STUDIES ON THE COMMON PENAEID PRAWNS OF THE KERALA COAST

By

V.J. KUTTYAMMA, M.Sc.

THESIS

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CERTIFICATE

This is to certify that this thesis is an authentic record of the work carried out by Mrs. V.J.Kuttyamma, M.Sc., under my supervision in the University Department of Marine Sciences and that no part thereof has been presented before for any other degree in any University.

Dr.C.V.KURIAN
Supervising Teacher

Ernakulam,
Oct. 30,'7[illegible]

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CONTENTS

INTRODUCTION

Prawns form a major constituent of the marine fish landings in India. The prawn industry in the country maintained the age old pattern till the beginning of the fifties of this century, supporting an export trade of dried and semi-dried prawns, worth a few million rupees at the most. However, rapid and phenomenal transformation has taken place within the last two decades, raising it to the status of an organised industry of considerable importance. All other fisheries are relegated to the background and a very modern, sophisticated industry of frozen and canned prawns has sprung up with an export record of over 1500 million rupees by 1977. These substantial changes have raised India to the status of one of the foremost prawn exporting countries of the world.

About 80% of the marine prawn catches come from the West Coast of India, while the rest from the East Coast. Along the West Coast, catches are higher in the northern sector, but the southern sector supports the fishery for the larger species resulting in a concentration of prawn processing industry in this area.

Studies on the marine prawns of the Indian Ocean date back to the end of the 19th century with the work of Bate (1888) who reported on the scientific results of the voyage of H.M.S. Challenger during the years 1873-1876. The first notable report on the penaeid prawns, inhabiting the Indian seas was by Alcock (1906). Later deMan (1911) in the Siboga Expedition Reports added some more species to the list. Apart from these, the earlier works which give some general information on the taxonomy, life history and distribution of the decapod crustaceans of the Indian coasts are those of Wood-Mason (1891), Handerson (1893), Handerson & Matthai (1910), Kemp (1913, 1915) and Sewell (1934). Later, remarkable contributions on the life cycle and distribution of the commercially important prawns in the Indian waters were given by Chopra (1939, 1943), Nataraj (1942), Chacko (1955) and Subramanyam (1968). The notable works on the life history, systematics, biology, distribution and fishery of prawns of the South West Coast of India especially of the Kerala coast include those of Menon (1933, 1937, 1951, 1952, 1954, 1955), Panikkar (1937), Panikkar and Menon (1956), Kurian (1954, 1965), George (1958, 1959, 1961, 1962, 1967, 1969), George et al (1968a, 1968b), Mohammed et al (1967), Mohammed and Rao (1971), Rao (1972), Kuttyamma (1974, 1975), Kuttyamma and Kurian (1976) Kurian and Sebastian (1976). Other scientific papers dealing with the different aspects of the bionomics and fisheries include those presented at the Prawn Symposia held in Tokyo (1955) and Mexico (1967) and in the Crustacean Symposium held in India (1965).

The commercial prawns of India belong to three major families, namely, Penaeidae, Palaemonidae and Sergestidae of the Decapod suborder Natantia. A few deep water forms belonging to the family Pandalidae are also gaining commercial importance as a result of the recent exploratory fishing activities. The genus Penaeus has a world wide distribution and the various species belonging to it are found in both tropical and temperate latitudes. Practically all of them are marine although some are known to spend a part of their life in brackish water. Of the 28 valid species of the genus Penaeus, only eight are represented in the Indian waters. They are Penaeus japonicus Bate, P. latisulcatus Kishinouye, P. indicus H. Milne Edwards, P. canaliculatus Olivier, P. monodon Fabricius, P. semisulcatus deHaan, P. merguiensis deMan and P. penicillatus Alcock. Most of the species belonging to this genus grow to large sizes and they support commercial fisheries in many parts of the world, accounting for over 50% of the total world production of prawns. All the eight species recorded from India are listed (Holthuis and Rosa 1965) as prawns of economic value, although some of them do not occur in commercial quantities. Species belonging to the genus *Metapenaeus* are distributed throughout the Indo-pacific region. 24 known species of *Metapenaeus* have been listed by Racek and Dall (1965) and George (1969). Out of these, 10 species have been recorded from the Indian waters. They are *Metapenaeus dobsoni* (Miers), *M. monoceros* (Fabricius), *M. affinis* (H. Milne-Edwards), *M. brevicornis* (H. Milne-Edwards), *M. ensis* (de Haan), *M. lysianassa* (de Man), *M. burkenroadi* Kubo, *M. stebbingi* (Nobili), *M. kutchensis* George and Rao and *M. alcocki* George and Rao.

Although the past two decades have proved to be a relatively ennobling period in the modern history of marine prawns, a review on the available literature (Menon 1955, Menon and Raman 1962, George 1961, 1962, 1967, Mohammed 1967, Mohammed and Rao 1971, Kuttyamma 1974, 1975, Kuttyamma and Antony (1975), Kuttyamma and Kurian 1976, Subramanyam 1964 and Subramanyam and Ganapati 1971) shows that these works come mainly from a very few restricted areas like Cochin waters and Godavary estuaries. Hence it would not be extravagant to assume that a significant portion yet remains in the dark and needs to be explored. Again our knowledge about many aspects of their biology and physiology is meagre.

In recent years increasing attention has been focussed on an approach which is based on the concept that a knowledge of the behaviour and functions of an organism in relation to the habitat is essential for developing methods and devices for increasing their production. A comprehensive knowledge of the habits and relationships to environmental factors of these animals is of decisive importance for devicing measures for getting the maximum catch. Even though the importance of the study of the nature of physiological adaptations and variations in animal populations has been stressed by many authors like Bullock (1955) and Prosser (1955, 1958), such works on the prawns are very scarce. Some of the few physiological studies on the penaeid prawns of India are those of Rao (1958), Subramanyam (1962), Kutty (1967), Kutty *et al* (1971) and Sreekumaran Nair and Krishnankutty (1975). Zein-Eldin (1963), Zein-Eldin and Aldrich (1965) and Zein-Eldin and Griffith (1966, 1967) have observed in the laboratory the effect of salinity and temperature on the growth of post larval *Penaeus aztecus* taken from Mexican waters. However the prawns and prawn larvae in the Cochin backwaters have received considerable attention in recent years (George 1962; George *et al*

1968b, Mohammed and Rao 1971, Rao 1972, Kuttyamma 1975, Kuttyamma and Kurian 1976). But very little is known about the tolerance of the penaeid prawns in Indian waters under varying environmental conditions. Except for a note on the effect of salinity on the growth of juvenile *Penaeus indicus* by Sreekumaran Nair and Krishnankutty (1975) there seems to be no work on this aspect. Further the oxygen consumption of *Metapenaeus dobsoni* which is a major constituent of the prawn fishery of this region has not been studied so far. The present work comprises studies on the occurrence and abundance of penaeid prawns in two major estuaries in Kerala- the Kayamkulam Lake and Cochin backwaters; the salinity and temperature tolerance, the effect of salinity on the growth of three commercially important prawns of Kerala namely *Penaeus indicus*, *Metapenaeus dobsoni* and *M. monoceros* and the respiratory metabolism of *Metapenaeus dobsoni*.

The thesis is presented in three parts:

PART I PRAWNS & PRAWN FISHERIES

PART II TOLERANCE OF PRAWNS TO SALINITY AND TEMPERATURE AND THE EFFECT OF SALINITY ON GROWTH

PART III OXYGEN CONSUMPTION OF *M. DOBSONI*

Part I gives a description of three important penaeid prawn species, a general account and an integrated picture of their occurrence and abundance in the Kayamkulam and Cochin estuaries. Part II deals with the salinity tolerance, its effect on growth and the temperature tolerance of both post larval and juveniles of *Penaeus indicus*, *Metapenaeus dobsoni* and *M. monoceros* in the laboratory conditions. Part III describes in detail the oxygen consumption of *Metapenaeus dobsoni* in varying salinity and different partial pressure of oxygen as observed in laboratory experiments.

PART I

PRAWNS AND PRAWN FISHERIES

(i) Physiography of the Vembanad and Kayamkulam lakes

Kerala has a coastline extending to about 560 km (Fig.1). The backwaters of Kerala consist of a chain of lagoons and estuaries extending over 325 km in length which serve as nurseries for the post larvae and juveniles of most of the commercially important penaeid prawns. The Vembanad and Kayamkulam are two major backwaters in Kerala.

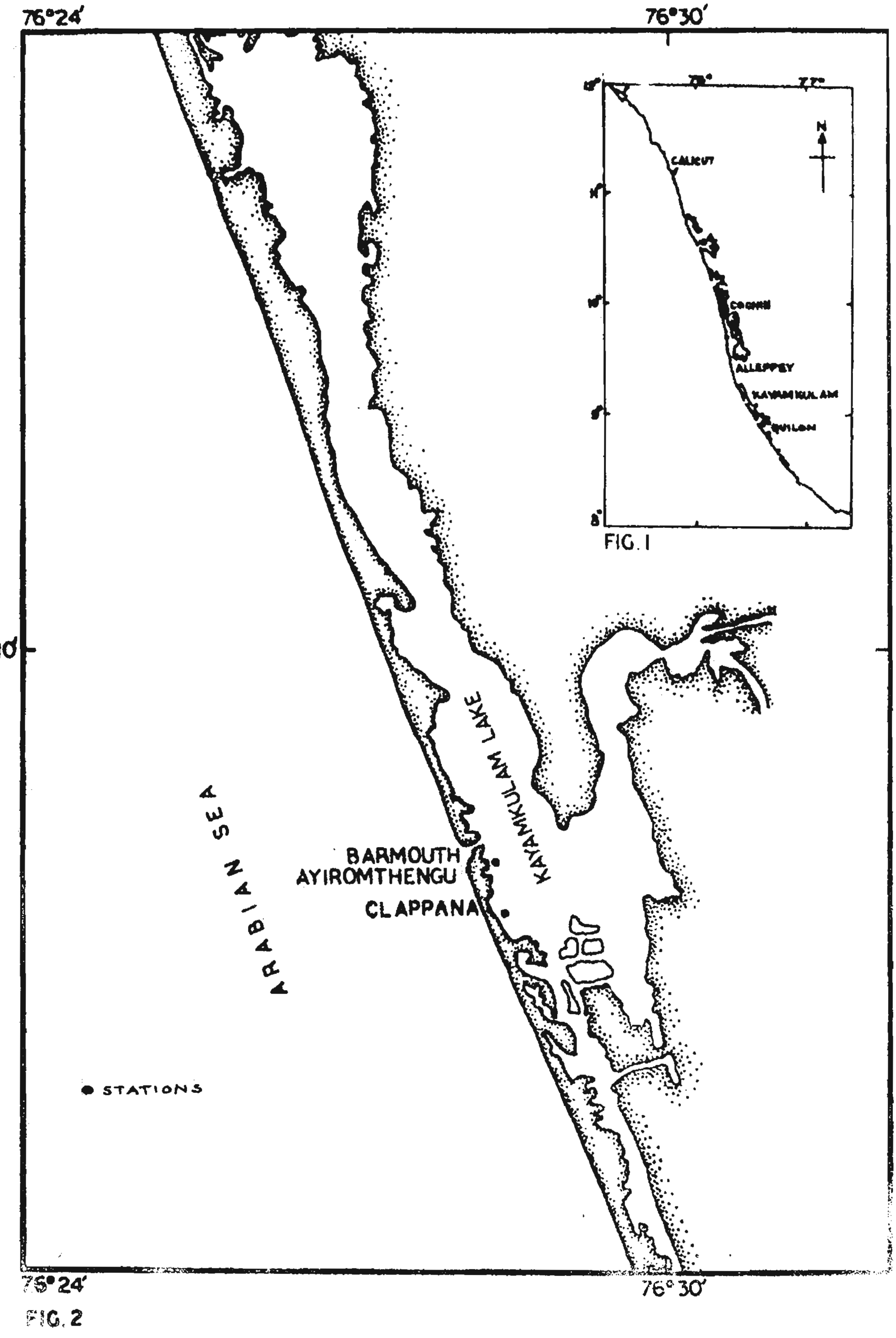
These backwaters are fed by rivers and canals and their hydrological conditions are largely controlled by the volume of fresh water discharged into them during the monsoon and the influence of tidal movements. In this respect the Kayamkulam lake and the Cochin backwaters at the northern end of the Vembanad lake can be considered as estuaries. But the Kayamkulam lake differs from Cochin backwaters in being cut off from the sea every year for a brief period of about three months from April to June. Description of the two study areas and stations are given separately.

KAYAMKULAM LAKE

The Kayamkulam lake is a narrow stretch of backwater lying between 9°2' and 9°16' N. latitudes and 76°26' and 76°32'E longitudes (Fig.2). It runs almost parallel

Fig. 1. Map of the Kerala Coast showing the Kayamkulam Lake and the Cochin backwaters.

Fig. 2. Map of the Kayamkulam Lake showing locations of the stations investigated.



76°24′
76°30′
CALICUT
COCHIN
ALLEPPEY
KAYAMKULAM
QUILON
N
FIG. I
9°10′
KAYAMKULAM LAKE
ARABIAN SEA
BARMOUTH
AYIROMTHENGU
CLAPPANA
● STATIONS
76°24′
76°30′

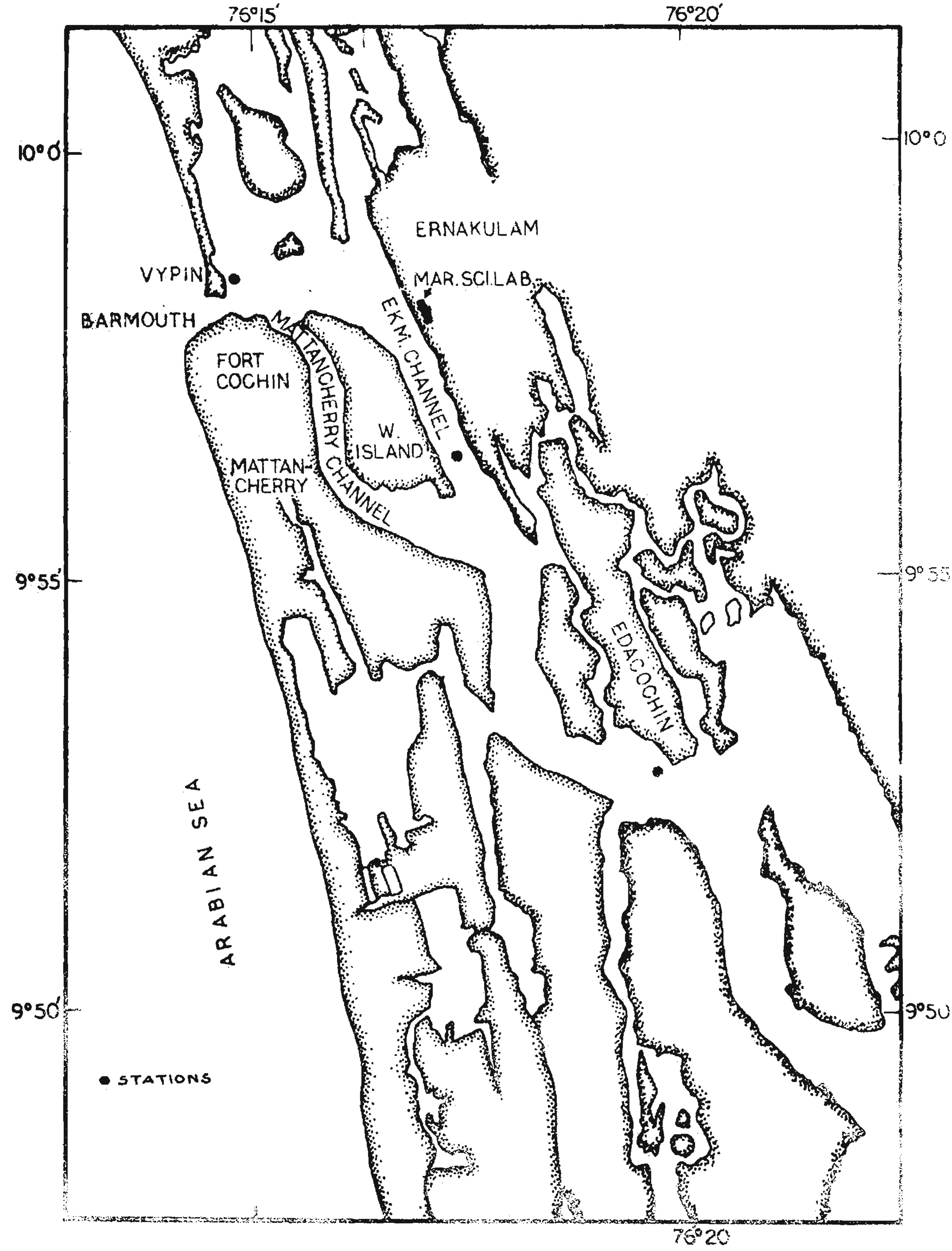
FIG. 2

to the coast. The sandy bar of the Kayamkulam estuary is situated almost midway between the northern and southern ends. In front of the barmouth the estuary is 2.74 km wide. From the barmouth the width decreases both towards the north and south. The southern half of the estuary is very narrow, the average width not exceeding 0.4 km. From the region opposite the barmouth an arm of the estuary extends to the Kayamkulam town in the north easterly direction. The estuary is supplied from the north by three canals, which discharge part of the flood water from the Pampa and Achankoil rivers into the estuary during the monsoon period. In the South, the estuary merges with 'Vattakayal' which forms a sort of reservoir for the flood waters brought down from the adjoining lands and canals during the monsoon. Two canals, one from the Achankoil river and another from the paddy fields open into the north-eastern arm of the estuary. The barmouth closes some time between March and April and from this time onwards the water in the estuary is almost stagnant till the middle of June when the flood water accumulates and the bar is cut open to allow the egress of flood water into the sea. The bottom sediment in the Kayamkulam estuary is composed of soft mud with shell fragments and pieces of decaying material predominantly of vegetable origin.

COCHIN BACKWATERS

The Cochin backwater is the northern part of the Vembanad Lake (Fig.3). The Vembanad Lake which is the biggest and most extensive one in Kerala is situated between 9°28' and 10°10'N and longitudes 76°13' and 76°31E. Its length is about 115 km and breadth upto 15 km. Near the northern end of this lake is situated the port of Cochin where the lake is permanently connected to the sea by a narrow channel. Two large rivers, the Periyar on the north and the Pampa on the south, flow into the Vembanad Lake. Fringed by the mainland and many thickly populated islands, the backwater also receives a complex system of canals, rain water and sewage drains, semi-perennial and seasonal rivers and their tributaries. The inflow of fresh water from several sources particularly during the monsoon months, is considerable and in the backwaters the mixing of salt and fesh water occurs. The continual discharge of fresh water on the one hand and the inward influx of sea water on the other, bring out highly dynamic conditions.

Fig. 3. Map of the Cochin backwaters showing locations of stations investigated.



76°15'
76°20'
10°0'
10°0
9°55'
9°55
9°50'
9°50
76°20
ERNAKULAM
VYPIN
MAR. SCI. LAB.
BARMOUTH
FORT COCHIN
MATTANCHERRY CHANNEL
EKM. CHANNEL
W. ISLAND
MATTAN-CHERRY
EDACOCHIN
ARABIAN SEA
• STATIONS

(ii) Materials and Methods

The materials for the larval studies were collected from Ayiramthengue 1 km south of barmouth in the Kayamkulam lake and from Ernakulam channel in front of the Marine Science Laboratory, 1 km south of barmouth in the Cochin backwaters. The collections from the two estuaries were taken during the same period ie. from June 1976 to May 1977. The plankton samples were collected twice a month regularly using a 50 cm diameter organdy net having a mesh size of 0.33 mm from a country boat which had a speed of 1½ knots/hr. The duration of the haul was 15 minutes and each time two such hauls were made. Collections were taken during day time as well as at night. The temperature and salinity at the stations were also recorded at the time of collection. Occasional samples of prawn larvae were taken from other places also for getting additional information. The plankton collected was immediately preserved in 5% formalin. In the laboratory, the larvae and post-larvae were sorted out for quantitative studies. The total number of larvae taken during the month were combined and averaged for each haul.

The material for the study of juveniles was drawn from the commercial catches from the Kayamkulam lake and Cochin backwaters twice a month from June 1976 to May 1977. Additional information was also collected from occasional sampling during the above period. Three fishing areas in the Cochin backwaters and two areas in the Kayamkulam lake were selected to collect samples from the three types of nets most commonly used in these areas. Random samples were taken from cast net, stake net and chinese dip nets from Ayiromthengu and Clappana in the Kayamkulam lake and from Edacochin, Thevara and Vypin in the Cochin backwaters. Data on catch, effort and other particulars were collected from the fishermen in each fishing unit. Preserved prawn samples were brought to the laboratory for recording the species composition and other biological data. Pooled monthly data of every station from each type of net from the two estuaries were taken for occurrence studies. The total length of the prawns were measured in millimetres from the tip of the rostum to the tip of the telson.

(iii) A brief history of the Biology and Fishery of *Penaeus indicus*, *Metapenaeus dobsoni* and *Metapenaeus monoceros*

Description of species

The three most important species of economic importance which constitute the major portion of the prawn catches in Kerala are *Penaeus indicus*, *Metapenaeus dobsoni* and *M. monoceros*. The present study is mainly based on these three species and the description of only these three species are given below. The local names used for these penaeid prawns are 'Naaran' for *P. indicus*, 'Thelly' and 'Poovalan' respectively for juveniles and adults of *M. dobsoni* and 'Choodan' for *M. monoceros*.

Phylum	.. Arthropoda
Class	.. Crustacea
Sub-class	.. Malacostraca
Super order	.. Eucarida
Order	.. Decapoda
Sub-order	.. Natantia
Section	.. Penaeidea
Family	.. Penaeidae
Sub-family	.. Penaeinae
Genus	.. *Penaeus* Fabricius

Penaeus indicus **H. Milne Edwards, (Fig.4)**

Diagnostic features: Rostrum toothed dorsally and ventrally. Rostrum slender, long with distinct double curve, 1½ to twice the length of carapace in the juvenile stages, often with 7-9 dorsal and 4-5 ventral teeth. Sub-hepatic ridge absent. Abdominal segments 4th and 5th keeled, keel on 6th segment ending acutely. Telson grooved, without lateral spines. Third maxilliped reaches to the 2nd segment of the antennular peduncle. Exopodite on the 5th pereiopod small, but well developed. Median lobe of petasma (Fig. 4a) rounded at the tip, projecting forward to the apex of the lateral lobe which is covered with sparsely set fine setae on the outer surface. Terminal portion of distal margin serrated with 12 well calcified teeth. Anterior median process of thelycum (Fig.4b) roughly semi-circular and relatively small, situated on sternite between the 4th pereiopods, minute apical spines present on the anterior margin of this process. Two large lateral plates housing seminal receptacles occupy most of last thoracic sternite. Lateral plates meet each other in median line where edges of plates are upcurved to form appearance of a valve.

Fig. 4. _Penaeus indicus_ H. Milne Edwards. Lateral view

4a Petasma; 4b. Thelycum

Fig. 5. _Metapenaeus dobsoni_ (Miers) Lateral view

5a Petasma; 5b. Thelycum

Fig. 6. _Metapenaeus monoceros_ (Fabricius) Lateral view

6a Petasma; 6b. Thelycum

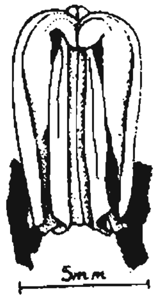


FIG. 4a

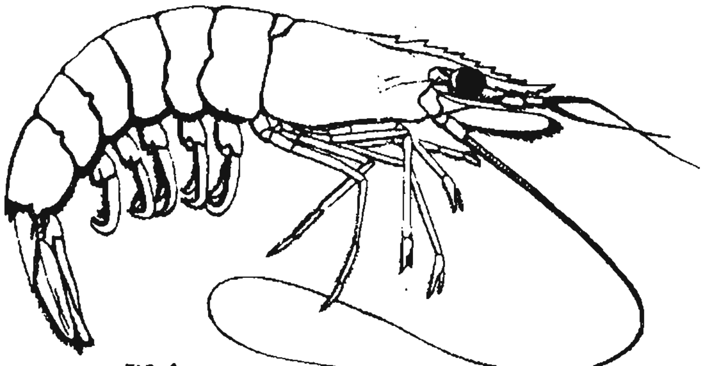


FIG. 4

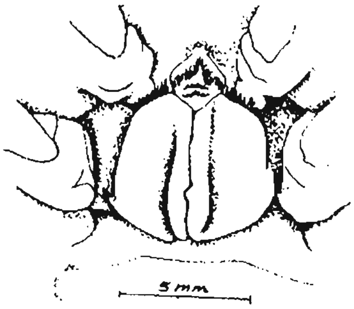


FIG. 4b

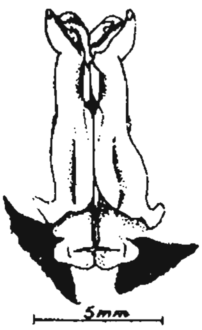


FIG. 5a

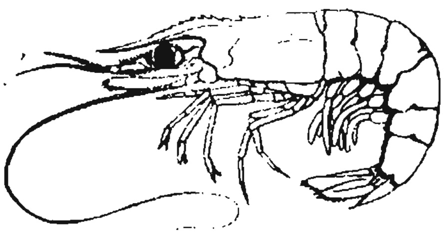


FIG. 5

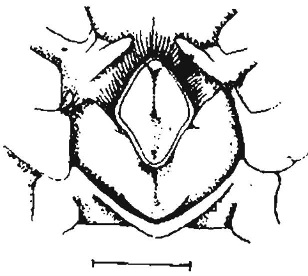


FIG. 5b

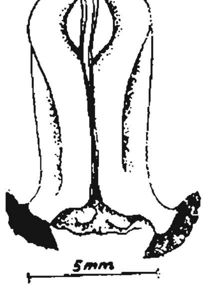


FIG. 6a

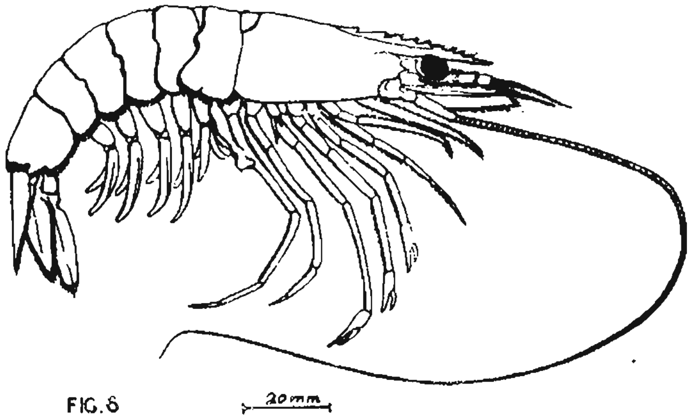


FIG. 6

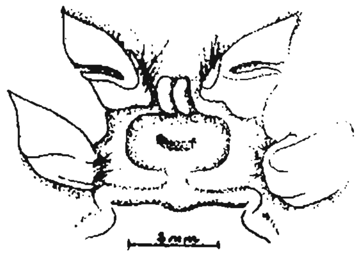


FIG. 6b

Genus - Metapenaeus Wood-Mason and Alcock

Metapenaeus dobsoni (Miers) (Fig.5)

Rostrum dorsally toothed only. Body tomentose, rostorum extending a little beyond the tip of the antennular peduncle with 8 or 9 dorsal teeth and having a well marked double curve. The antennular spine is not very strong and not continued backward as a strong ridge. The 5th abdominal somite about 2/3 length of the 6th, which is a little shorter than telson. The inner antennular flagellum longer than the outer, exceeding its peduncle in length. All the legs short, the chaelae weak. Strong spines present on the bases of all three pairs of chelipeds. The last pair of thoracic legs do not reach the middle of the antennal scale. In the adult female the last pair of thoracic legs is generally represented by a coxa to which is articulated a horny stump. No exopod on the 5th pair of legs. The petasma (Fig.5a) is quite symmetrical, and in the adults it consists of 2 rigid segments tightly folded throughout their length, interlocked all along their anterior margin, and in close opposition along a great part of their posterior margin so as to form a compressed tube. Distally the tube ends in a pair of simple distomedian spouts, and where the spouts originate there are four papillae or short filaments, 2 anterior and 2 posterior. The thelycum (Fig.5b) consists of a broad concave median tongue ensheathed posteriorly in a horse-shoe shaped process formed by the union of the larval lobes of the organ itself.

Metapenaeus monoceros (Fabricius) (Fig.6)

Rostrum with dorsal teeth only. Body covered with stiff, very short tomentum. Rostrum nearly straight, uptilted, reaching nearly to or a little beyond the tip of antennular peduncle, armed dorsally with 9-12 teeth. Post rostral crest continued to, or almost to, posterior border of carpace. Very small post-orbital tooth. Gastric region defined anteriorly by short oblique post-orbital groove. 5th abdominal somite about 2/3 length of 6th, 6th a little shorter than telson. Outer antennular flagellum slightly longer than inner, not much more than half the length of peduncle. When extended the dactylus of the last pair of thoracic appendage, reaches a little beyond the middle of antennal scale. No exopod on the 5th pair of legs. Petasma (Fig.6a) symmetrical, consists of 2 rigid segments, tightly folded longitudinally, interlocked all along the anterior margin so as to form a compressed tube; tube ends distally in a pair of large gargoyles with posterior lips convoluted. The thelycum (Fig.6b) concave, bounded laterally by pair of ear-like lobes with free edge incurved, bounded anteriorly by median projecting tongue embedded between 2 lobes of sternum corresponding with penultimate pair of legs.

Distribution

Penaeus indicus is fairly widely distributed in the Indo-Pacific regions, ranging from the coasts of India and Ceylon to the West through Gulf of Aden to the east coast of Africa and Madagascar, to the east to Andamans, Malaya, Singapore and Indonesia. It is a commercially important species in India, Ceylon, Malaya, Singapore, Mosambique and Madagascar. It is reported to be enjoying a scattered distribution in Australia, New Guinea and Philippines and found rarely in waters east and south east of Borneo.

In India this species supports commercial fisheries in both the marine and estuarine environments on the east and west coasts. De Bruin (1965) stated that they prefer sandy bottom and shallow waters of the sea within 3.7 to 11m. On the coasts of India the adults form part of the prawn fishery within 45 m depth in the sea. In Madagascar and other parts of East Africa fishable concentrations of adults are rarely found at depths greater than 10m (Crosnier, 1965).

Metapenaeus dobsoni is distributed in waters of India, Malaysia and Indonesia to Philippines. It is found in brackish water as well as marine environments.

In India the species is present in the juvenile stages in most of the estuaries and backwaters along the coast line and the adults in inshore areas upto 40m depth with muddy bottom. It is more common along the South West Coast of India, where it contributes to a major fishery.

Metapenaeus monoceros is distributed in South Africa, Mediterranean and Indian seas to Malaysia with the eastern limit as Malaca straight. Juveniles are found in estuaries and adults occur in the sea, usually in shallow waters, but to a depth of 50 to 60 m on the Cochin Coast of India (George *et al*, 1968b) and to 70m off Durban,South Africa (Joubert, 1965). Both juveniles and adults are usually found on substrates of mud, silt or muddy sand.

Life history

The life history of the above mentioned three species is completed in two environments. They are the marine environment and the brackish water environment. The breeding and the larval development take place in the sea and recruitment into the backwaters commences at the mysis or early post larval stages. There they feed and grow for about an year and then return to the sea for spawning. Different stages of larvae are also obtained in the lake collections during high tide.

Breeding

Penaeus indicus, Metapenaeus dobsoni and M. monoceros are heterosexual. Sexes can be distinguished by external characters such as the presence of sex organs, petasma and appendix musculine in male and thelycum in female. In the case of P. indicus Menon (1951) reported the size of mature individuals as 150 mm and over. Rao (1968) gives the minimum size at maturity for M. dobsoni as 64 mm in total length. The size at maturity for M. monoceros as cited by George (1963) is before attaining a length of 120 mm. All these species are promiscuous. During mating the sperm packs known as spermatheca are deposited by the male in the external genitalia of the female. The female carries the spermathoca and the sperms are dispersed at the time of spawning. Fertilisation is external. When the eggs are extruded from the genital opening of the female the sperms are dispersed from the spermathoca. Rao (1968) has estimated the fecundity of P. indicus as 68,000 in a female of 140 mm total length and that of M. dobsoni ranging between 34,500 and 159, 000 eggs.

Based on the occurrense of post larvae of the species in the Cochin backwaters, George (1962) recorded the breeding season of P. indicus as from October to May with two peak spawning periods, one in November-December and the other during February to April. Menon (1955) has reported the peak spawning period of M. dobsoni in Cochin coast as May to December. The spawning season of M. monoceros in these areas as noted by George (1959) is from October to December with a peak in November and December. By closely following the size of the spawners during breeding seasons Rao (1968) concluded that individuals of P. indicus and M. dobsoni spawn five times during a life time and that the interval between two successive spawnings is about two months. With regard to spawning grounds Panikkar and Menon (1956) stated that _P. indicus_ seemed to prefer deeper waters for breeding. Menon (1952, 1965) and George _et al_ (1968b) observed that _M. dobsoni_ spawns in the inshore waters, within the 30 m line. George and George (1964) have reported the spawning ground of _M. monoceros_ in a sandy area at a depth of 50 to 60 m off Cochin.

Larval history

Observations on the life cycles of a few prawn species have been carried out in recent years by several workers, based on field data and laboratory cultures (Menon 1937, Hudinaga, 1942, Subramanyam, 1965, Raje and Ranade, 1972). As observed by Subramanyam (1965) the egg of _P. indicus_ is spherical with considerable perivitelline space and measures 0.45 to 0.47 mm in diameter. According to Menon (1952) the egg of _M. dobsoni_ measures 0.35 to 0.44 mm and based on the studies of Raje and Ranade (1972) the egg of _M. monoceros_ measured 0.35 mm in diameter.

The larval development of _P. japonicus_ an allied species of _P. indicus_ is fully known now (Hudinaga, 1942). After fertilisation the embryo begins to show signs of movement within the egg-membrane and in 13 to 14 hours after spawning the nauplius emerges from it. There are six naupliar stages, each stage formed after the moulting of the previous stage. The 6th nauplius moults in about 36 to 37 hours and the first zoea emerges. After the 3rd zoea moults the mysis stage emerges. The size of the mysis stages varies from about 3.10 mm length in the first to 4.52 mm in the 3rd stage. The post larvae emerge after the third mysis moults. After 10 to 12 moults they begin to creep on the sand as the adults, and after 20 to 22 moults the shape of the body and appendages resemble those of the adults and when the prawn is about 6 cm long it gets its colour.

Menon (1952, 1965) has described the larval history of M. dobsoni. The larvae acquire most adult characters in the course of 21 moults. Three naupliar, 3 protozoeal, 3 mysis and 13 post larval stages. Rearing experiments by Menon (1952) showed that the nauplius phase in the life history lasts from 24 to 36 hours. After the last mysis stage, moulting occurred at intervals of 2 days at first and subsequently at intervals of 3 to 6 days. It took approximately 7 weeks for the 1st post-larva to reach the 13th stage.

A complete description of larval stages leading to the post larvae of _M. monoceros_ has been given by Raje and Ranade (1972). Here there were five naupliar, three protozoeal and five mysis stages before becoming post larva.

Juvenile and Adult history

Usually during the larval and post larval stages, prawns of all the three species mentioned above enter the backwaters and grow there for about a year after which they migrate to the sea for breeding. The largest recorded specimen of _P. indicus_ is a female of 9 inches (228.6mm) from the South West Coast of India (Panikkar and Menon 1956). For _M. dobsoni_ George _et al_ (1968b) observed the 125 to 130 mm group as the maximum size of females obtained in the trawl fishery of Cochin. In the case of _M. monoceros_ a maximum length of about 180 mm has been recorded in the trawl fishery of Cochin by George (1959).

The immature prawns found in backwaters are called juveniles and those mature prawns in the sea are mentioned here as adult prawns.

Nutrition and growth

Panikkar (1952) has reported that the food of P. indicus consisted mainly of vegetable matter and crustaceans. Panikkar and Menon (1956) observed that the food of M. dobsoni and M. monoceros consists of detritus, animal and plant matter. Hall (1962) found that the food of the juveniles of P. indicus from Malayan prawn ponds consisted of crustacea, vegetable matter and polychaetes. George (1972b) analysed the food contents of prawns of the backwaters of Cochin and found that in juveniles small crustaceans formed the major food item. As size increased, selective feeding was more evident. Kuttyamma (1974) has made a study of the feeding habits of five species of penaeid prawns ie. Penaeus indicus, P. monodon, Metapenaeus dobsoni, M. monoceros and M. affinis from the Cochin area and found that the prawns feed on both plant and animal matter together with mud. The food in general consisted of varying amounts of organic matter mixed with sand and mud. There appears to be some sort of selection for food in different species, eventhough they were collected from the same environments. Thus M. monoceros was found to feed more on vegetable matter and P. indicus on animal matter. (The reprint of the paper is given as Appendix)

The young ones exhibit a faster rate of growth than the larger prawns. From the size frequency distribution of the catches from the Cochin area George et al (1968b) estimated a growth rate of 20 mm in males and 15 mm in females during four months between first and second year classes for P. indicus. Using the length frequency method Menon (1952) concluded that a length of 60 to 80 mm is attained in 7 or 8 months by M. dobsoni. George et al (1968b) studying the catches of the mechanised fishery of Cochin, showed a growth of 20 mm in males and 25 mm in females during a period of 6 to 7 months in the first year. The fact that females of M. dobsoni show a faster rate of growth than males has been reported by Menon (1955) and George (1961) and George et al (1968b). Growth rate of M. monoceros in the laboratory as recorded by George (1959) varied between 6.25 and 10.25 mm per month. Differential rate of growth in the sexes, females showing the faster growth rate, has been recorded by George et al (1968b).

