

Meiofauna-Mangrove interaction: a pilot study from a tropical mangrove habitat

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Abstract

We studied meiofauna in the sediments and on the surface of roots of four mangrove vegetation types in Chorao Island, Goa, Central West coast of India. A total of 14 taxa were recorded from the mangrove roots while 12 taxa from the sediments. Nematodes dominate in the sediment of all vegetation and the density ranged from 71.2% - 76.3%. Like sediments, nematodes also dominated the mangrove roots and their contribution was in the range 48.5% - 61.6% followed by harpacticoids (30.9% - 36.9%). However, compared to sediments, their density was quite low per 10 cm². The total meiofaunal densities in the sediments of four mangrove vegetation types are less: 519.5±343.12 ind. 10 cm⁻² in *Sonneratia*, 343.5±283.13 ind. 10 cm⁻² for *Rhizophora*, 208.08±68.21 ind. 10 cm⁻² for *Avicennia* and 166.16±66.44 ind. 10 cm⁻² in *Bruguiera*. Among different vegetation, roots of *Sonneratia* had the largest density (31.45±19.29 ind./10 cm²), followed by *Bruguiera* (22.81±18.04 ind./10 cm²), *Avicennia* (11.55±7.92 ind./10 cm²), with the lowest in *Rhizophora* (10.66±5.89 ind./10 cm²). A significant variation was detected (P<0.01) in the meiofaunal density of the four mangrove vegetation types. A vertical profile of meiofauna in each vegetation suggested that the upper 5 cm of mangrove sediment contains >90% of the total meiofauna. The vertical variation of meiofaunal density was also strongly significant (P<0.001). However, from the *Rhizophora* sediments, nematodes were found to be existing below the Redox Potential Discontinuity (RPD) layer which is considered a hostile biotope. Future studies should consider these thiobiotic species (below the RPD layer), which are generally neglected. Investigation of their taxonomy, ecological interactions and physiological mechanisms for adaptation will provide a better insight about the role of the RPD layer and in what way they are different from the oxybiotic species (above the RPD layer). Studies pertaining to sedimentary characteristics of different vegetations will deepen our knowledge on meiofauna-mangrove interaction.

Key Words: Meiofauna, mangroves, vegetation types, vertical distribution, Central West coast of India.

French Résumé

Nous avons étudié la méiofaune dans les sédiments et sur la surface des racines des quatre types de végétation de mangrove dans Choraio île, Goa, du Centre-Ouest côtes de l'Inde. Un total de 14 taxons ont été enregistrés à partir des racines de palétuviers, tandis que 12 taxons dans les sédiments. Les nématodes dominent dans les sédiments de toute végétation et la densité variait de 71,2% - 76,3%. Comme les sédiments, les nématodes ont aussi dominé les racines de palétuviers et de leur contribution était de l'ordre de 48,5% - 61,6%, suivi par harpacticoïdes (30,9% - 36,9%). Cependant, par rapport aux sédiments, leur densité était très faible par 10 cm^2 . Les densités totales méiofaune dans les sédiments des quatre types de végétation de mangrove sont moins: $519,5 \pm 343,12 \text{ ind. } 10 \text{ cm}^{-2}$ dans *Sonneratia*, $343,5 \pm 283,13 \text{ ind. } 10 \text{ cm}^{-2}$ pour *Rhizophora*, $208,08 \pm 68,21 \text{ ind. } 10 \text{ cm}^{-2}$ pour *Avicennia* et $166,16 \pm 66,44 \text{ ind. } 10 \text{ cm}^{-2}$ dans *Bruguiera*. Parmi la végétation différente, racines de *Sonneratia* avait la plus grande densité ($31,45 \pm 19,29 \text{ ind./}10 \text{ cm}^2$), suivie par *Bruguiera* ($22,81 \pm 18,04 \text{ ind./}10 \text{ cm}^2$), *Avicennia* ($11,55 \pm 7,92 \text{ ind./}10 \text{ cm}^2$), avec l' plus bas dans les *Rhizophora* ($10,66 \pm 5,89 \text{ ind./}10 \text{ cm}^2$). Une variation significative n'a été détectée ($P < 0,01$) de la densité de la méiofaune des quatre types de végétation de mangrove. Un profil vertical de la méiofaune dans chaque végétal a suggéré que les 5 premiers centimètres de sédiments de mangrove contient $> 90\%$ de la méiofaune totale. La variation verticale de la densité de la méiofaune a été également fortement significative ($P < 0,001$). Cependant, à partir des sédiments *Rhizophora*, les nématodes ont été trouvés à être en vigueur en dessous de la discontinuité Redox (SPR) Potentiel couche qui est considéré comme un biotope hostile. Les études futures devraient considérer ces espèces thiobiotique (en dessous de la couche SPR), qui sont généralement négligées. Enquête sur leur taxonomie, les interactions écologiques et les mécanismes physiologiques d'adaptation permettra de mieux comprendre le rôle de la couche SPR et de quelle manière elles sont différentes des espèces oxybiotique (au-dessus de la couche SPR). Les études relatives aux caractéristiques sédimentaires de végétations différentes permettra d'approfondir nos connaissances sur la méiofaune-mangrove interaction.

Introduction

Meiofauna, being abundant in the benthic community both in terms of abundance and diversity, play an important role in mangrove ecosystems. They cause re-mineralization of organic matter and stimulation of microbial activity (Tietjen, 1980; Tietjen and Alongi, 1990; Castel, 1992; Coull, 1999) that sustains the mangrove food web. Also meiofauna (Hodda & Nicholas, 1985) are known to be preyed upon by the juvenile fish (Gee, 1989) and benthic macrofauna including shrimps, crabs, polychaetes and gastropods (Olafsson & Moore, 1990). Due to their contribution to the mangrove food web, several studies have been carried out worldwide (Gee and Somerfield, 1997; Somerfield et al., 1998; Olafsson et al., 2000; Gwyther and Fairweather, 2002, 2005; Gwyther, 2000, 2003; Armenteros et al., 2006; Mokievsky et al., 2011). However, studies on meiofauna densities in deeper layers are very scarce (Dye et al., 1983; Vanhove et al., 1992) and in an Indian context, this is the first report, although several studies have been carried out on the ecology of upper layer meiofauna (Ansari et al., 1993; Sarma and Wilsanand, 1994; Chinnadurai and Fernando, 2003, 2006, 2007).

