

**Population structure and reproductive biology of *Mesopodopsis orientalis*
(Crustacea: Mysida) in a tropical mangrove ecosystem in India**

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Abstract

The population structure and biological aspects of the shallow water mysid *Mesopodopsis orientalis* were studied in the Versova mangrove, Mumbai, India. The monthly collections ranged from 0 – 2104 ind.m⁻³ with an average of 78.6 ind.m⁻³. The sampled population was found in a wide range of temperature (25.5°C to 34°C) and salinities (20.3 to 37.1). Carapace length significantly correlated with total body length (P<0.01). *Mesopodopsis orientalis* breed throughout the year but there is a seasonal variation in the intensity of breeding. The size of mature males and females was at maximum during post-monsoon period. The species produced more than one generation per year and the number of embryo carried by a single female ranged from 6 – 18, and was correlated with female body length (R²=0.69). Egg size varied between 0.32 and 0.45 mm, with no correlation with length of females.

Key words: population, reproductive trait, *Mesopodopsis orientalis*, mangrove, India

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INTRODUCTION

Mysids crustaceans are one of the major components of coastal and estuarine zooplankton communities and play an important role as a resource for many organisms that use these areas as nurseries. Mysids are an important link in the food web of coastal ecosystem (Yamada *et al.*, 2007) and are prey for various fishes (Takahashi *et al.*, 1999; Baldo & Drake, 2002; Jumars, 2007) as well as for invertebrates, birds and seals (Mauchline, 1980) thereby linking primary and secondary production to higher trophic level. As an energy converter at different trophic levels, the significance of mysids in an ecosystem has been greatly underestimated. *Mesopodopsis orientalis* is one of the most important components of the shallow-water crustacean community (Hanamura *et al.*, 2008a) and dense shoals of this species exploited for human consumption in coastal areas of India and Thailand (Mauchline, 1980; Chaitiamwonges & Yoodee, 1982; Patil & Sankolli, 1991). *M. orientalis* are also food source of dolphin (Tattersall, 1915) and sea horses (Pinkaw *et al.*, 2001). Due their high nutritive quality, this species is suitable for aquaculture as a live feed (Biju *et al.*, 2009). Although considerable literature on the occurrence and abundance of this species from different areas exist (see Biju *et al.*, 2009), no published information is available on its population composition and reproductive biology in mangrove habitat. Hanamura *et al.* (2008a) reported the reproductive biology of *M. orientalis* from a tropical mangrove estuary, but subsequent studies found that these populations belong to a different species (*Mesopodopsis tenuipes*). Mauchline (1980) point out that life history characteristics of mysid species can vary considerably from one habitat to another, hence knowledge on the biology of local populations is essential for subsequent studies on related scientific field (Hanamura *et al.*, 2009). Considering the ecological and economic importance, the present study aims to elucidate the population structure, size variation within the population, breeding season and fecundity of *M. orientalis* in a mangrove habitat.

MATERIALS AND METHODS

Description of study area

Mangroves are salt tolerant forest ecosystem of tropical and subtropical intertidal regions. Where conditions are sheltered and suitable, the mangroves may form extensive and productive forests, which are reservoirs of a large number of species. The study site was located in the Versova mangrove (19° 7' 30"N and 72° 49' 30"E), it is a shallow salt marsh along the tidal creek of Mumbai (Figure 1) with a depth of about 1 to 1.5 m and has a width ranging from 30 to 40 m. During flood tide, flow of seawater towards the upstream progressively inundates the creek and during extensive

high tides, even the swamp vegetation is submerged. The dominant vegetation of swamp is the mangrove species *Avicennia alba* which has a height of 1 m (Stephen *et al.*, 2003). Vijay *et al.* (2005) reported that mangrove habitat around Mumbai is disappearing due to human interference.

Sampling procedure and data analysis

A total of four stations (V1–V4) were selected in the Versova mangrove, Mumbai, India for the present study (Figure 1). Station 1 (V1) is situated at the mouth of the shallow tidal creek with sandy substratum and the other three stations are located towards the northern end of the creek and are at equidistance. Monthly sampling was done regularly at all stations for 15 months from May 1991 to July 1992. Water samples from surface waters were collected using a polyethylene bucket for the estimation of temperature and salinity.

