

## **Spatial distribution and general population characteristics of *Pseudanchialina pusilla* (Crustacea: Mysida) in the eastern Arabian Sea.**

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Running head: Distribution and biology of *Pseudanchialina pusilla*

**Abstract:** The distribution and general population characteristics of *Pseudanchialina pusilla* (Sars, 1883) were evaluated based on zooplankton collections obtained from different seasonal surveys conducted in 2004-2006 in the eastern Arabian Sea as part of a multidisciplinary project Marine Research on Living Resources Assessment Programme. *P. pusilla* exhibits a wide range of variations in its population dynamics in the study area and their population density over the entire study area ranged from 0–12000 ind.1000 m<sup>-3</sup>. The highest abundance was during the Southwest monsoon (SWM) of 2004 (43.4% of the total sampled population) followed by the inter monsoon (IM) of 2005 (37.0%) and Northeast monsoon (NEM) of 2006 (19.6%). Temperature and salinity appeared to have little influence on the general distribution of *P. pusilla* in the study area. The number of egg/embryo carried by females varied from 4 to 8 exhibited a positive correlation with female and size. The egg diameter ranged from 0.30–0.42 mm and was independent of female size. Mature individuals total body size varied from 2.6–3.2 mm and 2.5–3.3 mm in males and females, respectively.

**Résumé:** La répartition et les caractéristiques générales de la population de *Pseudanchialina pusilla* (Sars, 1883) ont été évalués sur la base des collections de zooplancton obtenues à partir de différentes enquêtes saisonnières menées en 2004-2006 dans la mer d'Arabie orientale dans le cadre d'un projet de recherche marine multidisciplinaire sur le programme d'évaluation des ressources du vivant. *P. pusilla* présente une large gamme de variations dans la dynamique des populations de la zone d'étude et leur densité de population sur l'ensemble de la zone d'étude variait de 0 à 12000 ind.1000 m<sup>-3</sup>. La plus forte abondance durant la mousson du sud-ouest (SWM) de 2004 (43,4% de la population totale de l'échantillonnage), suivie par l'inter mousson (IM) de 2005 (37,0%) et le Nord-mousson (NEM) de 2006 (19,6%). Température et salinité semble avoir peu d'influence sur la distribution générale de *P. pusilla* dans la zone d'étude. Le nombre d'œufs / embryons portés par les femmes variait de 4 à 8 présentait une corrélation positive avec la femelle et la taille. Le diamètre des œufs variaient de 0,30 à 0,42 mm et est indépendante de la taille des femelles. Les individus matures taille totale du corps varie de 2,6 à 3,2 mm et 2,5-3,3 mm chez les mâles et les femelles, respectivement.

*Key words:* Crustacea, mysid, *Pseudanchialina pusilla*, eastern Arabian Sea

## Introduction

Mysids are highly adaptive group of Crustacea inhabiting a wide variety of aquatic environments and are one of the major constituents of macro-zooplankton. In general, mysids are omnivores, feeding on detritus, zooplankton and phytoplankton, and thus form a link between microbial producers and secondary consumers (Webb, 1973). The significance of mysids in the ecosystem, as energy converter at different trophic levels has been greatly underestimated (Rost et al, 1998). Mysids are substantial dietary component of many invertebrates and decapods shrimps (Hanamura & Matsuoka, 2003; Huang, 2004) and are also prey for many larger predators globally, such as various fishes (Thiel, 1996; Hostens & Mees, 1999), birds and seals (Mauchline, 1980), thus playing a part in energy transfer to higher trophic level. Mysids are rich and diverse in the Arabian Sea and their taxonomy is reasonably known (Biju & Panampunnayil, 2011). However a substantial gap exists on information regarding the ecology and biology of mysids in this area. A great understanding of the abundance and biology of mysids is highly necessary to implement the knowledge about the ecological role of these organisms in the oceanic water. *Pseudanchialina pusilla* (Sars, 1883) is the most widespread and abundant mysid in the Indian and Pacific waters (Pillai, 1973). Biju and Panapunnayil (2011) reported that this species is one of the dominant species in the EEZ of India. Although there is a considerable literature on the taxonomy of *P. pusilla* from different areas (Tattersall, 1960; Ii, 1964; Pillai, 1973; Panampunnayil, 2002; Biju & Panampunnayil, 2011) no literature is available on its distribution and general population characteristics. Considering its ecological importance the present study was initiated to elucidate the population structure, abundance, biological characters and ecology of *P. pusilla* from the eastern Arabian Sea.

## Materials and methods

### *Study area*

The present study area comprises the Exclusive Economic Zone of India in the Arabian Sea. This region is very important to India economically, since more than 73% of its annual fish landings originate from here (Madhupratap et al., 2001). The Arabian Sea is unique for its dramatic monsoonal reversal of surface currents and area of upwelling, and thick oxygen minimum zone in the intermediate depth (150 m-1200 m).