There has been a lot of effort in meiofaunal studies throughout the world and also in India, but what shapes the meiofauna variability is still not known. It has been shown that meiofauna are poorly correlated with selected biogeochemical properties of sediments in Australian mangrove forests (Tolhurst et al., 2010). It is a well known fact mangrove meiofauna is quite different from non-mangrove meiofauna because mangroves are rich in tannins and organic matter. Recently, a study revealed that plant-animal interactions are crucial nodes in the structure of communities and pivotal drivers of ecosystem functioning (Garcia et al., 2011). So we selected meiofauna-mangrove as a model for studying plant-animal interaction which will deepen our knowledge on how meiofauna interacts with mangroves. Whether mangroves affect meiofaunal diversity is still a debatable topic and needs further study from wide geographical areas. We attempted to answer three basic questions: i) Does meiofaunal composition and density vary vertically in different vegetations? ii) Are phytal meiofaunal groups host specific? iii) Are the phytal meiofaunal assemblages unique to mangrove roots?

Materials and methods

Study area

The area selected for the present study is Salim Ali Bird Sanctuary (SABS), Chorao Island, Goa. This is a part of central west coast of India. The studied area is a mixed mangrove area having patches of *Sonneratia alba*, *Rhizophora mucronata*, *Avicennia officinalis*, and *Bruguiera cylindrica*. Other species like *Lumnitzera racemosa*, *Aegiceras corniculatum*, *Excoecaria agallocha*, *Acanthus*

illicifolius, *Xylocarpus spp.* are sparsely distributed (Wafar, 1987). This area is a part of the Mandovi estuary which undergoes wide fluctuations in environmental parameters including salinity, temperature and DO (Wafar, 1987).

Field sampling

To get a clear picture about meiofaunal diversity in different vegetation types and its vertical distribution, an intensive sampling was carried out at SABS on the 12.05.2011. Four different vegetation types were selected: *Sonneratia* site (*Sonneratia alba*), *Rhizophora* site (*Rhizophora mucronata*), *Avicennia* site (*Avicennia officinalis*) and *Bruguiera* site (*Bruguiera cylindrica*). Meiofaunal samples upto 20 cm depth were collected in triplicate by the help of a plastic corer (length: 30 cm, internal diameter- 3.5 cm). The sediment core was sliced 0-1, 1-2, 2-3, 3-4, 4-5, 5-7.5, 7.5-10, 10-15 and 15-20 cm immediately to reduce the chances of migration. To distinguish the meiofaunal communities of roots from that of sediment, 10 roots of the above mangrove species were clipped. *Rhizophora* and *Bruguiera* roots were clipped from the base and trunk whereas those of *Avicennia* and *Sonneratia* were clipped from the base only and kept in separate polybags. Then all the samples were preserved in neutralised 5% formalin and Rose Bengal solution in the field and carried to the laboratory. Sediment samples from the surface in triplicate were collected to measure the sediment grain size and carried to the laboratory as such.

Laboratory analysis

The preserved sediment samples were sieved after 24 hours. But in case of roots, each unit was placed in a measuring cylinder, shaken vigorously with filtered water then decanted and sieved as described by Gwyther and Fairweather, 2002. Two sieves were used: the top being 500 μm and the bottom 45 μm . The fauna passing through the 500 μm and retained on 45 μm sieve was considered the meiofauna. Roots were processed three times and the defaunated unit was kept separately for the calculation of area later. For area calculation, diameter was measured by vernier calipers on three regions per individual unit- one is the base diameter followed by middle diameter and then tip diameter and average value was taken. The surface area was calculated as per the formula of a cylinder that is πdh , where d is the average diameter and h is the length of the root. All the meiofauna were enumerated in a counting chamber under a stereo microscope and the density was expressed per 10 cm^2 for comparison. The specimens were identified to mixed taxonomic levels, because of difficulties in taxonomy using the pictorial keys (Higgins and Thiel, 1988). The density of eggs and larvae (nauplii and others) were low and hence were excluded from the analysis. A two-way

ANOVA was applied on the relative abundance of meiofauna to test the significance of variation between different vegetations and vertical distributions.

Grain size was measured by sieving around 100 gm of each dried sample through a 63 μ sieve. Sediment retained on the sieve was considered as sand and passed through that was considered as silt and clay and after taking weight of each fraction, the result was represented in percentage (Buchanan, 1984).

Results

Density and diversity of meiofauna

Sediment

The total meiofaunal densities in the sediments of four mangrove vegetation types are low compared to that observed by several workers elsewhere (Olafsson, 2000; Armenteros et al., 2006; Vanhove et al., 1992): 519.5 ± 343.12 ind. 10 cm^{-2} in *Sonneratia*, 343.5 ± 283.13 ind. 10 cm^{-2} for *Rhizophora*, 208.08 ± 68.21 ind. 10 cm^{-2} for *Avicennia* and 166.16 ± 66.44 ind. 10 cm^{-2} in *Bruguiera* (Table 1). In case of *Rhizophora* sediments, meiofauna is distributed till 20 cm depth while in others it is limited to a depth of 10 cm. Although meiofauna are present up to 20 cm depth, they are more abundant in the upper 4-5 cm depth (Fig. 2).

The present study recorded 12 meiofaunal taxa (excluding eggs and larvae) from the sediments of the four vegetations. Nematodes dominate in the sediment of all vegetation and the density ranged from 71.2%-76.3% (Fig. 3.1a, 2a, 3a & 4a). *Sonneratia* harboured 11 taxa followed by *Rhizophora* (eight taxa), *Bruguiera* (eight taxa) and the minimum *Avicennia* (seven taxa). Harpacticoid copepods were the second dominant group in *Avicennia* and *Rhizophora* constituting 17.9% and 17.4% respectively (Fig. 2a & 3a); whereas in *Sonneratia* they were replaced by foraminifera (10.5%) (Fig. 2d) and in *Bruguiera* by oligochaetes (9.3%) although harpacticoids were present in significant numbers (9.1%) (Fig.4a). Other taxa such as bivalves, turbellarians, rotifers, oribatids, sipunculids, amphipods, nemertines, kinorhynchans and ostracods were recorded in very low numbers.

