THE INFLUENCE OF TIDAL AND RAINFALL CYCLES ON INTERTIDAL NEMATODES: A CASE STUDY IN A TROPICAL SANDY BEACH

Virag Venekey1*, Paulo Jorge Parreira dos Santos2 and Verônica Gomes da Fonseca-Genevois2

1Universidade Federal do Pará (Av. Augusto Corrêa, 01, 66075-110 Belém, PA, Brasil)
2Universidade Federal de Pernambuco (Av. Prof. Moraes Rego, 1235, 50670-901 Recife, PE, Brasil)

*Corresponding author: venekey@ufpa.br

http://dx.doi.org/10.1590/S1679-87592014061706204

ABSTRACT

The present study describes the nematode assemblage of the bay of Tamandaré (Brazil), a tropical sandy beach, during the low, flood, high and ebb tides of two consecutive tidal cycles in four different months of the year (May, July, September and November). The nematode assemblage was dominated by Metachromadora and Perepsilonema and varied significantly between months and tides. Densities were lower in July, and changes in assemblage structure occurred during the transitional periods between rainy and dry months, which showed the influence of rainfall. Flood and ebb tides appeared to exercise the greatest influences over the tidal cycle, although the patterns were not very clear. Identification at genera/species level is recommended for future studies, to better understand the patterns of nematode assemblages during tidal cycles.

RESUMO

O presente estudo descreve a associação de nematódeos da Baía de Tamandaré (Brasil), praia arenosa tropical típica, durante as marés (baixa, enchente, alta e vazante) de dois ciclos de maré consecutivos, em quatro meses diferentes do ano (Maio, Julho, Setembro e Novembro). A associação de nematódeos foi dominada por Metachromadora e Perepsilonema e variou significativamente entre meses e marés. Densidades foram mais baixas em julho e as mudanças na associação ocorreram durante meses de transição entre chuvoso e seco mostrando a influência do ciclo de chuvas. No ciclo de maré a enchente e vazante pareceram exercer a maior influência, embora os padrões não fossem muito claros. Recomenda-se que os estudos devam ser feitos ao nível de gêneros/espécies para melhor compreensão dos padrões das associações de nematódeos durante ciclos de marés.

Descriptors: Brazil, Intertidal environment, Marine nematodes, Meiobenthos, Seasonal variations, Tides.
Descritores: Brasil, Ambiente intermareal, Nematódeos marinhos, Meiobentos, Variações sazonais, Marés.

INTRODUCTION

The term “sandy beach” has been used in literature to characterize a series of environments that vary from high energy beaches with strong waves, to sheltered estuarine flats (McPALACHLAN, 1983). These environments are the most dynamic of all marine ecosystems and are predominant in the coastal zone of both temperate and tropical regions (McLACHLAN; TURNER, 1994).

In sandy beaches, biotic and abiotic features such as sediment, microphytobenthos, oxygen, temperature and organic matter regulate meioibenthos (GIERE, 2009). However, all these characteristics are directly regulated by the energy of waves and tidal amplitude, especially in the intertidal region where their effects are more prominent (McLACHLAN, 1983). During the tidal cycle, changes occur in the sediment column directly influencing the zonation of organisms (FENCHEL, 1978; PALMER; BRANDT, 1981). However, most studies have only sampled fauna during low tide, and have not considered other stages of the cycle (DYE, 1978).

Nematodes are highly heterogeneous and frequently the most abundant meioibenthos group in sandy beaches in coastal zones (HEIP et al., 1982). Nevertheless, few ecological studies identify them at genera/species level, and studies that do are mostly restricted to temperate regions, such as Europe.
(GHESKIERE et al., 2004, GHESKIERE et al., 2005, KOTWICKI et al., 2005, MARIA et al., 2012) and Canada (SHARMA; WEBSTER, 1983). In tropical regions, studies have been performed in Australia (NICHOLAS; HODDA, 1999, NICHOLAS, 2001, HOURSTON et al., 2005), Ecuador (CALLES et al., 2005) and French Polynesia (GOURBAULT et al., 1995). Despite the extensive coastline of Brazil, and the high diversity of the group in sandy beaches (VENEKEY et al., 2010), only a few surveys in the country have studied nematodes at low taxonomic levels (BEZERRA et al., 1997; NETTO et al., 2007; MARIA et al., 2008; MARIA et al., 2013, VENEKEY et al., 2014; MELO et al., 2013). Whether studied at phylum, or low taxonomic levels, temporal studies of marine nematodes usually employ a monthly or seasonal scale, and mostly compare periods with or without rain.

