

SEASONAL ABUNDANCE, ECOLOGY, REPRODUCTIVE BIOLOGY AND
BIOCHEMICAL COMPOSITION OF MESOPODOPSIS ORIENTALIS
W.M.TATTERSALL (MYSIDA) FROM A TROPICAL ESTUARY (COCHIN
BACKWATER) IN INDIA

BY

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ABSTRACT

Seasonal abundance, life history, and biochemical composition of Mesopodopsis orientalis Tattersall were investigated based on samples collected over a period of one year in tropical estuary, i.e., Cochin backwater. M. orientalis was recorded throughout the year and its peak abundance was observed during the monsoon period. The species produced more than one generation per year. The number of embryos carried by a single female ranged from 7 to 12, and was correlated with female length ($P < 0.05$), tending to increase with the size of the female. Egg size varied between 0.39 and 0.47 mm, with no correlation with length of the female, and size difference was observed in the same brood. Males and females attain sexual maturity after reaching the total length of 5 mm and 4.5 mm respectively. With the exception of chlorophyll *a*, the environmental parameters, dissolved oxygen, salinity, pH and water temperature do not have much influence on population density. The biochemical composition of the species reveals its high nutritional quality. Matured males and females showed higher protein contents than other stages, while carbohydrate content was high in immature stages, and lipid content was high in brooding females.

INTRODUCTION

Mysids occupy a wide variety of aquatic environments and are ubiquitous in estuarine ecosystems. Their ecological importance, in particular their role in food chains as a link between the benthic and the pelagic system, is becoming increasingly apparent. In general, mysids are omnivores, feeding on detritus, zooplankton and phytoplankton, as such forming a link between microbial producers and secondary consumers (Webb, 1973). Mysids have been recorded in the gut contents of marine and estuarine fishes (Darnell, 1958, 1961; Stickney et al., 1974; Mauchline, 1980) as well as of birds (Moffat, 1996), thus playing a part in energy transfer to higher trophic levels (Mees et al., 1994).

Mesopodopsis orientalis W.M.Tattersall, 1908 is the most widespread and abundant mysid in backwaters and estuaries on both the east and the west coasts of India. Its local significance in various ecosystems and as food source for, e.g., vertebrates, among which human, as well as in aquaculture has been well established already. (Larkin, 1948; Li, 1964; Mauchline, 1970; Rao, 1970; Lasenby & Langford, 1973; Jhingran, 1975; Morgan & Beeton, 1978; Guevara et al., 2005; Domingues et al., 1999, 2000, 2001). Although there is a considerable literature on the occurrence of this species from different areas (Panikker & Aiyar, 1937; Devasundaram & Roy, 1954; Dutta et al., 1956; George, 1958; Pillai, 1968; Battacharya & Kewalremani, 1972; Goswami et al., 1979; Gajbhiye et al., 1980; Chandramohan, 1983; Gupta & Gupta, 1984; Sarkar & Chowdhury, 1986) no literature is available on its population abundance, reproductive biology, and biochemical composition. Considering its ecological and economic importance, the present study aims to elucidate the seasonal population structure, ecology, and biochemical composition of Mesopodopsis orientalis.

MATERIAL AND METHODS

Study area

Cochin backwater is part of a long chain of lakes and canals, parallel to the coast, extending between 9° 40' 12" and 10° 10' 46" N and 76° 09' 52" and 76° 23' 57" E. The total area of the backwater is about 157 km², with depth ranging from 2 to 8 m. A large number of rivers discharges into it, and it opens into the Arabian Sea through one major and several minor outlets. The water is saline (5-32‰) during the dry season and almost

fresh during the monsoon (May-October). Salinity gradient in Cochin backwater ranges from oligohaline, through mesohaline to fully marine conditions. Of the three sampling stations, (fig. 1), station 1 (S1, harbour entrance) maintains a marine condition throughout the year. Station 2 (S2), situated in the northern limb of Cochin backwater is free from sudden tidal variations and has an intermediate condition with regard to salinity. Station 3 (S3) in the southern branch, experiences the maximum tidal variation, due to shipping channel. Distance between stations is approx. 7 km on average.