Movements

One of the methods employed for studying the movements is by tagging the prawns or 'the mark- recovery technique'. George (1967, 1972a, b), ~~and~~ Ranade (1967) and Rao (1972, 1973) have described the experiments on the movements of prawns by tagging. The technique consists in catching the prawns, marking them in different ways, releasing them into their natural habitat, and finally studying the results by recovery of the released ones. Except in the case of Parapenaeopsis stylifera the movements of almost all the penaeid prawns were similar in one respect. After attaining a particular size in the estuary they moved to the sea for spawning. Then the larvae are recruited into the estuary. The size attained by the different species in backwaters is different. The size attained by Penaeus indicus does not exceed 120 mm. The maximum size of Metapenaeus dobsoni in the backwaters usually does not exceed 80 mm in length. Although it can be considered as mature there is no record of breeding in backwater. The size attained by M. monoceros in the backwaters comes to 100 mm. In the case of Parapenaeopsis stylifera larval recruitment into the estuary or the movement of larger juveniles into the sea has not been reported so far. It is believed that this prawn spends its whole life in the sea itself.

Fishery

Depending on the areas from where prawns are caught, prawn fishery in India can be considered under three major heads- marine, estuarine and freshwater, the first accounting about 2/3 of the total catch. The known fishing grounds in the sea are seldom situated far away from the shore. Usually fishermen restrict their operations to the shallow areas within the 40 m line.

The very fact that prawns constitute 96% of the total marine crustaceans landed in India emphasises the importance of their fishery in the sub continent. About 80% of the total landing of shrimps from the Indian Ocean is from the Western Indian Ocean and the remaining 20% is from the Eastern Indian Ocean. At present most of the fishing grounds are along the West Coast. In the marine prawn fishery along the Indian coasts penaeids form a little over 50% of the total catch, the rest being non-penaeids. Among the latter, about 90% are hauled from Maharashtra and Gujarat coasts. Penaeid prawns are harvested mostly along the southern coasts and of these the major portion is from Kerala area.

The marine prawn fishery which supports the export industry is generally confined to shallow coastal areas within 40 m depth and is constituted by Penaeus indicus, P. monodon, P. merguiensis, P. semisulcatus, Metapenaeus dobsoni, M. affinis, M. monoceros, M. brevicornis and Parapenaeopsis stylifera. All these species, except Parapenaeopsis stylifera migrate to the estuaries and backwaters for feeding and growth, where they contribute to good fishery. Considering the size from the point of view of export potentiality, Penaeus monodon and P. indicus are the most important species.

The practice of growing prawns in rice fields on a commercial scale has formed an important part of the fishing industry of the Kerala State for many years past. The post larval stages of the shrimps are allowed to enter the paddy fields connected to backwaters after harvest and closed to prevent their escape. They grow in size and after 5 or 6 months the prawns are caught and processed.

In Kerala during the South West Monsoon season there is a pehnomenon at certain localities in the inshore areas called 'mud bank' formation or 'chakara' as it is locally called. Due to the calming effect of the area, and probably due to the presence of rich nutrients, mud bank regions are very rich in fishery. Fishes and prawns are caught in large quantities during this time. The fishing of prawns are more important because of the high prices and demand. The prawns here are aggregation of several separate schools of a few species of which Metapenaeus dobsoni is the major constituent.

A variety of conventional fishing implements are employed for the capture of prawns in India. Cast nets, bag nets, stake nets, chinese dip nets and a variety of traps are used in the estuaries, and shallow inlets of the sea. Boat seines, shore seines and dip nets are used in coastal waters. They are operated from indigenous catamarans along the east coast and dug-out canoes along the west. Chain dragging is an age old method of collecting prawns in the shallow lakes and canals in Kerala. Recent introduction of mechanised boats and trawl nets ensures larger hauls and greater safety. Otter trawls operated from mechanised boats is widely used now in the sea. It may be mentioned here about the findings of the presence of fairly good concentrations of penaeid prawns like Parapandalus spinipes.

Plesionika martia, *Plesionika ensis*, *Heterocarpus woodmasoni* and *Heterocarpus gibbosus* along with some other penaeid prawns in the deeper waters of 200-300 metres off Kerala coast by the introduction of modernised boats and trawls.

Though apart of the catch is marketed fresh, major portion of it is processed and preserved to meet the demand of the market abroad.

(iv) Occurrence of prawns and the prawn larvae in the Kayamkulam Lake and the Cochin backwaters

LARVAL STUDIES

Different stages of prawn larvae like nauplii, protozoea, mysis and post larvae were sorted out separately every month for numerical analysis. Among the different stages the post larvae were identified into species and the total number of each species during every month was taken for further studies. All the other stages were taken together as penaeid prawn larvae.

Percentage contribution of different stages:

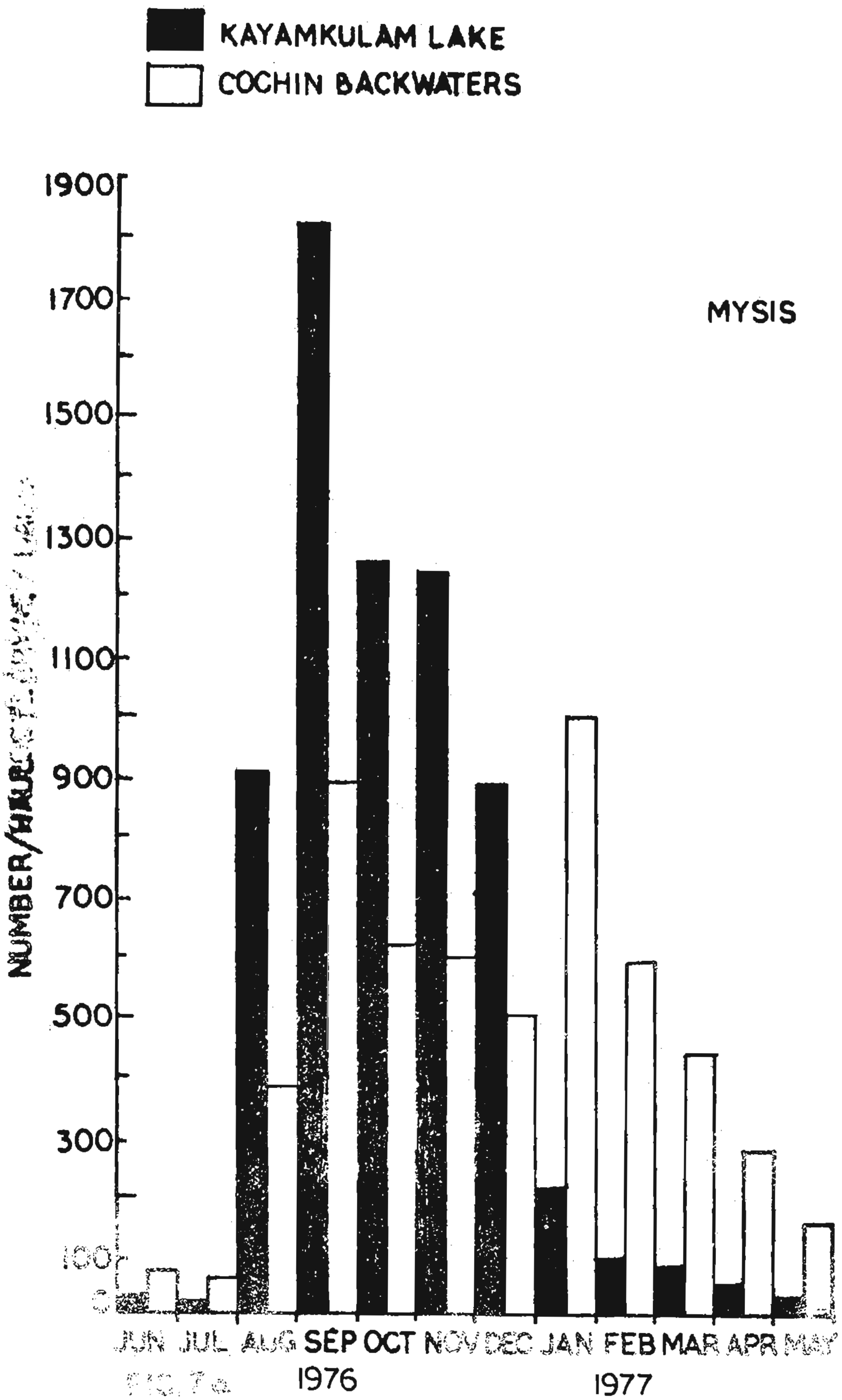
Of the total number of larvae collected in an year (1976-'77) from the Kayamkulam lake, nauplii constituted

12.6%, protozoea 19.1%, mysis 53.6% and post larvae 14.7%. When the percentages of different stages of larvae obtained from Cochin backwaters in an year were taken into consideration nauplii constituted 13.1%, protozoea 20.6%, mysis 57.7% and post larvae 8.6%.

Monthly occurrence of larvae:

Monthly occurrence and abundance of different larval stages in the areas studied are shown in Figs. 7a to 7d. From Fig.7a it is clear that the number of mysis, which is the predominant larval group in the Kayamkulam lake was more from August to December, the maximum being in September. They were poorly represented in the collections from February to July, the minimum being in July. As seen in Fig.7a in the Cochin backwaters mysis was abundant from August to December and from January to May, the maximum number being in September and January. They were scarce during June-July. The protozoea were abundant in the Kayamkulam Lake from August to January, with the maximum in October. As seen in Fig. 7b they were poorly represented in the collections from February to July, the minimum being in June and July. In the Cochin backwaters, protozoea occurred throughout the year, the maximum number occurring in February. From

Fig. 7a. Histogram showing the monthly occurrence of the mysis stage per haul in the Kayamkulam Lake and the Cochin backwaters during 1976-'77.



KAYAMKULAM LAKE
COCHIN BACKWATERS
MYSIS
NUMBER/HAUL
1900
1700
1500
1300
1100
900
700
500
300
100
0
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
1976
1977

FIG. 7a

August to October and from January to March peaks of occurrence were observed. In the Kayamkulam lake from September to December the nauplii stages occurred, the maximum number being in November. As shown in Fig.7c from December onwards upto August they were poorly represented in the collections. In the Cochin backwaters nauplii larvae were common from September to December and from February to May. The maximum number occurred in February and the minimum number during June-July.

Occurrence of post larvae

The prawn fries belonging to the size ranges from 6mm to 20mm for *Penaeus indicus*, 3mm to 17mm for *Metapenaeus dobsoni* and ~~2mm~~ 4mm to 18mm for *Metapenaeus monoceros* are mentioned as post larvae in the present investigation. As seen in Fig.7d on the whole the post larvae were abundant in the Kayamkulam lake from October to January, the maximum being in December. Minimum number of post larvae occurred in July. Two peaks of occurrence of post larvae were observed in the Cochin backwaters during October to December and from February to May (Fig.7d) the maximum number being in March and November and the minimum in June and July.

Species composition:

Post larvae of the following species occurred in

Figs. 7b to 7d. Histograms showing the monthly occurrence of the protozoea, nauplii and post larvae of penaeid prawns per haul in the Kayamkul Lake and the Cochin backwaters during 197 1977 (The black column depicts the Kayamkulam lake and the white column depicts the Cochin backwaters).

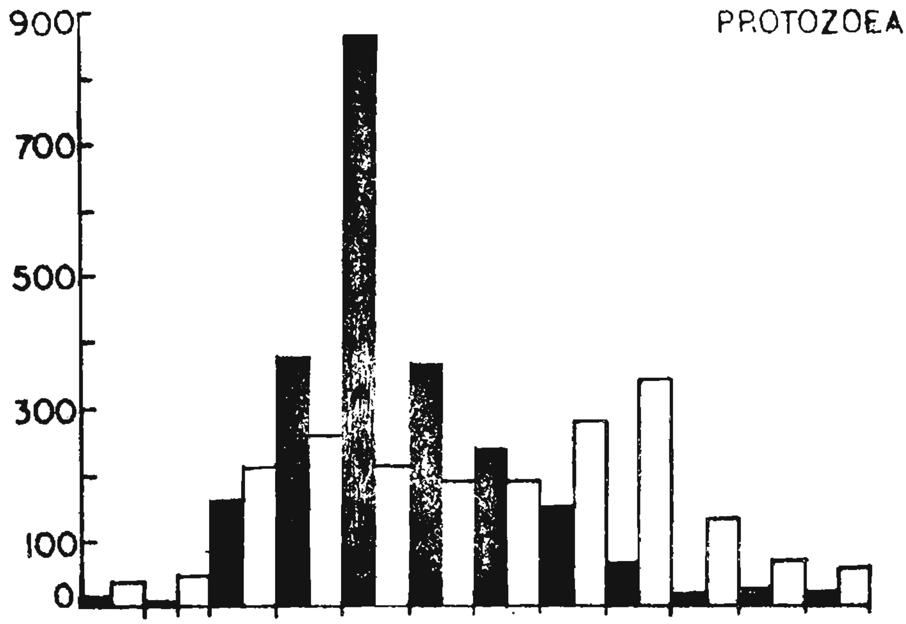


FIG. 7b

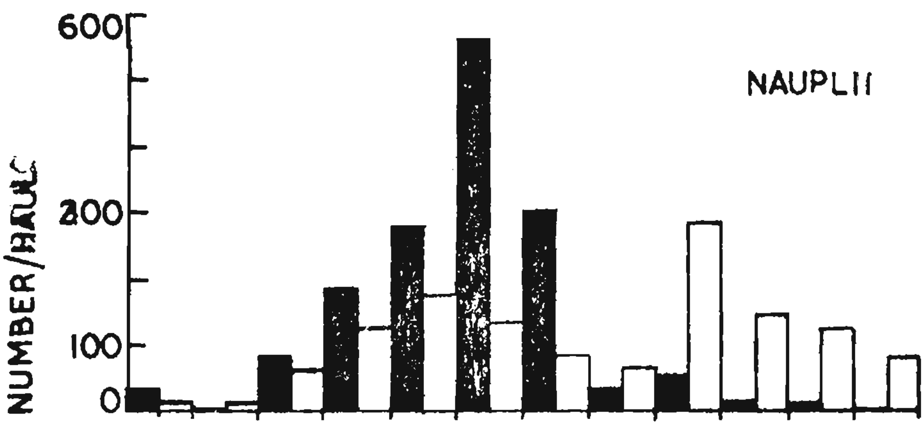


FIG. 7c

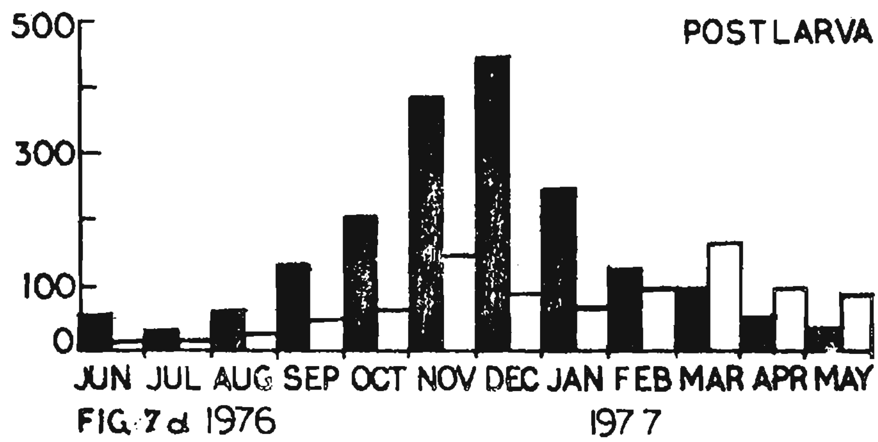


FIG. 7d

both the estuaries.

Penaeus indicus, *Metapenaeus dobsoni*, *M. monoceros*, *Penaeus monodon* and *Metapenaeus affinis*.

Among the species cited above post larvae of *M. dobsoni* and *P. indicus* were predominant in the collections. Post larvae of other species occurred in few numbers.

Percentage contribution of each species:

Of the total number of post larvae collected in an year from the Kayamkulam lake *P. indicus* constituted 50.1%, *M. dobsoni* 41.9%, *M. monoceros* 4.5% and others 3.5%. In the Cochin backwaters the total number of post larvae collected in an year, *M. dobsoni* constituted 62.1%, *P. indicus* 21.7%, *M. monoceros* 12.5% and others 3.7%.

Monthly occurrence:

Monthly occurrence of post larvae of each species from the two study areas are shown separately in Figs.8a to 8d.

Penaeus indicus

In the Kayamkulam lake post larvae of *P. indicus* were collected throughout the year and they were predominant almost throughout the period in the collections (Fig.8a). The peak of occurrence was observed during October to January the maximum number being in December. In November also they were abundant. They were poorly represented in the collections during April to July. In the Cochin backwaters although post larvae of *P. indicus* were collected throughout the year the percentage of occurrence was lower to that of the other area (Fig.8a). The maximum number occurred in two periods one from October to December and the other from February to May. They were scarce in the collections from June to August.

Metapenaeus dobsoni

As shown in Fig.8b in the Kayamkulam lake, *M. dobsoni* was represented in the sample throughout the year. But the peak of its occurrence was from October to January, the maximum number was observed in November. The minimum number of *M. dobsoni* occurred during July. During April, May and June they were poorly represented in the collections. In the Cochin backwaters also they were represented in the collection throughout the year. Fig.8b shows the peaks of occurrence from November to December and from February to May. The maximum number occurred in March and the minimum in June and July.

Metapenaeus monoceros

The post larvae of *M. monoceros* were relatively few in the Kayamkulam lake throughout the year (Fig.8c).

Fig. 8a to 8d. Histograms showing the monthly occurre[nce] of post larvae of different species of Penaeid prawns in the Kayamkulam Lake and the Cochin backwaters.

8a. Mean number of post larvae of _Penaeus indicus_ per haul;

8b. Mean number of post larvae of _Metapena[eus] dobsoni_ per haul;

8c. Mean number of post larvae of _Metapena[eus] monoceros_ per haul;

8d. Mean number of post larvae of other sp[ecies] of penaeid prawns per haul.

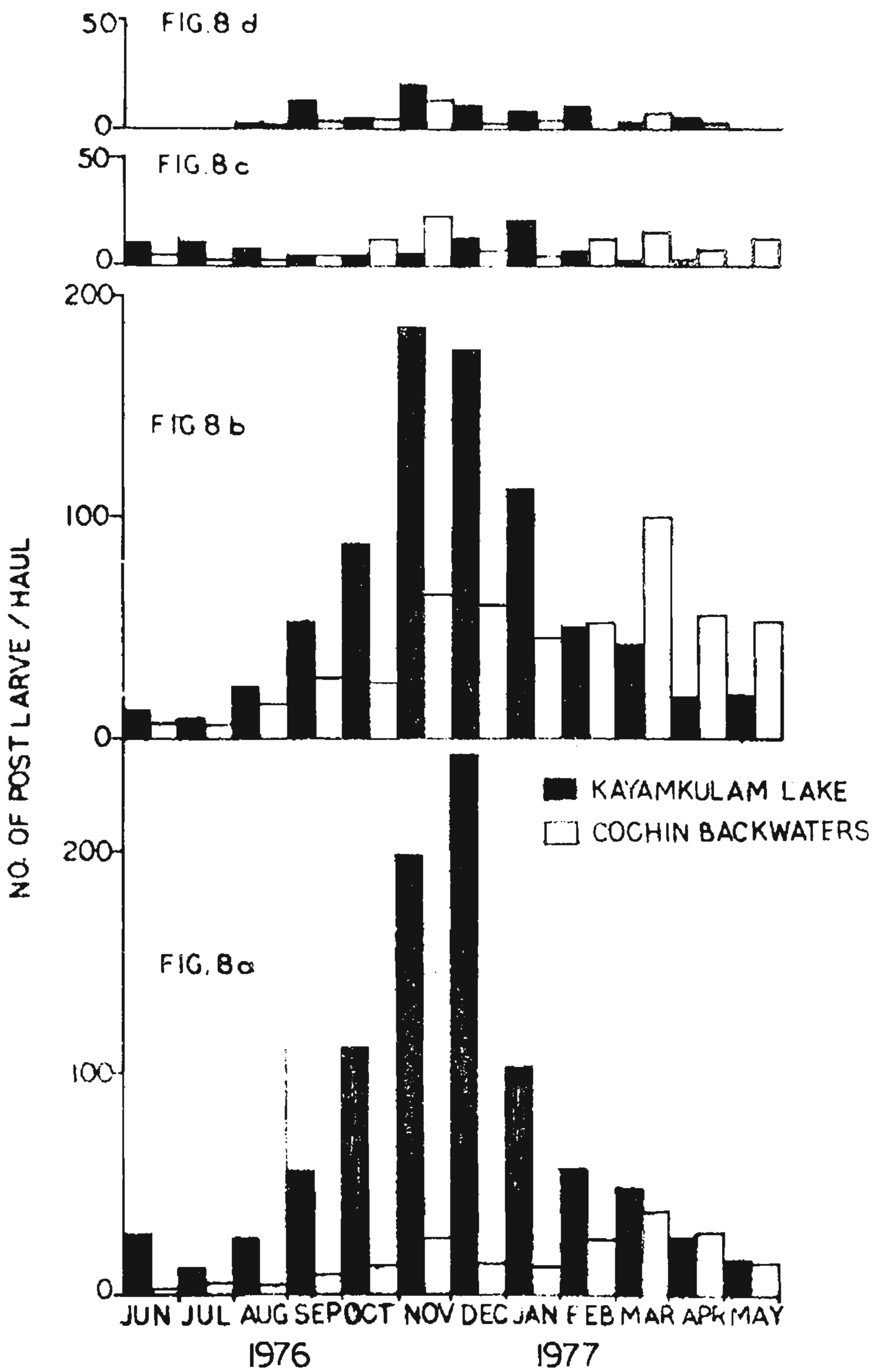


FIG. 8 d
FIG. 8 c
FIG 8 b
FIG. 8 a
50
0
50
0
200
100
0
200
100
0
NO. OF POST LARVE / HAUL
KAYAMKULAM LAKE
COCHIN BACKWATERS
JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY
1976
1977

Maximum number of them occurred during January, the minimum in April. In May there was no catch. In the Cochin backwaters post larvae of M. monoceros was represented in the collection throughout the year and their numbers were more than in the other estuary. The maximum numbers occurred in November. As the Fig.8c shows during July and August they were rarely represented in the sample. There were two peaks of occurrence for the post larvae of this species in the backwaters of Cochin one from October to December and the other from February to May.

Other species

Post larval stages of Penaeus monodon, and Metapenaeus affinis which occurred occasionally in the collections were taken together and dealt with here. In the Kayamkulam lake none of the above species was represented in May, June and July. Maximum number of them were obtained during November (Fig.8d). In the Cochin backwaters also they did not occur in monsoon months ie. during June and July as well as in February and May. Maximum number was obtained in November.

Size variations:

Post larvae of different sizes were caught in the collections. The total length of post larvae were taken and they were sorted into different size groups.

Penaeus indicus

The size of the post larvae of *P. indicus* obtained from the Kayamkulam lake ranged from 6mm to 20mm in total length. Post larvae of 11-15mm length were predominant in the collections during November, December and April (Table-1) and that of 6-10mm size was abundant in October and March than other size categories and those belonging to the group 16-20mm size were dominant in the sample during January and February. As Table 2 shows the sizes of post larvae obtained from the Cochin backwaters varied from 6mm to 20mm in total length. When the total number of larvae of *P. indicus* in an year were taken the most prominant category was 16-20mm size. They were abundantly distributed in the collections in November and February. In October and March 6-10 mm group was more in the sample. During January and April 11-15mm size group predominated.

Metapenaeus dobsoni

An analysis of the size groups of *M. dobsoni* occurring in the Kayamkulam lake during the period of investigation showed that their size varied from 3mm to 17mm (Table-1). All the post larvae were grouped into 3 size categories based on total length, the first group belonging to the length range 3mm to 7mm, the second group belonging to the length 8mm to 12mm and the third category being 13-17mm group. As Table-1 shows the post larvae belonging to 8-12 mm size dominated in the collections during most of the months. In January, March and April post larvae belonging to length group 13-17mm were dominant than other size groups and in August and September 3-7mm group formed the major category. As Table-2 shows the size of post larvae obtained from the Cochin backwaters also varied between 3mm to 17mm in total length. When the total number of post larvae were taken into consideration those belonging to the size group 13 to 17mm were dominant and post larvae belonging to 3 to 7 mm were the least dominant. As the table shows 3-7mm group was predominant in September while 8-12 group dominated in August and January.

Metapenaeus monoceros

In the Kayamkulam lake the total length of *M. monoceros* as observed from the collections ranged between 4-18mm. Post larvae belonging to the size group 9-13 mm were dominant during most of the months, especially in June, December, January and February. During August 4-8mm group was abundant in the collections. The post larvae of

Occurrence of different size groups of post larvae of Penaeid prawns per haul in the Kayamkulam Lake

Name of species	length-range (mm)	1976 Jun	Jul	Aug	Sept	Oct	Nov	Dec	1977 Jan	Feb	Mar	Apr	May
Penaeus indicus	6-10	7	5	6	15	57	81	49	31	9	28	6	--
	11-15	16	3	12	31	36	93	128	14	16	15	20	9
	16-20	4	3	8	12	20	23	65	58	32	5	-	5
Metapenaeus dobsoni	3-7	2	1	12	32	24	28	43	15	9	2	-	2
	8-12	6	4	5	11	47	89	98	37	25	14	5	18
	13-17	3	2	6	10	17	49	33	60	15	26	13	-
Metapenaeus monoceros	4-8	2	4	6	3	1	2	4	3	1	-	1	-
	9-13	5	4	1	1	1	3	7	12	5	1	1	-
	14-18	2	1	-	-	2	-	1	5	1	1	-	-

Occurrence of different size groups of post larvae of penaeid prawns per haul in the Cochin backwaters

Name of species	length-range (mm)	1976 Jun	Jul	Aug	Sep	Oct	Nov	Dec	1977 Jan	Feb	Mar	Apr	May
Penaeus indicus	6–10	-	1	-	2	12	6	4	2	5	27	2	-
	11–15	1	-	1	3	-	7	3	10	6	3	15	4
	16–20	1	2	2	3	-	12	6	-	13	8	11	10
Metapenaeus dobsoni	3–7	1	2	4	12	5	17	12	6	11	29	1	6
	8–12	3	-	7	8	5	21	16	22	16	23	13	17
	13–17	3	4	4	7	15	39	33	15	25	47	42	30
Metapenaeus monoceros	4–8	-	-	1	3	4	7	3	1	2	7	2	6
	9–13	2	1	1	1	6	11	2	3	6	4	2	2
	14–18	2	-	-	2	3	3	2	1	4	3	3	4

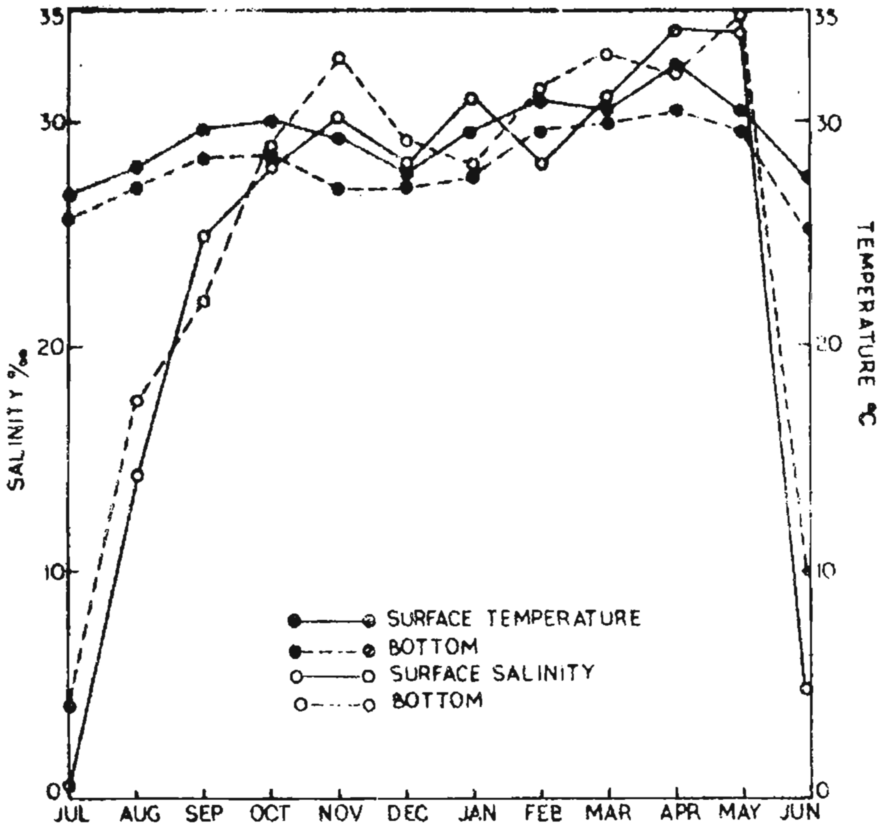
the length range 14-18mm were dominant in October only. In the Cochin backwaters also 9-13mm size group was predominant in the sample during most of the months (Table-2). They were abundant in October, November and February. In September and March 4-8mm group dominated and in April 14-18mm group was the major category in the collections from this area.

Factors affecting the occurrence of prawn larvae

The salinity and temperature are the two important hydrographical parameters which normally influence the fauna in a marine environment. The distribution of salinity and temperature of both surface and bottom water in the Kayamkulam and Cochin backwaters is shown in Figs.9 and 10 respectively. Data obtained from the Kayamkulam lake reveal that the estuary displays wide fluctuations in salinity ranging from 0.5‰ in July to 34‰ in April. In the Cochin backwaters the surface salinity ranged from 1.2‰ in July and 33.7‰ in March. In both the areas under investigation definite seasonal fluctuations in salinity are observed. During monsoon season (June to September) salinity was lower due to the influx of fresh water into the estuary. During this period in the Kayamkulam lake salinity varied between 0.5 to 25‰ and in the Cochin backwaters between 1.2 to 28‰. During the post monsoon season (October to

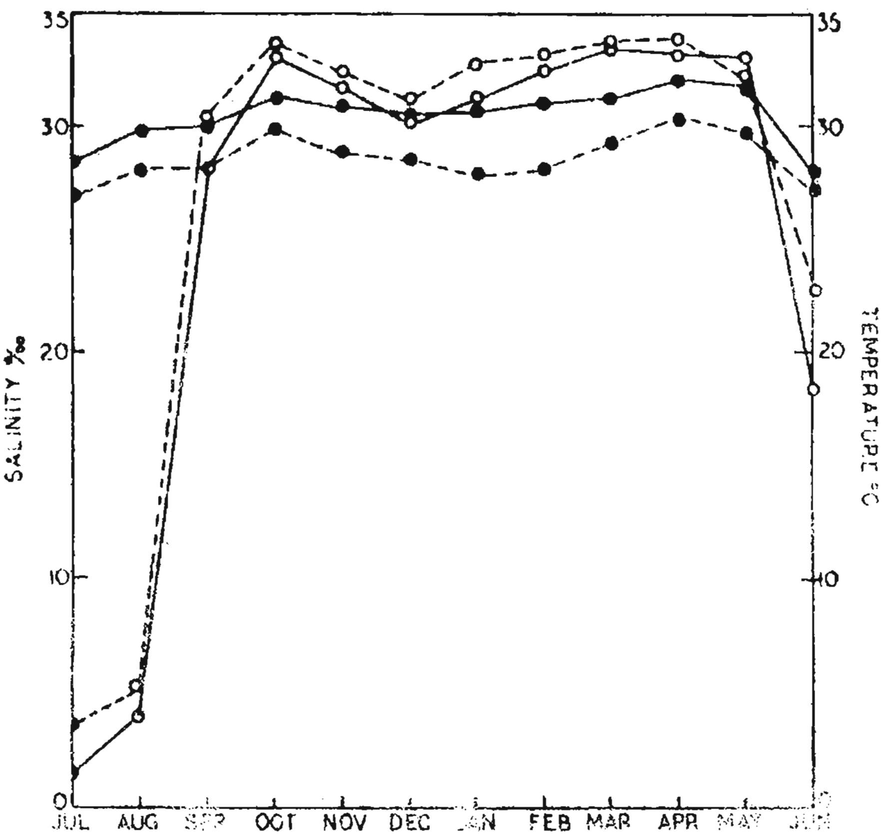
Fig. 9. Temperature and salinity variations in the Kayamkulam Lake during 1976-'77.

Fig.10. Temperature and salinity variations in the Cochin backwaters during 1976-'77.



SALINITY ‰
TEMPERATURE °C
SURFACE TEMPERATURE
BOTTOM
SURFACE SALINITY
BOTTOM
JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN
1976
1977

FIG. 9



SALINITY ‰
TEMPERATURE °C
JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN
1976
1977

FIG. 10

January) salinity rises and the range was between 28‰ and 30‰ and 31.2‰ and 33‰ in each estuary. During the pre monsoon period (February to May) high values have been recorded. In the Kayamkulam lake the salinity ranged between 31.0‰ and 34.0‰ and in the Cochin backwaters between 32.5‰ and 33.7‰.S.

The monthly variations in the surface and bottom temperatures during the period of investigation in the two estuaries are shown in Figs.9 and 10. As the figures show variations in temperature are not so pronounced as the salinity in both the areas. The temperature reaches its maximum during the premonsoon period. The range of temperature observed in the Kayamkulam lake (Fig.9) was between 25.6°C and 32.6°C and in the Cochin backwaters (Fig.10) the range was between 26.0°C and 32.0°C. Low temperatures have been observed during the monsoon season due to the heavy rains and fresh water influx.

Effect of Hydrographical variations on the occurrence and abundance of prawn larvae:

As Figs.7a to 7d shows, prawn larvae were abundant in the post monsoon season in both the areas when the salinity and temperature were moderate in the medium, scarcity of prawn larvae were noticed during the monsoon season when the salinity and temperature of water became lowered.

In the Cochin backwaters larvae were abundant during premonsoon season also, whereas in the Kayamkulam lake they were few in numbers. This can be attributed to the closing of the barmouth during this period in the Kayamkulam lake.

Tidal effect:

The tidal amplitude in the region is about 1m and despite tidal variations the depth of the area from where collections were made in the Kayamkulam lake remained 2-3m.

The number of prawn larvae obtained in the collections during low tide and high tide was worked out separately for each month. As shown in Table 3 except for a few instances the number of larvae was higher at high tide than at low tide in both the estuaries.

Lunar effect:

The number of larvae for the bright and dark halves of the month were taken separately and the results are shown in Table-3. From the table it can be observed that collections during the new moon fortnight were richer than those of the full moon fortnight in almost every month in both the estuaries and the yearly percentage of occurrence in the Kayamkulam lake during full moon fortnight was 37%

Occurrence of larvae of Penaeid prawns per haul in the Kayamkulam Lake and the Cochin backwaters to show the tidal effect, lunar effect and diurnal effect.

Area	Time of collection	1976 Jun	July	Aug	Sep	Oct	Nov	Dec	1977 Jan	Feb	Mar	Apr	May	Percentage in an year
Kayamkulam Lake	Low tide	55	31	385	669	1231	818	419	281	156	81	48	52	34
	High tide	70	41	812	1831	1376	1749	1458	361	171	127	88	31	66
	Full moon fortnight	59	23	586	688	531	1214	880	386	122	26	54	39	37
	New moon fortnight	66	49	611	1812	2076	1353	997	256	205	182	82	44	63
	Day	42	13	330	561	549	736	342	296	58	89	44	23	25
	Night	83	59	867	1939	2058	1831	1535	346	269	119	92	60	75
Cochin backwaters	Low tide	57	72	310	596	487	312	367	670	564	296	347	258	45
	High tide	87	66	361	704	569	732	473	812	718	561	205	112	55
	Full moon fortnight	26	64	283	689	514	363	482	888	473	426	196	205	47
	New moon fortnight	118	74	388	611	542	681	358	594	809	431	356	165	53
	Day	49	36	189	388	159	213	296	736	255	247	112	214	30
	Night	95	102	482	912	897	831	544	746	1027	610	440	156	70

whereas during new moon fortnight it was 63%. In the Cochin backwaters the yearly percentage of occurrence was 47% in the full moon fortnight and 53% in the new moon fortnight.

Diurnal effect:

The day and night collections were analysed separately to study the diurnal variations in the occurrence of larvae and the results are shown in Table-3. It was found that there was significant difference between day and night collections, from both the lakes. Larvae were abundant at night and scarce during day time. The yearly percentage of larvae obtained in day collection from the Kayamkulam lake was 25 whereas the percentage of larvae in the night collection from the same area was 75. In the Cochin backwaters the percentage of occurrence in day collection was 30 and in the night collection it was 70.

Recruitment:

From the foregoing study, the period of recruitment of larvae and post larvae of penaeid prawns could be assessed. In the Kayamkulam lake, larvae were recruited from August onwards and were abundant upto January showing only one peak of occurrence. In the Cochin backwaters larvae appeared in August and were abundant upto November. After a decrease in the magnitude of abundance during December, larvae occurred abundantly in the collections from January to May in this area. Thus there were two peaks of occurrence in the Cochin backwaters.

For studying the migration of post larvae of prawns into the Cochin backwater an investigation was conducted by collecting them during high tide at different depths near the barmouth (Kuttyamma and Kurian 1976). The results show that the intensity of migration depended on the hydrographical conditions of the area and that the number of post larvae were more in the surface waters and less in the bottom. At the same time the larger ones were more near the bottom. It was also observed that the post larvae of M. dobsoni were more abundant at all the three levels studied.

JUVENILE STUDIES

Here the term juvenile refers to the immature prawns obtained from the commercial catches from the estuaries.

Different types of nets are operated in the lakes for catching prawns. The simplest type of net is the cast net operated by a single man by throwing it over the water surface. The net is operated throughout the year. Bag like nets tied to poles driven to the bottom are called 'stake nets'. The Chinese dip nets are large dip nets supported on long poles. When these are operated at night lighted lamps are used to attract prawns.

The cast net is operated for 27 to 28 days in a month when the weather conditions are good. During the monsoon, fishing is suspended for a number of days.

