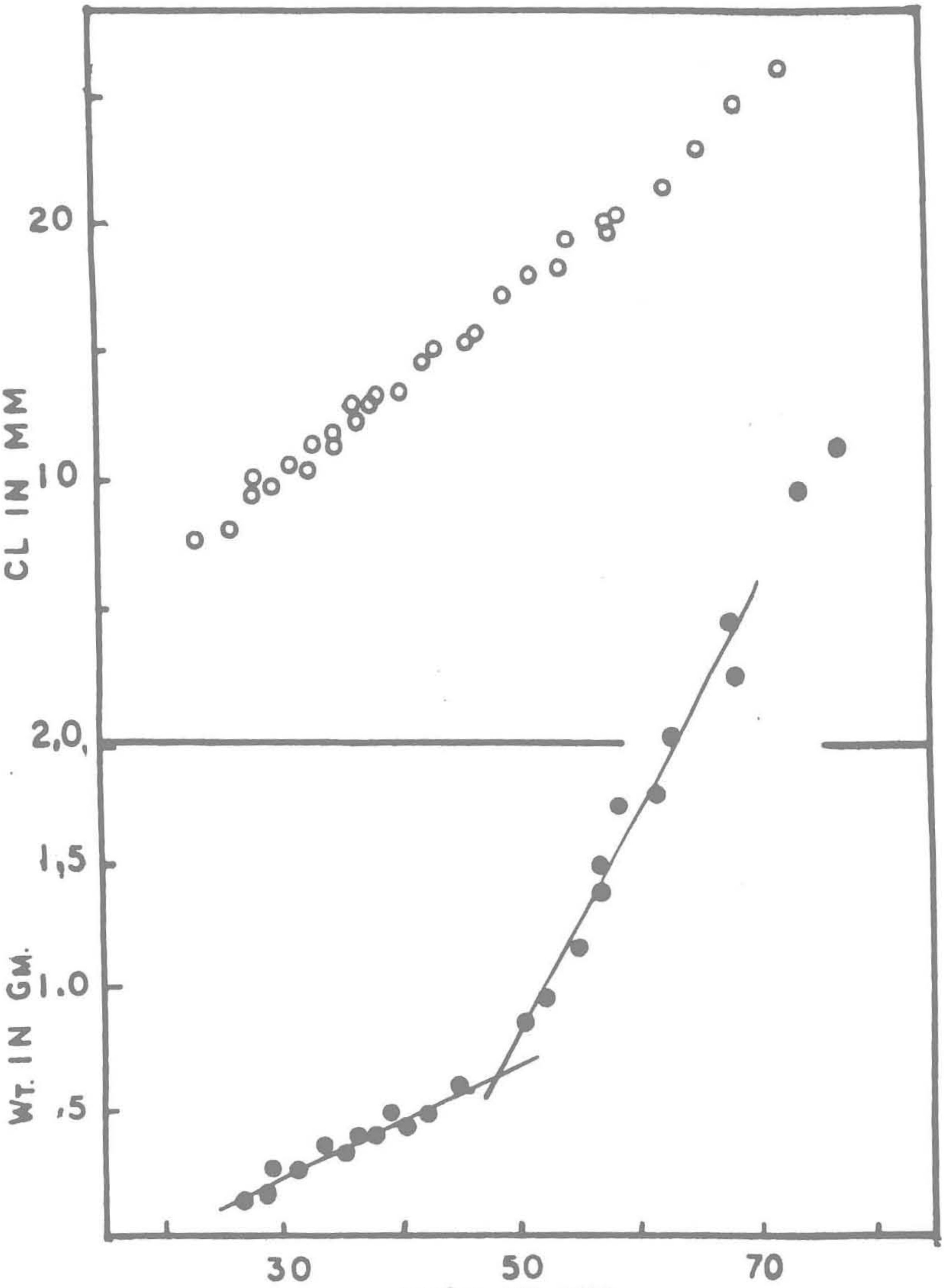


Fig. 3. Carapace length (above) and weight (bottom) against length of juvenile males.

The size, at which the adult features (fusion of lateral lobes) are attained, varies among the individuals, though synchronization within a narrow size range is obvious among large proportions of animals. The smallest such male recorded is 49 mm size in estuary and 48 mm among those reared in the laboratory and, however, males upto 59 mm size has been noted with unfused petasma. In marine catch, all males have been found with fused petasma and the smallest individual is 47 mm long with more rigid petasma than found in estuarine animals.

The percentage males with fused petasma against size give a positive linear slope in the form of a compertz curve and the 50% of such males fall at 54 mm length (Fig. 2). Similar size frequency distributions of the females attaining the adult characters are difficult for the doubtful nature of the transition as in males. However, the onset of reproductive phase towards the end of formation of the genital organs is evident in either sex from the upward tilts in linear slopes for length-weight relationships, being noted at 47 mm in male (Fig. 3) and 54 mm in female (Fig. 4).

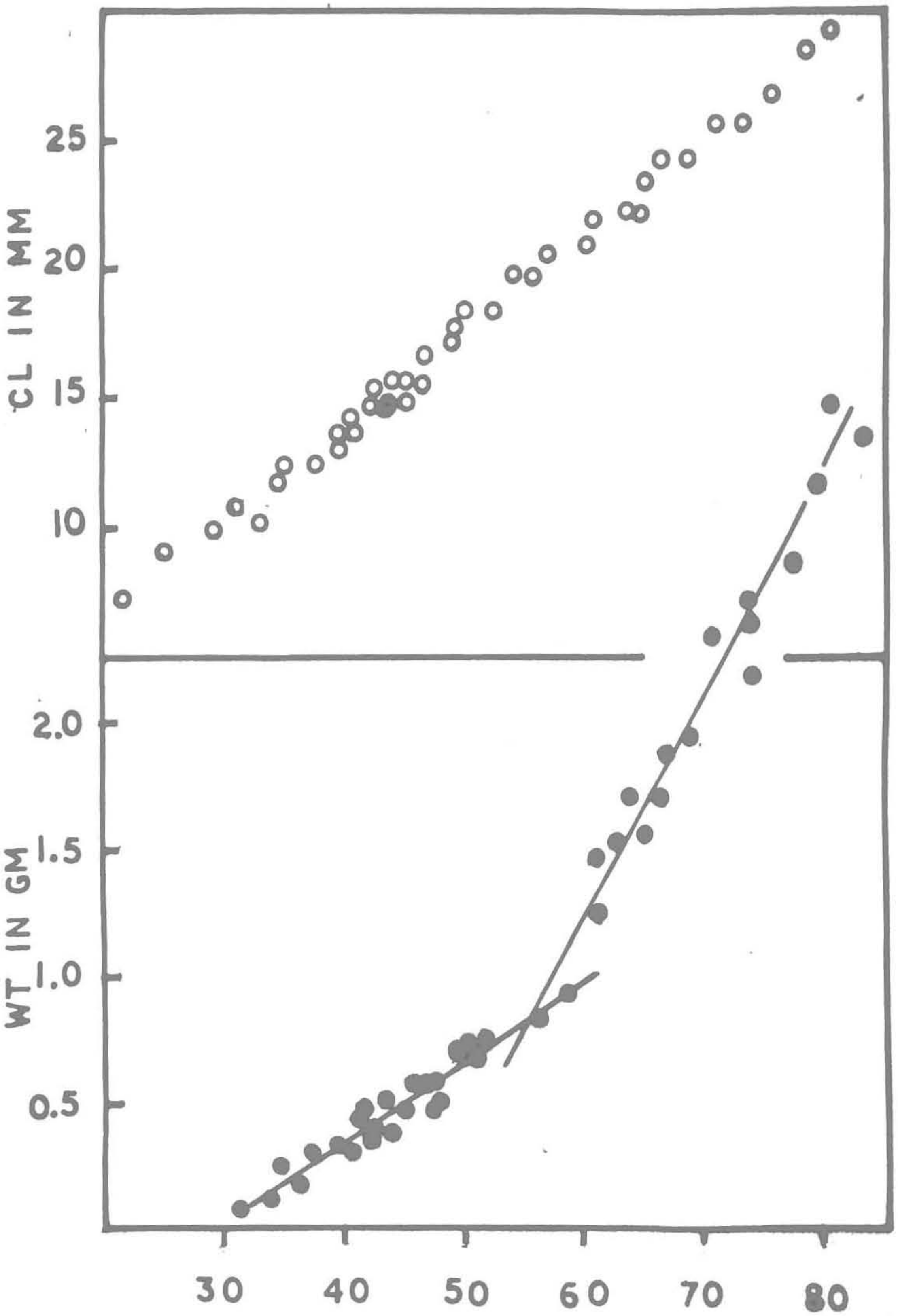


Fig. 4. Carapace length (above) and weight (bottom) against length of juvenile females.

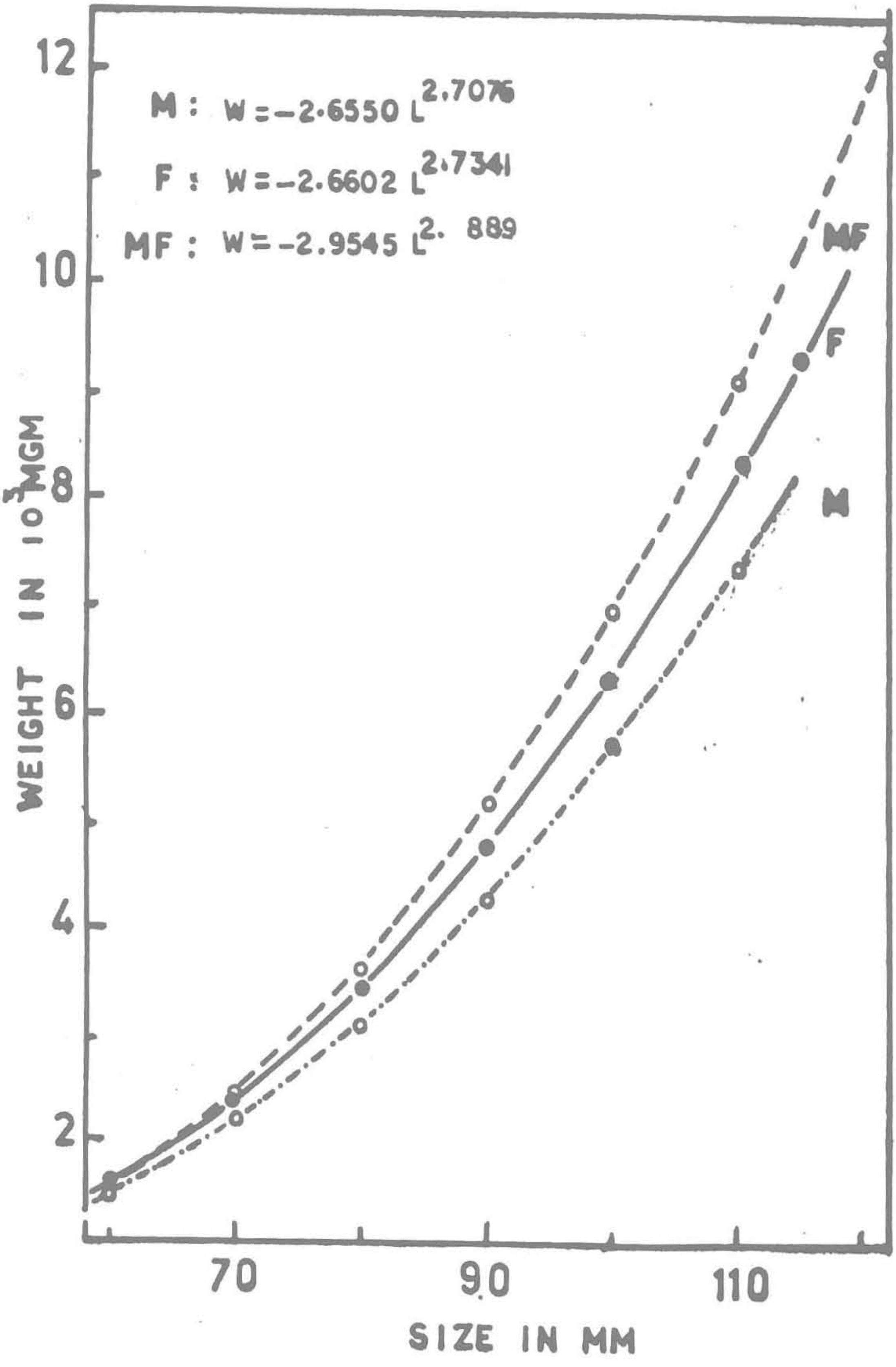


Fig. 5. L/W relationship of adults.
(M - Male; F - Female; MF - Mature female)

b. L/W Relationship

Adult males and females seem to have different weight at any specific length. The length-weight relationships of both sexes are in the form of a non-linear power function, $W = A\ L^b$, (Vivekanandan and James, 1986). which can also be explained in the linear or logrithmic form as: $\text{Log } W = \text{Log } a + b \text{ Log } L$, where W is the weight in mg; L, the length in mm and a and b are regression constants. The equations so calculated from the observed mean-weights against size are:

Reference given at the end.

Male : $\text{Log. } W = -2.6550 + 2.7067 \text{ log. } L$

Female : $\text{Log. } W = -2.6602 + 2.7341 \text{ log. } L$

From this the weight at different sizes have been estimated and presented in Fig. 5. It is evident that females in general are heavier than males and the older animals become plumper. The weight difference between male and female also increases with size, as noted that the disparity of 240 mg at 70 mm size gradually increases to 506 mg at 90 mm and 920 mg at 110 mm length.

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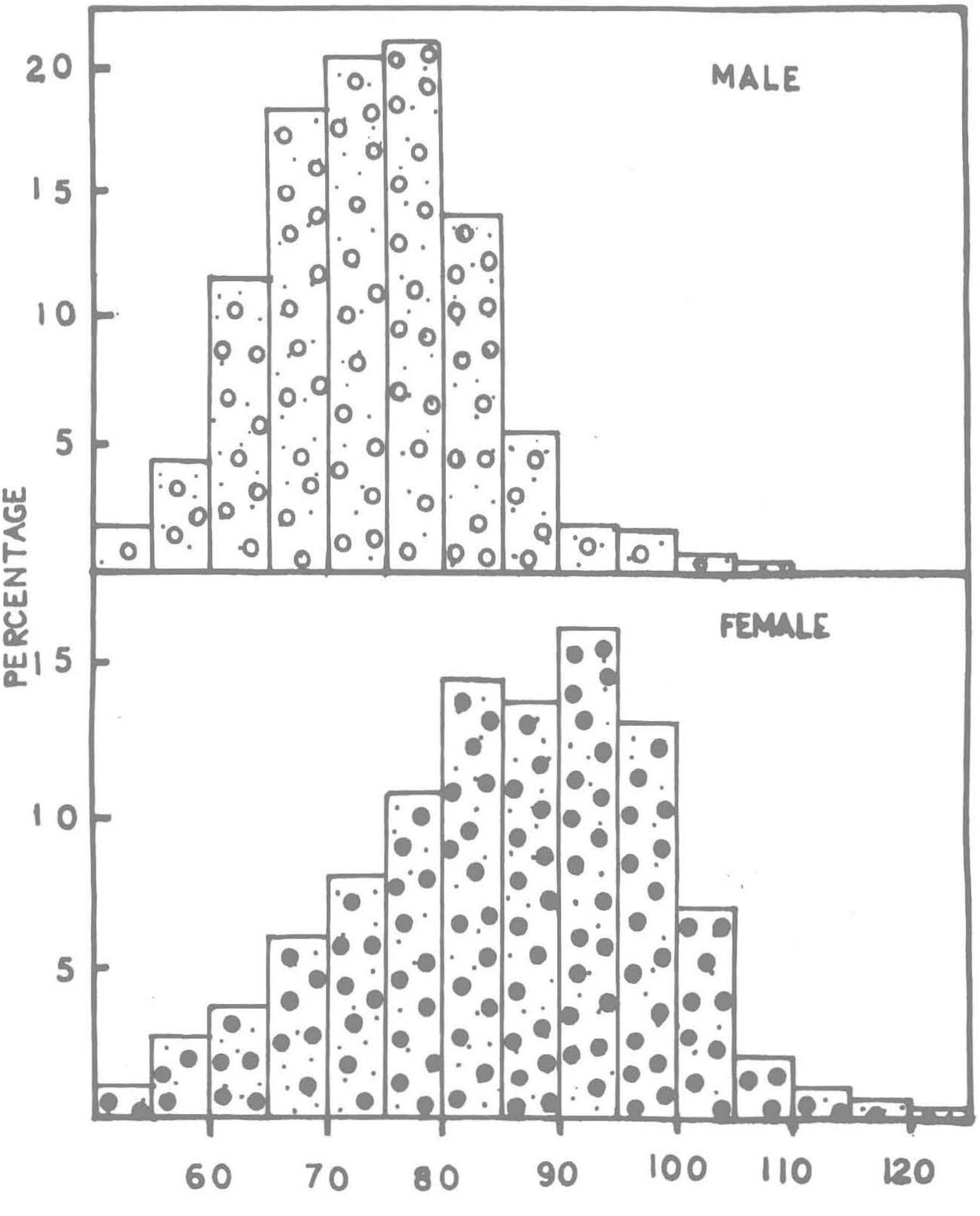

Fig. 6. Overall size distribution in samples.

Table 1: Mean size and sex-ratio of commercial populations of *M. dobsoni* landed at Madras

Months	Mean size (mm)				Sex-ratio (%)	
	1981		1982		1981	1982
	M	F	M	F	M : F	M : F
January	76.4	80.2	77.3	86.4	13 : 87	28 : 72
February	81.2	84.5	78.2	83.4	53 : 47	41 : 59
March	76.2	81.3	76.6	87.5	43 : 67	22 : 78
April	81.5	88.7	71.8	78.6	48 : 52	47 : 53
May	76.7	89.8	76.2	80.5	47 : 53	33 : 67
June	15.1	85.8	77.6	88.6	52 : 48	44 : 56
July	77.0	93.2	82.4	97.9	49 : 51	39 : 61
August	83.1	95.1	86.7	94.4	41 : 59	42 : 58
September	81.5	98.1	76.4	86.3	30 : 70	32 : 68
October	75.7	86.8	79.4	90.4	60 : 40	26 : 74
November	73.1	77.7	78.1	80.8	21 : 79	48 : 52
December	83.1	90.9	72.9	84.9	51 : 49	24 : 76

~~As~~ Sample size. given in Materials and Method (Page 21).
50 specimens for each weekly observation. ie N = 200.

c. Size Distribution

Sexual dimorphism in size distribution is clear from Fig. 6, which has been drawn for the marine populations landed in commercial catches pooled for all seasons. Though the populations range mostly between 56-100 mm in male and 56-115 mm in females, large numbers belong to 61-85 mm and 76-100 mm length respectively. Females are relatively larger in population and the disparity is more obvious among older groups. It is so evident that females upto 122 mm size are available in catches, whereas males over 110 mm size do not occur. The overall size distribution is unimodal (Fig. 6).for both sexes and the peak, at which the highest number of individuals occur, is noted at 76-80 mm for male and at 91-95 mm for female. About 60% of either sex belongs to the age group 6-12 months (82.3-109.6 mm for female and 76.1-100.7 mm for male) and only about 2% of the populations belong to more than 1 year age group. The monthly mean-size of the populations in fishery (Table 1) has been estimated to vary between 71.8 mm and 86.7 mm in males compared to 74.7 mm and 99.4 mm in females.

d. Age and Growth

Size between sexes at specific ages differs and the difference increases with age. The individuals of the same brood or age with enough strength form a distinct size-mode and their growth pattern could be traced through several months and connecting appropriately these modes into mode-chains, the growth-rate at different sizes could be calculated. Growth-rates of M. dobsoni, as in anyother animals, are usually age-specific and both sexes follows slow-fast-slow pattern, which could be fit into the popular von Bertalanffy growth equation,

$$Lt = L\infty [1 - e^{-k (t - t_o)}]$$

where,

t = age in months,

Lt = length in mm at age 't',

$L\infty$ = asymptotic length, when growth-rate is zero,

K = rate at which Lt approaches $L\infty$, and

t_o = theoretical age at which Lt equals zero.

The equation is calculated using Gulland and Holt method, which is basically the regression analysis of instantaneous growth-rate (y) on mean-length (x) of different

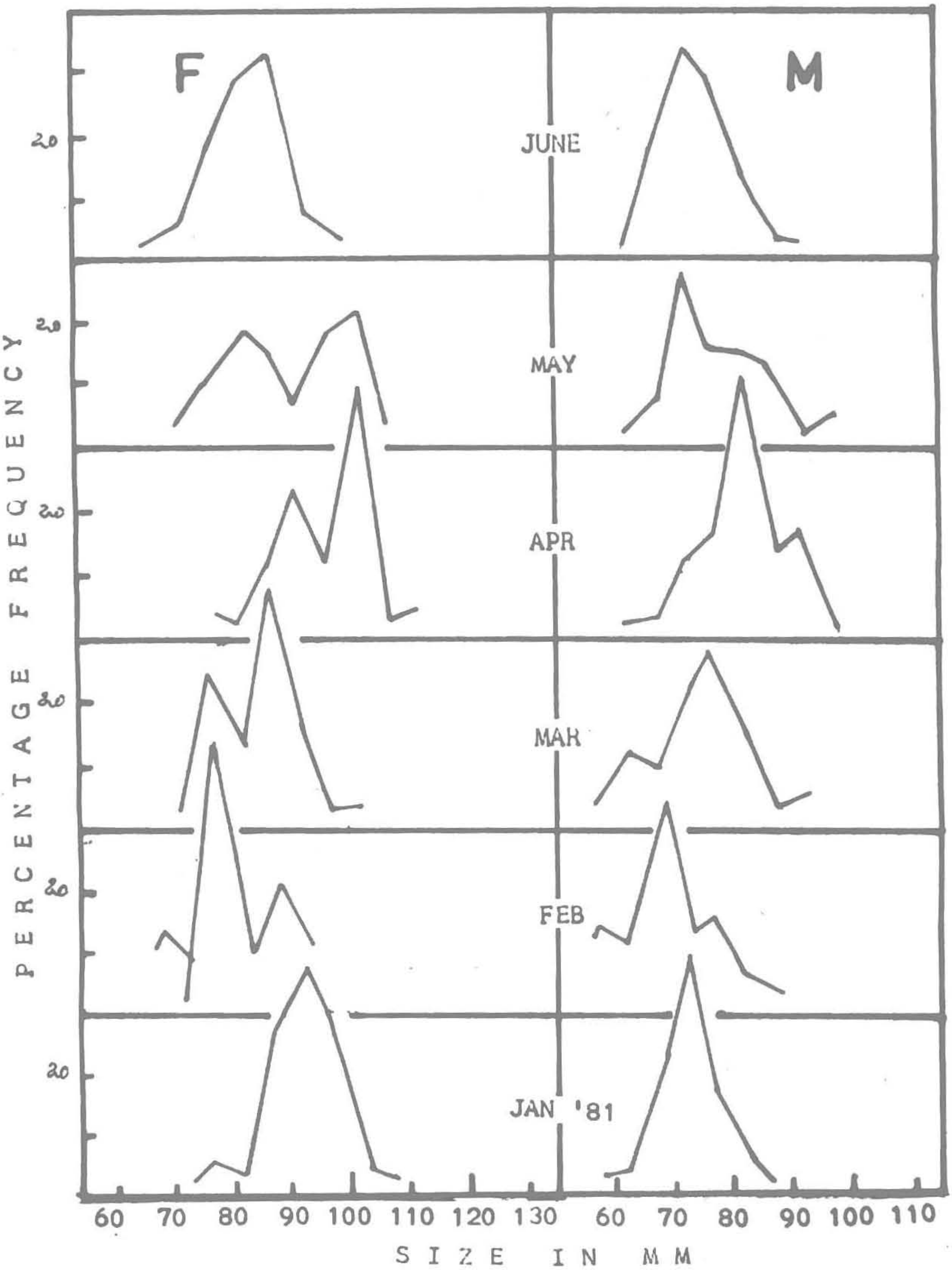

Fig. 7a. Length-frequency distribution (January 1981 to June 1981).

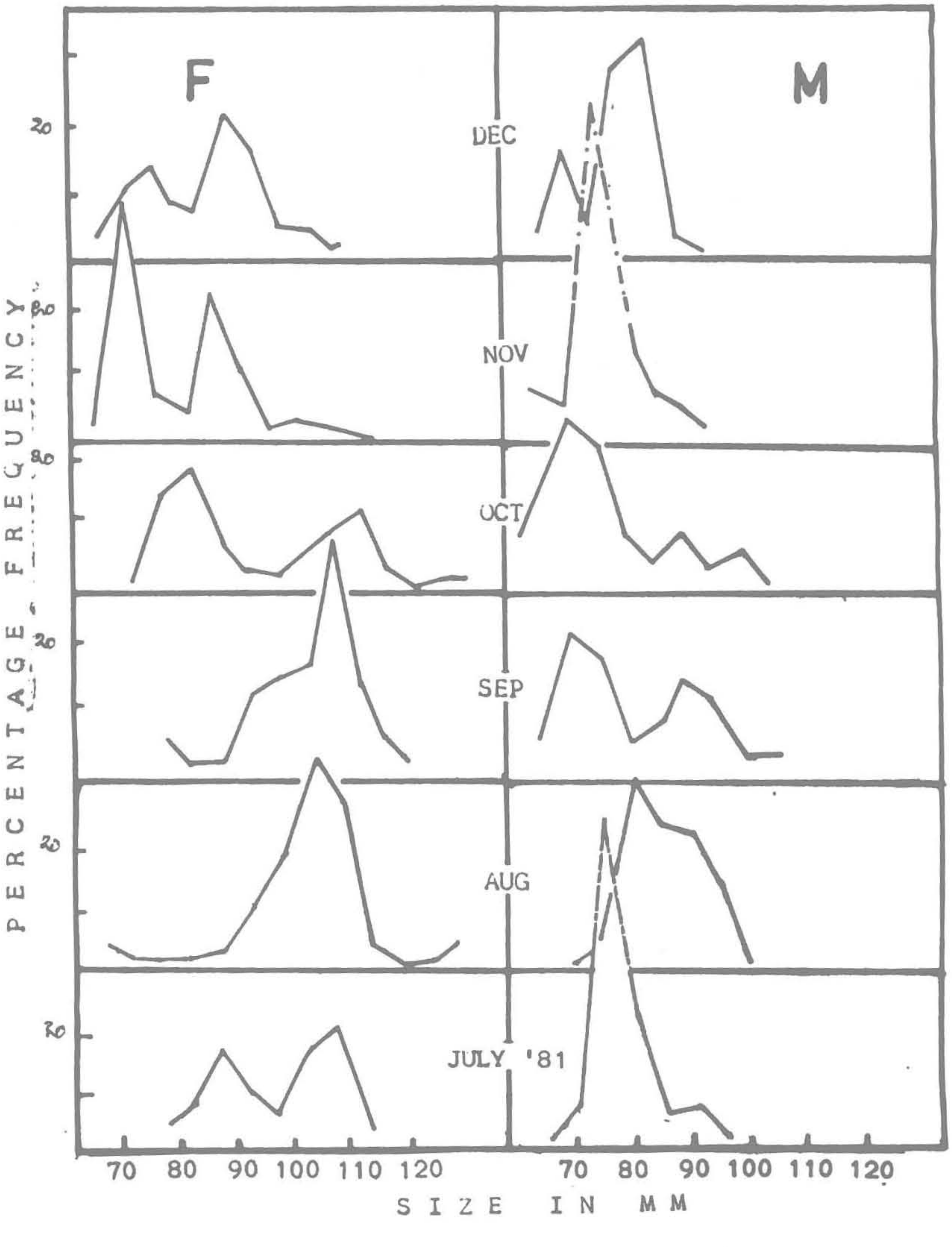

Fig. 7b. Length-frequency distribution (July 1981 to December 1981).

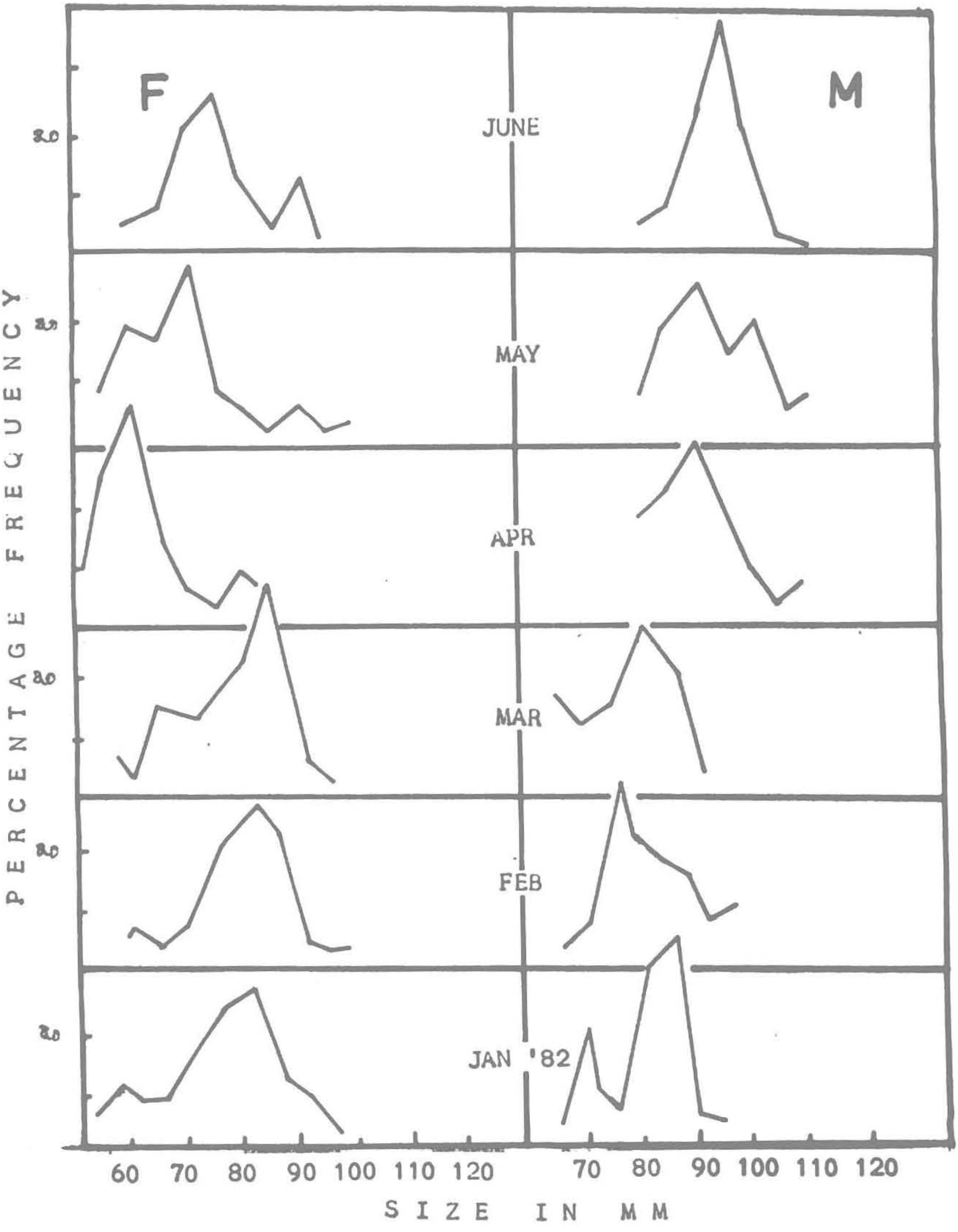

Fig. 7c. Length-frequency distribution (January 1982 to June 1982).

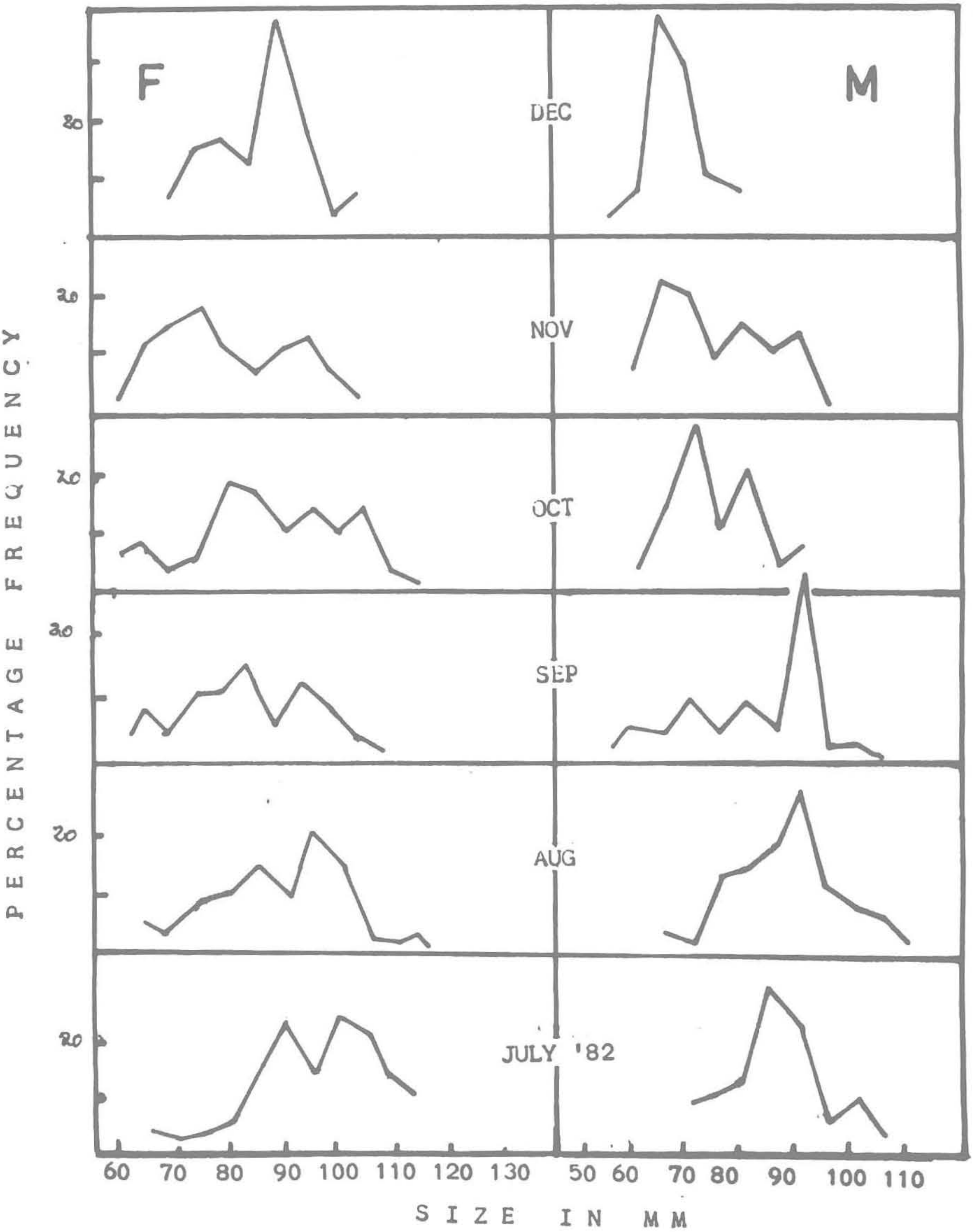

Fig. 7d. Length-frequency distribution (July 1982 to December 1982).

mode-chains, which are appropriately selected from the size frequency polygons, in such a way that a wide range of size-modes are included. The von Bertalanffy growth equation so computed are,

✓ for Female : $L_t = 129.20 \, [\, 1 - e^{-\,0.1601\,(\,t\,+\,0.6206\,)}\,]$

✓ for Male : $L_t = 112.93 \, [\, 1 - e^{-\,0.1832\,(\,t\,+\,0.1181\,)}\,]$,

from which the size at ages have been estimated and presented in the Fig. 7. The sizes in mm at ages are,

Month	Male	Female
6	76.0	82.3
12	100.6	109.8
18	108.0	121.9
24	111.5	126.2

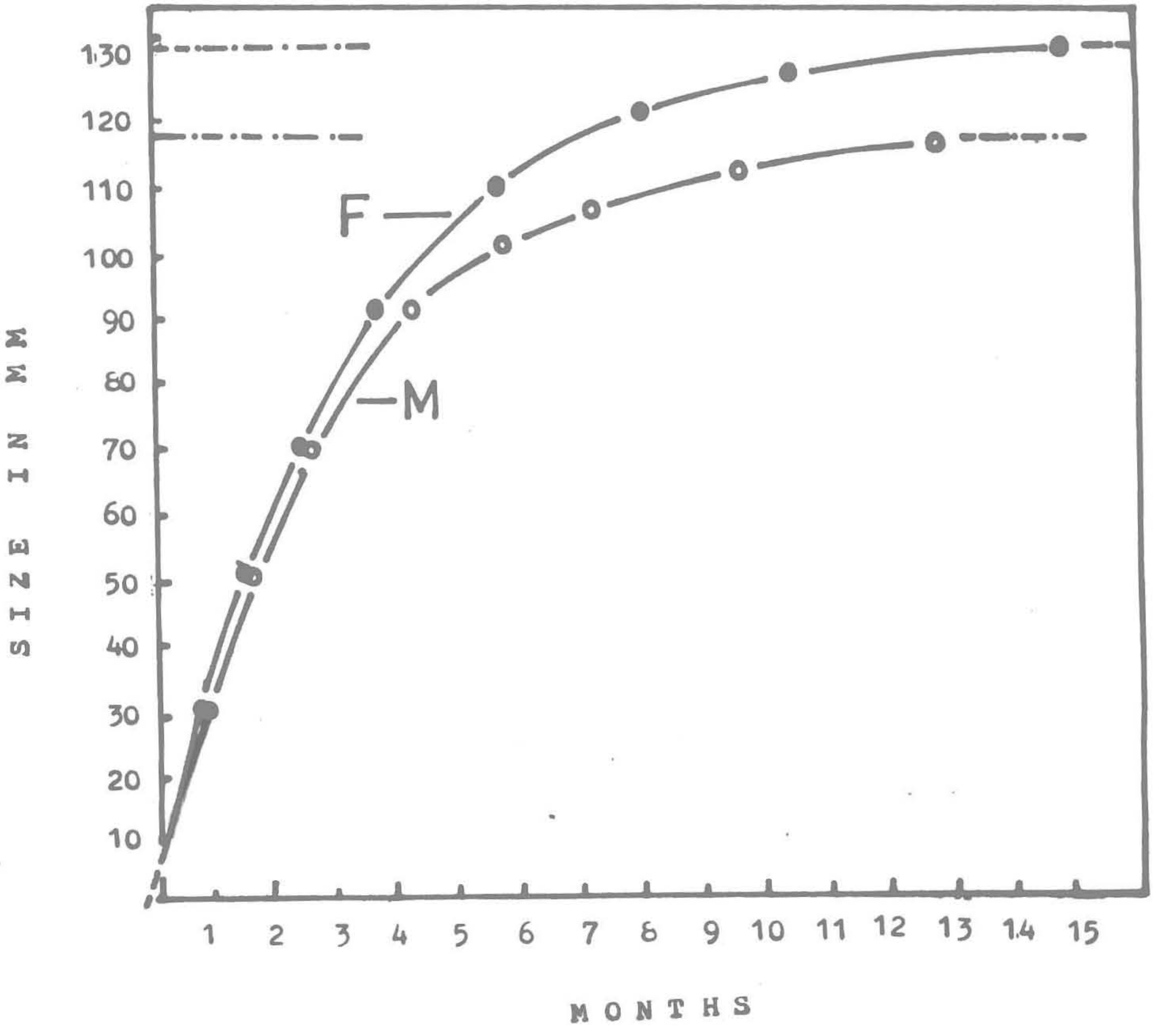

Fig. 7. Age and growth of *M. dobsoni*.

2. SEXUAL ANATOMY

The gross anatomy of the gonad shows the adult female has a pair of ovaries, which are partly fused and bilaterally symmetrical. Each ovary has a slender anterior lobe, a middle lobe with 6 or 7 finger like lateral lobules and a posterior lobe, which extends the entire length of the abdomen. The oviducts are short and narrow tubes connecting from the tip of the 6th pair of lateral lobules of ovary to the genital pores at the coxa of 3rd pair of pereopods.

In adult males, the testis and vasa deferentia are paired, of which the former is a translucent organ with a main body having lateral projections in the front regions and a pair of posterior lobes running through the entire abdominal length. The vasa deferentia arise from the posterior margin of either side of the main body of testis and open as genital pores at the coxa of 5th pereopods.

3. MATURATION AND SPAWNING

a. Maturity Stages

In females, based on the size, colour, texture and histological changes of ovary, five maturity stages have been arbitrarily classified as follows:

Stage I 'Immature': Ovaries are thin, transparent and not visible through the dorsal exoskeleton. On exposure, the ovary is like a colourless strand and histology shows that ova are uniformly small spherical bodies, which stain blue with haemotoxylin-eosin ([illegible]). The ova measure less than 0.07 mm.

Stage II 'Early mature': Ovaries appear as thin linear bands, which can be seen through the exoskeleton against strong light. On dissection, the anterior portion of the ovary is slightly expanded in size and colour changed to slightly yellow. All ova still stain blue with haemotoxylin-eosin stains ([illegible]) and their sizes vary from 0.07 to 0.17 mm.

Stage III 'Late mature': Ovaries are quite visible through exoskeleton as a thick dark band and on exposure, the anterior portions are considerably expanded and the posterior lobes enlarged in size. The texture of the ovary has become granular and colour into light green. Histologically, two groups of eggs are present, one smaller staining blue and another larger staining red with haemotoxyline-eosine stains ([illegible]). The size of ova varies between 0.15 and 0.23 mm in diameter.