### Sampling procedure and data analysis

The materials for the present study are based on samples collected in the eastern Arabian Sea (Fig. 1) during different cruises of the research vessel, FORV “Sagar Sampada” as part of a multidisciplinary project entitled “Marine Research on Living Resources (MRLR) Assessment Programme” funded by

Ministry of Earth Science, Government of India, from 2004-2006. In this study, we used different seasonal data collected from the same stations during different years. Details of sampling are given in table I. For the comparison of day and night samples, mysids collected between 6 am and 6 pm were considered day samples and those collected between 6 pm and 6 am were night samples. Seasons are divided into the inter-monsoon (IM, March-May), summer or Southwest monsoon (SWM, June-September), and the winter or Northeast monsoon (NEM) October- February). Sampling locations were categorized into inshore (depth < 200 m) and offshore (depth > 200 m) areas. The data were also pooled to analyze variation in northern and southern regions, northern region considered to north of 15°N (stations 30-47) and southern regions, 15°N and south of it (stations 1-29).

Surface mesozooplankton samples were collected from 47 stations using a Bongo net (BN) (Hydrobios - mesh size 0.2 mm; filtering cone length 250 cm; ring diameter 60 cm) fitted with a calibrated flow meter. The net was hauled for 10 minutes at the surface at a ship speed of two knot. Plankton samples were fixed in 5% buffered formaldehyde-seawater solution and preserved prior to subsequent analysis. The abundance of *P. pusilla* was calculated based on the volume of water filtered through the net, filtering rate was calculated by adopting the calibration formula provided with the flowmeter. A Sea-Bird electronic CTD (SBE 911 Plus, USA) was used to obtain the surface temperature and salinity values. Salinity values were corrected using values obtained from the Autosal (Guildline - Model 8400A) and the values are represented in psu (practical salinity unit).

In the laboratory, mysids were sorted from other zooplankton. All *P. pusilla* were counted and subjected to detailed analysis. Total body length (distance between the anterior margin of the carapace and the apex of the telson, excluding apical spines) was measured using a binocular microscope fitted with a micrometer eyepiece. If the sample contains less than 15 individuals, all the mysids were measured for body length, when exceeds this number, up to 15 specimens are measured. After mysids were sexed and measured, they were categorized into six developmental stages based on the following criteria: juveniles (J), immature males (IM), mature males (MM), immature females (IF), spent females (SF) and ovigerous females (carrying egg/embryo) or breeding females (OF) (Mauchline, 1980; Biju and Panampunnayil, 2010). Ovigerous females were classified into three categories corresponding with the developmental stages of eggs/embryos carried in their brood pouches, i.e. females with spherical egg-like embryos (stage I) (referred to as “egg” in this paper), females with eyeless embryos (stage II) and females with eyed embryos (stage III). The developmental stages of eggs/embryos were classified according to Hanamura et al. (2008): spherical egg like-embryos (E<sub>1</sub>); eyeless larvae (E<sub>2</sub>); and eyed larvae (E<sub>3</sub>). The oblong or polygonal egg

diameter was measured along the longest axis to the nearest 0.01mm under a dissecting microscope. In the same way stage E<sub>2</sub> and E<sub>3</sub> embryos were measured along the distance between the anterior ends of the eye (ventral side) to the posterior end of the uropod when straightened.

Multiple regression analysis (SPSS-10) was employed to assess the predictability of population density on the physico-chemical variables.

The model used for the purpose was,

$$Y = b_0 + b_1x_1 + b_2x_2$$

Where Y = population density, x<sub>1</sub> = sea surface temperature, and x<sub>2</sub> = sea surface salinity.

## Results

### *Environmental variables*

Surface temperature and salinity of the Arabian Sea, is given in table 2. The surface water temperature in the Arabian Sea varied from 26.6 to 31.7°C and maximum seasonal average temperature was during SWM (30.6°C ± 0.5) followed by IM (29.0°C ± 0.7) and NEM (28.7°C ± 0.8). Surface salinity ranged from 33.2 to 36.9 and maximum average salinity in the eastern Arabian Sea was during SWM (35.9 ± 0.8) and minimum during IM (35.0 ± 0.6).

### *Relation with environmental factors*

*Pseudanchialina pusilla* thrives in the eastern Arabian Sea throughout the year and tolerate wide range of temperature 26.6 to 31.2°C and salinity (33.2 to 36.6) (Table 2). The fitted multiple regression model for the data was found to be  $Y = 45745.358 - 317.336x_1 - 967.756x_2$

Statistical analysis reveals that temperature and salinity do not have much influence on the distribution of *P. pusilla* ( $R^2 = 0.049$ ).

### *Abundance and population structure*

The abundance of *Pseudanchialina pusilla* over the entire study area was ranges from 0–11960 ind.1000<sup>-3</sup> and maximum abundance was observed at northeastern Arabian Sea (lat. 17°N, long. 72°E) with temperature and salinity of 29.5°C and 35.1 respectively (Table 2). In the study area, there was a clear variation in population densities of *P. pusilla* collected during different seasons (Table 1). The highest abundance was during SWM of 2005 (43.4% of the total sampled population) with an average of 686 ± 1889 ind. 1000<sup>-3</sup> and was composed of 27.1% mature males, 10.8% immature males, 2.2% spent females, 9.9% breeding females, 12.4% immature females and 37.6% juveniles. During the IM of 2004, 37.0% *P. pusilla* occurred with an average of 584 ± 1971 ind.