The stake net has a mouth of about 18m in circumference and is operated for 12 to 18 days in a month. The operation is based on tidal effects. The time of operation is usually in the evenings extending into the early hours of the night or at day break. This net is expected to be operated in the lake only during low tide (Government order). Both during the bright and the dark halves of the month fishing is restricted to about half the period commencing on the tenth or eleventh day (Desami or Ekadasi) and ending on the fourth or fifth day after the new and full moon. In the Kayamkulam waters maximum effort by stake nets was observed during November to February, coinciding with the heavy landings by this gear. During this period fishermen used to get upto 25 kg of prawns/per day. During April-May fishing was suspended owing to the closing of bar mouth. In the Cochin backwaters the net is operated throughout the year but the maximum catch was from October to April.

Although Chinese dip nets are operated throughout the year, the main fishing season is from October to January in the Kayamkulam lake. During the best season about 50kg of prawns/net are obtained during a single night. Maximum catch was in December and January. In the Cochin back-waters also the net is operated throughout the year, the maximum catch being from November to March.

Prawns collected from the two estuaries by the above three types of nets were analysed separately. Collections from the different stations were pooled together and the average data were taken for the occurrence studies. Although the three types of gears under consideration ie. cast net, stake net and chinese dip net are operated mainly for prawns, small quantities of fish and crabs are also caught by these nets along with the prawns. The proportion of prawns varied from 20 to 60% in the case of cast net, 50 to 90% in the chinese dip net and 40 to 80% in the case of stake nets in the Kayamkulam lake and the prpportion of prawns varied from 15 to 70% in cast net, 30 to 80% in the chinese dip net and 20 to 70% in the case of stake nets in the Cochin backwaters during the period of investigation.

The species of prawns composing the catches in the different nets were not significantly varied, as revealed by the regular analysis of fortnightly samples from different centres in both the estuaries. The list of species recorded is given below:

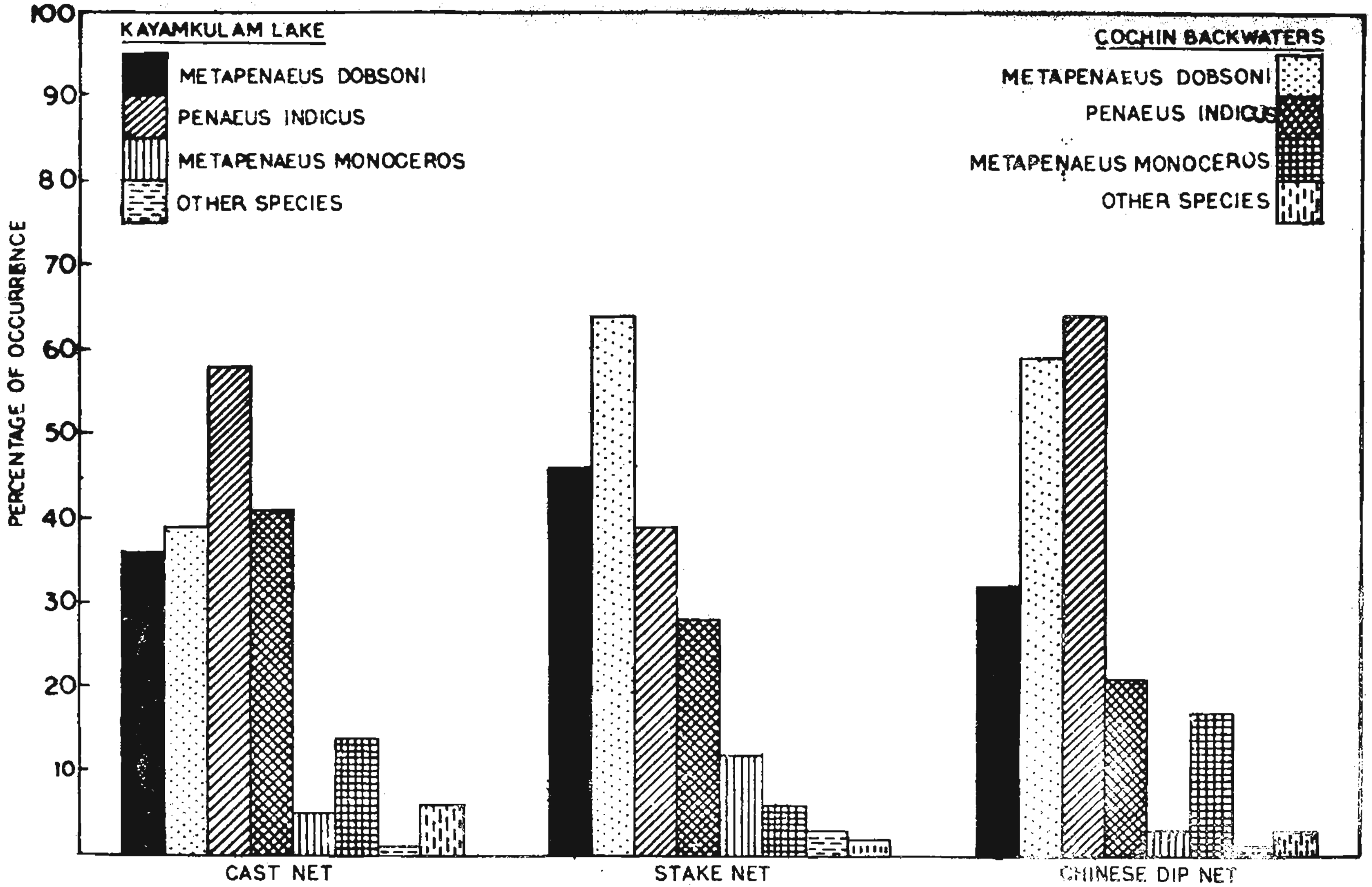
Penaeus indicus, P. monodon, Metapenaeus dobsoni, M. monoceros, M. affinis.

Among these, P. monodon and M. affinis occurred in insignificant numbers and therefore they were considered as 'other species'. The prawn fishery in the Kayamkulam lake and Cochin backwaters are supported mainly by the three species of penaeids viz. P. indicus, M. dobsoni and M. monoceros.

Gearwise percentage catch composition:

Data obtained from each type of net was analysed and the results are given in Fig.11. From the figure it will be seen that in the total catch taken from the cast net in the Kayamkulam lake, the percentage occurrence of P. indicus which was the major constituent of the catch was 58%,

Fig.11. Gearwise percentage catch composition of different species of penaeid prawns in the Kayamkulam Lake and in the Cochin backwaters during 1976-'77.



KAYAMKULAM LAKE
METAPENAEUS DOBSONI
PENAEUS INDICUS
METAPENAEUS MONOCEROS
OTHER SPECIES
COCHIN BACKWATERS
METAPENAEUS DOBSONI
PENAEUS INDICUS
METAPENAEUS MONOCEROS
OTHER SPECIES
PERCENTAGE OF OCCURRENCE
100
90
80
70
60
50
40
30
20
10
CAST NET
STAKE NET
CHINESE DIP NET

FIG. 11

M. dobsoni constituted 36%, *M. monoceros* 5% and other species together 1% . In the Cochin backwaters, of the total collections taken in an year, *P. indicus* constituted 41%, *M. dobsoni* 39%, *M. monoceros* 14% and others 6%. The stake net collections from Kayamkulam lakes showed that *P. indicus* constituted 39% of the total collections, *M. dobsoni* 46%, *M. monoceros* 12% and others 3%. In the Cochin backwaters the catch composition of *Penaeus indicus* was 28%, *M. dobsoni* 64%, *M. monoceros* 6% and others 2%. 64% of chinese dip net collections from the Kayamkulam lake was constituted by *P. indicus*, 32% by *M. dobsoni*, 3% by *M. monoceros* and 1% by other species. In the Cochin backwaters catches from Chinese dip nets were composed of 21% *P. indicus*, 59% *M. dobsoni*, 17% *M. monoceros* and 3% other species.

Monthly occurrence of different species in different nets

As Figs.12a and 12b show *Penaeus indicus* was the most dominant species of prawns obtained in the cast net in both the estuaries, although the percentage of occurrence was more in the Kayamkulam lake. In the Kayamkulam lake *P. indicus* was caught abundantly from November to April, the maximum being in December. In the Cochin backwaters they were abundant from October to December and from January to March, the maximum being in November. During June-July they were scarce in the Cochin backwaters.

M. dobsoni occurred abundantly in the cast net catches from the Kayamkulam lake from October to December and from January to May, the maximum being in January and the minimum percentage in July. In the Cochin backwaters M. dobsoni was dominant in the cast net catch from September onwards upto December, again from March to May, the maximum percentage of occurrence was in November and the minimum in June.

M. monoceros occurred in the cast net catches from the Kayamkulam lake from September to December and from January to May in small percentage, the maximum being in April. In the Cochin backwaters M. monoceros occurred from August to December and from January to May, the maximum number being in October.

Other species of penaeid prawns like P. monodon and M. affinis were caught only in few numbers occasionally in both the study areas.

The percentage occurrence of different species of penaeid prawns obtained from the stake net catches at the Kayamkulam lake and the Cochin backwaters are shown in Figs. 12c and 12d.

As seen in the Fig.12c, P. indicus was abundant from

Fig.12a to 12f. The percentage occurrence of different species of penaeid prawns in three x types of nets in the Kayamkulam Lake and the Cochin backwaters, during 1976-'77.

12a. Occurrence in the cast net catches in the Kayamkulam Lake

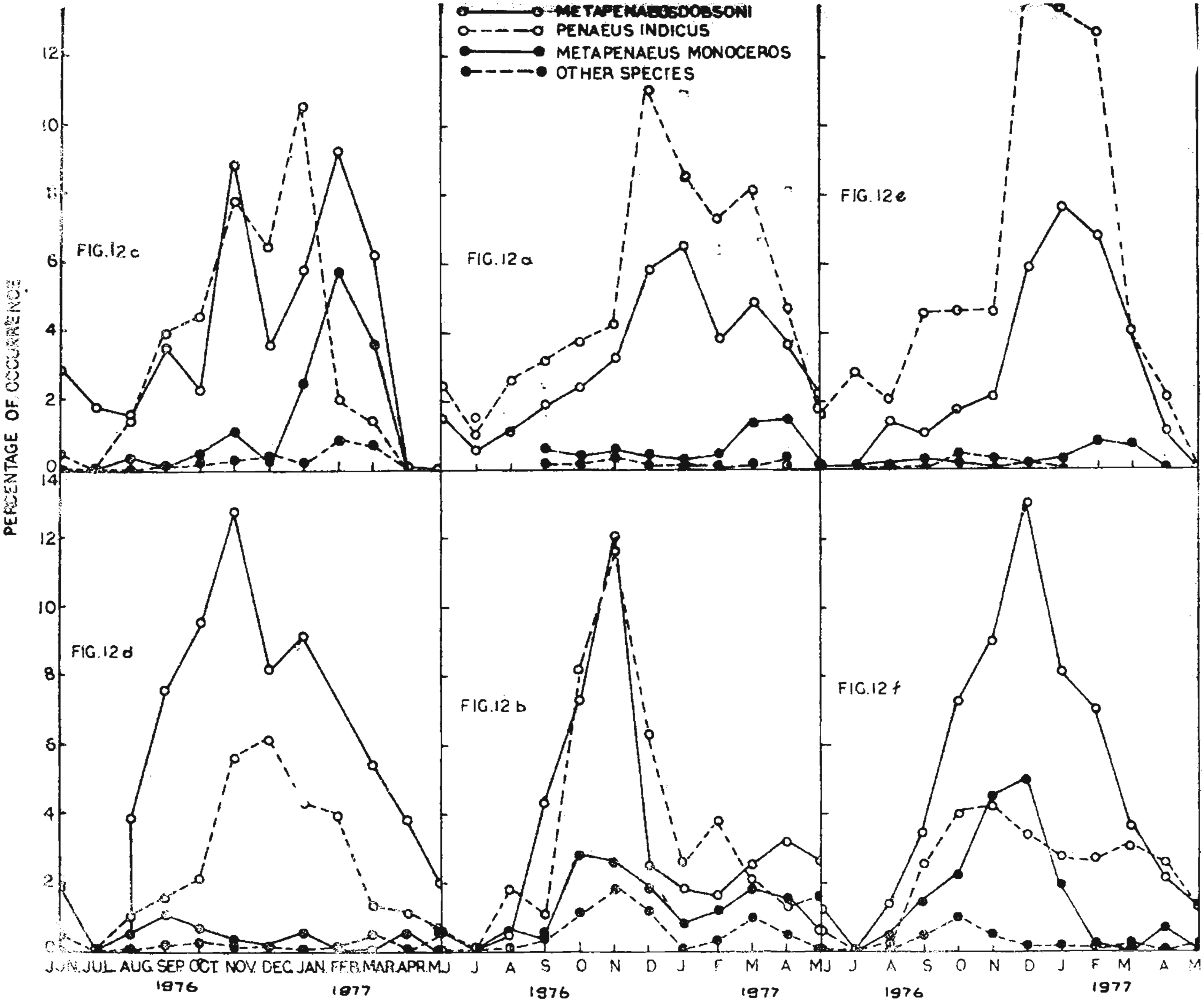
12b. Occurrence in the cast net catches in the Cochin backwaters

12c. Occurrence in the stake net catches in the Kayamkulam Lake

12d. Occurrence in the stake net catches in the Cochin backwaters

12e. Occurrence in the Chinese dip net catches in the Kayamkulam Lake

12f. Occurrence in the Chinese dip net catches in the Cochin backwaters


METAPENAEUS DOBSONI
PENAEUS INDICUS
METAPENAEUS MONOCEROS
OTHER SPECIES
PERCENTAGE OF OCCURRENCE
FIG. 12 c
FIG. 12 a
FIG. 12 e
FIG. 12 d
FIG. 12 b
FIG. 12 f
JUN. JUL. AUG. SEP. OCT. NOV. DEC. JAN. FEB. MAR. APR. M
J A S O N D J F M A M
J J A S O N D J F M A M
1976
1977

September to December and in January in the Kayamkulam lake. The maximum catch of this species was in January. In the Cochin backwaters P. indicus was plenty in November, December, January and February and the maximum percentage in December.

M. dobsoni was the prominant species in the stake net catches from both the backwaters, although the percentage of occurrence was higher in the Cochin backwaters. In the Kayamkulam lake they were plenty in November, January to March, the maximum number being in February. M. dobsoni was abundant in the stake net catches from the Cochin backwaters from October onwards to December and in January and February. Maximum number occurred in November.

M. monoceros showed their abundance in the stake net catches of the Kayamkulam lake in January and February and in the Cochin backwaters in September and October. Other species of penaeid prawns occurred occasionally in the catches, more in January to March in the Kayamkulam lake and in June and September in the Cochin backwaters.

Percentage composition of different species in the chinese dip net catches are shown in Figs.12e and 12f. P. indicus from the catches of chinese dip net showed their predominance from November to March in the Kayamkulam lake and from October to December and in March and April in the Cochin backwaters. Maximum number of them occurred in December in Kayamkulam and in November in Cochin.

<u>M</u>. <u>dobsoni</u> caught by chinese dip nets in the Kayamkulam lake showed their abundance in December, January and February with a maximum in January. In the Cochin backwaters <u>M</u>. <u>dobsoni</u> occurred abundantly from October to December and in January and February with maximum in December in this area.

<u>M</u>. <u>monoceros</u> was abundant in February and March in the Kayamkulam lake and in November-December in the Cochin backwaters, maximum number occurred in February in the Kayamkulam lake and in December in the Cochin backwaters.

Other species were scarce throughout the year.

<u>Size variations of the prawns in the Kayamkulam and Cochin backwaters</u>.

Samples from the cast net, stake net and chinese dip nets from the two backwaters were analysed separately to know the size variations of different species caught by different nets. The studies showed no significant difference in the variations of sizes of prawns caught in the two different areas by the same type of net. So

Fig.13. Size frequency distribution of *M. dobsoni*, *P. indicus* and *M. monoceros* in the cast net catches during 1976-'77.

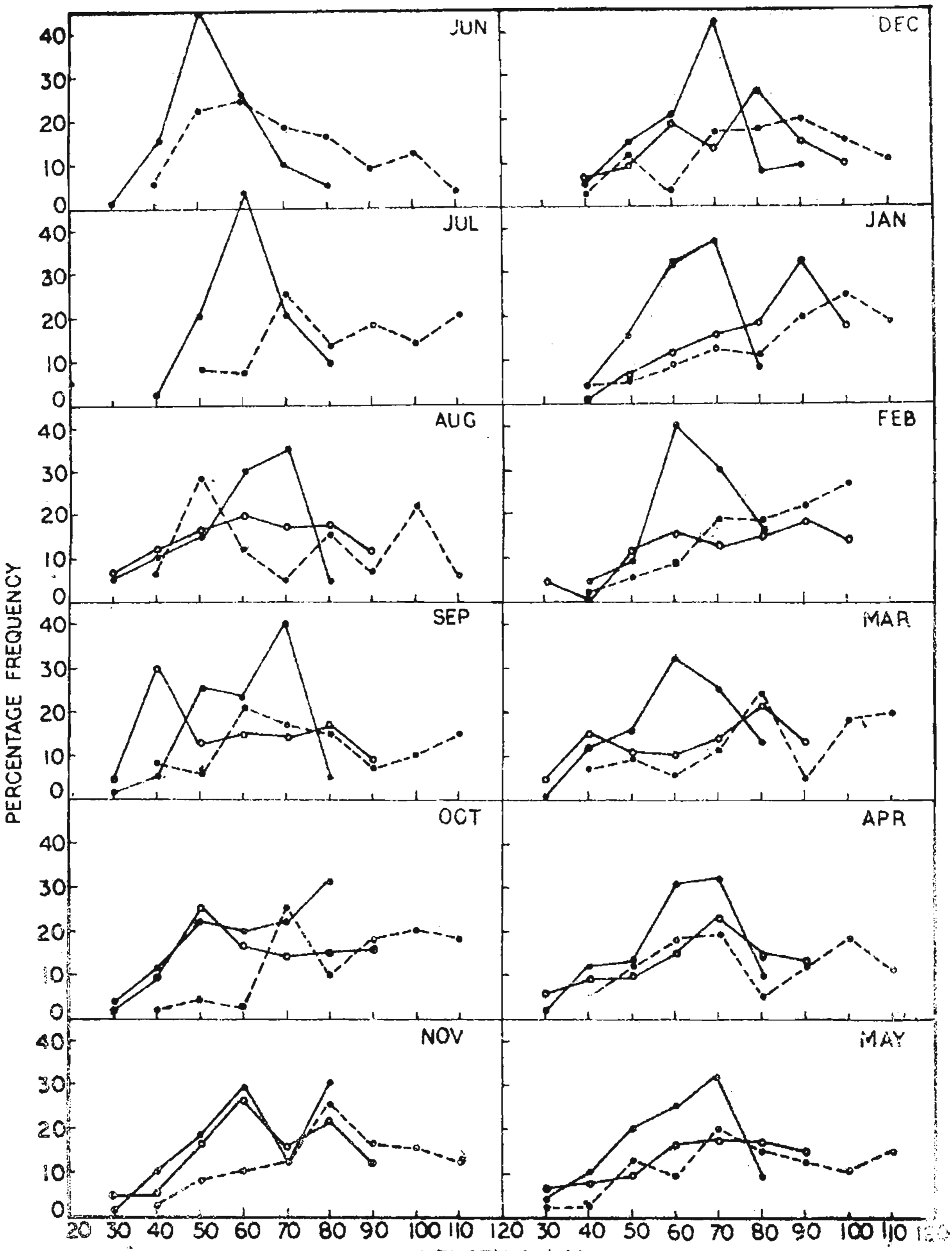


FIG. 13

CAST NET

METAPENAEUS DOBSONI — PENAEUS INDICUS — METAPENAEUS MONOCEROS pooled data of collections from each type of net for the two lakes were taken for length frequency studies.

Monthly length frequencies in respect of M. dobsoni, P. indicus and M. monoceros caught by the three types of nets are shown in figs. 13, 14 and 15. Insufficient numbers or absence of prawns in the samples account for the ommission of certain months in the length frequency curves.

M. dobsoni. Specimens measuring below 30mm were extremely rare in the cast net collections, the largest specimen recorded being 90 mm in length. The modal positions varied from 40-49mm in June to 60-69mm in September and from 50-59mm in November to 60-69mm in January. As shown in Fig.13 in cast nets, among the different size groups 60-69mm group predominated for most of the months particularly during the peak period of the fishery from December and January, while the cast net catch consisted of larger size groups, those in the stake net were generally smaller in size (fig.14). The size group 30-39mm showed their predominance in June; and in November 60-69mm group predominated after gradual increase in the modal length. During almost all the months the modal positions were between 30-39mm and 40-49mm. Specimens measuring over 70mm were rare in the stake nets. In the chinese dip net (fig.15)

Fig.14. Size frequency distribution of M. dobsoni, P. indicus, and M. monoceros in the stake net catches during 1976-'77.

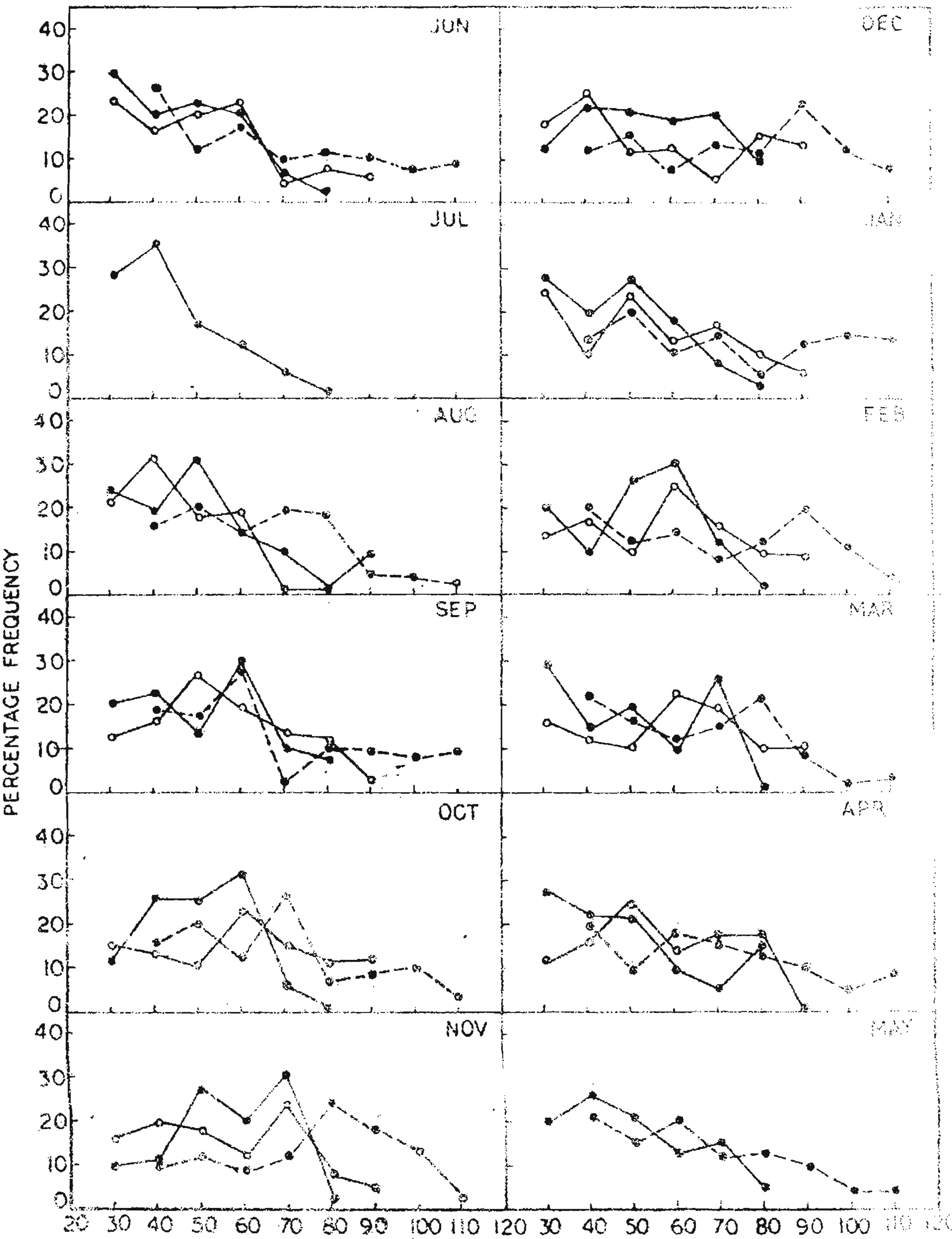


FIG. 14

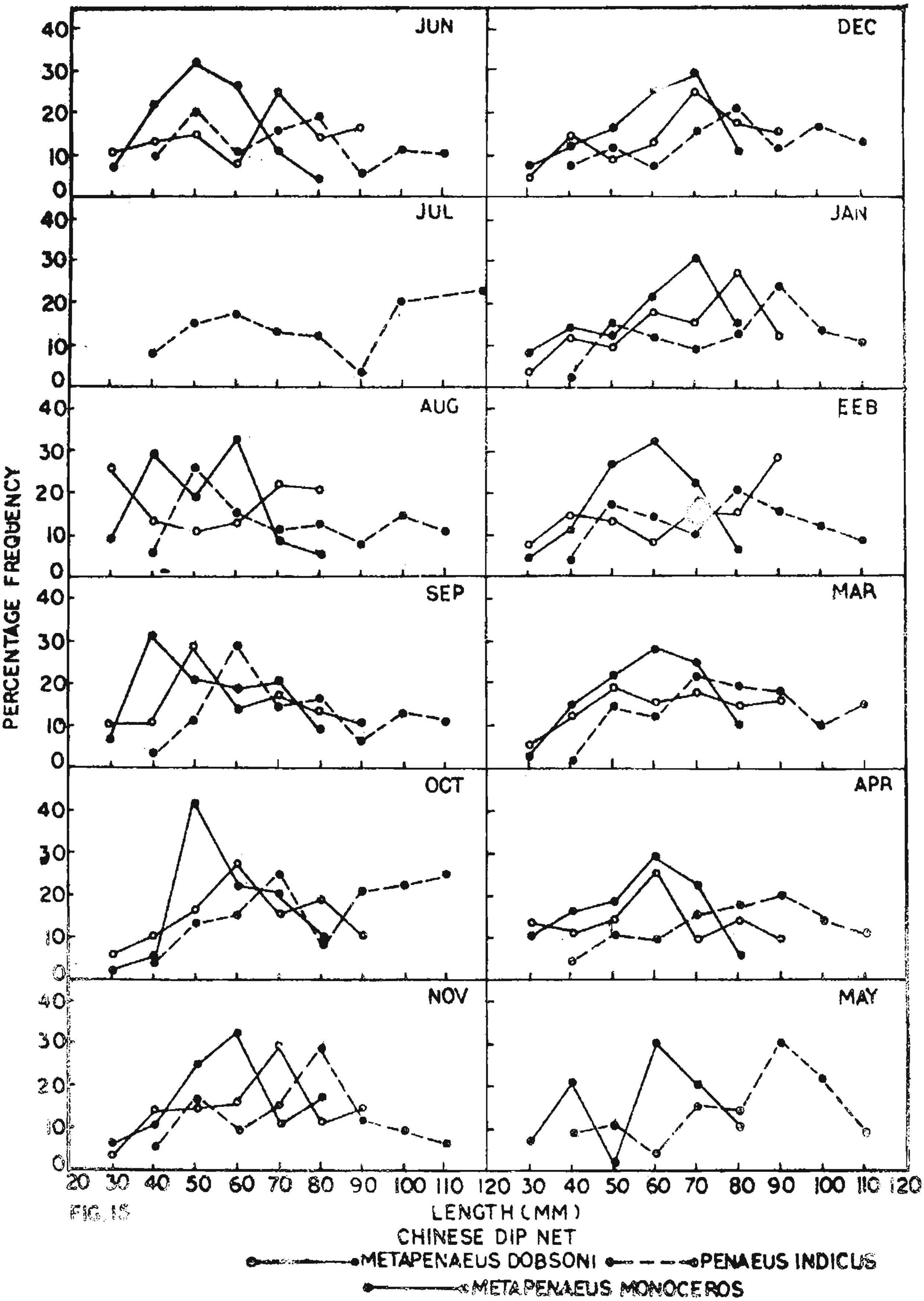
STAKE NET

METAPENAEUS DOBSONI — PENAEUS INDICUS — METAPENAEUS MONOCEROS the modal size group in September was 30-39mm. After gradual increase in their length during the following months, in December and January 60-69mm size group was predominant.

P. indicus. The samples from cast nets were represented by large size prawns of the size group 60-69mm in July, 70-79mm in November, 80-89mm in November and 80-89mm in December. In January and February the samples were represented by larger sized prawns of the size group 100-109mm. In the stake net catches in September 50-59mm size group predominated. The size gradually increased and in February the modal group was between 90-99mm. This gradually increased and in January most of the prawns were of 80-89mm size (Figs.13, 14)

M. monoceros. In the cast nets in August the size group 50-59mm size was predominant. From 30-39mm size in September there was a gradual increase till January when the predominant size group was 80-89mm. Then there was a gradual increase in size and in December the modal length range reached between 70-79mm. In the Chinese dip net catches in September the modal group belonged to the 40-49mm range. In October majority of them belonged to the 50-59mm group. In November and December 60-69mm size and

Fig.15. Size frequency distribution of *M. dobsoni* *P. indicus* and *M. monoceros* in the Chinese dip net catches during 1976-'77.



JUN
DEC
JUL
JAN
AUG
FEB
SEP
MAR
OCT
APR
NOV
MAY
PERCENTAGE FREQUENCY
0
10
20
30
40
20 30 40 50 60 70 80 90 100 110 120 30 40 50 60 70 80 90 100 110 120
LENGTH (MM)
CHINESE DIP NET
METAPENAEUS DOBSONI
PENAEUS INDICUS
METAPENAEUS MONOCEROS

FIG. 15

in January 70-79mm group predominated the catches (Figs. 13, 14 & 15).

The study of the length frequency distribution of the two sexes clearly shows that there is differential growth in the two sexes, females exhibiting a higher rate, as has been observed by Menon (1955 and 1957) and Kubo (1955).

<u>Sex ratio</u>

Gearwise percentages of males and females of different species obtained in the Kayamkulam lake and the Cochin backwaters for an year is presented in Table-4. It is evident that in the Kayamkulam lake the females predominated in the catches in the three different type of nets. A decline in the proportion of males was noticeable throughout the year in this area. In the Cochin backwaters the percentages of males and females did not vary significantly from each other but there was a slight dominance of females over males. All the three species obtained during the year exhibited almost the same sex composition.

(v) Discussion

The migration from the brackish water, the habitat of the juveniles to offshore breeding grounds and the

TABLE-4

Percentage sex composition of three species of penaeid prawns in three types of nets during 1976–'77 period.

Area	Name of species	Cast net		Stake net		Chinese dip net	
		Male	Female	Male	Female	Male	Female
Kayamkulam lake	*Penaeus indicus*	11.5	88.5	18.7	81.3	13.2	86.8
	Metapenaeus dobsoni	21.7	78.3	23.6	76.4	17.3	82.7
	M. monoceros	16.4	83.6	78.2	21.8	10.5	89.5
	Others	8.1	91.9	3.7	96.3	1.1	98.9
Cochin backwaters	*Penaeus indicus*	46.3	53.7	52.6	47.4	50.5	49.5
	Metapenaeus dobsoni	48.2	51.8	46.3	53.7	49.2	50.8
	M. monoceros	43.8	56.2	50.6	49.4	47.3	52.7
	others	47.4	52.6	48.3	51.7	46.2	53.8

recruitment of larvae and post larvae into the estuary have been recorded for a number of species of the genera *Penaeus* and *Metapenaeus*. *Penaeus setiferus* (Weymouth et al 1933, Williams 1955a, Ingle 1956), *P. duorarum* (Williams 1955a), *P. plebejus* (Dakin 1938, Racek 1955, 1957) *P. orientalis* (Lai 1955), *P. indicus* (Panikkar and Menon 1956), *Metapenaeus joyneri* (Yasuda 1956), *M. mastersii* (Yasuda 1956, Dall 1958), *M. ensis* (Yasuda 1956), *M. dobsoni* (Panikkar and Menon 1956), *M. macleayi* (Racek 1955, 1957), *M. monoceros* (George 1967) to name but a few. An almost complete absence of mature prawns in the estuarine catches may be attributed to a concerted departure of these populations towards the sea for breeding. The foregoing account of the larval as well as the commercial prawns in the two major estuaries in Kerala gives a picture of the occurrence and the abundance of the penaeid prawns in these areas. The results of the larval studies show the abundance of certain stages in the samples during certain periods. Both in the Kayamkulam lake and in the Cochin backwaters late larvae at the mysis stage constituted 53.6% and 57.7% respectively showing their predominance in the sample mainly during September to November. The presence of large numbers of larvae of later stages like mysis and the presence of earlier stages like nauplii and protozoea only in very small quantities indicate the absence of any spawning within the estuary. As Table-3 shows the percentages of the larvae obtained in the collections during low tide was significantly lower than the percentages of larvae obtained in the collections during high tide. It indicates that the movement of larvae was into and not out of the estuary.

When the abundance of prawn larvae in the plankton collections from the two estuaries are compared there are certain similarities as well as some differences. With regard to species variations and periodicity of occurrence and the size variations, there is similarity between the larval occurrence in the Kayamkulam lake and the Cochin backwaters. In the features like dominance of species, abundance of larvae and the peak season for the different species there are not much resemblances. In general, the total number of larvae obtained in a unit area in an year in the Kayamkulam lake was more than that of Cochin backwaters. Another aspect is that in the Kayamkulam lake post larvae of P. indicus dominated in the collections whereas in the Cochin backwaters post larvae of M. dobsoni dominated in the plankton samples.

It is obvious from the monthly observation that there is definite seasonal variation in the larval recruitment into the two estuaries although the larvae and post larvae occurred in the collections throughout the year. In the Kayamkulam waters only one peak period of larval occurrence ie. from September to January was observed. In the Cochin backwaters there were two peaks of occurrence for the prawn larvae, one from September to December and the other from February to May. In the monsoon season larval forms were scarce in both the areas. In the Cochin backwaters occurrence of larvae were at its maximum during post monsoon and pre monsoon season and in the Kayamkulam lake they were represented abundantly in the collections during the post monsoon season. In the latter area the reason for only one peak of larval occurrence can be attributed to the closing of the barmouth during the pre-monsoon season. More than one peak of occurrence of prawn larvae has been reported earlier by Wickstead (1958) in the Singapore strait. The penaeid mysis collected by Wickstead showed two peaks in June and November. Hall (1962) also reported the abundance of penaeid larvae in a Singapore pond during two peak periods ie. in March and December. George (1962) has observed two peaks of occurrence for the post larvae of P. indicus, one in November-December and the other in February-April in the Cochin area.

The abundance of penaeid prawn larvae in the estuaries gives an indication of the breeding season of adult prawns in the sea. As the larvae and post larvae occurred throughout the year in the backwaters in both the places the species seems to be continuous breeders. The peak of occurrence of the larvae denotes the peak of breeding season also. In the Kayamkulam waters as the period of larval occurrence is from September to December this period seems to be the principal breeding season. In the Cochin area breeding appears to take place both in September to December and from February to May. Panikkar and Menon (1956) indicated the existence of two breeding periods for P. indicus in the south west coast of India namely October to November and May to June. George (1962) recorded the spawning season of P. indicus from October to May with two peak spawning periods in November-December and February to August in the Cochin area. In the present studies also the findings obtained from the Cochin backwaters more or less agree with the findings of George (1962), because P. indicus were abundant in the area during the two periods, October to December and March to May. In the Kayamkulam lake the abundance of larvae was from October to January showing only one peak of occurrence. Menon (1952) while studying the breeding of the species M. dobsoni in the waters of Calicut on the S.W. Coast of India observed that many breeding females liberate their eggs in the inshore waters and he reported a spawning season from September to April with a peak from September to December or January. On the other hand, indirect evidences of the presence of post larvae in the backwaters of Cochin suggests that maximum numbers spawn from May to December. Similar indirect evidence of the presence of early post larvae in the Cochin backwaters and also the maturity conditions of adult females in the inshore fishery led George (1962) and George _et al_ (1968b) to conclude that the species breeds almost throughout the year with peaks in June to August and November-December. Rao (1968) observing the maturity conditions of the prawns also concluded that the species breed throughout the year, but he recorded one more peak spawning period, in April. The present observations on the post larval occurrence in the Cochin and Kayamkulam waters showed the presence of larval _M. dobsoni_ throughout the year with one peak in the Kayamkulam waters ie. from October to January and two peaks in the Cochin backwaters ie. from October to December and from February to May. These periods may denote the peaks of breeding of this species in the respective nearshore areas in the sea. In the case of _M. monoceros_ George (1962) studying the post larval abundance of the species in the backwaters of Cochin, recorded that the species breed throughout the year with two peaks, the first in July and August and the second in November and December. In the Gulf of Kutch area, the spawning season is from February to April (Srivastava, 1953). The present investigation on the occurrence of larvae in the Kayamkulam and Cochin backwaters gives an indication of their breeding period in the sea. In the Kayamkulam Lake they were abundant in December-January months, showing their breeding time during these months in the sea in this area. In the Cochin backwaters the two peaks of occurrence of _M. monoceros_ were from September to December and February to May showing these periods as their breeding time. Regarding one period of peak of occurrence in the Cochin backwaters ie. from September to December it agrees with the findings of George (1962).

Observations on the size distribution of post larvae of different species of penaeid prawns in the two areas studied do not show any significant variations. Post larvae above 8mm and below 12mm for _M. dobsoni_; above 11 and below 15mm for _P. indicus_ and 9mm and below 13mm for _M. monoceros_ were common in both the backwaters. Studies on the tidal effect, lunar effect and the diurnal effect on the occurrence of post larvae in the two areas show similarities. In both the lakes the occurrence and abundance of penaeid larvae are significantly influenced by the above factors. Larvae were abundant at high tide, new moon fortnight and in night (Table-3). Subramanyam and Ganapati (1971) reported that the full moon and new moon periods appeared to be equally good for the post larval recruitment in the Godavary estuarine system. This is different from the present observations. Hall (1962) has reported the abundance of prawn larvae in the hours of darkness than during day light. This is in agreement with the present findings.