The present study describes the effect of complete tidal cycles on nematode assemblage in a tropical sandy beach (Tamandaré, Pernambuco, Brazil) during rainy and dry periods of the year, testing the main hypothesis that assemblage structure is influenced by tides.

MATERIAL AND METHODS

The sampling station (08°45′58″S, 35°05′96″W) is located in the bay of Tamandaré, about 110 km south of Recife, Pernambuco, Brazil (Fig. 01). This sandy beach is characterized by quartz sediments, varying from fine to medium grain size (SOUZA–SANTOS et al., 2003), and the adjacent subtidal area has coral reef formations arranged parallel to the coast (MAIDA; FERREIRA, 1997). According to the criteria of MCLACHLAN (1980) the study area can be classified as a sheltered beach. The tidal amplitude in the area is about 2.5 m, and the cycle is semidiurnal. The climate is hot and humid, of type Aws, according to the Köppen system (mean lowest temperature in the colder months: >18°C). Based on the averages over the last 50 years, the region has two seasons: a dry summer season extending from September to February and a rainy winter season from March to August, with half of the annual rainfall occurring between May and July (SEMA – Science, Technology and Environment Department of Pernambuco state). There are around 12-13 hours of daylight per day.

Samples were exclusively collected in the upper intertidal zone, at hourly intervals, for 24h, in four different months of 1991: May, July, September and November. At each sampling, six meiofauna replicate cores were collected using a PVC hand-corer (inner diameter of 2.5 cm and depth of 10 cm) and fixed immediately in 4% formaldehyde solution. In the laboratory, samples were treated using the routine methods for meiofauna (humid sieving and manual centrifugation) suggested by ELMGREN (1973) and nematodes were sorted using Dollfus plates and a
stereoscopic microscope. Permanent slides were made for taxonomical identification of nematodes to genus and/or species level, as described by COBB (1917) and DE GRISSE (1969). The mean density for each tide (low, flood, high and ebb) was calculated using the density values obtained during each tidal peak, and at preceding and subsequent times.

Nematode Density (N), richness (S), diversity (Shannon-Wiener index – \( H' \) in \( \log_e \)) and evenness (Pielou index – \( J' \)) were calculated for each sample. PERMANOVA was applied to assess differences in nematode assemblage structure, after data were transformed to \( \log(x+1) \) and using the Bray Curtis index. Factors included months, tides and light/dark periods of the day. Pairwise \textit{a posteriori} comparisons were performed when significant differences were detected (\( p<0.05 \)).

Table 1. List of the nematode species found in Tamandaré Beach, Pernambuco State, Brazil.

| Phylum Nematoda       | Class Adenophorea | Subclass Enoplia | Order Enoplida | Suborder Enoplina |
|-----------------------|-------------------|------------------|----------------|------------------|
| Family Enchelidiida   | Bernardius        | Fonseca-Genevois | Smol           | Decraemer        | Venkekey         | 2009 |
|                        | **Bernardius lineatus** | Fonseca-Genevois | Smol           | Decraemer        | Venkekey         | 2009 |
|                        | **Eurystomina**   | Filipjev, 1921   |                |                  |                  |      |
| Family Ironidae       | Trissynchulus     | Cobb, 1920       |                |                  |                  |      |
| Family Oncholaimidae  | Viscosia          | De Man, 1890     |                |                  |                  |      |
| Family Oxytominidae   | Halalaimus        | De Man, 1888     |                |                  |                  |      |
|                        | *Oxytominina*     | Filipjev, 1921   |                |                  |                  |      |
|                        | sp.               |                  |                |                  |                  |      |
| Family Thoracostomopsida | **Enoploides**  | Saaweljev, 1912  |                |                  |                  |      |
|                        | **Mesacanthion**  | Filipjev, 1927   |                |                  |                  |      |
|                        | *Mesacanthion hirsutum* | Gerlach, 1953   |                |                  |                  |      |
|                        | Trileptium        | Cobb, 1933       |                |                  |                  |      |
|                        | *Trileptium stylium* | Gerlach, 1956   |                |                  |                  |      |
| Family Tripyloidiida  | **Bathyaimus**   | Cobb, 1894       |                |                  |                  |      |
|                        | **Bathyaimus**   | *capacous* | Hopper, 1962   |                  |                  |      |
| Family Trefusida      | **Lauratonematida** | **Lauratonema** | Gerlach, 1953  | **Lauratonema** | sp.              |      |
| Family Chromadoridae  | **Acantholaimus** | Allgin, 1933     |                |                  |                  |      |
|                        | **Chromadorita**  | Filipjev, 1922   |                |                  |                  |      |
|                        | *Chromadorita* Kreis, 1929 | *Chromadorita* | *Chromadorita* sp. | *Chromadorita* | *Chromadorita* sp. |      |
| Family Cyatholaimidae | **Marylynnia**    | Hopper, 1977     |                |                  |                  |      |
|                        | **Marylynnia**    | sp.              |                |                  |                  |      |
| Family Desmodoridae   | **Chromaspirinia** | Filipjev, 1918   |                |                  |                  |      |
|                        | **Chromaspirinia** | sp.              |                |                  |                  |      |
| Family Epsilonematida | **Perepsilonema** | Kellyae | Gourbault & Decraemer, 1988 | **Perepsilonema** | sp. |      |
| Family Microlaimidae  | **Calomicrolaimus** | **Calomicrolaimus** | **Calomicrolaimus** | **Calomicrolaimus** | **Calomicrolaimus** |      |