Sampling procedure and data analysis

Material was collected as a part of the studies on “Ecosystem Modeling of Cochin backwaters” in the period March 2003- February 2004. Weekly Samples were taken for one full year cycle and zooplankton was collected by day using a Working Party (WP) net (mesh size 200 μm , mouth area 0.6 m^2) fitted with a flow meter to estimate the volume of water filtered. The net was hauled for 10 min. at the surface. Samples were preserved in 4% formaldehyde. At each station, temperature, salinity (Digi Autosalinometer), dissolved oxygen (Winkler methods), pH (pH meter), and chlorophyll *a* (Strickland & Parsons, 1972) were measured.

In the laboratory, mysids were sorted from the samples and classified according to the degree of development of secondary sexual characteristics (Mauchline, 1980). Length is given as the distance between the anterior margin of the carapace and the apex of the telson, and was measured using a binocular microscope fitted with a micrometer eyepiece. In the same manner, eyeless larvae and eyed larvae were measured from the anterior to the posterior end when straightened (Hanamura, 1999). The egg or embryo was measured along the longest axis to the nearest 0.01 mm under a dissecting microscope. Brood size (number of eggs or larvae) was determined only for those females with an unruptured marsupium.

Biochemical analysis

Samples for biochemical analysis were collected from Cochin backwater during the monsoon period (June 2007) using a WP net as well. The organisms collected were transported in 10 L containers to the laboratory, where mysids were separated from other

organisms. Then species were identified and sorted into mature males, immature males, spawned females, females with embryos (brooding female), immature females and juveniles. The specimens were left to evacuate their guts in filtered seawater (for 12-24h). Samples from each group were lyophilized and refrigerated at -30°C; smaller portion portions of this material were later weighed and used for the determination of each biochemical constituent (analytical replicates) (Azeiteoro et al., 2001).

Proteins were quantified according to the Folin phenol method (Lowry et al., 1951) using bovine albumin as a standard. The quantification of total carbohydrates was performed according to the colorimetric method using phenol and sulphuric acid (Dubois et al., 1956), using glucose as a standard. Lipid extraction was carried out according to Bligh & Dyer (1959) by direct elution with chloroform and methanole (1 : 2 v : v). The extracted lipids were dried at 80°C (20 min.) and determined spectrophotometrically after carbonization at 18°C in concentrated sulphuric acid (Marsh & Weinstein (1966); with tripalmitine solution used as a standard.

Multiple regression analysis was employed to assess the predictability of population density on the physico-chemical variables.

The model used for this purpose was,

$$Y = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_4 x_4 + b_5 x_5$$

Where y = population density; x_1 = chlorophyll; x_2 = dissolved oxygen; x_3 = salinity; x_4 = pH; x_5 = water temperature. The significance of the fitted regression was tested using ANOVA.

RESULTS

Mesopodopsis orientalis was present in the estuary throughout the year. Although density fluctuated greatly at each sampling stations, they showed more or less similar trend in their annual peak (fig. 2). The highest population density was observed at S2 station (7086 ind./1000 m³) followed by S3 (5277 ind./1000 m³) and S1 with the lowest density (2129 ind./1000 m³). There was clear seasonal variations: during the premonsoon period 17.8% of M. orientalis occurred with an average density of 25.3 ± 59.3 ind./1000 m³ at S1,

130.4 ± 226.2 ind./1000 m³ at S2 and 78.3 ± 122.8 ind./1000 m³ at S3 and was constituted by 13.2% immature males 16% mature males, 2.9% spawned females, 6.1% females with eyed larvae, 2.4%, females with eyeless larvae, 2.3% females with egg, 19.3% immature females and 37.9% juveniles. Compared to that of other seasons, the high abundance of M. orientalis occurred in monsoon period (67.7% of total population) with an average density of 161 ± 231.4 ind./1000 m³. All development stages of M. orientalis were recorded from June to September, with a comparatively, high density and comprised of 13.6% immature males, 16.6% mature males, 6.6% spawned females, 5.2% females with eyed larvae, 3.6% females with eyeless larvae, 5.4% females with egg, 16.1% immature females and 32.6% juveniles. The three stations showed same trend during this period even though females with eyeless larvae and eyed larvae are absent in S1. After September density decline rapidly, only 14.5% of the total population of M. orientalis are present in the post-monsoon period of which 29.2% were immature males, 14.4% mature males, 1.8% spawned females, 1.5% females with eyeless larvae, 20.2% immature females and 32.9% juveniles. During post-monsoon, brooding female are completely absent at S2 and S3 stations. The monthly percentage shows that juveniles dominated most of the samples and the percentual composition of each life stages of M. orientalis varied with seasons (fig. 3).