Studies on the effect of environmental factors on the occurrence of prawn larvae in the two estuaries showed that salinity more than temperature is influencing the abundance in the backwaters. The larvae were numerous in the collections during September to December when moderate salinity and temperature prevails. During monsoon months ie. from June to August when salinity became very low in the water they were rarely represented in the collections. Eldred et al (1965), Christmas et al (1966), Temple and Fischer (1968) and Munro et al (1968) have reported higher abundance of Penaeid larvae as temperature of water increases. The variation of temperature in the present areas are not much and so the influence of temperature as such may not be significant.

The data on the commercial prawns taken from the three principal nets operated in the Kayamkulam lake and Cochin backwaters show that the prawn fishery of the above two areas is of considerable magnitude. Prawns are landed throughout the year with peak landings in October-January period in the Kayamkulam lake and from October to March in the Cochin backwaters. During June-July prawns were rare and the fishery was suspended for some time.

The Kayamkulam lake is very rich in prawn fauna. The prawn fishery of this area is unique in P. indicus contributing the major portion of the fishery ie. to well over 54% of the fishery. Further, an observation of the data shows that the fluctuations in the total backwater prawn landings are entirely dependent on the success of P. indicus fishery in this area. In cast nets and chinese dip nets this species was contributing 58% and 64% respectively of the total prawn catches. The fishery of this species shows a peak in October-January period. In the Cochin backwaters M. dobsoni constitutes to over 55% of the total catches, 64% of the stake net catches in this area was constituted by M. dobsoni. This species occurred throughout the year with a peak in October to December period. In the Kayamkulam lake M. dobsoni was the next abundant species in the commercial catches obtained mainly by stake nets and in the Cochin backwaters *P. indicus* ranked second in abundance obtained mainly by cast nets and chinese dip nets. The other species which were caught in small quantities were *M. monoceros*, *P. monodon* and *M. affinis* respectively in the order of their abundance. In the Kayamkulam lake *M. monoceros* forms an insignificant component of the prawn fishery unlike in the Cochin backwaters.

The size composition of the commercial catches of *P. indicus*, *M. dobsoni* and *M. monoceros* obtained by different nets show some differences. When the catches of the three nets were compared, prawns of bigger sizes were mainly caught by cast net and those of small sizes by stake net. From the length frequency distribution (Figs. 13, 14 and 15) it is evident that prawns of more than 80mm are rare in stake net catches and prawns below 50mm a length are rare in cast net and chinese dip nets. Because of these size differences the large sized species *P. indicus* were predominant in cast net and smaller sized *M. dobsoni* were predominant in stake nets. In chinese dip net both the large sized and small sized ones were more or less equally distributed, the abundance depending on the species distribution of the area. As shown in Figs.13, 14 and 15 the size of the commercial prawns ranges in the backwaters of Kayamkulam and Cochin between 30mm-90mm for M. dobsoni, 40mm and 120mm for P. indicus and 30mm and 100mm for M. monoceros. Mohammed and Rao (1971) stated that M. monoceros migrates to the inshore waters from Cochin backwaters at about a length of 85mm. On the contrary, George (1959) is of the opinion that the emigration commences after it reaches a length of about 100mm in the Cochin backwaters. The present observations of the size variations of M. monoceros in the Kayamkulam lake show the presence of only a few numbers of prawns belonging to 91-100mm group. The size obtained by M. dobsoni in the Kayamkulam lake and Cochin backwaters as observed in the present investigation is below 90mm. According to Menon and Raman (1962) the maximum size obtained belong to 91-100mm group, the proportion of which never exceeded 3% in any month in the Cochin backwaters. As the data show P. indicus grows upto 120mm in the Kayamkulam and Cochin backwaters. This is in agreement with the findings of George (1962, 1969), Menon (1965), Menon and Raman (1962). Hall (1962) observed the maximum size of the species in the Singaproe prawn ponds as 27mm carapace length. This is about 113.4m total length as per the conversion rate given by him. From the above it is apparent that the entire backwater fishery is supported by juveniles belonging to the commercially exploited species in the offshore waters of the region. The occurrence of the juveniles in the backwaters throughout the year indicates that spawning activity of many of the commercial species is protracted. It is also evident from the size frequency distribution that the size composition of the different species varied considerably.

The present investigations show that the abundance and occurrence of prawns in the Kayamkulam and Cochin backwaters are influenced by salinity, and temperature to a smaller extent. Optimum catch was from October to January or February in the Kayamkulam lake and from October to March in the Cochin backwaters. This was during the post monsoon season and in the early part of the pre-monsoon season when salinity varied between 28‰ and 30‰, and 31‰ and 33‰, and the temperature between 29.9°C and 31.0°C, and 30.0°C and 31.5°C respectively. In monsoon months especially during June-July the salinity becomes lowered sometimes very near to fresh water due to the rains and influx of fresh water from the rivers. During this time prawns were scarce. The temperature also becomes lowered sometimes to 26°C. The fluctuations in the prawn fishery are related to various factors by different workers. Gunter and Hilderbrand (1954), Thompson (1955), Menon and Raman (1962) are of the opinion that the rainfall of the corresponding year influences the prawn fishery to a great extent, while Subramanyam (1966) found that the magnitude of *Palaemon tenuipes* fishery of the Godavary estuary is directly related to the annual river discharges into the estuary. Baxter (1962), George (1962) and Subramanyam (1966) are of the opinion that the fishery of penaeid species is influenced to a great extent by the recruitment into the estuary. Slack Smith (1967) studying the prawn fishery of Sharks Bay, Western Australia, states that the prawn fishery is usually on one year old stocks and consequently violent fluctuations in recruitment are followed by similar fluctuations in the catch. In the present study it is found that the seasonal variations of the prawns are due to different factors. Salinity variations may affect the abundance of prawns and hence the prawn fishery is indirectly influenced by rainfall. Both the studies on salinity tolerance of different species of penaeid prawns in the laboratory conditions by the author (Part-II) showed that all these species can tolerate a salinity range of 3‰ - 43‰. Also studies on temperature tolerance of different species in the laboratory (Part-II) showed that they can survive upto 35°C. As temperature in the natural habitat never comes above 35°C and below 25°C this factor alone cannot affect the occurrence and abundance of the prawns in the estuaries. So it appears that a combination of different environmental factors and the availability of food in the area together influences the prawn fishery. Another factor which may cause the seasonal fluctuations in the backwater is the fluctuation in the recruitment of larvae and post larvae into the estuary because the present studies showed that there were peaks of recruitment of larvae and post larvae into the estuaries.

Generally the sex-ratio of estuarine prawns is more or less uniform (Menon, 1957; George, 1959; Rajalakshmi, 1961). In the present studies in the Kayamkulam lake females of P. indicus, M. dobsoni, M. monoceros and others significantly outnumbered the males and in the Cochin backwaters both males and females were more or less uniformly distributed throughout the year. No marked seasonal variations in the sex were observed. On the contrary Racek (1959) found that the sex ratio of Penaeus plebejus, Metapenaeus macleayi and M. mastersii from the estuarine areas in the central and northern coasts of New South Wales were more or less equal during Spring and Summer months and showed a predominant female ratio during autumn and winter months. Eldred *et al* (1961) observed that the sex ratio in *Penaeus duorarum* is predominantly female for 8 months in an year in Florida waters. The present observations on *P. indicus*, *M. dobsoni* and *M. monoceros* in the Kayamkulam lake agree with the above report by Eldred *et al* (1961). There were no significant variations in the sex ratio of prawns obtained by different nets such as cast net, stake net and chinese dip net. Another feature which is noted in the catches from the two estuaries is that the largest prawns recorded were always females and the males seldom appeared to reach that length. This may be because of the different tolerance capacity for varying salinities. Probably the males are less tolerant to low salinities and hence move seaward to high saline waters at a smaller size than the females (Lindner and Anderson, 1956; Dall, 1958).

PART II

TOLERANCE OF PRAWNS TO SALINITY AND TEMPERATURE AND THE EFFECT OF SALINITY ON GROWTH

In nature, aquatic animals are subjected to a variety of environmental changes, and they respond to the total resulting stimulus or stress rather than a single environmental factor . Ecological parameters like salinity and temperature and their fluctuations are of particular significance to those organisms like penaeid prawns, which spend certain portions of their life cycle in the open sea where salinity and temperature are relatively stable; and other portions in the estuarine area where both these parameters may change drastically. The variations in the salinity and temperature in an area may also affect the growth of animals.

Reviews on the effects of salinity on marine organism are available in the works of Beadle (1957), Black (1957), Pearse and Gunter (1957), Robertson (1957, 1960), Moore (1958), Remane and Schlieper (1958), Nicol (1960), Prosser and Brown (1961), Lockwood (1967), Newell (1970), Kinne (1971) and Vernberg and Vernberg (1972) which show that studies on this aspect on penaeid prawns are meagre. Likewise the majority of the studies on temperature tolerance and lethal temperatures of benthic animals reviewed by Gunter (1957), Kinne (1960), Newell (1966) are concerned with rocky shore species. Studies on the physiological mechanism and responses of prawns which are closely linked with their ecology have a significant role to play in the development of prawn fisheries.

Immature or juvenile Penaeus indicus, Metapenaeus dobsoni and M. monoceros are abundant in the Cochin backwaters. Hydrographical studies in and around Cochin from where the specimens for the present study were collected have shown that the temperature variations are within the limits of 25-32°C while salinity varied widely from that of nearly fresh water to 33.7‰ during the time of investigation. Previous studies (Panikkar, 1940, 1941; Panikkar and Viswanathan 1948; Menon 1951) have shown that all the above three species are euryhaline. In tropical waters the change of temperature of water is limited, and very rarely the temperature in the surface waters fall below 25°C. The normal range of 25°C to 35°C temperature is experienced by the species in the estuarine habitat.

The present study reports on the results which were obtained from the laboratory experiments done on three common penaeid prawns from the Cochin backwaters ie. Penaeus indicus, Metapenaeus dobsoni and Metapenaeus monoceros to study their responses to normal as well as various other salinities, the temperature tolerance and survial patterns of both post larvae and juveniles to elevated temperatures in different salinities and the effect of varying salinities on their growth.

(i) Materials and Methods

The prawns used for the salinity, temperature and growth experiments were collected from the Ernakulam channel, 1km south of Cochin barmouth. The specimens collected from the field were brought to the laboratory and transferred to different stocking tanks representing water of three acclimation salinities ie. 5‰, 15‰ and 30‰ for salinity and growth experiments and 10‰, 20‰ and 30‰ for temperature experiments. The acclimation period was for 10 days. The stock tanks were kept at room temperature ie. 29.0 (± 1°C). The water in the tanks was continuously filtered and aerated for 3 hours every day using the device described by Cheriyan (1967). During the storage time and also during the salinity and growth experiments the juveniles were fed on minced clam, boiled egg and cooked fish meat and post larvae were maintained on a diet of nauplii of Artemia and algal fragments. To avoid pollution, unfinished food particles, faecal waste and other substances that settle to the bottom were removed by siphoning twice a day. Various dilutions of sea water were prepared in the laboratory for different experiments. Salinities below 30‰ were prepared by diluting sea water with distilled water and hyper saline media were prepared by dissolving 'sea salt' in sea water. The salt was obtained by evaporating sea water from the respective habitats of prawns. Salinities were determined on duplicate samples by titration against silver nitrate solution using the formula of Knudsen (1901). The animals m were washed once with the water of the same salinity to which they were to be transferred, prior to the beginning of each experiment. An animal was considered dead when movement of any part could not be detected upon close examination. 'Dead' prawns do not recover from salinity deaths when they were returned to the appropriate acclimation conditions. Thorough inspection of each animal was necessary before death could be determined in low salinity experiments since prawns that are very weak and appear to be dead from the effects of the low salinity can recover completely within one or two hours when returned to acclimation conditions.

Juvenile prawns of the size range 40mm to 110mm in the case of P. indicus, 30mm to 80mm in the case of M.

dobsoni and 35mm to 90mm in the case of M. monoceros were used for the salinity tolerance experiments. For each salinity 10 litres of the water were kept in a glass tank and 10 animals of almost the same size were transferred to each salinity. The temperature was maintained at 29.0°C (±1°C). Experiments were conducted separately for each species. The animals were observed at short intervals and the duration of each experiment was for 10 days. The range of salinity causing mortality was identified by observing the trend in survival during the whole duration of the experiment. Those salinities which caused the death of atleast 50% of the animals during the period of the experiment have been termed lethal salinities. To avoid the effect of any natural death the following formula by Lance (1963) has been used in the calculation of % survival values.

$$\text{Per cent survival after exposure to various salinities for 10 days} \; \Big\} \; a_1/b_2 x b_1/a_2 \times 100$$

a_1 = the number of survivors in the experimental medium

a_2 = the number of animals initially placed in experimental medium

b_1 = the number of survivors in the control (acclimation medium

b_2 = the number of animals initially placed in the control (acclimation medium)

Each experiment was repeated twice and the average values were taken for the results.

Both post larvae having total length from 10mm to 20mm and juveniles of 35mm to 90mm of P. indicus, M. dobsoni and M. monoceros which were acclimated in 10‰S, 20‰S and 30‰S at room temperature 29°C (±1°C) were used for the temperature tolerance experiments. To know the tolerance capacity to elevated temperatures the test temperatures used were every 1.0°C from 30.0°C to 38.0°C and the upper lethal limits of the animals were calculated from the graphical data following Mcleese (1956). Temperature tests were performed in 3 litre glass beakers. The three test salinities used for experiments were 10‰, 20‰ and 30‰. The test beakers were filled with sea water of the required salinities and each beaker was kept in a thermostatically controlled water bath. Water in the beaker was kept mixed and saturated with O_2 by bubbling air through air stone. First the water was heated to 30°C and then the larvae or juveniles of prawns were transferred directly from the acclimation tanks to the test beakers in the water bath. The number of animals used in each test medium (salinity) at a time was 10 in the case of post larvae and 5 in the case of juveniles, of the same size group. Experiments were run for 24 hours and observations were made throughout the period. At the end of each observation dead animals were removed and measured and the condition of the survivors was recorded. Similarly experiments were conducted for noting the survival rate at higher temperatures upto 38°C in three different salinities mentioned above. Fry (1947) defined the upper incipient lethal temperature as that temperature above which 50% of the population cannot live indefinitely. Following the authors Black (1957) and Mcleese (1956) the lethal temperature in this study was taken as that temperature at which 50% of the animals died and 50% survived during 24 hours of exposure. Each experiment was repeated thrice and the average values were taken for the results.

Growth experiments were conducted in the laboratory, one set for a period of four weeks and another set for a period of one year. The post larvae and juveniles of P. indicus, M. dobsoni and M. monoceros which were taken from the acclimation tanks were introduced in separate 20 gallon glass tanks. The different salinities used for the growth study were 5‰, 10‰, 15‰, 20‰, 25‰, 30‰ and 35‰ for both post larvae and juveniles. 100 numbers of post larvae and 30 numbers of juveniles of each species were placed separately in each tank. Initial measurements in each experiment were obtained from samples of 10 post larval shrimps, and 5 juveniles withdrawn from the source population. After excess water on the body was removed by wiping with a blotting paper the length of each specimen was measured to the nearest 0.5mm (distance from the tip of the rostrum to the tip of telson) and its weight determined in mg. All the individuals were preserved for later studies. Subsequently samples from each experimental tank were similarly treated after being withdrawn at approximately 7 days' intervals. Both the largest and smallest specimens in each tank at each sampling period were included in order to determine size ranges, the remaining numbers were selected at random. After four weeks the surviving animals in each tank were taken out. After determining their length and weight they were preserved. Equal amount of food was given to the different species in each tank. The surviving post larvae which were acclimated in 30%S were kept in the tank in different salinity media (20‰, 25‰, 30‰, 35‰) for a period of one year to study the influence of salinity on the growth of these animals for a long term period.

(ii) Studies on salinity tolerance

1.1 Tolerance of *P. indicus* acclimated in 5‰ S

After acclimation in 5‰ S, animals were placed in salinities 0‰ (distilled water), 1‰, 2‰, 3‰, 4‰, 10‰, 15‰, 20‰, 25‰, 30‰, 35‰, 40‰, 41‰, 42‰, 43‰, 44‰, 45‰ and 50‰. Survival was 100% in salinities 15‰ to 30‰. Survival was nil in salinities 0‰, 44‰, 45‰ and 50‰. The lower and higher lethal salinities were found to be 3‰ and 40‰ respectively (Table-5).

1.2 Tolerance of *P. indicus* acclimated in 15‰ S.

Those animals which were acclimated in 15‰ S were transferred directly to salinities 0‰, 1‰, 2‰, 3‰, 4‰, 5‰, 10‰, 20‰, 25‰, 30‰, 35‰, 40‰, 41‰, 42‰, 43‰, 44‰, 45‰ and 50‰. All animals survived in salinities 10‰ to 35‰. Survival was nil in the media having salinities 0‰, 1‰, 45‰ and 50‰. The lower lethal salinity was found to be 3‰ and the higher to be 41‰ (Table-6).

1.3 Tolerance of *P. indicus* acclimated in 30‰ S.

Animals after acclimation in 30‰ S were abruptly transferred to various media having salinities 0‰, 1‰, 2‰, 3‰, 4‰, 5‰, 10‰, 15‰, 20‰, 25‰, 35‰, 40‰, 41‰, 42‰, 43‰, 44‰, 45‰ and 50‰. 100% survival was observed in 20‰-35‰ S. Survival was nil in salinities 0‰, 1‰, 45‰ and 50‰. 3‰ and 44‰ were found to be the respective lower and higher lethal salinities (Table-7)

2.1 Tolerance of M. dobsoni acclimated in 5‰ S.

Animals acclimated in 5‰ S were transferred to salinities 0‰, 1‰, 2‰, 3‰, 4‰, 10‰, 15‰, 20‰, 25‰, 30‰, 35‰, 40‰, 41‰, 42‰, 43‰, 44‰, 45‰ and 50‰ S. Survival was 100% in salinities 10‰-25‰ and nil in salinities 0‰, 42‰-50‰. 2‰ and 40‰ were found to be the lower and higher lethal salinities respectively (Table-8).

2.2 Tolerance of M. dobsoni acclimated in 15‰ S.

After acclimation in 15‰ S, animals were introduced in 0‰, 1‰, 2‰, 3‰, 4‰, 5‰, 10‰, 20‰, 25‰, 30‰, 35‰, 40‰, 41‰, 42‰, 43‰, 44‰, 45‰ and 50‰ S. 100% survival was observed in salinities 10‰ to 30‰. There was no survival in 0‰, 44‰, 45‰ and 50‰ S. The lower lethal salinity was found to be 3‰ while the higher 42‰ (Table-9)

2.3 Tolerance of M. dobsoni acclimated in 30‰ S.

The animals after acclimation in 30‰ S were directly transferred to salinities 0‰, 1‰, 2‰, 3‰, 4‰, 5‰, 10‰, 15‰, 20‰, 25‰, 35‰, 40‰, 41‰, 42‰, 43‰, 44‰, 45‰ and 50‰. No mortality occurred in salinities 15‰ to 35‰ whereas 100% mortality occurred in salinities 0‰, 1‰ and 45-50‰. The lower and higher lethal salinities were 3‰ and 43‰ respectively (Table-10)

3.1 Tolerance of *M. monoceros* acclimated in 5‰ S.

The animals after acclimated in 5‰ S were placed in salinities 0‰, 1‰, 2‰, 3‰, 4‰, 10‰, 15‰, 20‰, 25‰, 30‰, 35‰, 40‰, 41‰, 42‰, 43‰, 44‰, 45‰ and 50‰. Survival was 100% in salinities 5 to 30‰. In 0‰ S, 45‰ S and 50‰ S survival was nil The lower and higher lethal salinities were found to be 2‰ and 42‰ respectively (Table-11)

3.2 Tolerance of *M. monoceros* acclimated in 15‰ S.

Metapenaeus monoceros acclimated in 15‰ S were transferred to various media having salinities 0‰, 1‰, 2‰, 3‰, 4‰, 5‰, 10‰, 20‰, 25‰, 30‰, 35‰, 40‰, 41‰, 42‰, 43‰, 44‰, 45‰ and 50‰ S. 100% survival was observed in salinities 5-30‰. Survival was nil in salinities 0‰, 45‰ and 50‰ S. 2‰ and 41‰ were found to be the lower and higher lethal salinities respectively (Table-12).

Table 5

Per cent survival of _P. indicus_ at time intervals (days) when transferred to different salinities after acclimation in 5‰S.

Days	Salinity ‰ 0	1	2	3	4	10	15–30	35	40	41	42	43	44–50
1	0	60	80	90	100	100	100	100	80	90	60	70	0
2	0	60	40	90	100	100	100	100	80	90	60	70	0
3	0	30	20	40	100	100	100	100	80	70	60	40	0
4	0	20	20	30	90	100	100	100	70	60	50	40	0
5	0	10	20	20	80	90	100	100	70	60	50	20	0
6	0	10	20	20	80	90	100	100	60	60	50	20	0
7	0	10	20	20	70	80	100	80	40	40	20	20	0
8	0	10	10	20	60	80	100	80	40	40	20	10	0
9	0	10	10	20	60	80	100	80	30	20	20	10	0
10	0	10	10	20	60	80	100	70	30	20	10	10	0

TABLE-6

Per cent survival of *P. indicus* at time intervals (days) when transferred to different salinities after acclimation in 15‰ S.

Days	Salinity ‰ 0–1	2	3	4	5	10–35	40	41	42	43	44	45–50
1	0	60	80	100	100	100	100	100	60	50	50	0
2	0	60	70	100	100	100	100	100	60	50	50	0
3	0	60	70	100	100	100	100	100	60	50	40	0
4	0	50	70	80	100	100	90	90	50	40	40	0
5	0	50	50	60	100	100	90	80	50	40	40	0
6	0	50	40	60	90	100	90	80	40	30	30	0
7	0	40	30	70	90	100	90	70	30	30	30	0
8	0	40	30	70	80	100	80	40	20	20	20	0
9	0	20	30	60	70	100	70	40	20	20	10	0
10	0	20	30	60	70	100	70	40	20	10	10	0

TABLE-7

Per cent survival of P. *indicus* at time intervals (days) when transferred to different salinities after acclimation in 30‰S.

Days	Salinity ‰													
	0–1	2	3	4	5	10	15	20–35	40	41	42	43	44	45–50
1	0	50	70	100	100	100	100	100	100	100	100	100	80	0
2	0	50	70	90	100	100	100	100	100	100	100	100	80	0
3	0	40	70	80	100	100	100	100	100	80	100	100	80	0
4	0	40	50	60	100	100	100	100	100	80	100	100	70	0
5	0	40	50	60	90	100	100	100	80	80	90	100	70	0
6	0	30	50	60	90	100	100	100	80	80	90	90	50	0
7	0	20	40	60	90	100	100	100	80	80	80	80	50	0
8	0	20	40	60	80	100	90	100	80	80	80	70	40	0
9	0	10	20	60	80	80	90	100	80	60	80	70	30	0
10	0	10	20	60	80	80	90	100	80	60	70	70	30	0

TABLE-8

Per cent survival of *M. dobsoni* at time intervals (days) when transferred to different salinities after acclimation in 5‰ S.

	Salinity ‰										
Days	0	1	2	3	4	10–25	30	35	40	41	42–50
1	0	100	90	100	100	100	100	100	90	80	0
2	0	100	90	100	100	100	100	100	90	80	0
3	0	100	90	90	100	100	100	100	80	70	0
4	0	80	80	70	100	100	100	100	80	70	0
5	0	80	70	70	100	100	100	100	70	50	0
6	0	80	60	70	100	100	100	100	60	50	0
7	0	80	60	60	100	100	100	90	50	40	0
8	0	80	60	60	100	100	80	90	40	30	0
9	0	70	50	60	90	100	80	80	30	20	0
10	0	40	40	60	90	100	70	80	30	10	0

TABLE-9

Per cent survival of *M. dobsoni* at time intervals (days) when transferred to different salinities after acclimation in 15‰

Days	Salinity ‰												
	0	1	2	3	4	5	10–30	35	40	41	42	43	44–50
1	0	80	80	90	100	100	100	100	100	100	80	60	0
2	0	70	80	90	100	100	100	100	100	100	80	50	0
3	0	70	80	90	100	100	100	100	90	100	70	50	0
4	0	60	80	70	90	100	100	100	90	90	60	40	0
5	0	40	70	70	90	100	100	100	90	90	50	40	0
6	0	40	60	50	80	90	100	100	90	90	50	40	0
7	0	40	50	50	80	90	100	100	90	90	40	40	0
8	0	20	50	50	70	90	100	90	80	80	40	30	0
9	0	20	40	40	60	80	100	80	80	80	40	30	0
10	0	20	20	30	60	80	100	70	80	70	40	20	0

TABLE-10

Per cent survival of *M. dobsoni* at time intervals (days) when transferred to different salinities after acclimation in 30‰ S.

	Salinity ‰											
Days	0–1	2	3	4	5	10	15–35	40	41	42	43	44	45–50
1	0	70	90	100	100	100	100	100	100	100	100	60	0
2	0	70	60	100	100	100	100	100	100	100	100	60	0
3	0	70	60	100	100	100	100	100	100	100	90	50	0
4	0	50	50	80	100	100	100	100	90	100	90	40	0
5	0	40	50	80	90	100	100	100	90	100	80	40	0
6	0	40	50	80	90	80	100	90	90	90	80	30	0
7	0	40	50	70	80	80	100	90	90	90	70	20	0
8	0	30	50	70	80	80	100	90	80	90	60	20	0
9	0	30	40	70	80	80	100	90	80	80	50	10	0
10	0	20	40	70	80	80	100	90	70	80	40	10	0

Per cent survival of M. *monoceros* at time intervals (days) when transferred to different salinities after acclimation in 5‰ S.

Days	Salinity ‰ 0	1	2	3	4	5–30	35	40	41	42	43	44	45–50
1	0	100	100	100	100	100	100	100	100	100	100	60	0
2	0	100	100	100	100	100	100	100	100	100	90	60	0
3	0	90	100	100	100	100	90	100	100	90	80	40	0
4	0	90	80	80	100	100	90	100	90	90	60	30	0
5	0	80	70	80	100	100	90	100	90	80	40	20	0
6	0	70	70	80	80	100	90	90	80	70	40	10	0
7	0	70	60	80	80	100	80	90	80	60	20	10	0
8	0	60	60	80	80	100	80	90	80	50	20	10	0
9	0	50	50	80	80	100	70	80	80	40	20	10	0
10	0	40	40	70	80	100	70	80	80	30	10	10	0

TABLE-12

Per cent survival of *M. monoceros* at time intervals (days) when transferred to different salinities after acclimation in 15‰ S.

	Salinity ‰												
Days	0	1	2	3	4	5–30	35	40	41	42	43	44	45–50
1	0	100	90	100	100	100	100	100	90	100	80	70	0
2	0	90	90	90	90	100	100	100	90	100	70	70	0
3	0	80	80	90	90	100	100	90	90	80	70	60	0
4	0	70	70	90	80	100	90	90	90	80	60	50	0
5	0	70	60	70	80	100	90	80	90	70	40	50	0
6	0	70	60	70	60	100	90	80	80	70	40	50	0
7	0	60	60	70	60	100	90	80	80	50	40	40	0
8	0	40	50	60	60	100	90	80	80	40	30	20	0
9	0	40	50	60	60	100	80	80	80	40	30	10	0
10	0	30	40	60	60	100	70	60	30	30	20	10	0

TABLE-13

Per cent survival of *M. monoceros* at time intervals (days) when transferred to different salinities after acclimation in 30‰ S.

Days	Salinity ‰ 0	1	2	3	4	5	10–35	40	41	42	43	44	45–50
1	0	90	100	100	100	100	100	100	100	100	90	80	0
2	0	70	90	90	100	100	100	100	100	100	90	80	0
3	0	70	90	80	100	100	100	100	100	100	90	70	0
4	0	60	90	80	90	100	100	90	100	90	80	70	0
5	0	40	70	70	90	100	100	90	80	80	80	70	0
6	0	30	70	70	80	100	100	90	80	80	70	60	0
7	0	20	60	70	80	90	100	90	70	80	50	60	0
8	0	10	50	70	80	90	100	90	70	80	50	40	0
9	0	10	50	60	70	90	100	90	70	70	50	30	0
10	0	10	40	40	70	90	100	90	70	70	30	20	0

3.3 Tolerance of M. monoceros acclimated in 30‰ S.

Animals acclimated in 30‰ S were directly transferred to 0‰, 1‰, 2‰, 3‰, 4‰, 5‰, 10‰, 15‰, 20‰, 25‰, 35‰, 40‰, 41‰, 42‰, 43‰, 44‰, 45‰ and 50‰ salinities. 100% survival occurred in salinities 10‰-35‰. 100% mortality was observed in 0% and 45-50‰ S. The respective lower and higher lethal salinities were found to be 3‰ and 43‰ (Table-13).

(iii) Studies on the temperature tolerance

Temperature tolerance of P. indicus in 10‰ S.

After acclimation in 10‰ S at 29.0°C the animals were directly introduced in 10% S media and tested to temperatures of every 1.0°C from 30.0°C to 38.0°C. 100% post larvae survived at 30.0°C. All the juveniles in 30.0°C and 31.0°C also lived for 24 hours. Survival was nil at temperatures 36.0°C to 38.0°C for post larvae and at 37.0°C-38°C for juveniles. The upper lethal temperature for post larvae was found to be 33.6°C and that for juveniles as 34.2°C. (Figs.16 & 17).

Temperature tolerance of P. indicus in 20‰ S.

Animals after acclimation in 20‰ S at 29.0°C were directly transferred to water having 20‰ S and

Fig.16 to 21. Percentage mortality in various test temperatures at 24 hours for post larvae and juveniles of _P. indicus_ (Fifty per cent lethal temperatures are shown in each curve)

Fig.16 Percentage mortality of post larvae of _P. indicus_ acclimated in 10‰ S.

Fig.17 Percentage mortality of the juveniles of _P. indicus_ acclimated in 10‰ S.

Fig.18 Percentage mortality of post larvae of _P. indicus_ acclimated in 20‰ S.

Fig.19 Percentage mortality of juveniles of _P. indicus_, acclimated in 20‰ S.

Fig.20 Percentage mortality of the post larvae of _P. indicus_ acclimated in 30‰ S.

Fig.21. Percentage mortality of the juveniles of _P. indicus_ acclimated in 30‰ S.

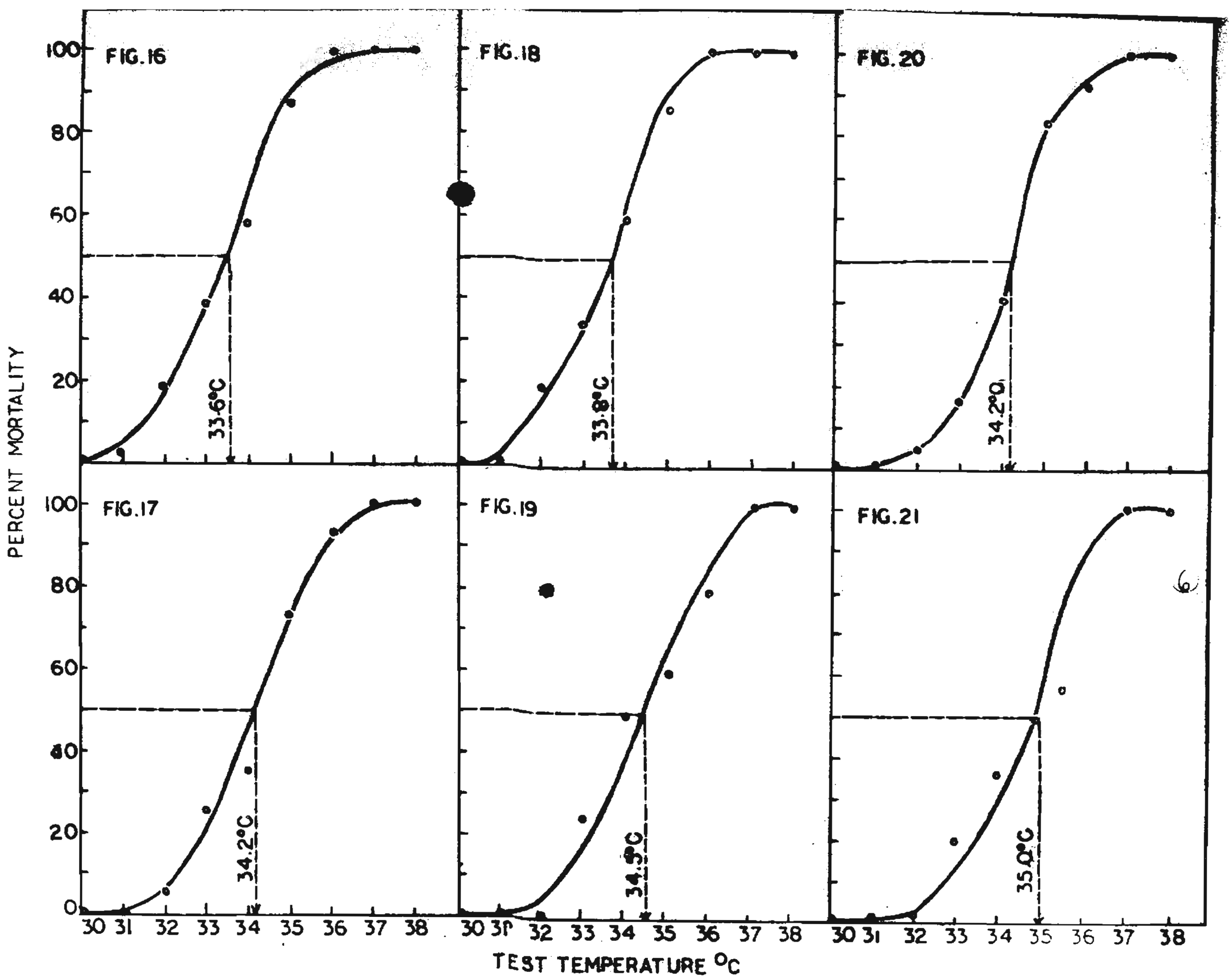


FIG. 16
FIG. 17
FIG. 18
FIG. 19
FIG. 20
FIG. 21
33.6°C
34.2°C
33.8°C
34.5°C
34.2°C
35.0°C
PERCENT MORTALITY
TEST TEMPERATURE °C

tested to temperatures of every 1.0°C from 30.0°C to 38.0°C. For post larval prawns 100% survival was noticed at 30.0°C to 31.0°C and for juveniles 100% survival was noticed in 30.0°C to 32.0°C. At 36.0°C-38.0°C and at 37.0°C and 38.0°C 100% mortality observed respectively for both post larvae and juveniles. The upper lethal temperature was found to be 33.8°C for the post larvae and 34.5°C for the juveniles (Figs. 18 and 19).

Temperature tolerance of *P. indicus* in 30‰ S.

P. indicus acclimated in 30‰ S at 29.0°C were abruptly transferred to 30‰ S media and tested to temperatures of every 1.0°C from 30.0°C to 38.0°C. No mortality occurred at 30.0°C and 31.0°C in the case of post larvae and at 30.0°C-32.0°C in the case of juveniles. For both post larvae and juveniles 100% mortality occurred in 37.0°C. The upper lethal temperature was found to be 34.2°C and 35.0°C for post larvae and juveniles respectively. (Figs. 20 and 21)

Temperature tolerance of *Metapenaeus dobsoni* in 10‰ S.

Animals acclimated in 10‰ S at 29°C were introduced in 10‰ S media and tested to temperatures of every 1.0°C

Figs.22 to 27. Percentage mortality in various test temperatures at 24 hours for the post larvae and juveniles of _M. dobsoni_ (Fifty per cent lethal temperatures are shown on each curve).

Fig.22. Percentage mortality of the post larvae of _M. dobsoni_ acclimated in 10‰ S.

Fig.23. Percentage mortality of the juveniles of _M. dobsoni_ acclimated in 10‰ S.

Fig.24. Percentage mortality of the post larvae of _M. dobsoni_ acclimated in 20‰ S.

Fig.25. Percentage mortality of the juveniles of _M. dobsoni_ acclimated in 20‰ S.

Fig.26. Percentage mortality of the post larvae of _M. dobsoni_ acclimated in 30‰ S.

Fig.27. Percentage mortality of the juveniles of _M. dobsoni_ acclimated in 30‰ S.