ANOVA demonstrated significant differences of meiofaunal density among the mangrove vegetations ($P < 0.01$) (Table 4).

Roots

Distinct meiofaunal assemblages were found on the surface of different mangrove roots. A total of 14 taxa were recorded from the surface of roots of four mangrove species. A maximum of 11 taxa

were found to be associated with *Sonneratia* roots followed by nine taxa with *Avicennia* roots, eight by *Bruguiera* roots and seven taxa by *Rhizophora* roots. Compared to the corresponding sedimentary environment, roots had lower meiofaunal abundance. Among different vegetations, roots of *Sonneratia* harboured the maximum density (31.45 ± 19.29 ind./10 cm²), followed by *Bruguiera* (22.81 ± 18.04 ind./10 cm²), *Avicennia* (11.55 ± 7.92 ind./10 cm²) and the lowest in *Rhizophora* (10.66 ± 5.89 ind./10 cm²) (Table 2). Like sediments, nematodes also dominated and their contribution was in the range 48.5% - 61.6% followed by harpacticoids (30.9% - 36.9%).

Vertical distributional patterns of meiofauna

***Sonneratia* (Fig. 2)**

Nematodes are abundant in the upper 1 cm of sediment (0-1 cm) and constitute 73% (159.9 ± 106.5 ind./10 cm²) of the total meiofauna at this interval. The upper two cm comprised of 65% nematodes and the upper four cm gathered 88% of total nematodes. The density of nematodes shows a gradual decline to 10 cm. This depth interval also contributed 12% (27 ind.) harpacticoids of the total meiofauna. Harpacticoid copepods were present in only the upper 3 cm. Foraminifera were more abundant in deeper sediment and 68% (38.00 ± 13.74 ind./10 cm²) were found in the 2-5 cm depth and they were found to a depth of 10 cm. Oligochaete showed a high abundance in the upper 2 cm comprising 89% (35.67 ± 17.55 ind./10 cm²) and were present to 7.5 cm. Other taxa such as nemertinea, turbellaria and oribatida were present in negligible numbers in the upper 3 cm depth.

***Rhizophora* (Fig. 2)**

Nematodes were found up to 20 cm depth; but 55% (137.0 ± 102.9 ind./10 cm²) of these were restricted to the upper 0-1 cm. The upper 5 cm contained 94% nematodes. Harpacticoids were to 65% (38.7 ± 55.9 ind./10 cm²) in the upper 2 cm and the density dropped suddenly with depth to 7.5cm. Oligochaetes were found abundantly in the 0-1 cm depth, constituting 55% (10 ± 9.53 ind./10 cm²). The upper 1cm harboured 45% (4.66 ± 5.68 ind./10 cm²) of total polychaetes. Other taxa such as foraminifera, turbellaria, rotifera and bivalvia are present rarely and in deeper sediment (2-5 cm).

***Avicennia* (Fig. 2)**

The upper 1cm comprises of 50% (74.8 ± 27.1 ind./10 cm²), upper 3 cm 86% (129.5 ± 50.9 ind./10 cm²) and upper 5 cm, 99% (148.7 ± 52.4 ind./10 cm²) of total nematodes. In the upper 1 cm fraction, nematodes comprised 80% of the total meiofauna. Nematodes were present to 7.5 cm depth. Harpacticoids were gathered in the upper 4 cm depth and the upper 2 cm constitutes 78% of the total

harpacticoids, foraminifera, bivalvia, ostracoda, polychaeta, nemertinea, oligochaeta and turbellaria were found; but rarely and to a depth of 10 cm.

***Bruguiera* (Fig. 3)**

The entire core was characterized by a low density of meiofauna (166.1 ± 66.4 ind./10 cm²). Nematodes were present to 10 cm depth and 89% of nematodes (47.2 ± 6.0 ind./10 cm²) were present in the upper 1 cm. Then their density showed a gradual decrease. Harpacticoids were found to a depth of 5 cm and more or less evenly distributed with depth. Oligochaetes dominated in deeper layers with 91% (14.0 ± 0.0 ind./10 cm²) present in the 4-5cm layer. Other taxa like foraminifera, turbellaria, polychaeta, nemertinea, bivalvia, ostracoda and unidentified sp. were present in negligible numbers in deeper layers (2-5cm).

ANOVA detected significant differences on the meiofaunal abundance vertically ($P < 0.001$) (Table 4).

***Sediment granulometry* (Table 5)**

The details of sediment granulometry of sediments of four mangrove vegetations are given in Table 5. Sediments of all the four mangrove vegetation sites are dominated by silt and clay and sand percentage is very less. There is not much variation in the sediment granulometry amongst all four vegetation sites.

Discussion

Compared to the tropical sandy beaches (meiofaunal density: 1000-8000/10 cm²), the mangrove ecosystem harbours less density i.e. 500 ind./10 cm² (Alongi, 1989). However several studies show mangrove sediments containing higher densities (Table 6). In general, in Choroa island, the density is lower than other mangrove sediments described in the literature. This could be due to large tannin concentrations in the sediment, derived from mangroves through litter fall and degradation (Alongi, 1987), but especially to seasonality and zonation (Dye, 1983). The meiofaunal density is inversely related to the increase in monsoonal precipitation, increasing tannin concentrations and to the increasing distance to the low water level (Dye, 1983).

Nematodes dominated in all vegetations as described by other workers. Their presence in deeper sediments suggests that some thioibiotic species are well adapted to the harsh environment, where soluble tannins and decomposing organic matter predominates (Armenteros et al., 2008). Harpacticoid copepods are the second most dominant taxa and values are lower and in between recorded values. Apart from these two dominant taxa, foraminiferans, oligochaetes and bivalves

contribute a significant amount. Chinnadurai and Fernando (2006) described foraminiferal density varying from 26%-47% in an *Avicennia* site and was the second dominant after nematodes, whereas in the present study, in the *Avicennia* site, they were present at only 2%. In the *Sonneratia* site, they were the second most abundant contributing 11% to the total meiofauna. As reported by Hodda & Nicholas (1985), Oligochaetes are present in substantial numbers in all sites, being second most abundant (9.3%) followed by harpacticoids (9.1%) in the *Bruguiera* site, whereas in *Sonneratia*, *Rhizophora* and *Avicennia*, they were present at 8%, 6% and 3% respectively.