1000<sup>-3</sup> and composed of 21.7% mature males, 13.4% immature males, 7.0% breeding females, 14.6% immature females and 43.3% juveniles. Only 19.6% of *P. pusilla* occurred during the NEM of 2006 with an average density of 310 ± 1449 ind. 1000<sup>-3</sup> and composed of 16.5% mature males, 7.2% immature males, 3.1% spent females, 10.3% breeding females and 62.9% juveniles. Seasonal percentage composition of each developmental stage in the study area is given in fig. 2. In the study area, day samples accounted for an average of 5.7% of mysids compared to 94.3% during the night.

Population density of this species was much higher in the offshore region (73.9%) than the nearshore area (26.1%). Average abundance of *P. pusilla* in the offshore and nearshore areas in the Arabian Sea are given in table 3.

In the southern part of the Arabian Sea, the maximum population abundance of *P. pusilla* was during the SWM (65.0% of the total for the three seasons) followed by IM (32.1%) and NEM (2.9%). In the northern part maximum abundance was during the NEM (52.1%) followed by IM (46.5%) and SWM (1.4%).

The mean sex ratio (female /male) was 0.66 and this ratio was significantly different (female < male;  $\chi^2 = 22.84$ , df = 2, p < 0.001). During the study period male individuals constituted 63.6%.

#### *Brooding females and broods*

Gravid females (OF) occurred in the size range from 2.5–3.2 mm (Table 4). The body length of ovigerous female had a general tendency to increase as the stage of the embryo progressed. The average value were, females with eggs (stage I), 2.7 ± 0.58 mm (n=20); females with eyeless larvae (stage II), 2.8 ± 0.65 mm (n=22); and females with eyed larvae (stage III) 3.0 ± 0.85 mm (n=10). The Kruskal Wallis test showed significant size difference among the three group pooled data (p<0.05). Size variation of eggs (E<sub>1</sub> embryos) ranged from 0.30–0.42 mm with an average of 0.37 ± 0.04. There was no correlation between the egg size and female body length ( $r^2 = 0.082$ , n=20). The body length of E<sub>2</sub> embryo was 0.50–0.81 mm with an average of 0.62 ± 0.073 and E<sub>3</sub> was 0.76–1.1 mm with an average of 0.94 ± 0.09. The brood number (BN) was closely correlated with female body length (BL) (Fig. 3), and the following regression equation was obtained,

$$BN = 5.311BL - 9.074, r^2 = 0.761, n = 52$$

The minimum brood size of *P. pusilla* was 4 (stage I embryo) female of 2.5 mm, and the maximum brood size was 8 (stage II embryo for female of 3.2 mm).

### *Body size and development*

Body sizes of *P. pusilla* during different seasons are given in Table. 4. The total length of the smallest free-swimming individual was 1.2 mm. Largest male (3.2 mm) and female (3.3 mm) of *P. pusilla* observed during the NEM period (Table 4). In some males and females individuals measuring 2.8 mm, secondary sexual characters were not yet visible, while in some male and female measuring 2.6 and 2.5 mm respectively, secondary sexual characteristic were noticed already (Table 4).

### **Discussion**

Even though *Pseudanchialina pusilla* is the most dominant and widely distributed mysids in the Indian and Pacific Oceans (Pillai, 1973), the population density of this species in the Arabian Sea showed wide range of fluctuation (0-11960 ind.1000 m<sup>-3</sup>). Statistical analysis shows that temperature and salinity have not much influence on the general distribution of *P. pusilla* in the Arabian Sea. Earlier reports reveals that temperature and salinity do not seem to be the main regulating factor of mysid distribution, which sees more susceptible to other factors, such as food availability, substrate type, predation and water depth (McKenny, 1994; Baldo et al., 2001). In the present study *P. pusilla* showed different pattern of variation in abundance with respect to seasons. The highest abundance of *P. pusilla* was observed during SWM followed by IM and NEM. This may result from production of respective season or difficulty of sampling mobile organisms with aggregated behavior and vertical migration (Mauchline, 1980; Allen, 1984). Differential movements of some size group (Morgan & Threlkeld, 1982) or migrations caused by water currents, light, hydrostatic pressure, turbidity, spectral sensitivity on light (Johansson 1992; Attramadala et al., 1985; Fosså, 1986; Feldman et al., 2010) may also affect size structure and catch rate of mysids. Calil & Borzone (2008) reported that samples with a high number of replicates would be necessary to effectively determine the pattern of variation in abundance during the year.