Stage IV 'Mature': Expanded portion of the ovary is larger and distinct and the posterior linear band is thicker. On dissection, the ovary appears dark green and the texture more granular. The ovaries have enlarged so much that they occupy the body upto 10% by volume and 7% by weight. Most of the ova are fully matured, staining red with haemotoxyline-eosin stains and possess radial bodies. The size of the ova varies from 0.17 to 0.30 mm, and slightly bigger matured eggs are noted in larger females. The mean-size of the egg

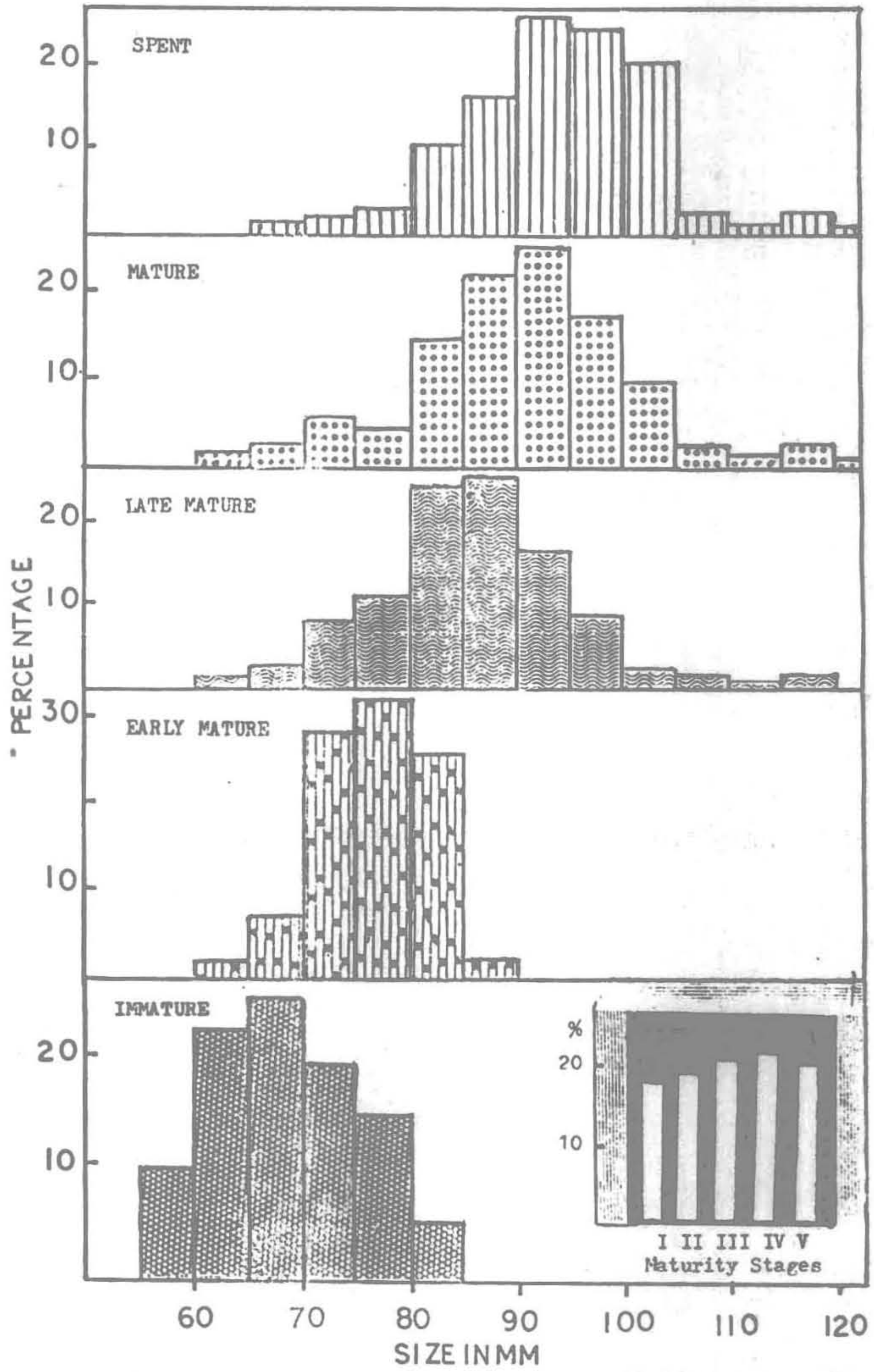

Fig. 8. Size-distribution of different maturity stages of female.

is calculated at 0.21 mm for females below 85 mm length compared to 0.25 mm for 95 mm long females.

Stage V 'Spent': Completely spawned ovaries appear outwardly as 'immature' stage and on dissection they are flaccid and yellowish cream in colour. Remains of unspawned eggs are evident and fresh batch of small eggs are common. The smaller eggs present stain blue with haemotoxyline-eosine and the egg size is less than 0.08 mm.

The differences of maturity stages of males are not so apparent as in females. The mature males may be sometimes ascertained from the presence of spermatheca in the terminal ampules at the basis of 3rd pereopods.

N: 200. (Page 22).

The overall percentage distributions of maturity stages of females (Fig. 8) reveal that the proportion of maturity stages in marine populations do not vary significantly. However, gradual increase in proportions with maturation of ovary dips again at 'spent' stage, though the widest margin is only about 5%

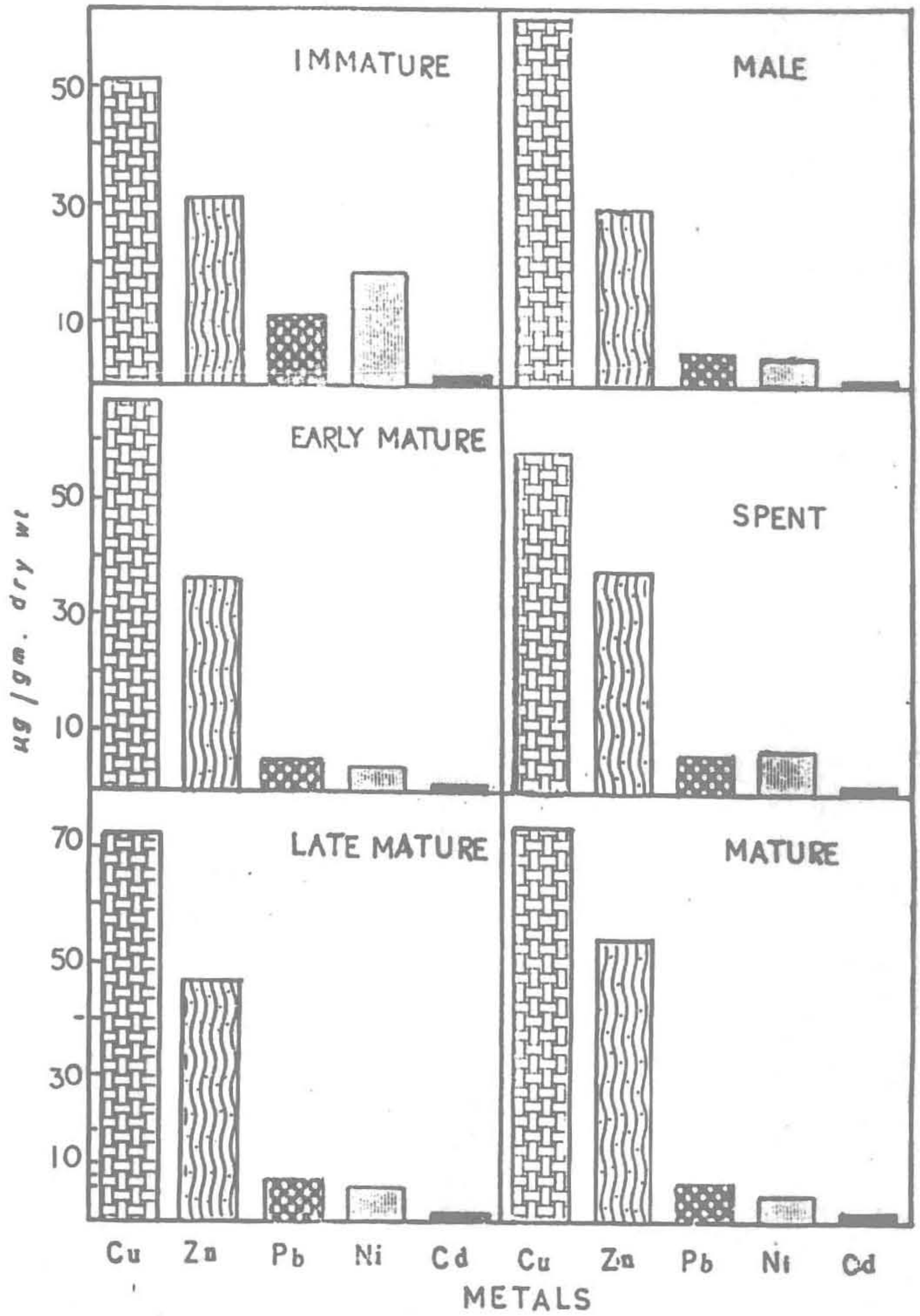

Fig. 9. Different maturity stages of female and male with trace metal concentrations.

between the minimum for 'immature' and maximum for 'mature' stages.

The size distributions (Fig. 8) of different maturity stages of females in marine catches show that the mean-size increases positively with maturation and spawning of eggs in ovaries. 'Immature' and 'early mature' are [redacted] closer in size range and so are the 'mature' and 'spent'. In particular, the pattern of size-distributions of 'early mature' are narrow between 81 mm and 90 mm, as against the 'late mature' through 'spent' recovery noted upto 121-125 mm size-class. Most of the immature populations belong to 61-75 mm size, eventhough their size-range extends from 56 mm to 85 mm.

b. Trace Metal Concentration on Maturation

Concentrations of heavy metals analysed for different maturity stages of female and also male vary considerably (Fig. 9 and 10) and a few of them are noted to reveal an interesting pattern of distribution. Contents of copper, followed by zinc, which are most abundant metals in all categories of animals, are

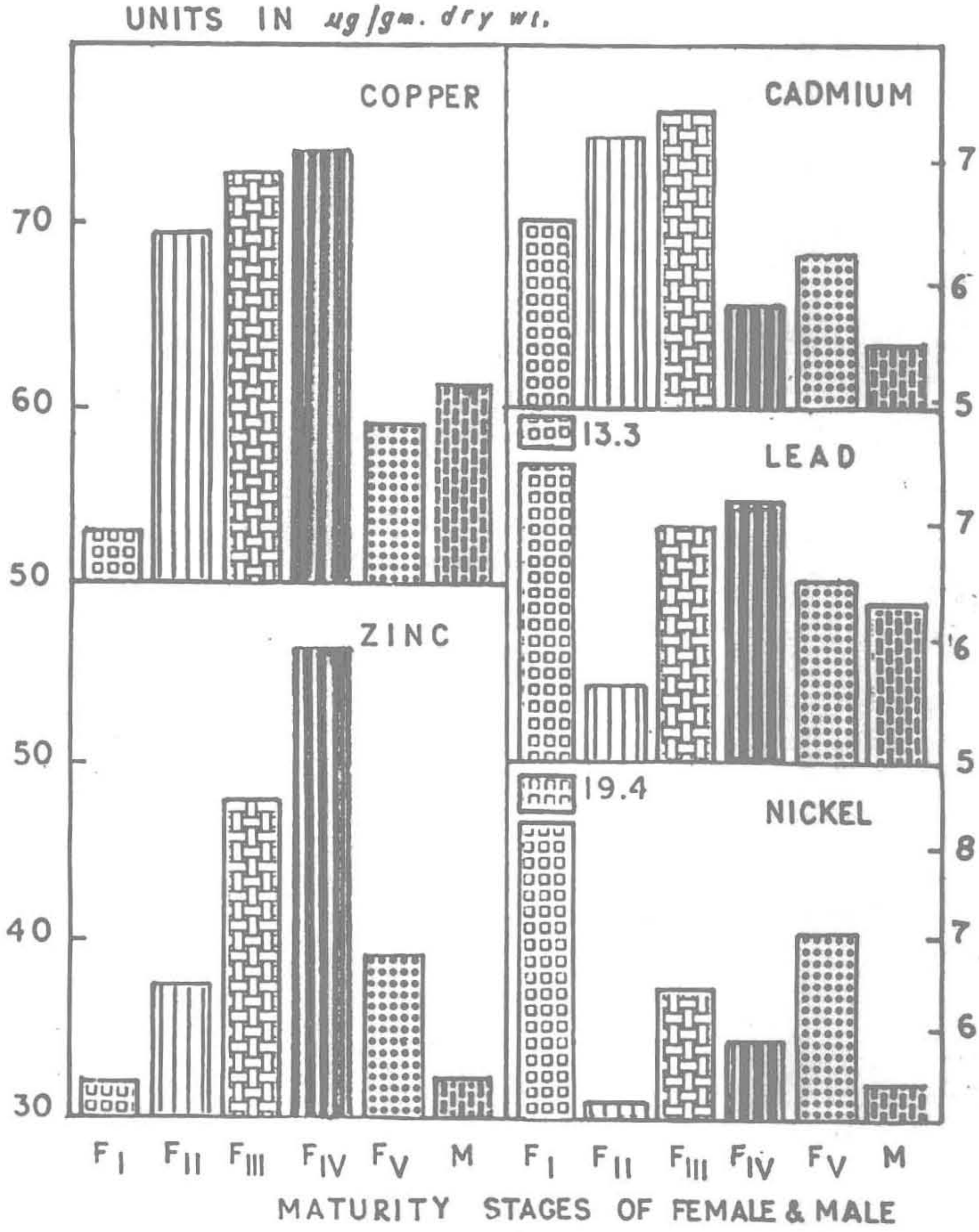

Fig. 10. Trace-metal concentrations among maturity stages of female and male.

particularly observed to present a positive relationship against the degree of egg developments in ovary. Both these two metals gradually accumulate from 'immature' through 'mature' and decline to early levels in 'spent' forms. Contents of copper are estimated to progressively increase from 52.75 µg/gm dry wt in 'immature' to 73.50 µg/gm dry wt in 'mature' and decrease then to 64.95 µg/gm dry wt in 'spent' and respectively zinc contents are calculated from 32.50 µg/gm dry wt to 66.25 µg/gm dry wt and then to 38.75 µg/gm dry wt in 'spent' females.

Metal burden of both lead and nickel are exceptionally high in 'immature' as compared to other maturity stages of females. Lead, which measures at 13.28 µg/gm dry wt in 'immature', declines drastically to maintain between 5.55 and 7.28 µg/gm dry wt among any other categories and similarly, nickel reduces from 19.35 µg/gm dry wt in 'immature' to 5.07-6.85µg/gm dry wt in other kinds of females. Contents of lead and nickel, which are estimated respectively at 6.33 and 4.23 µg/gm dry wt, for male are more closer to the values of females with advanced stages of maturity.

Cadmium contents in all animals vary between 0.580 and 0.735 µg/gm dry wt without any notable relationships to maturations.

The relative abundance of these heavy metals in different maturity stages of female and male (Fig. 9) can be ranked as follows:

Female - 'immature' : Cu > Zn > Ni > Pb > Cd;
"early mature' : Cu > Zn > Ni > Pb > Cd;
'late mature' : Cu > Zn > Pb > Ni > Cd;
'mature' : Cu > Zn > Pb > Ni > Cd;
'spent' : Cu > Zn > Ni > Pb > Cd;
Pooled male : Cu > Zn > Pb > Ni > Cd.

It is, thus, clear that burdens of copper, zinc and cadmium are positioned first, second and last respectively in the order of abundance in all categories with obvious margins, as noted the former measuring over 50 µg/gm dry wt in all against cadmium less than 1.0 µg/gm dry wt.

c. Size at Maturity

Presence of developing stages II-IV of ovary can be considered the positive evidence of sexual maturity of females. Such mature females with developing ovary have not been noted from the estuarine catches, though the external genital organs are fully formed and mating too occurs there in larger juveniles. Under over impounded conditions than normal stay, few males with oozing spermatheca and impregnated females are noted in the nearby Covelong lagoon during summer month, May, when the salinity is about 30‰ and temperature, 27-28°C. But no females with developed ovary among them have been observed. Hence it can be inferred that the maturation process is triggered off at estuary itself and further development of ovary needs life at sea.

Though female as small as 47 mm with fully formed thelycum is recorded in marine catches, the smallest individual with 'mature' ovary measures 62.5 mm size. The proportion of mature females over this minimum size increases against the length and most of the females over 90 mm size are virtually mature with developing or spent ovaries. The frequency distribu-

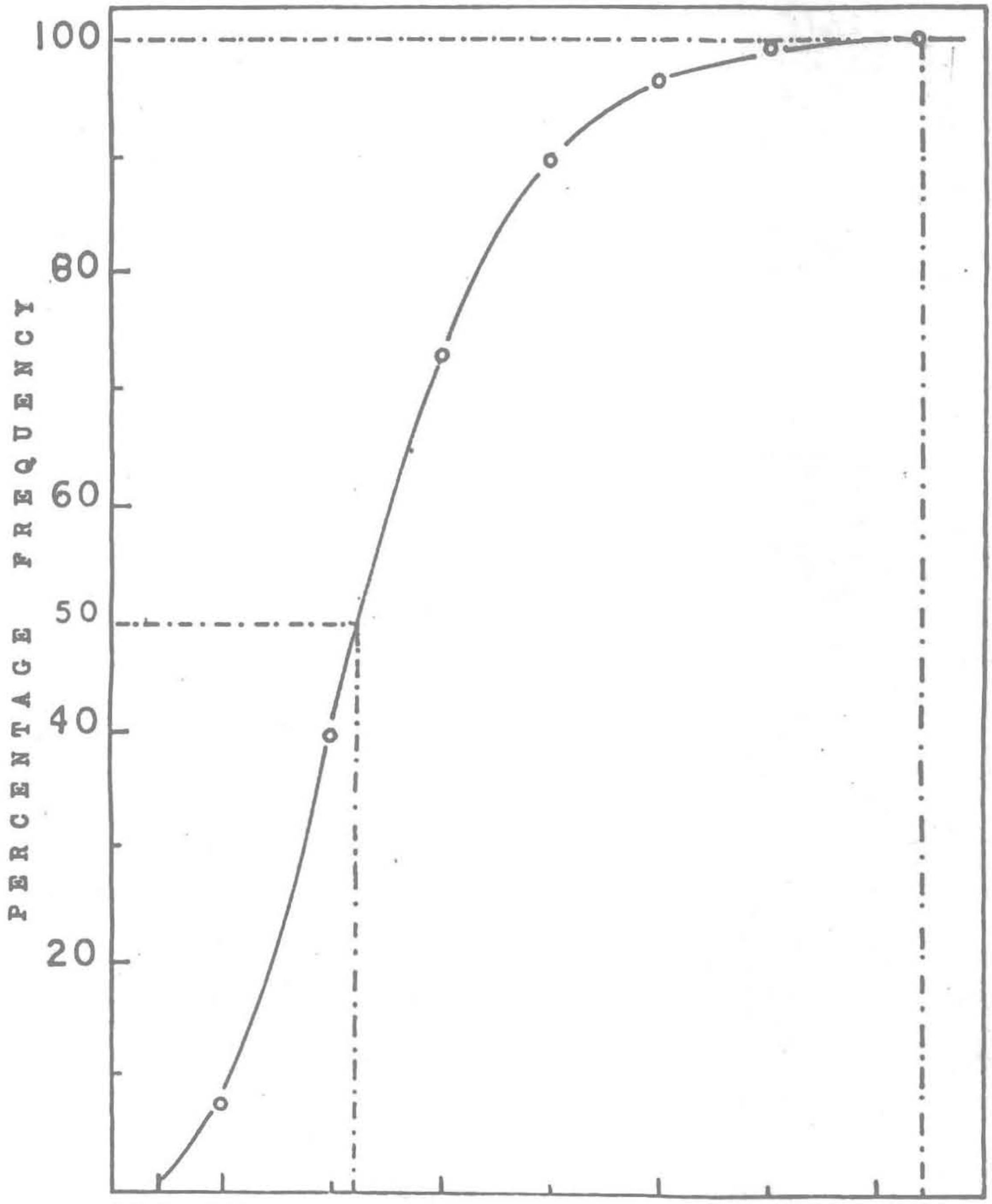

Fig. 11. Size at maturity of females.

tions of mature female, on plotting against size, appear a logistic form, fitting to a compurtz curve:

$$MF = 2.0011 - 1.1384\ (0.3550)^{L}$$

where, MF is the percentage mature female and L, the length in mm. Using the formula the percentage of mature female against sizes have been calculated and presented in the figure 11, from which it is clear that the minimum size at maturity of this species for all seasons is 60.3 mm; 50% at 69.4 mm and the maximum of 100% at slightly over 90 mm size. It is also obvious that about 75% of the females attain maturity at 65-75 mm size-ranges.

Also, it is noted that the size at sexual maturity is a function of season. The youngest modes, which can be considered the first time spawners or those in size at first maturity, shift with seasons against size. The general tendency (Fig. 12) is that the young females attain maturity at shorter sizes during the warm periods, April-June, as compared to wet seasons, September-December.

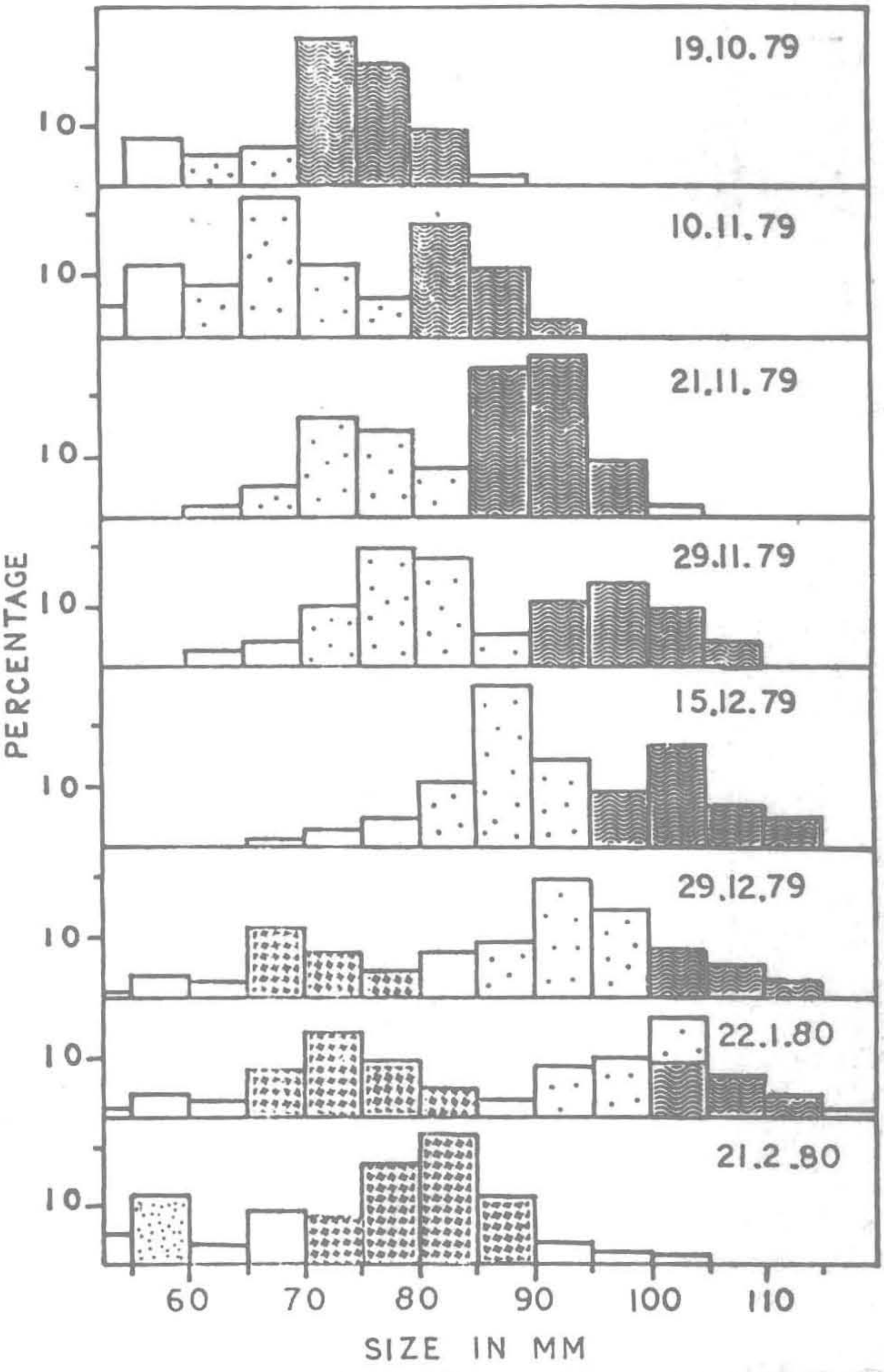

Fig. 13. Size-distribution and spawning periodicity in relation to different depth zones.

d. Maturation and Spawning Migration

Periodical experimental cruises off Cochin reveal that the post-monsoon fishery commences with only stray specimens from early November. The first wave of fishery actually extends from late November through January, with the peak catch in December. The date of cruises and the size distribution of pooled samples of female populations collected from three depth zones viz., ≤ 10 m, 15 M and ≥ 20 M depths, have been given in figure 12. It is evident clearly from the histogram for size distributions that three prominent broods constitute this first wave of fishery, of which the earliest stocklet, brood 'A', that commences the fishery, is slightly older group with its major size-classes at 76-85 mm, as on 19.10.1979. About 60% of them are then in 'late-mature' conditions and occur mostly within ≤10 M depth. Considering the size and the maturity conditions, this group can be assumed to be rematuring after an earlier spawning. It is traced to enter active spawning on 21.11.79, when the modal size has increased to 86-95 mm and about 72% of the females are either 'late-mature' or 'spent' conditions. Most of them are still remaining in $\leq$10 m depths, though some have dispersed towards 15 M depths and few numbers in 'spent' stages are recorded over $\geq$20 M depths. Occurrence of about 30% 'spent' females on 29.11.79 further substantiate the high spawning activities around the previous cruise mentioned. Next spell of spawning of this group is noted on 15.2.79, when the females have reached the modal size of 96-105 mm and about 80% of them are in 'mature' or 'spent' stages. Also, most of this have moved this time towards $\geq$20 M depths. This group becomes obliterated subsequently. Hence, since the previous spawning on 21.11.79, that is, after the lapse of about 24 days, this group enters the succeeding next spawning activities on 15.12.79 and can be otherwise considered as the duration of rematuration. Meantime, bathymetric movements, as the individuals grow older and mature, are also apparent. Though not more impressive as a mode, this group is again noted to be in advanced stages of maturity on 22.1.80, that is, after the lapse of 37 days. Hence, this group is traced to spawn four times before it disappears from the fishery, three times during observation and one possible spawning before commencement of the fishery.

The next, but, first fresh and strong brood 'B' meantime appears on 10.11.79, with its mode at 66-75 mm size and dominates till most part of this fishery wave. This group is found remaining 'immature' and some in 'early mature', while restricting within ≤10 M depths, on 21.11.79 and 29.11.79, while the other older group 'A' mentioned above has been in spawning activities and meantime moving towards slightly deeper waters. Thus, two sub-groups are not necessary to accomplish spawning simultaneously. However, this young group 'B' enters active spawning without moving to deeper waters on 15.12.79, when the modal size is at 76-85 mm and most of the females are in advanced stages of maturity. Hence, this group has required nearly about 30 days to enter its first spawning, that is, the maturation time lasts about 30 days since entry into the inshore catch. Again, it is noted that while this younger group restricts its spawning activities within ≤10 M depths, the earlier and older group, which is also in active spawning at this time, moves from 15 M to ≥20 M depths. Hence, synchronization of spawnings and spatial sharing are also apparent between the groups, older one going towards deeper waters. The group 'B' after the first spawning activities in 15.12.79, has been noted, to remature and enter spawning along with the earlier group around 22.1.80, with a lapse of about 35 dyas, while increasing the modal size to 91-100 mm, and good numbers have meantime moved towards deeper waters.

Yet one fresh brood 'C' appears in the catches on 29.12.79 with its modal size at 66-75 mm, mostly in 'immature' conditions remaining within ≤10 M depth. This group is also found to participate spawning activities in 22.1.80 limiting itself within ≤10 M depth, while the then dominent group 'B' is intensively spawning at deeper waters. Group 'C' is also noted to comprise larger proportion of 'mature' and 'spent' female in catches on 21.2.80, while increasing to 76-85 mm modal length and moving substantially towards 15 M depth. By this time, other two earlier groups have disappeared and the fishery has also gone very much down before regaining later from March till the culmination in April-May.

Thus, it is obvious from the overall picture of the three broods, which constitute the first wave of post-monsoon fishery after a long lapse or lean season

season, reveals that the earliest brood to appear is slightly older and spent group. The fresh broods require about a month before active spawning since entry into fishery and in all the groups, the duration of rematuration-cycle lasts about 20-40 days. Spawning occurs in all the three depth zones of ≤10 M, 15 M and ≥20 M, but older spawners move towards deeper zones and most of them remain there for rest of life. Also, a single brood 'A' is traced to spawn at least four times before it depletes in strength to impress enough as a mode.

Improved conditions of salinity and temperature appear to trigger off breeding activities during post-monsoon periods. The salinity has increased from 20‰ to about 33‰ and temperature from 26°C to 29°C by the time when the first spell of spawning activity is noted after the monsoon lapse. These improved environmental conditions remain stready till the end of the first wave of post-monsoon fishery.

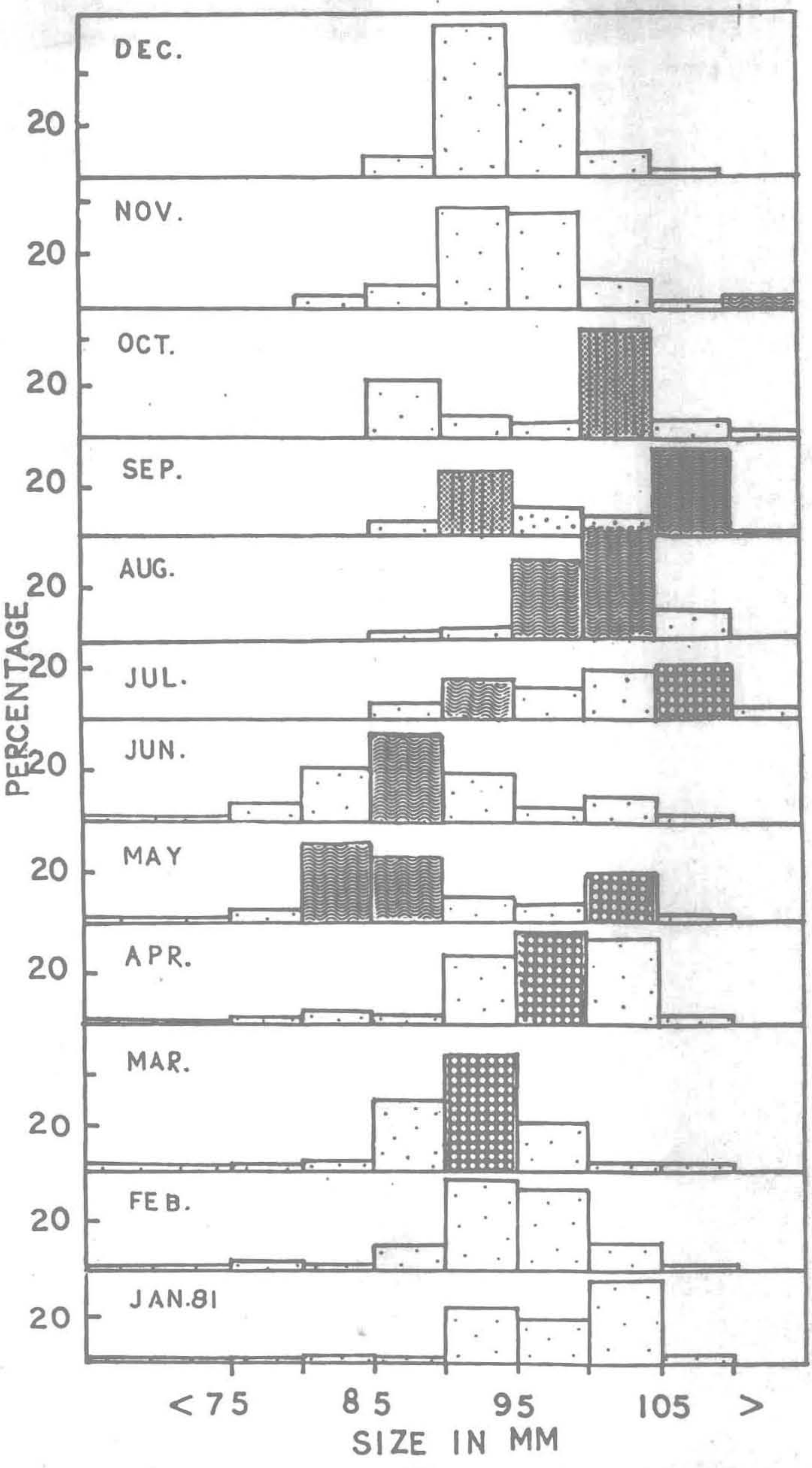

Fig. 12. Size distribution of spawners in different seasons.

e. Spawning Periodicity

The size-distributions of mature females (Fig.12) illustrate that the major groups, which are active in spawning, are present as distinct modes and their progression through successive months, indirectly indicates how often these groups participate spawning activities. Mass spawning by a single group more than once within the same breeding season or over more than one season is evident. The major spawning group in February, 1981 belongs to the modal-length 91-95 mm and, by its size, this group can be considered to be entering the second breeding season. The same group is later found dominant in March and April. Since 'mature' stage lasts a few days before spawning and rematuration requires less than a month, this group may be assumed to have spawned in all the three months, February-April. Successive two months, May and June, appear to be rest period and the next breeding season is initiated by the same group in July, when it has reached 106-110 mm modal size, though it obliterates in strength subsequently. Hence, this group may be believed to have seen through three breeding seasons, while spawning not less than five times.

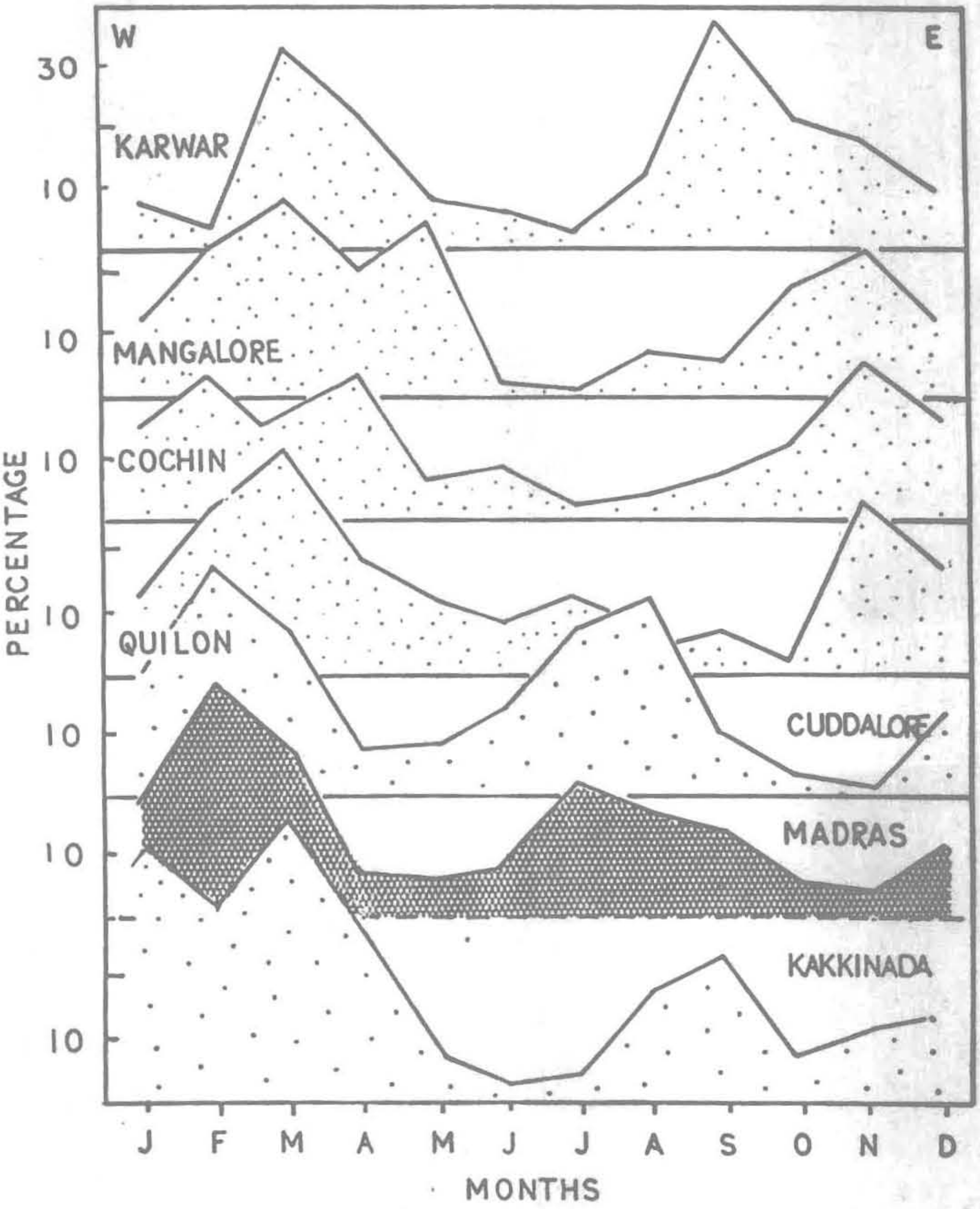

Fig. 14. Breeding seasonality along either coast of India.

Another young group with the modal-length at 81-90 mm is dominant in May-June 1981, though the spawning intensity is less. After a month's rest, the same group is noted actively spawning in August and September, presumably for two or three times. October is again recorded with poor spawning activities of this group, though slightly higher incidence of spawners is noted in November while reaching 106-110 mm size. Hence, this group also takes active part of spawning for a minimum of five times over three seasons involving about 7 or 8 months.

f. Breeding Seasons

Occurrence of 'mature' and 'spent' females in catches support year-round breeding activities of this species. However, preponderance of these two maturity stages (Table 3) indicates two annual breeding seasons, interrupted by the peak monsoon and mid-summer seasons. Also, the figure 14 reveals that each season commences with brisk spawning activities and continues moderately till the end of the season. It is, thus, seen that high incidence of spawning activities noted in July, 1981 extends moderately till September and October-

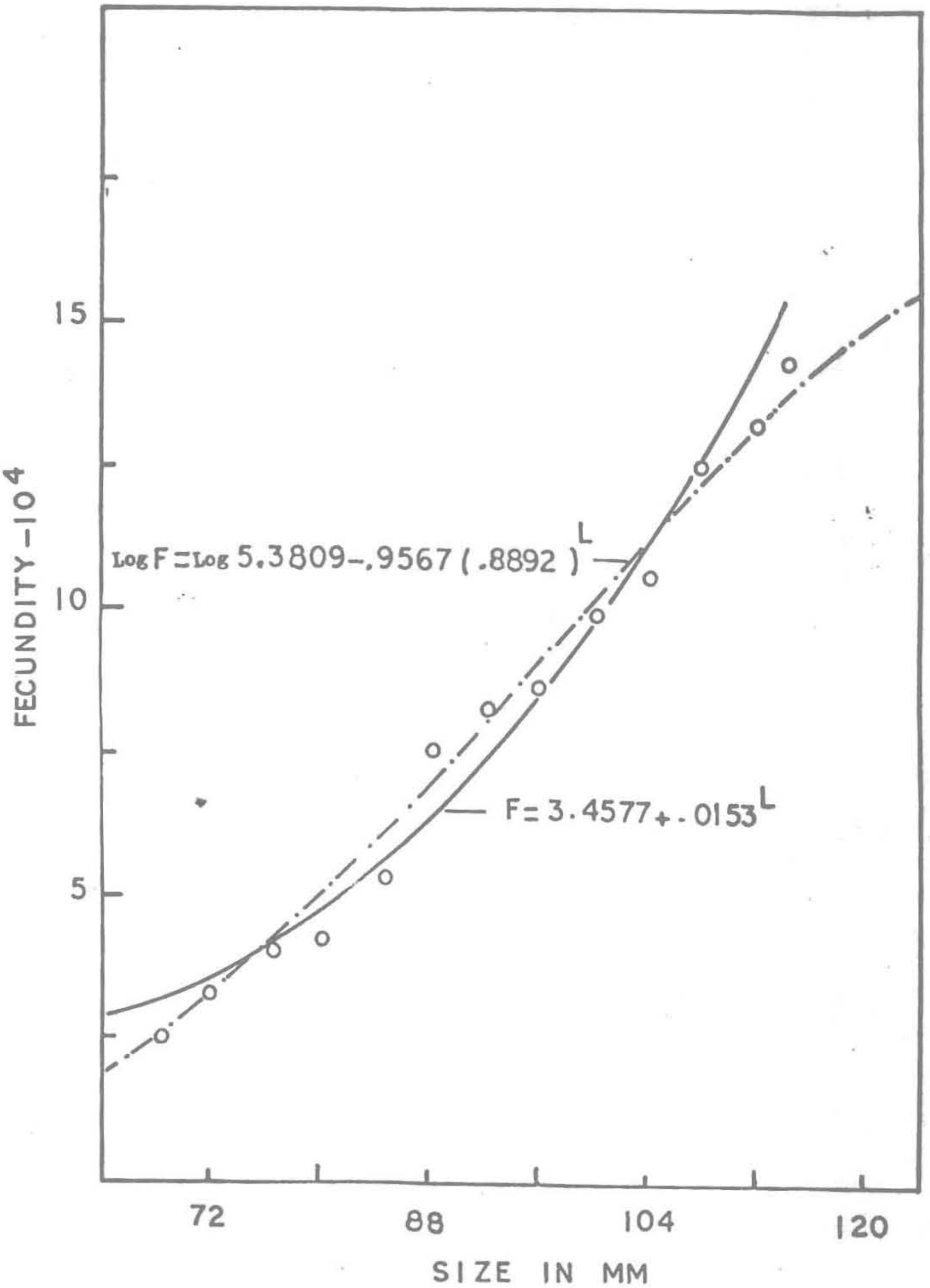

Fig. 15. Fecundity against size.

December, the year's most wet season here, records poor spawning activities. Earlier breeding season includes January to March, the peak being in February and the warmest periods of the year, April-June, record less frequency of breeders in populations landed. Hence, it appears to be obvious that the moderate environmental conditions prevailing over a few months before and after the monsoon season are more suitable for breeding activities.

4. FECUNDITY

The fecundities or egg numbers of gravid females vary between 27,600 and 1,34,200 for the animals measuring 68-112 mm size. The linear relationship, which exists between the fecundity and body length, is more fit to be a compurtz curve, though power function is also slightly less suitable. The linear regressions computed for all seasons are,

$\text{Log } F = \text{Log } 5.3809-0.9567\ (0.8892)^{L}$...Compurtz

$\text{Log } F = \text{Log } 3.4577 + \text{Log } 0.0153^{L}$ ...Power Function

where, F is the fecundity and L is the length in mm.