A circular hand net of 1 m length, having a mouth area of 0.08 m² and a mesh size of 0.1 mm, fitted with a calibrated TSK (The Tsurumi-Seiki Co, LTD) flow meter was used for the collection of zooplankton samples. Samples were preserved in 5% buffered formalin. In the laboratory, mysids were sorted and classified into different groups based on the degree of development of secondary sexual characteristics. Sexes can be distinguished by observing an extended fourth pleopod in male and the growing marsupium in females. Immature individuals were distinguished from juveniles by the presence of rudimentary oostegites (female) and a longer fourth pleopod (male). The total body length of each individual was measured, from the tip of the rostrum to the posterior end of the telson, excluding the setae. Carapace length (CL) was measured from the tip of the rostrum to the posterior lateral margin of the carapace with an accuracy of 0.01 mm. After sexed, they were categorized into six population categories based on following criteria: juveniles (J- secondary sexual characteristics are absent), immature males (IM-secondary sexual characteristics developing), mature males (MM-secondary sexual characteristics completely developed), immature females (IF- rudimentary marsupium present), brooding females (BF- carrying egg/embryo), and empty females (EF-secondary sexual characters fully developed, but no eggs or larvae are carried). Each breeding females were also classified in three categories corresponding with the stages of eggs/embryos carrying in their brood pouch, i.e. females with spherical egg like embryo (stage I) (as “egg” in this paper), females with eyeless embryos (stage II) and females with eyed embryos (stage III).

The developmental stages of eggs/embryo were classified according to Hanamura *et al.* (2008a): spherical egg like embryo (D₁); eyeless embryo (D₂); and eyed embryos (D₃). The egg diameter was measured along the longest axis. Stage D₂ and D₃ embryos were measured along the

distance between the anterior end (ventral side) and the posterior end of the uropod without stretching the body.

Monthly histograms with total length of each population category were used to analyse the population structure of *M. orientalis* using 1 mm size class intervals. All four sample stations were combined. The percentage of different categories was determined in relation to the total individuals collected each month. To identify the existence of significant difference between the proportions of each sex, we employed a χ^2 test, using the sex ratio (female/males) of the complete data set. The relationship between body length (BL) and carapace length (CL) and between the size of the breeding females and the number of embryos or larvae were investigated using regression analysis. To identify the existence of significant difference in environmental parameters and abundance of mysids among stations, we employed Kruskal-Wallis test.

RESULTS

Environmental variables

The surface water temperature varied from 25.2 to 35.0°C (av.29.8±2.35°C) with minimum and maximum respectively during January 1992 and June 1991 (Figure 2). The variation in temperature did not significantly differed among stations (Kruskal-Wallis test: $H=0.34$, $P>0.05$).

Salinity was generally low during monsoon period (June-September) which progressively increased from post-monsoon period (October –January) attaining maximum during the pre-monsoon period (February-May) (Figure 2). The salinity ranged from 28.8–36.7 with an average of 32.0±5.4 at V1, 20.5–36.6 with an average of 32.7±5.0 at V2, 20.1–36.1 with an average of 32.0±5.2 at V3, 18.1–36.2 with an average of 30.7±5.6 at V4. The variation in salinity between stations was not significant ($H=1.75$, $P>0.05$).

Biometrics

An allometric relationship between the carapace length CL (in mm) and the total body length BL (in mm) was calculated from measurements taken in some well-preserved individuals: $BL = \log 2.158 \log CL + 0.883$, ($r=0.912$, $n=108$, $P>0.01$).

ABUNDANCE AND POPULATION STRUCTURE

The population densities of *Mesopodopsis orientalis* in the study area were ranged from 0–2104 ind.m⁻³, with an average of 78.6 ind.m⁻³ (Figure 3). The variation in densities significantly differed among stations (Kruskal-Wallis test: $H=8.0$, $P<0.05$). Maximum population was recorded at station V1 (65.3%) followed by V2 (22.9%), V4 (6.9%) and V3 (4.9%). There was a clear seasonal variation in the distribution of *M. orientalis* during the present study. Compared with other seasons, the high abundance of *M. orientalis* occurred in the pre-monsoon period (February-May) (83.6% of the total population with an average of 813.0 ± 1212 ind.m⁻³). During the monsoon (June-September) and Post-monsoon (October-January) period *M. orientalis* occurred with an average of 130.4 ± 102.3 ind.m⁻³ and 32.2 ± 22.4 ind.m⁻³ respectively. Peak in mysid standing stock (av. 729.5 ± 993.2 ind.m⁻³) was in May 1991 followed by a second peak (av. 172.5 ± 345.0 ind.m⁻³) in April 1992 (Figure 3), in both the peaks, juveniles dominated constituting 93.7% and 89.6% of the respective population. In the present study, *M. orientalis* occurred in temperature and salinity range of 25.5°C to 34°C and 20.3 to 37.1 respectively.