The population density of *P. pusilla* is comparatively high in the offshore region than nearshore because it is truly an oceanic species (Pillai, 1973). In the southern part of the Arabian Sea, the maximum population abundance of *P. pusilla* was observed during the SWM and in the northern part it was during the NEM. Mysids are opportunistic omnivores capable of utilizing phytoplankton, zooplankton, bottom detritus and organic materials in suspension (Mauchline, 1971; Lasenby et al., 1986; Rudstam & Hansson, 1990). Since phytoplankton is one of the main food sources of mysids (Linden & Kuosa, 2004), it may be considered to be a reason for the abundance of mysids during those respective seasons. Several studies have confirmed the occurrence of high zooplankton abundance during the SWM period and attributed this to the result of phytoplankton

blooms caused by coastal upwelling (Haridas et al., 1980; Raj & Ramamithram, 1981; Madhupratap et al., 1990, Jyothibabu et al., 2008). Similarly, a few studies conducted in the northern Arabian Sea showed high zooplankton standing stock during the NEM, which was attributed to the winter blooms of phytoplankton (Haq et al., 1973; Paulinose & Aravindakshan, 1977). During the IM, similar to the NEM, northern region had high density of *P. pusilla* compared to south possibly as a continuance of high phytoplankton stock of the NEM or the prevalence of an active microbial loop, based on dissolved inorganic carbon originating from the high winter production (Jyothibabu et al., 2010).

The breeding females and juveniles occurred during all the sampling periods. In tropical waters many workers have reported the continuous reproduction in mysids (eg. Goodbody, 1965; Hanamura et al., 2009; Biju et al., 2009; Biju & Panumpunnayil, 2009; 2010). In sub tropical latitude (25°S), ovigerous females of *Metamysidopsis elongata atlantica* (Bacescu, 1968) and *Brasilomysis castroi* Bacescu, 1968 were found during all seasons of the year, although the existence of successive generation was not clearly identified (Almeida Prado-Por, 1974). An increase in the reproductive potential of a population is related to an accelerated ontogenetic development that results in a fast maturation of the individuals, allowing the production of many generations per year. Due to continuous breeding, determining the number of generations becomes more complex (Mees et al., 1994; Delgado, 1997) because generations overlap and can rarely be distinguished in field data; only additional laboratory observations on growth rate and brood production will help to determine the number of generations and life span of individuals (Mauchline, 1980).

The size of *P. pusilla* appeared to be greater in NEM when compared with these in the rest may associate with comparatively low temperature, such eco-physiological phenomenon is commonly observed in mysids (Wittmann, 1984). The number of eggs/embryos carried by females ranged from 4 to 8. The recorded strong positive correlation between the length of gravid females and their brood size is a general mysid characteristic (Mauchline, 1980). Fully mature individuals varied in size from about 2.6–3.2 mm and 2.5–3.3 mm in males and females, respectively. Embryos (all stages) range in size from 0.30 to 1.1 mm, with an overlap between neighboring stages. 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). Gorokhova & Hansson (2000) reported that, ~3% inter moult growth in length was observed in gravid females of *Mysis mixta* Lilljeborg, 1852 during the brooding period.

Because of its abundance, this species obviously plays an important role in the ecology of Indian Ocean (Pillai, 1973). Ecological studies mainly based on accurate knowledge of species

occurrence, relative abundance and their distribution in an ecosystem. So in future, present work will be useful in designing detailed research on mysids and other zooplankton.

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### References

- Allen D. M. 1984.** Population dynamics of the mysid shrimp *Mysidopsis bigelowi* W.M. Tattersall in a temperate estuary. *Journal of Crustacean Biology*, **4** (1): 25–34.
- Almeida Prado–Por M. S. 1974.** Sistemática dos Mysidacea (Crustacea) na região de Cananeia. *Boletim do Instituto Oceanográfico de São Paulo*, **23**: 47–87.
- Attramadal Y. G., Fosså J. H. & Nilsson H. L. 1985.** Changes in behaviour and eye-morphology of *Boreomysis megalops* G.O. Sars (Crustacea: Mysidacea) following exposure to short periods of artificial and natural daylight. *Journal of experimental Biology and Ecology*, **85**: 135–148.
- Baldo F., Taracido L. J., Arias A. M. & Rake P. D. 2001.** Distribution and life history of the mysid *Rhopalophthalmus mediterraneus* in the Guadalquivir estuary (SW Spain). *Journal of Crustacean Biology*, **21**: 961–972.
- Biju A. & Panampunnayil S. U. 2009.** Mysids from the shallow waters off Maharashtra and south Gujarat, India, with description of a new species. *Marine Biology Research*, **5**: 345–362.
- Biju A. & Panampunnayil S. U. 2010.** Seasonality, reproductive biology and ecology of *Mesopodopsis zeylanica* (Crustacea: Mysidacea) from a tropical estuary (Cochin backwater) in India. *Plankton Benthos Research*, **5** (2): 49–55.
- Biju A. & Panampunnayil S. U. 2011.** Mysids (Crustacea) from the Exclusive Economic Zone of India with description of a new species. *Marine Biology Research*, **7**: 332–364.
- Biju A., Gireesh R., Jayalakshmi K. J., Haridevi C. K. & Panampunnayil S. U. 2009.** Seasonal abundance, ecology, reproductive biology and biochemical composition of *Mesopodopsis orientalis* W.M. Tattersall (Mysida) from a tropical estuary, Cochin backwater-India. *Crustaceana*, **82**: 981–996.
- Calil P. & Borzone C. A. 2008.** Population structure and reproductive biology of *Metamysidopsis neritica* (Crustacea: Mysidacea) in a sand beach in south Brazil. *Revista Brasileira de Zoologia*, **25** (3): 403–412.