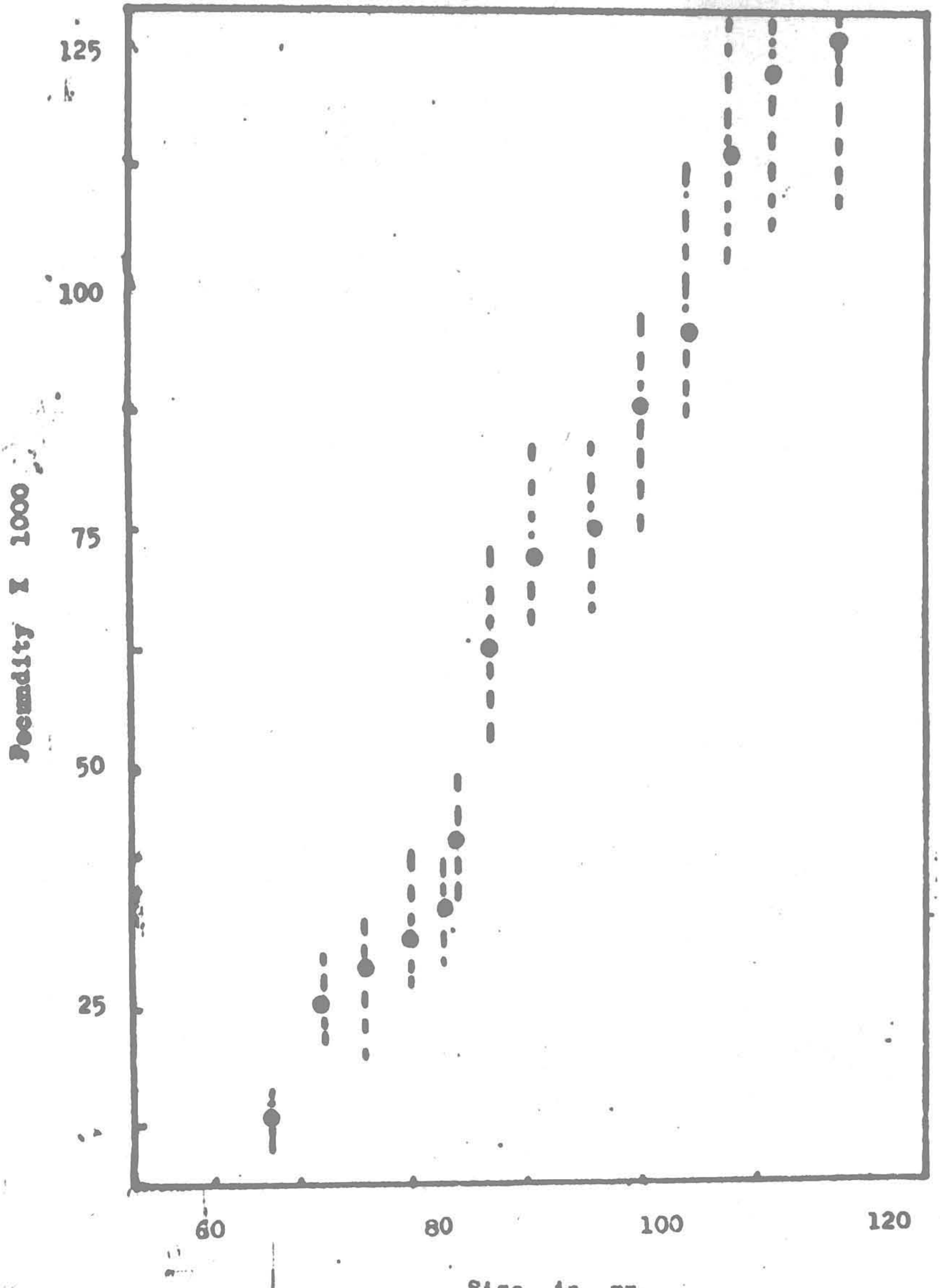

Fig.16 Scattered diagram of fecundity against size

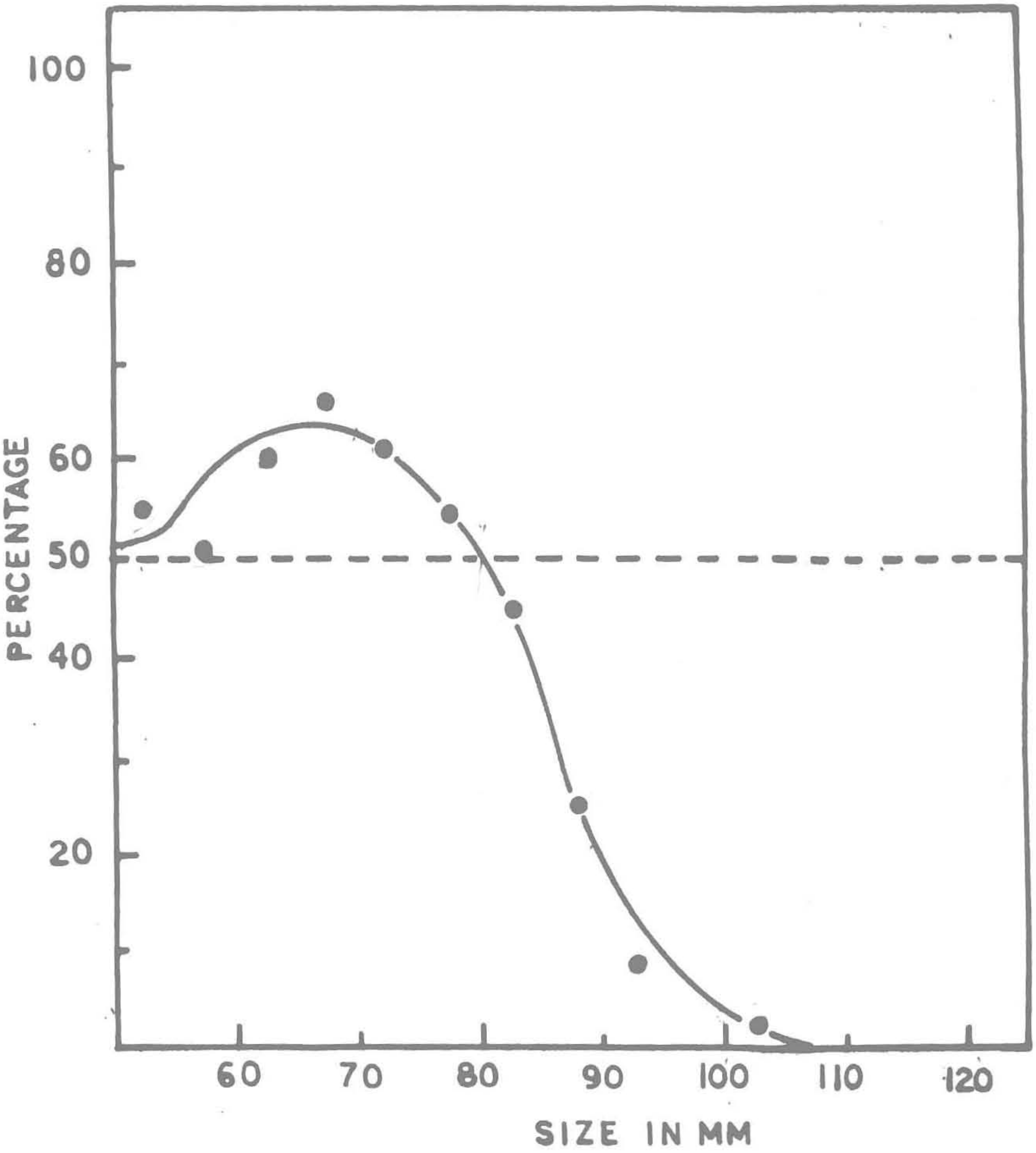

Fig. 17. Size-wise sex-ratio (percentage of male is given).

5. SEX-RATIO

Sex-ratio among the juveniles and sub-adults is more balanced, but in adults the females are more numerous than males (Table 1). The average monthly ratio of male in marine catches during this period varies from 13% to 60%, with an average of 41% and the X^2 value is estimated at 1.62 (P. 05 = 3.84), which is, however, not significant. A tendency of slightly higher frequency of male or evenly balanced with female is apparent when the population is young and fresh entrants.

Slopes of probability curves (Fig. 17), constructed for percentile males specific to size-classes, show negative pattern of linear relationship, with the slope being roughly in logistic form. It reveals that the adult males are slightly more (about 60%) among the size-range between 65-80 mm, above which the proportions of them are sharpely declined. The negative slope that has fallen sharpely down above 85 mm, takes slightly a right turn around 96-100 mm before touching the bottom or zero percentage around 110 mm size. However, females are noted in catches upto 120 mm size.

Table 2: Details on bathymetric distribution of sexes and maturity stages (I–V) of females of the populations which form the first post-monsoon fishery wave off Cochin.

Date	°C	‰	Percentage frequency and maturity stages of female																	
			≤10 M depth						15 M depth						≥20 M depth					
			% F	I	II	III	IV	V	% F	I	II	III	IV	V	% F	I	II	III	IV	V
19.10.79	28.1	18.8	58	27	9	64	-	-	-	-	-	stray	-	-	100	-	-	stray	-	100
10.11.79	27.0	18.1	61	90	6	4	-	-	-	-	-	stray	-	-	100	-	-	100	-	-
21.11.79	28.9	25.7	77	15	3	42	10	30	82	4	6	34	20	36	80	-	-	25	25	50
28.11.79	29.0	33.0	71	54	10	6	22	8	64	4	4	35	30	27	64	-	-	29	36	35
15.12.79	29.3	33.8	74	15	5	22	40	18	73	-	2	14	54	29	100	stray		100	-	-
29.12.79	28.2	30.9	79	60	5	20	3	12	87	6	4	52	2	40	96	-	-	8	36	57
22.01.80	29.2	32.2	57	52	14	19	10	5	84	7	37	26	22	26	100	-	-	stray	-	100
21.02.80	29.3	32.5	40	60	10	10	5	15	52	46	17	14	9	16	-	-	-	stray	-	-

The sex-ratio is also found to be the function of space and physiological conditions of the animals. During the experimental cruises, the first wave of post-monsoon fishery of M. dobsoni is recorded between 19.10.1979 and 21.2.1980 and the details of the distribution of sex-ratio, spawners and modal-size in relation to depth-zones are given in Table 2. The female ratio calculated are: 40-77% (mean = 64.5%) at ≤10 M depths; 52-87% (mean = 72.0%) at 15 M depths and 84-100% (mean = 98.2%) at ≥20 M depths. Hence, the females are more numerous than males in population inhabiting deeper waters. Males are slightly higher when the population is young and immature, as noted on 21.2.1980, that males outnumber (62%) females when the latter are mostly immature (60%).

Discussion

Penaeid prawns are peculiar in the sense that mating occurs in advance and the sperms are stored externally till the actual release of eggs at a later time, the lapse of which may last even more than a month. Transmission and anchoring of spermatophore in specific thelycal spots seem to be highly specialised works, which are presumed to be carried out by petasma (Hudinaga, 1942; King, 1948; Kubo, 1949; Tuma, 1966; Hassan, 1981). The spermatophores, which are simultaneously discharged from the genital pores of either side, are collected and compactly deposited usually as one mass in the posterior depression of the median plate of thelycum. ~~This~~ It is unlikely that the single petasma, which has only limited flexibility, alone carries out this complex process of works. At least few pereopods, which have greater manevourability, are likely to assist in manipulation and proper placements of spermatophores in thelycum. King (1948) also opines that appendix masculina and, to some extent, few pereopods participate in handling and deposition of spermatophore. The thelycum of M. dobsoni appears to be an open type as classified by Tuma (1967) and the spermatophores appear as simple moulds adher~~ed~~in to the depression of the median plate, though the overflowing materials are sometimes anchored into the crevices between the median and transverse plates. Hudinaga (1942) in *Penaeus japanicus* and Tuma (1967) in *P. meguiensis* have described 'closed' type of thelycum, in which the seminal vesicles are present as small depressions.

Genitalia in *M. dobsoni*, as also in other penaeids, do not appear as ~~a~~ miniature organs, but they develop gradually by series of changes in shape and size from simple rudimentary structures into complex adult forms. Sequences of development of these external genitalia of *M. dobsoni* have been adequately described by Menon (1951) and George and Rao (1968). The blunt bud-like rudimentary petasmal endopodite is the earliest structure observed at 15 mm size in the present study, which agrees with the observation of Menon (1951). However, George and Rao (1968) have traced it from 12 mm size onwards. Similarly, thelycum is seen at its first appearance as a median ridge at the length of.22 mm, as against 25 mm by Menon (1951) and 20 mm by George and Rao (1968).

Fusion of endopodites in male and expansion of transverse plate antero-laterally are considered to be the adult features in this species (Menon, 1951; George and Rao, 1968). Most of the males attain this stage at the narrow range of 50-55 mm size and females at 56-60 mm size and these observations agree to George and Rao (1968). Tuma (1967) has also pointed out a narrow size range (20-25 CL), within which most of the individuals develop petasma into adult form in P. merguiensis. But, Dall (1958) considers males of M. benettae as adult when the petasma is fully developed (usually containing spermatophore). The spermatophore is not observed in M. dobsoni under normal estuarine conditions; but on a rare occasion during the summer month, May, in an enclosed water, which has been disconnected for over 5 months from any source of water entering from outside, in the nearby Covelong backwater, a good proportion of males carrying spermatophore in the terminal genital ampules and a few females with impregnated thelycum have been noted. Males carrying spermatophores in this species have been also recorded from Cochin backwaters (Menon, 1951; George, 1965), which has a wide perennial bar-mouth. However, mature females with developed ovary are not met with in the present observation. It may be thus inferred that this species can initiate maturation under the conditions with higher salinity in the nursery water itself, but completes the maturity cycle only at sea.

The classifications of maturity stages of female into five stages viz., I 'immature', II 'early-mature', III 'late-mature', IV 'mature' and V 'spent', based on the changes that take place in size, colour and texture of the ovaries, have also been followed in several penaeids (Sheikmahmed and Tambe, 1961; George, 1965; Rao, 1967; Kunju, 1967; Kurup and Rao, 1974). Maturity stage I or 'immature' stage is also mentioned as 'u' or 'undeveloped' (King, 1948; Renfro and Brusher, 1963) and as 'quiescent' (Tuma, 1967) and they have all used the term 'developing' for the stage II. King (1948) has used as 'y' or 'yellow' and Tuma (1967) as 'early maturity' for the stage III and 'mature' stage is classified as 'ripe' and 'spent' only as 'spent' by both authors. The higher frequency of 'late mature' and 'mature' females in catches indicates that these stages have longer durations, while low frequency of 'spent' animals in maturity cycle, indicates that the females remature as soon~~er~~ as they spent the eggs. Renfro and Brusher (1963) are also of the similar opinion that 'developing' and 'yellow' stages consume more time ~~of~~ maturity cycle and no 'rest' or 'dormant' stage in *P. setiferus*. This is quite possible as they are capable of spawning several times with a single mating (Joshi and Nagabhushanam, 1982; Primavera, 1979; Beard and Wickens, 1980; AQUACOP, 1983).

Based on yolk contents of the oocytes, three broad categories *viz.*, young oocytes, previtellogenic and vitellogenic oocytes have been classified. Since eggs containing no yolk stain blue with haematoxylin-eosin staining technique (Tuma, 1966), stages I and II are found to have no yolks and the accumulation of yolk commences at stage III, in which blue colouration is half faded (previtellogenic) and fully stuffed at stage V (vitellogenic). It is, thus, evident that certain yolk contents are not present all along since the origin of the oocytes, but are incorporated during the course of development, evidently at stage II onwards. Teshima and Kanazawa (1983) have agreed that the ovarian lipid concentrations increase during the slight mature and yellow ovarian periods and remain roughly constant until their decrease to low levels at spent stage in prawns. They also observe both triglycerides and phospholipids are responsible for such concentrations on ovarian maturation. Highnam and Hill (1978) point out ~~it~~ that 'a major lipoprotein constituent of the yolk is synthesized outside the ovary, probably in the hepatopancreas~~,~~ and is transported in the blood to the vitellogenic oocytes'. It is, thus, clear that the gross changes in colour, size and texture of ovary are related to the histological changes, so that classifications of maturity stages of ovary become easier and reliable without being analysed under microscope.

Some of the heavy metals, although only in traces, are essential for all forms of life and thus uptake of them are strictly regulated in organisms, for most of them are toxic in excess (Albert, 1973). However, metal fluxes may vary due to external pressures and internal demands of the individuals, resulting in fluctuations of body burdens. This is obviously noticed particularly for copper and zinc, which are predominent and in large quantities, among maturity stages of female and male of *M. dobsoni*. Copper contents range from

52.75 to 73.50 µg/gm dry wt, registering about 50% variations and zinc burdens vary between 32.50 and 66.25 µg/gm dry wt, with about 104% fluctuations, among maturity classes. Variations in body burdens of metal contents in crustacea have also been reported by several workers. Bryan (1968) has noted the disparities of such metal in decapods and Shiber (1981) has estimated 43.0-70.4 µg/gm dry wt of copper and 42.5-126.4 µg/gm dry wt of zinc in another penaeid, Penaeus japonicus, occurring around Lebanon. Topping (1973) has recorded 40.0-113.0 µg/gm dry wt of copper and 102.0-122.0 µg/gm dry wt of zinc in the lobster, Nephrops norvigicus from various locations of European waters and suggested that the differences in metal burdens may be attributed more to natural effects than to man-made effects. Milington and Walker (1983) have similarly observed variations of zinc contents in the mollusc, Velesunia ambiguus, and opined more than satistical explanations for the differences. It may thus be logical to attribute the variations of metal burdens in body tissue of M. dobsoni to biological reasons. Fall of metal burdens in 'spent' females from peak levels in 'mature' to 'immature' and that of male levels supports that these metals accumulate in relation to maturation cycle of the females.

Thus, activities like moulting, generation of thousands of eggs stuffing with all essential ingredients and releasing them, which are all closely associated with maturation cycle, may be assumed to be the major causes for retention and release of metal contents in body tissues. Davis (1978) is also with similar opinion that moulting and egg-laying are the major routes of eliminations of some heavy metals in decapods. In a general pattern of penaeids, female at 'immature' moults, mates and develops eggs in ovary through 'mature' and release them attaining 'spent' stage, which functions like 'immature' to repeat the cycle, recalling moulting, that is kept lapsed throughout maturations of ovary.

Adult penaeids of this genus normally moult~~s~~ once in a fortnight (Dall, 1965); but maturation, when moulting is suspended, nay extend the intermoult period upto a month or slightly more (Rao, 1978; Crocos and Kerr, 1983; Joshi and Nagabhushanam, 1982). This extended period of moulting appears to influence higher buidling up of copper and zinc burdens in body tissues of M. dobsoni, as noted over a 50% and 100% respectively of copper and zince increase upon the 'immature' level during maturation. Martin (1970) similarly assumes that higher concentrations of zinc in zooplankton from deeper waters than from surface waters may be due to lesser frequency of moulting owing to poor food supply. Excess of these metals are reported accumulated in the cuticle and excreted with moults, resulting in fluctuating total body burdens in crustaceans. Arumugam and Ravindranath (1983) have estimated about 13% of the total copper contents in the crab, Scylla serra~~t~~ta ~~are~~ is present in cutcle and felt them substantially removed on moulting. Fowler et al. (1969) also agree to this that the copper contents, which represent about 41% of the body burdens, are excreted with moults in Euphosia pacifica. Among penaeids, Shiber (1981) has estimated 89.1 µg/gm dry wt of copper and 47.7 µg/gm dry wt of zinc in the exoskeleton of Penaeus japenicus, considerable part of which may be assumed to be removed with moults, though resorptions to some extent are possible, as reported by Arumugam and Ravindranath (1983) in another crustacean, Scylla serra~~t~~ta.

On the other hand, the possibility of limited increase of total metal contents on body tissues on higher metabolic activities, which may be associated with maturations, has to be also given due considerations.

Though larger penaeids produce more than half million eggs on a single spawning (Penn, 1980), M. dobsoni is estimated to produce about 36,000 to 1,50,000 eggs, stuffed with all essential energy ingredients to meet the needs of incubation and even the non-feeding and free moving hatched out larvae, nauplii. Thus, very high metabolic activities can be assumed to be stepped-up during maturation to fulfil these molecular functions, as noted by several authors in crustaceans (King, 1948; Subramanyam, 1963; Rehman, 1967; Adiyodi and Adiyodi, 1970; Pillai and Nair, 1971; Varadharajan and Subramanyam, 1983; Ajmal Khan and Natarajan, 1983). Along with these increased activities, copper and zinc, among other metals, may accumulate more in body, as they are reported closely associated with organisms as constituents of reactive biological molecules (Fowler and Heyraud, 1980). Reeve et al. (1976) have closely linked copper contents and egg productions in Acartia tonsa, as they have noted more numerous eggs when the animals are exposed to higher copper medium upto certain levels. Role of copper in the respiratory pigments, haemocyanin, in crustacean blood is well known and their increased demands on natal needs may also enhance its uptake, resulting in added body burdens.

Though lesser in quantity, the trend in increase of zinc against the maturity stages is more obvious than copper in M. dobsoni. The most appropriate explanation is that zinc is concerned with RNA synthesis, which is essential for protein build-up (Ozer, 1971). Subramanyam (1963) has found proteinous nitrogen increasing with maturation in Penaeus indicus and similar addition of proteins, as the animal matures, has been noticed in Portunus pelagicus by Rehman (1967). Hence, zinc increase may largely be attributed to protein increase in females with developing eggs. This is further supported by Pearse (1961) that metabolically essential zinc is taken up passively by cells and its uptake is probably excercised indirectly by variations in the protein contents of the cytoplasm. It is also relevant to mention Lowe and Moore (1979), who have demonstrated that the cellular distributions of this metal differ between sexes and oocytes appear as an additional means of excertion. This may partly explain why the zinc contents in male and 'spent' are relatively lower. Again, Pearse (1961) mentions that zinc is also involved with storage and utilization of the hormones. Thus, the complexity of hormone activities associated with reproductive cycle in crustacea, including prawns (Adiyodi and Adiyodi, 1970; Joshi and Nagabhushanam, 1983) may also cause considerable fluctuations of this metal concentrations.

Important aspects among other metals in relation to maturation in M. dobsoni may be the exceptionally higher quantities of lead and nickel in 'immature', as compared to other categories and explanation may be attempted to this that the 'immature' females, which are fresh entrants to the sea, may still carry these metal contents accumulated from the highly polluted urban estuaries, which form their nurseries, and subsequently diluted off in their later stages, as the life passes at relatively far less polluted sea. Contents of cadmium is consistantly low, measuring less than 1.0 µg/gm dry wt in all maturity stages of female and male. It may be appropriate to explain this low levels of cadmium in the present species with reference to Establier et al. (1978), who have found that Penaeus kerathurus is able to quickly build-up this metal contents upto 334.6 µg/gm wet wt on laboratory exposures and similarly reduce when returned to cadmium-free medium and also to Nimmo et al. (1977), who have seen excessive cadmium being walled off and sloughed at gill region in penaeids. Hence, the mode of excretion through gills, which is uninterrupted by maturation, and very low metal levels at the habitat, the sea, may be the major causes for consistently low concentration of cadmium among all categories.

Ovary is not fully emptied on spawning in *M. dobsoni* and it agrees to observations in *P. setiferus* (King, 1948; Renfro and Brusher, 1963) and in *P. merguiensis* (Crocos and Kerr, 1983). But, Beard and Wickens (1980) is of the view that each spawning is complete in itself, there being no evidence of partial spawning in *P. monodon*, though they admit the eggs are retained and released over two or more nights. Experiments of AWUOCOP (1983) also reveal complete spawning in a few penaeids. Since, the multiple spawnings in penaeids are common, the retained eggs may not be uniform at each successive spawning within one intermoult period, but it may taper gradually.

The estimated size at the onset of maturity of *M. dobsoni* is 60.3 mm, which is slightly lesser to early records, 64.1 mm (Rao, 1968), 65.0 mm (Menon,

1951) and 71.0 mm (Ramamoorthy et al., 1976). However, actual observation of female with 'mature' ovary at 62.5 mm size in the commercial catch favours the present estimate. The size distribution of females at first maturity, which fits to a logistic curve, indicates synchronization of large number of females maturing between 65 and 75 mm size and small numbers tapering at either end. Similar relationship has been noted in P. merguiensis (Crocos and Kerr, 1983). Most of the females emigrate to sea at 60-65 mm size (Menon, 1955; Banerji and George, 1967), but bulk of them attain maturity at 65-75 mm, the 50% being at 69.0 mm length. This size difference seems to show that they undergo 1-2 moults at sea, including the pre-mating moult, before maturity. It agrees to Staples (1980), who finds that the adolescents of P. merguiensis remain a couple of months near the mouth zone before moving to offshore, while increased by 15 mm size. The maximum size estimated attaining maturity at about 90 mm is closer to the largest immature specimens recorded at 88 mm (Suseelan, 1975). However, the smallest female rarely found in marine catch measures 47 mm size with adult features of thelycum, but in 'immature' ovarian condition and the possibility of such dwarf specimens attaining maturity at a shorter length less than 60 mm cannot be ruled out. Since, the growth-rate becomes age-specific in stunted animals (*vide infra*) the sexual maturity may also be attained at specific age, when such animals are relatively shorter than normal size for that age.

Size at sexual maturity has been studied for other few Indian penaeids of similar size ranges by Kakwade (1980) and her estimated values are,

Species	Minimum size	50% maturity
Metapenaeus brevicornis	64.0 mm	112.5 mm
Parapenaeopsis stylifera	76.0 mm	165.5 mm
Parapenaeopsis hardwickii	71.0 mm	85.5 mm
Metapenaeus dobsoni (present study)	60.3 mm	69.3 mm

The minimum size at maturity thus appears to be closer between the present study and her values, but the values for 50% maturity of her studies are in the very high order and more closer to the maximum life size of the species concerned. It may be because she has considered for maturity only the stage IV 'mature' females, which are only in small proportions in most of the maturation periods for the possible reasons that the stage lasts only a few days in maturity cycle, while stages II and III extend more time (Renfro and Brusher, 1963).

Seasonal variations of size at first maturity, as noted in the present observations, has also been reported for P. merguiensis (Tuma, 1967) and for an anomuran, Petrolisthus elangatus (Jones, 1977). Size at maturity is reported to be related to rate of growth (Mauchline, 1980). Within a single species the better fed individuals living in warmer waters are the first to mature (Royce, 1972). Hence, the more food abundance, coupled with lower temperature enabling preservation of more energy towards body building, during post-monsoon periods could result in larger body size of pre-adults and hence the maturity at larger size. Swendrup et al. (1942) and Paul (1942) put it in other way that the increased metabolic activities in high tropical temperatures result in rapid growth and earlier attainment of maturity in littoral animals compared to subtropical zones. Hence, warmer periods under local conditions can be considered to have hastened the maturity process at shorter length as compared to larger size during wet seasons.

Considering the laboratory growth of post-larvae through juveniles in the Chapter II of this study, the size at maturity (60.3 mm) is attained in 4.5-5.0 months and thus most of them can be considered attaining maturity in 5-6 months. This compares to other reports, which are mostly generalized for wild populations. Garcia and Le Reste (1981) inform that *Penaeus notialis* on the Ivory Coast achieves first spawning at 7 months and 50% of the shrimps are matured at 10 months and Meixner (1968) opines that *Crangon* sp. attains maturity at an age of less than a year. In another crustacea, *Squilla nepa*, which has similar population abundance in the inshore areas, the females are noted to attain first maturity in 5 months and the next spawning happens after 45 days (Alikunhi, 1975).

Transition from growth phase to reproductive phase in *M. dobsoni* appears to be evident even before emigration to sea. The petasmal and thelycal structures are fully formed at 50-55 and 56-60 mm sizes and the extra energy, which may be prerequisite for egg production seems, to be built up as noted from the upward tilt in the slope of length-weight relationships around these sizes. Under impounded and hypersaline conditions this species is also noted to bear spermatophore in the terminal ampules of the vasdeferentia and the same deposited on the thelycal spot, indicating commencement of maturation in nursery waters. However, females with 'mature' ovary are not recorded in nursery grounds, which emphasises the necessity of migration to the sea for completion of maturation cycle. Tuma (1967) has similarly opined that the insemination in *P. merguiensis* occurs only at 30 mm CL, though the genitalia is fully developed at 24 mm CL. Males reach the sexual maturity at shorter sizes by about 5 mm in *M. dobsoni*. Similarly Stephen *et al*. (1973) have estimated that the minimum size at onset of sexual maturity is 9 mm CL for males as against 13 mm CL for females, in rock shrimp, *Sciyonia brevirostris* and Royce (1972) is also of the opinion that in a single species of prawn males mature at an younger age than females.

Movements in masses at a set pattern, which is often defined as migration, becomes necessary for reproductive life, so that the animals themselves and/or the products are placed in the most favourable conditions. It is exhibited as inshore-offshore movements in penaeids. But the limits of space movements are inherent to each species, though subjected to slight modifications by specific environmental situations. Although spawners of M. dobsoni occur from near shore to 35 M depths, most of them are concentrated around 15 M depths and individuals occurring over 20 M depths are mostly spawners though less in numbers. The tendency of larger spawners moving into deeper waters is also obvious and slightly seasonal changes in distributive pattern of size are also apparent. George (1965) has also commented that a size oriented sex-wise movement is noticed in the population of this species. This supports the general consideration by Taylor and Taylor (1983) that 'in movements of animals the initiative, orientation and motive force itself are intrinsic, eventhough environmental forces have shaped them in the past and may influence them in the present'. Preference of wide range of depths (8-30 M) for spawning activities has also been noted in the temperate species, Penaeus setiferus (Isabel, 1969), though Menon (1951) has pointed out that Indian species of penaeids spawns comparatively in shallower waters.

Menon (1951) also agrees closely to the present observations that M. dobsoni liberates the eggs in the inshore waters upto or slightly beyond the 12-13 ft line and the same author (1957) opines that a good percentage of females of larger size groups move out of the 10 ft zone and return about a year sojourn outside. Although presence of few larger specimens in the beginning of the season seems to support his view, the catches of deep water fishing round the year do not give such evidence. It is noted that the first breeding population after monsoon break is larger group and later, new groups also join, meanwhile, the older groups move deepwards. Similarly George et al. (1968) have observed bathymetric movements of the adults, including spawners. Contrary to other local penaeids, M. dobsoni has been noted by them to move towards the near shore and migrate deepwards to 9-18 M and 18-24 M depth zones after monsoon rains.

Mohamed (1965) reports that the depth range of spawning ground of M. dobsoni is narrowed down to

20-25 m depth. In fact, in most of the seasons this depth zone presents very poor fishery and only a fraction of the annual spawning population has been recorded here, though it has to be accepted that only females with advanced stages of maturity move about this area. However, erratic mass movements and congregation of spawning populations of this species are evident from purse seine catches (Nair et al., 1982).

As mentioned, movements of larger and mature individuals of M. dobsoni to deeper waters are also noted in other penaeids. Crocos and Kerr (1983) have found that more mature animals of P. merguiensis are in deeper waters and immature are restricted to shallower depths. Boddeke (1976) explains the bathymatric migration of Crangon crangon to the sexually mature shrimps being more sensitive to temperature fluctuations at shallow waters, near shore than sexually immature shrimps and hence moving off to deeper waters. Eldred et al. (1961) are also of the same opinion that the adult penaeids generally seek cooler and deeper waters during the warm periods in temperate regions.

Oka (1967) is of the ~~thinks~~ view that the prawns move to calcium rich coastal waters in order to obtain calcium, which is required for the maturation of gonads and the formation of cuticle during the larval development. Considering the abundance of deep sea prawns in depths ranging from 300-400 M, and the distribution of mature individuals of coastal species spread over wide range of depths does not support significant relationship of that type. Laevastu and Hyes (1981) have made the general remarks that the larger and older specimens migrate to the colder boundaries of the distribution area of the species due to physiological needs, while smaller and immature specimens remain in the normal distribution area. Often the larger specimens do not return to the normal shallow water grounds.

Although *M. dobsoni* breeds in all seasons, two annual spells are apparent in January-March and July-September along Madras coast and these peak periods agree closely to other earlier reports on few penaeids along this region. *Penaeus indicus* has shown intensive breeding activities in February-March and June-September off Madras (Subramanyam, 1965) and in December-February

Table 5. Breeding seasonality of certain commercially important penaeids along the southern region of east and west coasts of India in comparison with the present one.

Centre	Season	Species	References
East Coast			
Kakkinada	July-October	*M. brevicornis*	Sudhakara Rao (1979)
Madras	January-March July-September	*M. dobsoni*	Present study
Madras	February-March July-October	*P. indicus*	Subramanyam (1965)
Cuddalore-Portonovo	December-February June-September	*P. indicus*	Author (MS)
Mandapam	January-February June-September	*P. semisulcatus*	Thomas (1974).
West Coast			
Goa	February-May	*M. dobsoni*	George and Goswami(1977)
Mangalore	April-June November-December	*M. dobsoni*	Ramamoorthy *et al.* (1976)
Mangalore	May-June October-November	*M. affinis*	Ramamoorthy *et al.* (1978)
Calicut	September-January	*M. dobsoni*	Menon (1951)
Cochin	June-August November-December	*M. dobsoni*	George *et al.* (1958)
Cochin	April-June October-December	*M. dobsoni*	Kurup and Rao (1974)
Cochin	April-June October-December	*P. indicus*	Kurup and Rao (1974)

and June-September off Portonovo-Cuddalore on the same coast (Author, MS). *Penaeus semisulcatus* has revealed more pronounced breeding activities in January-February and June-September off Mandapam in the south (Thomas, 1974) and *M. brevicornis* has but only one long breeding season in July-October off Kakkinada in the north (Sudhakara Rao, 1979). These breeding seasonalities of penaeids are also supported by other few crustaceans along this area. The two species of squilla, *Squilla nepa* and *S. holorostris* have been recorded with higher frequency of breeding activities in March-April and August-September off Madras (Alikhuni, 1967), but the pelagic crab, *Neptunus pelagigus* has a single season here in September-March (Rehman, 1967). Subramoniam (1979) has found the mole crab, *Emerita asiatica*, bredding during most part of the year with two apperent modes in January-March and July-September along Madras beach and Ajmalkhan *et al.* (1977) have noted maximum breeding activities of the crab, *Calibanarius longitarsus* in February-March and August along Portonovo coast.

The fore-going accounts of breeding seasons along the east coast show that the pre- and post-monsoon conditions are more conducive for reproductive activities. In other words the peak monsoon around November and summer in April-May are recorded with poor activities of breeding. Influence of monsoon on reproductive functions of this species and other penaeids can be substantiated by comparing the breeding seasonalities along the West and East coasts (Fig. 14), which receive monsoon in different periods, the former in June-September and the latter in October-December. Breeding intensity has distinct modes in July-September along the East coast in contrast to lean activities on the West coast, where the southwest monsoon is active then. Similarly, May is normally noted with poor breeding activities on the East coast, whereas, West coast with pre-monsoon condition records moderate activities of breeding. Thomas (1974) has also noted the breeding season of P. semisulcatus along East coast different from that of West coast and opines that monsoon variation is the key factor influencing such seasonal differences. Pre-monsoon and post-monsoon conditions are generally agreed to be more favourable for breeding activities in penaeids by several other workers (Pillai and Nair, 1971; Ramamoorthy et al., 1976; Rao, 1977; Kutty et al., 1977; Cheng et al., 1981). But, George et al. (1968) have noted good proportion of breeders in monsoon fishery during June-August along West coast of India. No monsoon fishery exists there except the sporadic shoaling of stranded populations as 'mudbank' fishery, supported by very heavy purse seine catches occasionally. Most of such rare monsoon catches are comprised of older specimens and many of them are noted breeding during the period. But these populations are very small, as compared to the seasonal fishery, when even still smaller proportion of populations may be cumulatively more productive of eggs. However, Menon (1951) has observed only limited hatching viability of eggs of this species collected during turbid and stormy rainy conditions. Hence, monsoon is not the suitable season for breeding, even if the population do occur.

Normally, reproductive seasons in animals are so timed that they avail the best use of time, space and food for the breeders and the larvae. The pre-monsoon and the post-monsoon breeding activities in penaeids may be assumed to be mainly associated with, wider-scope of survival on enlarged living space of nursery waters and the abundance of food meeting all phases of life consequent on monsoon floods and flushes. Same view is also suggested by Karmar (1978) that the reproductive seasonality is mainly controlled by adult or juvenile food availability. Ajmal Khan *et al*. (1977) correlate the peak breeding season of the crab, *Clibanarius longitarsus* and the bloom of phytoplanktons during post-monsoon seasons. The breeding activities during moderate environmental conditions may also be explained with opinion of Giesel (1976) that reproductive timing may be thought as a means to reduce the effects of environmental heterogeneity, which can otherwise demand more budgeting and less possibility for fitness maximum on the part of the population.

Multiple spawning in *M. dobsoni*, as evident from the seasonal size distributions of 'mature' females, and resorption and development of eggs in 'spent' ovaries, have been noted. Resorption of eggs after spawning has also been observed earlier in penaeids by King (1948), Crocos and Kerr (1983) and AQUACOP

(1983) and repeated spawning has been positively proved by recent direct studies (Febo, 1979; Primavera, 1980; Beard and Wickens, 1980; Brown *et al.*, 1980; AQUACAP, 1982; Joshi and Nagabhushanam, 1982). *Metapenaeus dobsoni* is traced to spawn averagely three times within a single breeding season and some of the broods continue actively participating in the succeeding breeding season with a break of few months. Since, large number of females live upto 110 mm size (1 year old). they may be assumed to see two breeding seasons, so that they would spawn about 6 times. But, specimens upto 125 mm size, which are occasionally noted in catches, may be presumed to participate about 4-5 breeding seasons, raising the number of spawning to about 12-15 times. Rao (1967) and Mohamed (1965) have suggested only about 5 time spawning in life time of this species. This is a very low estimate compared to direct observations on later studies on other penaeids, as noted 9-10 times in *Penaeus stylirostris* (Brown *et al.*, 1980). Several other studies report more numbers of spawnings even within a single inter-moult period, which may be considered lasting not more than one breeding season. *Penaeus kerathurus* repeats spawning

8 times (Febo, 1979), P. monodon spawns 1-6 times, with an average of 3-4 times (Beard and Wickens (1980) and Parapenaeopsis stylifera lays 2-3 batches of eggs (Joshi and Nagabhushanam, 1982) within one inter-moult period. Penaeus indicus has been estimated to require averagely 11 days and P. stylirostris 8 days in between successive spawnings (AQUACOP, 1983).

The duration of maturation for the fresh broods since entry into inshore grounds is traced in this study to be about 30 days in M. dobsoni. However, maturation period is reported widely varying for the same species, as noted that P. kerathurus (Febo, 1979) needs 10-69 days and P. indicus and P. stylirostris take 2-14 days. This time differences may be attributed to the seasonal variations of the environmental conditions or the maturity state of those fresh broods, since sub-adults may sometimes be forced to leave the nursery waters under distressed conditions like flooding or pollution.

The two broods of this species present on the same area may not synchronise spawning. This supports the view of Stephen et al. (1973) that ovarian development

Table 3: A comparison of earlier estimates of age and growth of <u>Metapenaeus</u> <u>dobsoni</u> with the present estimates.

Age in months	Author(s) and size in mm								
	Present o Observation		Banerji and George (1967)	Kurup and Rao (1974)		Panikkar and Menon (1956)		Ramamoorthy *et al*. (1976)	
	F	M	M & F	F	M	F	M	F	M
6	82.3	76.2	67.2	72.8	58.1	-	-	-	-
12	109.9	100.7	96.3	115.4	97.1	75.8	70.0	95.0	85.0
18	122.0	108.1	108.8	131.5	113.1	-	-	-	-
24	126.2	111.6	114.2	138.1	122.5	100.0-105.0	90.0-95.0	120.0	105.0
Maximum ($L\infty$)	129.2	112.9	118.3	144.6	128.9	120.0	110.0	120.9	109.1

in the rock shrimp, Sciyonia brevirostris is antogenic in small females, but seasonal in larger shrimps. Distribution of breeders also reveals that different broods may utilize different depths. Larger group moves deeper waters.

Females grow faster, reach higher sizes at ages and live longer life compared to males. The asymptote size computed for female is 129.20 mm as against 112.93 mm, which are more closer to the largest specimens actually observed in catches; 121-125 mm for female and 106-110 mm for male in the present studies; 124 mm and 111 mm respectively (Menon, 1955) and 125-130 mm size class for females in trawl catches off Cochin (George *et al*., 1968). Size at age by von Bertalanffy growth equation has been computed for this species by Banerji and George (1967) and Kurup and Rao (1974) and Menon (1955) has approximated the size at age from the size frequency distributions. The length for ages, especially at advanced ages, calculated by them differ considerably from the present estimates (Table 3).

Banerji and George (1967) have merged both sexes and obtained a common asymptote, which appears to be a compromised value between females and males. Kurup and Rao (1974) have arrived at the possible maximum size as 144.6 mm for females and 128.9 mm for males, which leave larger size gap between the actual specimens recorded and the estimates. Menon (1955) has, however, worked out shorter sizes for respective ages, as he computes 75-80 mm (female) and 70 mm (male) in one year compared to 109.86 mm and 100.66 mm respectively in this study. The recent field observations favour larger size at ages, as indirectly indicated that *P. merguiensis* breeds in 6 months (Beard et al., 1977) and *P. vannamei* in 6-8 months (AQUOCOP, 1982), so that *M. dobsoni* in the size range of 65-75 mm, when most of this mature may also be in that order of age.

Females are estimated to live little over 3 years, whereas males slightly less than that. However, most of the populations live just for a year and only a fraction exist beyond 2 years (over 120 mm size in females and 100 mm in males). Similarly, George *et al.*, (1968) have pointed out that only two year groups form the fishery. Longevity of 1-2 years has been suggested for *Trachypenaeus curisrostris*, *Metapenaeopsis barbata*, *M. acclivis*, *Penaeus japanicus* and *Metapenaeus monoceros*

Table 4: A comparison of fecundity of *M. dobsoni* with few other penaeids and the same species by others.

Species	Fecundity	Size(mm)	References	
M. dobsoni	27,000-1,34,200	68-112	Present study	
M. dobsoni	34,500-1,60,000	70-120	Rao	(1967)
M. dobsoni	50,000(spawned)	----	Thomas et al.	(1974)
M. affinis	88,000-3,63,000	95-160	Rao	(1967)
Penaeus japanicus	7,00,000	200	Hudinaga	(1942)
P. monodon (wild population)	5,00,000		Primavera	(1980)
(ablated)	3,00,000			
P. monodon	19,000-4,60,000		Beard and Wickens	(1980)
P. semisulcatus	51,600-6,60,000		Thomas	(1974)
P. semisulcatus	2,80,000	160-180	Hassan	(1982)
P. latisulcatus	1,05,000	123	Penn	(1980)
	6,50,000	217		

(Takeo Imai, 1977). *Penaeus vannamei* has been noted to live in the laboratory itself more than 30 months and attains maturity in 6-8 months (AQUACOP, 1982). Kubo (1955) is of the view that most of the individuals of *M. monoceros* live one year or a little more in warm waters and still more in cold-water zones and Garcia and Le Reste (1981) consider the maximum life of penaeids is in the order of 2-3 years.

The fecundity of *M. dobsoni* is widely estimated between 27,600 and 1,34,200 with a positive linear relationship against size in the form of a compurtz curve, though curvilinear structure is also slightly less fit. This agrees to mauchline (1977) who has suggested curvilinear forms of linear relationship for penaeids in general. Wide variations of egg numbers are found common in penaeids (Table 4) and larger species generally lay more maximum number of eggs, as recorded that *P. japonicus* lays approximately 7,00,000 eggs (Hudinaga, 1942), *P. semisulcatus* upto 6,60,904 eggs (Hassan, 1982) and 6,50,000 eggs (Thomas, 1974). Fecundity of *M. dobsoni* estimated are more closer to those of Rao (1967) (34,500-1,60,000 eggs) and Thomas *et al.* (1974) have counted about 50,000 eggs spawned by this species in the laboratory. Increase in variations of eggs against size and decrease in numbers towards the closure of the breeding seasons may be attributed to repeated or respawnings. But, Beard and Wickens (1980) do not see any significant variation in egg numbers among the batches within the same intermoult period. Variations of food availability in offshore grounds during the break off seasons for the older specimens may also result in differential energy built ups to be utilized later for generation of eggs, as compared to relatively more uniform chances of food from restricted nursery and inshore ground for the young prawns.

Sex-ratios within the populations of M. dobsoni are variable and females frequently outnumber males. Similar differences in sex-ratios have been described in this species earlier (Menon, 1955, 1957; George and Rao, 1967; George, 1970) and in other major Indian prawns (Menon, 1957; Sheikmahmed and Tambe, 1961; George and Rao, 1967; Kunja, 1970; Kurup and Rao, 1974; Thomas, 1974).

The seasonal variations of sexes, sometimes to significant levels, appear to be attributed to females migrating in larger numbers than males towards the deeper waters intentionally for breeding purposes, as it is evident from the increase of female ratio against increasing depth. George and Rao (1967) have analysed the trawl catches off Cochin for this species along with other few penaeids and suggested similar breeding migration as the major cause for the differential sex-ratios at times. Offshore catches comprising more of females have also been noted in P. setiferus (Isobel, 1969). Such partition of niches between sexes may help expansion of the total area of occupation, curtailing the intersexual competition for space and food. Rallis (1976) feels even to the extent that sexual dimorphism may often arise primarily because of the advantages of decreased intersexual competition for food.

Females are generally greater in populations primarily due to their increasing majority among larger sizes measuring over 85 mm. Similar predominance of females in larger sizes has been reported within species by Menon (1957) and in Sciyonia brevirostris (Stephen et al., 1973).

This variation of sex-ratio among the larger sizes may be due to difference in longevity and/or growth-rates or size at respective ages between the sexes. But, on consolidating their numbers for corresponding ages, the ratios do not vary much to indicate shorter life-span of males is less consequential, though profused mating of such polygamous species may be expected, to cause exhausion deaths and thus to tilt the sex-ratio in favour of females among older groups. Hence, the major reason is only the differential growth of sexes, the females growing faster and larger compared to males. Preservation of energy primarily for the function of generating lakhs of eggs during ensuing breeding season may also support females as life saving at adverse conditions, including scarcity of food, and hence it results in differential mortality between sexes. Since it is a polygamous species and female is able to spawn a few lakhs of eggs for several times, elimination of older and functionally weaker males by nature cannot be also ruled out.