The percentage of different demographic categories showed considerable temporal variation during this sampling period (Figure 4). Juveniles were found in all months and dominant in most of the samples. Highest percentage of juveniles obtained in May 1991 and April 1992 and lowest in July 1992 (9.7%). The size range of juveniles was 1.3 mm to 4 mm. The minimum and maximum body length value of juveniles was obtained in May 1991 and December 1991 respectively (Figure 5). The maximum percentage of immature females obtained from July 1992 (35.4%). The smallest body length was found in June 1992 (4.5 mm) and the highest in March and April 1992 (6.6 mm) (Figure 5). Breeding females reached maximum percentage in October 1991 (33.3%) and a minimum in May 1991 and April 1992 (1%) (Figure 4). Smallest individual was recorded in July 1992 (5.4 mm) the largest in (8.4 mm) January 1992 (Figure 5). Empty females were found in all samples except June, September, October and November 1991. The smallest body length (6.7 mm) value was found in July 1992 and the highest in December 1991 (8.7 mm) (Figure 5). Immature males reached maximum percentage in October 1991 (33.3%) and found in all samples except in June, July and September 1991. The smallest body length was found in July 1992 (2.7 mm) and the highest in January 1992 (6.8 mm) (Figure 5). Mature males were found in all samples except September, October and November 1991 with a maximum of 33.3% recorded in July and minimum of 1% recorded in May 1991 (Figure 4). Body length varied from 5.3 mm in July 1991 to 8.5 mm in December 1991 (Figure 5). The maximum percentage of empty females (20%) was recorded in June

1991 and 1992 (Figure 4). The body length of male and female individuals was at maximum during post-monsoon months (Figure 6a,b).

Presence of all categories during whole period and the overlap of different generations, suggests existence of more than one generation per year (Figure 5). The average sex ratio (female/male) calculated for the complete data was 1.4, and ranged from 0.6 (June/92) to 2.3 (April/92) (Figure 7). However, the sex ratio fluctuated along the sampling period, this was not significantly different from 1 (Chi-squared test, $P > 0.05$).

Breeding females and broods

Breeding females present all year round and making up 0.7% to 33.3% of the total population with an average of 13.4%. The composition of females with egg/embryo (stage I) varied from 25.0% to 76.0% of the total gravid female population with an average of 46.5%; that of female with eye less embryo (stage II) from 0% to 47.4% with an average of 27.01%; of that females with eyed embryo (stage III) from 0% to 33.3% with an average of 26.4% (Figure 8). The body length of ovigerous female had a general tendency to increase as the stage of the embryo progressed. The Kruskal-Wallis test showed significant size difference between groups ($H = 22.33$, $df = 2$, $P < 0.05$). The average value were, stage I females, 7.5 ± 0.77 mm ($n = 22$); stage II females, 7.6 ± 0.49 mm ($n = 26$); and stage III females 7.8 ± 0.87 mm ($n = 30$).

Size variation of eggs/embryos ranged from 0.32 – 0.45 mm with an average of 0.39 ± 0.06 . Brood size (number of embryo present in a brood) ranged from 6 – 18. There was no correlation between the egg size and female body length (Figure 9a). The body length of D_2 embryo was 0.5 – 1.0 mm with an average of 0.57 ± 0.073 and D_3 was 0.9 – 1.3 mm with an average of 0.99 ± 0.081 . The body size of smallest free-living individual was 1.3 mm. The brood number (BN) was closely correlated with female body length (BL) (Figure 9b), and the following regression equation was obtained,

$$BN = 3.23BL - 10.97 \quad (R^2 = 0.69, n = 78).$$

DISCUSSION

The study area in the Versova mangrove ecosystem sustains a moderate potential for mysids. The density variation did not show a fully synchronous pattern between the sampling stations. This probably indicates a heterogeneous distribution of the mysid. Population density of mysids in this

area (av. 78.6 ind.m⁻³) is comparable with that of mysids collected by the same method of adjust salt pan (Bhayander salt pan) (av.71.0 ind.m⁻³) (Biju & Panampunnayil 2010). In present study, *Mesopodopsis orientalis* occurred in wide fluctuating saline conditions (20.3-37.1). This species has also been recorded from highly fluctuating saline conditions (eg. Cochin backwater (0 – 34.25) and Bhayander salt pan (1.2 – 63.6) (see Biju *et al.*, 2009; Biju and Panampunnayil, 2010). Bhattacharya (1982) studied salinity tolerance in the laboratory and reveal that *M. orientalis* of Indian coastal waters could survive under an extremely wide range of salinity conditions, even though it tends towards a low salinity preference, particularly in the early life stages; this ability ensures its wide distribution from sea water to near fresh water conditions. McLusky and Heard (1971) reported that euryhaline species are well adapted to live in an environment with a wide fluctuation in salinity through their capacity to prevent excessive changes in their internal environment by maintain their blood hyper/ hypo-osmotic to the medium.