- Delgado L., Guerao G. & Ribera C. 1997.** Biology of the mysid *Mesopodopsis slabberi* (van Beneden, 1861) (Crustacea, Mysidacea) in a coastal lagoon of the Ebro Delta (NW Mediterranean). *Hydrobiologia*, **357** (1-3): 27–35.
- Feldman T., Yakovleva M., Lindström M., Donner K. & Ostrovsky M. 2010.** Eye adaptation to different light environments in two Populations of *Mysis relicta*: A comparative study of carotenoids and retinoids. *Journal of Crustacean Biology*, **30**(4): 636–642.
- Fenton G. E. 1994.** Breeding biology of *Tenagomysis tasmaniae* Fenton, *Anisomysis mixta australis* (Zimmer) and *Paramesopodopsis rufa* Fenton from south-eastern Tasmania (Crustacea: Mysidacea). *Hydrobiologia*, **287**: 259–276.
- Fosså J. H. 1986.** Aquarium observations on vertical zonation and bottom relationships of some deep-living hyperbenthic mysids (Crustacea: Mysidacea). *Ophelia* **25**:107–117.
- Goodbody I. 1965.** Continuous breeding populations of two tropical crustaceans, *Mysidium columbiae* (Zimmer) and *Remerita portoricensis* Schmidt. *Ecology*, **46**: 195-197.
- Gorokhova E. & Hansson S. 2000.** Elemental composition of *Mysis mixta* (Crustacea: Mysidacea) and energy costs of reproduction and embryogenesis under laboratory condition. *Journal of the Experimental Marine Biology and Ecology*, **246**: 103–123.
- Hanamura Y., Siow R. & Chee P-E. 2008.** Reproductive biology and seasonality of the Indo-Australasian mysid *Mesopodopsis orientalis* (Crustacea: Mysida) in a tropical mangrove estuary, Malaysia. *Estuarine, Coastal and Shelf Science*, **77**: 467–474.
- Hanamura Y., Sio R., Chee P-E. & Kassim F. M. 2009.** Seasonality and biological characteristic of the shallow water mysid *Mesopodopsis orientalis* (Crustacea: Mysida) on a tropical sandy beach, Malaysia. *Plankton Benthos Research*, **4**: 53-61.
- Hanamura Y. & Matsuoka M. 2003.** Feeding habits of the sand shrimp, *Crangon uritai* Hayashi and Kim, 1999, in the central Seto Inland Sea, Japan. *Crustaceana*, **76**: 1017–1024.
- Haq S. M., Khan J. A. & Chugti S. 1973.** The distribution of zooplankton along the post monsoon and premonsoon periods. In: Zeitzschel, B. (ed.), In: *The Biology of the Indian Ocean*. pp. 257–272, Springer Verlag, Berlin.
- Haridas P., Menon P. G. & Madhupratap M. 1980.** Annual variations in zooplankton from a polluted coastal environment. *Mahasagar- Bulletin of National Institute of Oceanography*, **13**: 239–248.
- Hostens K. & Mees J. 1999.** The mysid-feeding guild of demersal fishes in the brackish zone of the Westerschelde estuary. *Journal of Fish Biology*, **55**: 704–719.
- Huang M. 2004.** Study on feeding habits and nutrient level of four cephalopod species from Taiwan Strait and its adjacent areas. *Journal of Oceanography*, **23**: 331–339.
- Ii N. 1964.** *Fauna Japonica*, Mysidae. Biogeographical Society of Japan, Tokyo, 610 pp.
- Johansson O. E. 1992.** Life history and productivity of *Mysis relicta* in Lake Ontario. *Journal of Great Lakes Research*, **18**:154–168.