Compared to sediment biotope, surface of the mangrove roots contain slightly more number of taxa, indicating their biodiversity potential and needs further attention from conservation point of view. Although nematodes and harpacticoids are prevalent on the surface of the roots and in the sediment of all the vegetations, few meiofaunal taxa (uropodina, isopoda, amphipoda and sipunculida) seem to be present (although density is very less) only on the roots of particular species. Similarly the other taxa bivalvia, oribatida and ostracoda are found only in sedimentary biotope. Future studies should focus on the host specificity of these meiofaunal groups and their interaction with mangrove vegetations. The less abundance of meiofauna on the surface of mangrove roots compared to sedimentary biotope in all four mangrove vegetations could be due to three reasons: (1) very less amount of sediment available on the surface of roots limits the available interstitial space for meiofauna, (2) the thin sediment layer on the roots get desiccated during low tide exposing animals to dehydration and (3) hydrodynamics (turbulence and currents) might detach the animals from the roots.

The decrease in meiofaunal density with increasing depth may be attributed to several causes: i) vertical pH changes, ii) vertical decrease in O₂, iii) vertical decline in pore water content, iv) vertical decreases in organic carbon. Although these factors were not measured in the present study, the black sulphide rich layer indicated by colour (Pers. observation) suggests low oxygen conditions and high sulphide concentrations. This could be the primary factor (in combination with other above mentioned factors) responsible for the decrease in harpacticoid density with depth (Wieser et al., 1974). Due to similar granulometric composition of sediments in all mangrove vegetations, it is clear that sediment chemistry might have a profound influence on the meiofaunal community structure rather than sediment granulometry although we have not measured the tannin concentration.

Nematodes are already reported from the sulphide biome (Fenchel and Riedl, 1970). This study also finds a few nematodes below the 10 cm depth only in *Rhizophora* vegetation. These nematodes may be unique to this biome, in tolerating the reducing environment as per Vanhove and her coworkers (1992). Also these nematodes may be different from those of superficial layers in response to

tannins, as deeper layers would contain comparatively less tannin. In the case of other vegetations, the meiofauna is restricted to the upper 10 cm depth.

Fiddler crabs (*Uca* spp.) are the ecosystem engineers in mangroves and abundant in Chorao island (Pers. Observation). The bioturbation activities of the crab translocate sediment, organic matter and nutrients and enhance oxygen penetration into the deeper sediments (Kristensen, 2008). This might be influencing the abundance and distribution of several meiofaunal taxa, as reported by DePatra and Levin (1989).

The present study provides preliminary data for understanding the complexities existing between mangroves and meiofauna. For a better understanding about the role of the RPD layer and vertical distribution, a species level approach is required, particularly for the thiobiotic species (below RPD layer). A sound knowledge of ecological interactions is a necessity for improving management practice.

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References

- Alongi D. M. 1987.** The influence of mangrove derived tannins on intertidal meiobenthos in tropical estuaries. *Oecologia*.71: 537-540.
- Alongi D. M. 1989.** The role of soft bottom benthic communities in tropical mangrove and coral reef ecosystems. *Reviews in Aquatic Sciences*. 1: 243-280.
- Ansari Z. A. and Parulekar A. H. 1993.** Distribution, abundance and ecology of the meiofauna in a tropical estuary along the west coast of India. *Hydrobiologia*. 262: 115-126.
- Ansari Z. A., Sreepada R. A., Matondkar S. G. P. and Parulekar A. H. 1993.** Meiofauna stratification in relation to microbial food in a tropical mangrove mudflat. *Tropical Ecology*. 34: 63-75.

- Armenteros M., Martin I., Williams J. P., Creagh B., Gonzalez-Sanson G., Capetillo N. 2006.** Spatial and temporal variations of meiofaunal communities from the western sector of the Gulf of Batabano, Cuba. I. Mangrove system. *Estuaries and Coasts*. 29: 124-132.
- Armenteros M., Williams J. P., Creagh B. and Capetillo N. 2008.** Spatial and temporal variations of meiofaunal communities from the western sector of the Gulf of Batabano, Cuba: III. Vertical distribution. *International Journal of Tropical Biology*. 56(3): 1127-1134.
- Buchanan J. B. 1984.** Sediment analysis. In N. A. Holme and McIntyre (eds), Methods for the study of Marine Benthos. IBP No. 16, 2nd edn. Blackwell Scientific Publications. pp 387.
- Kathiresan K. and Bingham B. L. 2001.** Biology of mangroves and mangrove ecosystems. *Advances in Marine Biology*. 40: 81–251.
- Castel J. 1992.** The meiobenthos of coastal lagoon ecosystems and their importance in the food web. *Vie et Milieu*. 42: 125–135.
- Chinnadurai G. and Fernando O. J. 2003.** Meiofauna of Pichavaram mangroves along the southeast coast of India. *Journal of the Marine Biological Association of India*. 45: 158-165.
- Chinnadurai G. and Fernando O. J. 2006.** Meiobenthos of Cochin mangroves (South west coast of India) with emphasis on free-living marine nematode assemblages. *Russian Journal of Nematology*. 14(2): 127-137.
- Chinnadurai G. and Fernando O. J. 2007.** Meiofauna of mangroves of the southeast coast of India with special reference to the free-living marine nematode assemblage. *Estuarine, Coastal and Shelf Science*. 72: 329-336.
- Coull B. C. 1999.** Role of meiobenthos in estuarine soft-bottom habitats. *Australian Journal of Ecology*. 24: 327–343.
- DePatra K. D. and Levin L. A. 1989.** Evidence of passive deposition of meiofauna into fiddler crab burrows. *Journal Experimental Marine Biology and Ecology*. 125: 173-192.
- Dye A. H. 1983.** Vertical and horizontal distribution of meiofauna in mangrove sediments in Transkei, southern Africa. *Estuarine, Coastal and Shelf Science*. 16(6): 591- 598.
- Fenchel T. M. and Riedl R. J. 1970.** The sulphide system: A new biotic community underneath the oxidized layer of marine sand bottoms. *Marine Biology*. 7: 255-268.
- García, Daniel, Regino Zamora, and Guillermo C. A. 2011.** The spatial scale of plant–animal interactions: effects of resource availability and habitat structure. *Ecological Monographs*. 81:103–121.
- Gee J. M. and Somerfield P. J. 1997.** Do mangrove diversity and leaf litter decay promote meiofaunal diversity ? *Journal of Experimental Marine Biology and Ecology*. 218(1):13-33.