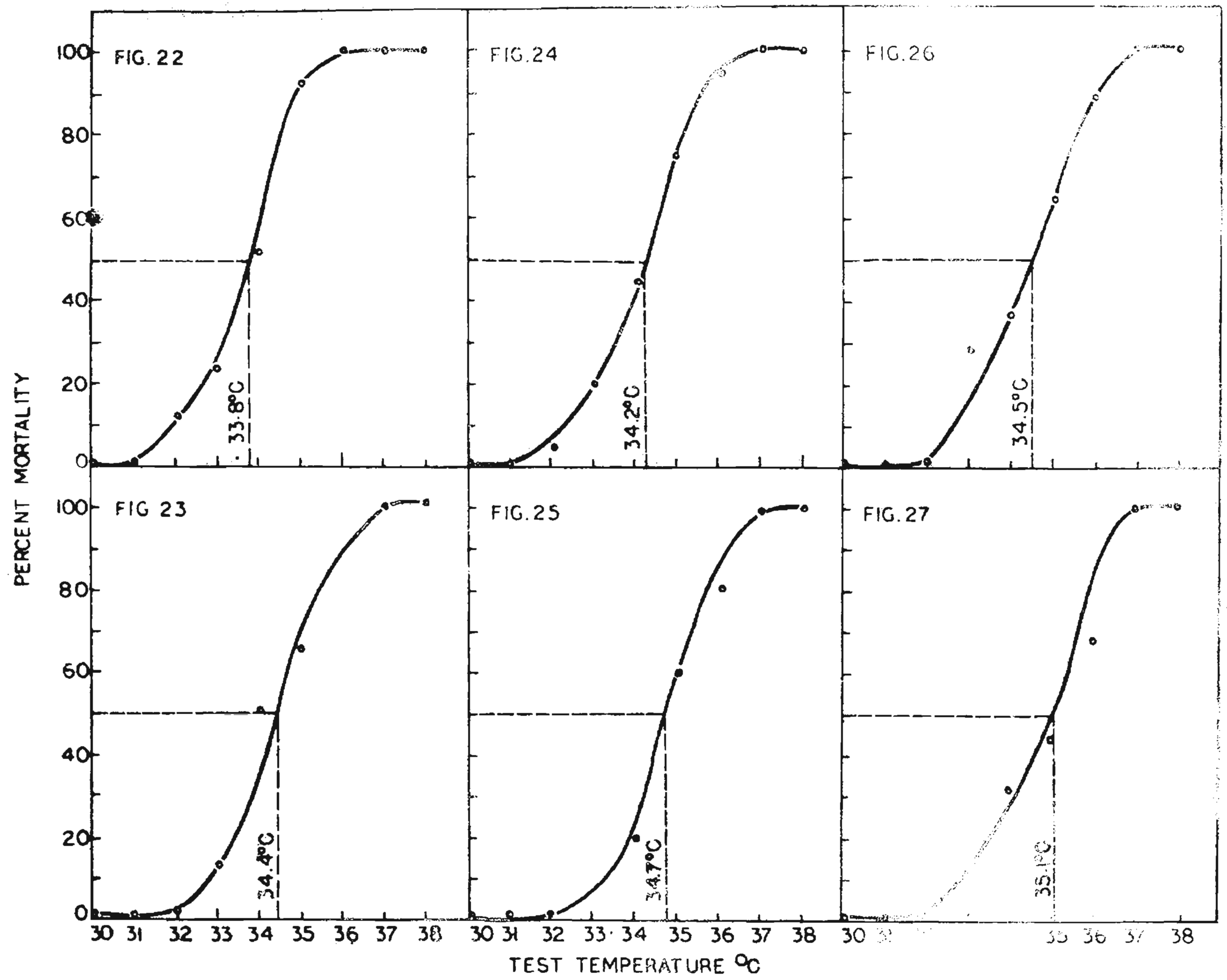


FIG. 22
FIG 23
FIG. 24
FIG. 25
FIG. 26
FIG. 27
33.8°C
34.4°C
34.2°C
34.7°C
34.5°C
35.1°C
PERCENT MORTALITY
TEST TEMPERATURE °C

from 30.0°C to 38.0°C. 100% mortality occurred at 36°C onwards for post larval prawns. 100% mortality occurred for juveniles at 37°C and all the post larvae survived from 30.0°C to 31.0°C and the juveniles at temperatures from 30.0°C to 32.0°C. The upper lethal temperatures for post larvae and juveniles were found to be 33.8°C and 34.4°C respectively (Figs. 22 and 23).

Temperature tolerance of *M. dobsoni* in 20‰ S.

After acclimation in 20‰ S at 29°C the animals were directly transferred to media having salinity 20‰ and tested to temperatures of every 1.0°C from 30.0°C to 38.0°C. Survival was 100% for post larvae in temperatures 30°C to 31°C and 30°C to 32.0°C for juveniles. At 37.0°C to 38.0°C 100% mortality occurred for both post larvae and juveniles. The upper lethal temperatures were found to be 34.2°C and 34.7°C respectively for post larvae and juveniles (Figs.24 and 25.)

Temperature tolerance of *M. dobsoni* in 30‰ S.

Animals were directly transferred from 30‰ S at 29.0°C to 30‰ S media and tested to temperature of every 1.0°C from 30.0°C to 38.0°C. No mortality occurred at 30.0°C to 32.0°C for both post larvae and juveniles.

Figs, 28 to 33 Percentage mortality in various test temperatures at 24 hours for the post larvae and juveniles of _M. monoceros_ (Fifty per cent lethal temperatures are shown on each curve)

Fig. 28. Percentage mortality of the post larvae of _M. monoceros_ acclimated in 10‰ S.

Fig. 29. Percentage mortality of the juveniles of _M. monoceros_ acclimated in 10‰ S.

Fig. 30. Percentage mortality of the post larvae of _M. monoceros_ acclimated in 20‰ S.

Fig. 31. Percentage mortality of the juveniles of _M. monoceros_ acclimated in 20‰ S.

Fig. 32. Percentage mortality of the post larvae of _M. monoceros_ acclimated in 30‰ S.

Fig. 33. Percentage mortality of the juveniles of _M. monoceros_ acclimated in 30‰ S.

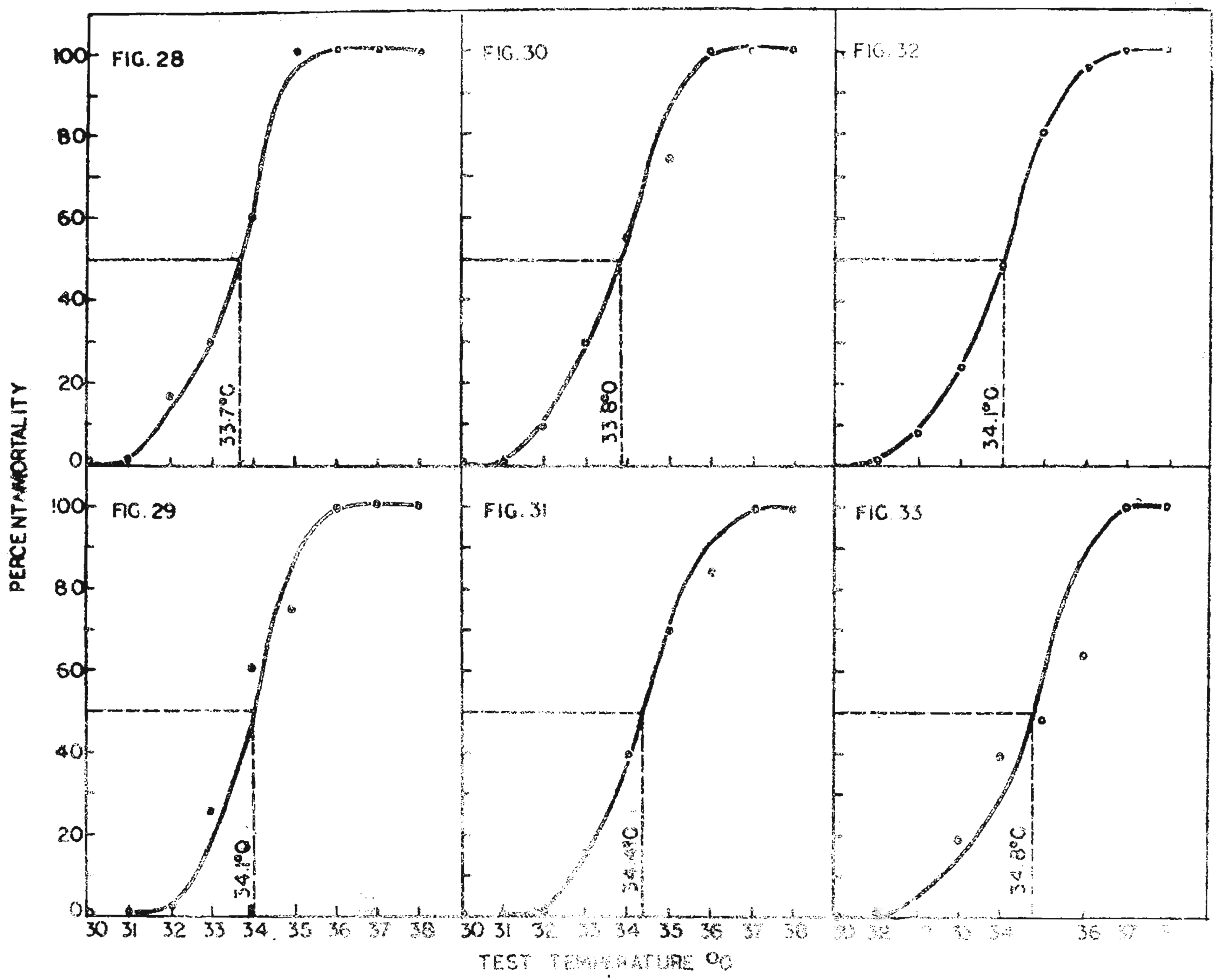


FIG. 28
FIG. 29
FIG. 30
FIG. 31
FIG. 32
FIG. 33
33.7°C
34.1°C
33.8°C
34.4°C
34.1°C
34.8°C
PERCENT MORTALITY
TEST TEMPERATURE °C

Survival was nil in 37.0°C to 38.0°C. Survival rate varied in other temperatures. The upper lethal temperatures of post larvae and juveniles were found to be 34.5°C and 35.1°C respectively (Figs. 26 and 27).

Temperature tolerance of *M. monoceros* in 10‰S

After acclimation in 10‰S at 29.0°C the animals were transferred to 10‰S media and tested to temperatures of every 1.0°C from 30.0°C to 38.0°C. 100% survival was found at 30.0°C to 31.0°C for post larvae and at 30°C to 32°C for juveniles. 100% mortality for both post larvae and juveniles occurred at temperatures 36.0°C to 38.0°C. The upper lethal temperatures for post larvae and juveniles were found to be 33.7°C and 34.1°C respectively (Figs. 28 and 29)

Temperature tolerance of *M. monoceros* in 20‰S

Animals acclimated in 20‰S at 29.0°C were directly transferred to 20‰S media and tested to temperatures of every 1.0°C from 30.0°C to 38.0°C. 100% survival was noticed at 30.0°C to 31.0°C for post larvae and at 30°C to 32°C for juveniles. 100% mortality of post larvae occurred at 36.0°C to 38.0°C and for juveniles at 37.0°C to 38.0°C. The respective upper lethal temperatures were found to be 33.8°C and 34.4°C for post larvae and juveniles respectively (Figs. 30 and 31)

Temperature tolerance of *M. monoceros* in 30‰S.

The animals after acclimation in 30‰S at 29.0°C were transferred to 30‰S media and tested to temperatures of every 1.0°C from 30.0°C to 38.0°C. Survival was 100% at temperatures 30.0 to 31.0°C for both post larvae and juveniles. 100% mortality occurred at 37.0°C to 38.0°C for both groups. The upper lethal temperatures for post larvae and juveniles were found to be 34.1°C and 34.8°C respectively. (Figs. 32 and 33)

(iii) Studies on the effects of salinity on growth

Effect of salinity on the growth of *P. indicus* which were acclimated in 5‰S.

100 numbers of post larvae of *P. indicus* which were acclimated in 5‰S were transferred to salinities 5‰, 10‰, 15‰, 20‰, 25‰, 30‰ and 35‰ to study the influence of varying salinities on the rate of growth. The experiments lasted for four weeks (roughly one month). Growth rate was highest in 15‰S and lowest in 35‰S, the respective rate being 13.0mm and 7.3mm during the period (Table-14).

30 numbers of juveniles which were also acclimated in 5‰ were introduced in different media having salinities

5‰, 10‰, 15‰, 20‰, 25‰, 30‰ and 35‰. Maximum growth was observed in 20‰ salinity, the rate being 9.5mm in one month. The minimum growth was noticed in 35‰ Salinity, the rate being 5.1mm during one month (Table-15).

__Effect of salinity on the growth of *P. indicus* which were acclimated in 15‰ S__

After acclimation in 15‰ S post larvae were directly transferred to salinities 5‰, 10‰, 15‰, 20‰, 25‰, 30‰ and 35‰. The highest growth of 15.1mm in the first month was observed in 20‰ S and the lowest gorwth of 7.7mm was noted in 35‰ S (Table-16).

Juveniles which were acclimated in 5‰ S was introduced in 5‰, 10‰, 15‰, 20‰, 25‰, 30‰ and 35‰ salinities. Growth was maximum in 25‰ S and lowest in 5‰ S. They were 10.7mm and 6.8mm respectively during the experimental period (Table-17).

__Effect of salinity on the growth of *P. indicus* which were acclimated in 30‰ S.__

Post larvae which were acclimated in 30‰ S were transferred to varying salinities of 5‰, 10‰, 15‰, 20‰, 25‰, 30‰ and 35‰. Growth rate was highest in 25‰ S and lowest in 35‰ S, the respective growth rate being 14.5 mm and 7.1mm in the first month (Table-18).

Juveniles were also kept in different media having the salinities 5‰, 10‰, 15‰, 20‰, 25‰, 30‰ and 35‰ and the effect of varying salinities observed. Maximum growth rate was noticed in 30‰ S, the rate being 9.2mm during the month. The minimum growth was in 5‰ S, the rate being 5.4mm in the period. In 10‰ and 35‰ salinity also the growth became lower being 6.5mm and 5.7mm for the first month respectively (Table - 19)

The surviving post larvae in 20‰ S, 25‰ S, 30‰ S and 35‰ S after one month were allowed to remain for a duration of one year in the same tanks and their monthly growth rates were observed. Maximum growth rate was noticed in 30‰ S, the average rate being 7.1mm per month. The minimum growth rate was in 20‰ S, the rate being 6.2mm per month (Table-20).

<u>Effect of salinity on the growth of *M. dobsoni* which were acclimated in 5‰ S</u>

After acclimation in 5‰ S, post larvae were introduced in salinities 5‰, 10‰, 15‰, 20‰, 25‰, 30‰ and 35‰ S for growth studies. Growth rate was found to be highest in 10‰ and the lowest in 35‰ S, the respective growth being 10.5mm and 7.2mm in the period (Table-21).

Juveniles of *M. dobsoni* which were acclimated in 5‰ were transferred to various salinities of 5‰, 10‰, 15‰, 20‰, 25‰, 30‰ and 35‰ S. Maximum growth of 8.1mm was observed in 15‰ S and minimum growth of 5.2mm in the month was noticed in 35‰ S (Table-22).

<u>Effect of salinity on the growth of *M. dobsoni* which were acclimated in 15‰ S.</u>

Post larvae of *M. dobsoni* which were acclimated in 15‰ were placed in various media having salinities 5‰, 10‰, 15‰, 20‰, 25‰, 30‰ and 35‰ S. Maximum growth of 12.4mm in one month was noted in 15‰ S and a minimum growth of 9.6mm in the period was observed in 35‰ S (Table-23).

After acclimation in 15‰ S juveniles were transferred to varying salinities of 5‰, 10‰, 15‰, 20‰, 25‰, 30‰ and 35‰. The highest growth of 7.6mm during the first month and the lowest growth of 5.2mm in the period were noted in 20‰ S and 5‰ respectively (Table-24).

<u>Effect of salinity on the growth of *M. dobsoni* which were acclimated in 30‰ S</u>

From the acclimation salinity of 30‰ post larvae were directly transferred to different media having salinities 5‰, 10‰, 15‰, 20‰, 25‰, 30‰ and 35‰. The

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maximum growth rate of 11.9mm per month was noticed in 20‰ S, whereas the minimum growth 6.4mm per month in 35‰ S. The growth of 9.5mm in one month which was observed in 25‰ S was the next highest rate. In 5‰ S the growth was 6.5mm in the first month (Table-25).

Juveniles of M. dobsoni from an acclimation salinity of 30‰ were abruptly transferred to 5‰, 10‰, 15‰, 20‰, 25‰, 30‰ and 35‰ to study their growth pattern. The highest growth occurred in 25‰ S, the increase in length being 6.5mm in one month. The lowest growth was noticed in 5‰ S, the increment in length being 3.4mm for the month (Table-26).

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The monthly growth rate of the remaining post larvae in 20‰ S, 25‰ S, 30‰ S and 35‰ S was observed for one year. The maximum average monthly growth rate of 5.3mm was observed in 25‰ S and a minimum growth rate of 4.5mm per month was noted in 35‰ S (Table-27).

Effect of salinity on the growth of M. monoceros which were acclimated in 5‰ S

Post larvae of M. monoceros after acclimation in 5‰ S were transferred to various media having salinities 5‰, 10‰, 15‰, 20‰, 25‰, 30‰ and 35‰ to study the effect of varying salinity on the growth. Maximum growth of

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11.4mm in one month was observed in 15‰ S. Minimum growth of 8.7mm in the period was noted in 35‰ S (Table-28).

Juveniles of *M. monoceros* also after acclimated in 5‰ S were introduced in 5‰, 10‰, 15‰, 20‰, 25‰, 30‰ and 35‰ and their growth rate in different media observed. The highest growth of 7.9mm and the lowest growth of 5.0mm during the month were noted in 20‰ and 5‰ respectively (Table-29).

Effect of salinity on the growth of *M. monoceros* which were acclimated in 15‰ S.

Post larvae of *M. monoceros* acclimated in 15‰ S were directly transferred to 5‰, 10‰, 15‰, 20‰, 25‰, 30‰ and 35‰ S. The maximum growth of 12.5mm and a minimum growth of 7.4mm during the period were observed in 15‰ S and 35‰ S respectively (Table-30).

Juveniles of *M. monoceros* which were acclimated in 15‰ were introduced into 5‰, 10‰, 15‰, 20‰, 25‰, 30‰ and 35‰ media. The highest growth of 8.7mm and the lowest growth of 5.1mm were noted in 20‰ and 5‰ respectively (Table-31)

Effect of salinity on the growth of *M. monoceros* acclimated in 30‰ S

Post larvae of *M. monoceros* acclimaté in 30‰ S were kept in salinities 5‰, 10‰, 15‰, 20‰, 25‰, 30‰ and 35‰ for growth studies. The animals showed a maximum growth in 20‰ S, the increase in total length being 12.2mm and a minimum growth of 5.9mm in 35‰ S during the first month (Table-32).

From an acclimation medium of 30‰ S juveniles were transferred to varying media of 5‰, 10‰, 15‰, 20‰, 25‰, 30‰ and 35‰ S. A growth of 8.1mm during the first month was the highest, which occurred in 25‰ S. In 5‰ S the lowest growth of 4.5 mm in the first month had been noticed. 7.1mm, 5.9mm and 6.3mm were observed respectively in 20‰, 10‰ and 15‰ salinities during the time (Table-33).

The post larvae in 20‰ S, 25‰ S, 30‰ S and 35‰ S were allowed to remain in the same media for one year and their monthly rate of growth was observed. The highest average growth rate of 5.7mm per month and the lowest average monthly growth rate of 5.3mm per month were noted in 25‰ S and 35‰ S respectively (Table-34).

(v) Discussion

According to Gunter (1961), Gunter *et al* (1964) and Williams (1965) salinity is the factor most commonly correlated with abundance of juvenile and sub adult penaeids.

TABLE-14

Growth increment in mean length and weight of post larvae of *P. indicus* in different salinities after acclimation in 5‰S.

Level of sal. (‰)	Initial length (mm)	Initial weight (mg)	Growth increment in successive weeks: 1 Length (mm)	1 Weight (mg)	2 Length (mm)	2 Weight (mg)	3 Length (mm)	3 Weight (mg)	4 Length (mm)	4 Weight (mg)	Growth during the first mth in length (mm)	Growth during the first mth in weight (mg)	Rate of growth per day in length (mm)	Rate of growth per day in weight (mg)
5	16.6	22.2	19.7	42.8	22.0	57.1	24.8	87.9	26.4	114.8	9.8	92.6	0.35	3.3
10	16.9	21.3	20.3	48.1	23.0	71.3	25.5	111.2	27.8	151.4	10.9	130.1	0.39	4.6
15	14.5	15.9	18.1	42.2	21.2	54.5	24.5	72.3	27.5	148.2	13.0	132.3	0.43	4.7
20	15.4	17.5	17.1	30.9	20.9	46.5	22.3	58.4	24.5	86.4	9.1	68.9	0.33	2.5
25	17.8	24.9	19.8	46.9	22.1	56.2	23.8	73.5	25.4	92.7	7.6	67.8	0.27	2.4
30	15.9	18.1	17.4	29.5	19.2	36.9	20.9	59.5	23.4	77.5	7.5	59.3	0.27	2.1
35	14.8	13.2	16.9	24.8	18.6	35.9	20.4	43.0	22.1	63.5	7.3	50.3	0.26	1.8

TABLE-15

Growth increment in mean length and weight of larger juvenile P. *indicus* in different salinities after acclimation in 5‰ S.

Level of sal. (‰)	Initial length (mm)	Initial weight (mg)	Growth increment in successive weeks: 1 Length (mm)	1 Weight (mg)	2 Length (mm)	2 Weight (mg)	3 Length (mm)	3 Weight (mg)	4 Length (mm)	4 Weight (mg)	Growth during the first mth. in length (mm)	Growth during the first mth. in weight (mg)	Rate of growth per day in length (mm)	Rate of growth per day in weight (mg)
5	59.4	1132	61.2	1213	63.3	1362	64.9	1417	65.6	1553	6.2	421	0.22	15.0
10	62.2	1043	64.3	1131	65.9	1351	67.8	1631	69.3	1799	7.1	756	0.25	19.0
15	61.6	1112	63.0	1409	65.3	1521	66.6	1612	67.0	1696	5.4	584	0.19	21.0
20	63.8	1420	67.2	1582	69.3	1838	71.5	2116	73.3	2312	9.5	892	0.34	32.0
25	59.2	1019	61.9	1232	63.0	1346	65.4	1581	67.0	1784	7.8	765	0.28	27.0
30	64.5	1504	66.5	1614	68.5	1762	69.8	1911	71.5	2187	7.3	683	0.26	24.0
35	60.3	1258	62.1	1282	63.5	1446	64.6	1694	65.8	1799	5.1	541	0.18	26.0

TABLE-16

Growth increment in mean length and weight of post larvae of *P. indicus* in different salinities after acclimation in 15‰ S

Level of sal. (‰)	Initial length (mm)	Initial weight (mg)	Growth increment in successive weeks: 1 Length (mm)	1 Weight (mg)	2 Length (mm)	2 Weight (mg)	3 Length (mm)	3 Weight (mg)	4 Length (mm)	4 Weight (mg)	Growth during the first month in lth. (mm)	Growth during the first month in Wt. (mg)	Rate of growth per day in length (mm)	Rate of growth per day in weight (mg)
5	16.2	18.9	18.4	36.2	20.6	48.2	22.1	63.5	24.3	79.2	8.1	60.3	0.29	2.2
10	16.3	24.3	19.1	48.3	21.3	59.9	23.2	70.4	25.5	94.7	9.2	70.4	0.33	2.5
15	15.4	26.2	18.2	42.5	21.9	61.2	24.4	91.9	27.9	130.8	12.5	104.6	0.44	3.7
20	15.7	30.1	20.9	54.1	25.4	93.8	28.6	131.0	30.8	179.5	15.1	149.4	0,54	5.4
25	17.0	28.1	19.5	49.7	21.6	67.2	24.5	88.5	27.4	123.5	10.4	95.4	0.37	3.4
30	17.2	29.6	19.8	49.7	21.4	63.9	24.0	78.4	25.9	97.6	8.7	68.0	0.31	2.3
35	16.1	27.2	18.9	38.2	20.8	57.1	22.1	60.5	23.8	78.2	7.7	51.0	0.28	1.8

TABLE-17

Growth increment in mean length and weight of larger juvenile P. *indicus* in different salinities after acclimation in 15‰.S.

Level of sal. (‰)	Initial length (mm)	Initial weight (mg)	Growth increment in successive weeks: 1 Length (mm)	1 Weight (mg)	2 Length (mm)	2 Weight (mg)	3 Length (mm)	3 Weight (mg)	4 Length (mm)	4 Weight (mg)	Growth during the first mth. in length (mm)	Growth during the first month in Wt. (mg)	Rate of growth per day in length (mm)	Rate of growth per day in weight (mg)
5	62.1	1316	64.9	1459	66.2	1511	67.4	1612	68.9	1794	6.8	478	0.24	17.0
10	63.2	1380	64.8	1456	66.6	1710	68.2	1830	70.5	1910	7.3	530	0.25	19.0
15	64.7	1462	66.9	1610	68.3	1892	70.5	1911	72.6	2081	7.9	619	0.28	22.0
20	59.2	1113	62.0	1246	64.1	1520	65.9	1720	68.1	1892	8.9	779	0.32	28.0
25	60.5	1124	65.1	1580	67.1	1794	69.4	1921	71.2	2001	10.7	877	0.38	31.0
30	61.3	1192	63.6	1380	65.2	1636	67.4	1741	70.2	1880	8.9	688	0.32	25.0
35	62.6	1251	65.0	1510	66.9	1720	68.4	1811	71.2	1932	8.6	681	0.31	24.0

Growth increment in mean length and weight of post larvae of P. *indicus* in different salinities after acclimation in 30‰ S.

Level of sal. (‰)	Initial length (mm)	Initial weight (mg)	Growth increment in successive weeks: 1 Length (mm)	1 Weight (mg)	2 Length (mm)	2 Weight (mg)	3 Length (mm)	3 Weight (mg)	4 Length (mm)	4 Weight (mg)	Growth during the first mth in length (mm)	Growth during the first month in Wt. (mg)	Rate of growth per day in length (mm)	Rate of growth per day in weight (mg)
5	18.9	35.4	21.0	50.7	22.9	74.2	25.6	99.6	27.9	130.7	9.0	95.3	0.32	3.4
10	18.5	34.5	20.7	51.2	22.6	66.9	24.9	91.4	26.8	126.0	8.3	92.5	0.30	3.4
15	20.0	41.3	22.5	70.2	24.5	89.6	27.6	126.6	30.7	175.0	10.7	133.7	0.37	4.7
20	19.7	39.2	21.4	64.7	24.6	98.0	27.9	144.5	32.2	228.2	12.5	189.0	0.45	6.7
25	19.1	37.6	22.0	60.9	25.2	96.2	29.2	188.2	33.6	296.0	14.5	258.4	0.52	9.2
30	18.8	34.9	21.8	62.2	23.9	74.2	26.6	95.3	29.4	162.2	10.6	127.3	0.38	4.5
35	19.5	38.2	20.8	60.2	23.5	84.7	25.9	98.6	26.6	108.2	7.1	70.6	0.25	2.5

TABLE-19

Growth increment in mean length and weight of larger juvenile *P. indicus* in different salinities after acclimation in 30‰ S.

Level of sal. (‰)	Initial length (mm)	Initial weight (mg)	Growth increment in successive weeks: 1 Length (mm)	1 Weight (mg)	2 Length (mm)	2 Weight (mg)	3 Length (mm)	3 Weight (mg)	4 Length (mm)	4 Weight (mg)	Growth during the first mth in length (mm)	Growth during the first mth in weight (mg)	Rate of growth per day in length (mm)	Rate of growth per day in weight (mg)
5	63.7	1396	64.7	1452	66.5	1502	68.0	1599	69.1	1692	5.4	296	0.19	10.6
10	64.3	1456	65.8	1554	67.1	1638	68.8	1729	70.8	1842	6.5	386	0.23	13.8
15	57.2	1021	59.0	1086	61.3	1181	62.7	1264	63.8	1416	6.6	395	0.23	14.1
20	67.1	1580	68.4	1649	69.5	1712	71.9	1891	73.8	2005	6.7	425	0.24	15.1
25	56.4	1004	58.5	1084	60.2	1169	62.4	1346	64.5	1506	8.1	502	0.29	18.0
30	62.1	1241	64.6	1604	67.1	1815	69.4	2116	71.3	2232	9.2	991	0.33	31.8
35	65.1	1551	66.3	1622	67.5	1710	69.2	1805	70.8	1896	5.7	345	0.21	12.3

TABLE-20

Growth increment for one year in mean length and weight of P. *indicus* in different salinities after acclimation in 30‰ S

Level of sal. (‰)	Initial length (mm)	Initial weight (mg)	Growth increment after every 3 months: 3 months Length (mm)	3 months Weight (mg)	6 months Length (mm)	6 months Weight (mg)	9 months Length (mm)	9 months Weight (mg)	12 months Length (mm)	12 months Weight (mg)	Rate of growth per mth in length (mm)	Rate of growth per mth in weight (mg)	Rate of growth per day in Length (mm)	Rate of growth per day in weight (mg)
20	19.7	39.2	41.5	497.0	60.0	168.3	78.4	3412.0	93.5	5712.0	6.2	473.0	0.20	15.8
25	19.1	37.6	43.6	592.5	62.7	229.6	81.5	4237.0	96.3	5937.0	6.5	492.0	0.21	16.4
30	18.8	34.9	45.6	781.6	68.3	278.6	87.9	5258.0	104.8	6892.0	7.1	572.0	0.24	19.0
35	19.5	38.2	43.4	607.6	64.5	1889.0	81.3	4952.0	98.8	6043.0	6.6	501.0	0.22	16.7

TABLE-21

Growth increment in mean length and weight of post larvae of M. idella in different salinities after acclimation in 5‰ S.

Level of sal. (‰)	Initial length (mm)	Initial weight (mg)	Growth increment in successive weeks: 1 Length (mm)	1 Weight (mg)	2 Length (mm)	2 weight (mg)	3 Length (mm)	3 Weight (mg)	4 Length (mm)	4 Weight (mg)	Growth during the first mth. in length (mm)	Growth during the first month in Wt. (mg)	Rate of growth per day in length (mm)	Rate of growth per day in weight (mg)
5	13.7	10.6	16.9	26.1	19.5	40.6	21.8	61.2	23.9	82.4	10.2	71.8	0.36	2.6
10	14.1	13.8	17.2	29.3	19.6	38.2	22.9	68.4	24.6	126.5	10.5	112.7	0.38	4.0
15	12.8	11.5	15.1	20.8	17.6	34.2	20.1	49.2	22.9	81.6	10.1	70.1	0.36	2.5
20	13.6	12.7	15.3	23.6	18.0	30.9	21.3	53.1	23.5	88.2	9.9	75.5	0.35	2.7
25	13.2	11.1	15.4	21.0	17.3	30.8	20.4	46.6	22.8	78.1	9.6	67.0	0.34	2.4
30	12.7	9.7	14.9	19.8	16.9	29.2	19.8	43.7	21.5	63.5	8.8	53.8	0.32	1.9
35	13.4	12.3	15.2	26.3	16.4	31.0	26.3	23.6	20.6	57.8	7.2	45.5	0.26	1.6

TABLE-22

Growth increment in mean length and weight of larger juvenile M. *dobsoni* in different salinities after acclimation in 5‰.S

Level of sal (‰)	Initial length (mm)	Initial weight (mg)	Growth increment in successive weeks: 1 Length (mm)	1 Weight (mg)	2 Length (mm)	2 Weight (mg)	3 Length (mm)	3 Weight (mg)	4 Length (mm)	4 Weight (mg)	Growth during the first mth in length (mm)	Growth during the first month in Wt. (mg)	Rate of growth per day in length (mm)	Rate of growth per day in Weight (mg)
5	50.4	932	52.3	1001	53.1	1092	55.5	1287	56.9	1402	6.5	470	0.23	16.9
10	47.3	783	49.2	729	50.5	841	52.0	986	53.2	1117	5.9	334	0.21	12.0
15	48.2	836	50.4	886	52.4	1114	54.9	1263	56.3	1480	8.1	644	0.29	23.0
20	50.1	903	52.9	995	53.8	1185	54.5	1286	56.7	1501	6.6	598	0.24	21.0
25	52.6	1019	54.1	1192	55.5	1282	57.9	1354	58.2	1546	5.6	527	0.20	19.0
30	48.1	834	49.8	776	50.9	901	52.1	1083	53.7	1214	5.5	380	0.20	14.0
35	53.6	1123	54.7	1211	55.9	1327	57.5	1466	58.8	1583	5.2	460	0.19	17.0

TABLE-23

Growth increment in mean length and weight of post larvae of *M. dobsoni* in different salinities after acclimation in 15‰ S.

Level of sal. (‰)	Initial length (mm)	Initial weight (mg)	Growth increment in successive weeks: 1 Length (mm)	1 Weight (mg)	2 Length (mm)	2 Weight (mg)	3 Length (mm)	3 Weight (mg)	4 Length (mm)	4 Weight (mg)	Growth during the first mth. in length (mm)	Growth during the first month in Wt. (mg)	Rate of growth per day in length (mm)	Rate of growth per day in Weight (mg)
5	13.7	11.1	16.1	25.9	18.3	36.1	21.4	69.6	23.6	87.0	9.9	75.9	0.35	27.0
10	13.2	8.4	16.6	26.5	20.2	45.8	23.4	78.2	25.2	123.0	12.0	114.6	0.43	41.0
15	13.9	10.3	17.2	31.0	20.6	48.0	23.9	89.1	26.3	147.0	12.4	136.7	0.44	49.0
20	12.7	6.6	16.1	25.2	19.3	44.5	22.1	68.7	24.9	93.0	12.1	86.4	0.43	31.0
25	12.0	5.8	15.2	18.9	17.5	32.6	20.3	49.1	23.7	87.0	11.7	81.2	0.42	29.0
30	14.6	16.1	17.3	31.4	19.3	43.7	22.5	71.6	24.8	96.0	10.3	79.9	0.36	28.0
35	14.5	12.8	16.8	28.2	19.1	42.2	22.6	69.5	24.1	108.0	9.6	95.2	0.34	34.0

TABLE-24

Growth increment in mean length and weight of larger juvenile *M. dobsoni* in different salinities after acclimation in 15‰ S

Level of sal. (‰)	Initial length (mm)	Initial Weight (Mg)	Growth increment in successive weeks 1 Length (mm)	1 Weight (mg)	2 Length (mm)	2 Weight (mg)	3 Length (mm)	3 Weight (mg)	4 Length (mm)	4 Weight (mg)	Growth during the first mth in length (mm)	Growth during the first month in Wt. (mg)	Rate of growth per dayin length (mm)	Rate of growth per day in weight (mg)
5	44.4	616	45,8	756	47.0	749	47.9	791	49.6	899	5.2	283	0.19	11.0
10	45.6	612	47.1	692	48.2	788	50.3	842	51.6	981	6.0	369	0.21	13.0
15	51.7	969	53.4	1012	54.5	1182	55.7	1286	57.9	1416	6.2	447	0.22	16.0
20	49.2	818	51.8	978	53.6	1096	55.2	1210	56.8	1404	7.6	586	0.27	21.0
25	47.1	624	49.8	776	51.2	884	53.0	995	54.1	1133	7.0	509	0.25	18.0
30	43.7	529	45.1	728	46.3	773	48.4	812	49.8	926	6.1	397	0.22	14.0
35	48.3	838	50.2	936	51.3	1015	52.9	1126	54.0	1228	5.7	390	0.20	14.0

TABLE-25

Growth increment in mean length and weight of post larvae of M. dobsoni in different salinities after acclimation in 30‰ S.

Level of sal. (‰)	Initial length (mm)	Initial weight (mg)	Growth increment in successive weeks: 1 Length (mm)	1 Weight (mg)	2 Length (mm)	2 Weight (mg)	3 Length (mm)	3 Weight (mg)	4 Length (mm)	4 Weight (mg)	Growth during first mth. in length (mm)	Growth during the first month in Wt. (mg)	Rate of growth per day in length (mm)	Rate of growth per day in Weight (mg)
5	14.3	11.3	16.4	22.1	18.1	31.4	20.2	43.1	20.8	63.6	6.5	52.3	0.27	1.8
10	15.1	16.9	18.2	32.6	20.7	52.1	22.4	69.4	23.9	88.5	8.8	65.0	0.32	2.3
15	13.1	6.8	15.7	21.2	17.9	31.1	20.7	46.0	21.5	68.1	8.4	61.3	0.30	2.1
20	13.2	9.7	16.2	25.2	19.1	41.4	22.0	62.7	25.1	114.0	11.9	104.3	0.43	3.7
25	12.4	5.9	15.1	17.8	18.0	29.2	20.3	44.6	21.9	71.9	9.5	66.0	0.34	2.3
30	14.6	16.5	17.3	30.0	19.2	44.3	21.9	60.1	23.2	78.3	8.6	61.8	0.31	2.2
35	14.8	17.7	16.5	26.6	18.3	38.3	19.6	52.6	21.1	68.2	6.4	50.5	0.23	1.8

TABLE-26

Growth increment in mean length and weight of larger juvenile M. dobsoni in different salinities after acclimation in 30‰S.

Level of Sal. (‰)	Initial length (mm)	Initial weight (mg)	Growth increment in successive weeks								Growth during the first mth. in length (mm)	Growth during the first month in Wt. (mg)	Rate of growth per day in length (mm)	Rate of growth per day in Weight (mg)
			1		2		3		4					
			Length (mm)	Weight (mg)	Length (mm)	Weight (mg)	Length (mm)	Weight (mg)	Length (mm)	Weight (mg)				
5	48.4	703	50.6	790	51.7	84.1	52.6	905	53.3	1012	3.4	309	0.18	11.0
10	50.1	837	50.9	852	51.5	893	52.1	942	53.2	1014	4.9	177	0.12	6.3
15	44.3	684	45.3	728	46.4	779	48.2	836	49.5	892	5.2	208	0.19	7.4
20	50.6	896	51.8	991	52.9	1094	54.8	1257	56.2	1380	5.6	484	0.20	17.3
25	51.4	932	52.4	1007	53.6	1109	55.9	1304	57.9	1502	6.5	570	0.23	20.3
30	33.3	1199	55.0	1282	56.3	1334	57.6	1428	59.2	1615	5.9	416	0.21	14.5
35	49.2	722	49.9	772	51.2	823	52.8	916	53.9	1025	4.7	303	0.17	10.8

TABLE-27

Growth increment for one year in mean length and weight of M. *dobsoni* in different salinities after acclimation in 30‰.8

Level of sal. (‰)	Initial length (mm)	Initial weight (mg)	Growth increment after every 3 months: 3 months Length (mm)	3 months Weight (mg)	6 months Length (mm)	6 months Weight (mg)	9 months Length (mm)	9 months Weight (mg)	12 months Length (mm)	12 months Weight (mg)	Rate of growth per mth in length (mm)	Rate of growth per month in wt. (mg)	Rate of growth per day in length (mm)	Rate of growth per day in weight (mg)
20	13.2	9.7	34.2	352.6	48.3	838.1	59.1	1587.4	68.3	2184.0	4.6	181.0	0.15	6.0
25	12.4	5.9	38.7	511.5	52.5	979.1	64.6	1832.9	76.4	3412.0	5.3	284.0	0.18	9.5
30	14.6	16.5	36.6	386.4	49.3	786.6	61.5	1683.0	70.7	2912.1	4.7	241.0	0.16	8.0
35	14.8	17.7	32.5	205.8	47.2	788.0	60.1	1615.4	69.3	2681.0	4.5	222.0	0.15	7.4

TABLE-[illegible]

Growth increment in mean length and weight of post larvae of [illegible]. [illegible] in different salinities after acclimation in 5‰ S.