- Jyothibabu R., Ashadevi C. R., Madhu N. V., Sabu P., Jayalakshmy K. V., Jacob Josia., Habeebrehman H., Prabhakaran P., Balasubramanian T. & Nair K. K. C. 2008.** The response of microzooplankton (20–200 µm) to coastal upwelling and summer stratification in the south-eastern Arabian Sea. *Continental Shelf Research*, **28**: 653–671.
- Jyothibabu R., Madhu N. V., Habeebrehman H., Jayalakshmy K. V., Nair K. K. C. & Achuthankutty C. T. 2010.** Re-evaluation of ‘paradox of mesozooplankton’ in the eastern Arabian Sea based on ship and satellite observations. *Journal of Marine Systems*, **81**: 235–251.
- Lasenby D. C., Northcote T. G. & Furst M. 1986.** Theory, practice and effects of *Mysis relicta* introduction to North American and Scadinavian lakes. *Canadian Journal of Fisheries and Aquatic Science*, **43**: 1277–1284.
- Linden E. & Kuosa H. 2004.** Effects of grazing and excretion by pelagic mysids (*Mysis* spp.) on the size structure and biomass of the phytoplankton community. *Hydrobiologia*, **514** (1-3): 73–78.
- Madhupratap M., Nair S. R. S., Haridas P. & Padmavati G. 1990.** Response of zooplankton to physical changes in the environment: coastal upwelling along central west coast of India. *Journal of Coastal Research*, **6**: 413–426.
- Madhupratap M., Nair K. N. V., Gopalakrishnan T. C., Haridas P., Nair K. K. C., Venugopal P. & Gauns M. 2001.** Arabian Sea oceanography and the fisheries of the west coast of India. *Current Science*, **81**: 355–361.
- Mauchline J. 1971.** The biology of *Neomysis integer* (Crustacea, Mysidacea). *Journal of Marine Biological Association of U. K.*, **51**: 347–354.
- Mauchline J. 1973.** The broods of the British Mysidacea (Crustacea). *Journal of Marine Biological Association of U. K.*, **53**: 801–817.
- Mauchline J. 1980.** The biology of mysids and euphausiids. In Blaxter J.H.S., Russell F.S. and Yonge M. (ed.) *Advance in Marine Biology*. pp. 1–677. Academic Press, London.
- McKenney C. L. 1994.** Resistance pattern to salinity and temperature in an estuarine mysid (*Mysidopsis bahia*) in relation to its life cycle. *Comparative Biochemistry and Physiology, Part A. Physiology*, **109** (1): 199–208.
- Mees J., Abdulkerim Z. & Hamerlynck O. 1994.** Life history, growth and production of *Neomysis integer* in the Westerschelde estuary (S. W. Netherlands). *Marine Ecological Progress Series*, **109**: 43–57.
- Morgan M. D. & Threlkeld S. T. 1982.** Size dependent horizontal migration of *Mysis relicta*. *Hydrobiologia*, **93**: 63–68.
- Omori M. 1978.** Zooplankton fisheries of the world: a review. *Marine Biology*, **48**: 199–205.
- Panampunnayil S. U. 2002.** The Mysidacea of the Andaman Sea. *Journal of Plankton Research*, **24**: 371–390.

- Paulinose V. T. & Aravindakshan P. N. 1977.** Zooplankton biomass, abundance and distribution in the north and northeastern Arabian Sea. In: *Proceedings of Symposium on Warm Water Zooplankton*, pp. 132–136. National Institute of Oceanography, Goa.
- Pillai N. K. 1973.** Mysidacea of the Indian Ocean. *IOBC Handbook*, **4**: 1–125.
- Raj I. D. & Ramamithram C. P. 1981.** Distribution of mesozooplankton biomass, fish eggs and larvae along the west coast of India. *Journal of Marine Biological Association of India*, **23**: 86–140.
- Roast S. D., Thompson R. S., Widdows B. J. & Jones M. B. 1998.** Mysids and environmental monitoring: a case for their use in estuaries. *Marine and Freshwater Research*, **49**: 827–832.
- Rudstam L. G. & Hansson S. 1990.** On the ecology of *Mysis mixta* (Crustacea, Mysidacea) in a coastal area of the northern Baltic proper. *Annales Zoologici Fennici*, **27**: 259–263.
- Tattersall O. S. 1960.** Report on a small collection of Mysidacea from Singapore waters. *Proceedings of Zoological Society of London*, **135**: 165–181.
- Thiel R. 1996.** The impact of fish predation on the zooplankton community in a southern Baltic bay. *Limnologica*, **26**: 123–137.
- Webb B. F. 1973.** Fish population of the Avon Heathcote Estuary. 3. Gut contents. *New Zealand Journal of Marine and Freshwater Research*, **7**: 223–234.
- Wittmann K. J. 1984.** Ecophysiology of marsupial development and reproduction in Mysidacea (Crustacea). *Oceanography and Marine Biology: an Annual Review* **22**, 393–428.

**Table 1.** Station details and average population density (ind. 1000 m<sup>-3</sup>) of *Pseudanchialina pusilla* in the Arabian Sea during different seasons (IM- Inter-monsoon, SWM- Southwest monsoon, NEM-Northeast monsoon)

Latitude (°N)	Longitude (°E)	Seasons and collection date	Population density of <i>Pseudanchialina pusilla</i> (%)	Number of sampled stations
8°–22° (Transects–8°, 10°, 11° 30', 13°, 15°, 17°, 19°, 21° & 22°)	66°–77°	IM, 19 March –18 April, 2004	584 ± 1971 (37.0)	44
		SWM, 27 June –24 July, 2005	686 ± 1889 (43.4)	45
	NEM, 29 November- 28 December, 2006	310 ± 1449 (19.6)	45	

**Table 2.** Population density (ind.1000 m<sup>-3</sup>) of *Pseudanchialina pusilla* and environmental parameters in the Arabian Sea during different seasons of 2004-2006.