- Gwyther J. 2000.** Meiofauna in phytal-based and sedimentary habitats of a temperate mangrove ecosystem—a preliminary survey. *Proceedings of Royal Society of Victoria*. 112: 137–151.
- Gwyther J. 2003.** Nematode assemblages from *Avicennia marina* leaf litter in a temperate mangrove forest in south-eastern Australia. *Marine Biology*. 142: 289–297.
- Gwyther J. and Fairweather P. G. 2002.** Colonisation by epibionts and meiofauna of real and mimic pneumatophores in cool temperate mangrove habitat. *Marine Ecology Progress Series*. 229: 137-149.
- Gwyther, J. and Fairweather P. G. 2005.** Meiofaunal recruitment to mimic pneumatophores in cool temperate mangrove forest; spatial text and biofilm effects. *Journal of Experimental Marine Biology and Ecology*. 317: 69-85.
- Higgins, R. P. and Thiel, H. 1998.** Introduction to the study of Meiofauna. Smithsonian Institution Press, Washington DC.
- Hodda M. and Nicholas W. L. 1985.** Meiofauna associated with mangroves in the Hunter River estuary and Fullerton Cove, Southeastern Australia. *Australian Journal of Marine and Freshwater Research*. 36: 41-50.
- Hogarth P. 1999.** *The Biology of Mangroves*. Oxford University Press, New York. ISBN 0198502230, pp 228.
- Kristensen E. 2008.** Mangrove crabs as ecosystem engineers with emphasis on sediment processes. *Journal of Sea Research*. 59: 30-43.
- Olafsson, E. and Moore C. G. 1990.** Control of meiobenthic abundance by macroepifauna in a subtidal muddy habitat. *Marine Ecology Progress Series*. 65: 241-249.
- Olafsson E., Carlstrom S. and Simon G. M. N. 2000.** Meiobenthos of hypersaline tropical mangrove sediment in relation to spring tide inundation. *Hydrobiologia*. 426: 57–64.
- Mokievsky V. O., Tchesunov A. V., Udalov A. A. and Toan N. D. 2011.** Quantitative distribution of meiobenthos and the structure of the free-living nematode community of the mangrove intertidal zone in Nha Trang Bay (Vietnam) in the South China Sea. *Russian Journal of Marine Biology*. 37(4):272-283.
- Saenger P. 2002.** Mangrove ecology, silviculture and conservation. Kluwer Academic Publishers, Dordrecht. 360.
- Sarma A. L. N. and Wilsanand V. 1994.** Littoral meiofauna of Bhitarkanika mangroves of river Mahanadi system, East coast of India. *Indian Journal of Marine Sciences*. 23: 221-224.
- Somerfield P. J., Gee J. M. and Aryuthaka C. 1998.** Meiofaunal communities in a Malaysian mangrove forest. *Journal of the Marine Biological Association of the United Kingdom*. 78: 717–732.

- Tietjen J. H. 1980.** Microbial-meiobenthos interrelationships: a review. *Microbiology*. 335-338.
- Tietjen J. H. and Alongi D. M. 1990.** Population growth and effects of nematodes on nutrient regeneration and bacteria associated with mangrove detritus from northeastern Queensland (Australia). *Marine Ecology Progress Series*. 68: 169–179.
- Tolhurst T. J., Defew E. C. and Dye A. 2010.** Lack of correlation between surface macrofauna, meiofauna, erosion threshold and biogeochemical properties of sediments within an intertidal mudflat and mangrove forest. *Hydrobiologia*. 652: 1-13.
- Vanhove S., Vincx M., Vangansbeke D., Gijssels W. and Schram D. 1992.** The meiobenthos of 5 mangrove vegetation Types in Gazi Bay, Kenya. *Hydrobiologia*. 247: 99-108.
- Wafar S. 1987.** Ecology of mangroves along the estuaries of Goa. Phd Thesis. The Karnatak University, Dharwad, India.
- Wieser W., Ott J., Schiemer F. and Gnaiger E. 1974.** An ecophysiological study of some meiofauna species inhabiting a sandy beach at Bermuda. *Marine Biology*. 26: 235-248.
- Wolanski E. and Boto K. 1990.** Mangrove swamp oceanography and links with coastal waters. *Estuarine, Coastal and Shelf Science*. 31: 503–504.

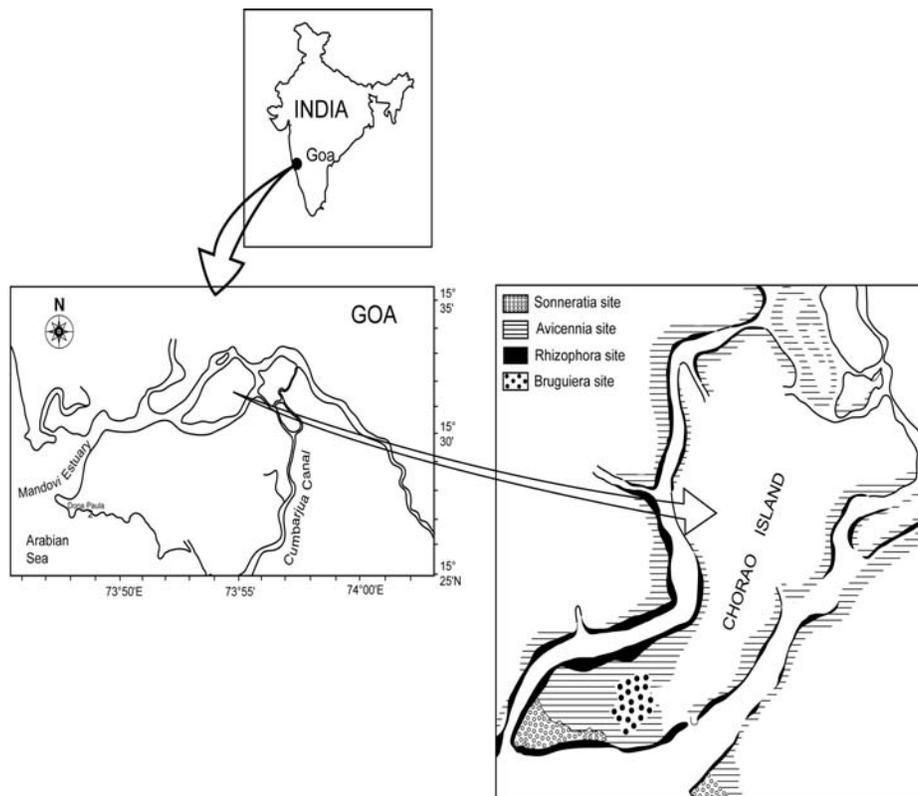


Fig. 1. Sampling location
(after Wafar, 1987)