As in many other mysid species, *M. orientalis* presented considerable fluctuation in its abundance. Principle factor of seasonal abundance of mysid (*Mesopodopsis slebberi*) is reproduction, which is controlled primarily by environmental temperature (Moffat and Jones, 1993). In the present study, greatest abundance occurred in May 1991 and April and May 1992 (pre-monsoon period), when juveniles constituted 93.72%, 89.56% and 86.10% of the total population respectively. Intensity of breeding was at the lowest during August 1991 and July 1992 (monsoon period) when the contribution of juveniles to the total population were only 13.97% and 9.71% respectively. *M. orientalis* shows variation in their seasonality in abundance with respect to different population. For example, in Cochin backwater, abundance of this species associated with monsoon period (Biju *et al.*, 2009) while in Hooghly estuary, the periodicity in abundance of *M. orientalis* weekly correlated with the monsoon season (Sarkar & Choudhury, 1986). Hanamura *et al.* (2009) reported that there is no evidence of periodicity in the abundance of *M. orientalis* in the Malaysian sandy beach. These observations suggest that the intensity of breeding varies within different population of the same species. The water temperature significantly affects the periodicity and reproductive biology of mysids (Mauchline, 1980; Wittmann, 1984; Johnston *et al.*, 2001). Hanamura *et al.* (2009) state that stable water temperature reduces the seasonality of mysids in tropical shallow-waters.

The number of females exceeds the number of males in most of the sampled months, a pattern also reported for *M. orientalis* collected from sandy beach, Malaysia (Hanamura *et al.*, 2009) and other species of mysids (e.g. *Neomysis Americana* (Pezzack and Corey, 1979); *Metamysidopsis*

neritica (Calil and Borzone, 2008). Variation in sex ratio of *M. orientalis* during sampling period was not significantly different from 1. The same was reported for *Metamysidopsis neritica* (Calil and Borzone, 2008) and *M. elongata atlantica* (Gama and Zamboni, 1999).

The population structure of *M. orientalis* at Versova mangrove demonstrates the difference in length composition of population and reproductive conditions of the species. The fully-grown specimens reach a length of 8.7 mm though sexual maturity is attained at a smaller size of 5.4 mm. This suggests that growth is continuous even after sexual maturity has attained. Some immature females collected in July 1992 were larger than ovigerous females collected in the same month. This reveals that total length alone does not determine maturity.

The number of broods carried by females ranged from 6 to 18. Even though large females carried more young, the number of young carried by females of equal body length also varied. The average body length of breeding females increased with the progress of larval development. A similar size increase in breeding females has been reported in various species of mysids and has been explained as inter-moult growth causing the stretching of the abdomen (Mauchline, 1973; Fenton, 1994). Hanamura *et al.* (2009) pointed out that somatic growth of the abdomen is not the factor leading to size increase in breeding female population of *M. orientalis* in the Malaysian sandy beach. Unfortunately, in the present study, the somatic growth of abdomen is not measured.

Since in *M. orientalis* breeding goes on all the year round many broods must be produced by a single female as instanced by the presence of two to three size classes of juveniles in most of the collections, but how long a single individual lives is not known. Calil and Borzone (2008) point out that many species of mysids in shallow water environments have several generations within the year and individual females within a generation may produce several successive broods. An increase in the reproductive potential of a population is related to an accelerated ontogenic development that results in a fast maturation of the individuals, allowing the production of many generations per year. This can hardly be distinguished in field data. However, the study of length-frequency histograms of mature mysids often aid in the interpretation of population biology (Mauchline, 1980). In the present study, the life history of *M. orientalis* interpreted as follows; the first generation started in April and May with a large cohort. These juveniles become immature males and females observed in June and July, which developed to mature males and ovigerous females in August and September. These ovigerous females originated a new generation in October/November. The generation of October/November becomes immature males and females in December and January and mature individuals in February and March that developed new generation and closing the annual biological

cycle of *M. orientalis* (Figure 5). Nair (1939) has described in detail the formation and extrusion of eggs in *M. orientalis*. The incubating period is not more than 96 hours at 25-29°C and the female then moults and immediately lays again.