Station No.	Latitude (°N)	Longitude (°E)	IM (2004)			SWM (2005)			NEM (2005)		
			<i>P. pusilla</i> density	Temperature (°C)	Salinity	<i>P. pusilla</i> density	Temperature (°C)	Salinity	<i>P. pusilla</i> density	Temperature (°C)	Salinity
1	8	76° 30'	-*	29.8	34.2	-*	29.9	35.0	-	29.3	35.2
2	8	76	281*	29.7	34.2	-	30.2	35.2	-	29.3	34.9
3	8	75	-	30.2	34.4	45	30.7	35.1	-	29.1	35.6
4	8	74	2436*	30.0	34.3	-*	30.3	34.2	-*	29.0	36.0
5	8	73	-	29.9	34.2	148*	30.5	34.7	-*	28.9	36.6
6	8	72	4924*	30.1	34.3	141*	30.4	34.7	-	28.2	36.3
7	10	69	N	N	N	-	28.7	36.9	-	29.3	35.2
8	10	70	720	29.8	34.7	960	30.7	35.4	-*	29.3	34.9
9	10	71	-	29.3	35.3	1770*	30.8	35.1	-*	29.3	34.9
10	10	72	-	29.8	34.8	7	30.5	34.8	-	29.1	35.6
11	10	73	-	29.9	34.8	-	30.5	34.9	-	29.0	36.0
12	10	74	-*	30.2	34.0	9577*	30.4	35.1	-	28.9	36.6
13	10	75	1200*	30.3	33.2	21	30.1	35.1	-	28.2	36.3
14	10	75° 30'	-*	30.4	33.6	-	30.2	35.4	-*	28.4	36.3
15	11° 30'	75	N	N	N	1743	30.1	35.7	-*	29.3	35.2
16	11° 30'	74	-	30.3	34.0	1095*	30.4	35.4	-*	29.3	34.9
17	11° 30'	73	N	N	N	-*	30.3	35.7	-	29.1	35.6
18	11° 30'	72	801*	30.1	34.7	3800*	30.3	35.4	-	29.0	36.0
19	11° 30'	71	-*	29.6	35.3	-	30.1	35.8	-*	28.9	36.6
20	13	70	-	29.1	35.4	-*	30.5	35.8	-*	28.2	36.3
21	13	71	67	30.0	34.6	3699*	30.5	35.5	-*	28.4	36.3
22	13	72	-	30.3	34.2	-	30.3	35.9	N	N	N
23	13	73	2160*	30.2	34.1	7017*	30.0	35.7	-*	29.3	35.2
24	13	74	-*	30.1	34.0	-*	30.0	35.9	-*	29.3	34.9
25	15	74	-	30.2	35.7	-	30.4	36.2	-*	29.3	35.2
26	15	73	478*	29.9	35.3	-	30.8	36.2	-	29.3	34.9
27	15	72	-	29.7	35.0	-	30.7	35.9	890*	29.1	35.6
28	15	71	663*	29.4	35.0	-	30.7	35.8	432	29.0	36.0
29	15	70	-*	29.0	35.6	N	N	N	-*	28.9	36.6
30	17	69	-	29.1	36.0	-*	31.7	36.9	-	28.2	36.3
31	17	70	-	29.7	35.1	-	31.4	36.8	9406*	28.4	36.3
32	17	71	-	29.9	35.0	852	31.2	36.5	266*	29.2	36.3
33	17	72	11960*	29.5	35.1	-	30.9	36.3	-*	28.8	35.5
34	17	73	-*	29.4	35.2	-*	30.9	35.7	-*	28.8	34.7
35	19	72	-	28.4	35.0	-	30.6	36.4	-	29.4	36.1
36	19	71	-	28.9	35.9	-*	30.6	36.3	150	29.2	36.5
37	19	70	-	28.9	35.0	-*	31.1	36.8	-*	27.6	35.7
38	19	69	-*	28.5	35.1	-*	31.4	37.0	-	27.9	35.8
39	19	68	-*	28.4	35.2	-*	31.1	36.9	142	27.3	36.6
40	21	66	-*	28.9	35.9	-	31.5	37.0	-	26.6	36.8
41	21	67	-	28.5	35.1	-	31.1	36.8	2666*	28.3	35.8
42	21	68	-	28.4	35.0	-	30.5	36.3	-*	26.7	36.5
43	21	69	-	28.9	36.0	-*	31.4	37.1	-	29.0	36.5
44	21	69° 45'	-*	28.5	35.1	-*	31.1	36.8	-	26.6	35.8
45	22	68	-	28.9	35.0	N	N	N	N	N	N
46	22	67	-	28.5	35.1	-	31.4	37.0	-*	29.2	36.5
47	22	66	-	28.9	35.0	-	30.5	36.4	-*	27.6	35.7

(N- collection not made, - mysids absent, \* night collections)

**Table 3.** Average population density (ind. 1000 m<sup>-3</sup>) of *Pseudanchialina pusilla* in different regions of the Arabian Sea during different seasons ( $\pm$ SD).

Seasons	Offshore area	Nearshore area
IM 2004	698 $\pm$ 2226	96 $\pm$ 53
SWM 2005	745 $\pm$ 2072	554 $\pm$ 581
NEM 2006	399 $\pm$ 1636	-

- Absent; IM, inter-monsoon; SWM, Southwest monsoon; NEM, Northeast monsoon.