Level of sal. (‰)	Initial length (mm)	Initial weight (mg)	Growth increment in successive weeks								Growth during the first mth in length (mm)	Growth during the first month in wt. (mg)	Rate of growth per day in length (mm)	Rate of growth per day in weight (mg)
			1		2		3		4					
			Length (mm)	Weight (mg)	Length (mm)	Weight (mg)	Length (mm)	Weight (mg)	Length (mm)	Weight (mg)				
5	13.7	13.9	16.5	31.3	18.8	48.1	21.5	60.2	23.2	80.4	9.5	66.5	0.34	2.4
10	14.5	16.6	17.3	41.0	19.6	56.3	22.9	69.1	25.1	96.2	10.6	79.6	0.38	2.8
15	14.8	18.8	19.9	49.5	22.7	66.5	24.5	83.7	26.2	122.0	11.4	103.2	0.40	3.6
20	13.9	13.5	16.2	39.6	18.6	52.1	21.3	66.4	24.8	96.1	10.9	82.6	0.38	2.9
25	14.1	16.2	17.4	47.3	21.2	60.5	24.4	71.3	24.6	92.1	10.5	75.9	0.37	2.7
30	13.8	14.5	17.5	44.7	19.4	55.8	21.8	62.1	23.7	78.8	9.9	64.3	0.35	2.3
35	14.2	15.4	17.6	40.5	19.9	58.1	21.2	59.7	22.9	68.6	8.7	53.2	0.31	1.9

TABLE-29

Growth increment in mean length and weight of larger juvenile *M. monoceros* in different salinities after acclimation in 5‰ S.

Level of sal. (‰)	Initial length (mm)	Initial weight (mg)	Growth increment in successive weeks 1 Length (mm)	1 Weight (mg)	2 Length (mm)	2 Weight (mg)	3 Length (mm)	3 Weight (mg)	4 Length (mm)	4 Weight (mg)	Growth during the first mth in length (mm)	Growth during the first month in Wt. (mg)	Rate of growth per day in length (mm)	Rate of growth per day in weight (mg)
5	61.9	1384	63.5	1438	64.4	1495	65.7	1586	66.9	1731	5.0	347	0.18	12.0
10	64.3	1596	66.1	1631	67.2	1712	68.1	1832	69.9	2045	5.6	449	0.20	16.0
15	63.8	1612	65.2	1732	67.0	1849	68.6	1912	69.9	2064	6.1	452	0.21	16.0
20	60.8	1384	63.2	1386	65.6	1506	67.5	1739	68.7	2109	7.9	725	0.28	26.0
25	64.2	1796	66.6	1871	68.8	1980	70.0	2082	71.1	2318	6.9	522	0.25	19.0
30	59.9	1247	62.0	1332	64.3	1429	66.4	1612	67.3	1848	7.4	601	0.26	21.0
35	62.4	1552	64.6	1681	66.7	1766	68.3	1899	69.1	2036	6.7	484	0.24	17.0

TABLE-30

Growth increment in mean length and weight of post larvae of *M. monoceros* in different salinities after acclimation in 15‰ S.

Level of sal. (‰)	Initial length (mm)	Initial weight (mg)	Growth increment in successive weeks								Growth during the first mth. in length (mm)	Growth during the first month in Wt. (mg)	Rate of growth per day in length (mm)	Rate of growth per day in weight (mg)
			1		2		3		4					
			Length (mm)	Weight (mg)	Length (mm)	Weight (mg)	Length (mm)	Weight (mg)	Length (mm)	Weight (mg)				
5	13.6	14.1	16.3	37.1	18.6	42.1	21.0	53.0	22.9	83.0	9.3	68.9	0.33	2.5
10	13.7	11.9	14.5	22.7	17.6	36.1	19.8	50.3	21.9	87.1	8.2	75.2	0.30	2.7
15	13.4	12.9	16.8	46.5	20.0	68.2	23.1	86.3	25.9	142.6	12.5	129.7	0.45	4.6
20	14.1	13.6	16.9	30.9	20.2	45.3	22.9	58.9	24.0	94.4	9.9	80.8	0.35	2.9
25	13.2	13.1	16.2	39.3	18.9	44.5	22.3	59.7	24.6	109.1	11.4	96.0	0.40	3.4
30	14.8	16.2	18.6	40.5	20.0	49.6	221	59.1	24.3	94.6	9.5	78.4	0.34	2.8
35	13.8	12.8	15.3	26.4	17.2	32.7	19.6	46.5	21.2	78.3	7.4	65.5	0.26	2.3

TABLE-31

Growth increment in mean length and weight of larger juvenile of _M. monoceros_ in different salinities after acclimation in 15‰ S.

Level of sal. (‰)	Initial length (mm)	Initial weight (mg)	Growth increment in successive weeks 1 Length (mm)	1 Weight (mg)	2 Length (mm)	2 Weight (mg)	3 Length (mm)	3 Weight (mg)	4 Length (mm)	4 Weight (mg)	Growth during the first mth in length (mm)	Growth during the first month in wt. (mg)	Rate of growth per day in length (mm)	Rate of growth per day in weight (mg)
5	63.5	1640	65.1	1701	68.6	1756	67.7	1876	68.6	1990	5.1	350	0.18	13.0
10	62.6	1594	63.7	1652	65.5	1753	66.8	1856	67.9	1987	5.3	393	0.19	14.0
15	59.7	1319	61.4	1387	63.8	1483	65.1	1692	66.0	1884	6.3	565	0.22	20.0
20	63.6	1634	65.7	1756	68.2	1968	70.1	2121	72.3	2363	8.7	729	0.31	26.0
25	64.3	1686	66.0	1851	67.9	1937	69.7	2014	70.8	2278	6.5	592	0.23	21.0
30	60.4	1288	63.3	1392	65.1	1539	67.4	1750	67.7	1989	7.3	701	0.26	25.0
35	59.7	1239	61.1	1372	63.4	1496	65.2	1608	66.3	1882	6.6	643	0.24	23.0

TABLE-32

Growth increment in mean length and weight of post larvae of M. monoceros in different salinities after acclimation in 30‰ S

Level of sal. (‰)	Initial length (mm)	Initial weight (mg)	Growth increment in successive weeks: 1 Length (mm)	1 Weight (mg)	2 Length (mm)	2 Weight (mg)	3 Length (mm)	3 Weight (mg)	4 Length (mm)	4 Weight (mg)	Growth during the first mth in length (mm)	Growth during the first month in wt. (mg)	Rate of growth per day in length (mm)	Rate of growth per day in weight (mg)
5	16.4	27.1	16.8	41.0	21.0	55.1	22.6	70.2	24.3	87.4	7.9	63.3	0.28	2.3
10	14.0	13.2	16.1	22.8	18.7	37.2	20.5	53.6	22.4	79.4	8.4	66.2	0.30	2.4
15	16.1	23.0	19.1	38.2	21.4	48.3	23.6	69.4	25.0	92.3	8.9	69.2	0.32	2.8
20	15.9	21.2	19.1	41.5	21.8	59.4	25.6	99.2	28.1	168.6	12.2	147.4	0.44	5.3
25	15.2	16.5	18.2	34.3	21.1	45.4	22.8	59.1	24.8	88.7	9.6	77.2	0.34	2.7
30	16.2	26.8	18.9	37.1	20.5	46.6	22.4	61.0	24.3	92.4	8.1	65.6	0.29	2.3
35	14.9	17.2	16.8	23.4	18.9	32.5	19.2	42.7	20.8	68.9	5.9	51.7	0.21	1.8

Growth increment in mean length and weight of larger juvenile of *M. monoceros* in different salinities after acclimation in 30‰

Level of sal. (‰)	Initial length (mm)	Initial weight (mg)	Growth increment in successive weeks: 1 Length (mm)	1 Weight (mg)	2 Length (mm)	2 Weight (mg)	3 Length (mm)	3 Weight (mg)	4 Length (mm)	4 Weight (mg)	Growth during the first mth in length (mm)	Growth during the first month in wt. (mg)	Rate of growth per day in length (mm)	Rate of growth per day in weight (mg)
5	68.7	2097	70.0	2119	71.1	2216	72.3	2301	73.2	2446	4.5	349	0.16	12.5
10	63.0	1607	64.4	1681	65.7	1759	67.1	1865	68.9	1993	5.9	386	0.21	13.8
15	58.0	1158	59.9	1266	61.0	1382	62.8	1492	64.3	1596	6.3	438	0.22	15.6
20	65.7	1825	67.3	1931	69.6	2100	71.4	2281	72.8	2468	7.1	643	0.25	22.9
25	70.1	2163	72.1	2255	74.5	2496	77.2	2691	78.2	2985	8.1	822	0.28	29.3
30	64.8	1882	66.5	1918	68.3	2008	70.2	2146	71.4	2321	6.6	439	0.24	15.7
35	70.2	2398	71.3	2445	72.4	2555	73.8	2696	75.1	2820	4.9	422	0.18	15.1

Growth increment for one year in mean length and weight of M. [redacted] in different salinities after acclimation in 30‰ S.

Level of sal. (‰)	Initial length (mm)	Initial weight (mg)	Growth increment after every 3 months: 3 months Length (mm)	3 months Weight (mg)	6 months Length (mm)	6 months Weight (mg)	9 months Length (mm)	9 months Weight (mg)	12 months Length (mm)	12 months Weight (mg)	Rate of growth per mth. in length (mm)	Rate of growth per month in wt. (mg)	Rate of growth per day in length (mm)	Rate of growth per day in weight (mg)
20	15.9	21.1	37.6	412.1	54.1	984.5	68.4	1896.2	79.3	3291.0	5.4	272	0.18	9.0
25	15.2	16.4	39.2	689.2	58.1	1389.9	72.5	3012.3	83.6	3812.0	5.7	316	0.19	15.3
30	16.2	26.8	38.7	534.7	57.8	1112.2	70.6	2596.5	81.0	3533.0	5.5	294	0.18	10.5
35	14.9	17.2	36.6	401.8	56.2	936.7	69.4	2112.3	78.2	3115.0	5.3	258	0.17	8.6

Assessment of salinity tolerances based only on field observations is difficult since the effects of salinity may be modified by other environmental factors (Kinne 1971). Laboratory experiments conducted under controlled environmental conditions using acclimated specimens give more detailed information on the responses of organisms to variations in salinity. The present study supplemented by field observations shows that these three penaeid prawns are essentially euryhaline, since they can tolerate wide range of salinity between 3‰ S and 43‰ S. This is in agreement with the studies of Panikkar (1968) and Panikkar and Viswanthan (1948) who reported that the penaeid prawns can withstand wide fluctuations in salinity.

It has been found that in general, acclimation in low salinities tends to shift the lower lethal limit downward and acclimation to higher salinities tends to shift the upper limit upward (Kinne 1964). This generalisation is in agreement with the present finding to some extent in the case of M. dobsoni and M. monoceros only. In the case of P. indicus although there is a shift in the higher lethal salinities upward in accordance with the increase in the acclimation salinity, the lower lethal limit do not show a corresponding decrease with the decrease in the acclimation salinity. Thus Penaeus indicus shows the same lower lethal limit of 3‰ for all the three groups acclimated in 5‰, 15‰ and 30‰ salinities (Tables 5, 6, 7). Except for the lower lethal limits of this species, the generalisation of Kinne (1964) is applicable in the present findings. The upper lethal salinities of P. indicus increased due to the increase in the acclimation salinity from 5‰ to 30‰. Moreover, there is a marked increase in the number of survivors in the upper lethal salinities corresponding with the increase from 1‰ to 30‰ in the acclimation salinity. The lower and higher lethal limits of M. dobsoni show a corresponding decrease and increase in accordance with the decrease and increase in the acclimation salinity. (Tables 8, 9, 10) In the case of M. monoceros there is no change in the lethal limit inspite of the increase in the acclimation salinity from 5‰ to 15‰. Acclimation in 30‰ shift the upper limit upward (Tables 11, 12, 13).

Zein Eldin and Griffith (1967) studied the salinity tolerance of post larvae of Penaeus aztecus, and Penaeus setiferus from the northern coast of America and found that the post larvae can tolerate a salinity range of 2 to 40‰ and the survival was 90-100%. This range of post larval tolerance in temperate waters is very near to the tolerance range observed in the present experiments for juveniles. The present study has revealed that P. indicus, M. dobsoni and M. monoceros thrive well in salinities 3 to 43‰. It is a well established fact that penaeid prawns spawn in the sea where the salinity is high. Then they undergo their succeeding stages of development and growth in a relatively unstable environment- the estuary. The salinity of the estuary from where the present collections were made is very low during the South West Monsoon season, sometimes near to fresh water. During summer season salinity increases upto 34‰. Based on the rate of survival in the experimental media it can be concluded that the penaeid prawns can well survive in salinities between 3 to 43‰. But none of them can survive in 0‰ S. In 1‰ S, 2‰ S and 44‰ S survival was poor, although field observations reveal that juvenile prawn can exist in near fresh water conditions. The laboratory experiments also reveal that they prefer a salinity between 5‰ and 30‰ when acclimated in 5‰ S and between 10‰ and 35‰ when acclimated in 30‰ S.

A comparative study of the effects of salinity on the three species of prawns suggests that there is not much significant difference in their tolerance capacity.

100% survival occurred in 15‰ to 30‰ S when acclimated in 5‰ S, in 10‰ -35‰ when acclimated in 15‰ S and in 20‰ - 35‰ when acclimated in 30‰ S in the case of P. indicus. In the case of M. dobsoni in all the animals survived in 10-25‰ S after acclimation in 5‰ S, in 10-30‰ S after acclimation in 15‰ S and in 15-35‰ S after acclimation in 30‰ S. 100% survival for M. monoceros occurred in 5-30‰ S after acclimation in 5‰ S, also in 5-30‰ S after acclimation in 15‰, in 10-35‰ S after acclimation in 30‰ S. It has been suggested by Gunter (1956) that the abundance of shrimp is greatest in low salinity, and that the smallest animals occur in the lower salinities. This statement is not in agreement with the present findings since all the species thrive well in low as well as high salinities viz. 5-35‰. It has been pointed out by Gunter (1956) that the lower salinity limits for estuarine species cannot be sharply defined. Pearse and Gunter (1957) have stressed that once an animal has adjusted to salinity changes, its range of tolerance may exceed the usual environmental changes, so that it could survive unusual conditions. The results indicate clearly that the salinity ranges tolerated by the juveniles of P. indicus, M. dobsoni and M. monoceros are not of considerable importance in determining their distribution, because the salinity of the habitat does not come usually above 35‰ S or below 2‰ S. Although during the monsoon season due to the fresh water influx into the estuary there may occur sometimes a lowering of salinity below 1‰. But the period does not extend for a long time. It can be concluded that the distribution of the penaeid prawns in the area under investigation would not be limited by salinity alone. It can also be stated that there are no significant variations in the tolerance capacity of the three species under investigation.

Acclimation to a high temperature, with resulting increase in the high temperature tolerance of the species, has been demonstrated by several workers (Sumner and Doudoroff, 1938; Brett, 1946; Mellanby, 1954; McLeese, 1956; Todd and Dehnel, 1960). Temperature tolerance in conjunction with salinity has been studied less extensively, and it was of interest to find that salinity had a very marked effect on the temperature tolerance of the species. The possible influence of temperature on osmoregulation and its bearing on the problem of crustacean distribution have been pointed out earlier by Panikkar (1940). In Crangon crangon Broekema (1941) found that the adults seek higher salinities in cold weather and lower salinities in warm weather and the young in summer tolerate lower salinities than the Adult. Zein-Eldin and Aldrich (1965) observed that the growth of Penaeus aztecus was not affected by salinity except at extreme temperatures. Present experiments on high temperature tolerance in the laboratory have shown that the three species of penaeid prawns viz. P. indicus, M. dobsoni and M. monoceros can survive well in temperatures upto 36.0°C. But the ranges of temperature tolerated by each species vary depending on the size of the individuals and the salinity of the medium. Thus in 10‰ S P. indicus tolerated temperatures upto 34.2°C, M. dobsoni upto 34.4°C and M. monoceros upto 34.1°C. Experiments using animals acclimated in 20‰ S showed that P. indicus survived well at temperatures upto 34.5°C, M. dobsoni upto 34.7°C and M. monoceros tolerated well upto 34.4°C. Animals in 30‰ S showed the following upper limit of tolerance: P. indicus 35°C, M. dobsoni 35.1°C and M. monoceros 34.8°C. The results show that there is more tolerance in higher salinities than in lower salinities at higher temperatures. Broekema (1941) demonstrated that the temperature and salinity relations were independent in the shrimp Crangon crangon. When survival in various combinations of the two was tested, a low salinity was endured better when the temperature was high. Wikgren (1953) showed that there was almost a continuous loss of ions from the cray fish Potamobius fluviatilis, as the temperature dropped below 2°C from about 18°C. The lobster, Homarus americanus was shown to have a higher lethal point when both salinity and temperature were high during the period of acclimation. A decrease in salinity with the acclimation temperature held constant resulted in the lowering of thermal resistance (McLeese 1956). Kinne (1958) reported the shifting of heat tolerance in three species of animals, the polychaete Nereis diversicolor, the amphipod Gammarus duebeni and the isopod Sphaeroma hookeri. The salinity of the pond from which all the three species were collected was about 12‰ and in all of them when kept at salinities below this, heat resistance is lowered. Increased heat resistance results in animals from the higher salinities, above 12‰. Kinne (1958) suggested that the alteration of water and ion balance resulting in increased water content at extremely low salinities decreased the heat tolerance; the lowered water content at higher salinities favourably affects the resistance to high temperatures. In the present study also it is evident that the higher salinities are favourable for withstanding upper lethal temperatures.

Some species difference in tolerance to high temperatures is found to exist among the three species of prawns. When compared, M. dobsoni shows more tolerance to higher temperatures than the other two species. *P. indicus* comes next and *M. monoceros* the lowest. Thus in 30‰ S the upper lethal limit of the three species are 35.1°C, 35.0°C and 34.8°C respectively for *M. dobsoni*, *P. indicus*, and *M. monoceros*. However, the differences between the three species are not significant.

There is a diversity of responses reported in literature concerning size in relation to death of animals at high temperature. Huntsman and Sparks (1924) and Belehradek (1935) claim that resistance to heat diminished as size increases. Hart (1952) found a size effect in only three of the fourteen species of fresh water fish that he studied. In two of these species, resistence diminished with increasing size but in the third, resistance increased. McLeese (1956) concluded that in the size renage of lobsters studied, from 21 to 28cm there is identical response to upper lethal temperatures. Tests were performed with two size groups of prawns in the present study (10mm-25mm and 35mm-90mm) to determine whether the size is related to death at high temperature. The upper lethal temperatures of both the size groups were slightly different. The larger size groups are having the higher lethal limit than the smaller ones. It may be concluded that small (10mm-25mm) and larger (35mm-90mm) prawns from the same area and acclimated to the same temperature respond differently to high temperatures. This is in agreement with the findings of Edwards and Irving (1943) on _Emerita talpoida_. All the three species studied exhibited the same relationship.

The effect of sex on heat tolerance was found to vary in different animals as reported by several workers. Todd and Dehnel (1960) found that in _Hemigrapsus nudus_ and _Hemigrapsus oregonensis_, there was no difference in temperature tolerance between the sexes. Edwards and Irving (1943) found no difference in tolerance in _Emerita talpoida_ between males and females. Kinne (1958) showed a decreased tolerance in female _Gammarus duebeni_ to high temperatures and increased tolerance in smaller animals of both sexes. In agreement with the studies of Todd and Dehnel (1960) in the present study also there is no difference in high temperature tolerance between the two sexes. The sex difference of prawns do no affect the heat tolerance.

The results obtained from the present studies (Figs. 16 to 33) show that the three species of prawns from the Cochin backwaters, _P. indicus_, _M. dobsoni_ and _M. monoceros_ can tolerate temperatures as high as 35.1°C. The upper temperature in the natural habitat usually come below this temperature limit. So it can be concluded that the temperature is an environmental factor which do not affect the abundance and distribution of the above three common penaeid prawns in the Cochin backwaters.

Transferring penaeid prawns to different salinities to study their rate of growth has been done by a few authors both in temperate and tropical waters. Zein-Eldin (1963) studied the growth rate of *Penaeus aztecus* and *Penaeus setiferus* in the laboratory and observed that under the conditions tested (restricted temperature and diet) post larval shrimp can both survive and grow over a wide range of salinities. Zein-Eldin and Aldrich (1965) reported that the growth of *Penaeus aztecus* is not affected by salinity except under extreme temperatures. Venkataramaiah, Lakshmi and Gunter (1974) disagree with this findings. They found that the post larvae of *Penaeus aztecus* showed faster growth in low saline waters. Sreekumaran Nair and Krishnankutty (1975) observed that the growth rate of *Penaeus indicus* was significantly high in low salinity for the post larval prawns but the larger juveniles showed a significantly high growth rate in high saline waters.

The present studies show that even though both the post larval and larger juveniles of *P. indicus*, *M. dobsoni* and *M. monoceros* can tolerate wide range of salinities there are differences in the growth rate in each salinity. Slight differences in mean length and weight between salinity groups were detectable as early as in the first week and the differences increased in magnitude during the experimental period. The maximum growth of post larvae of *P. indicus* was in 20‰ S and that of juvenile *P. indicus* was in 25‰ S. Post larvae of *M. dobsoni* grew maximum in 15‰ S and the juveniles in 20‰ S. The same growth pattern had been exhibited by both the post larvae and juveniles of *M. monoceros* also.

The effect of acclimation in extending ranges of post larval and juvenile growth is clearly evident from the tables. It has been found that in general, acclimation to low salinities tends the animal to grow more rapidly in lower salinities and acclimation to higher salinities induce the animals grow rapidly in higher salinities. Thus post larvae of *P. indicus* which were acclimated in 5‰ S grew 13.0mm in the first month in 15‰ S, whereas those which were acclimated in 30‰ S grew 10.7mm only in the first month ~~only~~ in the same salinity. The juvenile *P. indicus* which were acclimated in 5‰ showed a growth rate of 9.5mm during the first month in 20‰ S and those animals which were acclimated in 30‰ S showed a growth rate of 6.7mm during the same period in 20‰ S. At the same time those animals which were acclimated in 15‰ S grew 8.7mm in the first month in 20‰ S. Both M. dobsoni and M. monoceros also showed variations in their growth pattern in their acclimation medium.

When different species are compared, P. indicus grow well in slightly higher salinities than the other two species. Both the post larvae and juveniles exhibit this character. The table 14 shows that post larvae of P. indicus grew 13.0mm in the period in the 15‰ S after acclimation in 5‰. M. dobsoni grew 10.5mm during the first month in 10‰ S after acclimation in 5‰ S and M. monoceros grew 11.4mm in 15‰ S after acclimation in 5‰ S. Juveniles of P. indicus which were acclimated in 30‰ S grew 9.2mm during the first month in 30‰ S, M. dobsoni which were acclimated in 30‰ S grew 5.9mm in 30‰ S and M. monoceros which were acclimated in 30‰ S grew 6.6mm in 30‰ S. The rate of growth studied by rearing experiments by Rao (1973) on the post larvae of Parapenaeopsis stylifera and Metapenaeus monoceros showed that the post larvae of the former species measuring between 4.0mm and 17.6mm grew at an average rate of 0.45mm per day. Viosca (1920) estimated a growth rate of approximately 25mm per month for Penaeus setiferus in the length range 30 to 150mm while Gunter (1950) observed a rate of 25 to 40mm per month for the same species growing from 28 to 100mm. George et al (1968b) while studying the offshore prawn fishery of Cochin, from the length frequency data estimated a growth rate of 20mm in males and 15mm in females of P. indicus during 4 months between the first and second year classes (126-130mm for males and 141-145mm for females represent the 1st year class and 161-165mm for males and 171-175mm for females represent the 2nd year class). Banerji and George (1967) and George et al (1968b) showed a growth rate of 0.35 to 0.37mm per day in the juvenile stages for M. dobsoni occurring in the Cochin backwaters and paddy fields in the first year of life. Rearing experiments on M. monoceros conducted by George (1959) in the paddy fields showed a growth of 10-15mm during the course of 3 months in the case of juveniles. Srivastava (1953) has reported that in the Gulf of Kutch area, growth of M. monoceros was rapid and it attained a length of 4 inches (102mm) in 5 months. All India Co-ordinated Research Project on Studies on Marine Prawn Biology and Resources during 1971-1974 (1975) reports the following growth rates for M. dobsoni, P. indicus and M. monoceros based on the length frequency analysis at different centres.

For M. dobsoni in the coastal waters of Ambalapuzha, they have estimated that the males and females respectively attain a length of 97/115mm at the end of the 1st year of life and 122/138mm at the end of the 2nd year, thereby showing an average of 6.2 mm and 7.3 mm per month respectively for males and females. P. indicus from the same area showed a growth rate of 9.8 mm and 7.2 mm respectively for the males and females during the same period. In the Covelong backwaters in Madras P. indicus of a modal size of 53mm after 89 days attained 123mm, thus showing a rate of 23.3mm per month. M. monoceros in Bombay waters showed an average monthly rate of 4.5mm per month, the females of this species grow to 54mm at the end of 1st year and 108mm at the 2nd year. The references cited above on the growth rate of prawns are related to growth in the field, not considering the effect of different salinities on the growth rate. In the present study where importance was given to the effect of salinity on growth, a maximum growth of 10.7mm during the first month was obtained in the case of juvenile P. indicus in 25‰ S (Table-17). This comes to a rate of 0.38mm per day. In the case of juvenile M. dobsoni the maximum growth of 8.1mm in the above period was obtained in 15‰ S (Table-22) This works to a rate of 0.29mm per day. A maximum growth of 9.7mm in the first month was obtained in 20‰ S for juvenile *M. monoceros*, which is about 0.31mm per day (Table-31). During the first year *P. indicus* showed a growth of 86mm in 30‰ S while in 25‰ S *M. dobsoni* 64mm and *M. monoceros* 68mm. The mean monthly growth rates reported here for all the three species do not approach to that of the values obtained from the length frequency studies from the field data as observed by Srivastava (1953), Banerji and George (1967), George *et al* (1968b) and also from that of Project Report (1975) on the growth of *P. indicus* and *M. dobsoni*. A similarly low rate of growth has been recorded for aquarium held *Metapenaeus mastersii* by Dall (1958). As his data showed, laboratory animals grew only 10mm in total length per month as against a natural rate of 20 to 30 mm per month.

In the present experiment, it is seen that the growth rate of all the three species of prawns is influenced by varying salinities. From the tables 14 to 34 it is evident that the post larvae and juveniles of all the three species show differences in their growth in various salinities. Thus post larvae of *P. indicus* which were acclimated in 5‰ S grow at its maximum of 13.0 mm in the first month in 15‰ S and a minimum of 7.3mm in 35‰ S. The juveniles showed its maximum growth rate of 9.5 mm in 20‰ S and a minimum of 5.1mm in 35‰ S during the period. Post larvae of *M. dobsoni* grew at a maximum rate of 10.5 mm in 10‰ S and a minimum of 7.2mm in 35‰ S and juveniles grew at a maximum of 8.1mm in 15‰ S and a minimum of 5.2mm in 35‰ S in the first month. Metapenaeus monoceros in their post larval stage grew at a maximum of 11.4mm in 15‰ S and a minimum of 8.7mm in 35% S during the first month. Juveniles grew a maximum of 7.9mm in 20% S and a minimum of 5.0mm during the period of experiment in 5‰ S. From the results from the long term experiments (Tables 20, 27 and34) it is evident that although the magnitude of the increase in size in all salinities is lower than that observed for one month in most cases the trend of growth is almost the same to that of the juveniles. Both length and weight increased much more rapidly in 30‰ S for P. indicus and 25‰ S for both M. dobsoni and M. monoceros, the average monthly growth rate being 7.1mm, 5.3mm and 5.7mm respectively in each salinity. Similarly P. indicus showed a minimum rate ie. an average 6.2mm per month in 20‰ S and both M. dobsoni and M. monoceros showed a minimum monthly average growth rate of 4.5mm and 5.3mm in 35‰ S. The above results show that there are variations in the growth pattern in different salinities. Zein Eldin (1963) found that under controlled temperature, salinity did not have significant influence on the growth of the post larvae of penaeid prawns. The present study with P. *indicus*, M. *dobsoni* and M. *monoceros* do not agree with this finding. This may be because of the climatic differences, for in a temperate country temperature is more important and the life there may be affected more by temperature than by salinity. Venkataramiah, Lakshmi and Gunter (1974) and Sreekumaran Nair and Krishnankutty (1975) found that the post larvae of P. *aztecus* and P. *indicus* showed faster growth in low saline waters. The present study with P. *indicus*, M. *dobsoni* and M. *monoceros* also agrees with the above finding. Although all these species live under euryhaline conditions, the results showed that they prefer low salinity during post larval period and some what higher salinities during the later juvenile period. Gunter *et al* (1964) pointed out that the adaptation to low salinity is highly developed in younger stages, while Panikkar (1968) has indicated that osmoregulation in dilute media is less effective in full sized individuals especially in their reproductive phase. Panikkar considers this feature as one of the principal factors which forces them to migrate back to the sea. The present study on the effect of varying salinity on the growth of both post larvae and juveniles of three species of prawns indicates that physiological changes take place gradually in these organisms.

Based on the results obtained in the present studies (Tables 14-34) the following facts can be concluded. Growth rate in both post larvae and juveniles is influenced by varying salinities in the medium. Post larvae grow at a faster rate in relatively low salinities ie. at 10‰ and 15‰ S and the larger prawns grow rapidly in some what higher salinities ie. in 25‰ and 30‰. Variations in salinities affect differently on different species. P. indicus favours slightly higher salinities for maximum growth than the M. dobsoni and M. monoceros. Regarding the rate of growth also there is species differences. P. indicus is having higher rate of growth, M. dobsoni having the lowest rate and M. monoceros possesses a growth pattern in between P. indicus and M. dobsoni. In the same medium having the same salinity all the three species exhibit different growth rate. As there was adequate uniform food supply during the course of the experiments, the differences in the growth rate noticed cannot be attributed to the availability of food.

The above observations seem to indicate that the salinity affects the growth rate of different species in the natural surroundings. The data on the post larval and juvenile growth in different salinities show that they prefer low salinities below 25‰ S for faster growth.

This may be one of the main reasons for the abundance of post larvae and juveniles of penaeid prawns in estuaries. The abundance of suitable food in the estuary may also be a contributory factor.

PART III

OXYGEN CONSUMPTION OF *METAPENAEUS DOBSONI*

Considerable amount of work has been done on the oxygen requirements of a variety of invertebrates, with special reference to their respiratory quotients and metabolism. Since any change or regulation of metabolism is directly reflected in respiration, the uptake of oxygen by an animal is taken as a measure of its metabolism. Kinne (1971) and Vernberg and Vernberg (1972) have reviewed the pertinent literature on the physiological adaptations of marine and estuarine poikilotherms in relation to environmental conditions. The metabolic rate of invertebrates changes directly with body size, temperature, salinity, pH of the medium, activity and nutrition.

The environmental factors which affect the metabolic rate have been categorised into two: controlling factors like salinity and temperature and limiting factors like the availability of oxygen and substrate supply (Blackman, 1905; Fry, 1947; Newell, 1970). Besides these environmental factors the metabolism of an animal is influenced by certain endogenous factors like the body size and the level of activity. Obviously the influence of these 'intrinsic factors' (Vernberg and Vernberg 1972) must be eliminated before other factors can effectively be studied.

The relationship between metabolism and body size is now well established. The influence of body size on metabolism has been studied by Kleiber (1932, 1947), Brody and Procter (1932), Brody (1945), Zeuthen (1947, 1953), Hemmingsen (1950, 1960) and Bertalanffy (1957). In recent years more information on the relationship between body size and O_2 uptake of poikilotherms has been added to the above works and detailed reviews on this aspect are available in the works of Wolvekamp and Waterman (1960), Prosser and Brown (1961), Lockwood (1967) and Newell (1970).

In general, metabolism is proportional to a constant power of the body weight. (Zeuthen 1947, 1953; Hemmingsen 1950, 1960). This relation between the metabolism of the whole animal and body weight is expressed as

$$O_2 = aW^b \qquad (1) \text{ where } \quad b < 1$$

Where 'O_2' is the total oxygen consumed in unit time, 'W' is the body weight 'a' is a constant denoting the level of the logarithmic regression line (intercept on

Y- axis) and 'b' is a constant denoting the slope of the logarithmic regression line. As pointed out by Bertalanffy (1957) the weight specific metabolic rate (ie. O_2/body weight/hr) can be expressed in a modified form of equation:

$$\frac{O_2}{W} = aW^{(b-1)} \qquad (2) \text{ where } b < 1$$

which shows a decreasing function of the metabolic rate with increasing size and the slope of the logarithmic plot is negative.

Considering the apparently fundamental relationship between metabolism and body weight several attempts have been made to explain the mechanism underlying the phenomenon. Zeuthen (1953) suggested that the metabolism of metazoans would be related to their aggregate cell surface and expected the metabolism to increase with the $\frac{2}{3}$ or 0.67 power of body weight. According to Hemmingsen (1950, 1960) metabolism is proportional, not to the cell surface itself, but to factors like internal convection, vascularisation and the development of respiratory systems. He showed that metabolism varies more nearly with the $\frac{3}{4}$ or 0.751 power of the body weight. Bertalanffy (1957) reviewing the relationship between body size and metabolism distinguished three types:

proportionality of metabolic rate to surface area or to weight; intermediate between surface area and weight and intermediate between surface and weight proportionality. Eventhough the metabolism of large animals exceeds that of small animals, it does not increase at the same rate of body weight. Thus weight specific metabolism expressed as oxygen consumed per unit time, of small animals is greater than that of large ones.

The fact that salinity variations may modify the metabolic rate of aquatic invertebrates has been established by the works of Wolvekamp and Waterman (1960), Lockwood (1967), Newell (1970), Kinne (1971) and Vernberg and Vernberg (1972). Yet the relation between salinity and oxygen consumption in marine invertebrates is not very clear. Wolvekamp and Waterman (1960) in their review conclude that in some organisms respiration varies inversely with salinity, while in others there appears to be no correlation. The modifying effects of salinity changes on respiration rates have also been shown to depend on temperature body size and oxygen concentration as revealed by the studies by Dehnel (1960) on *Hemigrapsus oregonensis* and *H. nudus* and Rao (1958) on *Metapenaeus monoceros*

The role of dissolved oxygen as a limiting factor in the respiratory metabolism is of vital importance in the ecology of estuarine animals. Henze (1910) generalised the relation between oxygen concentration and respiration stating that the respiration of simpler, bulkier invertebrates is oxygen dependent while it is independent in higher invertebrates. Later Ledebuhr (1939) showed that marine animals could withstand large variations in respiratory rate are exhibited only at low levels. Reviews on the metabolic responses to oxygen tension are available in the works of Tang (1933), Krogh (1941), Zeuthen (1955), Wolvekamp and Waterman (1960), Prosser and Brown (1961), Lockwood (1967), Newell (1970), Vernberg (1972), Vernberg and Vernberg (1972) and Subrahmanyam (1962). Most of these studies were made on marine Crustacea of the Arctic and temperate regions. It has been proved that the level of dissolved oxygen in the surrounding medium has a definite effect on oxygen consumption in Crustacea (Chen, 1932; Van Weel et al 1954; Wolvekamp and Waterman, 1960; Teal and Carey, 1967).

Studies on the oxygen consumption of animals of economic value are of special interest, since an estimate of the energy requirements of an animal can usually be obtained from the measurements of its oxygen consumption in an aerobic state. Though the respiratory physiology, especially with reference to oxygen consumption, has been studied extensively in the case of fishes and crustaceans other than prawns (reviews by Fry, 1957; Wolvekamp and Waterman, 1960) only a few workers have paid attention to the oxygen consumption of prawns. Rao (1958), Subrahmanyam (1962), Kutty (1969) and Kutty *et al* (1971) have made studies in this field in India. Whereas the influence of weight and ambient oxygen concentration in the oxygen consumption of *Penaeus indicus* has been studied by Subrahmanyam (1962), the oxygen consumption as a function of size and salinity in *Metapenaeus monoceros* has been investigated by Rao (1958). Reports by Kutty (1969) and Kutty *et al* (1971) provide information on the influence of starvation on the metabolism of *Penaeus indicus* and *P. semisulcatus* and on the influence of salinity and temperature on the oxygen concentration in young juveniles of *P. indicus*. Hitherto there is no work available on the oxygen consumption of *Metapenaeus dobsoni*, one of the most dominant species present in Indian waters. The present work is an attempt to evaluate the influence of weight, salinity and ambient oxygen concentrations on the oxygen consumption of *Metapenaeus dobsoni*.

(i) Materials and Methods

Collection and acclimation of animals used for the experiments are described in Part II. Prawns of both sexes, of weights ranging from 0.4gm to 6.6gm were used in the experiment. Larger specimens above 4gm were taken from the inshore areas of Cochin as the specimens above 4gm were not common in backwaters.