Chapter 4

Culture

Results

1. SPAWNING AND LARVAL DEVELOPMENT

Spawning takes place at night between 22.00 and 06.00 hrs. Of the five experimental 'mature' females, three specimens spawned under the conditions with 32-34‰ salinity and 25-31°C(±1°C) temperature and two kept in 23‰ salinity and 25-31°C(±1°C) temperature failed to spawn and died. Among the successful spawners, two died the next day and another one, which survived upto five days, rematured upto stage III, 'late mature', at the time of death.

The larval life of this species comprises 6 naupliar, 3 protozoeaic and 3 mysid stages and the descriptions of the sub-stages follow the general pattern of the penaeids. The chronology of the larval phases ~~are~~ is illustrated in the figure 18. Detailed descriptions of the larval phase of this species have been given and adequately illustrated earlier (Menon, 1951; Rao, 1973; Thomas <u>et al.</u>, 1974; Thomas and Kathirvel, 1976; Muthu <u>et al.</u>, 1978) and hence, only the salient features are projected in this thesis.

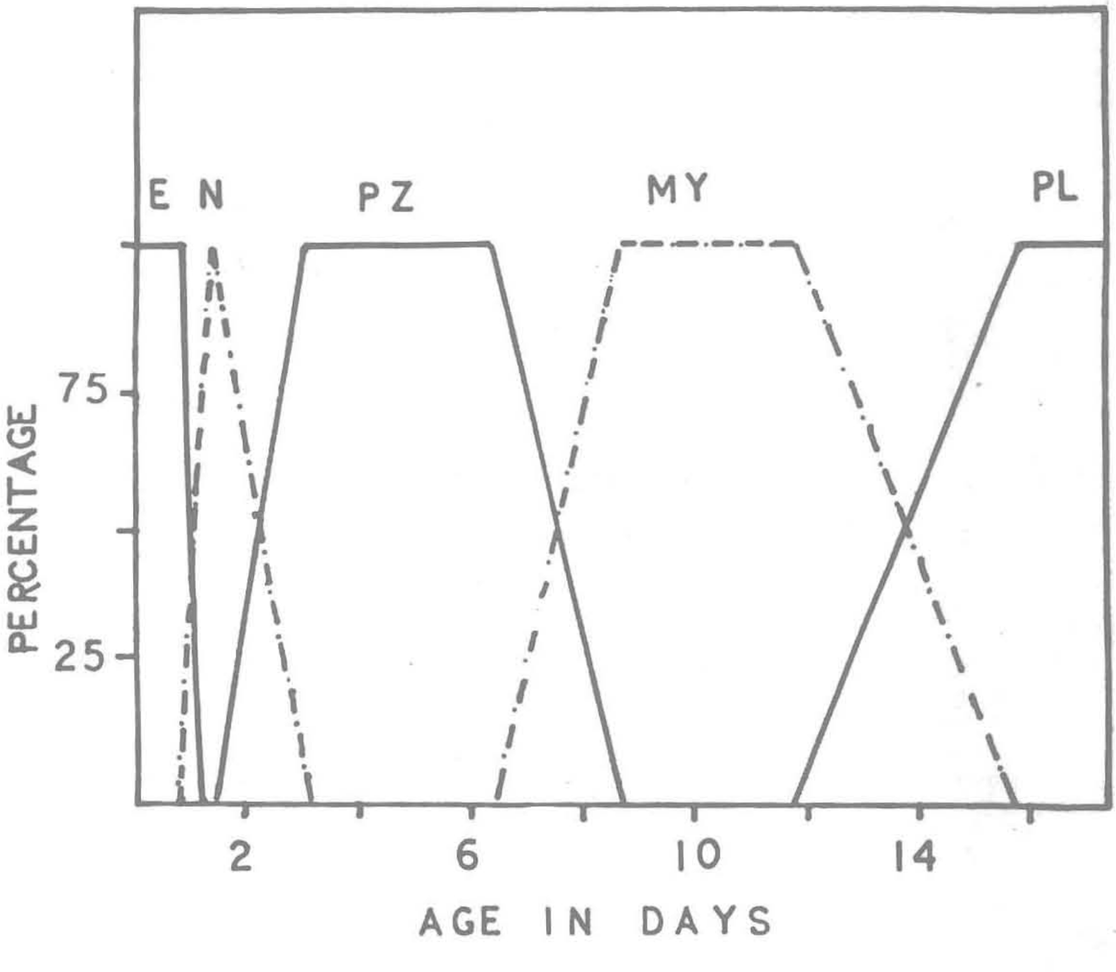

Fig. 18. Chronology of larval development.

Egg

Viable eggs are spherical, greenish cream in colour and lightly translucent. After being spawned, the size of the eggs increases until hatching, measuring 0.22-0.37 mm on release and 0.33-0.45 mm with embryo. The mean hatching time since spawning is 13 hrs.

Naupliar Stages (Fig. 19)

The larvae are non-feeding, highly phototactic and include six sub-stages lasting about 50 hrs.

N_I : Mean-length, 0.27 mm; mean-width, 0.13 mm. The antennules uniramous; antennae and mandibles biramous; antennae with 5 setae; ocellus present at the anterior end; the furcal spine formula is 1+1; the antennules and antennae are used for swimming with the support of the mandibles; duration 3 hrs.

Major naupliar changes on each moult to next sub-stage are the difference in setation; furcal spines and shape of the posterior region of the body. The furcal

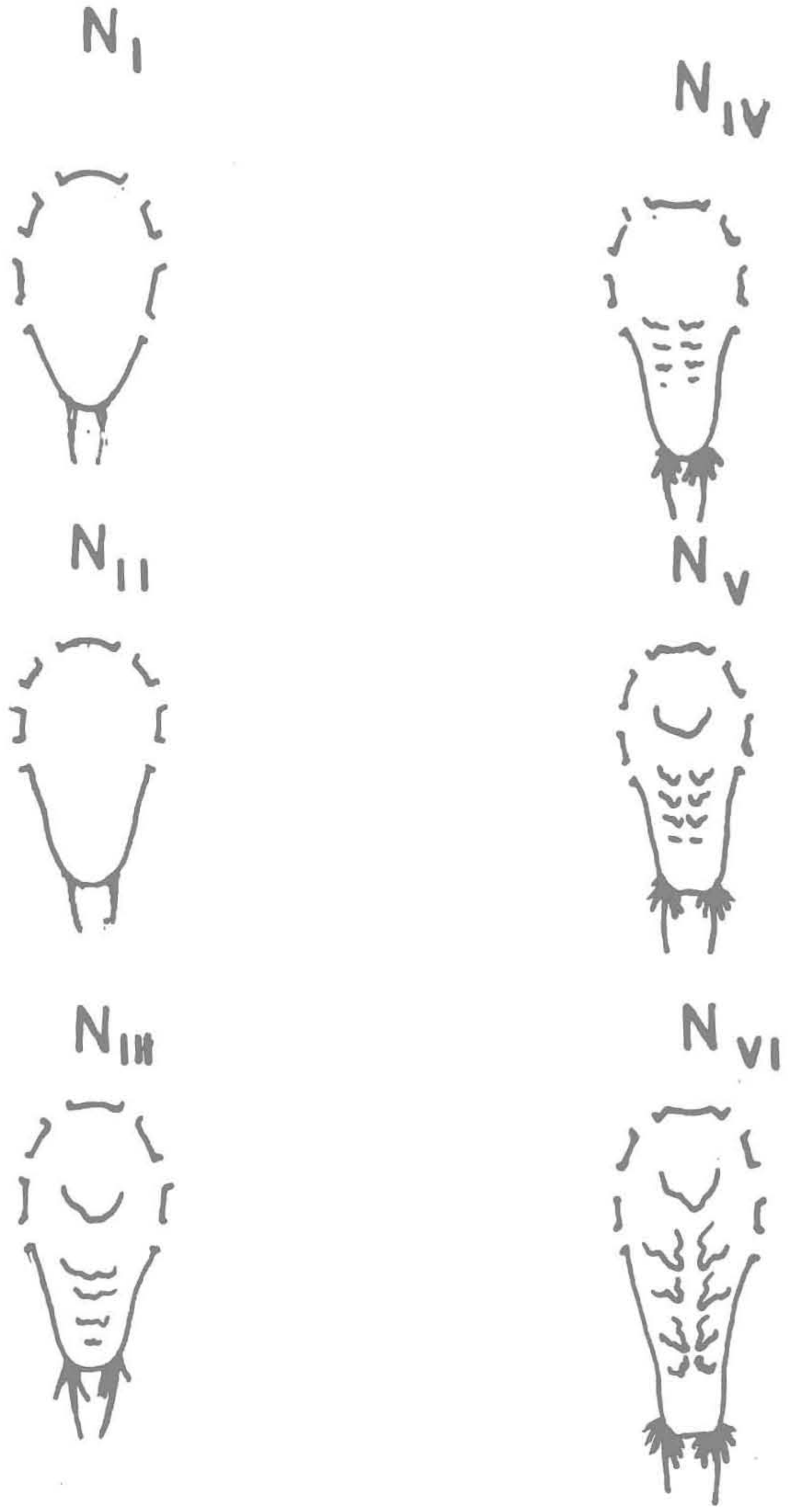

Fig. 19. Salient features of naupliar stages.

spines also increase in numbers and the body elongates posteriorly.

N_{II} : Mean-length, 0.28 mm; mean-width, 0.14 mm; the duration of this sub-stage is 4 hrs. The exopod of the antennae bifurcate, which is the characteristic of N_{II} to N_{VI}.

N_{III}: :Mean-length, 0.30 mm; mean-width, 0.16 mm; furcal setae 3+3; antennal setae increase from 5 to 6; duration 6 hrs.

N_{IV} : Mean-length, 0.32 mm; mean-width, 0.17 mm; furcal formula becomes 4+4; antennules develop segmentation and 1 or 2 setae added; mandible with slight swelling at the base; duration 4 hrs.

N_V : Mean-length, 0.34 mm; mean-width, 0.17 mm; furcal formula 6+6; frontal organ present; antennules with 9 setae; swelling at the base of mandibles becoming obvious; duration 14 hrs.

N_{VI} : Mean-length, 0.35 mm; mean-width, 0.17 mm; furcal formula 7+7; antennules with 9 setae;

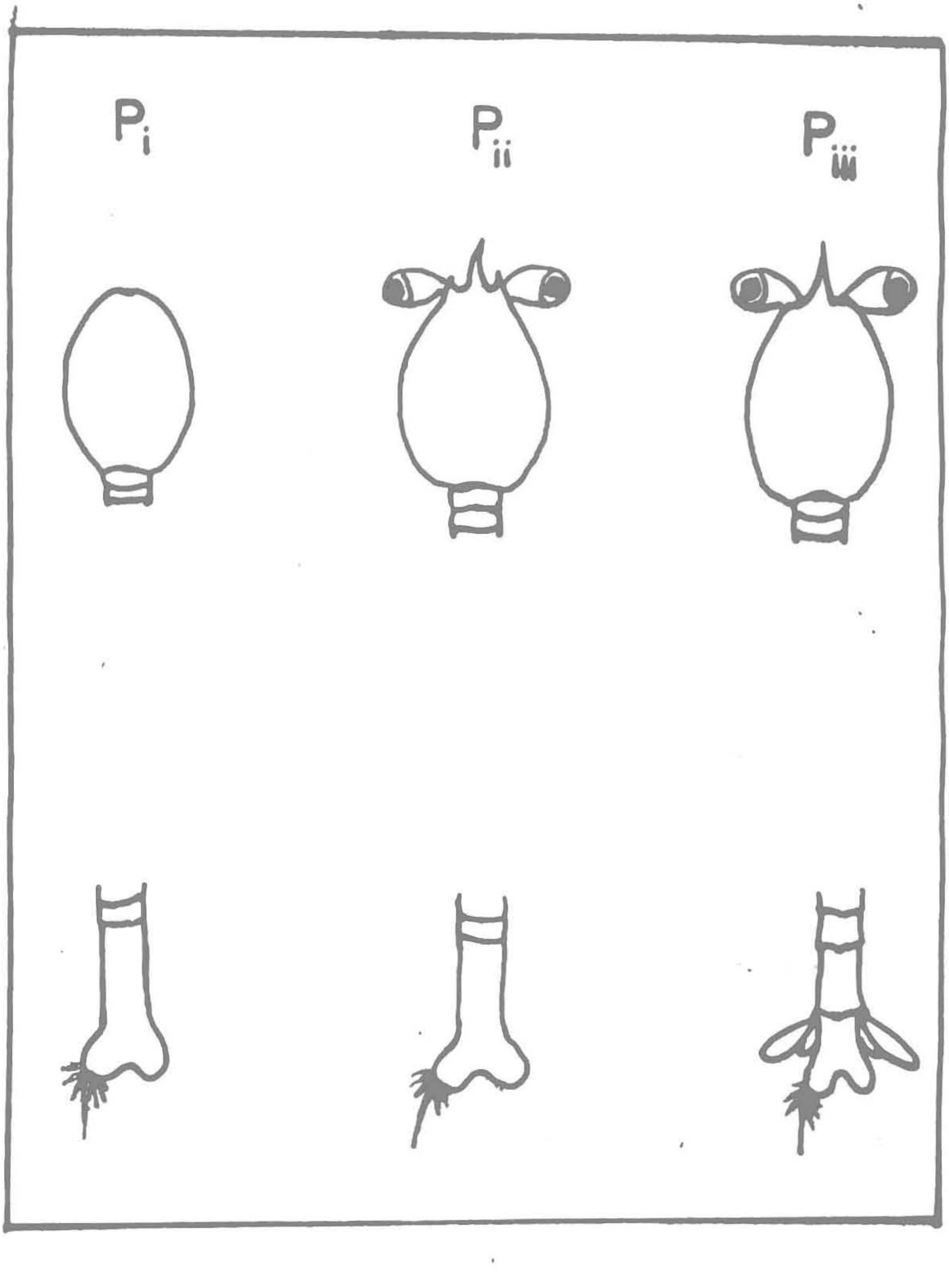

Fig. 20. Salient features of protozoeaic stages.

basal swelling of the mandibles more prominently spherical; duration 22 hrs.

Protozoeaic Stages (Fig. 20)

The 6th nauplius moults into protozoeaic phase, which has undergone radical changes from that of previous stages. Feeding commences as a filter feeder of phytoplanktons and hence they seem to be more critical stages. Disparity of developmental time between individuals appears to be more widening since these stages. The body elongates more pronouncingly and is divisible into two distinct parts, carapace anteriorly and segmented thorax and unsegmented abdomen posteriorly. Feeding appendages develop. This phase consists of 3 sub-stages and the characteristics of each sub-stage are,

P_I : Mean total length (MTL), 0.74 mm; mean carapace length (MCL), 0.32 mm; feeding appendages appear to be functional; caudal spines are further prominently developed; the simple eye-spot present in N_{VI} is still slightly visible; telson with 7 setae on each furcal lobe; duration 42 hrs.

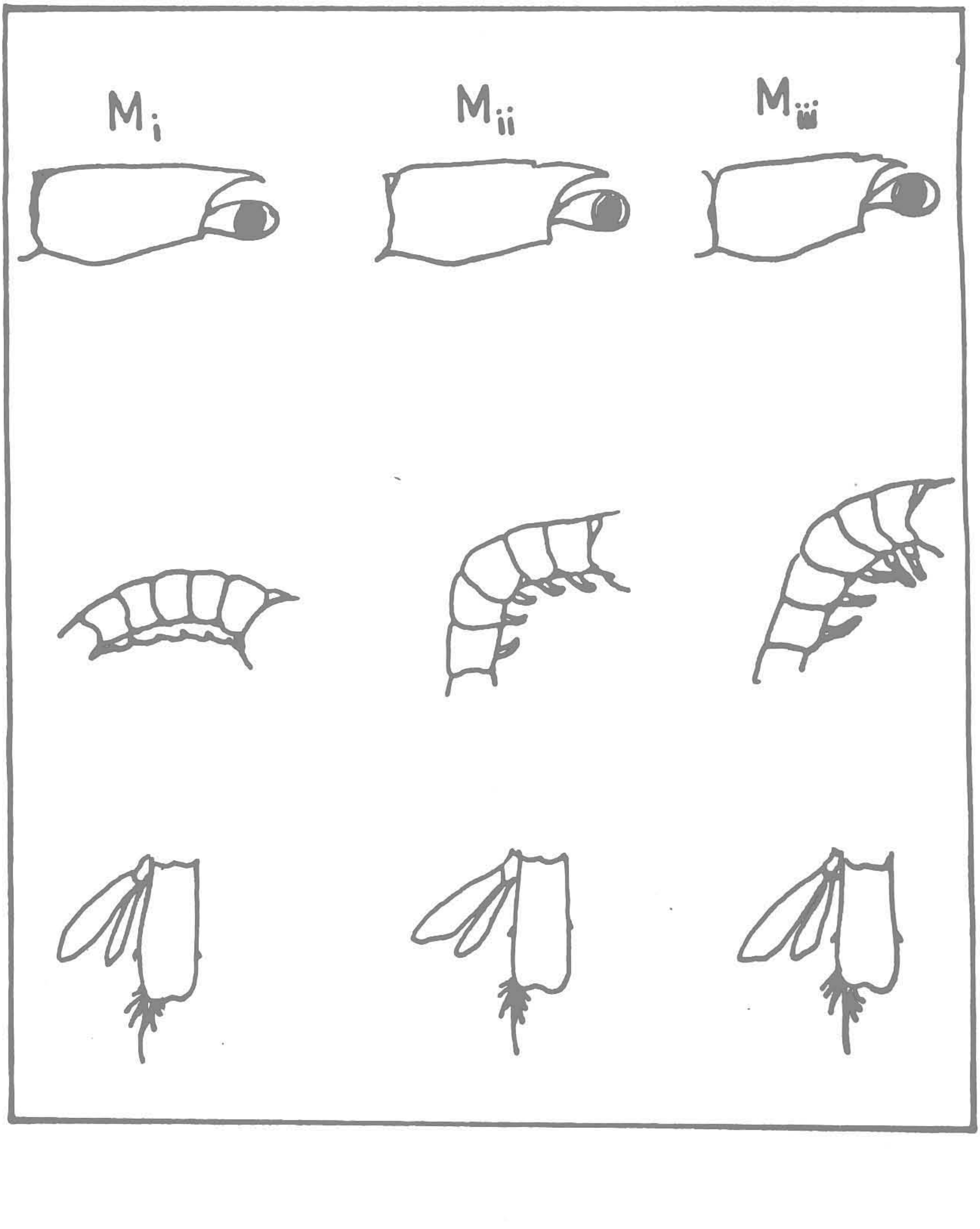

Fig. 21. Salient features of mysid stages.

P_{II} : MTL, 1.25 mm; MCL, 0.43 mm; the sub-stage has developed a pair of compound eyes for the first time; one rostral and two supra-orbital spines have appeared; abdomen further elongates and antennae tilts anteriorly; telson bears 7 setae on each side; duration 55 hrs.

P_{III}: MTL, 1.57 mm; MCL, 0.54 mm; rostrum extends prominently; supra-orbital spines sliced down in size; abdominal segments (1-5) with postero-dorsal spines and 5th segment also with postero-lateral spines. Uropods make their appearance; telson with 7 setae on each furcal lobe; duration 48 hrs.

Mysid Stages (Fig. 21)

The 3rd protozoeaic moults to mysid phase, which is more closer to adult form. Swim head down position in zig-zag pattern; feeding habits gradually changes from phytoplanktonic to zooplanktonic.

M_I : MTL, 1.95 mm; MCL, 0.75 mm; carapace fits to the abdomen covering almost all the

6 thoracic somites; dorsal abdominal spines present only on 5th and 6th segments; rostrum may or may not bear a tooth; pereopods with brush-like exopods and no pleopods present; telson with 7+7 setae; the uropod is developed and consisting of protopod, endopod and exppod; telson is cleft deeply behind; duration 31 hrs.

M_{II} : MTL, 2.15 mm; MCL, 0.64 mm; distinguishing feature of the sub-stage is the appearance of the rudimentary and uniramous pleopods on the ventral surface of the abdominal segments; duration 54 hrs.

M_{III}: MTL, 2.45 mm; MCL, 0.71 mm; characteristics of this sub-stage is the development of the pleopods with two segments, which bear setae at the tip; two rostral spines present; telson almost truncate; duration 56 hrs.

Post-larvae

Main features of the adults are attained and further developments are the rostral teeth and genitalia.

Table 6: The observed mean-size at age of post-larvae and juveniles of M. dobsoni reared in the laboratory

Age in months	Size in mm		
	'Fast'	'Slow'	'Pooled'
1 month	16.00	6.50	12.50
2 months	37.75	29.25	33.00
3 months	52.25	43.75	47.00
4 months	61.75	52.75	57.00
5 months	67.25	57.00	62.50
6 months	70.50	-	65.00

PL_I : MTL, 2.55 mm; MCL, 0.73 mm; rostrum blunt with 2-3 dorsal spines; 5th abdominal segment with spine; chromatophores on the uropods arranged in a semicircular arc position, which is characteristic of this post-larva~~e~~ from other species.

2. GROWTH OF POST-LARVAE AND JUVENILES

a. Age and Growth

Linear growth in post-larvae of M. dobsoni, as general in crustacea, takes place principally at moulting and thus, a truely descriptive growth curve of an individual is stepwise. However, the 'smoothed-out' size of several individuals gives a logistic form of curve if plotted against the age showing the slow-fast-slow pattern of growth (Table 6). The mean size of juveniles including of both sexes reared in similar conditions over 6 months could be thus fit to the popular von Bertalanffy growth equation:

$$L_t = L_\infty [1 - e^{-K (t - t_0)}] \qquad \ldots\ldots\ldots (3.1)$$

where, Lt = the size at time t,

$L\infty$ = the maximum size that Lt can reach,

K = growth coefficient at which Lt reaches $L\infty$, and

t_0 = t when Lt is zero.

The three basic parameters of the equation 2.1 viz., $L\infty$, K and t_0, for the post-larvae through adolescents are computed from the mean monthly size increment against age following the method suggested by Rafail (1973) as follows:

Equation 3.1 can be put as,

$$\log_e (dLt/dt) = A\ Kt \qquad \text{..........(3.1.1)}$$

where,

$$A = \log_e K + \log_e L\infty + Kt_0 \qquad \text{..........(3.1.2)}$$

Equation 3.1.1 is a straight-line relationship between the natural logrithms of growth increment per month, $\log_e (dLt/dt)$ and age, t, as the independent variate, with a slope, as a measure of the parameter K. The calculated equation by least square method is,

$$\log_e (dLt/dt) = 3.8387 - 0.4816\ t,$$

in which $K = 0.4816$, $\therefore\ e^k = 1.6190$

Derived from equation 3.1,

$$L\infty = \frac{e^{k}\sum_{2}^{n} Lt - \sum_{1}^{n-1} Lt}{(n-1)\,(e^{k}-1)} \qquad \ldots\ldots\ldots(3.1.3)$$

Substituting appropriately the values of e^k obtained by 3.1.1 and the cumulative totals of Lt from Table 5 in the Eq. 3.1.3,

$$L\infty = \frac{(1.6190 \times 265) - 212}{(6-1)\,(1.6190-1)}$$

$$= 70.12 \text{ mm}$$

Replacing with the values of L∞ and K in Eq. 3.1.2,

$$A = -\log_e 0.4816 + \log_e 70.12 + 0.4816\, t_0$$

$$3.8387 = -0.7308 + 4.2501 + Kt_0$$

$$\therefore Kt_0 = 3.8387 - (-0.7308 + 4.2501)$$

$$= 0.3194$$

$$t_0 = \frac{0.3194}{K} \qquad \frac{0.3194}{-0.4816}$$

$$= -0.6632$$

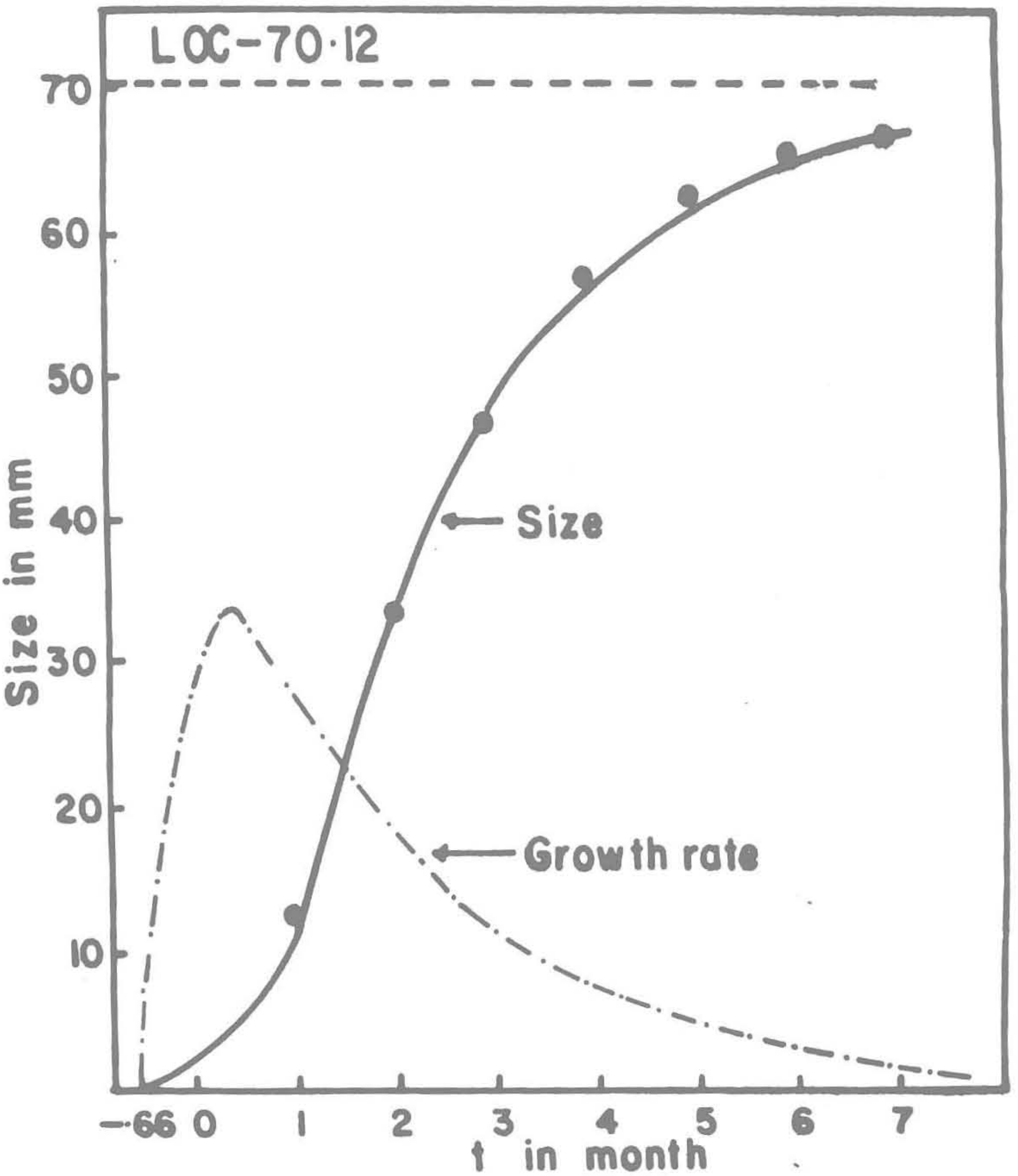

Fig. 22. Age and growth of juveniles (pooled).

Hence, the von Bertalanffy growth equation 3.1 calculated for the young M. dobsoni common to both sexes is,

$$Lt = 70.12 \left[1 - e^{-0.4816\,(t + 0.6632)}\right] \;....(3.1.4)$$

where,

$L\infty = 70.12$,

$K = -0.4816$, and

$t_o = -0.6632$

The age-for-size estimated by the Eq. 3.1.4 is presented in figure 22, from which it is apparent that the maximum size increase is attained during second month of life and then gradually decreased with age till the zero growth is noted at 70.12 mm in about 9.5 months.

The post-larvae are computed to reach 56.06 mm in 4 months and require another 5.5 months to grow further about 14 mm for the asymptote length of 70.12 mm. About 60 mm size, around which the species generally migrate to the sea or harvested in culture operations, is attained in 4.5-5.0 months of life, inclusive of about 0.5-1.0 month for larval phase at sea.

The rate of growth of the post-larvae can be calculated from the equation:

$$\frac{l_2 - l_1}{t_2 - t_1} = K\left(L\infty - \frac{l_1 + l_2}{2}\right) \qquad \ldots\ldots\ldots (3.2)$$

where, l_1 and l_2 are the length at successive months, t_1 and t_2 respectively and $L\infty$ and K are the estimated parameters of Eq. 2.1.4. The calculated growth rates are presented along with growth curve for Eq. 3.1.4 in figure 22, which indicates an early sharp increase and gradual decrease after a peak.

The highest growth-rate of 23.22 mm/month is recorded for the second month of life and maintained above 10 mm/month until the larvae are 3 months old. After 5 months the growth-rate declines below 5 mm/month and at the age of 6 months, when the juveniles attain the size of emigration in nature, the rate of growth is about 2.5 mm/month.

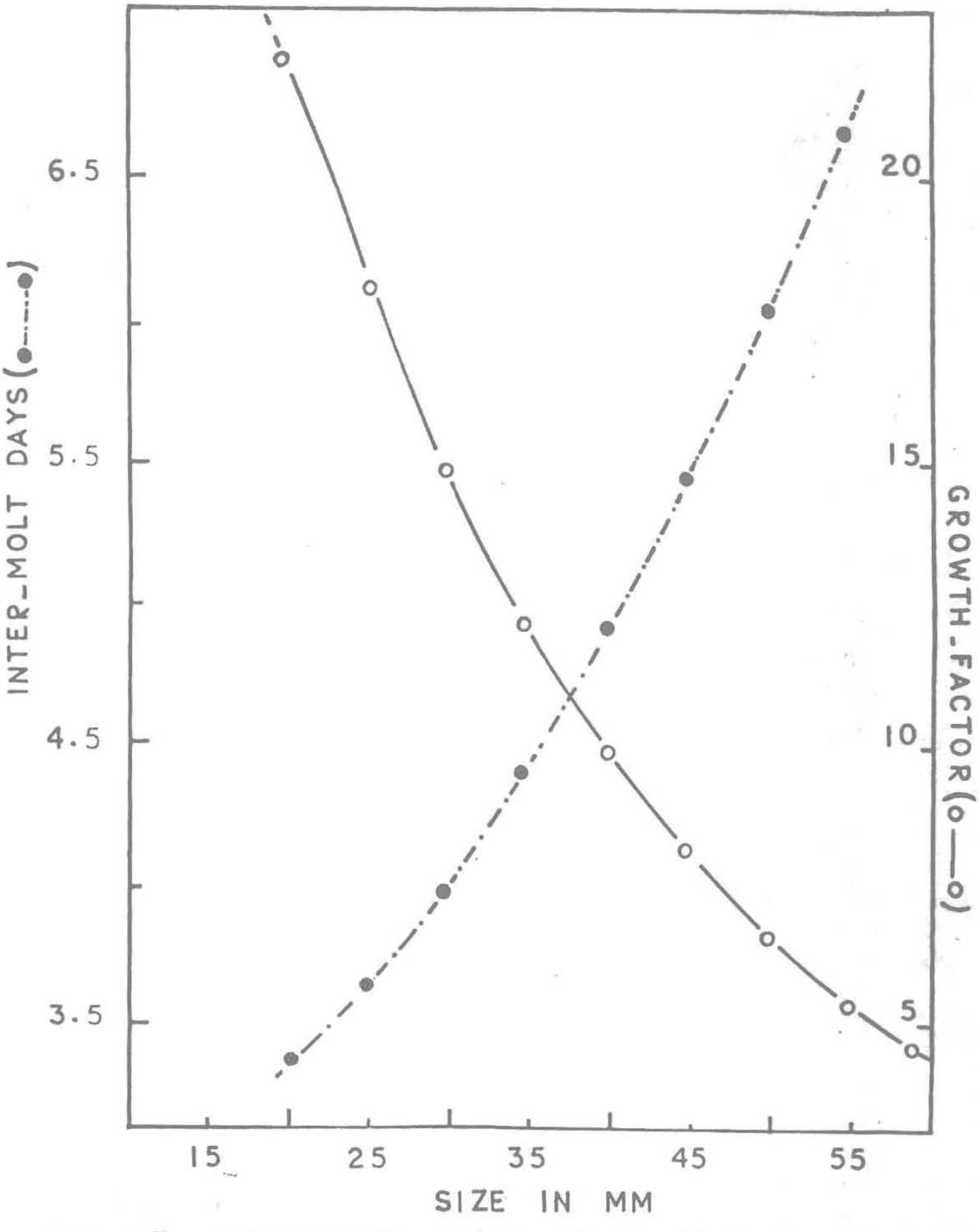

Fig. 23. Inter-moult period and Growth-Factor against size of juveniles.

b. Moulting and Growth

Length increases only at moulting in crustacea and thus, growth curve is step-wise. Moulting involves two principal processes, which jointly impose growth at a given period. They are the inter-moult period, which is the time interval between successive moults, and moult-increase, which is expressed as Growth-factor, the percentage moult-increase upon the pre-moult body length. Both these factors show linear relationship against body size.

The moult-history, noted for several post-larvae from 15 mm through 50 mm, reveals that inter-moult period has the positive relationship, increasing logrithmically, when plotted against body length. The regression calculation from the mean inter-moult period against pre-moult length is,

$$\log IP = 0.4201 + 0.0090\ L \qquad \ldots\ldots\ldots\ldots(3.3)$$

where, IP is the inter-moult period and L is the corresponding length in mm. The estimated inter-moult periods against length, which are presented in the figure 23, reveal that the inter-moult period of about

3.5 days at 15 mm size gradually extends to 5 days around 30-35 mm and 7.4 days at 50 mm lengths. Further extrapolation of inter-moult periods over 50 mm size is not attempted considering the non-inclusion of larger individuals than 60 mm size, when the maturity is onset, disrupting the moulting periodicity.

On the contrary to inter-moult period, growth-factor of moulting, decreases logrithmically when plotted against body length. The regression equation calculated for the post-larvae of the size range between 15 mm and 50 mm is,

$$\log GF = 1.5168 - 0.0173 L \qquad \text{........(3.4)}$$

where, GF is the growth-factor and L is the length of the post-larva in mm. The growth-factor estimated for the size upto 50 mm (Fig. 22) shows that the percentage increase at moulting upon pre-moult size gradually decreases from 22.07% at 10 mm size to 14.82% at 20 mm; 9.95% at 30 mm; 6.68% at 40 mm; and 4.48% at 50 mm body length and thus moult increment does not change proportionate to the body length throughout. Hence, the decrease in growth-rate, as the animal grows older is mainly due to increase in inter-moult period, but not much to the size increase at moult.

c. Inheritance of Growth

Size of individuals produced by the same mother at a single spawning varies considerably at any age, eventhough they are reared under identical rearing and feeding conditions throughout. That is, the individuals are found to grow at different pace though majority of them closely synchronize. Gradual widening of the range of developmental durations for successive larval phases (Fig. 18) appears to indirectly indicate differential accelerations of growth among individuals. Hence, the first post-larval stage is attained over a span of 12-18 days after spawning by different individuals resulting in a maximum difference of 6 days' growth. Size disparity, which is likely influenced by genetics, is further illustrated by comparing the widely varying size groups of individuals referred as 'fast' and 'slow' groups.

On the 24th day of age, the 'fast' group measures 12-13 mm length and the 'slow' group measures 5-9 mm and they increase to the mean size of 16.0 mm and 8.5 mm (Table 6)

Table 7: Estimated size-for-age of 'fast' and 'slow' groups of juveniles of *M. dobsoni* and their differences

Age in months	Size in mm		Difference in mm
	'fast' group	'slow' group	
1.00 month	14.87	7.30	7.57
2.00 months	37.94	29.75	8.19
3.00 months	52.26	43.47	8.79
4.00 months	61.18	51.89	9.29
5.00 months	66.18	57.05	9.67
6.00 months	70.16	60.02	9.96
7.00 months	72.16	62.14	10.15
9.50 months L_∞	-	65.20	10.60
9.64 months	75.80	-	

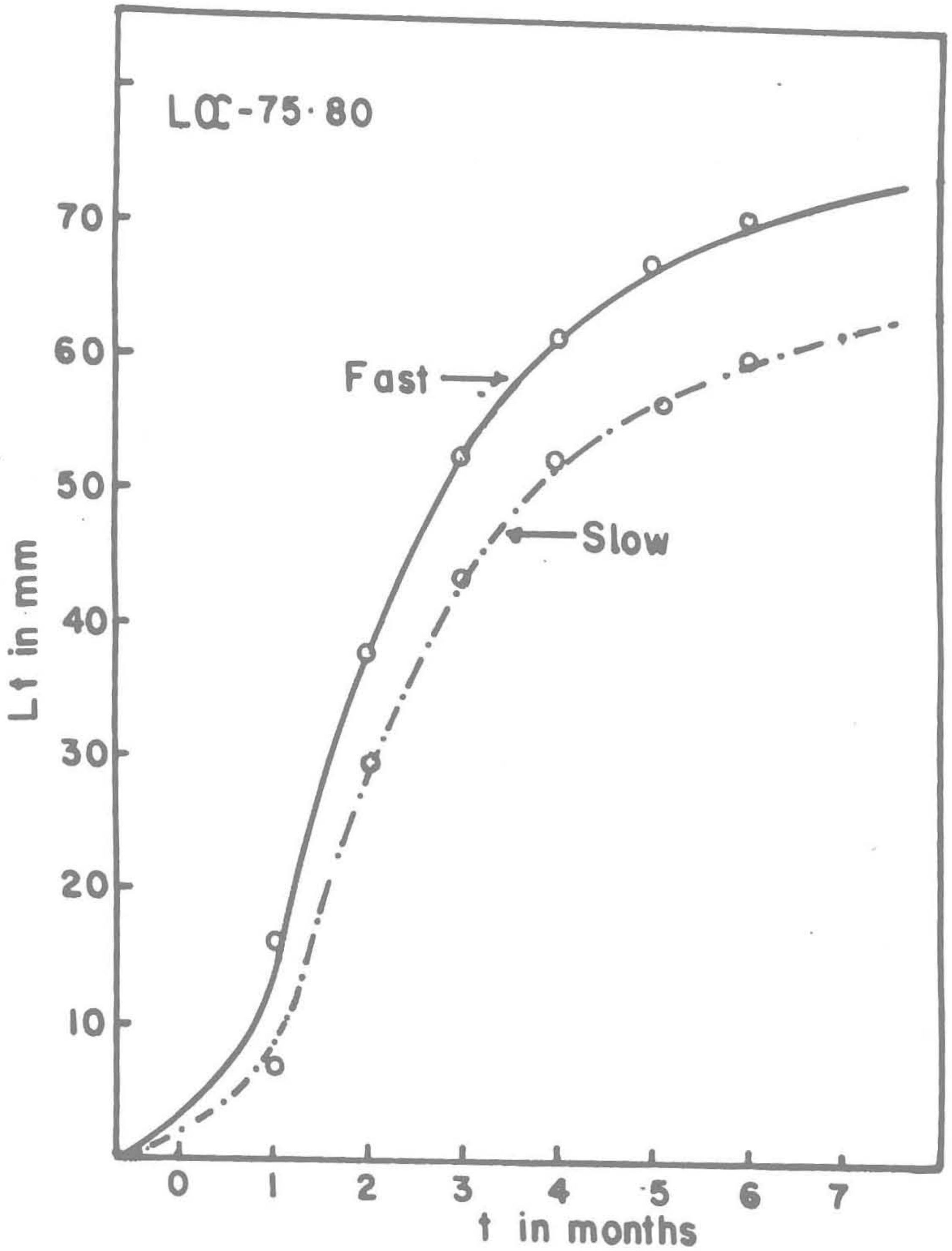

Fig. 24. Age and size of 'fast' and 'slow' groups.

respectively by the end of the first month. Following rapid growth in second month, the 'fast' group reaches 52.25 mm and 'slow' group attains 43.75 mm at the end of third month, and subsequently both groups appear to slow down their growth progressively. The 'fast' group, thus, reaches 61.75 mm in 4 months and 67.25 mm in 5 months, whereas, the 'slow' group attains 52.75 mm and 57.00 mm in corresponding periods. The von Bertalanffy growth equations 3.1 computed for both groups are,

$$\text{'Fast'} : Lt = 75.80 \, [1 - e^{-0.4758 \, (t + 0.5414)}] \quad \ldots (4.1)$$

$$\text{'Slow'} : Lt = 65.20 \, [1 - e^{-0.4901 \, (t + 0.7580)}] \quad \ldots (4.2)$$

From which, it is estimated that the 'fast' group can reach the asymptotic length of 75.80 mm at the rate of change of increment at 0.4758 in 9.64 months, compared to the corresponding values of 65.20 mm at 0.4901 in 9.5 months for the 'slow' group. The calculated size at age of both groups and their differences are given in Table 7.

It is, thus, evident from the calculated values that the most advantage in growth is gained by the 'fast' group during the first month of life, when this

Table 8: Estimated growth-rate of 'fast' and 'slow' groups of juveniles of *M. dobsoni* and their differences

Age in months	Grwoth-rate in mm/month		Difference in mm
	'fast' group	'slow' group	
1st month	32.50	30.16	2.34
2nd month	23.50	22.87	0.63
3rd month	14.61	14.01	0.60
4th month	9.08	8.59	0.49
5th month	5.64	5.26	0.38
6th month	3.50	3.22	0.28

group reaches 14.87 mm against 7.30 mm by the 'slow' group, leaving a difference of 7.57 mm in between the groups. Henceforth, the difference progressively increases to cross 10 mm around the age of 7 months. After rapid growth during the first two months, the 'fast' group is estimated to reach 52.26 mm and the 'slow' group 43.47 mm at the end of 3 months. Also the 'slow' group attains 51.89 mm in 4 months, which is still less than the size attained in 3 months by the 'fast' group. At the age of 5 months, when the juveniles normally emigrate to the sea in nature (considering the average size for both groups being 61.89 mm) the 'fast' group grows to 66.72 mm size and 'slow' group to 57.05 mm and beyond 6 months the growth is very slow before reaching the asymptote 75.80 mm in 9.64 months by the former and 65.20 mm in 9.5 months by the latter.

The growth-rates calculated by Eq. 3.2 and as given in Table 8, further show that the maximum rate is estimated for the first month and progressively diminishes later against age. The growth-rate, which is estimated at 32.50 mm/month for the 'fast' and 30.16 mm/month for the 'slow' group in one month, decreases by 9 mm to 23.50 mm/month by the former and by 7.29 mm to 22.87 mm/month by the latter in the 2nd month and hence, the difference in rate at 2.34 mm in the first month is reduced sharpely to 0.63 mm in the second month. From third month onwards the growth-rates of the groups are closer, though the 'fast' group is maintaining the marginal advantage throughout. Hence, the difference of growth-rates are less than 0.5 mm between the groups for 4th month and above, when the growth-rates are meantime declining below 10 mm/month.