Field observations on the different population of *M. orientalis* appear to be inconsistent in certain reproductive characters (Table 1). For instance, the maximum size of the ovigerous females of the estuarine population was 7.4 mm, while populations in sandy beach, salt pan and mangrove habitat, those was 8.3 mm, 8.1 mm and 8.4 mm respectively. Clutch sizes of *M. orientalis* collected from different localities also have some variations. At present, highest number (29) of broods of *M. orientalis* recorded at Hazira, India (Biju & Panampunnil, 2009), while the lowest number (6) was at Sandy beach, Malaysia (Hanamura *et al.*, 2009; Table 1) and Versova mangrove, India (present study) (Table 1). Biju and Panampunnayil (2009) reported that *M. orientalis* collected from different populations of Maharashtra and South Gujarat, India showed wide variation in the clutch size. The average egg diameter of sandy beach population was 0.37 mm (Hanamura *et al.*, 2009) while those of mangrove population were 0.39 mm. Some other species of mysids also shows difference in reproductive characters with respect to habitat, Ishikawa and Oshima (1951) reported that the egg /embryo carried by *Neomysis japonica* Nakazawa, 1910 was smaller in the population collected in a low salinity environment than that in that collected in a high salinity area. However, Sawamoto (1985) obtained an opposite result for the same species in neighboring water of Japan. Delgado *et al.* (1997) mentioned that clutch size of *Mesopodopsis slabberi* (van Beneden) vary depending on the geographic populations or different generations. Even though many factors affecting the mysid reproduction, different pattern of reproductive traits may be related with their genetic variability. Hanamura *et al.* (2008b) reported that the difference in life history trait of mysids linked with their genetic background and recent taxonomic analysis with molecular data has revealed high genetic diversification and /or cryptic speciation in several cosmopolitan species of mysids (Audzijonyte & Väinölä, 2005, Remerie *et al.*, 2006, Hanamura *et al.*, 2008b). From this viewpoint, more morphometric and genetic analyses are needed to clarify the difference in life history features within different population of the same species.

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Figure captions

Figure 1. Map showing the study area and sampling locations in the Versova mangrove system, India.

Figure 2. Temporal variations in the water temperature and salinity observed at the sampling sites in the Versova mangrove system, India.

Figure 3. Abundance of *Mesopodopsis orientalis* averaged four stations from May 1991 to July 1992 in Versova mangrove system, India.

Figure 4. Seasonal changes in population structure of *Mesopodopsis orientalis* collected in the Versova mangrove system, India. MM, matured male; IM, immature male; EF, empty female; BF, breeding female; IF, immature female; J, juveniles.

Figure 5. *Mesopodopsis orientalis*. Length-frequency histograms from May 1991 to July 1992 in Versova mangrove. (histogram for October 1991 were not included due to low occurrence of mysids on these sampling). *n* indicates number of individuals collected.

Figure 6. *Mesopodopsis orientalis*. Seasonal variation of the mean body length of immature and mature males (a) and immature and mature females (b).

Figure 7. Monthly variation in sex ratio (female/male) of *Mesopodopsis orientalis* in the Versova mangrove.

Figure 8. Seasonal changes in the percentage occurrence of brooding females of *Mesopodopsis orientalis* in the Versova mangrove.

Figure 9. *Mesopodopsis orientalis*. Relationship between egg diameters and body length (n=35) (a) and between brood number per female and body length (n=78) (b).

Table 1. Comparison in reproductive character of *Mesopodopsis orientalis* with different population

Different populations	Geographical area	Largest male (mm)	Largest female (mm)	Size of ovigerous female (mm)	Egg size (mm)	Clutch size (mm)	References
Estuary	9°40'12"N-76°23'57"	7.6	8.3	4.7–7.4	0.39–0.47	8–12	Biju <i>et al.</i> , 2009
Sandy beach	5°17'09"N-100°14'02"E	7.1	8.3	5.2–8.3	0.30–0.42	6–24	Hanamura <i>et al.</i> , 2009
Salt pan	19°03'42"N-72°48'45"E	8.6	9.8	6.0–8.1	–	10–18	Biju & Panampunnayil, 2010
Mangrove	19°07'30"N-72°49'30"E	8.5	8.7	5.4–8.4	0.32–0.45	6–18	Present study