Fry(1947) has recorded three methods for measuring oxygen consumption in aquatic animals. They are (1) following the depletion of oxygen in a sealed container (closed system respirometry) (2) measuring the loss of oxygen and the rate of flow of water through a small chamber (open system respirometry) and (3) manometric methods. Of these the closed system respirometry was used to measure the total and weight specific oxygen consumption of M. dobsoni in the present study. The experiments were done using a respiratory chamber described earlier by Job (1955). The respiratory chambers used were of 1000ml capacity Ehrlenmeyer (conical) flasks. The chamber was closed with a rubber stopper carrying both the inlet and the outlet. The former was a burette, which by opening the stopcock, could deliver through a long capillary measured volume of water to the bottom of the chamber. At the time of sampling, the outlet which was normally kept plugged was opened so that an equal volume was simultaneously expelled. By using coloured water under identical conditions and by repeated tests, the above procedure was adopted so that the water drawn off for sampling did not become contaminated with the water that was introduced, and it represented only the true sample from the chamber.

The animals selected for the experiments were transferred from the aquarium tank and kept in glass troughs containing filtered and aerated water of the same acclimation salinity and without food for 24 hours for getting emptied the gut before they were used for experiments. After setting the apparatus one animal was introduced in the respiratory chamber in the experimental salinity for one hour before each experiment was started in order to get it accustomed to the new surrounding. They were not fed and kept in darkness during the experiment. The respiratory chambers were held in a water bath at 29°C and maintained constant to $\pm$ 1.0°C throughout the duration of the experiment. The pH was measured both at the beginning and at the end of the experiment and the change was always less than 1.0 in the range 8.5 to 7.2.

Samples were taken at the beginning of the experiment to note the initial O_2 content and at one hour intervals till the death of the animals. The animals were considered dead when the pleopod and gnathopodite beating ceased and the body turned upside down. Wet weight of the animal was taken at the end of each experiment after carefully wiping it between folds of blotting paper. The weight was recorded to the nearest 0.1mg. Unmodified Winkler technique was employed for measuring dissolved oxygen and 10ml samples were usually analysed.

15 to 22 animals of different weights were tested in each salinity medium. Besides the experiments in the acclimation medium of 30‰ S, animals were directly transferred from the acclimation salinity to varying media of 10‰, 20‰, and 40‰ S. Since these animals spend much of their time buried in the bottom substrate, locomotor activity is minimum in the natural habitat. In the respiratory chamber also, they keep their place at the bottom most of the time. In this case since the animal is in a routine state of activity and obviously not executing any consistently active swimming movements, the term 'routine-active' could be employed here. The measurements of oxygen consumption made under such conditions can be termed as 'routine metabolic rate' (Job, 1955; Fry, 1957; Kutty, 1969).

The numerical data obtained on the oxygen consumption of *M. dobsoni* in relation to salinity, body weight and oxygen tension were statistically analysed using the models:

$$(1)\ \ O_2 = aW^b \ \text{ and } (2)\ \frac{O_2}{W} = aW^{(b-1)}$$

The parameters 'a' and 'b' were estimated by the method of least square after converting the model into linear forms by taking the logarithms of O_2 and W, ie.

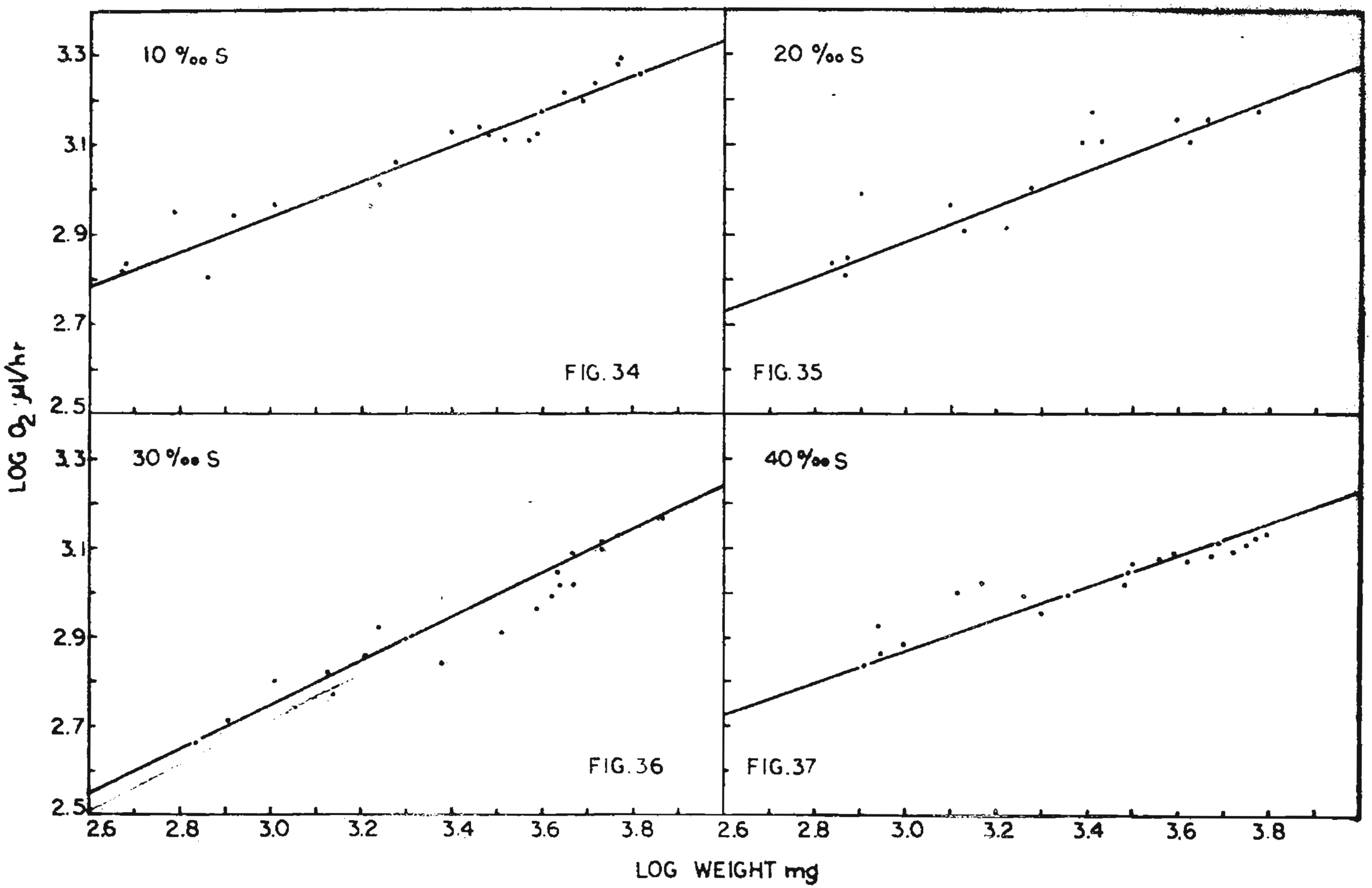
$$\text{(i)}\ \log O_2 = \log a + b \log W \ \text{and}$$
$$\text{(ii)}\ \log O_2 - \log W = \log a + b \log W - \text{Log } W$$

(ii) Experiments and Results

1. Oxygen consumption of *M. dobsoni* in relation to body weight in the acclimation medium of 30‰ S in pO_2 160 mm Hg.

Data obtained on the oxygen consumption of *M. dobsoni* in the acclimation salinity of 30‰ in pO_2 (partial pressure of oxygen) 160 mm Hg are presented in Table 35. The oxygen uptake per unit time showed an increasing tendency with increasing body weight. The regression coefficient 'b' of the oxygen uptake against body weight was obtained as 0.5031. The line is plotted in Fig.36

Figs.34 to 37. Relationship~~s~~ between oxygen uptake (µl/h) and body weight of *Metapenaeus dobsoni* in 10‰ S, 20‰ S, 30‰ S and 40‰ S in pO_2 160 mm Hg.


10 ‰ S
FIG. 34
20 ‰ S
FIG. 35
30 ‰ S
FIG. 36
40 ‰ S
FIG. 37
LOG O_2 µl/hr
LOG WEIGHT mg
3.3
3.1
2.9
2.7
2.5
2.6
2.8
3.0
3.2
3.4
3.6
3.8

which shows a positive linear relationship. The metabolic rate in terms of oxygen uptake per unit weight in unit time (O_2/µl/g/h) are given by the formula $\frac{O_2}{W} = aw^{b-1}$ showed a decline with the increasing body weight resulting in a negative linear relationship (Fig.40). The regression value for the weight specific oxygen consumption (metabolic rate) which is b-1 in the above formula was obtained as -0.4969.

2. <u>Oxygen consumption of M. dobsoni in relation to variations in salinity and body weight in pO_2 160 mm Hg</u>

Animals were directly transferred from the acclimation medium to higher and lower salinities and their respiratory rates in pO_2 160mm Hg were studied.

a) <u>Oxygen consumption when transferred from the acclimation medium of 30‰ S to 10‰ S</u>.

The respiratory rates of *M. dobsoni* transferred to 10‰ S at 160mm Hg pressure from the acclimation medium of 30‰ are given in Table-36. The regression lines are given in Figs. 34 and 38. The values of 'b' and 'b-1' were obtained as 0.3898 and -0.6102 respectively.

b) <u>Oxygen consumption when transferred from the acclimation medium of 30‰ S to 20‰ S</u>.

Data obtained on oxygen consumption in 20‰ S at 160 mm Hg are presented in Table-37. The regression lines

Figs.38 to 41. Relationship between metabolic rates (µl/g/h) and body weight of *M. dobsoni* in 10‰ S, 20‰ S, 30‰ S and 40‰ S in pO_2 160 mm Hg.

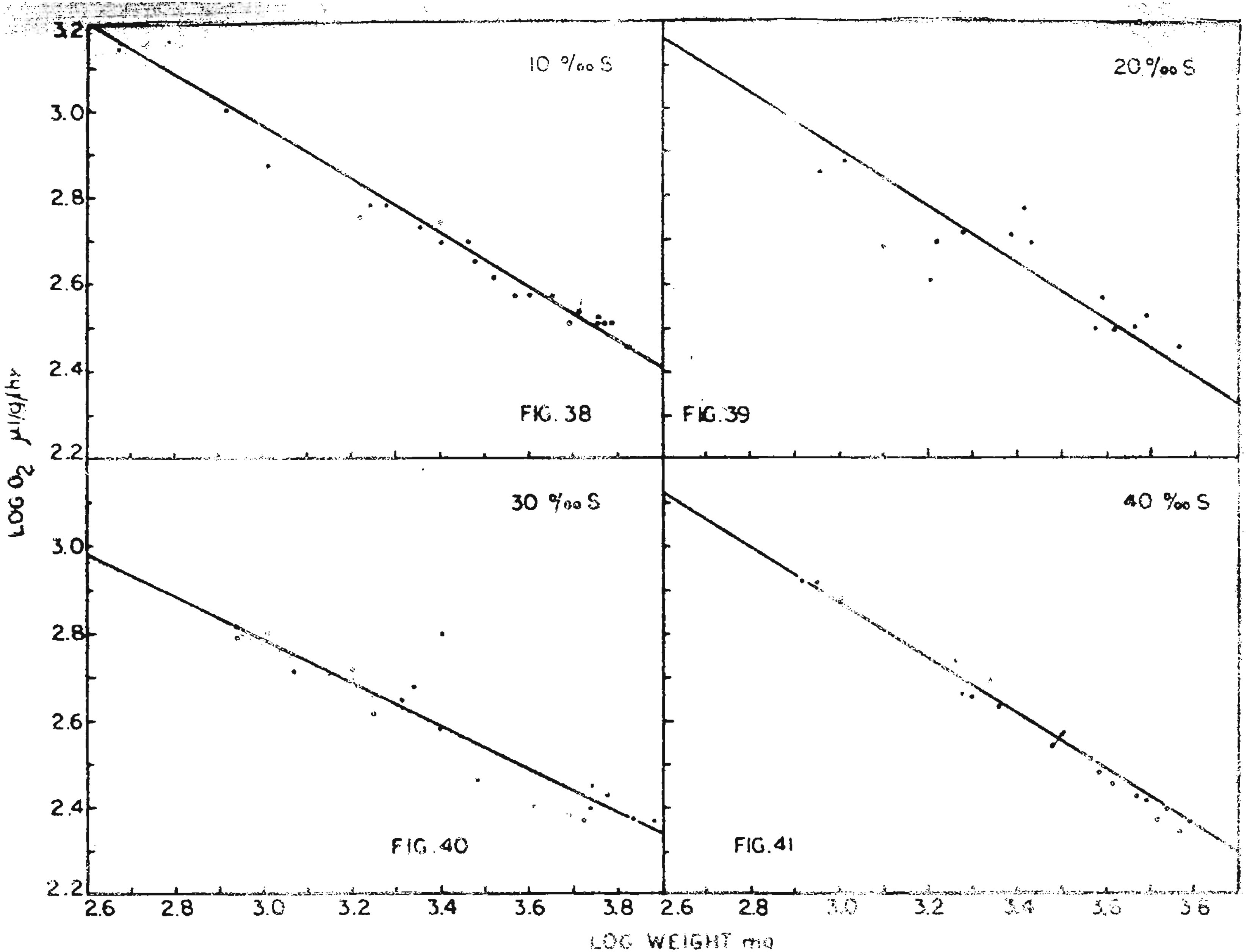


FIG. 38 FIG. 39 FIG. 40 FIG. 41

are shown in Figs.35 and 39. The estimates of 'b' and 'b-1' were 0.3926 and -0.6074 respectively.

e) <u>Oxygen consumption when transferred from the acclimation medium of 30‰S to 40‰S</u>.

Animals acclimated in 30‰S were directly transferred to 40‰S and the data obtained on the oxygen consumption in pO_2 160 mm Hg are presented in Table-38. The relationship between body weight and oxygen uptake, and between body weight and metabolic rate are shown in Figs.37 and 41. The values of 'b' and 'b-1' were found to be 0.3584 and -0.6416 respectively.

Statistically refined values for oxygen uptake and metabolic rates of standard weights 500, 1000, 2000, 3000, 4000, 5000 and 6000 mg when subjected to salinity variations are given in Table-39. Results of the statistical analysis of the data on oxygen consumption when subjected to variations in salinity are presented in Table-40. The regression coefficients obtained under different experimental salinities were compared and the results are shown in Table-41.

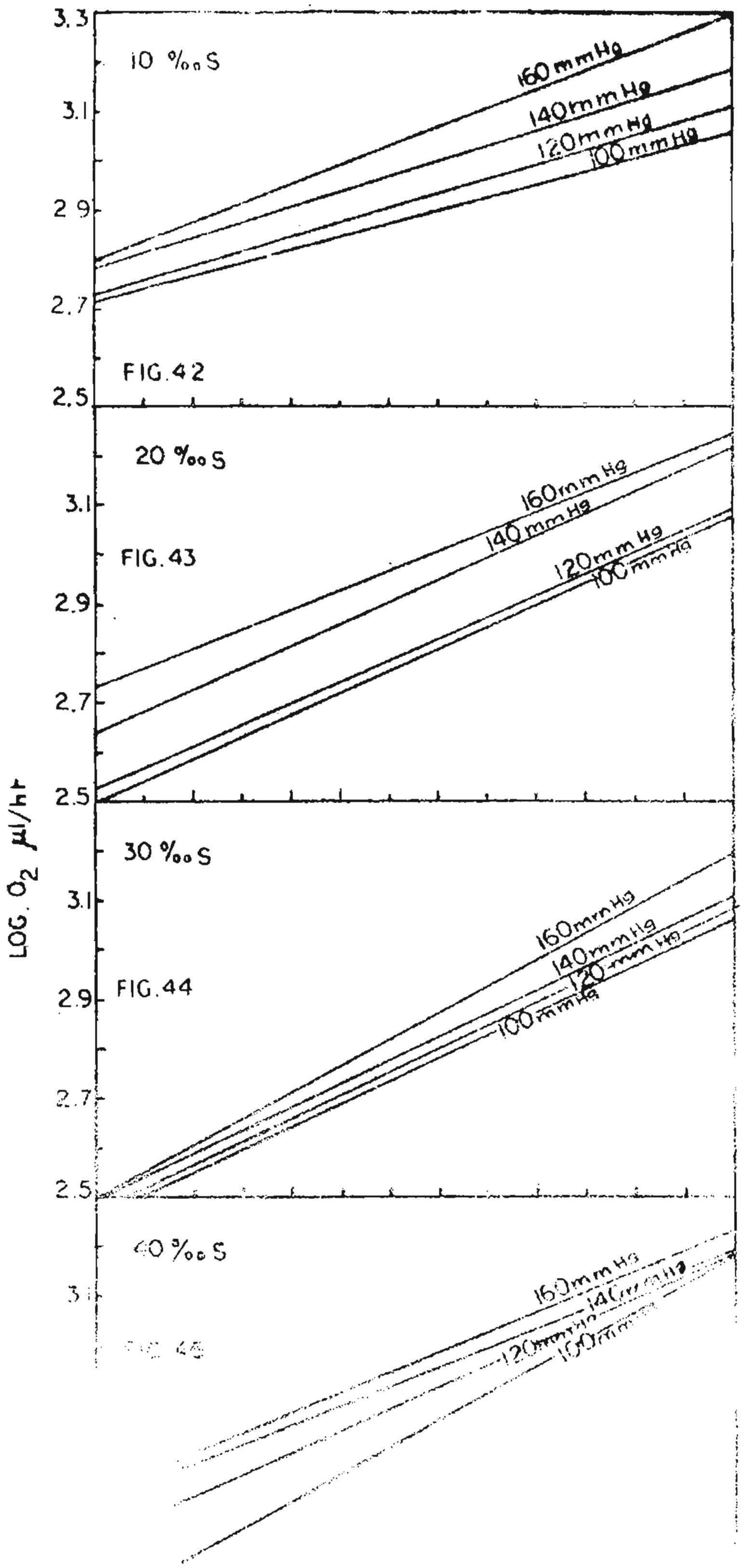
3. Oxygen consumption of *M. dobsoni* in relation to body weight and declining oxygen tension in the acclimation medium of 30‰ S.

The regression lines obtained under declining partial pressure of oxygen (pO_2) in the acclimation medium of 30‰ S are shown in Fig.44. The values of 'b' obtained in pO_2 160, 140, 120 and 100 mm Hg were 0.5031, 0.4684, 0.4756 and 0.4558 respectively. Respiratory rates for standard weights 500, 1000, 2000, 3000, 4000, 5000 and 6000 mg in pO_2 160–100 mm Hg are given in Table-42.

4. Oxygen consumption of *M. dobsoni* in relation to body weight and salinity in declining oxygen tension

Specimens of M. *dobsoni* were directly transferred from the acclimation medium to media of higher and lower salinities and their respiratory rates under declining oxygen tension were observed. Results of the statistical analysis of the data on oxygen consumption when subjected to different partial pressures of oxygen in various salinities are presented in Table-43. The regression coefficients obtained under declining oxygen tensions in the same salinity media and various salinities were compared and the results are shown in Tables-44 and 45.

Figs.42 to 45. Relationship~~s~~ between oxygen uptake (µl/h) and body weight of M. dobsoni in declining oxygen tension (pO_2) when subjected to salinity changes.


LOG. O2 µl/hr
3.3
3.1
2.9
2.7
2.5
10 ‰ S
160 mm Hg
140 mm Hg
120 mm Hg
100 mm Hg
FIG. 42
20 ‰ S
160 mm Hg
140 mm Hg
120 mm Hg
100 mm Hg
FIG. 43
30 ‰ S
160 mm Hg
140 mm Hg
120 mm Hg
100 mm Hg
FIG. 44
40 ‰ S
160 mm Hg
120 mm Hg

a) <u>Oxygen consumption in declining pO_2 when transferred from the acclimation medium of 30‰ S to 10‰ S.</u>

The regression lines for oxygen consumption against body weight obtained for animals transferred to 10‰ from the acclimation medium of 30‰ S in declining pO_2 are shown in Fig.42. The values of 'b' obtained for pO_2 160, 140, 120 and 100 mm Hg were 0.3898, 0.3036, 0.3003 and 0.2590 respectively. The respiratory rates for standard weights 500, 1000, 2000, 3000, 4000, 5000 and 6000 mg in pO_2 160–100mm Hg are presented in Table-46.

b) <u>Oxygen consumption in declining pO_2 when transferred from the acclimation medium of 30‰ S to 20‰ S.</u>

The regression lines obtained for animals transferred to 20‰ S from the acclimation medium of 30‰ S are shown in Fig.43. The estimates of 'b' in pO_2 160, 140, 120 and 100 mm Hg were 0.3926, 0.4618, 0.4386 and 0.4535 respectively. The respiratory rates for standard weights 500, 1000, 2000, 3000, 4000, 5000 and 6000 mg in pO_2 160–100 mm Hg are given in Table-47.

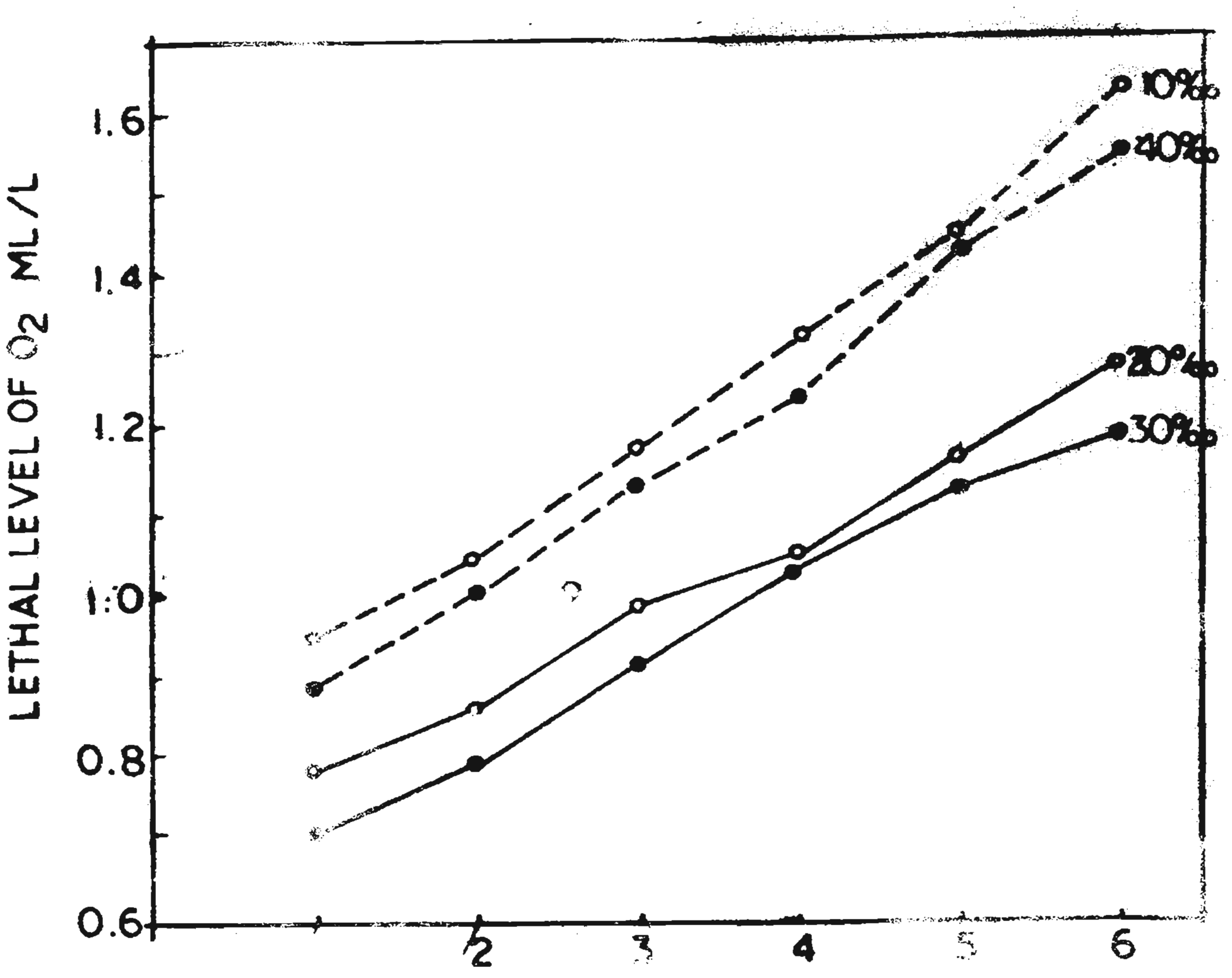
(c) Oxygen consumption in declining pO_2 when transferred from the acclimation medium of 30‰ S to 40‰ S.

Fig.45 shows the regression lines obtained under declining pO_2 for animals transferred from the acclimation medium of 30‰ S to 40‰ S. The 'b' values obtained were 0.3584, 0.3527, 0.3986 and 0.4929 respectively in pO_2 160, 140, 120 and 100 mm Hg. The oxygen uptake and metabolic rates for standard weights 500, 1000, 2000, 3000, 4000, 5000 and 6000 mg in pO_2 160–100 mm Hg are given in Table-48.

5. Lethal level of oxygen concentration of *M. dobsoni* in various salinities

In each experiment the volume of dissolved oxygen in the experimental medium at the time of death was estimated and expressed as the lethal level for the animal in the particular medium. The observed lethal values of oxygen in the different salinity media for the animals were statistically analysed to find out their relationship with body size of the animals and their variations in the different salinity media. Results obtained are presented in Fig.46.

Fig.46. Relationship between body weight and lethal level of oxygen content in the different salinity media in *M. dobsoni*.



10‰
40‰
20‰
30‰
1.6
1.4
1.2
1.0
0.8
0.6
LETHAL LEVEL OF O_2 ML/L
2
3
4
5
6
WEIGHT GM

FIG. 46

TABLE-36

Oxygen uptake and metabolic rate of M. dobsoni in 10‰.8 in pO_2 160 mm Hg.

Body weight mg	Oxygen uptake µl/h	Metabolic rate O_2 µl/g/h
481	690	1434.5
612	850	1388.5
837	880	1051.3
1242	930	748.7
1672	940	562.2
1744	1030	590.5
1921	1160	603.8
2287	1240	542.1
2522	1370	543.2
2891	1400	484.2
2992	1350	451.2
3295	1300	394.5
3674	1380	375.6
3873	1430	369.2
4018	1520	378.2
4476	1680	375.3
4904	1600	326.2
5074	1720	338.9
5738	1880	327.6
5872	1920	326.9
6013	1950	324.2
6612	1890	285.8

TABLE-37

Oxygen uptake and metabolic rate of M. dobsoni in 20%.S in pO_2 160 mm Hg.

Body weight mg	Oxygen uptake µl/h	Metabolic rate O_2 µl/g/h
699	450	643.7
742	530	714.2
792	640	808.0
1232	588	477.2
1346	666	494.7
1667	712	427.1
1895	696	367.2
2468	781	316.4
2578	812	314.9
2700	911	337.4
3728	892	239.2
3915	992	253.3
4132	1091	264.0
4617	1012	219.1
5824	1132	194.3

TABLE-38

Oxygen uptake and metabolic rate of M. dobsoni in 40‰ S in pO_2 160 mm Hg.

Body weight mg	Oxygen uptake µl/h	Metabolic rate O_2 µl/g/h
810	490	604.0
880	830	943.0
895	720	804.4
992	750	756.0
1332	1010	758.2
1492	1040	697.0
1820	980	538.4
2010	900	447.7
2316	995	429.6
3016	1049	347.8
3115	1110	356.3
3163	1150	363.5
3648	1185	324.8
3921	1197	305.2
4126	1174	284.5
4632	1210	261.2
4938	1280	259.2
5229	1230	235.2
5623	1294	230.1
5948	1315	221.0
6211	1358	218.6

TABLE-39

Oxygen uptake and metabolic rate of *M. dobsoni* of standard weights 500, 1000, 2000, 3000, 4000, 5000 and 6000 mg when subjected to salinity variations in pO_2 160 mm Hg.

Accl. Sal. ‰.	Exp. Sal. ‰.	Body weight mg	O_2 uptake µl/h	Metabolic rate O_2 µl/g/h	Average metabolic rate O_2/µl/g/h
		500	686.3	1372.6	
		1000	899.3	899.3	
		2000	1179.0	589.5	
30	10	3000	1380.0	460.0	620.8
		4000	1544.0	386.0	
		5000	1684.0	336.8	
		6000	1808.0	301.3	
		500	582.0	1164.0	
		1000	804.6	804.6	
		2000	1056.0	528.0	
30	20	3000	1239.0	413.0	547.2
		4000	1387.0	346.8	
		5000	1514.0	302.8	
		6000	1626.0	271.6	
		500	377.1	754.2	
		1000	534.6	534.6	
		2000	757.5	378.7	
30	30	3000	929.0	306.6	387.0
		4000	1074.0	268.5	
		5000	1201.0	240.0	
		6000	1317.0	219.5	
		500	571.0	1142.0	
		1000	731.9	731.9	
		2000	938.3	469.1	
30	40	3000	1085.0	361.6	571.1
		4000	1203.0	301.0	
		5000	1303.0	260.6	
		6000	1391.0	231.8	

TABLE-40

Statistical analysis of the data obtained on the oxygen consumption of *M. dobsoni* in relation to variations in salinity in pO_2 160 mm Hg.

n = number of experiments; b = regression coefficient r = correlation coefficient, S_b = standard error of b, t_b = student's t value, P = probability level.

Accl. Sal. (‰)	Exp. Sal. (‰)	n	b	b-1	r	S_b	t_b	P
30	10	22	0.3898	-0.6102	0.9857	0.1183	3.2950	<0.01
30	20	15	0.3926	-0.6074	0.8828	0.1244	3.1559	<0.01
30	30	20	0.5031	-0.4969	0.6468	0.1853	2.7146	<0.01
30	40	21	0.3584	-0.6416	0.8954	0.1649	2.1740	<0.01

TABLE-41

Comparison of regression coefficients obtained for *M. dobsoni* when subjected to changes in salinity in pO_2 160 mm Hg

Comparing media (‰)	Probability
30 and 10	N.S.*
30 and 20	N.S.
30 and 40	N.S.
10 and 20	N.S.
10 and 40	N.S.
20 and 40	N.S.

* N.S. Not significant

TABLE-42

Oxygen uptake and metabolic rate of *M. dobsoni* of standard weights of 500, 1000, 2000, 3000, 4000, 5000 and 6000 mg in declining pO_2 in the acclimation medium of 30‰ S.

pO_2 mm Hg	Body weight mg	O_2 uptake µl/h	Metabolic rate O_2 µl/g/h
	500	377.1	754.2
	1000	534.6	519.2
	2000	757.5	375.7
160	3000	929.0	311.0
	4000	1074.0	271.2
	5000	1201.0	245.2
	6000	1317.0	225.1
	500	351.4	702.8
	1000	486.1	486.1
	2000	672.3	336.2
140	3000	812.9	271.0
	4000	930.5	232.6
	5000	1033.0	206.6
	6000	1126.0	187.7
	500	333.5	667.0
	1000	456.1	456.1
	2000	625.5	312.8
120	3000	752.5	250.8
	4000	858.0	214.5
	5000	949.9	190.0
	6000	1032.0	172.0
	500	332.6	665.2
	1000	463.1	463.1
	2000	644.0	322.0
100	3000	781.1	260.4
	4000	895.6	223.9
	5000	995.9	199.3
	6000	1086.0	181.0

TABLE-43

Statistical analysis of the data obtained on the oxygen consumption of *M. dobsoni* acclimated in 30‰ S in relation to salinity and oxygen tension. n = number of experiments, b = regression coefficient, r = correlation coefficient, S_b = standard error of b, t_b = student's t value, P = probability.

pO_2 mm Hg	Exp. Sal. (‰)	n	b	b-1	r	S_b	t_b	P
140	10	22	0.3036	-0.6964	0.6459	0.0707	4.2942	< 0.01
	20	15	0.4618	-0.5382	0.7336	0.1389	3.3246	< 0.01
	30	20	0.4684	-0.5316	0.9593	0.1479	3.1670	< 0.01
	40	21	0.3527	-0.6473	0.5319	0.0916	3.8504	< 0.01
120	10	22	0.3003	-0.6997	0.8035	0.0774	3.8798	< 0.01
	20	15	0.4386	-0.5614	0.9277	0.1417	3.0952	< 0.01
	30	20	0.4756	-0.5244	0.5291	0.1385	3.4339	< 0.01
	40	21	0.3986	-0.6014	0.6666	0.1048	3.8034	< 0.01
100	10	22	0.2590	-0.7410	0.2089	0.0316	8.1462	< 0.01
	20	15	0.4535	-0.5465	0.7006	0.1135	3.9955	< 0.01
	30	20	0.4558	-0.5442	0.9593	0.1478	3.0818	< 0.01
	40	21	0.4929	-0.5071	0.6670	0.1144	4.3085	< 0.01

TABLE-44

Significance of differences between the regression coefficients obtained under different partial pressures of oxygen in the same medium.

Media (‰)	Comparing partial pressure of oxygen					
	160 and 140	160 and 120	160 and 100	140 and 120	140 and 100	120 and 100
10	N.S.*	N.S.	N.S.	N.S.	N.S.	N.S.
20	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
30	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
40	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

* N.S. Not significant

TABLE-45

Significance of difference between the regression coefficients obtained for *M. dobsoni* in different media under different partial pressure of oxygen

Comparing media (‰)	160 mm Hg	140 mm Hg	120 mm Hg	100 mm Hg
	Probability			
30 and 10	N.S.*	N.S.	N.S.	N.S.
30 and 20	N.S.	N.S.	N.S.	N.S.
30 and 40	N.S.	N.S.	N.S.	N.S.
10 and 20	N.S.	N.S.	N.S.	N.S.
10 and 40	N.S.	N.S.	N.S.	N.S.
20 and 40	N.S.	N.S.	N.S.	N.S.

* N.S. = Not significant

TABLE-46

Oxygen uptake and metabolic rate of *M. dobsoni* of standard weights 500, 1000, 2000, 3000, 4000, 5000 and 6000 mg in declining pO_2 in 10% S.

pO_2 mm Hg	Body weight mg	O_2 uptake µl/hr	Metabolic rate O_2 µl/g/h
	500	686.3	1372.6
	1000	899.3	899.3
	2000	1179.0	589.5
160	3000	1380.0	460.0
	4000	1544.0	386.0
	5000	1684.0	336.8
	6000	1808.0	301.3
	500	651.0	1302.0
	1000	805.4	805.4
	2000	993.8	496.9
140	3000	1124.0	374.6
	4000	1227.0	306.7
	5000	1313.0	262.6
	6000	1388.0	231.3
	500	566.1	1132.2
	1000	696.9	696.9
	2000	831.6	415.8
120	3000	922.3	307.4
	4000	992.4	248.1
	5000	1051.0	210.2
	6000	1101.0	183.5
	500	567.0	1134.0
	1000	697.1	697.1
	2000	858.2	429.1
100	3000	969.4	323.1
	4000	1057.0	264.3
	5000	1131.0	226.2
	6000	1193.0	198.8

TABLE-47

Oxygen uptake and metabolic rate of *M. dobsoni* of standard weights 500, 1000, 2000, 3000, 4000, 5000 and 6000 mg in declining pO_2 in 20‰ S.

pO_2 mm Hg	Body weight mg	O_2 uptake µl/h	Metabolic rate O_2 µl/g/h
160	500	582.8	1165.6
	1000	804.6	804.6
	2000	1056.0	528.0
	3000	1239.0	413.0
	4000	1387.0	346.8
	5000	1514.0	302.8
	6000	1626.0	271.6
140	500	476.2	952.4
	1000	656.0	656.0
	2000	903.5	451.7
	3000	1089.0	363.0
	4000	1245.0	311.2
	5000	1379.0	275.8
	6000	1501.0	260.2
120	500	368.1	736.2
	1000	498.9	498.9
	2000	676.1	338.1
	3000	807.6	269.2
	4000	916.2	229.1
	5000	1010.0	202.0
	6000	1095.0	182.5
100	500	350.0	700.0
	1000	479.9	479.9
	2000	657.2	328.6
	3000	789.8	263.3
	4000	899.9	225.0
	5000	995.6	199.1
	6000	1081.0	180.2

TABLE-48

Oxygen uptake and metabolic rate of *M. dobsoni* of standard weights 500, 1000, 2000, 3000, 4000, 5000 and 6000mg in declining pO_2 in 40%.S.

pO_2 mm Hg	Body weight mg	O_2 uptake µl/h	Metabolic rate O_2 µl/g/h
160	500	571.0	1142.0
	1000	739.9	739.9
	2000	938.3	469.2
	3000	1085.0	361.6
	4000	1203.0	301.0
	5000	1303.0	260.6
	6000	1391.0	238.8
140	500	533.8	1067.6
	1000	681.7	681.7
	2000	870.4	435.2
	3000	1004.0	334.7
	4000	1111.0	277.8
	5000	1202.0	240.4
	6000	1282.0	213.7
120	500	453.9	907.8
	1000	598.4	598.4
	2000	788.6	394.3
	3000	928.5	309.5
	4000	1040.0	260.0
	5000	1137.0	227.4
	6000	1221.0	203.5
100	500	342.6	785.2
	1000	482.0	482.0
	2000	678.2	339.1
	3000	721.3	240.4
	4000	954.5	238.6
	5000	1065.0	213.0
	6000	1166.0	194.3

(iii) Discussion

Both the metabolic rate and the level of activity in animals are affected by a variety of environmental factors, such as temperature, salinity, amount of available oxygen and also by the body size and the physiological state of individuals. Further, the experimental techniques and the unit for the oxygen consumption rates reported in the literature are quite varied. It is, therefore, difficult to make absolute comparisons among the oxygen uptake rates of various species or of the individuals within the species. The effects of various factors influencing the respiratory metabolism of _M. dobsoni_ are discussed below.