Fig. 1. Emplacement d'échantillonnage
(après Wafar, 1987)

Table 1. Total Meiofaunal density/10 cm² (Mean±SD) in the sediment of different vegetation types
 Tableau 1. Méiofaune totale density/10 cm² (moyenne ± écart-type) dans les sédiments des différents types de végétation

Taxa	<i>Sonneratia</i>	<i>Rhizophora</i>	<i>Avicennia</i>	<i>Bruguiera</i>
Nematoda	369.71±199.93	249.10±158.89	150.80±49.44	126.79±33.96
Harpacticoida	37.36±50.24	59.65±90.55	37.28±5.66	15.16±10.72
Foraminifera	54.41±53.72	3.28±2.27	4.00±1.49	1.47±0.30
Turbellaria	7.21±6.98	1.31±1.14	0.00±0.00	2.11±2.98
Oligochaeta	39.99±20.40	20.32±18.30	5.27±5.06	15.37±14.00
Nemertinea	4.92±4.92	0.00±0.00	1.68±1.19	1.47±1.49
Polychaeta	4.26±4.09	8.85±10.27	4.84±5.06	2.53±1.79
Oribatida	0.33±0.57	0.00±0.00	0.00±0.00	0.00±0.00
Rotifera	0.00±0.00	0.33±0.57	0.00±0.00	0.00±0.00
Bivalvia	0.00±0.00	0.66±1.14	3.37±1.79	0.84±0.60
Ostracoda	0.00±0.00	0.00±0.00	0.42±0.00	0.21±0.30
Unidentified sp.	1.31±2.27	0.00±0.00	0.42±0.00	0.21±0.30
Total	519.5±343.12	343.5±283.13	208.08±68.21	166.16±66.44

Table 2. Meiofaunal density/ 10 cm² (Mean±SD) on the surface of the roots of different vegetation types
 Tableau 2. La densité de la méiofaune / 10 cm² (moyenne ± SD) à la surface des racines de différents types de végétation

Taxa	<i>Sonneratia</i>	<i>Rhizophora</i>	<i>Avicennia</i>	<i>Bruguiera</i>
Nematoda	15.25±6.96	6.56±4.12	6.79±3.64	12.64±9.06
Harpacticoida	11.06±6.60	3.53±1.18	3.57±2.04	8.39±6.95
Rotifera	2.04±1.19	0.28±0.23	0.41±0.73	0.35±0.35
Polychaeta	0.75±1.44	0.00±0.00	0.06±0.19	0.11±0.15
Oligochaeta	1.14±1.47	0.14±0.18	0.29±0.41	0.29±0.34
Kinorhyncha	0.17±0.38	0.00±0.00	0.00±0.00	0.00±0.00
Foraminifera	0.15±0.22	0.07±0.08	0.12±0.25	0.00±0.00
Turbellaria	0.70±0.67	0.04±0.05	0.12±0.24	0.30±0.31
Sipunculida	0.02±0.05	0.00±0.00	0.00±0.00	0.00±0.00
Amphipoda	0.02±0.05	0.00±0.00	0.00±0.00	0.00±0.00
Nemertinea	0.00±0.00	0.00±0.00	0.13±0.24	0.19±0.19
Uropodina	0.00±0.00	0.00±0.00	0.06±0.18	0.54±0.69
Isopoda	0.00±0.00	0.04±0.05	0.00±0.00	0.00±0.00
Unidentified sp.	0.15±0.26	0.00±0.00	0.00±0.00	0.00±0.00
Total	31.45±19.29	10.66±5.89	11.55±7.92	22.81±18.04

Table 3. Vertical profile (Mean± SD/ 10 cm²) of Nematoda (N) and Harpacticoida (H) in different vegetation types

Tableau 3. Profil vertical (moyenne ± SD / 10 cm²) de nématodes (N) et Harpacticoida (H) dans différents types de végétation

Depth (cm)	<i>Sonneratia</i>		<i>Rhizophora</i>		<i>Avicennia</i>		<i>Bruguiera</i>	
	N	H	N	H	N	H	N	H
0-1	159.9±106.5	27.2±32.6	137.0±102.9	21.6±31.5	74.8±27.1	16.0±2.4	47.2±6.0	4.2±1.2
1-2	80.6±48.3	9.2±15.9	40.0±23.2	17.0±24.4	33.5±21.7	12.8±1.5	21.1±1.2	3.6±2.7
2-3	44.6±25.0	1.0±1.7	29.2±9.7	7.5±13.1	21.3±2.1	6.1±4.5	26.3±6.9	3.8±4.2
3-4	40.3±28.1	0.0±0.0	12.8±9.4	4.6±7.9	12.0±1.5	2.1±1.8	15.0±7.4	1.7±2.4
4-5	25.2±17.1	0.0±0.0	15.7±13.5	6.2±10.8	7.2±0.0	0.0±0.0	9.5±6.3	1.9±2.7
5-7.5	13.1±8.8	0.0±0.0	6.6±6.9	2.3±3.2	1.7±0.0	0.2±0.3	6.1±4.5	0.0±0.0
7.5-10	5.9±5.5	0.0±0.0	6.6±4.4	0.3±0.6	0.4±0.0	0.0±0.0	1.7±1.8	0.0±0.0
10-15	0.0±0.0	0.0±0.0	0.3±0.6	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
15-20	0.0±0.0	0.0±0.0	1.0±0.7	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
Total	369.6±239.3	37.4±50.2	249.2±171.3	59.5±91.5	150.9±52.4	37.2±10.5	126.8±34.0	15.2±13.1