The studies on moult-history of individuals of both 'fast' and 'slow' groups of the size range of 15-50 mm, reveal linear relationships between the inter-moult period and the growth-factor, which is the moult-increment upon pre-moult size expressed in percentage, on the one hand and the body length on the other hand. As explained in the previous chapter, the inter-moult period increases logrithmically in both groups, but at obviously different rates. The regression calculated for them are,

'Fast' : $\log IP = 0.2535 + 0.0127\,L$

'Slow' : $\log IP = 0.4929 + 0.0075\,L$

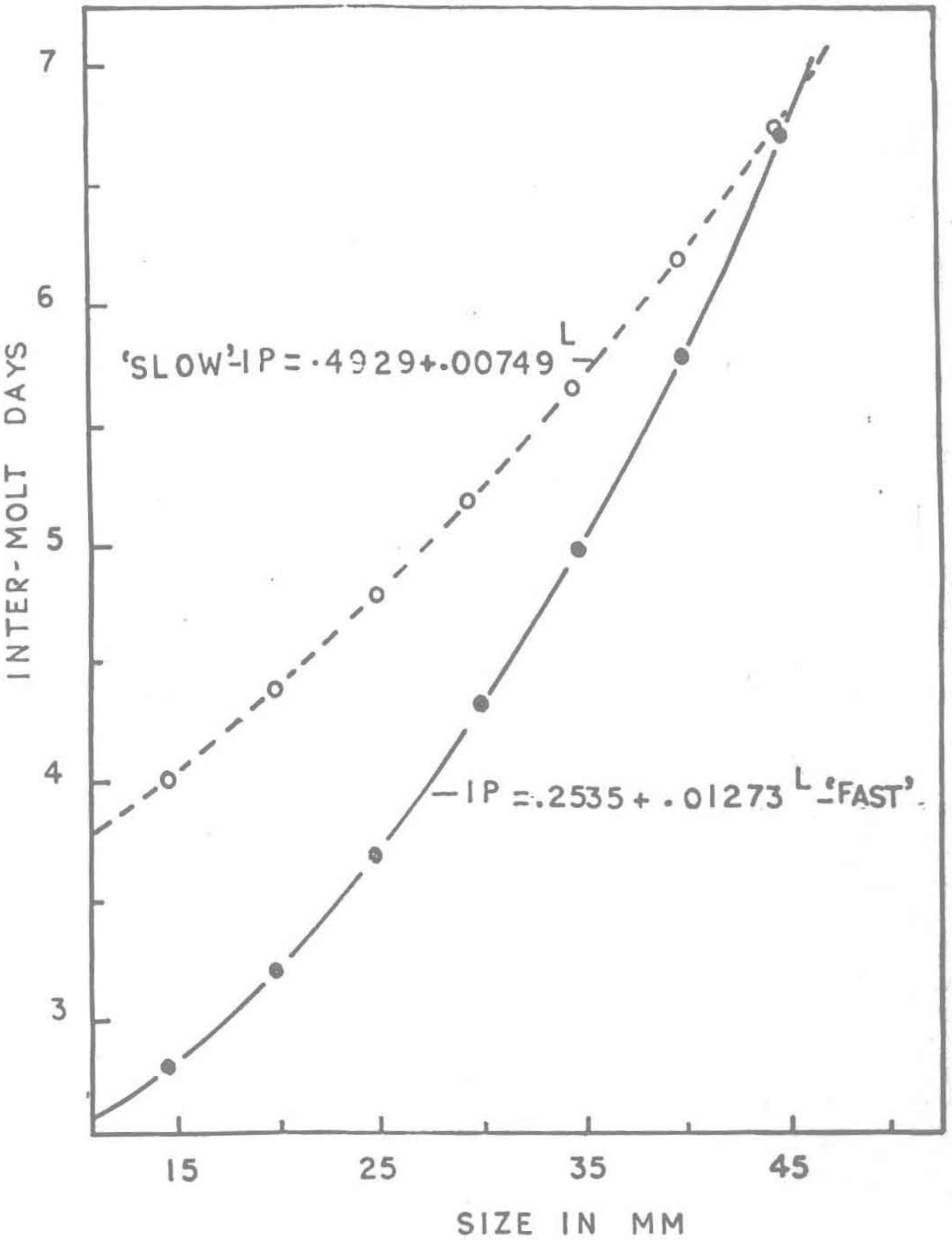

Fig. 25. Inter-molt period against size for the 'fast' and 'slow' groups.

(next line).

where, IP is the inter-moult period/~~and~~ ;L is the length in mm. The inter-moult periods calculated for the size series from the equations and presented in figure 25, which reveals that the inter-moult days increase relatively quicker from 2.78 days at 15 mm size to 7.76 days at 50 mm length for the 'fast' group, as compared to 4.02-7.38 days at respective sizes for 'slow' group. However, more than 1 day advantage to 'fast' group at every moult upto 25 mm size, which is generally the quick growth phase in life, enables this group advancing in size sooner as compared 'slow' group. Besides, a reversal of inter-moult days at 45 mm in favour of 'slow' group is evident, but not enough to match the early disparity favouring 'fast' group before 50 mm size is reached. Since, moult-history is not traced and included in calculations beyond 50 mm sizes, when drastic changes in trend of growth and migratory behaviour in nature occur, as noted in earlier chapter, further extrapolation for inter-moult time against size is avoided for any comparisions between the groups.

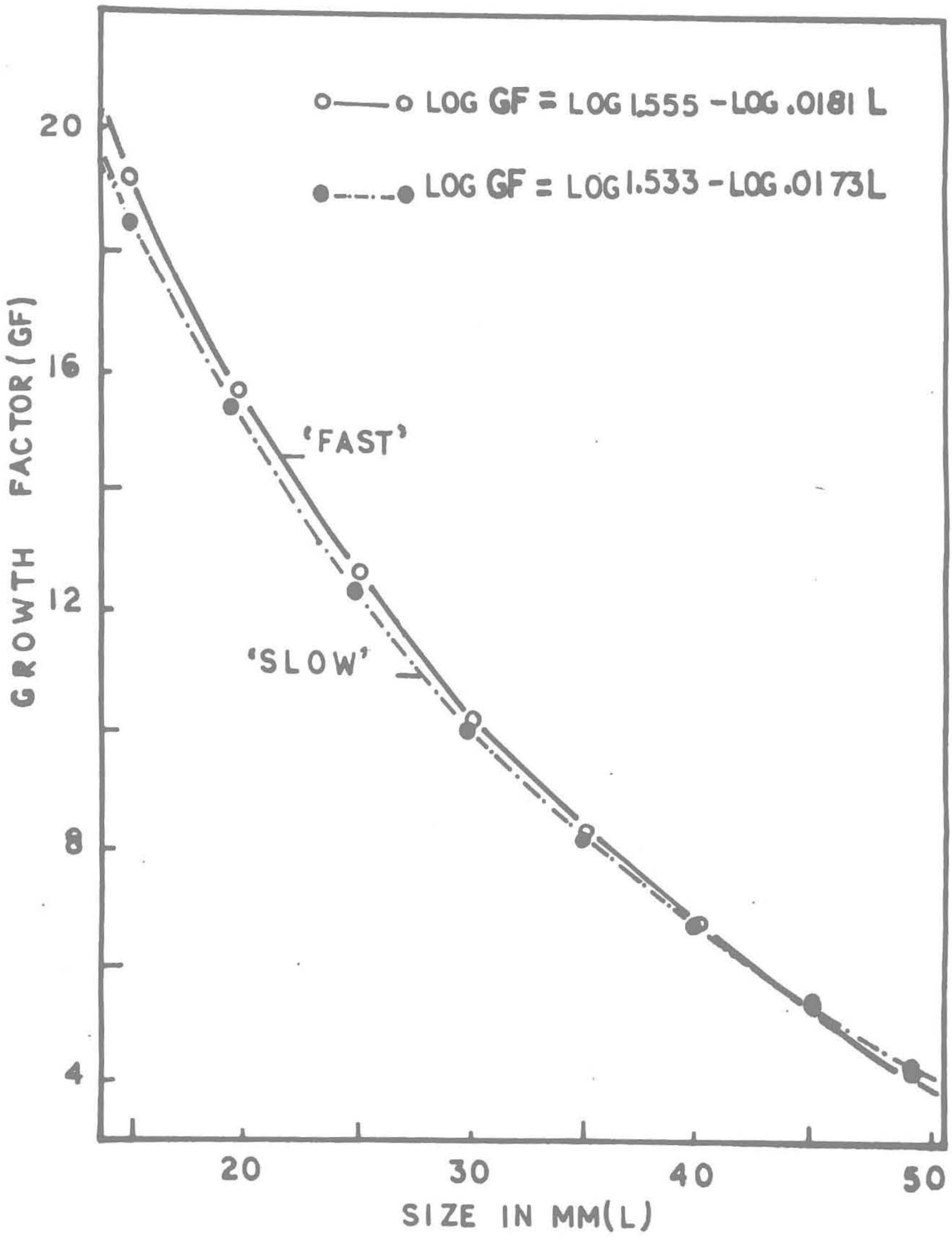

Fig. 26. Growth-factor (GF) of 'fast' and 'slow' groups.

On the contrary to inter-moult period, growth-factor decreases logrithmically against size in both groups without significant variations as much the inter-moult period has for the corresponding sizes. The equations estimated by least square method for the post-larvae measuring 15-50 mm size are,

'Fast' : $GF = 1.5313 - 0.0173\,L$,

'Slow' : $GF = 1.5550 - 0.0181\,L$,

where, GF is the growth-factor of moulting and L is the length in mm. The values of constants in the equations and the growth-factors calculated for the size series (Fig. 26) show that the difference between the groups is marginal and does not exceed 1% at any size. Growth-factor appears to favour either groups alternatively during the course of growth upto 50 mm size. The 'fast' leads upto 25 mm size and remaining near equal till 30 mm length, it trails behind the 'slow' group subsequently. Hence, growth-factor does not seem to influence much disparity on growth between the groups under comparisions, though it compensates slightly on growth for 'low' group when it is relatively in disadvantage of inter-moult periods.

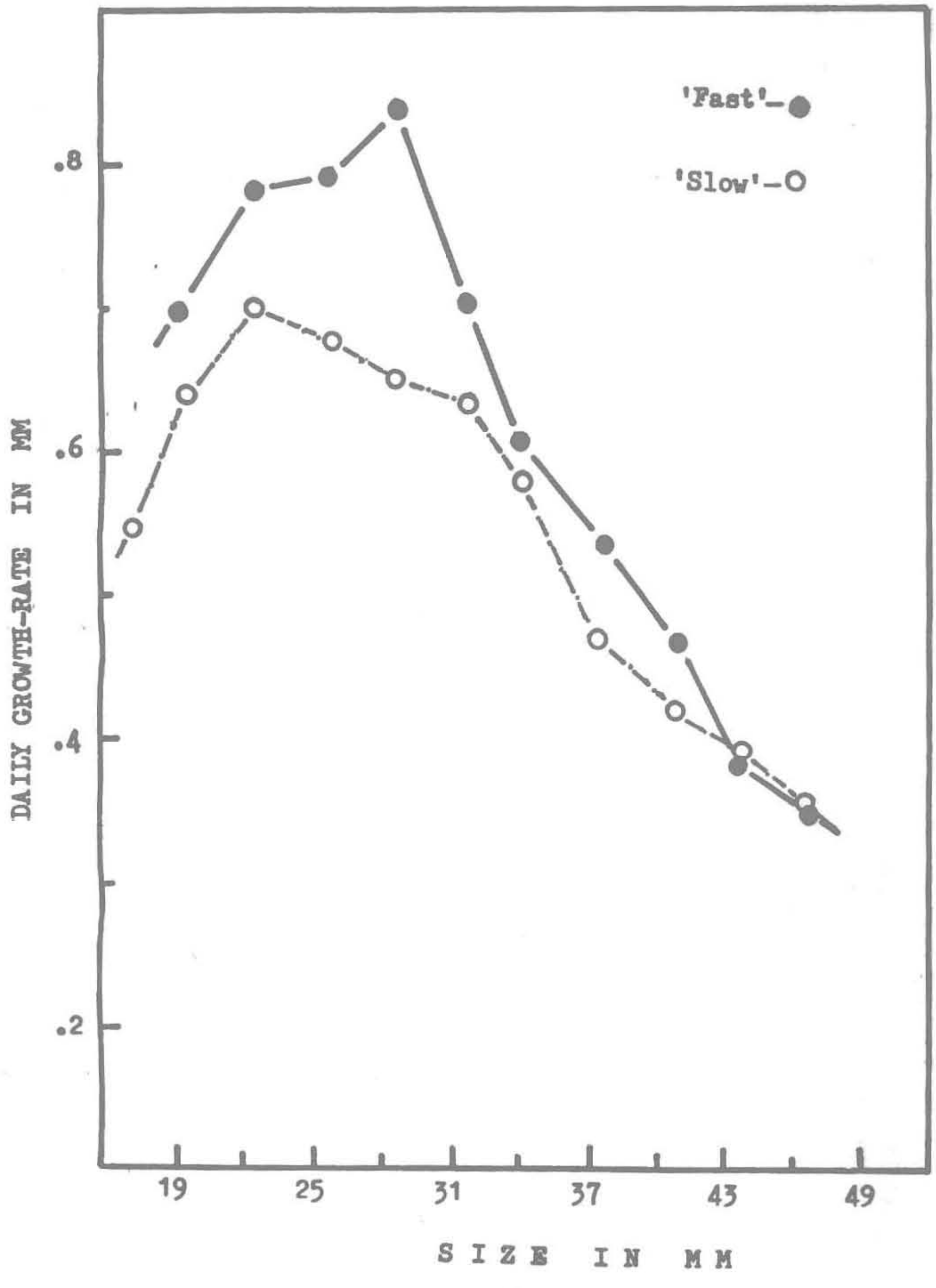

Fig. 27. Growth-rates against size of 'fast' and 'slow' groups.

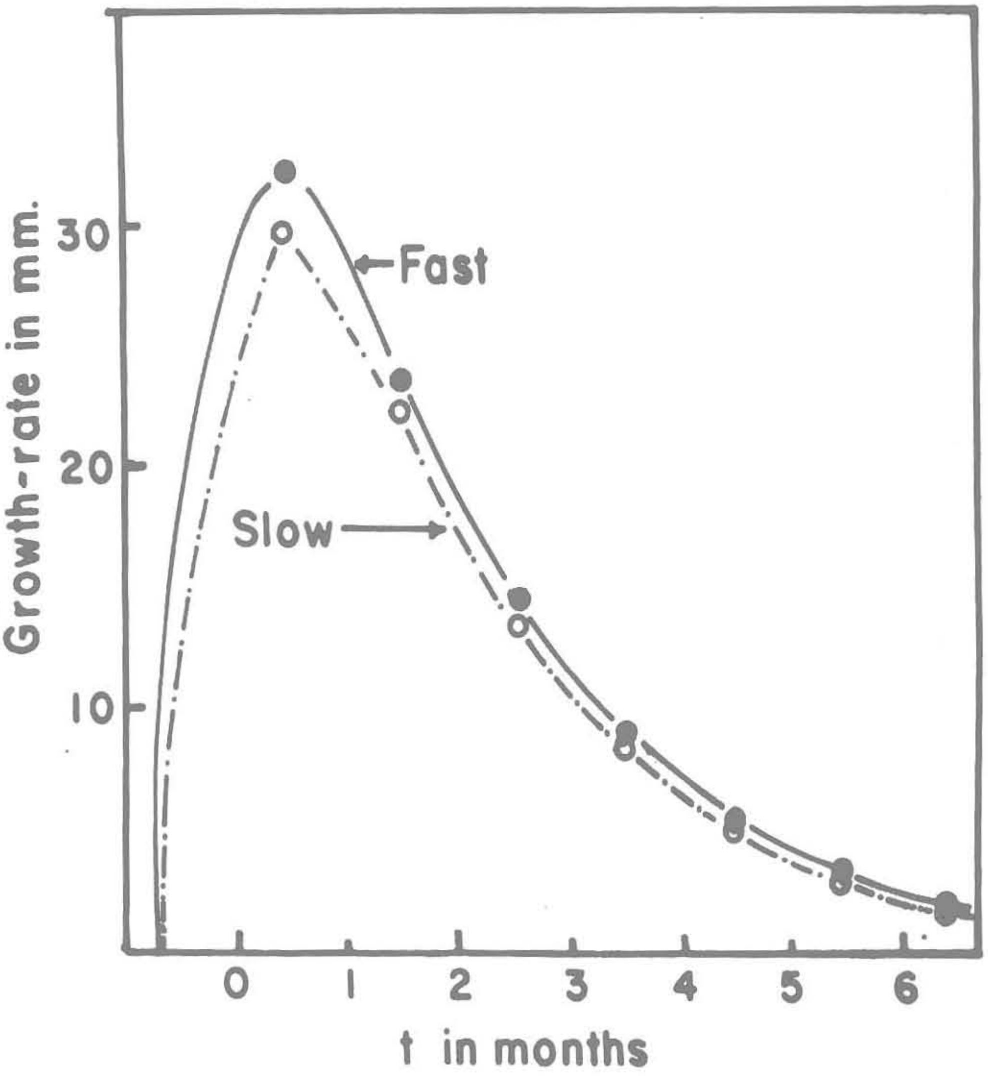

Fig. 27. Growth-rate against size of juveniles of 'fast' and 'slow' groups.

Besides, the mean daily growth-rate, which is calculated from inter-moult period and respective moult-increment, forms a single peak polygon (Fig.27), with their modes at 20-35 mm size for both 'fast' and 'slow' groups. The highest growth rate of 0.83 mm/day at 28.5 mm size and 0.70 mm/day at 22.5 mm size for the respective groups are noted and the widest disparity of 0.18 mm/day prevails at 28.5 mm size in favour of 'fast' group. Also the daily growth-rate is in clear advantage to 'fast' group until 40 mm size, when it tilts, but with negligible margin, in favour of 'slow' group.

d. Eyestalk-ablation and Growth

Eyestalk-ablation accelerates moulting in postlarvae and juveniles of this species and as a result, those ablated animals grow at a better rate than the non-ablated individuals. The moult-history of animals in Experiments I and II have been illustrated in figure 28, from which the number of moults involved, size increase at each moult and the time of eyestalk-ablation can be understood. The animal in Experiment I progresses from 24.75 mm size to 41.75 mm size, with

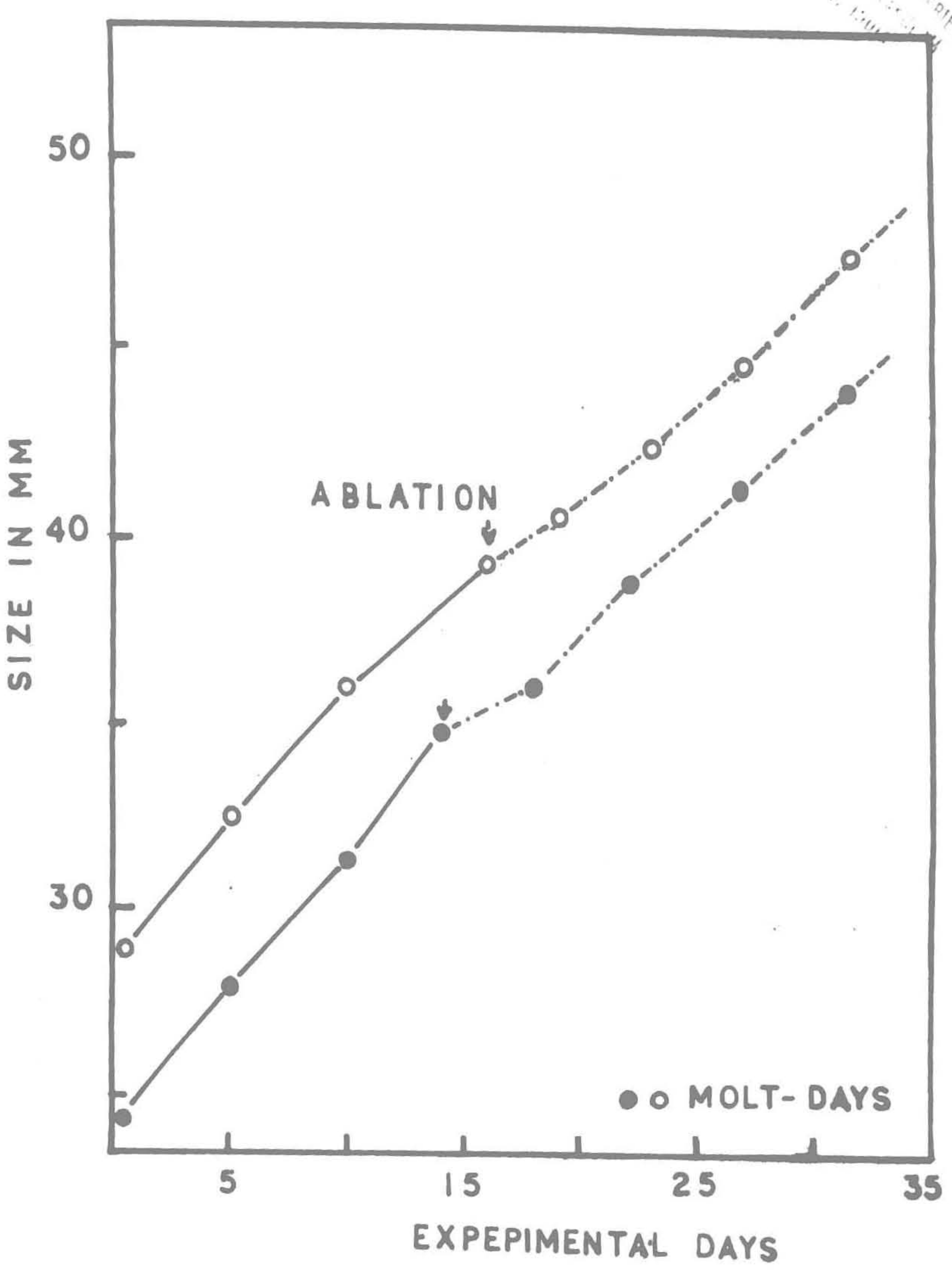

Fig. 28. Effect of eyestalk-ablation on growth of juveniles.

a net increase of 17.00 mm in 33 days involving 7 moults, including 3 pre-ablation moults, ablation-moult and 3 post-ablation moults. Initially, the animal measures 24.75 mm and reaches 35 mm size at the end of 3 pre-ablation moults in 14 days, with an average of 4.67 days per moult. The same animal then grows by 1 mm to 36 mm size at ablation-moult in 4 days and later increases to 41.75 mm after 3 post-ablation moults in 14 days, giving an average of 5 days per moult.

The individual in Experiment II is slightly larger in size as it initially measures 30.00 mm. It increases to 39.00 mm size after 3 pre-ablation moults in 15 days, with an average of 5 days per moult; improves by 1.50mm to 40.50 mm at ablation-moult and to 48.50 mm later at the end of 3 post-ablation moults in 15 days, averaging 5 days per moulting.

As found in earlier chapter that inter-moult period increases with size and the growth-factor, the size increase upon pre-moult size expressed in percentage, decreases against length, the inter-moult periods and growth-factors for the corresponding sizes at pre-ablation moults, ablation-moult and post-ablation moults have been calculated from the Eq.3.3 and 3.4, computed for the general pool of post-larvae in the early chapter, and compared with the experimental animals.

$$\text{Log IP} = \log 0.4201 + \log 0.0090 \text{ L} \;......(3.3)$$

$$\text{Log GF} = \log 1.5168 + \log 0.0173 \text{ L} \;......(3.4)$$

where, IP is the inter-moult period in days, GF is the growth-factor and L is the pre-moult size. The computed values along with the observed values for the corresponding sizes and periods have been presented in Table 9, from which it is evident that the inter-moult period is 5% shorter in observation animals during pre-ablation periods in both experiments compared to the control animals (computed values from the equation) during pre-ablation periods and still shortens sharpely to be varying by 23.34% in Experiment I and 32.20% in Experiment II at the ablation-moult. These values, however, decline gradually to the mean of 15.25% and 22.00% rrespectively, during the 3 post-ablation moults. The sudden fall in inter-moult period on ablation and

Table 9: Particulars giving effects of eye-stalk ablation on inter-moult period, growth-factor and growth-rate of experimental animals, as compared to computed values for the general pool of post-larvae in Chapter 4.2.

Experimental period	Mean-size in mm	Mean inter-moult period (days)			Mean growth-factor			Growth-rate (mm/day)		
		Comp.	Obs.	Dif. in %	Comp.	Obs.	Dif. in %	Comp.	Obs.	Dif. in %
EXPERIMENT I:										
Pre-ablation (3 moults)	31.13	4.88	4.67	- 4.30	10.09	9.64	- 4.46	0.630	0.626	- 1.28
Ablation	35.50	5.43	4.00	-23.34	8.15	2.86	-64.90	0.556	0.250	-55.02
Post-ablation (3 moults)	40.29	5.90	5.00	-15.25	7.00	7.32	4.57	0.479	0.585	22.13
EXPERIMENT II:										
Pre-ablation (3 moults)	34.67	5.21	5.00	- 4.03	8.81	8.94	1.44	0.570	0.603	5.79
Ablation	39.75	5.90	4.00	-32.20	6.95	3.85	-44.60	0.488	0.375	-23.08
Post-ablation (3 moults)	44.59	6.41	5.00	-22.00	5.89	6.19	5.09	0.410	0.552	34.63

gradual increase is further clear from the fact that the 4 days at ablation-moult reaches greadually 6 days on the 2nd post-ablation moult in Experiment I and 3rd in Experiment II.

But, moult-increase, as expressed growth-factor, differs inter-moult period in this experiments in the manner that the recovery from the sharp fall at ablation of eye is quicker, from the very subsequent moult onwards, and maintains subsequently without significant difference from the control. It is evident thus that the mean GF estimated respectively at pre-ablation moults, ablation-moult and post-ablation moults are 9.64%, 2.86% and 7.32% for Experiment I and 8.94%, 3.85% and 6.19% for Experiment II animals. Since, the GF decreases gradually with size, a comparision has been made with the control values as estimated from Eq. 3.4 and the measure of deviations have been expressed in percentage (Table 9). The difference in GF values of observed from control respectively at pre-ablation moult, ablation-moult and post-ablation moult are -4.46%, 64.90% and 4.57% in Experiment I and 1.44%, -44.60% and 5.09% in Experiment II and hence the fall at ablation-moult is very sharp, but regained to be slightly advantageous during subsequent moults.

The growth is the product of moult-interval and size increase at moult and both these factors are not found above in similar manners at post-ablation periods and the specific growth-rate of the individuals in Experiments I and II have been calculated from the size difference divided by moult-intervals and compared with controls estimated from Eq. 3.2 in earlier chapter. The deviation from the control value is expressed in percentage, which shows that the observed value is different by, -1.28%, -55.02% and 22.13% in Experiment I and 5.79%, -23.08% and 34.63% in Experiment II respectively at pre-ablation, ablation and post-ablation moults. Hence, the disadvantage of growth at ablation-moult is being made up and surpassed to advantage cumulatively through subsequent several moults. Considering the percentage of size differences at the three durations and number of moults involved, an average overall advantage of about 15% and 43% in Experiments I and II have been estimated for growth-rate due to ablation. A comparision between the two experimental animals also shows that the pre-ablation advantage in growth is reflected with lesser fall at ablation-moult and better growth at post-ablation moults.

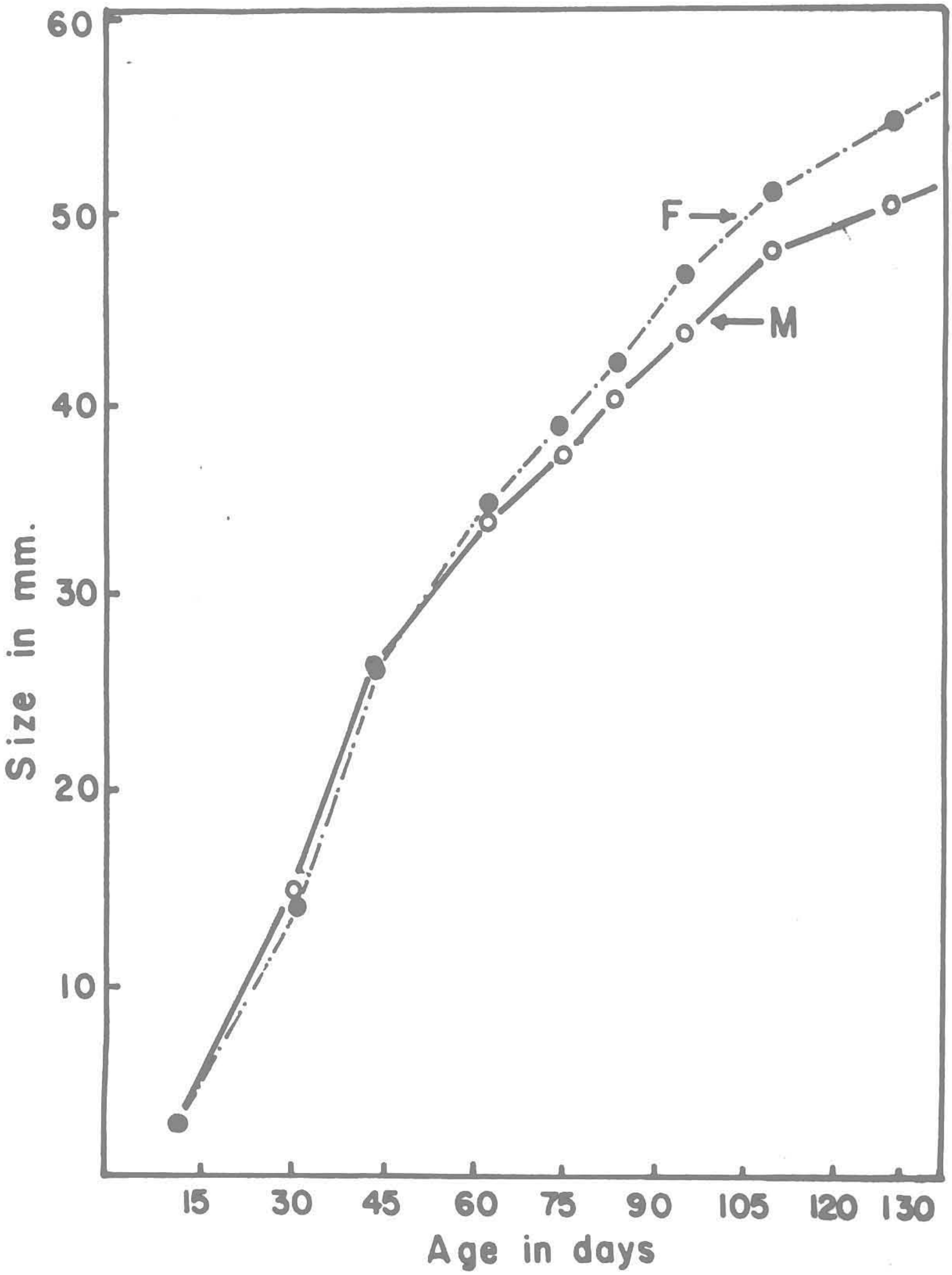

Fig. 29. Sexual difference in growth.

e. Sexual Difference in Growth

Laboratory rearing of larval through juvenile stages of M. dobsoni reveals that both female and male follow the general pattern of slow-fast-slow growth. However, the age-specific size of either sex (Fig. 29) shows that the growth is almost similar upto 2 months initially, when they reach about 34 mm size and thenceforth, disparity develops in growth-rate in favour of female, though reared under identical conditions. Also, the difference, which is 3 mm at the end of 3 months, increases to 5 mm at the end of 4 months and finally, the females reaches 55 mm as against 50 mm in 124 days, when the experiment ends. Hence, the sexual difference in size widens as they grow with age.

f. Starvation and Growth

Short-time Effects:

Two experiments conducted reveal that the short-time starvations affect the growth immediately, extending the moult-interval and reducing size increase at moult and the recovery of growth from the effects is also gradual though well fed again. Each animal in separate experiment is traced for 9 moults,and during the

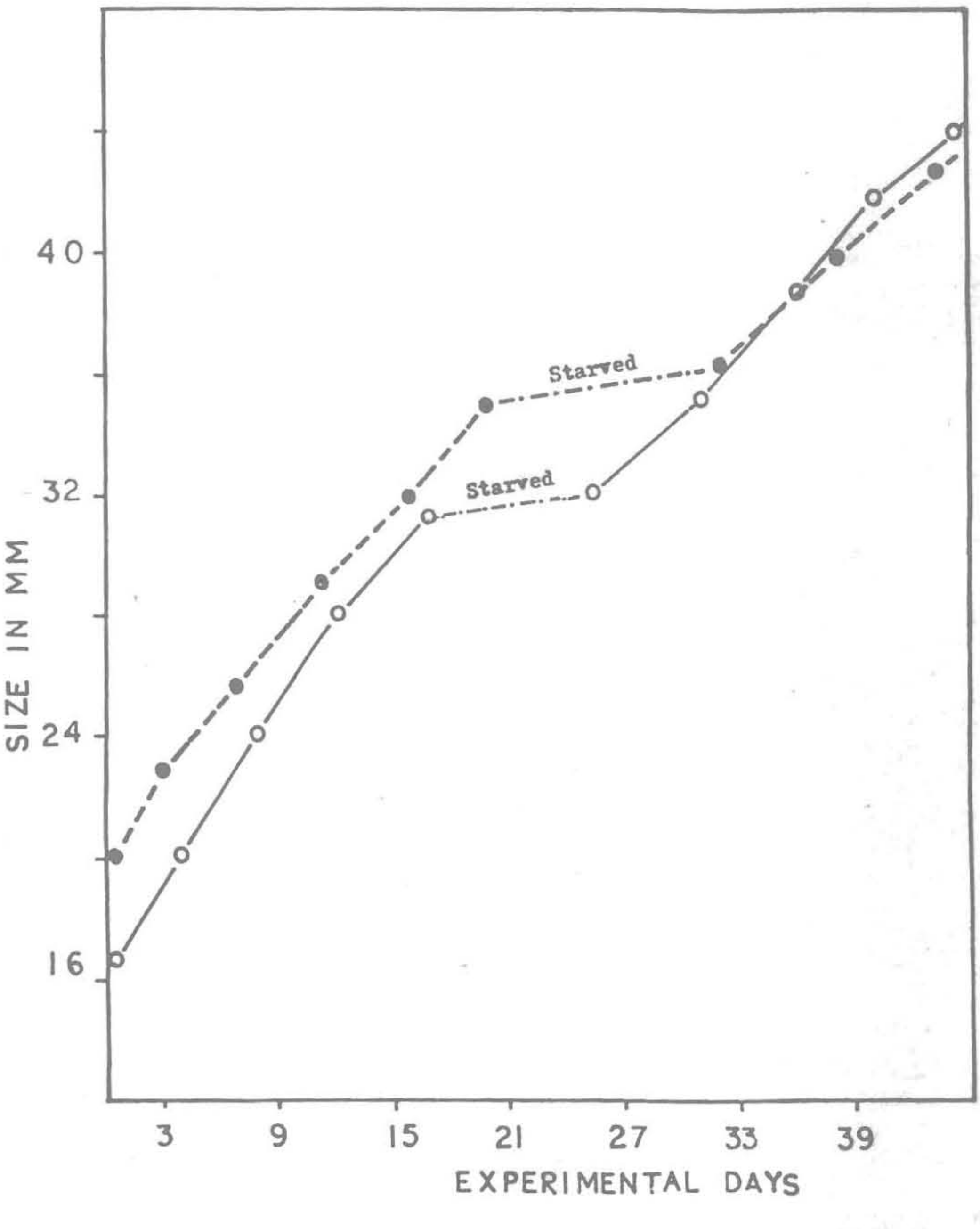

Fig. 30. Effect of short-term starvation on growth of juveniles.

interval of 5 or 6th moult the animals are completely deprived of food. Details of moult-history and duration of starvation are presented in figure 30.

In Experiment I, the animal grows from 16.5 mm size to 31.25 mm size in 17 days involving 4 moults. After complete starvation during the next, 5th intermoult period, it moults again on the 25th experimental day, increasing in size to 32 mm. Later the animal attains 43.75 mm size on the 44th day, moulting 4 more times. Similarly, in Experiment II, the animal increases in length from 19.75 mm to 35.00 mm in 20 days, involving 5 moults and it moults again after starvation on the 32nd day of experiments. Later on feeding, the animal grows to 45.5 mm size on the 49th day after 3 more moults.

Analysing the details of inter-moult periods and size-increase at moult, which are jointly reflecting the magnitude of growth, it is evident that in Experiment I, the moult-interval extends from 5 days in the preceding moult to 8 days at starvation-moult, registering thus an increase of 60% and also returns to normal gradually, involving 3 post-starvation moults.

Table 10: Difference of growth-rates on starvation during the entire inter-moult period as compared to tha estimates for the general pool of fed post-larvae

Experimental Duration	Size-range in mm	Days Taken	Growth-rate, mm/day		Difference from control	
			Control	Observed	Size	%
<u>Experiment I:</u>						
Pre-starvation (3 moults)	20.00-31.25	13	0.714	0.865	+0.151	+21.51
Starvation	31.25-32.00	8	0.618	0.094	-0.524	-84.79
Post-starvation (3 moults)	32.00-41.50	16	0.546	0.594	+0.058	+10.82
<u>Experiment II:</u>						
Pre-starvation (3 moults)	25.50-33.00	13	0.640	0.731	+0.091	+14.22
Starvation	33.00-36.00	12	0.556	0.063	-0.473	-85.07
Post-starvation (3 moults)	36.00-45.00	17	0.476	0.529	+0.053	+11.13

Size increase at moult is also affected by the short-time starvation. In Experiment I, the moult-increment decreases from 3.00 mm in the preceding moult to 0.75 mm at starvation-moult and in Experiment II, it reduced from 3.00 mm to 1.00 mm. However, the recovery from starvation effects is immediate from the very next moult onwards as for moult-increase.

The daily growth-rates against the mean-size of pre-starvation, starvation and post-starvation periods, calculated arithmatically for the experimental animals (Table 10), show striking reduction at starvation periods. Further, in view of the fact that growth-rate decreases as the animal increases in size, the growth-rates for the corresponding lengths have been estimated for the control animals using the Eq. 3.2 and then compared with that of experimental animals. It is, thus, evident that the growth-rates are far lesser to the extent of 85% at starvation moults, in experimental animals, compared to the control animals, though slightly better than them during normal feeding periods.

g. Stunted Growth and Rehabilitation

Deleberate restrictions of nutrition result in stunted growth in the juveniles of M. dobsoni. Hence, the animals in the 'stunted group', in which the food is completely deprived ~~off~~ for the first 19 experimental days and fed regularly as in the other 'control group' till the experiments terminated after 71 days, trail in growth largely during the starvation periods compared to the control animals and the difference in size between them remain virtually the same during the post-starvation or post-stunted periods. Details of sizes attained by both 'stunted' and 'control' groups are presented in figure 31, from which it is seen that the animals in 'stunted group' grow from 22.5 mm to 24.0 mm size compared to 22.5 mm to 36.0 mm length in 'control group' in 19 days, during which the former group is starved and thus the starved animals are shorter by 12.0 mm than the fed animals by then. Thenceforth, animals in both groups grow steadily reaching 53.0 mm and 41.0 mm respectively by 'control' and 'stunted' groups in 71 days, when the experiment is terminated, showing thus the difference in size still remains at 11.9 mm between the groups. Significantly,

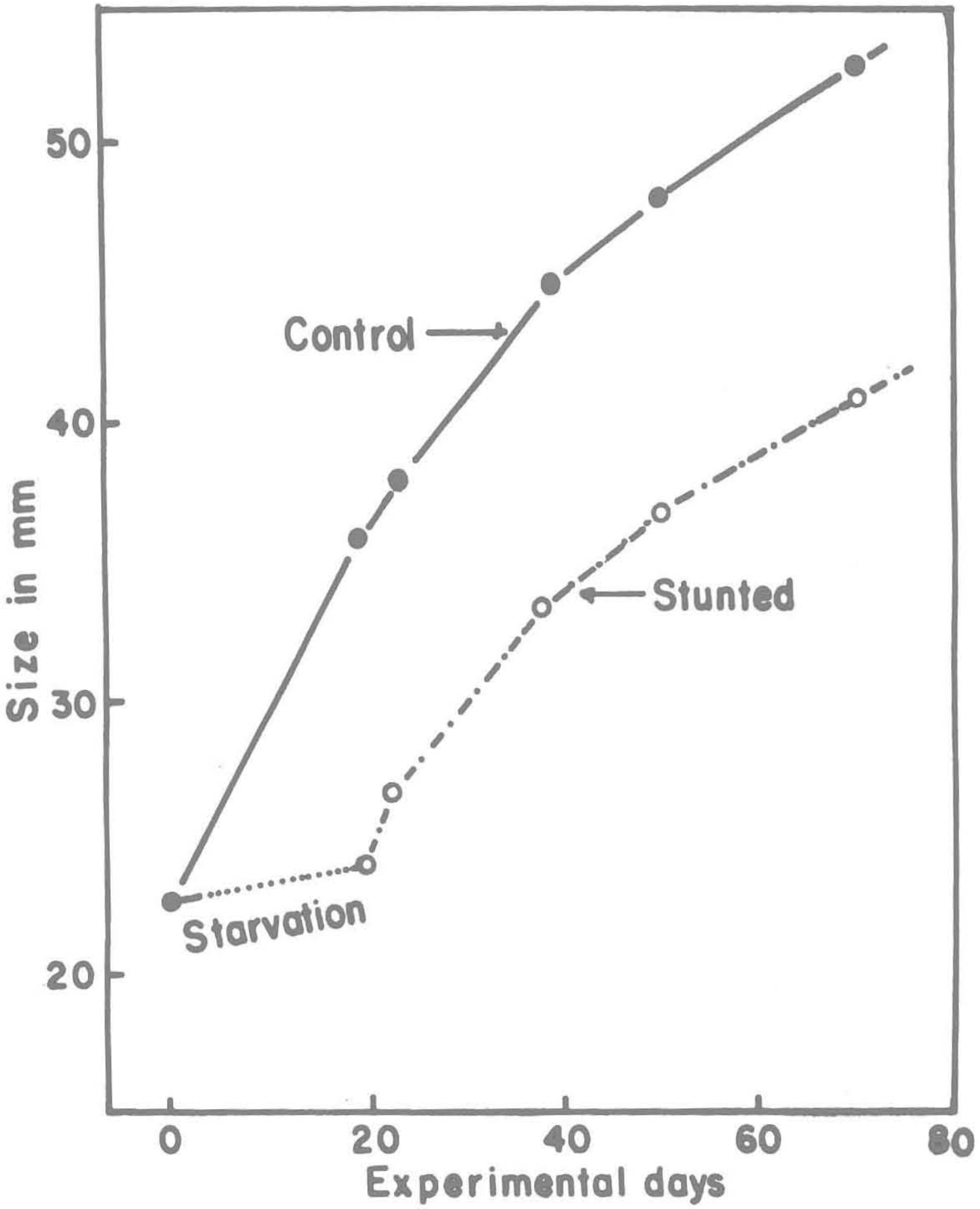

Fig. 31. Stuntedness on long-term starvation and the pattern of growth on rehabilitation of juveniles.

the size-curve of both groups are almost parallel with the difference of 12.0 mm during the post-starvation periods, though they are of same age and hence the length lost at starvation is not regained or compensated in stunted animals on refeeding. The growth-rates are 0.71 mm/day and 0.08 mm/day respectively for the 'control' and 'stunted' groups during the first 19 days, when the latter is starved. However, there is a jerk in growth for a shortwhile among the stunted animals on refeeding, as it is noted that these animals have the growth-rate of 0.70 mm/day compared to 0.53 mm/day by the 'control' animals on 23rd day, 4 days after termination of starvation. However, the growth-rates between the groups do not vary much thereafter, as the difference has reduced to a nominal 0.02 mm/day throughout.