Oxygen consumption in relation to body weight

The oxygen uptake of whole individuals of _M. dobsoni_ increased with increasing body weight and the metabolic rate in terms of weight specific oxygen consumption (O_2 µl/g wet wt/h) showed a decline with the increase in body weight in all the tested salinities of 10‰, 20‰, 30‰ and 40‰. This means that the total oxygen consumption of smaller animals is less than that of larger ones, but the metabolic rate ie. oxygen uptake per unit weight in unit time is more in the former. Tables 35, 36, 37 and 38 and Figs. 34, 35, 36 and 37 show that the total oxygen consumption in *M. dobsoni* acclimated in 30‰ S and tested in 10‰ S, 20‰ S, 30‰ S and 40‰ S varied with size in 160mm Hg partial pressure of oxygen. It is well established that oxygen consumption is a power function of body weight and the biological significance of the exponential value (b) has been reported by various workers. The b-values reported for crustaceans generally fall between 0.67 and 1.0 (Zeuthen 1953, Hemmingsen 1950, 1960, Bertalanffy 1957) showing a range between surface area related and weight related respiration. Hemmingsen (1960) suggested a common value of 0.75 for poikilotherms.

The 'b' values obtained in the present study for *M. dobsoni* in pO_2 160mm Hg in different salinities differ from the above values (Table-40). Here the 'b' values obtained for prawns which are acclimated in 30‰ S and tested in 10‰ S, 20‰ S, 30‰ S and 40‰ S are 0.3898, 0.3926, 0.5031 and 0.3584 respectively. Statistical analysis of the data in different salinities (Table-41) shows that they are not significantly different and so a common 'b' value can be attributed to the relationship between size and oxygen consumption in different media. The regression coefficient reported here for *M. dobsoni* in pO_2 160 mm Hg in the acclimation salinity of 30‰ is 0.5031 and this value can be taken for comparison with the 'b' values reported for other crustaceans. The 'b' values reported for various crustaceans by Ellenby (1951) Edney and Spencer (1955), Bertalanffy (1957), Robertson (1957), Subramanyam (1957, 1962), Barnes and Barnes (1959), Teal (1959), Ganapati and Rao (1960), Small and Hebard (1967), Bulnheim (1974) etc. are between 0.67 and 1.0. But several others have reported instances of smaller 'b' value in crustaceans. Conover (1959) obtained values less than 0.67 for calanoid copepods. Dehnel (1960) reported 'b' values for the intertidal crabs *Hemigrapsus oregonensis* and *H. nudus* varying between 0.315 and 0.667 and stated that only very few values approached the generally known regression coefficients for crustaceans. Newell and Northcroft (1965) have obtained low values for the barnacle *Balanus balanoides*. Values like 0.37 and 0.48 which are appreciably below the common range have been noticed by Haq (1967) for the copepod *Metrida lucens* and *M. longa*. Very low values ranging from 0.037 to 0.444 have been recorded for the amphipods *Bathyporeia pilosa* and *B. pelagica* by Fish and

and Preese (1970). Cheriyan (1973) obtained values as low as 0.3428 and 0.4463 for the wood boring isopod *Sphaeroma terebrans*. For the isopods *Sphaeroma annandalei*, *Cirolana fluviatilis* and *C. willeri* Cherian (1977) has reported low values ranging from 0.2495 to 0.5976 in the acclimation salinities of 17 and 33‰.

Rao (1958) has reported that in *Metapenaeus monoceros* the 'b' value varied from 0.5 to 1.05 according to the variations in salinity. Subrahmanyam (1962) has reported the 'b' value for *Penaeus indicus* as 0.604 in 14.5‰ S, but the value varied with the partial pressure of the oxygen in the medium. Kutty (1969) in his investigation on *P. indicus* obtained a 'b' value of 0.501 in a salinity of 36‰ at 28.30°C. While studying the oxygen consumption of the juvenile *P. indicus* Kutty *et al* (1971) have noticed the 'b' value as 0.553. The 'b' value obtained for *M. dobsoni* in the present study is 0.5031 in 30‰ S at 29°C. This value comes within the range of values mentioned above for other prawn species. From Table-41 it will be seen that the differences between 'b' values in various salinities are not significant. The 'b' values obtained under different partial pressure of oxygen in different salinity media were also not significantly different from each other (Table-45). This shows that in general, the same relationship with regard to the rate of oxygen consumption and size is maintained under varying oxygen concentrations.

Rao (1958) reported the metabolic rate (O_2ml/g/hr) of M. monoceros as 0.80 in 33.5‰S, 0.66 in 16.75‰S, 0.74 in 8.4‰S and 1.00 in tap water at 30°C. Subrahmanyam (1962) has reported the metabolic rate of P. indicus to be varying between 0.787 and 0.200 ml/g/h. Kutty et al (1971) found the oxygen uptake of juvenile P. indicus as 0.352 mg/h. In the present studies the metabolic rates obtained for M. dobsoni (0.6 to 6.3 gm wet weight) vary from 218.9 to 657.0 μl O_2/g/h in 30‰ S in pO_2 160 mm Hg. This shows that the metabolic rates of M. dobsoni and P. indicus are comparable.

Oxygen consumption in relation to variations in salinity and body weight

Oxygen consumption of M. dobsoni in relation to salinity of the medium is illustrated in Figs.34-37. The oxygen uptake in abruptly changed salinities is markedly weight dependent and the metabolic rate falls rapidly with increasing body weight. But the regression coefficients of oxygen uptake against body weight do not show significant variations under four different salinities ie. in 10‰, 20‰, 30‰ and 40‰. Assessing the literature available, only a few papers on the respiratory metabolism of prawns contain information on the relationship between oxygen uptake and body weight in relation to changes in salinity. Rao's (1958) work on brackish water and marine populations of M. monoceros showed that the regression coefficient of oxygen consumption against weight is not the same for different salinities and for the two populations. He has reported that in M. monoceros the 'b' value varied from 0.5 to 1.05.

Table-39 shows that the metabolic rates of M. dobsoni of standard weights 500 to 6000 mg vary between 1372.6 and 219.5 μl O_2/g/h when animals are subjected to salinity variations. The average metabolic rate of animals is the minimum in the acclimation medium of 30‰ S. As shown in Figs.47-50 and Table-39 when the salinity becomes higher or lower from that of the acclimation salinity there is an increase in the rate of oxygen uptake. Kinne (1971) has stated that many aquatic invertebrates respire at the most economic rates in salinities to which they are genotically adjusted. It has also been proved by several authors that the respiratory rates of euryhaline crustaceans

Figs.47to50 Trend of variations in the rate of oxygen uptake of *M. dobsoni* of standard weights 1000, 2000, 3000, 4000, 5000 and 6000 mg in various salinities.

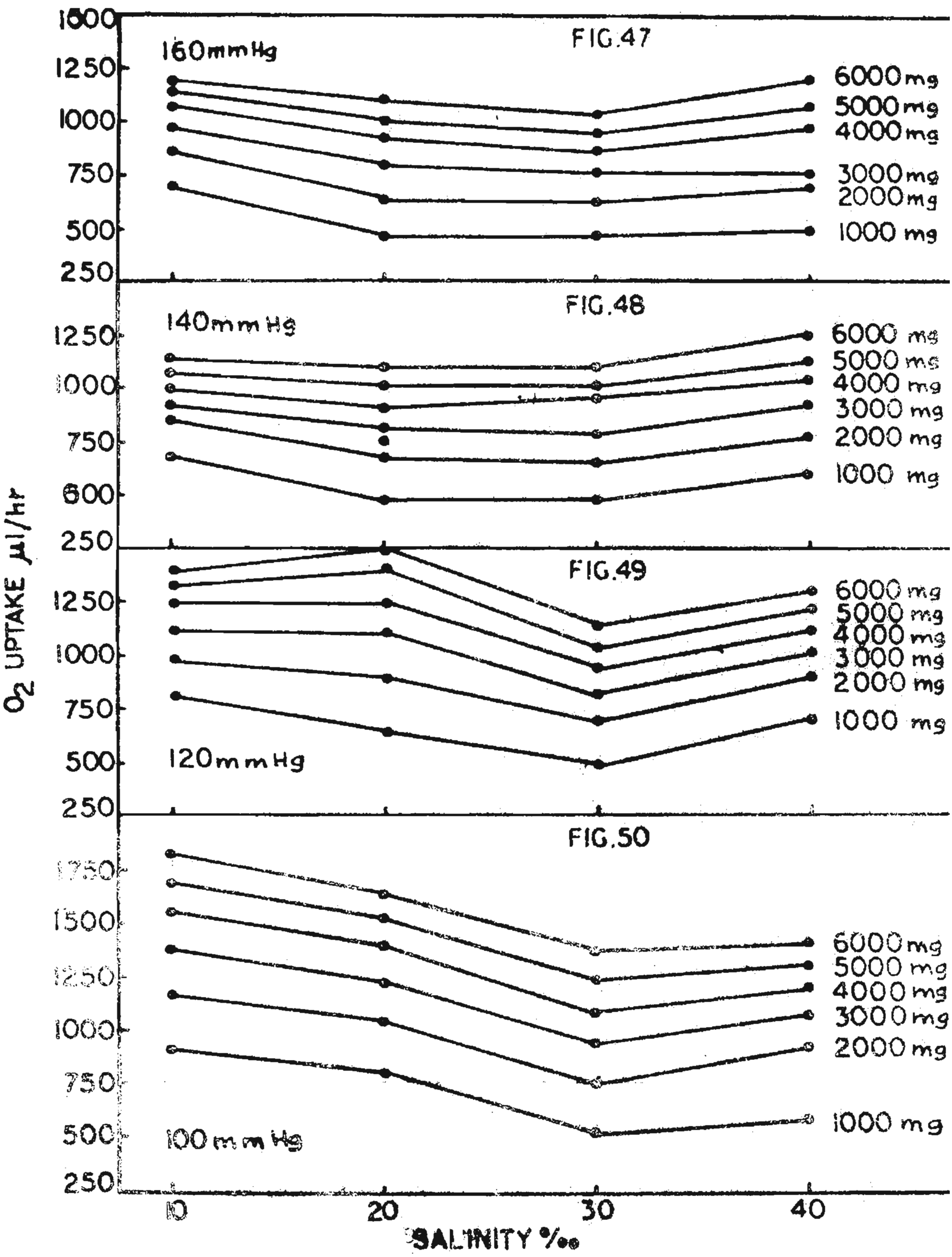


FIG.47
160mmHg
6000mg
5000mg
4000mg
3000mg
2000mg
1000 mg
FIG.48
140mmHg
6000 mg
5000 mg
4000 mg
3000 mg
2000 mg
1000 mg
FIG.49
120mmHg
6000 mg
5000 mg
4000 mg
3000 mg
2000 mg
1000 mg
FIG.50
100mmHg
6000mg
5000mg
4000mg
3000mg
2000mg
1000 mg
O_2 UPTAKE µl/hr
SALINITY ‰

change under conditions of osmotic stress mostly as an increase under adverse conditions. According to these views the increase in metabolic rates of *M. dobsoni* in the changed salinities appears to be due to the stress of the animals in adjusting to the sudden changes in the media.

It is stated by several authors who have worked on Crustacea, that when animals acclimated in a higher salinity medium are transferred to lower salinity media, there is an increase in oxygen uptake as has happened in the present study on *M. dobsoni* and according to them, this increase is required to maintain the concentration of their body fluid. Experiments on such lines have been done on *Carcinus maenas* (Schlieper, 1929), *Gammarus chevreuxi* (Lowenstein, 1935), *Ocypode albicans* (Flemister and Flemister, 1951), *Hemigrapsus oregonensis* and *H. nudus* (Dehnel, 1960), *Potamobius fluviatilis* (Schwabe 1933), *Eriphia spiniformis* and *Pagurus longicarpus* (Buddenbrock, 1948), *Gammarus duebeni* (Kinne, 1952), *Artemia salina* (Eliassen 1952), *Sphaeroma terebrans* (Cheriyan 1973), *Idotea neglecta* and *Idotea emarginata* (Jones 1974), *Sphaeroma annandalei* (Cherian 1977) etc. Others also have noted an increase in the rate of oxygen consumption on transfer from higher to lower salinity media, but they do not consider the increase is due to osmoregulatory activity alone. Gross (1957) maintains that the increase in the rate of oxygen consumption is due to the struggle of the animal to escape from that medium. The studies by Gopalakrishnan (1953) on Madras penaeids by keeping the animals held tight in glass jackets show that the rise in oxygen consumption in lower salinities is not due to the muscular activity of the animal. The view of Dehnel (1960) is also that the increased rate in low salinity does not result from increased muscular activity. There are other views also that the rate of respiration decreases when animals from higher salinity media are transferred to low salinity media (Kreps 1929; Prasada Rao 1965). Some authors like Eltringham (1965), Krogh (1939), Gilchrist (1956) and Frankenberg and Burbanck (1963) have observed the same respiratory rates for the animals they studied in different salinities. In the present studies M. dobsoni showed an increase in the rate of respiration when animals from a higher salinity media (30‰ S) were transferred to lower media of 10‰ S and 20‰ S. They also showed a slight increase in oxygen uptake when transferred to the higher salinity medium of 40‰ S.

But from Table-39 and Figs.47-50 it is clear that the oxygen uptake in 40% S is lower than that in 10% or 20% . This may be an indication that in media other than the acclimation medium, the animal is unable to adapt immediately to carry out its usual life activities and to overcome the osmotic stress.

<u>Oxygen consumption in relation to oxygen concentration</u>

Figs.42-45 which show the oxygen consumption of prawns of different weights at the four partial pressures of oxygen tested indicate that the linear relationship between the body weight and the oxygen consumption is maintained throughout the experiment. As evident from the figures above cited and Tables 35-38 the total oxygen consumption in *M. dobsoni* increased with the increase in the body weight in all the four salinities tested under the various partial pressures of oxygen. Statistical analysis of the 'b' values obtained in 160 mm Hg, 140 mm Hg, 120 mm Hg and 100 mm Hg shows that they are not significantly different from each other (Tables 44 and 45). Studies on the effect of ambient oxygen tension on the metabolism- body size relationship are few for comparison. Subrahmanyam (1962) observed a 'b' value of 0.43 in 180 and 150 mm Hg, 0.45 in 100 mm Hg and 0.33 in 75 mm Hg in 14.5‰ S for

Penaeus indicus. He also reported that there is very little change in the relationship between body weight and oxygen consumption in different partial pressures of O_2. In the case of *M. dobsoni* also there is no significant differences between the 'b' values obtained in different partial pressures of oxygen in different salinities as shown in Table-45.

As shown in Tables 42, 46, 47 and 48 and Figs.51-54 there are differences in the oxygen uptake and metabolic rate in the four partial pressures of oxygen tested. In general the oxygen uptake is the maximum in 160 mm Hg and as the pO_2 decreases, the rate of oxygen uptake also decreases. These variations in the rate of oxygen uptake and metabolic rate in different partial pressures of oxygen show that there is influence of declining oxygen tension on oxygen consumption of *M. dobsoni*.

Investigations have been carried out by various authors on the relation between external oxygen tension and the rate of oxygen uptake on the basis of which aquatic animals are classified as 'conformers' and 'regulators' (Lockwood, 1967; Vernberg, 1972). Species in which respiration is limited by the amount of oxygen present in the surrounding medium are called conformers. In other words they are oxygen dependent. Those species in which oxygen consumption remains unaffected until some critical oxygen tension is reached are regulators or they are oxygen independent groups. Both the types are met with in Crustacea. Figs.51-54 show that the oxygen uptake of M. dobsoni is not the same in different oxygen tensions in different salinities. The rate of oxygen uptake is gradually decreasing due to the declining oxygen tension in the different salinity media and it can be said that the oxygen consumption is dependent on oxygen concentration in the medium in the case of M. dobsoni. So it can be called a 'conformer'. In the case of M. dobsoni it can be said that the oxygen consumption is influenced by declining oxygen tension to a certain extent, but the nature of their dependency in the oxygen uptake does not affect their distribution, because in their habitat the chances of oxygen tension reaching very low values are remote as revealed by the oxygen data of the area. Therefore, the need for regulation of the respiratory rates doesnot arise in their case.

Figs.51 to 54. Trend of change in the rate of respiration in *M. dobsoni* of weights 1000, 2000, 3000, 4000, 5000 and 6000 mg in 10‰,20‰,30 and 40% S at different oxygen pressures.

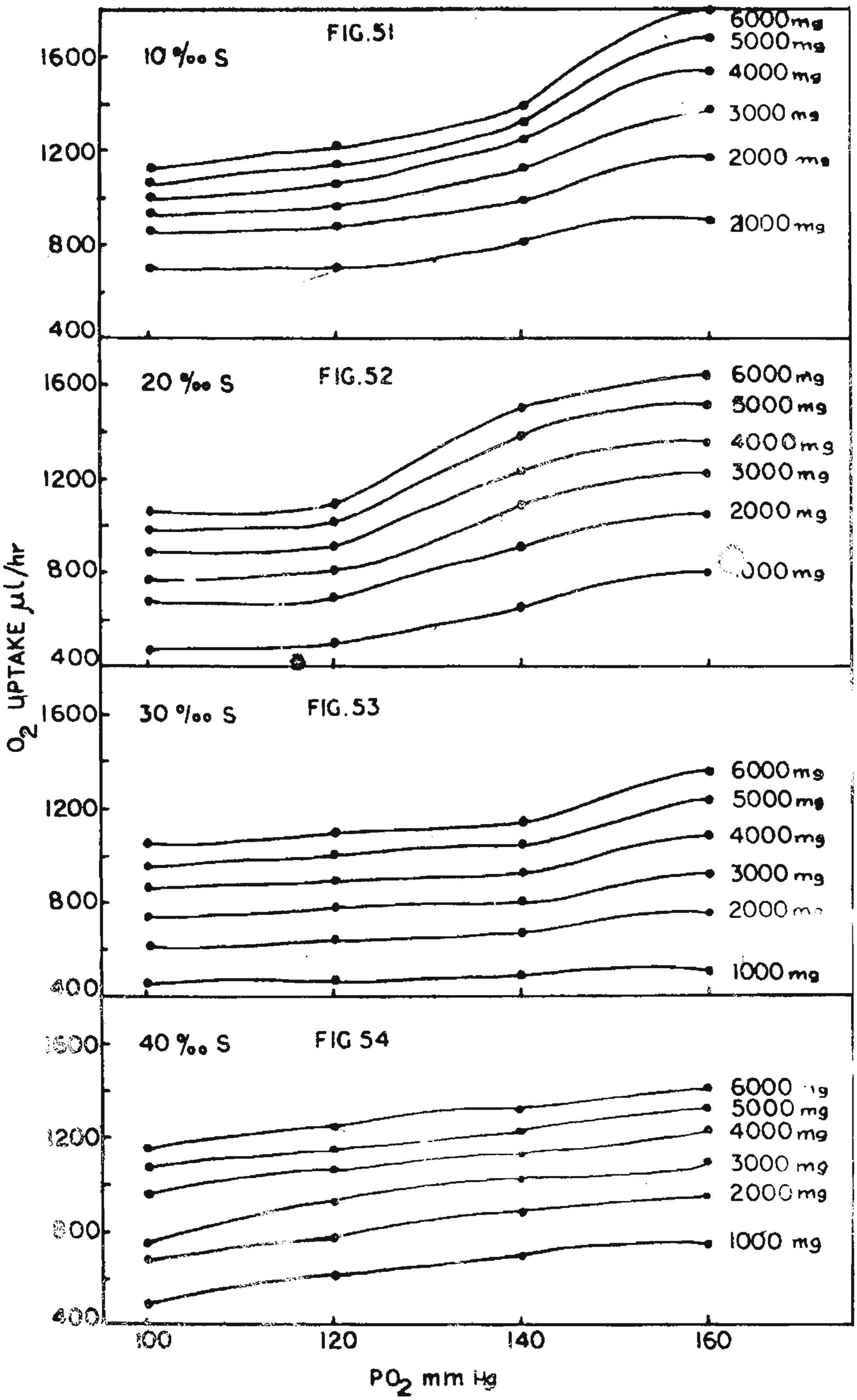


FIG. 51
10 ‰ S
FIG. 52
20 ‰ S
FIG. 53
30 ‰ S
FIG 54
40 ‰ S
6000 mg
5000 mg
4000 mg
3000 mg
2000 mg
1000 mg
400
800
1200
1600
O_2 UPTAKE µl/hr
100
120
140
160
PO_2 mm Hg

<u>Lethal level of oxygen concentration in different salinity media</u>

The level of oxygen concentration in the medium at the time of the death of the animal is termed as the lethal level. The lethal level is the highest in 10‰ S and the lowest in the acclimation medium of 30‰ S (Fig.46). It was also noticed that the lethal level in 40‰ S is lower than that in 10‰ S. This indicates that the stress due to osmoregulation is more when the animal is transferred to very low salinity than when transferred to higher salinity. There is not much variation in the lethal level of O_2 when the animal was transferred to 20‰ S. Subrahmanyam (1962) has conducted experiments on P. *indicus* to find out the relationship between the weight of the animal and the lethal level of oxygen concentration. According to him in P. *indicus* the lethal level of oxygen increased with the weight of the animal and the value varied from 1.49 ml/l to 3.80 ml/l for animals weighing from 0.60 gm to 10.0 gm and he got an exponent value of 0.345. In isopod crustaceans Cheriyan (1973) and Cherian (1977) have found no significant differences in the lethal levels of animals of different weights. But the present studies indicate that in M. *dobsoni* the lethal level increases with the weight of the animal.

SUMMARY

The most common species of penaeid prawns that occur in the Kayamkulam and Cochin backwaters, (two major estuaries in Kerala) are Penaeus indicus, Metapenaeus dobsoni and M. monoceros. It was obvious from the monthly observations carried out during 1976-1977 that there was definite seasonal variation in the larval recruitment into the two estuaries. In the Kayamkulam backwaters there was only one peak of larval occurrence and that was from September to January. In the Cochin backwaters there were two peaks of occurrence for the prawn larvae, one from September to December and the other from February to May. The total number of larvae obtained in a unit area in an year in the Kayamkulam lake was more than that of the Cochin backwaters. Post larvae and juveniles of Penaeus indicus were predominant in the Kayamkulam lake and that of Metapenaeus dobsoni dominated in the Cochin backwaters. When the size variations of prawns caught in the three common nets operated in the lakes viz. cast net, stake net and chinese dip net were compared, it was found that those obtained in the cast net were larger, whereas the catches in the stake net were smaller. Both large and

small prawns were obtained in the chinese dip net. Another factor which was observed in the present studies was that the females significantly outnumbered the males in the Kayamkulam lake whereas in the Cochin backwaters males and females were more or less uniformly distributed. The abundance and occurrence of prawns in both the estuaries were influenced mainly by salinity and to a lesser extent by temperature. During the monsoon season when the salinity and temperature were low the catch was poor, whereas during post monsoon and pre monsoon periods when the temperature and salinity were high there was good catch.

The three species of penaeid prawns, *Penaeus indicus*, *Metapenaeus dobsoni* and *M. monoceros* which are known to contribute largely to the commercial fishery in the Cochin backwaters were taken up for investigations on the salinity tolerance, the effect of salinity on growth, and the temperature tolerance. Oxygen consumption in relation to size, salinity and oxygen concentration of *M. dobsoni* were also studied in the laboratory.

Laboratory experiments on salinity tolerance revealed that these prawns were essentially euryhaline and they could tolerate wide ranges of salinity from 3‰ to 43‰. Three series of salinity tolerance tests have been carried out using animals acclimated in low (5‰) medium (15‰) and high (30‰) salinities representing the three seasonal salinities in the habitat. The lower and higher lethal salinities for each species acclimated in the above salinities have been found out. For M. dobsoni and M. monoceros acclimation to low salinity tended to shift the lower limit downward and the upper limit upward. For P. indicus acclimation to low salinities did not shift the lower limit downward. When the three species were compared, the differences found in their tolerance capacity in varying salinities from 0-50‰ were not significant.

Experiments in the laboratory on the tolerance of the three species of prawns at elevated temperatures have shown that both the post larvae and juveniles could survive in temperatures upto 36°C. But the number of survivors varied. Some species differences with regard to their tolerance capacity to high temperatures have been noticed. M. dobsoni showed more tolerance than the other two species whereas M. monoceros showed the least tolerance. It has also been found that the ranges of temperature tolerated by each species varied depending on the size of the individuals and the salinity of the medium, the larger specimens tolerating more in higher salinities. The smaller post larval prawns were more susceptible to death in higher salinities. The upper lethal temperature slightly varied in different species as well as for both post larvae and juveniles.

Both post larvae and juveniles of _P. indicus_, _M. dobsoni_ and _M. monoceros_ were used for laboratory experiments to study the effects of salinity on growth. The results of the study for about one month showed that the growth of both post larvae and juveniles of all the three species was affected by variations in salinity to certain extent. The maximum growth of post larvae of _P. indicus_ occurred in 25‰ S and that of the juveniles in 30‰ S. The maximum growth of post larvae of _M. dobsoni_ and _M. monoceros_ was noticed in 20‰ S and that of the juveniles of both the species in 25‰. _P. indicus_ showed the highest growth rate whereas _M. dobsoni_ showed the minimum growth rate. When the size ranges were taken into consideration post larval prawns showed greater rate of growth than the juveniles within a limited period of about one month in all the different salinities.

Studies on the effect of varying salinity on the growth of the above mentioned three species for a period of one year were also conducted in the laboratory. In the case of *P. indicus* the highest rate of growth was noted in 30‰ S (8.6 cms in the first year) and the lowest rate of growth was observed in 20‰ S. Both for *M. dobsoni* and *M. monoceros* growth was maximum in 25‰ S (*M. dobsoni* 6.4 cms and *M. monoceros* 6.84 cms in the first year) and minimum in 35‰ S.

The oxygen consumption in relation to salinity and oxygen concentrations was investigated in the prawn *M. dobsoni*. It was found that the regression coefficient of oxygen consumption against body weight was not significantly varied in different salinity media. In those prawns which were tested in the acclimation salinity of 30‰ S at pO_2 160 mm Hg the 'b' value was found to be 0.5031. This value is not significantly different from that of *P. indicus* reported previously. An increase in the oxygen uptake had been observed with a decrease in the salinity of the medium below that of the acclimation salinity. The oxygen consumption in the higher salinity of 40‰ was also higher than that in the acclimation salinity.

The rate of oxygen uptake per hour under falling oxygen tension in different salinity media showed variations. In all the salinities of 10‰, 20‰, 30‰ and 40‰ the animals were oxygen dependent from 160 mm Hg downwards, since there was a gradual decrease in the rate of oxygen uptake in relation to the declining oxygen tension. Under the same laboratory conditions, in the same salinity medium significant differences have been noted in the lethal levels of oxygen, for the different weight groups of animals. The larger animals showed higher lethal levels than the smaller ones. The lethal levels were weight dependent and held a linear relationship with the body weight. The tolerance capacity to low oxygen content decreased as the animal became larger.

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A P P E N D I X

Observations on the food and feeding of some Penaeid Prawns of Cochin area

V.J.Kuttyamma
Department of Marine Sciences
Cochin

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OBSERVATIONS ON THE FOOD AND FEEDING OF SOME PENAEID PRAWNS OF COCHIN AREA

V. J. KUTTYAMMA

Department of Marine Sciences, Cochin

ABSTRACT

An investigation into the food and feeding habits of 5 species of penaeid prawns viz. *Metapenaeus dobsoni, Penaeus indicus, Metapenaeus monoceros, Metapenaeus affinis*, and *Penaeus monodon* found common along the Kerala coast has been carried out based on samples collected from the inshore regions of Cochin during 1971-72. It has been observed that all the above species are omnivorous and detritus feeders, depending much on the benthos. The food in general consists of varying amounts of organic matter mixed with sand and mud. However, some amount of seasonal variation in the food and selective feeding has been noticed in some species particularly depending on the ecological conditions. Proportionately larger quantity of debris was noticed in the young prawns, while adults mostly depended on the common bottom animals including small molluscs and plant matter.

INTRODUCTION

PRAWNS form one of the most economically important constituents in the marine fish landings in India. At present most of the catch comes from the inshore regions within the 20 fathom line. For increasing the production, it would be necessary to explore offshore resources and also to start intensive pond culture. Though prawn culture is carried out in some parts of the country, it has not yet overcome the various difficulties and reached a stage comparable to the one carried out in Japan. In this connection it would be advantageous to study the biology of the common forms with special reference to the food and feeding habits. An investigation into the food and feeding habits of the various species may help in gathering data for their successful culture in ponds.

Some of the important works on the food and feeding habits of penaeid prawns are those of Williams (1955) on some North American shrimps, Eldred *et al.* (1961) on *Penaeus duorarum*, Dall (1967) on some Australian penaeid prawns, Hall (1962) on the food of the Indo-west Pacific penaeids, and Tiews *et al.*(1968) on some Philippine shrimps. In India, Gopalakrishnan (1952) has studied the gut contents of *Penaeus indicus*. Panikkar (1952), Panikkar and Menon (1956), Kunju (1967) and George (1959) have recorded the food contents of penaeid prawns while studying the biology of different species. The present paper deals with the observations made on the food and feeding habits of some economically important penaeid prawns of the Kerala coast.

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MATERIAL AND METHODS

The material for the present study was collected by random sampling twice a week from the commercial catches from the inshore regions of Cochin during 1971-72. The specimens were preserved in formalin immediately after the catch. The

Penaeus indicus H. Milne-Edwards

This species is common in the estuaries and backwaters almost throughout the year, although the size differs with the season. In the sea, it is generally caught during the post monsoon months. Of the 330 specimens of length 29-132 mm examined, 13 had no food materials in their stomachs.

The stomach contents showed a high percentage of debris (50.7%). Animal matter constituted 22.0% and plant 25.0%. Hall (1962) classified *P. indicus* and *P. monodon* as species feeding mainly on large crustaceans. More vegetable matter were noticed in the present study thus differing from the observation of Hall. This may be due to the differences in the environmental conditions. Hall also observed that in *P. indicus* the 'small' specimens fed mainly on plant tissue(Cladophora and Angiosperm tissue), while the large specimens fed predominantly on large crustaceans. But no size-oriented differences in the diet were noticed in the present observations.

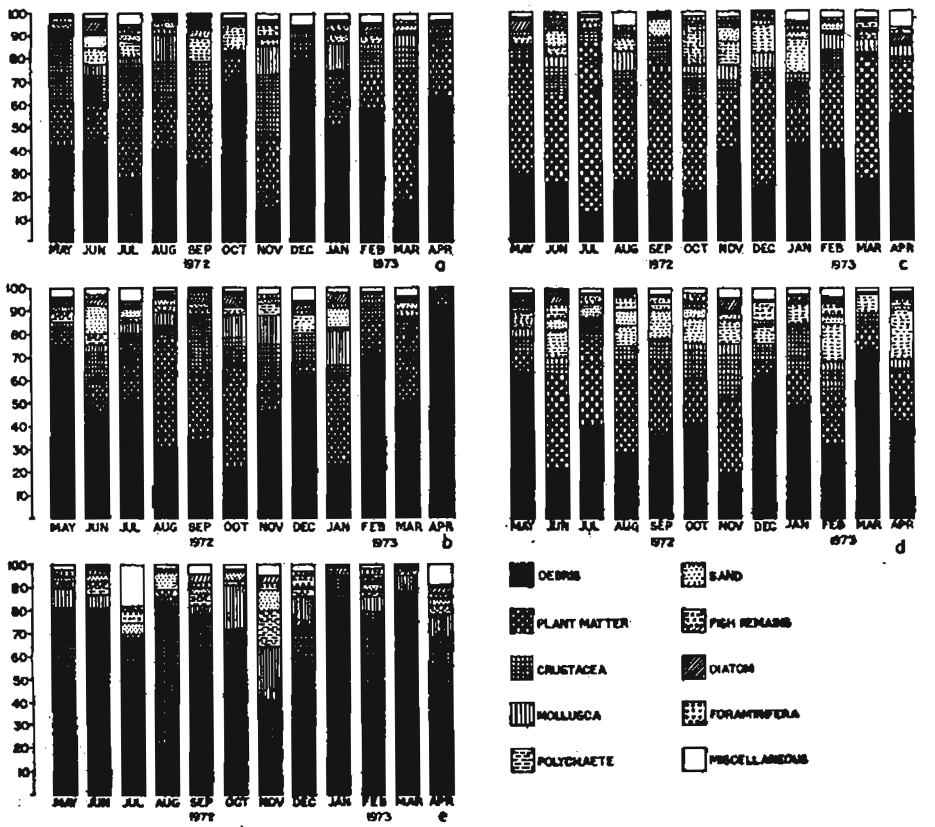

Fig. 1 a-e. Percentage composition of different food items in the common penaeid prawns collected from Cochin area during 1971-72. a. *Metapenaeus dobsoni*, b. *Penaeus indicus;* c. *Metapenaeus monoceros*; d. *Metapenaeus affinis*; and e. *Penaeus monodon.*

Algal fragments were observed in the stomach in plenty during August and October. Small quantities of diatoms such as *Fragilaria, Rhizosolenia and Coscinodiscus* were noticed during all the months except in November. Vegetable matter formed the dominant food item of this species, while crustaceans ranked next in importance. Heavy feeding on crustacean was observed during June and September. Juvenile gastropods and bivalves formed the major part of the diet during November and January. Some of the minor food items encountered were small nematodes and foraminiferans. During June and January sand grains were abundant. Polychates were dominant in December. Gopalakrishnan (1952) observed that vegetable matter and crustaceans formed the bulk of the food consumed by *P. indicus*. The present observation also shows the presence of large quantities of algal matter (Fig. 1b).

Metapenaeus monoceres Fabricius

This species constitutes to a rich fishery along the east and west coasts of India. Stomach contents of 210 specimens measuring 30-128 mm were examined; 20 specimens had empty stomachs.

The species showed a preference to vegetable matter, mainly seaweeds and algae during the greater part of the year. Diatoms were abundant during April, May and June. Comparatively lesser amount of debris was noticed in this species than in others (Fig. 1c). The common crustaceans met with were copepods, ostracods, amphipods and decapod larvae. During the post monsoon months large number of setae, tentacles and fragments of polychaetes were present. Small bivalves and gastropods, fish larvae, fish scales and muscles were also noticed. Sand particles were more during June and September. Tiews (1968) in his studies on the food and feeding habits of *M. monoceros* from Manila Bay and San Miguel Bay has observed that the main food was benthic foraminiferans, while the dominant item of food observed in the present study was vegetable matter. The difference in the diet may be due to the change in the habitat.

Metapenaeus affinis H. Milne-Edwards

This is also one of the important commercial species occuring along the west coast and the southern region of the east coast. Of the 120 specimens ranging in size 29-120 mm examined, 29 had empty stomachs.

The items of food found in the stomach in the order of abundance were vegetable matter mainly consisting of algae; polychaete remains, crustaceans, fish remains and molluscan remains. Amphipods and calanoid copepods were observed frequently during November and January. During April and July algal filaments were abundant. The polychaetes formed an important food item as they were present during almost all the months (Fig. 1d). Diatoms were noticed more in November. *Fragilaria* was the common diatom observed.

According to Subramanyam (1963) *M. affinis* is an omnivorous feeder and larger ones showed a preference to molluscan diet. Hall (1962) in his observation on the specimens caught from the Straits of Malacca has shown that the species feeds mainly on vegetable matter. But in the present study it is seen that the larger prawns showed a preference to polychaete diet whereas the younger ones preferred vegetable matter.

Penaeus monodon Fabricius

This is probably the largest marine prawn in India, but it does not form a dominant fishery anywhere. Out of the 56 specimens with a size range of 39-212 mm examined, 3 were with empty stomachs.

Debris composed of mud and organic matter constituted the main portion of the stomach content as in other forms while crustaceans ranked next in importance (Fig.1e). Rao (1967) examined the stomach contents of *P. monodon* from Chilka Lake and observed this species feeding mainly on molluscan remains. Hall (1962) classified *P. indicus* and *P. monodon* as species feeding mainly on large crustaceans. In the present study also, crustaceans were observed, the maximum being during August. Larval bivalves and shell fragments were abundant in October and November. Polychaetes were largely observed in November. Fish remains and diatoms were present frequently in the stomach. Sand constituted a significant portion of the stomach contents during August and November. Nematode fragments and other miscellaneous items were more during July and April.

GENERAL OBSERVATIONS

Feeding habits

From the analysis of the stomach contents it is evident that all the above five species may be considered as omnivorous and detritus feeders. Studies by Gopalakrishnan (1952), Williams (1956) and Eldred *et al.* (1961) have shown that animal remains, algal fragments, sand and detritus comprise recognizable components. Williams (1955) noted in the N. American shrimps that unrecognizable debris formed a major component and suggested that "soft material" may form the bulk of the diet. In general, penaeid prawns have been described as "omnivorous scavangers" or "detritus feeders". A purely herbivorous or carnivorous feeding habit is not seen in any of the species. The food in general consists of varying amounts of organic matter mixed with sand and mud. In almost all the prawns examined, a considerable portion of the stomach contents consisted of unidentifiable finely ground up matter. It was not possible to decide whether the "debris" had been ingested as such or ground up in the stomach. The average debris content was more in *P. indicus* and less in *M. monoceros*. There was greater amount of debris in young prawns and lesser amount in larger specimens, a fact noted in all the species. *M. monoceros* was found to feed more on vegetable matter than the other species.

Occurrence of benthic forms such as polychaetes, amphipods, bivalves, gastropods, foraminiferans, nematodes and also sand and mud indicates the pronounced bottom feeding habit of the prawns. However, the specimens collected from the areas connected to the paddy fields showed a large amount of plant matter showing that the species could adjust to various types of environmental conditions.

Seasonal variations in the food

Some amount of seasonal variations in the food have been observed in the different species examined. In the case of *P. indicus*, algal content was more in the stomach during the monsoon season, whereas the molluscan remains were more during the post monsoon months. During the premonsoon and the monsoon period, plant matter was more in *M. dobsoni* while the vegetable contents were low during the post monsoon period. In *M. affinis* and *M. monoceros* there was more vegetable content during the monsoon season. Crustaceans were common in the stomachs of *M. dobsoni* during the monsoon months, but in *M. affinis* and *P. indicus* they were prominant during the postmonsoon season. In *P. monodon* crustacean fragments were more during the premonsoon and monsoon periods. The above observations show that some sort of selection for food exists as there are variations in the stomach contents of the different species collected from the same habitat.

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