Figure 1

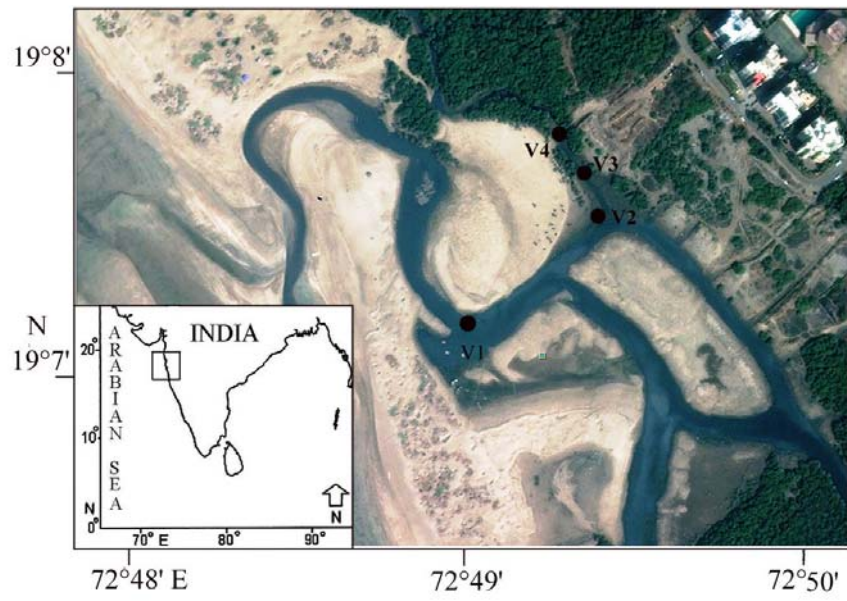


Figure 2

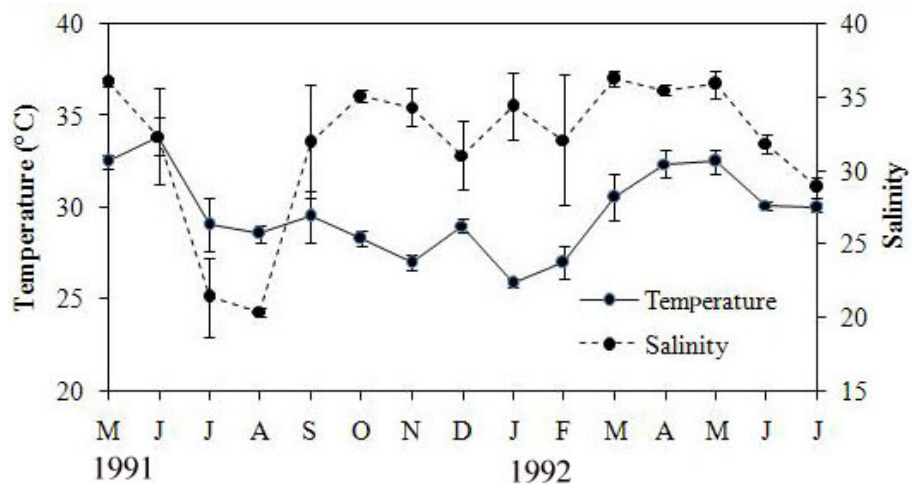


Figure 3

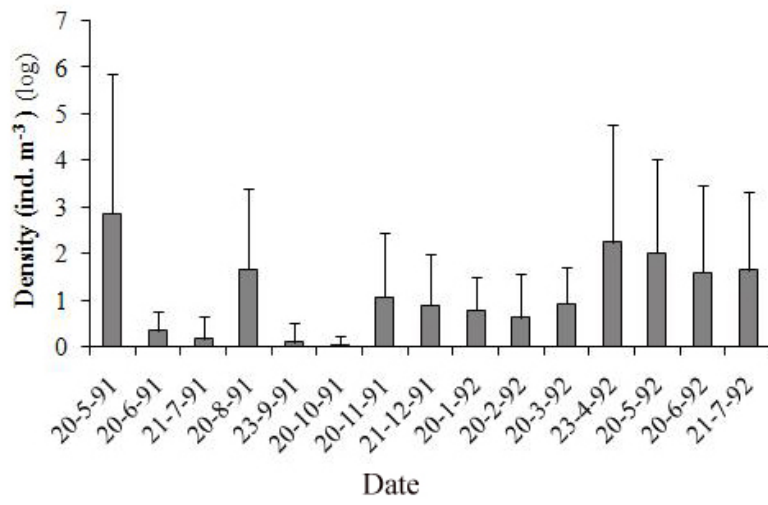