M. orientalis tolerates a wide range of temperature and salinity: during the study period, it occurred at salinities of 0 to 34.25‰, and temperatures of 27.2- 32.8°C. The fitted multiple regression model for the data was found to be $y = 1309.398 - 25.678x_1 - 3.525x_2 - 41.648x_3 - 13.128x_4 + 1.269x_5$.

Statistical analysis reveals that dissolved oxygen, salinity, pH, and water temperature did not have much influence on population density of M. orientalis, while chlorophyll *a* some influence on their distribution. The fitted regression model for the data is significant ($R^2 = 0.135$) as can be seen from the ANOVA (table I).

Brood characteristics

The numbers of embryos or larvae in the marsupium of females of different size at different times of the year were examined. Brood size was positively correlated with female length ($P < 0.05$) (fig. 4). The minimum number of brood recorded was 8 (4.5 mm

females) and the maximum 12 (6.3 -7.4 mm). Egg (early embryo) size varied between 0.39 and 0.47 mm, with no correlation with the length of female. Size difference was also observed in the eggs of the same brood.

Post-marsupial development

The total length of the smallest free-swimming individual was 1.2 mm. Males and females matured at 5.2-7.6 mm and 4.7-6.4 mm length, respectively, and attained their maximum size in May (7.6 mm) and September (8.3 mm), respectively (table II). The total length of immature males and females ranged from 4.2 to 5.8 mm and 4.3 to 6.5 mm, respectively. The largest immature male was collected in December and the largest immature female in April. The appearance of eggs in the marsupium occurred when the body length was in the range of 4.7- 6.4 mm, and eyeless and eyed larvae occurred in the marsupium at a length range of 4.5- 6.3 mm and 5.3-7.4 mm, respectively. In some individuals measuring 4.6 mm, secondary sexual characters were not yet visible, while in some others measuring 4.3 mm, secondary sexual characteristics were noticed already.

Biochemical composition

There is a significant variation in biochemical composition between different development stages (Table III) ($P < 0.01$). The Proteins contributed the primary body component in all life stages. Protein content in immature individuals was lower than in adult males and females. The amount of total carbohydrates was exceedingly low, but immature individuals showed a higher carbohydrate proportion than mature male and females. High lipid contents occurred in females, especially in brooding females (table IV).

DISCUSSION

Mesopodopsis orientalis is a euryhaline and eurythermal form, commonly found in the backwaters and estuaries at both the east and the west coasts of India (Devasundaram & Roy, 1954; George, 1958; Pillai, 1967; Panikkar & Aiyar, 1937). It has also been recorded from the prawn ponds on Singapore Island and fish rearing lagoons of Java (Ii, 1964). The species has also been recorded from the Bhayanda saltpan, Mumbai at salinity and temperature ranges from 1.2 to 63.6 and 23.5 to 37°C, respectively (Panampunnayil,

1999) as well as from the inner reaches of rivers where the water is almost fresh (George, 1958; Panikker & Aiyyer, 1937). Belyaev (1949), Remane & Schlieper (1958) and McLusky & Heard (1971) pointed out that euryhaline species are well adapted to live in an environment with wide fluctuations in salinity though their capability to prevent excessive changes in their internal environment by maintaining their blood hyper or hypo osmotic to the medium. A series of experiments was carried out by Battacharya & Kewalremani (1972) and Battacharya (1982) to determine the reaction of adults and juveniles of M. orientalis to varying salinities at different temperatures. The salinity tolerance range of this species in the backwaters (0- 34.25‰) is more or less similar to laboratory values found (1.75-35‰).

The peak abundance of M. orientalis occurred during the period of low salinity; all development stages of M. orientalis occurred in this period. This has at least two reasons: one is related to reproduction. Second is coinciding with less predation. Estuaries are the breeding ground of many fishes and prawns (George, 1958; Rao, 1970; Jhingran, 1975) and during monsoon periods these migrate to coastal waters from the estuaries. They breed there, because the juveniles may not be able to survive in the estuaries, where the salinity is low in the rainy season. Adults and juveniles of M. orientalis occurred in great abundance during the monsoon period. They also occurred in pre-monsoon and post-monsoon, but in lower in abundance (Bhattacharya & Kewalrami, 1972). It is apparent from the continuous presence of juveniles that M. orientalis breeds throughout the year and can survive and reproduce in a wide range of salinities (0-34.25). The failure to collect brooding females in all months may be due to low densities and to the migratory nature of the species, or it may be due to predation.