The size-specific growth-rates (Fig. 31) can be further illustrated that the stunted animals do not grow at a pace of the control animals even at rehabilitation periods. The estimated growth-rates at a few sizes for a comparision during the rehabilitation periods are:

Size in mm	Growth-rate in 'control' group in mm	Growth-rate in 'stunted' group in mm
37	0.53	0.29
41	-	0.21
48	0.27	-
53	0.23	-

It is, thus, clear that the growth-rate of the control animals is almost double that of stunted animals at 27.0 mm size though then the rearing conditions are same for both groups. Also, considering the fact that the growth-rate decreases gradually as the animals grow in size, the stunted animals measuring 41 mm size increase by 0.21 mm/day, which is still lower than that of control animals measuring 53 mm length. Hence, the growth-rate specific to the size is not maintained among the stunted animals though they are reared under optimum conditions. In other words, growth becomes age-specific during rehabilitation period in stunted animals. It also emphasises adequate nourishments at young ages for normal growth.

Table 11: Effect of salinity gradients on growth of *M. dobsoni* reared in the laboratory

Salinity ‰	Size in mm		Increase in size	Time lapsed in days	Growth-rate in mm/day
	Initial	Final			
5	27.75	41.00	13.25	67	0.198
5*	26.00	39.75	13.25	63	0.218
10	25.50	42.00	16.50	65	0.254
18	22.50	45.50	23.00	60	0.383
18**	26.00	46.00	20.00	46	0.435
24	25.50	40.50	15.00	40	0.375
28	26.50	44.25	17.75	56	0.317
33	24.00	41.00	17.00	58	0.293

* Water temperature 2.5-3.0°C more than others

** Provided with sand substratum

h. Salinity, Substrate and Growth

The growth-rate (Table 11) of juveniles of *M. dobsoni* reared under the serial of salinity gradients ranging between 5‰ and 33‰ reveal that moderate salinities are favourable for growth. The estimated growth-rates vary between 0.198 mm/day in 5‰ and 0.383 mm/day in 17‰ among those kept without any substratum and hence the maximum growth-rate is almost double of the minimum. Also, it is seen that the growth-rate does not vary much between the maximum in 18‰ (0.383 mm/day) and in 23‰ (0.375 mm/day) and beyond this range of salinity there is obvious decrease in growth-rate. Hence, it may be considered that the optimum salinities for growth of juveniles of this species are around 18-24‰ under natural temperatures that fluctuate between 25°C and 32°C. It is also noted that the growth-rates are sharply decreased towards lower salinities than towards higher salinities from the optimum ranges. Thus, the growth-rate in 33‰ is recorded at 0.295 mm/day as against 0.218 mm/day in 10‰ and 0.198 mm/day in 5‰ salinities.

It is further observed a specimen kept in fresh water (well water) has moulted once, though dies subsequently.

Sand substratum, which enables the burrowing habits of the animals, seems to assist better growth. The animals kept in the pot with substratum in 17‰ salinity have the better growth-rate of 0.435 mm/day compared to 0.383 mm/day by the animals kept without substratum in the same salinity, thereby registering an advantage of 14% by the former upon the latter.

A marginal difference (2.0-3.0°C) of temperature in the rearing medium appears to influence obviously the growth in the juveniles. The animals reared in 5‰ salinity but with 2-3°C temperature differences reveal that the specimen at higher temperature has recorded with the growth-rate of 0.218 mm/day as against 0.198 mm/day by the other animal kept in lower temperature. Hence, an advantage of 10‰ is estimated in growth by an increase of 2.0-3.0°C in temperature of the medium. It may be recalled here another part of this study that the post-larvae are not in normal habits and eventually died in temperature raising over

34.0°C and decreasing below 18°C. Invariably deaths happen in a short-time below 10°C and over 35°C temperature. Hence, the advantage of growth in higher temperature applies only within the range of tolerance.

3. BURROWING HABITS OF JUVENILES

The juveniles of M. dobsoni (25-50 mm TL) are active at night and inactive (buried) at day time. Light appears to be a major factor influencing such nocturnal habits, as it is positively evident from the fact that most animals deburrow under darkness during day time and bury at night against artificial illuminations. Transit times of the day-night cycle of burying habits are recorded to be coinciding with sunset and sunrise under natural light conditions. However, the time lag between the sunset and total activeness of animals varies depending upon the prevailing intensity of light.

The aquarium tanks in the shed and in the verandah receive slightly different light intensity at any day time and as such all the animals in the shed emerge within 5 minutes after sunset, whereas, those in the

Table 12: Percentage frequency of deburrowed animals at different times around sun-set

Time of observation (P.M.)	% of animals emerged	
	in Shed	in Verandah
4.30	5	nil
5.00	26	3
5.30	33	6
6.00	40	13
6.30	89	15
(Sun-set at 6.36 P.M.)		
6.40	100	44
7.00	100	100

verandah come out after 26 minutes on the same clear day. Also the sign of transition, as indicated by the number of individuals emerged, is evident about 1.30 hrs earlier than the scheduled sunset in the shed, as against just 25 minutes in the verandah. The percentage of animals deburrowed around sunset (6.36 P.M.) on a clear day in the shed and verandah respectively are given in Table 12.

Similar differences have been appropriately noted during sunrise, when the animals in the shed bury later than those in the verandah.

Number of animals emerged during day time increases on cloudy or rainy days in both tanks. Over 50% of animals in the shed are emerged at any time, whereas, it is not more than 15% in the verandah on such cloudy days. However, 100% emergence occurs only after sunset always.

Response to light-darkness stimulii appears to vary between the size classes of juveniles. Smaller animals emerge earlier at dusk and bury later at dawn, besides forming bulk of those emerging at day time under any disruptive circumstances. Animals below 25mm length have the negative response to light and hence do not burrow, as the larger specimens behave. Animals in the tank without any substrate rest quietly at day time and move about freely at night, convincing the diel rhythm of activity. In a tank with partly sand substratum and partly without it, animals are found prefering the substratum 19 times out of 20 observations at day time.

a. Feeeding and Burrowing Habits

Availability of food disrupts and normal burrowing habits, animals, which are otherwise burrowed, emerge if food is placed into the aquarium tank. The time lag between feeding and emergence extends over 1-30 minutes for different individuals. Smaller animals usually deburrow earlier and stay longer consuming the food before reburrowing beneath the substrate and the time of consumption is noted to be extending upto 1.30 hrs. The animal's reaction to food is more visibly observed in the tank without substratum, in which they start moving about erratically in search of food from a near still condition.

b. Temperature and Burrowing Habits

Temperature obviously disrupts burying behaviour of the juveniles beyond certain limits. Sand substratum and sea water (17%. salinity) in a glass trough exposed to direct sun rays, are recorded with different temperatures upto 3°C variations owing to their varying conductivity of heat. No visible changes are noticed in the behaviour of the animals released into the trough until the temperature crosses 32°C around midday. When the temperature exceeds 32°C the animals bury deeper than in lower temperatures; but emerge as the sub-soil temperature also increases to 34°C, though the water temperature is 3°C more than that then. The emerged animals swim restlessly, while the water temperature reaches 38°C and the sub-soil temperature still more at 39°C and later rest quietly upon the thin and fade shadow of the vertical glass wall of the trough around 2 P.M., when the temperature of the water is recorded at 35°C and sub-soil at 36°C. However, if the animals are then released into a trough with less than 32°C, they behave the normal burrowing pattern. Further, if the animals from lower temperature (28-30°C) are suddenly released into the trough with water temperature at 34°C and sub-soil temperature at 37°C, they immediately bury in spite of the temperature beneath the substrate ~~is~~ being higher and emerge to the lower water temperature after sometime. Then they swim restlessly and rest calmly as mentioned above. Likewise, animals emerge at temperature below 18°C even against strong light. On lowering ~~down~~ the temperature the juveniles are noticed to fall on their sides and drifted along the currents when the temperature drops below 15°C. Exposure of the animals to less than 10°C for more than 10 minutes invariably causes irreversible damages and eventually the death for post-larvae of 20-25 mm size.

c. Salinity and Burrowing Habits

Salinity does not seem to be an effective factor, as temperature is, controlling the burrowing behaviour of the juveniles. Animals do burrow in 100% sea water and fresh water, though the frequency of deviations from normal habits increases against extreme salinities. About 50% of the specimens emerge within 15 minutes since salinity is changed beyond 10-30‰.

and reburrow after less than an hour. Large number of animals are noted to emerge and actively swim when fresh sea water (17‰ salinity) is changed undisturbed and settle to the normal rhythm after about 30 minutes.

Discussion

Commercial marine prawn farming, which has gathered much momentum in most part of the world involved in fishing industry, has a wide scope of expansion not far in future. A surging demand for seed prawn (post-larvae) of the choicest species could be, thus, a facing problem. Hence, a great enthusiasm in this field of research is recently evident. The hatchery technique, spawning and rearing of eggs through post-larvae, introduced by Hudinaga (1942) on *Penaeus japonicus* has been attempted with varied degree of success rapidly in a long list of species all over the countries (Cook, 1967; Liao and Huang, 1972; Fielder *et al.*, 1975; Beard *et al.*, 1977; Motoh, 1979; Motoh and Buri, 1979; Primavera, 1980; Ceccaldi, 1982; Kanazawa *et al.*, 1982; Kitani and Alvarado, 1982; Ganapathy, 1983). In India, where the prawn fishery is well established, but aquafarming is at take off stage from experimentations, virtually all the commercial species have been reared and authentic illustrations of the larval history of them are available (Bull. 28, CMFRI, India, 1978).

The larval stages of M. dobsoni have been adequately described earlier both from planktonic collections (Menon, 1951; Rao, 1974) and laboratory rearing (Rao and Kathirvel, 1973; Thomas et al., 1974; Muthu et al., 1978) and most of these accounts do not significantly vary from the present descriptions. Menon (1951) has observed 3 naupliar sub-stages, while Rao (1974) has added 2 more, making it 5 sub-stages. However, 6 naupliar sub-stages have been noticed in the present study, agreeing to Thomas et al. (1974) and Muthu et al.(1978). Menon (1951) has not included naupliar sub-stages N_{III} and N_{IV} and clubbed N_I and N_{II} as N_I and similarly Rao (1974) has merged N_I and N_{II} as N_I.

The 3 protozoeaic sub-stages are common in all observations including this study. Similarly the 3 mysid sub-stages, which are marked at present, have been reported in all, but Muthu et al. (1978) have additionally recorded two intermediate stages before the first post-larva. These authors identify the intermediate stages based on the characteristics a) length of the pleopods, b) the size of the larvae, and c) the number of the setae on the scaphocerite and exopod of Mx_2, but it is not clear whether these stages are sequential to the 3 mysid sub-stages, or the products of variability of developments. Disparity in growth among the individual larvae commences from protozoea onwards, which coincide with the beginning of feeding. The variability in larval growth ~~during~~ among the individuals reared even in the same aquarium is common (Zein-Eldin, 1963). Hubschman and Rose (1969) ~~feel~~ find ~~it~~ in palaemonid that the moulting or development synchron~~y~~ise in first larval phase and variation in moulting frequency appears in the later stages of development. Hence, it can be explained that the development of early phase, the non-feeding naupliar sub-stages, is inherent, though later on it is largely influenced by extrinsic factors. This supports Primavera (1980) who classifies the penaeid eggs based on stuffed yolk materials into five types, which are likely to influence different growth-rates at least among naupliar stages, which depend only on yolk food.

The mean duration of larval development in M. dobsoni differ between the estimates of authors. While the present record and Muthu et al. (1978) compare closely, Thomas et al. (1974) differ widely. Naupliar stages, which are completed in 66 hours in this study is closer to 64 hours by Muthu et al. (1978), but much higher than 43.30 hours by Thomas et al. (1974). Similarly, 242 hours are required in this observation to reach mysis I as against 238 hours (Muthu *et al.*, 1978) and 178.30 hours (Thomas *et al.*, 1974). Such temporal differences of larval development have also been noted for *M. affinis* by Muthu *et al.*, (1978) and Thomas *et al.*, (1974) as they record 236 hours and 170.30 hours to reach mysis I respectively.

Disparity in developmental duration among the observations by different authors may be largely attributed to temperature variations on space and time, when the experiments were conducted, since a difference of 2.5°C in temperature has been reported to have caused a disparity of 102 days in developmental duration from 12 mm to 15 mm size in *Penaeus azetecus* (Zein-Eldin and Graffith, 1965).

Repeated spawning without remating is also noticed in other penaeids. Beard and Wickens (1980) have recorded 1-6 (mostly 3-4) spawnings within one intermoult period in *P. monodon*. Joshi and Nagabhushanam (1982) have also observed in the Indian species, *Parapenaeopsis stylifera* 2-3 spawnings successively lasting over a month without further mating. Hence, the sperms deposited in a single mating are alive for such a long period and are released in batches at each spawning.

Growth is a gradual increase with time in size, mass or some kind of a living unit and rate of it is usually characteristic of the animal's age. Though the pattern of growth is inherited from the parents, it usually follows the general pattern that the specific growth rate is slow at the earliest stages, fast at the intermediate stages and slow again at the latest stages of the animal's life. But M. dobsoni appears to be a minor exception. This species is amphibiotic, having post-larval through adolescent life at estuaries and adult and larval life at sea and it changes its habitats at appropriate times under normal circumstances. This complex life-cycle makes it very unlikely that the growth-rates of all life stages in two bio-systems could be combined into a single growth-curve. Growth of post-larvae and juveniles in estuary continues in adults at sea. Any late emigration could thus affect the otherwise normal growth-curve. It is evident in the laboratory experiments that the slow-fast-slow growth-pattern of post-larvae through juvenile heads on for an asymptotic size as they are continued rearing in estuarine conditions.

Estimates of Bertalanffy Growth Equation reveal that the juvenile could reach a maximum length of 70.12 mm in 9.5 months with the steepest increase in size of 22.8 mm during the second month of life under estuarine conditions. Age at size of juveniles in the present laboratory studies agree closely to other estimates from wild populations. The size of 64.7 mm in 6 months in this studies is thus more comparable to 67.0 mm calculated by Banerji and George (1967) and 58.1 mm for male and 72.8 mm for female by Kurup and Rao (1974). Menon (1955) states that a vast majority of the estuarine populations of this species do not grow beyond 60-65 mm size and migrate to sea around this length and it is substantiated by Banerji and George (1967), from large abundance of those size-ranges in marine catches. But, specimens measuring 20-30 mm more than such emigration size-range have been widely recorded in natural estuarine populations; 80 mm from backwaters of Calicut (Menon, 1951) and 75 mm in Chilka Lake (Kemp ,as mentioned by Menon, 1951); 86-90 mm (Menon and Raman, 1961) and 66-70 mm (George, 1975) in Cochin backwaters; 88 mm in Manakkudy estuary (Suseelan, 1975) and 84 mm among those population entrapped for a prolonged period in Covelong backwater under the present study. However, these maximum sizes are far shorter compared to asymptotes estimated for adults at sea: 117 mm (Banerji and George, 1967) and 127 mm for males and 145 mm for females (Kurup and Rao, 1974). Hence, it is reasonable to conclude that the juveniles have a size ceiling if it were to remain in estuarine conditions and further growth proceeds only at sea. One of the reasons for specimens occurring upto the ceiling sizes in nursery waters may be over-stay, as stated by Garcia and Le Reste (1981) 'under some particular hydrological conditions the shrimps can stay in the estuary until an abnormally advanced age'. Stranding in remote spaces of extensively larger backwaters and impoundments in seasonal estuaries, the bar-mouth of which closes for certain periods, could force over-stay in nursery waters.

Size-ceiling of young prawns of this species in estuarine phase is further evident from the steep decrease in growth-rates as the animals grow older. The post-larvae reach 56.06 mm in the first 4 months, but they take another 5.5 months to grow further about 14 mm to attain the asymptote. Menon (1951) also calculated this species growing in the laboratory from 3.5 mm to 44.0 mm in 80 days (0.506 mm/day); but to increase by 5 mm from 60 mm to 65 mm it needs 40 more days (0.125 mm/day) and one of the reasons, that he suggests, is that the inadequacy of space in the aquarium tank could impede growth as the animal grows in size, though he agrees to Pearlson that 'a limitation in maximum growth occurred quite independently of the period of confinement or the amount of food consumed'.

Growth-rates and longevity of estuarine phase of penaeids are primarily concerned to plan the tenure of crops for optimum yields in culture operations. The normal emigration size of M. dobsoni has been mentioned at 60-65 mm by Menon (1955) and Banerji and George (1967) and this size-range is estimated in the present studies to be attained in 5-6 months, inclusive of larval stages extending over a month at sea in nature. But, this juvenile life span is reported widely varying for wild populations: 5-6 months (Nair and Kutty, 1980), 6-7 months (Kunju, 1977) and 9-10 months (Menon, 1955; George, 1959). These variations may have been largely influenced by the rate of growth and the size at emigration considered by the authors. The mean growth-rate has been calculated thus for natural populations at 6.7 mm/month (Menon, 1951), 11.2 mm/month (George, 1969) and 5-15 mm/month (Paulinose et al., 1981). The size at emigration in nature could also vary, since 'young shrimps are introduced into the bay fishery as a function of the time of year' (Grant and Griffin,1979). Besides, growth in laboratory rearing is slower than in nature, as George (1969) has noted a growth-rate of this species at 11.16 mm/month in culture fields, as against 9.75 mm/month in experimental animals. Hence, considering all these findings, it may be generalized that the juvenile life of *M. dobsoni* lasts 4-5 months exclusive of the larval life of about a month at sea. Similarly, Hudinaga (1942) has obtained the harvestable size of 80-100 mm of *Penaeus japanicus* in 5 months of rearing. Beard *et al.*, (1977) have found that *P. merguiensis* breeds in the laboratory in 6 months of age and AQUACOP (1983) experiments on *P. vannamei* show that the species requires 6-8 months of growth in ponds to become breeders.

The process of moulting, which effects growth in crustacea, has been described by Passano (1960) and the dynamics of it analysed by Mauchline (1977). The act of moulting has been reported in *P. esculentus* (Wassenberg and Hill, 1984), *Palaemonetes varians* (Jefferies, 1964), the spiny lobster, *Jasus lalande* (Fielder,1964) and *Panulirus argus* (Travis,1954; Lipcius and Herrnkind,1982).

Nocturnal habits of moulting, as noted in this study in juveniles of M. dobsoni, have been widely reported in crustaceans: Metapenaeus sp. (Dall, 1965), Penaeus durorarum (Bishop and Hernnkind, 1976), P.donodon (El Hag, 1984), P. esculantus (Wassenberg and Hill, 1984) and the spiny lobster, Panulirus argus (Travis, 1954;Lipcius and Herrnkind, 1982). However, Bishop and Herrnkind (1976) have found moulting being restricted between 12 and 24 hrs, if P. duorarum is exposed to 00:24 LD regimes. Jefferies (1964) has noted moulting in larvae of Palaemonetes sp. taking place at day and night, whereas Hubuschman (1963) reported the moulting of adults at night in the same species. Fielder (1964) has observed in the lobster Jasus lalandei that moulting takes place late at night or during the early hours of morning. Hence, moulting at night appears to be a general phenomenon in crustacea and an obvious advantage of nocturnal habits of moulting could be the better escaping chances from the predators under darkness for those freshly moult animals, which are then more vulnerable for predation.

Growth in M. dobsoni is found primarily to be the product of moulting frequency of inter-moult period and size increase at moult, which is usually expressed as growth-factor, the percentage size increase upon premoult length. The linear relationship of these two factors, moulting-frequency and growth-factor, against body length agrees to the general law of moulting in crustacea as described by Mauchline (1977) that 1) log inter-moult period (day) on a measurement of body length or on successive moult numbers, and 2) log growth-factor (%) on a measurement of body length or on successive moult numbers.

Mauchline (1980) quotes Mechintosh having calculated similar logrithmic linear relationship for moulting-frequency against length in Euphausiid sp. and the coefficient (b) is quite the same at 0.009 as estimated here for the juveniles of M. dobsoni, though the other constant (a) slightly varies between them. The inter-moult periods worked-out for the post-larvae of this species are also more closely comparable to other records. It is, thus, estimated that the post-larvae with the mean-size of 15 mm have the inter-moult period of 3.5 days in M. dobsoni in this study compared to 2-3 days for early post-larvae and 3-4 days as they slightly grow in M. monoceros and Parapenaeopsis stylifera (Rao, 1973); 4-5 days in the early post-larvae of Palaemonetes sp. (Jefferies, 1964); mean of 2.3-2.5 days, but not exceeding

5 days in the post-larvae of *Palaemonetes pugio* (Hubschman, 1963) and 2.1-3.6 days in larvae of *P. vulgaris* (Broad, 1957).

Similar logrithmic linear relationship between moult-interval against age has been used in the crab, *Dissodactylus primitivus*, by Pohle and Telford (1982) and they have so estimated 6.6 days of inter-moult days for instar 7, increasing to 49.8 days for instar 27. However, Motah (1981) has used the regression of inter-moult period against the cubes of length in young and adults of *P. monodon*. In any case, the inter-moult periods of adults in crustaceans are far wider than that of post-larvae and juveniles. Thus, the moult-interval of adults has been estimated at 2-4 weeks in *Metapenaeus* sp. (Dall, 1965) and at 27 days in *Penaeus mergueinsis* (Crocos and Kerr, 1983). Still extremely, Fielder (1964) has observed that the spiny lobster, *Jasus lalandii*, moults in captivity at the mximum interval of 287 days and Flint (1975) has noted that the crayfish, *Pacifastacus* sp. greater than 30 mm CL does not moult more than once in a year. Further, Farmer (1975) has reported that the lobster, *Nephrops norvegicus*, may sometimes live for upto 3 years without moulting. Periodicity of moulting at adult stages in crustaceans is not progressively changing as smoothly as in juveniles, since the reproductive cycle, during which the animal does not moult, intervenes at times. Jefferies (1964) has thus pointed out that adults of Palaemonetes sp. moult in 3 annual spells (seasons), the number of moults being, however, reduced during successive seasons. Hence, it is safer that the law of linear relationships of moult-interval against length be restricted within adolescent stages and be used as a measure of growth efficiency along with other parameters for a system analysis.

Growth in crustacea does not necessarily accompany moulting (Travis, 1954; Fielder, 1964), hence size increase at moult has to be essentially considered along with moulting frequency. Growth-factor, which is an expression of moult-increase in percentage upon pre-moult size, has widely been reported to be reducing with body length in crustacea. Mauchline (1980) has used similar logrithmic relationship for Ephausiid sp., as in the present one, and calculated the coefficient (b) at 0.0109, which is closer to 0.0173 for M. dobsoni estimated here. Also, the values of growth-factor, which have been computed at 20.1% at 10 mm negatively reducing to 4.5% at 50 mm are comparable to other reports: 3.87-51.31% in M. dobsoni, 4.47-76.96% in Parapenaeopsis stylifera and 4.25-25.27% in M. monoceros

(Rao, 1973); 0-14% in early instars of the crab, *Dissodactylus primitius* (Pohle and Telford, 1982), 6.1-21.2% for first post-larva to adult measuring 50 mm CL in *Nephrops norvegicus* (Farmer, 1975) and 2.5-8.9% for the animals measuring 40-49 mm to 80-89 mm in the spiny lobster, *Panulirus argus* (Travis, 1954). In all, it is clear that the growth-factor varies with size of the crustacean. The gradual decrease of growth-factor as the individual grows in length reveals the fact that the juveniles of *M. dobsoni* maintains similar size increase at successive moults and the same has been inferred by Fielder (1964) in *Jasus lalandii* and Travis (1954) in *Panulirus argus*.

Reay (1979) comments that the individual size differences occur even among the siblings and this can be a problem in aquaculture, because in many species size heirarchies develop, resulting in inter-size competitions, which can lead to casualities, including canabolism, but he is not certain whether the cause of this early growth advantage is genetic or environmental. Hence, the size heirarchy seen among the siblings of *M. dobsoni* here agrees to his general observations. While a few animals, 'fast' group, here reach 16.0 mm size, another 'slow' group grows to 8.5 mm size, at the end of one month and the respective group requires 4.0 and 6.5 months to attain about 62 mm, the usual size of emigration in nature and also can be the optimum size of harvesting in culture operations. It may be mentioned here that a difference of 2.5 months in harvest time of a crop is of a great concern to culturists, considering the possibility of genetic manipulations and pure culture of the 'fast' group to reduce the operational cost and increase the number of crops. Zein-Eldin (1963) has also observed in Penaeus sp. that the growth-rate of post-larvae varies considerably among individuals within the same aquaria and he has measured that the animals ranging between 6.5-10.0 mm size increase after 29 days to 17.0-36.5 mm size indicating that the smallest has increased by 10.5 mm size compared to the largest by 26.5 mm size during the same period. The occurrence of immature specimens which are evident of newly entered in marine catches, measure between 46 mm and 66 mm size, the latter being also supported by their records in the brackishwater catches (Menon and Raman, 1961; Suseelan, 1975). Such wide variations of size presuming all belong to same age while entering the sea, may also be indicating the existence of size heirarchy or size variations among the wild populations of this species.

Travis (1954) and Fielder (1964) infer that in normal pattern of crustacean growth, the inter-moult period is size-specific, but the size increase at moult under similar conditions does not much vary against size of the animal. This is being partially contradicted, if the 'fast' and 'slow' groups of the present observations in M. dobsoni were to be compared. The 'fast' group has relatively shorter moult-interval compared to 'slow' group at a given length, but both groups do not show significant difference in size increase at the moult then. Rearing conditions being identical to both groups, factors of endogenous origin may be, thus, considered to be the causes of differential growth among them. One of such factors, which have influenced rapid growth in 'fast' group, may be related to larger amounts of yolk contents in those eggs. In that case, initial advantage of growth at early larval phase of those progeny is possible, as Primavera (1980) has pointed out that 5 types of eggs on the basis of yolk contents are discharged by a penaeid, Penaeus monodon, each type having different influence on hatching and health conditions of the larvae. Possibility of variations in yolk contents among eggs may be supported by the evidence of resorption and rematuration of undischarged oocytes as reported by King(1948) and Joshi and Nagabhushanam (1982). It looks quite reasonable that the yolk materials in the eggs could favour good health of those non-feeding naupliar stages and even may be possible tracingly through the entire larval phase. But it is unlikely that this initial advantage of growth is being carried over through the entire post-larval and juvenile phases and the size at age differs throughout between individuals considerably. Hence, it could be logical to infer that such size disparity between the 'groups' or size heirarchy among the siblings attributes to genetic origins or inheritance.

Inheritence of growth-rate among the larvae has been also noted by Hartnoll and Dalley (1981) in *Palaemon elegans*, in which the individual larvae grow at different pace and are checked at particular instars; that too upto certain instar, beyond which the individuals grow at their own pace, irrespective of other external factors. Similarly, different individual growth-rates among the larvae of *Macrobrachium rosenbergii* has been noted by Nathan (1981) and an isochronal development upto instar 5 and loss of it beyond that has been observed in *Balanus imprivius* by Lang and Marcy (1982). Temporal difference of larval growth in crustacea due to reasons other than of exogenous factors is still more clear from Childress and Price (1978) who have noted that in the larval development of the mysid, Gnathophausia ingius, the 13 instar is covered in 166 days by the earliest compared to 253 days by the oldest. Such wide disparity in developmental time might not have been simply attributed only to extrinsic factors. It is likely that the disparity would continue resulting in size-heirarchy.

Difference in growth pattern between the 'fast' and 'slow' groups, indicating thus the inheritence of growth, is further emphasized by their moult-history. The regression analysis reveals that inter-moult periods vary significantly, but not the size increase at moults between the groups. The moult-interval for a post-larva measuring 15 mm size is estimated at 2.76 days for 'fast' group, as against 4.02 days for 'slow' group and the advantage of more than one day in each inter-moult duration is kept up till 25 mm by the 'fast' group. Besides, the highest daily growth-rate is estimated at 0.83 mm/day for 'fast' group and 0.70 mm/day for 'slow' group and they are attained respectively at 28.5 mm and 22.5 mm size, indicating better growth-rate till longer size-range is maintained by 'fast' group compared to 'slow' group. In all characteristics of growth thus both groups are distinct, supporting the view that growth among siblings are inherited.

One of the possibilities of genetic variations among the siblings is the mixed-up fertilizations by sperms of different males. The possibility is the multiple mating within the same-inter-moult period or retention of some sperms deposited earlier even after moulting to be mixed up with fresh stock of sperms on next mating. Multiple mating and mixing up of sperms have been noted in insects (counterpart of crustacea on land) by Parker (1970), who comments 'though some loss of receptivity for a time after insemination appears to be the rule in insects, further mating of the same female and mixing up of sperms have been found in innumerable species'. There is no reason to reject multiple mating happening on a few cases similarly in penaeids. Relevantly, Racek (1972) views that several males are usually involved in fertilization of eggs of one female in *Metapenaeus* sp. It may also be pertinent here to mention that although the spermatophore is usually present as one block attached to the thelycum of the female, it is noted sometimes as more than one mass, unconnected to each other, in a few females. Those blocks of sperms having been deposited by more than one male may not be ruled out. Sperms being potent enough to fertilize 2-3 spawnings lasting over a month has been observed by Joshi and Nagabhushanam (1982) and even more times are reported by Beard and Wickens (1980) in penaeids. Hence, the chance that residues of sperms of previous mating to mix up with next batch of sperms deposited on mating by another male is potentially possible. But, some authors like, Hudinaga (1942), Primavera (1979) and Crocos and Kerr (1983) observe that the spermatophore deposited on thelycum is lost on moulting, which is the prerequisit of next mating.

Another possibility is the accidental crossing over of sperms between pairs of mating in a swarm, in which synchronization of copulation is common, as noted in the sample that as many as 90% females are sometimes impregnated. This is further possible because the attachment of sperms to thelycum is only external by a simple adhesive process. Also, the sperms in the spermatophore are released at the time of spawning to effect fertilization of the discharged eggs and hence some of the millions of free moving sperms may find their ways to mix up with the sperms of another pair during the process of mating and deposition of spermatophore. Hence, it is likely that the sperms of different males may influence different growth characteristics. Genetic alterations in a few gametes of the same father or mother prawn may also be another possibility for such differences in growth.

It can be agreed with Weatherly (1972), who has stated that the studies on growth in penaeids cannot neglect hormones; because they affect growth; its extent, duration and intensity. Unilateral eyestalk-ablation enhances the overall growth-rate of the post larvae of *M. dobsoni* for certain periods and returns to normalcy. There is a general agreement that the neuro-secretory complex present in the eyestalk is the controlling centre of growth in decapods and the specific action is through inhibition of moulting until appropriate time interval in regular course of life (Abramowitz and Abramowitz, 1940; Smith, 1940; Passano, 1960; Hubeschman, 1963; Dall, 1965; Costlow, 1966; Kleinholz, 1967; Nagabhushanam and Rao, 1967; Ponnuchamy *et al.*, 1980; Freeman *et al.*, 1983; Radhakrishnan and Vijayakumaran, 1984). Invariably they have inferred from the fact that the inhibitory action is lost in eyestalk-ablated animals so as increasing the moulting-rate and thereby the growth-rate increases during the post-ablation periods.

Growth-rate is the product of inter-moult period (IP) and size increase at moult, expressed as growth-factor (GF). Both these factors are not similarly altered by ablation of eyestalk. Both IP and GF decrease sharply at ablation-moult, indicating possibly the premature moulting and however, the latter factor resumes to near normalcy from the subsequent moult onwards, while the moult-frequency is noted to be returning to normalcy only gradually through several moults. Total non-feeding on the day of ablation by the animal itself and the possible loss of blood on ablation have to be also considered for the steep fall in growth-rate at ablation-moult. Dall (1965) has noted induced moulting by eyestalk-ablation in *Metapenaeus* sp. and observes that the extrinsic factors and the nutritional state are to be optimal for better response. Smith (1940) has recorded in the crayfish, *Cambarus clarkii*, as in the present studies, that the removal of both eyestalks are always fatal and the average moulting-rate in animals with single eyestalk is almost half that of normal animals. But, Ponnuchamy *et al*. (1980) have succeeded in bilateral eyestalk-ablation in the palaemon species, *Macrobrachium lanchesteri*, and estimated the growth increase being little over double that of unilateral ablated animals. The restoration of normal moult-frequency gradually after few moults after one eye-stalk-ablation in *M. dobsoni* points out that the inhibitory action is slowly built up by the compensated secretions of the hormones from the remaining neuro-secretory complex. Decrease in inter-moult periods, without corresponding decrease in size increase during post-ablation moults may also indicate extra energy than in normal are being available for body build up. Freeman *et al.* (1983) state this that eyestalk restricts water uptake at ecdysis and expansion of cuticle. Hence, a loose restriction in uptake of water and expansion of cuticle may have also lead to full increase at moults in ablated animals, though moult-interval is shortened.

Starvation seems to have quick effects on growth of juveniles in *M. dobsoni*. Deprival of food during inter-moult periods delays moulting and drastically cuts the size increase at moulting. This result confirms the observation of Dall (1965) that lack of food adversely affects moult-rate in *Metapenaeus* sp. and reserve energy is very limited and rapidly depleted by starvation. Broad (1957) has made it further clear that the moult-frequency of *Palaemon pugio* and *P. vulgaris* depends upon the availability of food quantity. Teshima and Kanazawa

(1983) have observed poorer growth-rates in larvae of Penaeus japanicus when fed once a day compared to twice feeding daily and Bordner and Conklin (1981) have noted that daily feeding is required to sustain maximum growth in juvenile lobsters, meaning that failure to feed daily would result in poorer growth. Extended moult-intervals and retarded growth owing to starvation have also been noted by Nagabhushanam and Rao (1967) in the crab, Ocypoda macrocera and by Ikada and Dixon (1982) in the ephausiid, Ephausia superba.

Even on complete starvation since a moult the juvenile moults again, though delayed and the size increase is nominal. Travis (1954) has noted it earlier in lobster, Panulirus argus, that growth does not necessarily occur with moulting and these cases are virtually recorded with poor living conditions. Ponnuchamy et al. (1983) have viewed in the similar context that moulting is a metabolic necessity for the prawns, Macrobrachium lanchestri and Caridina weberi, and occurs even at the expense of organic reserves of the starving prawns.

Long-term starvation obviously leads to stunted growth in the juveniles of M. dobsoni and rehabilitation is also possible with resumed feeding. However, recovery is not effective enough to compensate the size that might have otherwise increased at the stunted periods. That is, during the rehabilitation periods the growth-rates become age-specific compared to the normal animals. Though the stunted animals are relatively very smaller, their growth-rates on refeeding are more comparable to slightly advanced age and the size-specificity in growth-rate is lost. Hence, the stunted animals remain shorter, at least, throughout juvenile life compared to normal individuals, though rehabilitated with normal conditions. Weatherly (1972) has relevantly stated that under carefully controlled experimental conditions animals can be made to remain stunted for a long period by no other means than severe dietary restrictions and when fed fully these artificially deprived animals can grow to full-size normal adulthood. Kurata and Shigueno (1979) have pointed out that accumulations of pollutants at the media of the culture ponds lead to serious retardation of growth in *P. japonicus*. Cole and Waugh (1958) have highlighted the stunted growth in large populations of oysters in natural beds of British waters and they have suggested among other reasons that a low level of nutritions during early life may lead to permanent stunting. To be more precisely, they state 'bad start cannot be recovered later and leaves after effects, which will remain throughout the animal's life. This appears to be in agreement with the present results in M. dobsoni, in which early retardation of growth on prolonged starvations is not compensated at least until late juvenile stage.

Stunted growth seems to be indirectly evident from a few dwarf specimens with adult characteristics of either sex, measuring below 50 mm size, while vast majority over 60 mm lengths, occurring among the marine populations. A small jerk of growth noted in the stunted animals during a few days on feeding after prolonged starvation may be associated with a possible synchronization of moultings, which might have been hitherto arrested at premoult state. Even in normal moult cycle, premoult state is reported to be occupying major periods in Metapenaeus sp. (Dall, 1965), indicating any acceleration or inhibition of moulting being likely happened at this state.

The dominant influence, that varying salinity conditions have on estuarine biota, is well documented (Kinne, 1971). There are opposing views, substantiating and negating, that low salinity is a requirement for the growth of post-larval penaeids. In the present studies on the post-larvae of *M. dobsoni*, within a wide range of moderate salinities the growth rates do not vary significantly and the optimum conditions appear to be about 50-70% (18-24‰ salinity) sea water, though growth is recorded in all salinities ranging from 5‰ to 33‰. Lower salinities below 10‰ is more unsuitable for growth compared to the other extreme, 33‰ salinity. Hence, moderate to higher salinities promote better growth than lower salinities on the post-larvae measuring over 22.0 mm size. It can be assumed that animals are confined to ideal conditions in their habitats, unless interrupted by any barriers, and growth there can be expected to be better. Paulinose *et al.* (1981) have thus recorded abundance of post-larvae of *M. dobsoni* in higher salinities upto 25‰in natural grounds. Nair and Kutty (1975) have, however, observed that the young post-larvae of this species grow better in lower salinities, whereas larger post-larvae juveniles prefer higher salinities.

Gunter (1961) comments on the preference of penaeids to wide range of salinities that 'salinity in broad ranges is inconsequential to young prawns, as they are not killed or percluded by high salinity as if it were poison'. Spaagaren (1980) does not find any physiological necessity for the young animals of Crangon crangon to live in lower salinities, as he inferred from the fact that many of such individuals are found remaining in open sea. Zein-Eldin and Aldrich (1965) have not observed any significant variations of influence on growth of young Penaeus aztecus by salinities except the extreme values and the maximum is, however, indicated with slight difference at 25‰ salinity. Zein-Eldin (1963) also endorses the same that under controlled temperature, salinity does not have significant influence on the growth of post-larvae of P. aztecus and Dall (1965) has not noted any significant variation in growth-rates of young Metapenaeus sp. reared in salinities ranging between 10‰ and 35‰. Hence, most of these early studies support the present results that salinity variation per se, not lower than 10‰, does not pose significant problems on the growth of young M. dobsoni. Salinity range of 18-25‰ is, however, found optimal and outside this range higher salinities are relatively more preferable compared to lower salinities.

Temperature is found a sensitive factor, which influences growth, higher the temperature resulting in better growth within the limits of 20-32°C. Response to temperature is also quick, as the juvenile of 20 mm size usually dies if exposed in temperature less than 10°C for more than 10 minutes. Even the variation of 2-3°C in daily average temperature within the optimum range has influenced 10% growth difference among the post-larvae reared from 25 mm to 45 mm size. Similarly, Zein-Eldin and Graffith (1965) have observed that the post-larvae of Penaeus aztecus require to develop from 12 mm to 15 mm size 260 days at 15°C, which is gradually decreased to 108 days at 17.5°C and 30 days at 20°C. But, the difference in developmental duration in temperature over 20°C is insignificantly smaller and the growth in lower temperature at 15°C, unlike in M. dobsoni may be attributed to acclimatization of P. aztecus in temperate conditions or be inherent. Hess (1941) has also observed that a rise of average temperature by about 3.5°C leads to 22.1% decrease in moult-interval, increasing thereby the growth-rate in Crangon armillatus.

Temperatures prevailing in tropical estuaries, barring one or two summer months, appear to be normally suitable for the optimum growth of most crustaceans, which are cultured in marine farming. Zein-Eldin and Aldrich (1965) have noted the maximum growth of young

P. aztecus at 30-32.5°C and no growth at 10°C and hence, the thermal limitations are only slightly different between the tropical and temperate species as for growth. The thermal tolerance appears to influence the geographical limits of distributions of the penaeids. Though the populations of M. dobsoni are very thick in southern region and subjected to heavy pressure of dispersements, the distribution of this species is restricted to south of Bombay on the west coast and Puri on the east coast of India. The lower temperature limits in the northern latitudes may be thus the barrier of distributions. The thin fishery during the most wet and hot periods may also be attributed to the temperature effects. The same temperature ranges have been reported suitable for growth also in other crustaceans, as Travis (1954) has noted in Panulirus argus that no moulting occurs in temperature below 18°C and the maximum rates are recorded at 28-30°C ranges. Hence, temperature in this region may not pose any problems except in mid-summer, when the temperature would normally rise over 34°C.

Substrate influence on growth in M. dobsoni is obvious and the advantage of growth (14%) influenced by substrate may be attributed to the burying habits against daylight. Being quite beneath the soil at day time may preserve considerable energy, which may be used in constructions of body tissues. Dall (1965) has laso indirectly reported that inhibition of moulting occurs on exposure to constant light in Metapenaeus sp. and Bishop and Herrnkind (1976) have noticed significant retardation of growth in P. duorarum left to constant light. Substrate preference in nature is common in penaeids, as soft muddy substratum is preferred by most young penaeids (Rajyalakshimi, 1973; Garcia and Le Reste, 1981). Such preferred substrata could enable better growth among these young penaeids, besides sheltering from the predators and adverse conditions. Hence, the suitable substratum in adequate depths is one of the major prerequisites in prawn culture for optimum yields.

It is generally agreed that most prawns bury beneath the substrate and emerge to be active at night (Fuss and Ogren, 1966; Hughes, 1968; Kutty and Murugapoopathy, 1968; Bishop and Herrnkind, 1976; Aziz and Greenwood, 1982; Wassenberg and Hill, 1984). This seems the underlying fact that the prawn fishing is carried out around dawn before the animals are settling down from the nocturnal activeness. Timings of transits, coinciding sunset and sunrise, have also been reported to be inherent (Fuss and Ogren, 1966; Hughes, 1968; Kutty and Murugapoopathy, 1968). However, certain exogenous factors also have been noted to disrupt this day-night cycle.

Light intensity is one of the key factors, which disrupts the normal rhythm of burrowing habits of prawns, as noted the total darkness in day time and higher illuminations at night reversing the then normal habits. The transit timings of active-inactive phase are also not absolutely coinciding with sunset and sunrise; but a time lag between the transits of sun and 100% emergence of the animals exists. The interval of the time lag appears to be under the control of light intensity prevailing at the habitat. Thus, all the animals in the tank kept in the shadow shed emerge within 4 minutes from sunset on a clear day, whereas, it delays upto 26 minutes in the tank at verandah. Such a time lag has been noted between 20 and 30 minutes since sunset for Penaeus duorarum (Hughs, 1968) and another penaeid, P. semisulcatus, has been observed to emerge at 1900 hrs and bury at 0600 hrs at Mandapam in this same coast (Kutty and Murugapoopathy, 1968). Meantime it looks significant that the 100% emergence of individuals occur around the same time (4-26 minutes after sunset) during both on a clear and cloudy or rainy days, though the light intensity varies. This seems to indicate inherent periodicity of burrowing habits. Persistance of nocturnal circadian activity pattern in penaeids even on exposures to constant darkness and light for longer durations than a day has been reported by several workers (Fuss and Ogren, 1966; Dall, 1958; Bishop and Herrnkind, 1976). Dall (1958) has found Metapenaeus mastersii exhibiting a nocturnal activity pattern in constant darkness for at least seven days. Fuss and Ogren (1966) have noted that P. duorarum does not show a diel periodicity under controlled dark conditions, but does show some pattern of activity under constant light conditions. Bishop and Herrnkind (1976) have observed a circadian burying rhythm for P. duorarum kept in continuous white light; but no such rhythm for the same kept in continuous darkness or UV light. Hence, it is suggested that this dark-light cycle is being controlled by the hormones of X-organ and Sinus-gland complex present in the eyes, which can be activated by light (Fuss and Ogren, 1966; Bishop and Herrnkind, 1976).