Figure 4

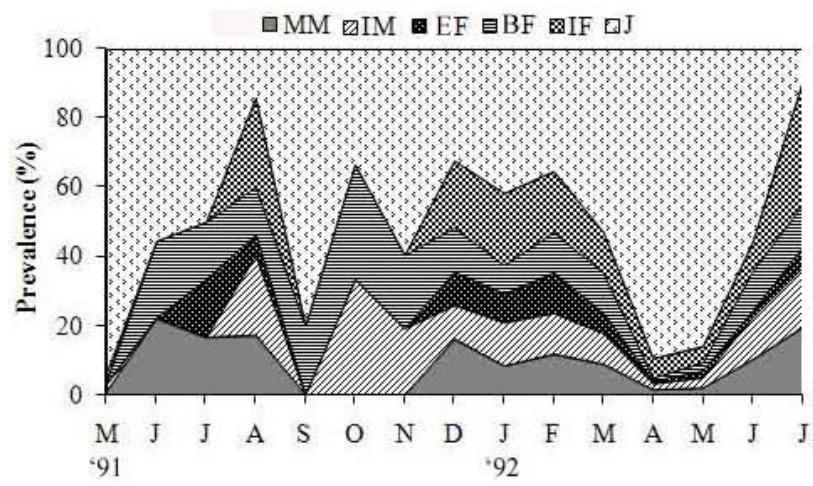


Figure 5

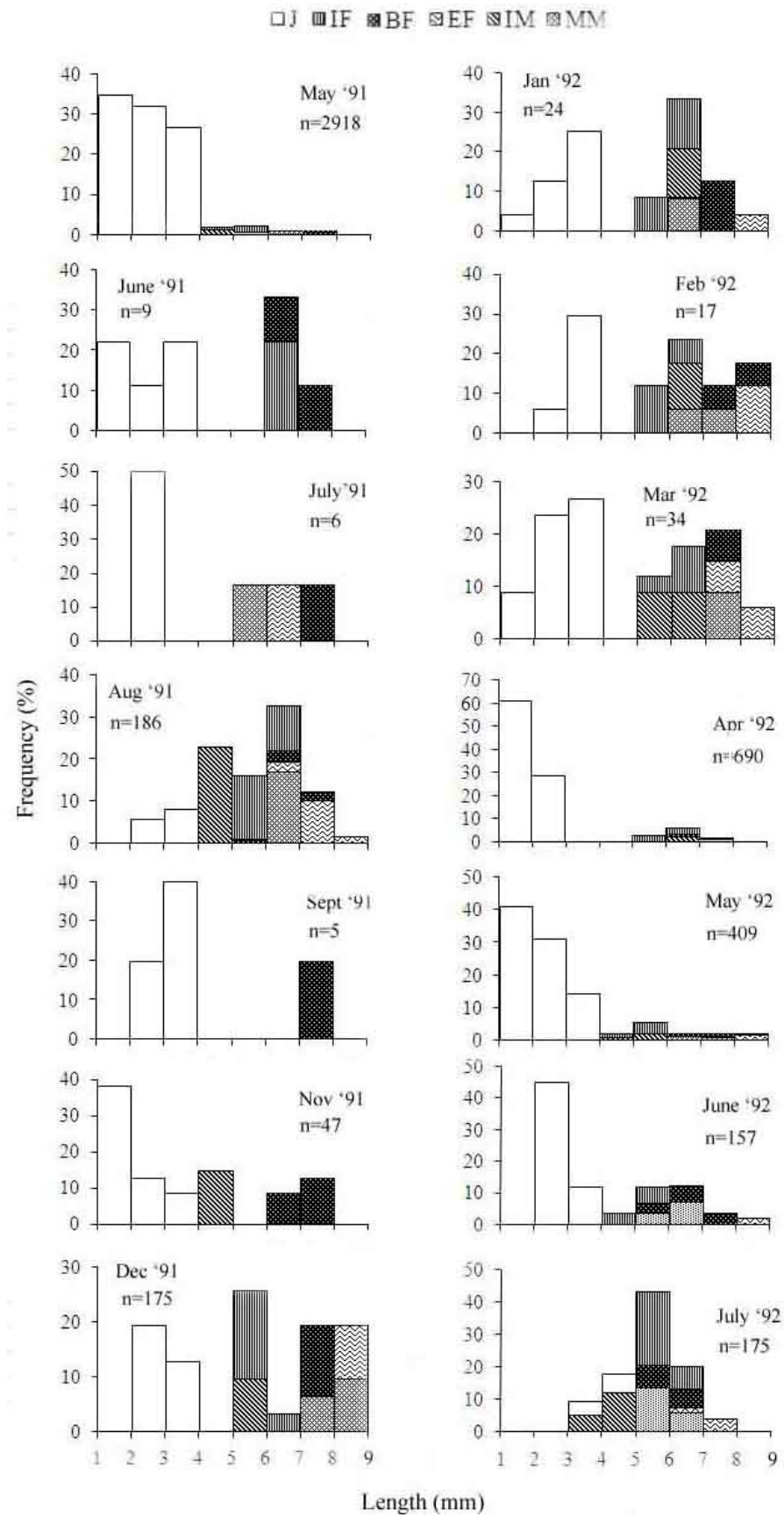


Figure 6