An analysis of the population structure of Mesopodopsis orientalis demonstrates the difference in length composition of the population, and reveals the reproductive condition of the species. In males the secondary sexual characters start to develop at a total length of 4.2 mm, and they attain sexual maturity at a length of 5.2 mm, whereas in females the secondary sexual characters start to develop at 4.3 mm and sexual maturity is attained at 4.5 mm. Some immature females collected in May were larger than ovigerous female collected in the same months. This reveals that total length alone does not determine maturity.

Even though large females carried more young, the number of young carried by females of equal body length also varied. In the present study, number of brood carried by females ranged from 7 to 12. Nair (1939) recorded the number of eggs carried by females as 8-10, while Panampunnayil (1999) reported 6-29 eggs or larvae in M. orientalis collected from coastal regions of Mumbai. Nair (1939) described in detail the formation and extrusion of eggs in M. orientalis: the incubation period is only 96 hours at 25-29°C and the female then moults and immediately spawns again. In mysids the shortest duration (4 days) of marsupial development is reported for M. orientalis, while the developmental time of its European congener M. slabberi (Van Beneden, 1861) was 9 to 19 days (Greenwood et al., 1989). Mysis relicta Loven, 1862, a cold-water species, has the longest (150-170 days) reported development time. The pattern of reproduction and succession of generations varies among species and between populations of the same species at different latitudes. Since in M. orientalis, breeding take place all year round, many broods will be produced by a single female as indicated by the presence of different size classes of juveniles in most of the collections, which suggest the occurrence of more than one generations per year, although the longevity of a single individual lives is not known. The population consists of mixed age groups due to this continuous reproduction, and hence makes it impossible to trace the development of a particular group through to maturity by overlapping generations.

From the regression analysis, it is evident that except chlorophyll a, other environmental parameters like salinity, water temperature, pH, and dissolved oxygen have not much influence on the distribution and abundance of M.orientalis in the Cochin backwater. The system is highly productive during monsoon period, which may be due to the nitrogenous input that comes through monsoonal river flow, and the feeding activity of M. orientalis also increased. Therefore, according to changes in phytoplankton biomass, the distribution and abundance also varied. Linden & Kuosa (2004) reported that, mysids can alter the size structure and the biomass of the phytoplankton community: directly through selective grazing or nutrient recycling (excretion) and indirectly through predation on the main herbivores and subsequent cascading effect.

Between three stations, the population density has considerable variations. This may be correlated with the geographical conditions of particular stations. Even though

breeding peak was observed in monsoon period, the population density was comparatively low in bar mouth station (S1) and shipping channel station (S3). This may be due the effect of tidal current of that particular area. Many workers described the influence of tidal current on the distribution of zooplankton and mysids. (Heubach, 1969; Wooldridge & Erasmus, 1980; Wooldridge & Bailey, 1982; Hill, 1991; Hough & Naylor, 1991; 1992; Moffat & Jones, 1993)

Biochemical composition

Protein was the principal body component in all life stages Earlier studies on biochemical composition of other invertebrates especially zooplankton and mysids indicates that protein constitute the major fraction in terms of dry weight (Raymont et al., 1964; Reeve et al., 1970; Raymont, 1971; Bhat & Wagh, 1992). The present results were also consistent with other reports obtained for mysids (Nair et al., 1975) and zooplankton in general (Gopalakrishnan et al., 1977) collected from Cochin backwater. Compared with that of carbohydrate and lipid, large amount of protein content, suggest that protein is the main metabolic reserve in mysids. Ortega et al. (1984) reported that proteins are the main body component and their fluctuations related to the tissue water content. Fluctuation in the hydration level of the tissues in the different developmental stages quantify the protein content of the particular stages and also capacity or need of the protein content in different developmental stages are also varied. The variation in protein content may be either due to its utilization as a metabolic substrate or seasonal changes, life stage at the time of collection and salinity (Raymont, 1972). Verslycke & Janssen (2002) studied the effect of ecdysis on the protein metabolism in mysids. They assumed that the exoskeleton of mysids contains large amounts of protein. A highly developed exoskeleton thus may be one of the reasons of large amount of protein present in the matured males and females