Feeding not alone disrupts the normal burrowing cycle, but also it can create its own 'feeding rhythm' if fed at regular time for a few days (Hughs, 1968; Kutty and Murugapoopathy, 1968). Since variations with regard to burrowing response ha~~s~~ve also been noted by Hughes (1968), which agrees ~~to~~ with the present observations, that smaller animals emerge or burrow earlier and later respectively than larger individuals on transits from one phase to another. He is of the opinion that smaller animals are relatively lesser regulated by inherent factors and thus are more sensitive to the external stimulii. This view is endorsed by larger proportion of smaller specimens being actively on movements during cloudy day time and emerging earlier when food is made available. It can also be assumed from the negative response to the light and darkness by the post-larvae of less than 25 mm length that the circadian burying rhythm is gradually built up as the young prawn grows. Fuss and Ogren (1966) have similarly found that the specimens less than 55 mm size of the larger species, P. duorarum, are active (non-burried), instead of burrowing like the larger animals, when they are exposed to bright light. This may be one of the reasons that after entering the estuaries the post-larvae concentrate in shallow areas of less than one meter depth and as they grow, migrate towards the deeper zones, where the light intensity is gradually reduced (Garcia and Le Reste,1981; Dall, 1958; Williams, 1958;

Gunter et al., 1964). Shy of glaring day light for the larger individuals is also indicated from the fact that they rest quietly over the black border of the transparent glass aquarium tank avoiding the transparent bottom in day time and similarly take shelter under the thin and light shadow of the trough with sand substratum exposed to extremely high midday sunlight and temperature. Wassenberg and Hill (1984) have found extended period of burrowing during moulting day in Penaeus esculentus.

The estuarine distribution of prawns is also marked by considerable time and space variations. Concentration of populations are reported to be associated with the nature of substrates. Strong concentrations suitable for exploitation are found above soft sediments with a content of rich silt and organic matter. However, preference of substrate combinations varies for different species (Garcia and Le Reste, 1981). Aziz and Greenwood (1982) have found that Metapenaeus bunnettae prefers silt and fine sand substrates among the gradients of substrate particle sizes and they quote Ruello who has suggested that the particle size is more important than food in the substratum in determining the prawn distributions.

Response to burrowing habits is found disrupted beyond the temperature range of 18-32°C in *M. dobsoni* and similar range has been noted at 14-33°C for *P. duorarum* (Fuss and Ogren, 1966), but in both observations the point of irreversible changes is noted at 10°C. These temperature ranges may guide to choose the season suitable for the crops in culture operations and also the management of water depths in ponds to avoid extreme temperatures at the substratum levels. Activity of the juveniles is largely reduced below 18°C and even they fall on sides and drifted along the currents on sudden drop in temperatures lower than 15°C. These facts may be the underlying behind why the populations disappear en mass on rain floods which may be as chill as the lower range and also the distributions being not extended to northern latitudes of India, where the minimum temperatures are normally very low, in spite of population pressure in the southern regions.

Salinity does not have impressive effects, as the temperature has, on burrowing habits of this species. Burrowing and emergence are seen even at 100% sea water and fresh water, though incidence of change from the normal pattern is increasingly more beyond the range of 10-27% .. Similarly, Fuss and Ogren (1966) have found an increasing activity, though insignificantly, beyond the range of 18.7-35.8‰ salinity in *P. duorarum*. Paulinose *et al*. (1981) suggest that *M. dobsoni* can tolerate higher salinities as deduced from its abundance during February-March, when the salinity is very high. Gunter (1961) also does not find higher salinities having any consequences on juvenile distributions of penaeids. Zein-Eldin (1963) finds from his growth experiments on *P. setiferus* that salinity tolerance *per se* may not play a direct role in the growth and survival of juveniles in the estuarine environments.

Burrowing and orientation facing the water currents by the juveniles of *M. dobsoni* is probably an adaptation giving more resistance to avoid drifting along with the currents. Fuss and Ogren (1966) have also noted in *P. duorarum* that burying shrimps show a positive rheotaxis in water current at velocities about 0.2/sec. and the burying angle to the current axis decreases against the increasing current.

The obvious advantage being active at night and to some extent on cloudy day times is the better escaping chances from the predators on poor sights. This diel cycle also helps conservation of energy by reducing the metabolic activities to near minimum during normal day time. High temperatures, which can disrupt the normal behaviour of the prawns; have been among the major problems in tropical waters for culture operations and some of the measures to tackle these difficulties can be indicated out of this studies. Provision of suitable substrate can support enough as a shelter from moderately higher temperatures in certain seasons and excavation of ditches over the ponds deep enough to give thermocline effects may save substantially from highly disruptive temperatures of the hot summer months. Provision of large shadows not only reduces the temperatures, but also shelters from the glaring sun light. Inter-size canabolism, which has been the problem in stocking in culture ponds with different sizes, can be considerably reduced by a sloping of depths, so that larger animals, which are more sensitive to light, disperse towards deeper waters, while smaller individuals can utilize the shallow areas.

Chapter 5

Fishery

Results

1. FISHERY OF *METAPENAEUS DOBSONI* MIERS OFF MADRAS

a. Seasonal Abundance

The seasonal fluctuations of catch rates, which reflect the abundance, for both total penaeids and M. dobsoni along with environmental parameters have been presented in Table 13 and Figure 32 for the two year period under this study. The fishery, if splitted into calender year, is bimodal in 1981 and trimodal in 1982. Hence, the fishery seasons are not necessary to be the same in each year. However, the fishery in the beginning of the year is only the extension of the fishery that occurs towards the end of the previous year. Hence, the fishery has actually one protracted season commencing from October/November to end with March and another small wave may also appear in July-August during some years.

Early in 1981, February records the highest rate of 3.21 kg/hr of the season and maintains moderately at 2.75 kg/hr in March and slumps to 0.84 kg/hr in April. A wide trough follows upto August, the dismal minimum being 0.22 kg/hr in July. The next season then commences from September and steadily improves to reach the year's maximum of 3.41 kg/hr in

Table 13: Monthly catch-rate (kg/hr) of total prawns and *M. dobsoni*; percentage of *M. dobsoni* in total prawns and environmental parameters - rainfall, salinity and temperature (mean of readings at 8.30 A.M. and 5.30 P.M.)

Months	Catch-rate of total prawns (kg/hr)	Catch-rate of *M. dobsoni* (kg/hr)	% of *M. dobsoni* in prawn catch	Rainfall (mm)	Salinity (%.)	Temperature (°C)	% of Mature Females
1981							
January	2.83	0.34	12.0	61.9	32.24	25.07	23.2
February	12.75	3.21	25.2	--	32.26	23.70	22.0
March	8.21	2.75	33.5	2.7	33.20	28.60	19.7
April	3.42	0.84	24.6	--	34.22	31.28	9.4
May	1.82	0.32	17.6	39.6	33.76	32.95	14.3
June	1.64	0.26	15.9	12.7	33.24	33.40	8.5
July	2.12	0.22	10.4	224.3	30.64	31.05	14.6
August	2.50	0.68	27.2	128.3	30.72	30.13	19.6
September	4.40	1.30	29.5	181.3	30.36	29.28	57.1
October	6.20	3.04	49.0	271.4	27.68	28.50	26.2
November	8.52	3.41	40.0	126.7	26.42	26.63	12.8
December	4.62	1.78	38.5	136.6	29.70	25.40	10.8
1982							
January	5.18	2.68	51.7	1.1	33.68	25.30	25.3
February	6.62	2.20	33.2	--	32.96	26.80	17.0
March	10.14	3.95	39.0	--	32.66	28.80	27.9
April	3.12	0.75	23.4	1.2	34.48	31.13	6.1
May	1.10	0.30	27.3	0.3	34.89	32.50	14.6
June	2.24	0.06	2.7	97.4	33.44	32.93	6.8
July	3.86	1.96	50.8	52.1	32.90	30.18	12.8
August	4.20	1.62	38.6	138.0	31.36	30.70	42.9
September	1.44	0.12	8.3	82.4	31.48	30.58	26.1
October	2.20	0.42	19.1	189.4	30.12	29.05	24.5
November	2.62	1.64	70.2	219.0	29.92	27.50	14.5
December	5.40	1.92	31.9	20.9	30.84	26.05	11.0

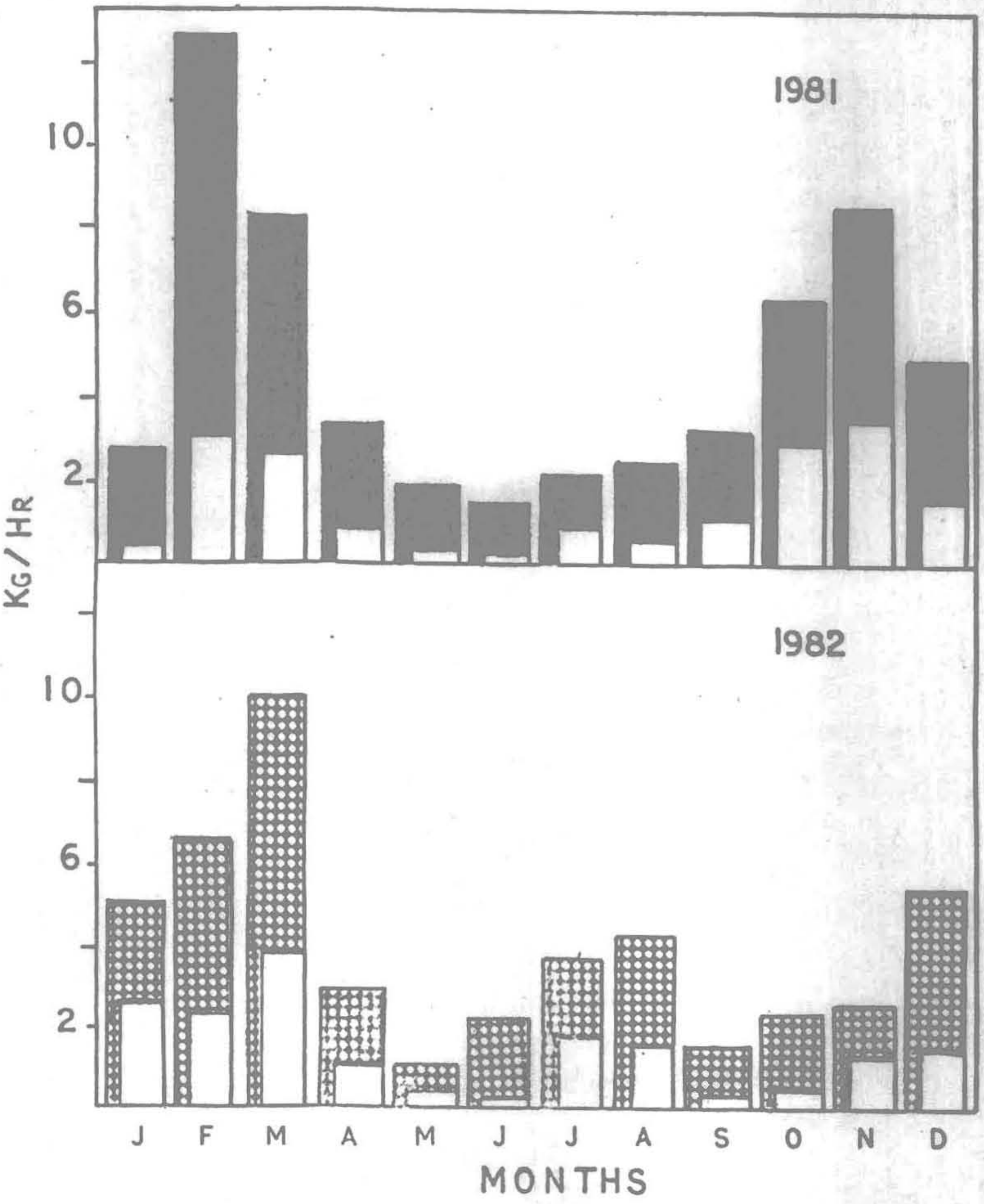

Fig. 32. Fishery of penaeid prawns and *M.dobsoni* off Madras.

November and slightly reduces in December before improving and extending further into next year. The succeeding year, 1982, presents a slightly different picture. The previous year season prolongs till reaching the highest rate of 3.95 kg/hr in March and a steady decline follows to end with the lowest of 0.06 kg/hr in June. In contradiction to the previous year, 1981, July-August of 1982 has registered better fishery as an intermediate wave in annual fishery, as September-October reveals low catches. However, November-December shows better fishery as in the previous year.

The percentage composition of this species among the penaeids reveals considerable influence on the overall prawn productions of this centre. It contributes 10.4% to 49.0% with an average of 27.0% in 1981 and dominates well over 25% during February-April, and again a long spell, during August-December of the year. The percentage distribution ranges between 2.7% and 70.2%, with an average of 33.0% in 1982 and at least, in three months, January, July and November, the species shares more than half of penaeid catches during this year. Except in two months, when the fishery is very poor, the species contributes more than 20% of the landings.

b. Rainfall and Fishery

The monthly catch of this species and the rainfall appear to have some indirect positive relationships as seen from Table 13. The increased rainfalls are followed by enhanced fishery with a gap of one or two months. The long spell of north-east monsoon rains from July through December 1981, with the highest rainfall of 271.4 mm in October, is associated with a protracted fishery from September through March, 1982. Similarly, some rainfall (97.4 mm) in June 1982 is followed by moderate fishery in July-August, when the corresponding months in the previous year have meagre rains and dull fishery. Again regular north-east monsoon rains from August onwards are followed by substantial fishery from November till the end of December, when the observations end.

It can also be put otherwise that the dry spell from February through June appears to be followed by poor fishery from April through August in 1981. Similarly scarcity of rains from January through May is followed by thin fishery from April through June, 1982.

c. Salinity and Fishery

The two small rivers, which are near the place of sampling of salinity, are Adyar and Coovum. They are mostly rain-fed and as such their influences on salinity fluctuations are limited and most events of fall in salinity are caused by local rain floods. The mean monthly salinity (Table 13) varies between 27.68‰ in October and 34.22‰ in April during 1981. Such minor variations of salinity do not seem to have any relationship to productions of prawns and also this species. However, salinity below 30‰ during October-December appears to coincide with higher catches. But, another peak in fishery during February-March of this year occurs when the salinity is moderate around 32-33‰.

During 1982, the salinity ranges between 29.92‰ in November and 34.89‰ in May, lower ranges of less than 30‰ being in October-December and higher over 34‰ in April-May. Abudnance of fishery appears to be associated with moderate or lower ranges of salinity. In otherwords, higher salinity over 33‰ does not seem to be productive of this species.

d. Temperature and Fishery

The monthly mean temperature (Table 13) does not vary much, as it ranges between 23.7°C in February and 33.4°C in June during 1981 and between 25.3°C in January and 32.9°C in June during the succeeding year. Temperature lower than 29°C is associated with favourable fishery and over 31°C coincides with poor fishery on most occasions in both years. It is noted, thus, that the fishery in April-July 1981 has been very low, when the temperature is consistently higher at 31.0-32.9°C. The temperature then drops gradually to reach 25.3°C in January 1982, and remains below 30.0°C until March 1982, during which the fishery has been good.

e. Breeding Season and Fishery

Most of the populations of this species harvested from the coastal waters belong to "0" year group and in particular dominated by the new recruits, which are about 5-6 month old. Hence, abundance of fishery depends upon the strength of new recruits, which in turn is largely influenced by intensity and extent of corresponding breeding populations, though survival through larval and juvenile phases in brackishwater nurseries is also vital. The breeding stocks and their products which

Table 14: Depth-wise distribution of *M. dobsoni* off Cochin

Period	Depth					
	≤10 M		15 M		≥20 M	
	kg/hr	%	kg/hr	%	kg/hr	%
November, 1978	1.03	79.2	0.25	19.2	0.02	1.5
December, 1978	3.43	67.5	1.05	20.7	0.60	11.8
January, 1979	5.00	78.7	1.30	20.5	0.05	0.8
February, 1979	0.25	15.4	1.35	83.3	0.02	1.2
February, 1980	1.45	57.5	1.05	41.7	0.02	0.8
May, 1980	2.05	78.8	0.50	19.2	0.05	1.9
Mean	2.20	67.7	0.92	28.3	0.13	4.0

enter the catches later could be fairly identified in fishery from the chronology of events. It is obvious from the percentage of 'mature' individuals among females in fishery (Table 13) that the local populations have apparently two peak breeding seasons in January-March and August-October. Hence, the products of the former season are likely to form the chore of fishery in September-December and of latter season may contribute largely to fishery in January-March. However, the abundant fishery in July-August (1982) may have a link to intensive breeding noted earlier in January-March of the same year, 1982.

2. BATHYMETRIC DISTRIBUTION OF *METAPENAEUS DOBSONI* MIERS

The catch rate and the distribution of M. dobsoni in relation to depths have been presented in Table 14, for a few months representing a cross section of post-monsoon through pre-monsoon seasons. The overall picture reveals a negative relationship between the abundance of the species and depth within the range of distributions, which extends upto 35 M, though occurrence of them are negligibly scarce beyond 25 M depth. The mean catch rates for the 6 months, which are given in the Table 14 work out at 2.20 kg/hr, forming 67.7% in

Table 15: Depth-wise distribution of *M. dobsoni* off Cochin in relation to surface water temperature and salinity

Period	Depth								
	≤10 M			15 M			≥20 M		
	°C	‰	kg/hr	°C	‰	kg/hr	°C	‰	kg/hr
November, 1978	29.7	23.3	1.03	30.0	25.4	0.25	30.2	26.0	0.02
December, 1978	28.7	30.0	3.43	28.8	32.4	1.05	28.9	33.6	0.60
January, 1979	29.4	31.3	5.00	29.3	33.1	1.30	29.1	33.6	0.05
February, 1979	28.4	31.8	0.25	29.6	32.4	1.35	29.8	33.5	0.02

≤10 M depths; 0.92 kg/hr, sharing 28.3% in 15 M depth and 0.13 kg/hr, contributing 4.0% in ≥20 M depths and the range of concentrations are 0.25-5.00 kg/hr, 0.25-1.35 kg/hr and 0.02-0.60 kg/hr in the respective depth zones. Slight bathymetric shifting of the fishery at times is however apparent. About 65-80% of the fishery is recorded at ≤10 M depths in all months, except in February of both 1979 and 1980, when considerable fishery has shifted towards 15 M depth, as noted 83.3% and 41.7% of the catches in respective years. The deepest ground at ≥20 M depths are poorly recorded with less than 2.0% of the catch in all months, except in December 1978, when it is estimated at 11.8% of the landings.

The values of surface water temperature and salinity (Table 15) against the catch collected from the three depth zones do not show any obvious relationship. However, a slow increase in salinity of shallow grounds is coincided with the gradual deepward shifting of sizable populations. But, heavy congregation of the populations at 15 M depth to the extent of 83.3% in February 1979 is not found with any drastic changes of these factors correspondingly.

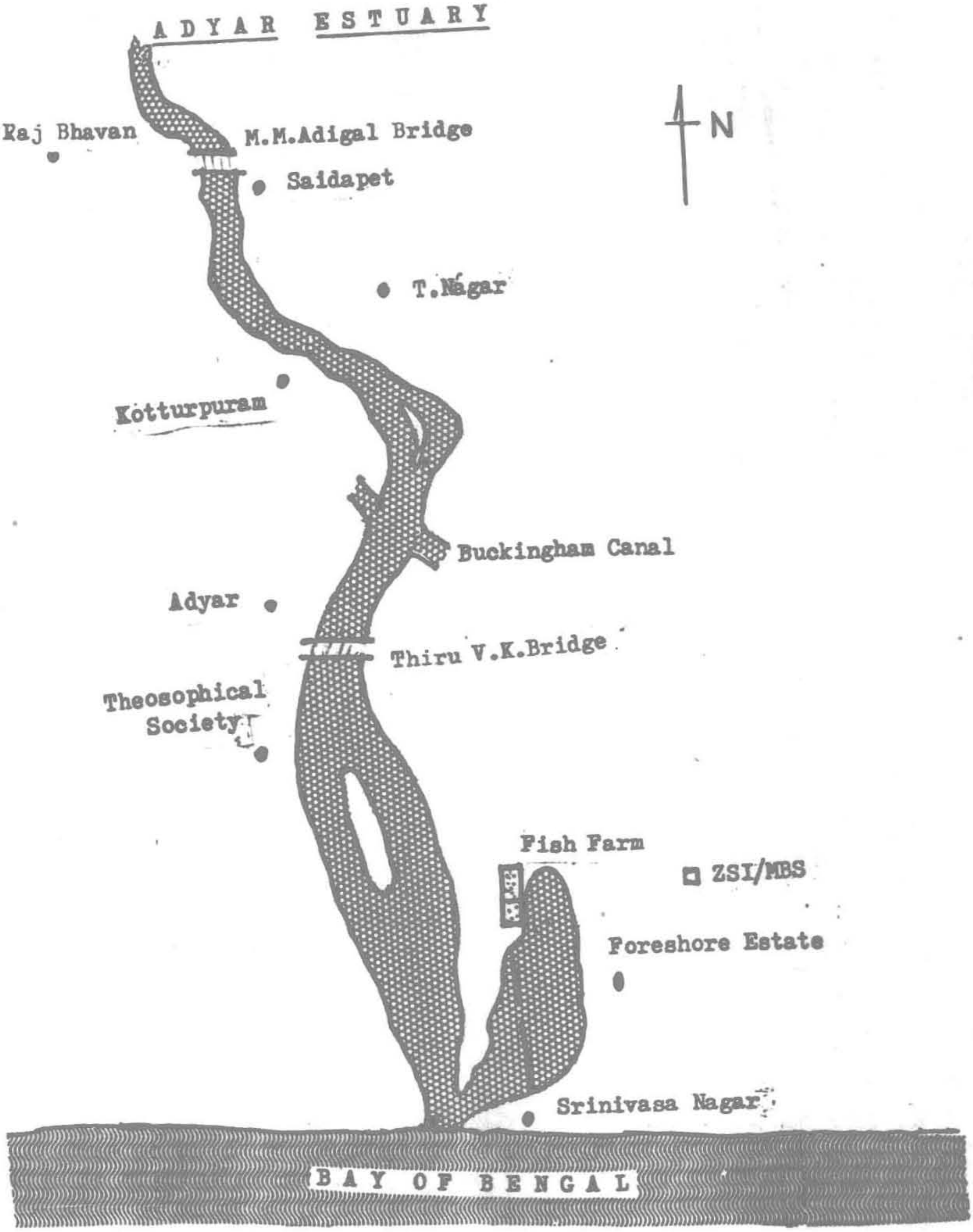

Fig. 33. Out-line sketch of Adyar Estuary.

3. JUVENILE FISHERY OF *METAPENAEUS DOBSONI* MIERS IN ADYAR ESTUARY OF MADRAS

a. Description of Adyar Estuary

It is a small seasonal estuary (Fig. 33), that forms the fag end of Adyar River, which runs through southern out-skirts of Madras city. The bar-mouth is narrow and opens only during northeast monsoon months and the estuarine conditions exist upto 6 km from the bar-mouth during the peak rains and floods. The main area of the estuary is the vast expansion in front of the bar-mouth and the areas aboue Thiru. Vi. Ka. bridge are in tracks under normal flowing conditions, though small troughs are present here and there. Two major features, which may be considered ecologically important on the life of this estuary, are the addition of city sewage by Buckingham Canal on either side about 2 km above the bar-mouth and the presence of one of the city's major 'Dhobighanas' (Washerman's washing site), where larger number of washermen are used to wash clothes, releasing huge quantities of detergents from just ahead the estuarine limits.

The large backwater and the adjoining mud-flat near the bar-mouth described by Panikkar and Aiyyar (1937) are now left as an remeniscent on encroachments by Urban

Housing Schemes and the Fish Farm managed by Government Department. A small island situating in the middle of the vast expansion of estuary in front of the bar-mouth and the dense trees on the southern boundary of the same area around Theosophical Society have been the asylum for migratory birds during monsoon period, which is also the active fishery season here.

b. Fishing Method and Season

The major gear which is used for fishing in this estuary is the cast-net, numbering 10-35 units, with an average of about 20 units daily. Other fishing methods here are angling and crab-traps, being found occasionally here and there. Most of the cast-net operations are seen around the margins of the large expansion and the island present at the foot of the estuary, though at times extend little beyond Thiru. Vi. Ka. bridge. Cast-net operations are normally noted in the early hours upto 9 A.M. and again around noon, if the catch is good and more profitable.

Fishing season associates with northeast monsoon months, September-February, during which the river flows keep the bar-mouth open. Thus, the end of the season

Table 16: Estimated monthly weights of total catch, prawns and M. dobsoni, for cast-net operations in Adyar Estuary at Madras during the fishery seasons of 1983-84

Period	Catch in kg			
	Total catch	Total prawns	*M. dobsoni*	
			Catch	%
October, 1983	820	140	45	32.1
November, 1983	3,420	750	190	25.3
December, 1983	3,720	778	372	47.9
January, 1984	2,790	930	310	33.3
February, 1984	1,993	1,400	720	51.4
March, 1984	2,325	730	248	33.9
April, 1984	3,020	620	84	13.6
May, 1984	640	210	60	28.6
Total	18,728	5,558	2,029	36.5

Proportion of prawns in total catch 29.7%
Proportion of M. dobsoni in prawns 36.5%

depends upon the intensity and extend of the monsoon and this year it extended till the end of May.

c. Fishery

The fishery, as landed by cast-net catches, includes mainly fishes, prawns and crabs, which are mostly the juvenile forms of marine origins. The total catch is estimated at 18.7 tonnes (Table 16) for this year season, which extends from October 1983, through May 1984, co-inciding with the northeast monsoon. Fishing activities are seen throughout except on heavy floods. The monthly catch is calculated to vary between 640 kg in May and 3720 kg in December and the fishery is relatively better during November-January and again March-April, with a slight dip in February. The catch in the beginning of the season sharply increases from 820 kg in October to 3420 kg in November itself, as it similarly decreases at the end from 3020 kg in April to 640 kg in May. Among fishes, mullets, perches, Tilapia and cat-fishes form bulk of the catches and <u>Scylla seratta</u> and <u>Neptunus pelagicus</u> are the major crabs présent in fishery.

Prawns are estimated at 5.5 tonnes, which form about 29.7% of the total catch during the season and its fishery shows gradual increase and decrease. A mere

140 kg in October steadily improves to reach the season's maximum of 1400 kg in February and reduces to about half in next two months before declining further down to 210 kg in May. After bar-mouth closure in early June, the fishery is noted to be negligible and eventually fishing is stopped June itself. But, interestingly, after about a month since bar-mouth closure, an unseasonal rain is noted to flood the estuary without beaking open the barrier at bar and the resumed fishery then comprises good amount of Macrobrachium spp. for a nearly a month before feasing out. The catch of prawns is mainly contributed by Metapenaeus monoceros, M.dobsoni and Penaeus indicus and other species occurring in catches are P. monodon, P. semisulcatus, P. canaliculatus, P. merguiensis, M. affinis, M. burkenroadii, M. rosenbergii and M. idella. Metapenaeus monoceros is the most abundant species sharing averagely about half of the catches; M. dobsoni contributes about 36% and P. indicus about 10% and rest by other species.

Metapenaeus dobsoni is estimated at about 2.0 tonnes, that forms about 36.5% of the total prawns in cast-net catches during the season. This second most abundant species next to M. monoceros forms a fishery throughout the season, though higher concentrations are noted only during December-March. The monthly catch varies between 45 kg in October and 720 kg in February, the two months on either end of the season being recorded with relatively poor catches, indicating gradual increase and decrease of the fishery. The species shares about 51% in February, when its catch is at maximum and about 48% in December. Except in April, when it contributes only 13.5% of prawns, more than one-fourth of the prawn catch is supported by this species in all months during the season.

d. Population Characteristics

The sexes can easily be identified above 30 mm size and the sex-ratio among those analysed does not deviate much from 1:1. The overall sex-ratio of juveniles of this species is estimated at 52:48% in favour of females and in no months the ratio is recorded deviating more than 5% in favour of any sex. No specimens with mature gonads is noted for either sex, though external genitalia, petasma in males and thelycum in females, have been found fully developed.

. The size distribution of M. dobsoni in cast-net catches here ranges between 25-65 mm, with distinct size modes in both sexes. The bulk of the catches are

Table 17: Progression of size modes and growth pattern of <u>M. dobsoni</u> in Adyar Estuary

Period	Modal size (mm) and their progression							
	Females				Males			
	I	II	III	IV	I	II	III	IV
October 20, 1983	26				26			
November 17, 1983	38				38			
December 14, 1983	50	32			47	32		
January 21, 1984	59	44			56	41		
February 12, 1984		53				50		
March 15, 1984		61	23			56	23	
April 13, 1984			35				35	
May 28, 1984			47	26			44	26
Daily growth-rate	0.366	0.318	0.324	--	0.333	0.263	0.283	--
Average daily growth rate	0.333 mm/day				0.293 mm/day			
Average monthly growth-rate	10.080 mm/month				8.890 mm/month			

represented by 30-55 mm sizes and in particular specimens over 60 mm are very rarely seen in catches. Further, analysis of size compositions shows that the population is mostly unimodal or bimodal structures. January-February catch is relatively more complex. Dominant length-modes have been identified and their progression through successive periods is given in Table 17, from which it can be noted that the earliest prominent brood with its modal-size at 26 mm for both sexes enters the fishery in late November and progresses in size to 59 mm by female and 56 mm by male towards late January, after which this group is not impressive as a mode, thereby indicating emigrations during the course of following month.

Meantime, another group, with its modal size at 32 mm for both sexes, is noted in the middle of December and later followed to attain 61 mm by female and 56 mm by male in the middle of March and disappear from next month's catch. In its place, however, another fresh brood, with its modal-length at 23 mm for both sexes, appears dominating the catch from middle of March and continues so till the end of May, when it has grown to the size of 47 mm by female and 44 mm by male. A small and last group appears at the end of May and perishes as the bar-mouth closes and fishing activities in this estuary come to an end, for the season in June.

It is, thus, clear that at least three prominent broods have entered the fishery each at the interval of about two months and each brood lasts about four months as a clear mode. Hence, considering the life-span before entering the fishery, the species can be assumed to return to the sea at the age of about 5-6 months. From increase in modal-size and the corresponding time lapse, the daily growth rate is estimated at 0.366 mm/day, 0.318 mm/day, and 0.324 mm/day for female, and 0.333 mm/day, 0.263 mm/day and 0.263 mm/day for male for the respective broods mentioned above. It gives an average of 0.336 mm/day and 10.08 mm/month for female and 0.293 mm/day and 8.89 mm/month for male.

Samller specimens measuring below 30 mm are observed to prefer shallow waters along the margin and in particular they congregate in small creeks and ditches along the fringe areas. Larger specimens on the other hand are caught in abundance from middle and deeper part of the estuary not far away from the bar-mouth.

4. FISHERY AND DISTRIBUTION OF *METAPENAEUS DOBSONI* MIERS IN INDIAN WATERS

a. General Status of the Species in Indian Prawn Fishery

Prawns form a valuable fishery, substaining an industrial fishing around Indian coasts. The status of present day exploitations and prospects of future expansions are being continuously assessed to stem the management programmes in order to maintain a sustainable yield, if not to improve upon the existing ones. Hence, an array of informations are available from the proceedings of symposia and reports of special projects on the subject, besides individual publications. Among other literatures, proceedings of 'Symposium on Crustacea' held at Cochin in 1965, 'The World Meeting on the Biology and Fishery of Prawns and Shrimps' held by FAO at Mexico in 1967, 'Symposium on the Living Resources of Seas around India' held at Cochin in 1968, 'Indo-Pacific Fisheries Research Council, FAO', 'Prawn Fishery of India' (Bull. 14, 1969) of ICAR Institute, the report of the 'All India Co-ordinated Research Project for Studies on Marine Prawn Biology and Resources, 1971-74' by ICAR Istitute, and the books on 'Prawn Fisheries of India' (Kurian and Sebastian, , 1975) are the major documents giving the consoli-

Table 18: Specieswise break-up of All India prawn landings and percentage during 1978 and 1980

Species	1978		1980	
	Total landings in tonnes	%	Total landings in tonnes	%
Penaeus indicus	18,085	10.1	10,298	6.0
Penaeus monodon	1,014	0.6	2,656	1.6
Penaeus semisulcatus	6,029	3.3	1,713	1.0
Penaeus merguiensis	1,179	0.7	496	0.3
Metapenaeus dobsoni	21,969	12.2	18,998	11.1
Metapenaeus affinis	20,704	11.5	7,232	4.2
Metapenaeus monoceros	16,447	9.1	5,608	3.3
Metapenaeus brevicornis	1,124	0.6	836	0.5
Parapenaeopsis stylifera	30,306	16.9	50,829	29.8
Parapenaeopsis hardwickkii	240	0.1	2,214	1.3
Acetes indicus	39,002	21.7	41,282	24.2
Hippolysmata ensirostris	2,533	1.4	3,092	1.8
Palaenaon tenupes	6,078	3.4	12,654	7.4
Selenocera crassicornis	3,019	1.7	6,389	3.7
Others	12,127	6.7	6,442	3.8
Total	1,79,856	100.0	1,70,737	100.0

Sources: MFIS, 10 & 35

dated picture of Indian prawn fishery and its developments through recent years.

India ranks second, sharing 13% of the world prawn productions, as estimated for the year 1967. The prawn landings in India has been estimated at an annual average of 81,699 tonnes, forming 10.5% of the total marine fish catches in ten year period of 1959-1968 and substantial increase has been recorded later, as known from the figures available for a few years. The production has been estimated at 1,63,849 tonnes in 1972 and at the maximum of 2,03,893 tonnes in 1973. Still later, the yield is calculated at 1,79,856 tonnes in 1978 and 1,70,737 tonnes in 1980. Prawns, that support the fishery, are catagorised into penaeids and non-penaeids which share approximately in the ratio 60 : 40% and the major species, which contribute to Indian fishery, have been presented in Table 18. Penaeids are relatively larger in size and commercially valuable, as compared to non-penaeids, and among penaeids M. dobsoni tops by quantity next to Parapenaeopsis stylifera. The landings of M. dobsoni are estimated at 21,969 tonnes, sharing 12.2% of total prawns in 1978 and at 16,998 tonnes, contributing 11.1% in 1980. The species should be furthermore abundant in numbers considering the smaller

Table 19: Annual landings of M. dobsoni and its percentage to total penaeid prawns at major fishing centres of India during 1980

Centres	Total penaeids in tonnes	Catch of M. dobsoni		
		Annual landing in tonnes	Percentage	Catch-rate (kg/hr)
Veraval	1,590	--	--	--
Bombay	6,431	traces	--	--
*Goa	456	140	30.7	1.15
Karwar	562	143	25.4	2.28
Mangalore	980	484	49.4	3.40
Calicut	355	92	25.8	1.75
Cochin	3,466	2,066	59.6	1.69
Quilon	36,558	1,170	3.2	1.38
Tuticorin	1,014	83	8.2	0.26
*Portonovo-Caddalore	860	190	22.7	0.86
Madras	183	30	16.6	1.38
Kakkinada	1,972	252	12.8	1.25
Puri	56	traces	--	--

* Pertain to 1973-74 (Report on Co-ordinated Prawn Project, ICAR, 1974)

Source: MFIS, 35, 1982

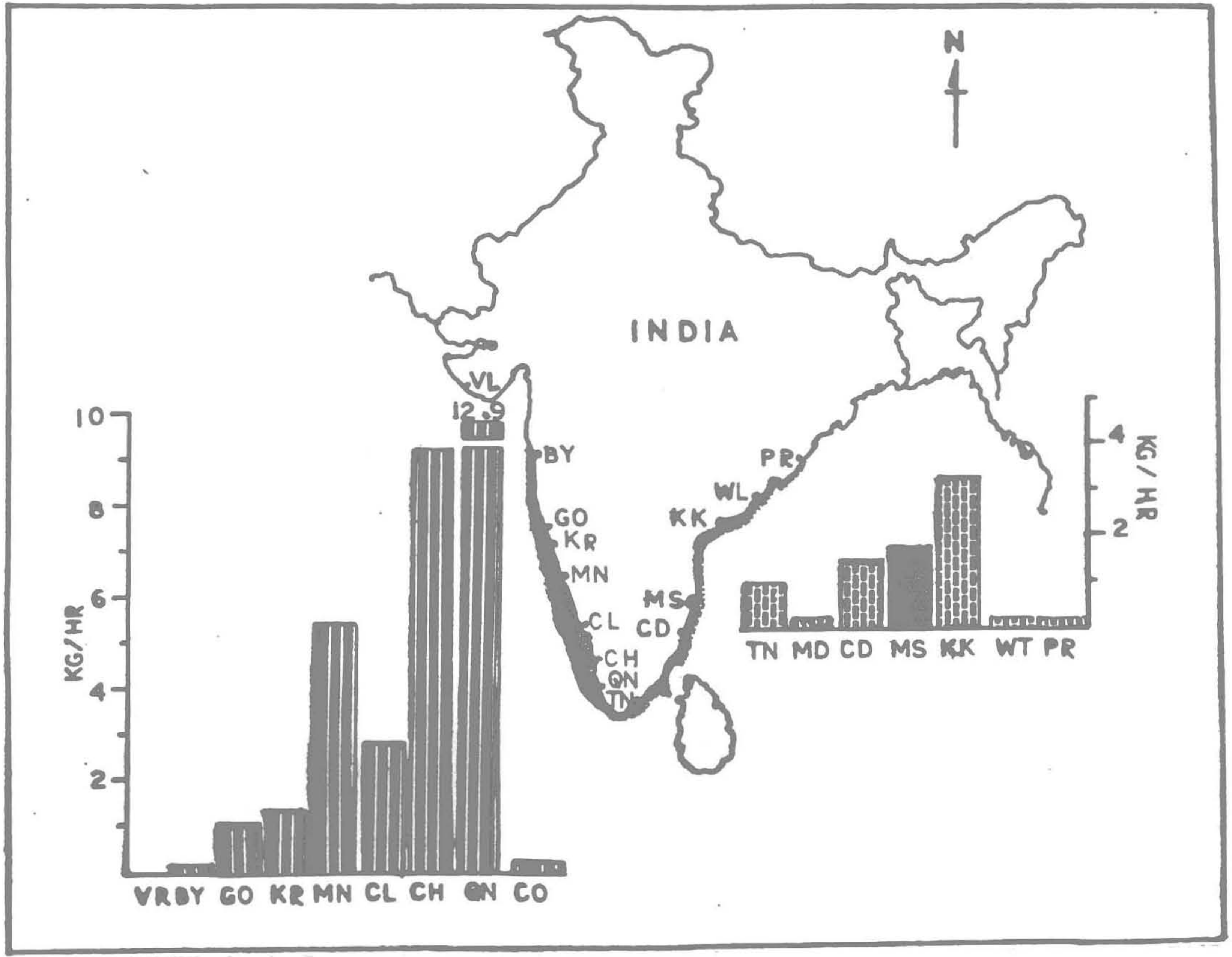

Fig. 34. Abundance of M. dobsoni along either coast of India.

size as compared to most of the other Indian penaeids enlisted (Table 18).

Metapenaeus dobsoni is the species endemic to southern latitudes, supporting substantial fishery south of Goa till Quilon on the west coast and Kakkinada till Cauvery base on the east coast, though occurring upto Bombay and Puri on the north of respective coasts and Cape Comerine, the southern extreme, where both west and east coasts merge. Informations on distributions and abundance of this species in major fishing centres around Indian coasts, which are based on data extracted from MFIS (ICAR) bulletins and other sources mentioned therein, are presented in Table 19 and in Figure 34 for the year 1980. It reveals that bulk of the country's productions come from south-west coast, particularly a narrow region of about 100 miles length between Cochin and Quilon. Though the abundance of this fishery differs much between the coasts, parallel distributions on either coast are apparent.

b. West Coast Fishery

Goa is the centre at northern extreme on the west coast supporting fishery of this species and an average, of 140 tonnes of it at the rate of 1.15 kg/hr, forming 30.7% of total penaeids, has been estimated for the year

Table 20: Seasonal occurrence (given in kg/hr) of *M. dobsoni* in selected centres of West and East Coasts of India during 1980

Months	West Coast			East Coast	
	Karwar	Cochin	Quilon	Madras	Kakkinada
January	0.45	6.40	3.15	0.28	0.96
February	2.64	7.74	0.80	1.08	1.73
March	1.01	5.73	0.40	0.57	1.71
April	0.12	10.82	0.63	0.23	0.81
May	5.25	9.90	2.20	0.27	0.04
June	1.25	1.15	3.36	0.54	0.27
July	0.65	0.22	10.40	0.68	2.41
August	1.54	0.20	1.80	0.70	3.30
September	4.75	0.01	0.22	1.23	1.08
October	1.02	0.01	0.48	2.93	1.19
November	1.86	3.30	5.50	4.20	1.25
December	6.84	7.45	5.80	2.49	2.10

Source: Extract from MFIS, 35, 1982

1973-74. Towards south the neighbouring Karwar centre has harvested 143 tonnes at the rate of 2.25 kg/hr, which forms 25.4% of total penaeids, in the year 1980. Also, the Table 20 for the seasonal abundance of the fishery of this species in various centres shows that Karwar has intermittent spells of fishery, with two major and two minor peaks. The highest catch rate of 6.84 kg/hr in December, followed by 5.25 kg/hr in May, has been recorded for the year and February and September are other months with slightly better fishery.

Mangalore has still better fishery and it has landed 484 tonnes of this species at the catch rate of 3.40 kg/hr sharing about 50% of the total penaeids landed during the year. Sporadically purse seine operations during monsoon month have fetched more than 500 kg/unit off this centre, but such occasions last a few days only (Nair et al., 1982). Calicut, another centre about a hundred miles away in south, has registered slightly lesser catch. This centre is estimated to have harvested 92.0 tonnes at the rate of 1.75 kg/hr, that forms about one-fourth of the total penaeid catch.

The maximum concentration and quantity of landings of this species have been recorded at Cochin. It has fetched 2,066 tonnes at the rate of 7.69 kg/hr, that forms about 60% of the total penaeids during the year 1980. This centre, unlike the other northern centres mentioned above, shows only one protracted fishery season extending from November till May, with the highest catch rate of 10.82 kg/hr in April, followed by 9.90 kg/hr in May during the year. Southwest monsoon period, which is intensive and prolonged here in June-September, appears to be associated with poor fishery. But, on a few occasions during monsoon purse seine catches have been noted to slightly exceed 4,500 kg/unit, though they last a few days only. Quilon, which is less than a hundred miles away in south from Cochin, is the most productive of penaeid prawns and it has landed 1,170 tonnes of M. dobsoni at the rate of 1.38 kg/hr forming only 3.2% of the total penaeids for the year. 'Mud Bank' fishery during the monsoon is the unique feature of this Cochin-Quilon belt.

c. East Coast Fishery

In general, prawn fishery, so also the fishery of M. dobsoni, on the east coast is in patches, though the distribution is contiguous. Turning towards north from the southern tip, Tuticorin, compared to the most productive Quilon, which is almost lateral on the west coast to this centre, has landed contrastingly a far less quantity of 83 tonnes of this species at the rate of 1.0 kg/hr forming 8.2% of the total penaeids for the year. Portonovo-Cuddalore, the twin centres at the base of Cauvery delta area, have recorded an annual catch of 190 tonnes of this species in 1973-1974 at the rate of 0.88 kg/hr, sharing 22.1% of the total penaeids.

About a hundred miles away in further north is Madras, which has the prawn fishery largely influenced by the vast Pulicat backwaters and moving populations. This centre has registered landing of 30 tonnes of this species, sharing 16.6% of total penaeids at the catch rate of 1.62 kg/hr in the corresponding year, 1980. This species seems then to have only one protracted fishery season from September through February, with a dip in January. The maximum catch rate recorded for the year is 4.20 kg/hr in November and the warm April-May months are noted with poor fishery.

Kakkinada, which is at the base of fertile Godavari delta, is the most productive for prawns on the east coast and it has landed 252 tonnes of this species forming 12.8% of the total penaeids at the rate of 1.25 kg/hr in 1980. Two prominent fishery seasons in November-December and July-August, with the highest catch rate of 3.30 kg/hr in August, are recorded here. The warm season of the year, March-June shows poor fishery, with the lowest value in May. North of Kakkinada only meagre fishery of this species has been sporadically observed. A small fishery of M. dobsoni has been noted in May 1978 at Puri, though rare in other seasons.