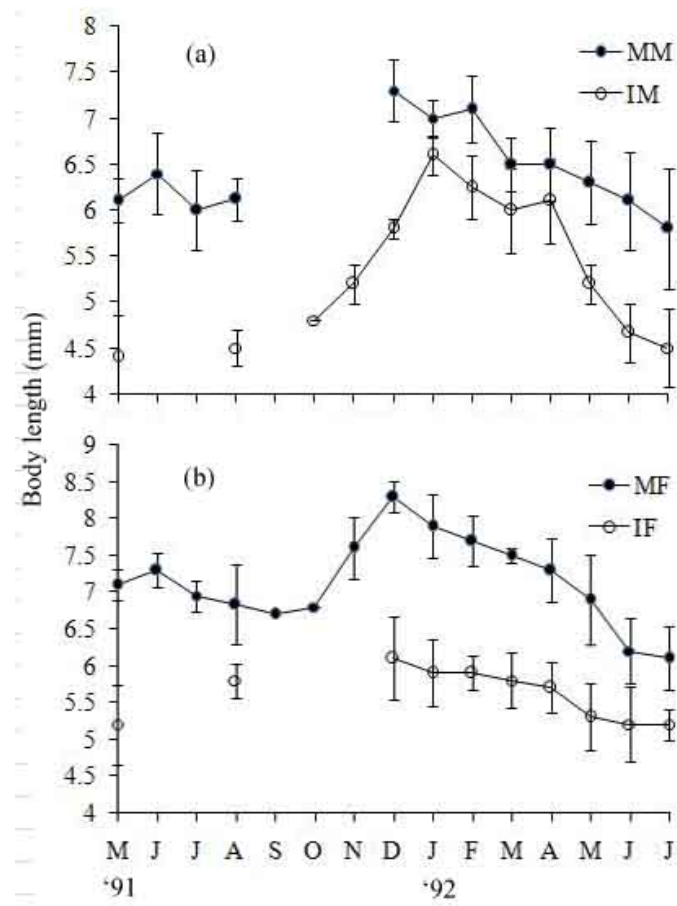


Figure 7

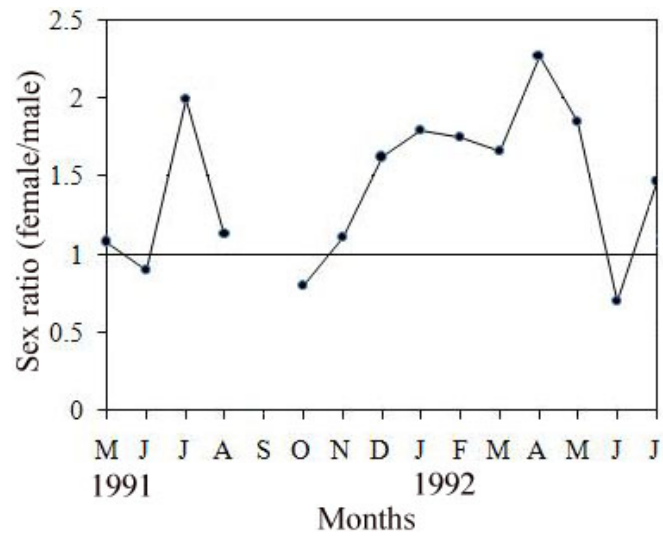


Figure 8

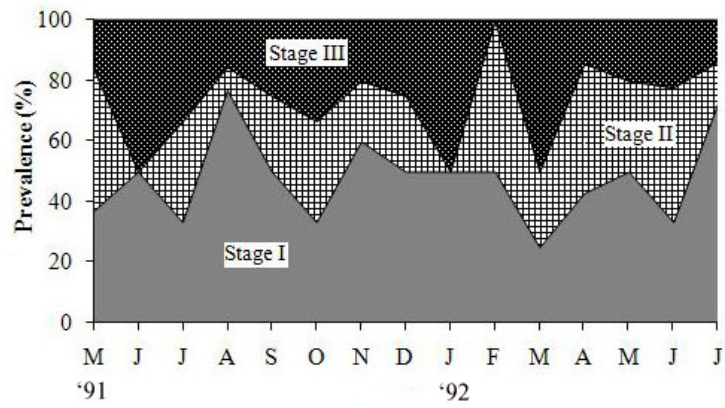


Figure 9