Low carbohydrate values have been reported in zooplankton by earlier workers in their respective studies in temperate as well as tropical seas (Krishnakumari & Achuthankutty, 1989; Stephen et al., 1979). This very low contribution by carbohydrate is almost identical with earlier studies in mysids (Raymont et al., 1964, 1966; Raymont & Linford, 1966; Vinogradove, 1964; Goswami et al., 1981; Azeitero et al., 2001, 2003), which suggest that the main energy storage in this group of organisms is not in the form of

long carbohydrate chains, i.e. glycogen and the usual storage carbohydrate in mysids might not contribute substantially to body reserves and energy flow. Carbohydrate cannot be utilized to noteworthy degree, since they constitute only a very small fraction in most planktonic organisms (Anger & Nair, 1979). Although protein and lipid utilization is variable in crustaceans, in general, carbohydrate is used before protein and lipid as the preferred fuel for metabolic process (Garret & Grisham, 1995; Morris, 1999). Immature male and female show comparatively high carbohydrate content than other development stages may be due to relatively high storage of glycogen than others.

Lipid variation is a fluctuation of metabolism and reproductive strategy, depending up on the species life cycle (Pastorinho et al., 2003). During the present study, all females, but especially brooding females showed high lipid content. The egg of mysids contains high amounts of lipids and the lipid metabolism of ovigerous female can be assumed to be different from males (Linford, 1965; Verslycke & Janssen, 2002). The variation in lipid metabolism observed might be partially caused by a sex specific lipid metabolism (Verslycke & Janssen, 2002). Adult female may show high lipid contents and this is related with reproduction (Raymont et al., 1969). Lipid accumulation is the most widespread long-term energy storage strategy in aquatic crustaceans and their reproductive potential is largely dictated by lipid content (Sargent & Henderson, 1989).

Effective utilization of resources depends upon accurate knowledge of their occurrence, relative abundance and distribution. In conclusion, a high abundance, a wide range of tolerance with environmental parameters, and a short life cycle of this Indo-Australasian mysids may be suitable for bioassay test and have great potential use in aquaculture as a feed, because of their biochemical composition can satisfy the nutritious needs of a wide variety of animals, and also complies with the recommendations of FAO (1989).

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Figure captions

Figure 1. Station locations in the Cochin backwater.

Figure 2. Population density of Mesopodopsis orientalis Tattersall, 1908 at three stations in Cochin backwater.

Figure 3. Composition of different age group of Mesopodopsis orientalis Tattersall, 1908 in Cochin backwater. IM, immature males; MM, mature males; SF, spent females; ED, females with eyed larvae; EL, females with eyeless larvae; EG, females with egg; IF, immature females; J, juveniles.

Figure 4. Relation ship between the total length of females and the brood size of Mesopodopsis orientalis Tattersal,1908 in Cochin backwater.

Table I

Results of ANOVA for environmental parameters with population density of Mesopodopsis orientalis Tattersall

Source	SS	df	MS	F	Significance
Regression	995742	5	199148.451	3.475	<u>P</u> <0.01
Residual	6364132	111	57334.520		
Total	7559874	116			

SS, sum of square; df, degree of freedom; MS, mean square; F, table value. ($R^2=0.135$)

Table II

Variation in length (mm) of age groups of Mesopodopsis orientalis Tattersall in different months

Month	IM	MM	SF	ED	EL	EG	IF	J
March 2003	4.5-4.9	5.6 -6	5.2-5.8	-	-	-	5.4	2.2-3.2
April	4.9-5	5.7-5.8	-	-	-	-	5-6.5	3-3.6
May	5.2	6-7.6	-	5.4-5.9	5.9-6.2	5.7-6.1	5.3-6.3	1.2-3.9
June	4-4.9	5.2-6.2	4.9-7.2	7.2	4.5	-	4.8-5.4	2.7-3
July	4.7-5	5.2-6.3	7.1-7.3	6.2-6.4	5.2-6	4.7-6.2	5.1-6.2	1.7-3.3
August	5.1-5.3	5.7-5.9	5.7-5.8	5.3-6.3	6.3	5.2-5.8	6-6.2	3.2-4.6
September	5.3-5.5	6.2	6.7-8.3	6.1	5.9-6.1	6.1-6.4	4.3-6.2	2.1-3.7
October	4.9-5.4	6	7.6-7.7	-	-	-	4.7-5.8	1.9-3.4
November	5.2-5.3	5.8	-	-	-	-	-	1.8-3.2
December	5.2-5.8	5.3-5.9	-	-	-	-	-	2.1-3.5
January 2004	4.2-5	6-6.3	-	-	5.8	-	5.2-6.1	2.4-3.5
February	5.1-5.3	6.1-6.3	5.7-6	7.4	-	-	5-6.1	2.3 -4