Discussion

The fact that the presence of only two minor rivers in the neighbourhood of Madras city, which are not more than drainage channels, must have considerable importance as far as life in the coastal waters is concerned, since not much of organic and inorganic food material is brought down into the sea, nor is there such a drainage of freshwater into it as to make any great variation in the salinity (Menon, 1931). Since his days the city has enormously expanded gradually adding several millions of inhabitants to this date and the huge quantities of urban sewages, which are added into the neighbouring coastal waters may be thus expected to manure high fertilizing effects to support substantial life. This may be fairly true to record a fishery of this species as good as or better than any other areas within this region including of fertile deltaic areas (Table 19) of south-east coast. This view is further supported by the presence of good catches during the season adjoining the city, though the nearest nurseries, Pulicat Lake in the north and Covelong in the south are about 50 km away from here. In otherwords, the perennial sewage flush of the city into the fore-grounds may form favourable feeding grounds, attracting the moving populations as far away from Krishna and Cauvery deltaic areas, which form the major source of fresh stocks. Long distance coastal movements by penaeids have been substantiated by mark-recovery experiments (Anderson, 1956; Ruello, 1976; Silas et al., 1981). Ruello (1975) points out that new broods emigrating from the nurseries would mix up and move along the coasts and Garcia and Le Reste (1981) have found strong concentrations of penaeids above soft sediments with contents of silt and organic matters. Williams (1958) considers food and substrate types are paramount factors to shrimp distributions.

The seasonal and interannual variations are more common in penaeid stocks. Hence, July-August in 1982 record better catch rates to form a small wave, as compared to poor fishery during these months in the previous year, 1981. Garcia and Le Reste (1981) mention this fact that the seasonal pattern of penaeid abundance may be different in successive years at the same fishing site or at different sites during the same year, reasons being largely attributed to hydrobiological factors.

Metapenaeus dobsoni, like most of penaeids, has short life-span and as such the catch abundance mostly depends upon the strenth of 0-1 year classes in populations and in particular the share of new recruits is well pronounced. Thus, the local estuarine conditions, which are associated with output of fresh stocks of young prawns into the sea, are the major factors operating on the catch fluctuations in coastal waters. The dry conditions of most of the estuaries with their barmouth closed along this part of coast may be thus attributed to the dull fishery here during the summer months, April-July and this view may be substantiated by the fact that the fishery of this species is at maximum in April-May at Cochin (Kurup and Rao, 1974) a near parallel centre on the west coast, which has, but, extensive stretches of deep backwaters with perennial connections to the sea. Prolonged dry weather has also been reported to affect the prawn productions in Australian waters (Racek, 1955; Ruello, 1973). The severe scarcity of fishery in summer may also be partly due to bathymetric migrations of the older specimens, as Boddeke (1976) opines that sexually mature shrimps are more sensitive to temperature rise.

The higher fishery associated with wet seasons, as noted here for this species, has been observed for penaeids in general by several workers (Gunter and Hildebrand, 1954; Racek, 1955; Gunter and Edwards, 1969). Garcia and Le

Reste (1981) quote Gunter and Hilderbrand (1954) showed positive relationship between fisnery of Penaeus setiferus and the rainfall of the previous two years (r = 0.66) or during the current and two previous years (r = 0.70). These autnors suggest the desalination may be the cause for the time-lag between the rainfalls and the productivity. Ruello (1973) substantiates this time-lag that the sub-adults migrate en mass on rainfalls and floods and such crowded populations may have better reproductive potential and hence the spurt in catch in corresponding future. Extension of rains further enlarges the nursery grounds enhancing the chances of larval recruitments and their survival, resulting in corresponding increase in coastal fisnery during the succeeding seasons. Though such annual correlation is not possible from the present two year studies, a long and heavy spell of rains from July 1981 through December, is obviously followed by better fishery from September 1981, through March 1982, leaving a time-lag at either end. This short time-lag may be explained that the local estuaries, which are cut off from the sea and/or stagnated with highly polluted urban sewages for prolonged period prior to these monsoon rains, are not possible to release any old stocks of young prawns at the initial months of rains though resumed the free connection with the sea. Hence, bulk of the initial fishery after a gap of two months since the onset of monsoon are likely the migratory populations attracted by the urban sewage sediments flushed into the fore-grounds. The fishery here is noted high even during the peak monsoon rains, while it is observed poor at Cuddalore-Portonovo at the base of Cauvery river systems (Author manuscript) and at Cochin (Kurup and Rao, 1974) during such seasons. It may be explained that the absence of any big rivers to discharge persistant floods during these periods may keep the salinity relatively higher favouring better shelter for the moving populations from the more distressingly diluted neighbouring deltaic areas. This congregation of population may also be attributed to availability of plenty of larval food, the plankton mass, owing to high fertilizing effects of large sewage run-off. The expansions of estuarine areas, which were hitherto dried up or stagnated, on floodings since monsoon set in, may be also supporting higher concentrations of juvenile populations, which form later the chore of the post-monsoon fishery.

Salinity does not seem to have any effect on productions of this species here, as the fluctuations are narrow and the catch rate has been fairly higher at the lowest (3.04 kg/hr at 27.68‰ in October 1981) as well as towards the upper ranges (2.75 kg/hr at 33.20‰ in March 1981). Observing many penaeid animals remaining in the open sea during summer time, Spaagran (1980) suggests no physiological necessity to live in lower salinities. However, he feels that the viscosity of the seawater is influenced by salinity and temperature and it is concerned with sinking rate, which eventually transports the animals to typify the area with population density or segregation.

Population or environmental stress may also add seaward migrations of juveniles at pre-mature age, resulting in enhanced catches in inshore waters. The fishery of M. dobsoni here commences around pre-monsoon months, July-August, and extends far late into post-monsoon periods, February-March, with or without intermittent falls. Productions of penaeid fishery in rainy periods have been widely reported. Chang et al. (1981) have observed higher occurrence of juveniles of M. ensis in relation to heavier rains and quote such relationship more common in penaeids, as noted that Metapenaeus spp., in Japan and Indonesia show two peaks in July and in

October, which coincide with the end and beginning of rainy season respectively. Glaister (1976) has also recorded mass movement of *M. macleayi* into the oceanic waters after increased river discharges enhancing the density of populations to be more susceptible for fishing off the mouth of Clarence River. Similar observations have been made by Racek (1959) and Ruello (1973), who explain the mass movements of juveniles from nurseries in such conditions are due to suffocations on turbid floods frequently. Gunter and Edwards (1969) have recorded a positive relationship between optimum river discharges and productions of prawns in Texas Lousiana waters. Subramanyam (1964) has observed in Indian waters a positive relationship between the higher catches of *P. monodon* and the Godavari river discharges of the previous year, but of *P. tunuipes* and the discharges of the same year. Resumption of moderate salinity, in combination with moderate temperature, in pre-monsoon periods from the extremely high summer conditions in tropics may also be assumed to have permitted the dispersed populations returning to normal fishing grounds. Pullen and Trenk (1969) observe that peaks of white shrimp emigration are correlated closely with rapidly decreasing temperature and salinity. Hence, all these previous studies are confering the present observations of better fishery of this species during wet periods of the year. Existence of such fishery in the absence of any persistent heavy river discharges and larger nurseries enough to sustain a fishery may be explained, however, that the enormous sewage sediments washed into the fore-grounds on rains from all over this city with 6 million inhabitants and innumerable live stock populations may be the major attractions to be the prawn populations from neighbouring areas.

Metapenaeus dobsoni has also been reported to be a major species by several workers in adjoining areas. Muthu (1973) in Madras, Ganapathy and Subramanyam (1966) in Godavari estuarine system, Sudhakara Rao (1975) and Muthu et al. (1975) in Kakkinada water, Sundararaj et al. (1975) in Marakkanam estuary near Pondichery, Evangeline et al. (1975) in Killai Backwaters and Author (manuscript) in Portonovo-Cuddalore waters, both at the base of Cauvery delta, Rao and Durairaj (1973) in Gulf of Mannar off Mandapam, Sivalingam (1956) in Balapatya lagoon in northeast Ceylon coast and Samarkoon and Raphael(1970) in Negombo lagoon of northwest coast of Ceylon and Suseelan (197) in Manakkudy estuary near Cape Comerin.

The foregoing accounts thus reveal that M.dobsoni forms an integral part of southeast coast fishery, with two annual waves, coinciding moderate wet to most wet conditions. Areas off Madras with urban sewage sediments seem to attract better fishery of moving populations more obviously during the peak monsoon seasons, when normally other regions with heavy freshwater inflow record poor catches.

Bathymetric distribution and in and offshore migrations of penaeid populations in space and time are well known. Being a dioecious species waves of young cohorts may be expected to be pressed into inshore grounds from nursery waters during peak fishery season and hence dispercement of populations becomes a necessity of survival under such swelling pressure of competitions between the grown individuals. In an area of heterogeneous fishery such species may be characteristically selective of its depth range of distribution, as it is noted in the present survey that most of the populations of M. dobsoni prefer 8-15 M depths, and the thickest concentration is around 8-10 M depths while that of P. indicus, and M. affinis appear to concentrate at 15-25 M depths. George et al. (1967) have also similarly noted that M. dobsoni is more abundant in 12-15 M region and *M. affinis* and *P. indicus* are dominant in 16-20 M regions off Cochin. Kurup and Rao (1974) have recorded peak fishery of *M. dobsoni* in April-May, when the trawler operations, they mention, are more active in 10-25 M depths off Cochin. George (1969) has reported this species being distributed upto 20 fm in inshore grounds, preferably with muddy bottom, along Indian coasts and this limit confirms the highest depth of 35 M, at which a few specimens have been collected in the present cruises.

Laevastu and Hyes (1981) explain such spatial preference of a species that 'cold-blooded animals like shrimps have the ability to perceive and select a limited thermal ranges, in which they tend to congregate and this is usually the opporutnity for maximum expression of activity and is ultimately manifested in their abundance and distribution'. Howard (1960) puts it simply that the individuals are genetically pre-disposed to disperse. Another view is that those individuals, that avoid contact and are asocial, are most likely to disperse (Garcia and Le Reste, 1981) and this may also be a reason why stray specimens are sometimes met with in far deeper waters (30-35 M) without any contaguity of distribution for quite a long gap. This phenomenon is observed in some other way by Grant and Griffin (1979), who state that bulk of shrimps remain in 1-19 M depths and assume about 1% of the populations move to the deeper 20-90 M offshore areas each day.

Several hypotheses have been proposed to elucidate proximate and ultimate causes for dispersal and distribution. Garcia (1977) shows that the upper limit of distribution of P. notialis on the West African coasts is determined by the nature of sediments and that the lower limit seems to be more associated with hydrological conditions. Temperature does not reveal much variations between depth zones as far as surface water is concerned and, if at all, salinity may have any influence on the pattern of distribution of the species here. A slight inverse relationship between the catch and depth is noted on most of the occasions. Generally, the lowest salinity coincides with highest catch rate; but a drastic shifting of highest concentration of fishery to 15 M in February of both 1979 and 1980, while hydrological conditions remain the same pattern as in other months, deserves much more explanations. Similarly, sporadic occurrence noted in purse seine catches measuring over 1000 kg/unit during lean season off Cochin (Nair *et al.*, 1982) attract several explations. Such bathymetric shifting is indicated by Linder and Cook (1970) that the abundance of penaeids is maximal either at the centre of the bathymetric distribution or towards the coast. George *et al.* (1968) have observed the bathymetric movements of *M. dobsoni* as a function of season. The populations, they say, are closer to the shore in monsoon and more deeper zones after tainy season. This view is further supported by the major share of this species in mud-bank fishery along the south-west coast during monsoon months.

Bathymetric distribution may also be a function of age and physiological status of the animals. As explained *vide supra* a positive relationship between the size, female ratio and proportion of mature females on the one hand and the depth zones on the other hand is quite evident. Laevastu and Hyes (1981) explain this that larger and older specimens migrate to colder boundaries of the distribution areas of the species due to physiological need, while smaller animals remain in the normal distribution areas. Boddeke (1976) has concluded that the migration in *Crangon crangon* is triggered off by temperature fluctuations, the sexually mature shrimps being more sensitive than sexually immature shrimps and the same is also viewed by Eldred et al. (1961). Tuma (1967) has noted deepward migrations of P. merguensis for mating purposes, as he finds 17% of the inseminated females available within 1-7 fm, as against 73% between 8-10 fm, while the distribution extends over 1-15 fm. Anderson (1956) feels that the inshore-offshore movements of the penaeid, P. setiferus is largely due to temperature changes and spawning habits and the population would also wander in search of food. Tolerance to variations in salinity or other associated factors and turbidity on floods may also be the causative factors for deepward movements of populations (Garcia and Le Reste, 1981). Considering all these factors, the shifting of fishery to 15 M depths from the normal ≤10 M depths may be attempted to explain that as the fishery season advances since December, the populations become more complex of old and young, increasing the intra-specific competitions, upon which or on physiological needs, specifically breeding, which includes mating and spawning, substantial portion of the populations may migrate towards deeper waters. The dynamic nature of the populations of this species is also indicated by George et al. (1968) from the fluctuations of mean size and abundance at depth zones.

'Mud-bank' fishery and purse seine catches in larger quantities for a few days closer to the shore during monsoon, which is otherwise lean fishery season of this species, may indicate erratic movements of those thin populations and centrifugations under the turbulant monsoon currents. This is substantiated by the presence of all catagories of individuals, which would, othersise, have been distributed in a depthwise pattern as explained vide supra.

The area under coastal aquaculture is fast expanding in recent years and every potential area is being constantly explored in view of the very high profits with the culture produce, expecially of, prawns, that can be reared with more assured success, gaining knowledges from global researches on this subject. The estuaries in coromandel coast in southeast coast of India have high potential, though not in practice even at the crude form, as found in southwest coast and Gangetic deltaic regions. It has been reported by Panikkar (1951) that 'the marine lagoons and brackishwater impoundments, so characteristics of the Coromandel coast of India, form the distinct zone of great potentiality for pisciculture operations, which could be developed like the 'Thampaks' of Indonesia, and these areas indicated by the surveys carried out in Chilka Lake, Madras backwater, etc., have a higher biological productivity as shown by their rich fauna, both in numbers and species'. Panikkar and Aiyar (1937) have again emphasised it that Adyar Estuary with rich and specialised fauna, shows interesting peculiarities both in mode of life and life history. The have, however, recorded only 3 species of prawns out of the 92 species totally for Invertebrates and in addition to those three species, nine more prawn species have been observed in the course of the present studies.

Domination of *M. monoceros*, *M. dobsoni* and *P.indicus* in prawn fishery have been also reported from neighbouring brackishwaters, such as from the nearby Covelong Estuary, Madras (Muthu, 1974), Marakkanam backwater (Sundararaj *et al.*, 1975), Killai backwaters at the base of Cauvery delta (Evangeline *et al.*, 1975; Palaniappan *et al.*, 1982), from Balapatya lagoon on the northeast coast of Ceylon facing the Bay of Bengal (Sivalingam, 1956) and from Kakkinada backwaters (Sudhakara Rao, 1975).

Though small in size and connected with sea for a short season, this estuary appears to support rich fauna of prawns, few of which are in good concentrations. The active season is northeast monsoon through a few post-monsoon months and in other seasons it is stagnant with fouling city sewage. The monsoon rains and floods may initially wash off the sewage leaving a mat of rich silt which could support as nutritious diet to the dwelling juveniles. Abundance of prawn fingerlings in soft muddy substrate with rich silt has also been reported by Rajyalakshmi (1973) and Garcia and Le Reste (1981).

Incidence of increased prawn fishery coinciding monsoon is a common phenomenon. As noted in the present studies, Nammalwar (1982) has observed in the Adyar Estuary and nearby brackishwaters two peak breeding seasons, as indicated by larval abundance, in October-December. Muthu (1974) has noted one of the two fishery modes recording in December-February at nearby Covelong Estuary for prawns in general and the other mode is pointed out there when Adyar Estuary is dry on its bar-mouth closure. Sudhakara Rao (1975) has recorded two annual peaks in fishery at distant Kakkinada backwaters in the north during April-July and October-December. Evangeline et al. (1975) have observed better fishery in September-March, the peak being in November and later the author (manuscript) has recorded the peak fishery in December-January for the Killai backwaters, about a hundred miles south on the same coast. The post-monsoon peak fishery of prawns has also been observed in December-January at Cochin Backwaters on the west coast of India. Samarkoon and Raphael (1970) have noted higher abundance in juveniles of M. dobsoni during October-November at the neighbouring Negombo lagoon in Ceylon coast. Chang et al. (1981) have recorded higher occurrence of M. ensis in relation to enhanced rainfall and also they mentioned that the Metapenaeus spp. have two peak fishery in July and October in Japan and Indonesian waters coinciding with the end and the beginning of the rainy season respectively. Besides, relationship between prawn productions and freshwater discharges has been reported by several authors (Racek, 1959; Menon and Raman, 1961; Gunter and Edwards, 1969; Rajyalakshimi, 1973).

The maximum size-ranges of this species obtained in cast-net catches at this Adyar estuary is relatively lower than several other records in Indian brackishwaters. Specimen measuring 61-63 mm, that too during a couple of months, January and March, are the largest size-group ever recorded during this study. But, Suseelan (1975) has recorded the maximum length at 88 mm in Manakkudy estuary; Sudhakara Rao (1975) at 80 mm in Kakkinada backwaters; George (1975) at 66-70 mm and Menon and Raman (1961) at 86-90 mm in Cochin backwaters. The largest specimen is recorded at 80 mm by Menon (1951) in Pulicat Lake and estuaries of Calicut and he also mentions Kemp obtaining largest length in Chilka Lake at 75 mm, which is also the maximum size recorded by the author (manuscript) in Killai backwaters. However, Kutty and Nair (1980) have noted that a specimen measuring 59 mm is the largest in the estuary of Goa and this size-range is more comparable to Adyar estuary. The difference in size-ranges between these brackish-waters may be attributed to mostly the nature of hydrographical conditions of the nursery. Being extensive and deeper, most of those nurseries may have lesser fluctuations of hydrological features and hence the more sensitive larger specimens may remain longer to grow to larger size. On the other hand high concentrations of pollutants, especially the huge contents of detergents, which are washed behind from the 'Dhobi Ghana', the washerman's site at Saidapet, just above the estuarine limits in Adyar River, and the city's sewages drained in by Buckingham Canals, may drive off the sensitive sub-adults pre-maturely. Having also a good city market nearby over-fishing at premature lengths is also a reason.

The smaller specimens measuring 20-35 mm, which are about 1-2 months old and freshly recruited from the sea, are common throughout the season, October-June, when the bar-mouth is opened, though higher abundance is noted in October-March. Similar observation has been made by Menon (1951), who has found the larvae of this species in plankton collected from Madras waters, including Adayar River mouth area, present throughout the year, with maximum in September-March. Rao (1977) has also reported this species breeding throughout the year, with two annual peaks in June-August and November-December, the former peak falling in monsoon period as in the present studies. George (1962) and George, Raman and Nair (1968) have also endorsed the year-round breeding activities of this species in Cochin backwaters. However, George (1961), Menon (1955) and Paulinose et al. (1981) have suggested one extended period of spawning of it from their studies in Cochin backwaters. It is also noted that the first group of this season leaves the nursery by late January and thereafter one new brood in the middle of March and another small one in May are recorded in the catch. It may suggest that the early products of breeding season may grow upto complete the estuarine life-phase and participate spawning towards the later part of the season itself. The abundance of smaller sizes in May, the mid-summer, shows that the salinity, which may be very high then, is not an inhibitive factor for the distribution of young prawns. This seasonality is further substantiated by higher abundance of _P. indicus_ during January-April in Pulicat near Madras (Subramanyam and Rao, 1968). Gunter (1961) also reports that salinity in broad ranges is inconsequential to young prawns and he emphasises it 'small shrimps are not killed or precluded by high salinity as if it were poison; they simply do not do well in it for reasons unknown'.

The sex-ratio has been mostly found even, as in the present observations, with minor deviations in favour of either sex on different occasions (George, 1974, 1975; Suseelan, 1975; Paulinose _et al._, 1981). The difference of growth-rates between sexes in juveniles of this species have not been highlighted by those who have studied growth in general. There is a difference of about 1.2 mm/month between the sexes in favour of females and earlier, Author (manuscript) has calculated 0.2 mm/month difference between them. In observation the difference of growth-rate becomes visible when they are about 35-40 mm size, when they are about 2.5 months old and similarly, Motah (1981) has observed the sexual difference in growth-rate of P. monodon commencing from 2.5 month old animals. But, Subramanyam and Ganapathy (1975) have noticed no sexual difference in growth of juvenile P. monodon.

Paul (1942) has reported that many forms of sedentary animals, he studied in Madras waters, show rapid growth largely under the influence of tropical temperature here. It is true that the growth-rate estimated at about 10.0 mm/month for female and 6.8 mm/month for male is somewhat comparable to the values for highly productive backwaters. Paulinose et al. (1981) have calculated the growth rate of this species in culture ponds varying between 5-15 mm/month; George (1969) at 11.2 mm/month; Mohamed and Rao (1971) at 9.88 mm/month; George (1975) at 10.5 mm/month; and Tambi et al. (1978) in the culture fields of Cochin backwaters. Suseelan (1975) has computed a growth-rate of 10.0 mm/month for both sexes in Mankkudy estuary near Cape Comerin and Author (manuscript) has estimated at 10.5 mm/month for female and 9.7 mm/month for male in Killai backwaters. But, Menon (1951) has calculated a very low rate of 6.7 mm/month for juveniles measuring 18-65 mm in the laboratory rearing experiments and even in such aquarium rearing, the species is recorded to grow at the rate of about 12.0 mm/month for the size-range 26-55 mm in the present studies. Slight differences in these field studies may be attributed to the selection of length-modes, as the growth-rate is a function of age and size, though other few biotic and abiotic factors can modify, as explained in the previous chapter. Poor growth-rate obtained by Menon (1951) may be due to less suitable rearing conditions and the maximum size (65 mm) upto which he has reared that single animals.

Seaward migration of sub-adults at the age of about 5-6 months has also been suggested by Achuthan Kutty and Nair (1980). But, Menon (1951, 1955) and George (1959, 1967) have suggested 9-10 months of estuarine life from their field studies. However, recent direct experiments in the culture ponds and laboratory agree more to the present estimates. Garcia and Le Reste (1981) point out Penaeus notialis attains age maturity in 7 months. AQUACOP's (1982) experiments show that P. vannamai requires about 6-8 months to breed for first time. But it cannot be ignored that the larger sizes occurring in such deeper backwaters and the poor growth-rate obtained in laboratory rearing by Menon(1951) may have influenced them to infer higher life-span in estuary.

Though Adayar estuary is a small one, it has several potential reasons to attract prawn farming and major among them are,

1. It has rich fauna of prawn species like, *P. indicus*, *P. monodon*, *P. merguiensis*, *P. semisulcatus*, *M. monoceros* and *M. dobsoni*, many of which are highly demanded in culture operations;
2. Considering the on-growing phase of those penaeids in general, one crop during post-monsoon months, December-March, is ensured and another crop in June-September is also possible if the thin bar-mouth can be manually kept open;
3. Being located in this metropolitan city of Madras, financing for the enterprenuers may not be a problem as faced in other remote areas; and
4. Properly treated sewage effluents can be converted into the nourished food for farming animals.

True to these facts, there is already a fish-farm in Adyar estuary itself under the management of the Tamil Nadu Fisheries Department and another larger one, with main emphasis on prawn farming, is just in take-off stage at Muttkkadu about 20 km away from Madras in the south under the ICAR Institute.

Prawns in coastal waters of India have been traditionally exploited by artisanal fisheries over centuries. Mechanised fishings with more powerful crafts and grears stepped in during late 1950s and the attractive international markets for the Indian penaeids intensified the fishing activities rapidly over the entire coasts since then. Extension of such exploitations seems to be reflected upon the enormous increase in penaeid landings of India through all these years. Banerji (1969) has earlier analysed the trend in prawn catch over a decade ending 1968. He has estimated the average annual landings of penaeids steadily increasing from 27,632 tonnes in 1959 to 68,102 tonnes in 1968, with few minor fluctuations, giving an overall average of 47,538 tonnes. He has also fitted the increasing trend to the quandratic equation by the method of least squares,

$$y = 29.6278 + 4.0913\ t - 0.0189\ t^2,$$

where, y is the annual production in thousand tonnes and t is the year, the base year 1959 being taken as, $t = 0$.

At this stage, Mohamed (1969) has opined that the exploitation is at a level, from where further increase may not be advisable. However, landings have steadily increased since then to manyfolds in several centres. At least, the catch in 1980 (1,12,037 t) for penaeids is more than double that of landed in 1960's, and no serious effects on fishery has been anywhere reported.

Splitting into species-wise, Banerji (1969) has also calculated at annual average of 16,072 tonnes of _M. dobsoni_, which forms 18.9% of total penaeids, topping all the species in abundance, during the periods. Hence, this species has slipped slightly down to second position of abundance in 1980, next to _P. stylifera_, though its catch has meantime increased to about 22,000 tonnes. This reversion appears to be attributed specific to enormous 'mud-bank' fishery of _P. stylifera_ off Quilon during the year, as can be noted from the very low percentage of _M. dobsoni_ at this centre during that period in spite of large quantity of annual landings. He has again estimated 14,559 tonnes of this species being landed in Kerala alone (90.5%) out of 16,072 tonnes for entire country. This position has indeed changed much in 1980 mainly owing to development of fishery outside the state, though Kerala still occupies a preeminent position in production of penaeid prawns in India. Substantial fishery has been later developed along Tamil Nadu and Andhra Pradesh coasts, in particular the improved activities in centres like, Cuddalore-Portonovo and Kakkinada, which are found to be fertile for this species.

The fishery aspects of *M. dobsoni* have hitherto been extansively studied only from the restricted regions around Cochin on the southwest coast, where the fishery is far more flourishing compared to other area. Earliest, Menon (1955, 1957), and later, George (1961, 1967), George *et al.* (1967) and Banerji and George (1967), and further, Kurup and Rao (1974) have all dealt on marine fishery of this species from Cochin waters and Subramanyam (1967) from Malabar coasts and Ramamoorthy *et al.* (1976) from Mangalore are the important works on the fishery of this species.

In early periods of exploitations with the introduction of mechanised fishings, the catch rates have been reported very high (Banerji and George, 1967), as compared to the present day fishery, of this species. They have worked out the catch trend for 5 fishing seasons from 1958-59 to 1962-63 and found the average rate varying between 13.27 kg/hr and 41.63 kg/hr. They have also noted the season generally extending from

September through June, with the highest abundance around April-May. Besides, George et al. (1967) have noted a set pattern within the season of fishery, according to which the fishery commences with small percentage early in the season and increases gradually to share well over 70% of the prawn catch towards the end, with one exception in 1960-61, when the fishery, unlike in other four years, has a dip in the middle of the season. Later, Kurup and Rao (1974) have reported similar seasonal abundance, but with reduced catch rates off Ambalaphuzha, near Cochin. They have estimated the catch rate ranging between 0.81 kg/hr and 15.2 kg/hr, with the highest concentrations around April-May and have also noted considerable landings in June-August, the peak southwest monsoon period, by artisanal fishery occasionally. Hence, all these early reports on seasonal abundance of this species for Cochin regions confer to the recent records in 1980, though a reduction in concentrations is apparent.

Earlier, Kuthalingam et al. (1966) have estimated a catch of 433.8 tonnes in 1962-63 and 345.7 tonnes in 1964-65 for M. dobsoni, which forms about 50% of the total prawns off Mangalore. The peak abundance is recorded in February-March during 1962-63 and May in

1964-65. But, Ramamoorthy et al. (1976) have analysed the trend in fishery of M. dobsoni off Mangalore during 1962-71 and recorded bimodal annual seasons in March-April and September-October.

The fishery seasons on either coasts appear to be generally antegonistic, though common on a few months. March-June records higher fishery in west coast, when it is dismal in east coast, and December is normally recorded with better fishery in both coasts. Being within tropical region,the temperature may not have much impact on the seasonal abundance and thus the another major ecological factor, monsoon rains, is possible to have larger influence on such temporal variations. The fishery season in west coast is generally a single protracted one, extending over the period omitting the peak monsoon months, June-September, and the east coast fishery, on the other hand, is in addition disrupted by peak summer months, April-May. Nature of nurseries, which eventually supports the fishery of the neighbouring coastal waters, vary considerably between the east and west coasts, in such ways that the former, with mostly shallow and seasonal estuaries, is likely to be largely influenced by warm summer temperature unlike the west coast, which is endowed with deep, extensive and perenniel backwaters. The pre-monsoon weather and ocean conditions prevailing in west coast may also be the major factor for disparity in summer fishery. A similar correlation between the wet periods and the production of prawns, in general, have been reported by Gunter and Edwards (1969) in Lousiana waters and between river discharges and prawn productions by Racek (1955) in Australian waters and that of lobster, another commercial crustacean, productions in Gulf of Lowrance by Sutcliffe (1972).

The seasonal abundance of fishery among the centres within the same coast varies considerably on several occasions and it may again be attributed to the effects of monsoon, which onsets and withdraws gradually through north-south axis. However, catch rate of 10.82 kg/hr and 5.73 kg/hr respectively in April and March at Cochin are in quite contrast to mere 0.63 kg/hr and 0.40 kg/hr correspondingly at the neighbouring Quilon, though they are closer by and linked with the net work of extensive nursery waters. Such disparity may be explained in the line of Ruello (1975), who reports that the swarms of penaeid stocks from nurseries would emigrate to mix up and move along the coastal waters. The moving populations thus may converge in some areas leaving other areas sparsely occupied within the region. Likewise, July-August in 1980 records relatively low fishery at Madras, when it is highest at Kakkinada, which are the two distant fishing centres on the east coast. The copious deltaic water flows and variation in monsoon effects may be the major reasons for these differences. Shoal formation and movements along the coast may also be considered for variations of fishery within the region. Coastal migration of this species is substantiated by mark recovery experiments, in which the animal has been recorded to have gone upto 60 km from the place of release in 10 days (Silas et al., 1981).

Metapenaeus dobsoni has also been reported as a dominant species in areas around south-east coast of India and adjascent Ceylon coast by several authors; Sudhakara Rao (1979) in Kakkinada waters, Rao and Dorairaj (1973) in Gulf of Mannar, Suseelan (1975) in Manakkudy areas near Cape Comerin and Sivalingam (1956) on the Ceylon coast; Evangeline et al. (1975) and Palaniappan et al. (1981) in Killai backwaters.

Chapter 6

Summary and Conclusion

Summary and Conclusion

Metapenaeus dobsoni Miers, a marine penaeid, is dioecious, the young living in brackishwaters and the adults in inshorewaters. The heterosexual genitalia, petasma in male and thelycum in female, are prominent in adults and they develop gradually through sequences of changes in shape and size from the rudimentary structures, which are visible earliest around 20 mm lengths. Formation of adult features of genitalia and the tilt in the slope of length/weight relationship indicate the onset of maturity around 50-55 mm size and this is substantiated by presence of spermatheca in the terminal ampules of vasdiferentia and on the thelycal pad, indicating mating, in some of the impounded adolescents measuring 60-65 mm size in estuary itself. However, completion of maturation needs sea life, as none of the impounded specimens are noted to carry developed ovary.

Females are heavier than males and older individuals are more plumper. The regression of their length/weight relationships are,

Male : $\log W = -2.6550 + 2.7067 \log L$

Female : $\log W = -2.6602 + 2.7341 \log L$

The variations of size-specific weight increase against length. 'Mature' females are the heaviest of all categories.

Sexual difference in size is obvious. The commercial catches of Madras are mostly contributed by the population of 6-12 month old, measuring about 75-100 mm length in male and 80-110 mm length in female and the monthly mean-size varies from 71.8-86.7 mm and 74.7-99.4 mm in respective sexes for 1981 and 1982. Females are estimated to grow faster and reach higher asymptote and their popular von Bertalanffy Growth Equations are,

$$\text{Male} : L_t = 112.93 \, [1 - e^{-0.1832 \, (t + 0.1181)}]$$

$$\text{Female}: L_t = 129.20 \, [1 - e^{-0.1601 \, (t + 0.6206)}]$$

It is computed from the formula that the female reaches 109.8 mm and 126.2 mm lengths and male 100.6 mm and 111.5 mm sizes respectively in 12 and 24 months.

The gross anatomy of the gonad shows that the adult has a pair of ovaries, which are partly fused and bilaterally symmetrical. The genital openings of vasdiferentia and oviduct open respectively at the coxa of 5th and 3rd peréopods. Based on the sequences of changes in size, colour, texture and supported by histological modifications of ovary, the females are classified into 5 maturity classes viz., 'immature', 'early-mature', 'late-mature', 'mature' and 'spent'. Larger the size, greener the colour and more grannular the texture of the ovary are the advanced stages of maturity. Fat accumulation in developing eggs intensifies from 'late-mature' stage onwards.

Size-distribution of maturity stages shows slight preponderance of 'mature' females, indicating the animal remaining relatively longer duration at this stage. The mean-size of the females increases positively with maturation. Most of the 'immature' females belong to 61-75 mm and females over 105 mm length are predominently 'spent', indicating slow rematuration in older individuals. On the otherhand, scarcity of young females in 'spent' conditions support that they remature sooner they spawned.

Body burden of trace metals, viz., copper, zinc, nickel, lead and cadmium, presents a positive relationship between copper and zinc against maturation of eggs in the ovary and other metals reveal erratic variations. Copper gradually increases from 52.75 µg/gm dry wt in 'immature' to 73.50 µg/gm dry wt in 'mature' females and similarly, zinc increases from 32.5 to 66.25 ug/gm dry wt correspondingly. The values of 'immature', 'spent' and male are more comparable. Range of other metals are, lead, 5.55-13.28; nickel, 4.85-19.35; and cadmium, 0.55-0.73 µg/gm dry wt. It can be inferred from early knowledges that extension of inter-moult period and enhanced enzymic activities for copper and intensive protein synthesis for zinc are the probable reasons for increase of these metals during maturation processes.

Minimum size at maturity, as estimated by regression calculation of percentage mature female against size, is 60.3 mm and the 50% maturity is at 69.4 mm. About 70% of the females mature at 65-75 mm and females over 90 mm size are all noted to be matured. The tendency of individuals maturing relatively at shorter lengths during warmer seasons is also apparent.

Fresh broods, which enter the fishery from the nursery, need about a month before participating in active spawning and rematuration requires about 20-40 days. Though spawners occur at all depths, largest number of them are concentrated around 15 M depths. Mean-size of the spawners increase~~s~~ positively against depth and most of the females occurring $\geq$20 M depths are either 'mature' or 'spent'. Two broods are not necessarily coinciding active spawning at an area and space utilization by different broods ~~are~~ is also apparent. Most of the older spawners, which move to deeperwaters, remain there until death.

Repeated spawning of a single brood is noted within the same or successive breeding seasons and few broods are traced to spawn upto 5 times lasting about 7-8 months. Spawning takes place at all seasons, with two annual peaks obviously in January-March and July-September. Hence, severe environmental conditions during the peak north-east monsoon and mid-summer are avoided for hectic spawning activities. Fecundity varies between 27,600 and 1,34,000 eggs for the females measuring 68-112 mm length, revealing a positive relationship against size. Females of 80-90 mm size are the most productive of eggs for per unit body volume and the variations of egg numbers specific to size increase with length. Spawners in the later part of the season are less productive, which may be attributed to repeated spawning.

Monthly sex-ratio fluctuates in catches, often in favour of females. The mean male ratio ranges from 13% to 60%, with an average of 41% for different months in 1981 and 1982. Sex-ratio specific to size shows that males out-number females slightly upto 80 mm length and decline drastically above 85 mm size. Males are rare beyond 110 mm length though females occur upto 125 mm size in catches. Females move discriminatively towards deeper waters, as evident from their ratio: 54.5% in ≤10 M; 72.0% in 15 M; and 98.2% in ≥20 M depths. The overall minority of males in population and wide disparity among the older specimens may be due to differential mortality among the sexes, males having shorter life-span.

Gravid females collected from sea spawn successfully under laboratory conditions, with 32-35%. salinity and 25-28°C temperature. Spawning occurs invariably at night and rematuration is evident. Eggs metamorphose through post-larvae, fed with cultured diatom and rotifers respectively at protozoeaic and mysid stages. The larval-history comprises 6 nauplius, 3 protozoea and 3 mysid sub-stages lasting about 12-18 days under conditions, 25-31°C temperature and 32-34%. salinity. The chronology and the general pattern of the larval development do not vary much from the previous studies. Protozoeaic stages appear to be the most critical of survival and also the take off stages for differential acceleration of growth among individual larvae.

The growth pattern of the juvenile prawns, which form the crops in culture operation, is sigmoidal, suitable to be fit to von Bertalanffy Growth Equation with the asymptote estimated at 70.12 mm size, if it were continued life in estuarine conditions (15-25‰ salinity and 22-32°C temperature). The normal size of emigration in nature which is also the size at harvest in culture operations (60-65 mm size) is attained in 4.5-5.0 months of life. Hence, excluding pre-stock life, the farming durations may be required to last 3.5-4.0 months. The growth-rate against length is unimodal and the maximum monthly growth-rate of 22.8 mm/month, is estimated for the second month and it gradually reduces to less than 2.5 mm/month when the animal grows over 60 mm length.

Growth is manifested by moulting and the growth-rate is the product of moult-interval and moult-increase. Moult-interval increases logrithmically against size, whereas, moult-increase does not significantly change with size. Hence, the moult-interval, which is 3.5 days at 15 mm size, increases to 7.5 days at 50 mm length, but the moult-increase, which is 22.07% upon pre-moult size at 10 mm length decreases logrithmically to 4.48% at 50 mm size.

Size heirarchy develops among the siblings of the same spawn. Growth rates differ between individuals and thus, two groups, a 'fast' growing and 'slow' growing, have been traced for their growth characteristics. The 'fast' group attains the asymptote of 75.80 mm in 9.64 months compared to 65.20 mm in 9.5 months by 'slow' group. Most of the advantages of growth by the 'fast' group is attained during the first two months. The optimum harvest size in culture (62 mm) is reached in 4.0 months by 'fast' group compared to 6.5 months in 'slow' group. Hence, an advantage of 2.5 months is highly appreciable in culture operations. Also, the highest growth-rate of 0.83 mm/day is recorded at 28.5 mm size in 'fast' group, whereas, it is 0.70 mm/day at 22.5 mm size in 'slow' group, hence the advantage of growth-rate is carried over till larger size-range in 'fast' group.

Even few days of starvation affects obviously growth in post-larvae and juveniles. Deprival of food during inter-moult period delays moult and depresses moult-increase. However, re-feeding resumes normal moult-increase immediately from the next moult, but recovery to normal moult-interval is gradual through a few moults. Long-term starvation leads to stunted growth in young prawns and the growth lost is not regained on rehabilitation. Growth in stunted animals appears to be arrested at pre-moult stages and the size specificity of growth-rate in stunted animals on rehabilitation is lost and becomes age-specific. Hence, a stunted animal grows at a rate, which would be otherwise normally the rate of larger or older animals. -Hence, a bad start in growth leads to a permanent imprint in the growth characteristics of the individuals.

Salinity per se in a broad range does not show much difference in growth influence on young prawns. However, the optimum conditions appear to be 17-23‰ salinities, higher range of which are relatively more suitable for growth than lower ranges.

Temperature appears a more sensitive factor influencing juvenile growth. A mean temperature of 26-28°C with the range of 22-34°C ~~are~~ is the most favourable for growth. Within this optimum range, even the slight variation of 2-3°C seems to promote more than 10% of the growth. Normal habits, which influence growth, are disrupted beyond 18-34°C temperatures and become more critical around 15°C and 35°C. And the temperatures below 10°C and over 37°C are fatal, the former being quicker.

Substrate favours growth. An advantage of 14% in growth for the larvae growing from 26.0 mm to 39.75 mm size kept in 5‰ salinity under 22-32°C temperature with substratum is estimated upon the larvae provided no substratum.

Sexual difference in growth is evident from 2.5 months of life onwards and the disparity increases gradually with size and the difference is 5 mm at 50-55 mm length.

Hormones control on growth is evident from eye-stalk ablation experiments. Bilateral eyestalk-ablations are fatal or the larvae could not live beyond one moult. Unilateral eyestalk-ablation favours as much as 30% of growth in juveniles growing from 35 mm through 45 mm involving 4 moults, of which first moult has negative effect. Better growth is due to rapid frequency of moulting and the size increase at moulting is not significantly varying between the ablated and control animals.

Activeness of the post-larvae and juveniles, as measured from burrowing and free-movement, is normally related to the amount of light they are exposed. A diel rhythm, burrowing at day and free-movement at night, is obvious, the sun-rise and sun-set being the changing phase with the margin of about 5-15 minutes on a clear day. However, this rhythm is interfered by certain other factors than light. Cloudiness, widely fluctuating temperature beyond 15-32°C and salinity beyond 10-30‰ and availability of food are the some of the factors altering burrowing habits. Smaller animals are less sensitive to light, but more sensitive to feed and early to deburrow under disruptive conditions. Orientation of burrowing animals pose a positive rheotoxis against water current and stressed animals loss their grip to the substratum and are found drifted along with the currents.

<u>Metapenaeus</u> <u>dobsoni</u> forms an integral part of prawn fishery off Madras. The protracted annual season in fishery commences from September till March, with

slight dip in catches during December-January. Hence, the fishery coincide~~s~~ with the wet to most wet seasons of the year and, in particular, the mid-summer conditions are excluded. Increased rainfall is followed by enhanced fishery with a gap of few months. The two annual breeding seasons correspond the fishery waves with the interval of about 5-6 months. Salinity and temperature do not significantly vary off Madras to influence much on fishery, though 32-33%. salinity and 29-30°C prevail during better fishery.

An intrinsic limit of distribution of this species is noted and specimens are rarely collected beyond 30 M depths. A negative relationship is obvious between the catch and depth within the limit, 8-35 M depths. The mean catch forms 67.7% at ≤10 M, 28.3% at 15 M and 4.0% at ≥20 M depths. Bathymetric distribution of the population is also the function of physiological status of the animals. Larger and mature animals move deepwards. However, 'mud-bank' fishery and huge purseseine catches indicate sporadic and erratic congregations of mixed populations under turbulant monsoon conditions.

The juvenile fishery of this species for the seasonal Adyar Estuary at Madras was studied for one full season, which extended from September, 1982 to May,

1983. The catch of M. dobsoni amounts to nearly 2.0 tonnes, sharing 36.5% of the total prawns for this season. The actual fishery commences from December and culminates in February before gradually declining till the bar-mouth closure in early June. Availability of enough quality prawn seeds, presence of shallow mud-flats and financial resources around the neighbouring city and the possibility of converting the otherwise polluted urban sewage into productive prawn feeds favour this Adyar Estuary as a potential centre for prawn farming.

The fishery of this species is restricted to the middle latitudes, between Goa and Quilon on the west coast and Kakinada and Cauvery base on the east coast of India, though its distribution is extended upto Bombay and Puri of respective coasts in the north and to the southern tip of this country. Metapenaeus dobsoni, which ranked first in 1969 forming 18.9% of the total penaeids in India, slips later to second position next to Parapenaeopsis stylifera in 1978 and 1980, though the catch has substantially increased. This species is estimated to contribute 12.2% of 1,79,856 tonnes in 1978 and 11.1% of 1,70,737 tonnes in 1980. The west coast is more productive, with the highest catch-rate of 7.69 kg/hr at Cochin, than the east coast, where the maximum catch is 1.38 kg/hr off Madras.during 1980. The fishery seasons at either coasts appear to be antagonistic, largely influenced by southwest monsoon and the contrasting oceanic and nursery conditions during summer. The pre-monsoon conditions and the deep and extensive backwaters in west coast are more productive during summer, May, compared to those dry and mostly closed up nurseries of east coast during the season. Catch-rates of neighbouring centres sometimes vary widely, indirectly indicating coastal movements of stocks.

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*Originals not seen.