Table 4. Results of two-way ANOVA on vertical sections and vegetations, significance is shown at *P≤0.01 and **P≤0.001 level

Tableau 4. Les résultats de deux ANOVA sur des sections verticales et des végétations, la signification est indiquée en * P ≤ 0,01 et ** p ≤ 0,001 niveau

<i>Factor</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>
Vertical sections	59893.74	8	7486.71	12.15**
Vegetations	8431.25	3	2810.42	4.56*
Total	83110.7	35		

Table 5. Granulometric composition (in %) of the sediments in different mangrove vegetations

Tableau 5. Composition granulométrique (en%) des sédiments dans la mangrove différents

	<i>Rhizophora</i>	<i>Avicennia</i>	<i>Sonneratia</i>	<i>Bruguiera</i>
Sand	16.4	12.8	15.6	7.6
Silt+Clay	83.6	87.2	84.4	92.4

Table 6: A comparative account of meiofaunal densities in different mangrove vegetation types as reported from different parts of the world

Tableau 6: Un comparatif des densités de la méiofaune dans les différents types de végétation de mangrove comme signalés dans différentes parties du

Location	Meiofauna*	Nematoda*	Harpacticoida*	Vegetation	Reference
Chorao island, India	520	383	37	<i>Sonneratia alba</i>	Present Study
Chorao island, India	344	249	60	<i>Rhizophora mucronata</i>	Present Study
Chorao island, India	209	151	37	<i>Avicennia officialis</i>	Present Study
Chorao island, India	166	127	15	<i>Bruguiera gymnorhiza</i>	Present Study
Island of Santa Catarina, Brazil.	77-1589	196—810	6-20	<i>Avicennia</i> sp., <i>Laguncularia racemosa</i> , <i>Rhizophora mangle</i> .	Netto & Gallucci, 2003
East & West coast of Zanzibar, Africa.	205 – 5263	166-4435	3-394	<i>Avicennia marina</i> , <i>Sonneratia alba</i> , <i>Ceriops tagal</i> , <i>Rhizophora mucronata</i> , <i>Bruguiera gymnorhiza</i>	Olafsson, 1995
Unguja island, Zanzibar	271-656	380-571	39-223	<i>Avicennia marina</i>	Olafsson, 2000
Gulf of Batabano, Cuba	0 – 1298	5-591	0-15	<i>Avicennia germinans</i> , <i>Rhizophora mangle</i> , <i>Laguncularia racemosa</i>	Armenteros et al., 2006
Pichavaram	508	260-342	3-20	<i>Avicennia marina</i>	Chinnadurai & Fernando, 2006
Pichavaram, India	827-890	0-800	0-105	<i>Avicennia marina</i>	Chinnadurai et al., 2007
Cochin, India	18	11-78	0-5	<i>Rhizophora apiculata</i>	Chinnadurai & Fernando, 2006
Cochin, India	508	260-342	3-20	<i>Avicennia marina</i>	Chinnadurai & Fernando, 2006
Cochin, India	189	155	0	<i>Sonneratia caseolaris</i>	Chinnadurai & Fernando, 2006

Gazi bay, Kenya	3442	2329	315	<i>Avicennia marina</i>	Vanhove et al., 1992
Gazi bay, Kenya	6707	4205	1113	<i>Bruguiera gymnorrhiza</i>	Vanhove et al., 1992
Gazi bay, Kenya	1976	1709	61	<i>Ceriops tagal</i>	Vanhove et al., 1992
Gazi bay, Kenya	3998	3500	83	<i>Rhizophora mucronata</i>	Vanhove et al., 1992
Gazi bay, Kenya	2889	2555	51	<i>Sonneratia alba</i>	Vanhove et al., 1992
Khe Nhan, Vietnam	1156-2082	968-1759	52-155	<i>Rhizophora, Avicennia</i>	Xuan et al., 2007