**Table 4.** Variation in body length (mm) of the various age groups and egg size of *Pseudanchialina pusilla*. (MM, mature male; IM, immature male; SF, spent female; OF, ovigerous female; IF, immature female; J, juvenile)

Season	MM	IM	SF	OF			IF	J	Eggs (E <sub>1</sub> )
				Stage I	Stage II	Stage III			
IM	2.6-3.0	1.9-2.2	2.9-3.2	2.6-3.0	2.7-3.2	2.8-3.1	1.8-2.4	1.4-1.8	0.30-0.37
SWM	2.9-3.0	2.2-2.7	-	2.5-2.8	2.9-3.2	2.7-3.2	2.2-2.8	1.2-1.6	0.35-0.36
NEM	2.7-3.2	2.4-2.8	3.0-3.3	2.8-3.0	2.6-2.8	-	1.9-2.6	1.5-2.0	0.38-0.42

- absent; IM, inter-monsoon; SWM, Southwest monsoon; NEM, Northeast monsoon.

### Figure captions

Fig.1. Location of sampling stations in the Arabian Sea

Fig. 2. Composition of the population of *Pseudanchialina pusilla* by age groups in the Arabian Sea.

J, juvenile; IF, immature female; SF, spent female; OF, ovigerou female; IM, immature male; MM, mature male.

Fig. 3. Relationship between the brood numbers per females and maternal size of *Pseudanchialina pusilla*.

Figure 1

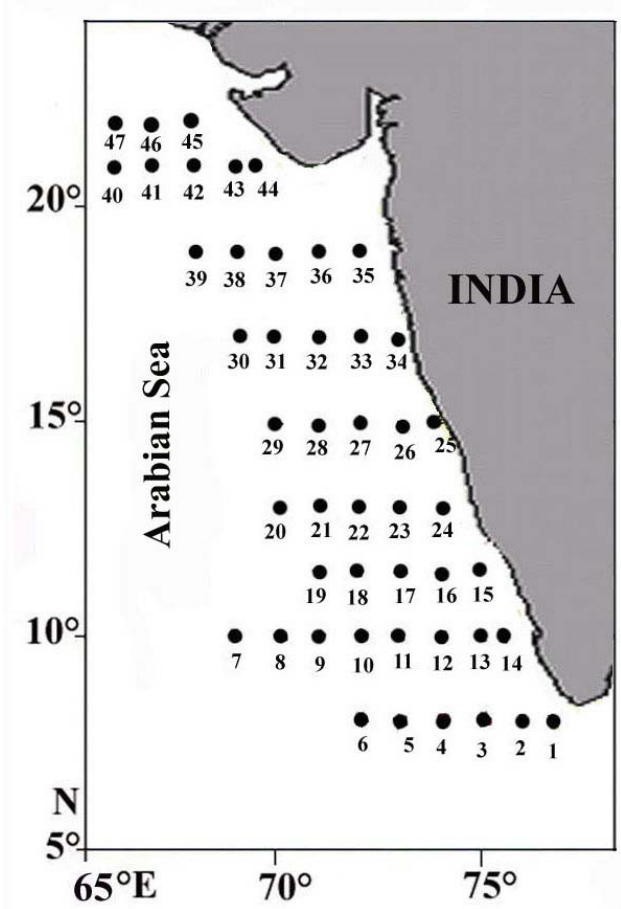




Figure 2

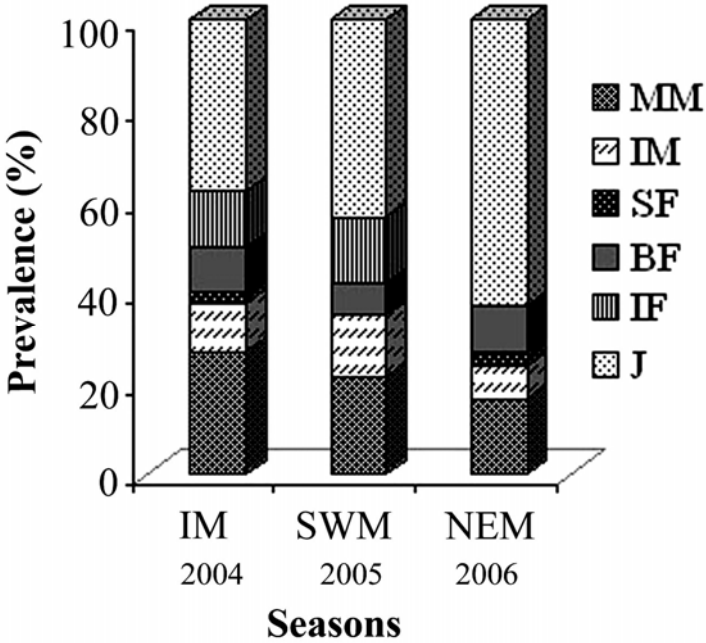


Figure 3