IM, immature males; MM, mature males; SF, spent females; ED, females with eyed larvae;

EL, females with eyeless larvae; EG, females with egg; IF, immature females; J, juveniles

Table III

Results of ANOVA for biochemical analysis of Mesopodopsis orientalis Tattersall

Source	SS	df	MS	F	Significance
Between stages	14452.3	2	7226.148	1045.876	P<0.01
Within stages	103.6377	15	6.909181		
Total	14555.93	17			

SS, sum of square; df, degree of freedom; MS, mean square; F, table value.

Table IV

Biochemical composition (% dry wt) of different development stages of Mesopodopsis orientalis Tattersall from Cochin backwater. (n=3-4 subsamples)

Developmental stages	Proteins	Carbohydrates	Lipids
Mature male	71.73±1.37	3.59±3.28	15.23±1.92
Immature male	65.83±1.76	4.27±2.15	16.80±2.69
Spawned female	74.75±1.12	4.62±2.31	18.09±3.38
Brooding female	73.41±1.41	3.12±2.36	20.10±3.21
Immature female	66.97±1.82	4.94±1.20	18.11±4.37
Juveniles	65.60±1.40	4.32±1.58	15.03±2.55

Figure 1

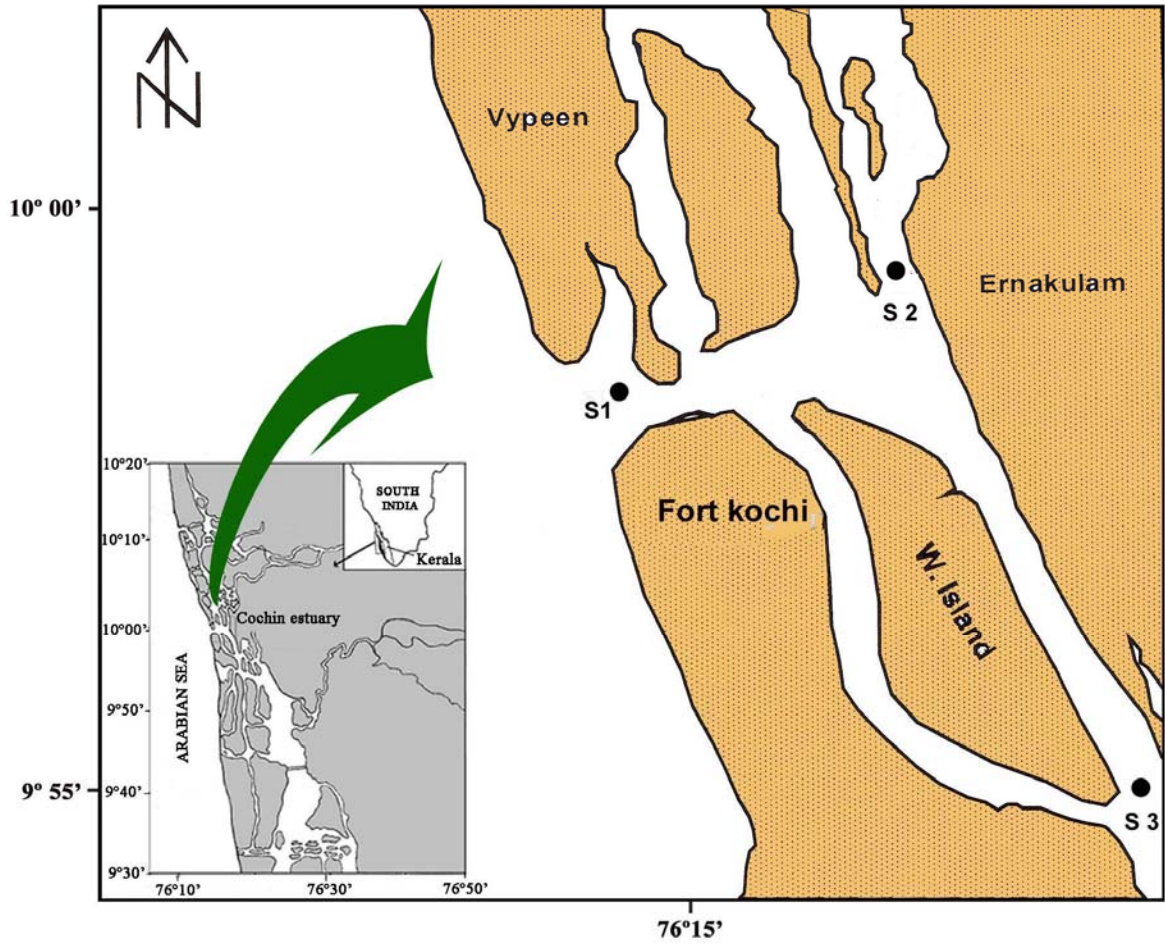


Figure 2

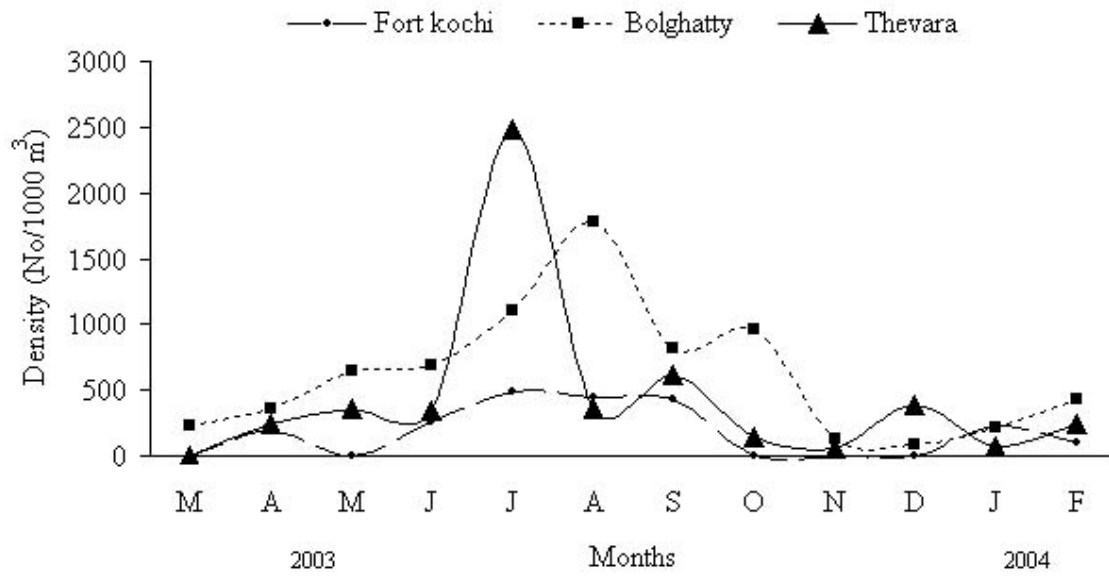


Figure 3

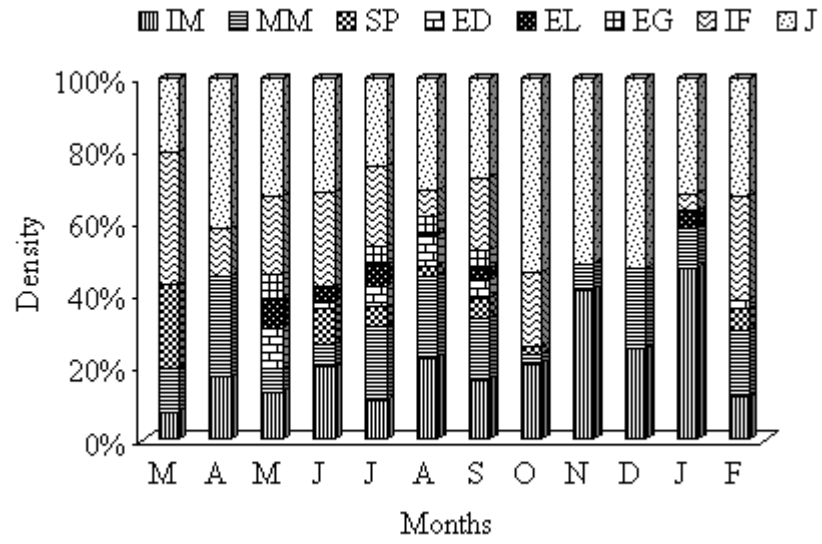


Figure 4