*represents individuals per 10cm²

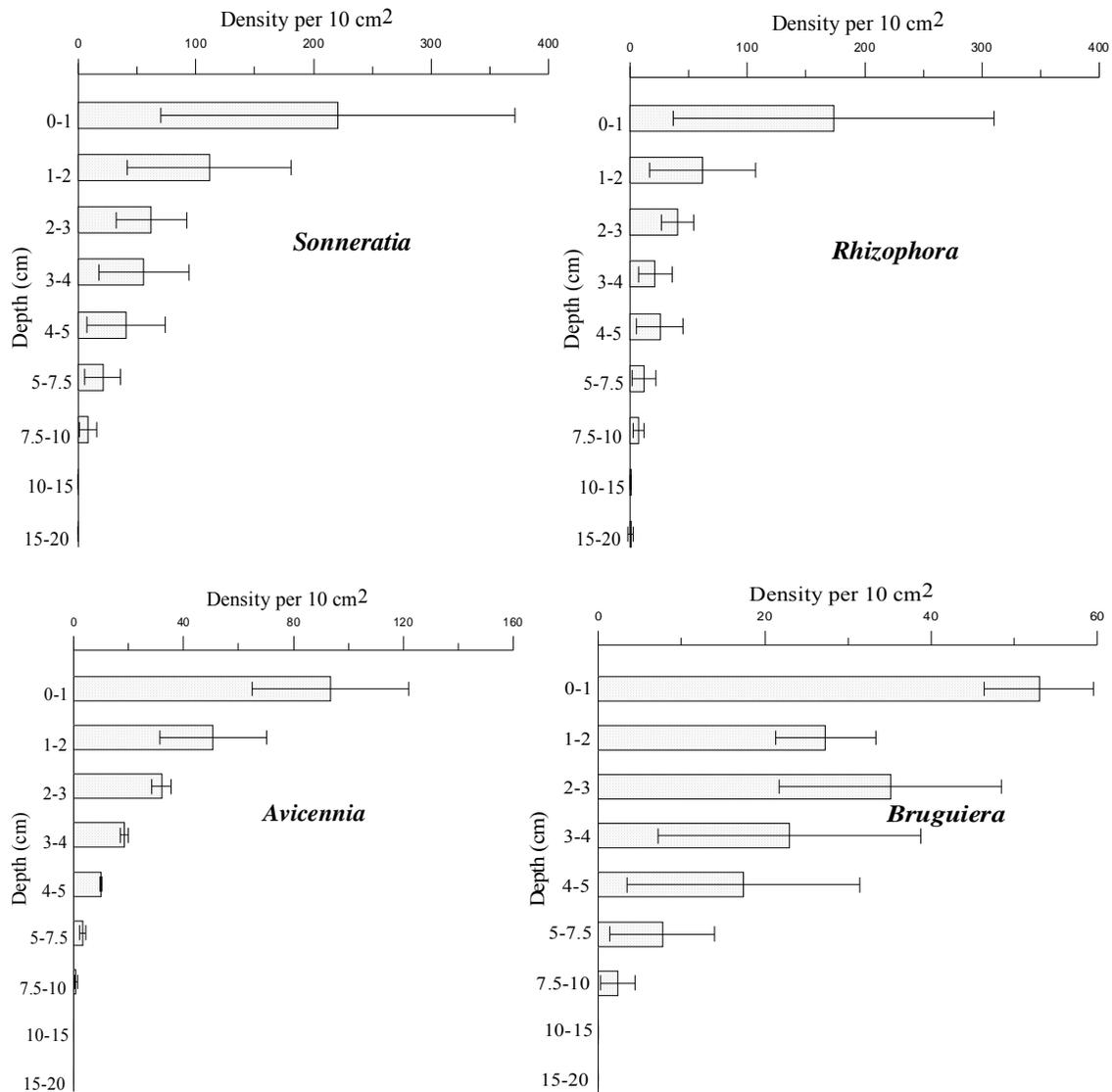


Fig. 2. Vertical profile of meiofaunal density (Mean±SD/ 10 cm²) in different vegetation types

Fig. 2. Le profil vertical de densité de meiofaunal (Signifié±SD/ 10 cm²) dans les types de végétation différents

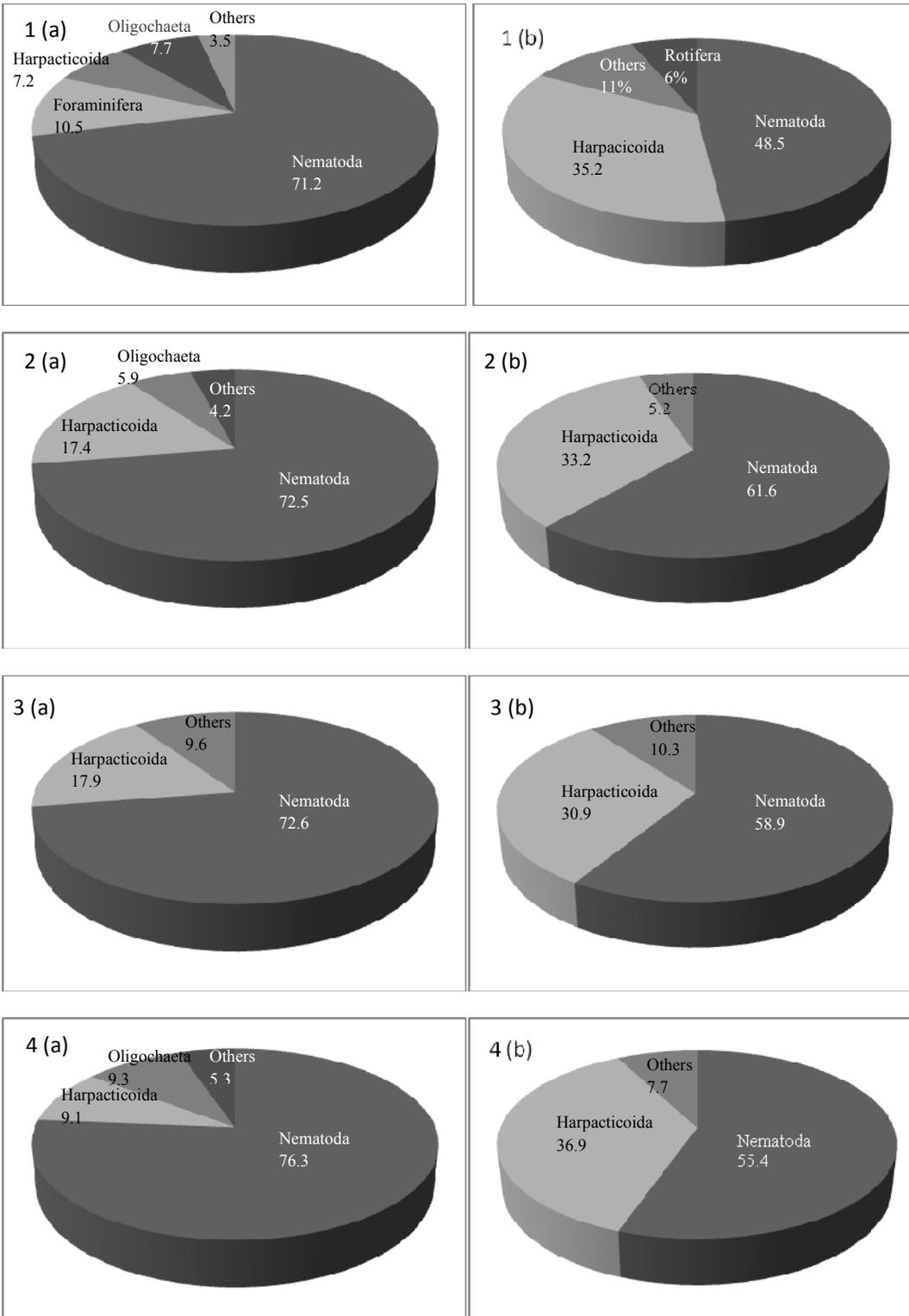


Fig. 3. Meiofaunal composition (%) in the sediment (a) and on the surface of roots (b) of different vegetation types (1- *Sonneratia*, 2- *Rhizophora*, 3- *Avicennia* and 4- *Bruguiera*).

Fig. 3. Composition méiofaune (%) dans le séparateur (a) et sur la surface des racines (b) de différents types de végétation (1- *Sonneratia*, 2- *Rhizophora*, 3- *Avicennia* and 4- *Bruguiera*).