RESULTS

The nematode assemblage of Tamandaré beach consisted of 48 genera (with 41 named/putative species), 21 families and 4 orders (Table 1). Fluctuations were observed in genera numbers when tides and months were compared (Fig. 02) but differences in richness were significant only in comparisons between months (\( \text{Pseudo-F}=12.896; p=0.0001 \)). Diversity also varied significantly between months, with values ranging from 1.26 to 1.97 in May, 1.58 to 2.24 in July, 1.44 to 2.31 in September and 2.13 to 2.44 in November (\( \text{Pseudo-F}=12.323, p=0.0001 \)). These results indicated that May was the least rich and least diverse month, while November was the richest and most diverse month. July and September provided intermediate results. Evenness values were continuously high (>0.9) and, similar to other measures, only varied significantly between months (\( \text{Pseudo-F}=8.4635, p=0.0004 \)).
Fig. 2. Mean density (ind./10 cm²) (bars indicate average ± standard deviations) and number of nematodes genera during two consecutive tidal cycles (1 and 2) in four different months (L = low tide; F = flood tide; H = high tide; E = Ebb tide) at Tamandaré beach, Brazil.
Results from PERMANOVA for nematode assemblage showed significant differences between months and tides, but not for periods of the day (Table 2). Nematode densities were lower in July (38-84 ind/10 cm$^2$) than in the months of May (146-570 ind/10 cm$^2$), September (45-1013 ind/10 cm$^2$) and November (84-334 ind/10 cm$^2$) (Fig. 2). Post-hoc pairwise comparisons showed that nematode assemblages were different in each month (Table 2). The differences between months were evident from MDS analysis (Fig. 3).

Fig. 3. Non-metric scaling plot of months at Tamandaré beach, Brazil.

Table 2. PERMANOVA results for the structure of nematode assemblages as between monthly, tidal and daily periods on Tamandaré beach, Brazil. Asterisks represent significant differences (p<0.05).

| Factor                | DF | MS     | Pseudo-F | P(perm) |
|-----------------------|----|--------|----------|---------|
| Months                | 3  | 21127  | 19.393   | 0.0001* |
| Tides                 | 3  | 1762   | 1.6173   | 0.0449* |
| Days                  | 1  | 1268.5 | 1.1643   | 0.3296  |
| Months x Tides        | 9  | 2052   | 1.8835   | 0.0001* |
| Months x Day Periods  | 3  | 2084.2 | 1.9131   | 0.0103* |
| Tides x Day Periods   | 3  | 1598.1 | 1.4669   | 0.0783  |
| Months x Tides x Day  | 9  | 1518.5 | 1.3938   | 0.0319* |
| Residue               | 62 | 1089.5 |          |         |
| Total                 | 93 |        |          |         |

There was no clear pattern of nematode densities in all months when the four tides (low = L, flood = F, high = H, ebb = E; 1 and 2 = first and second cycles) were compared. Densities varied from 45 (L2 in July) to 373 (L2 in September) ind/10 cm$^2$ at low tide, and from 45 (F2 in September) to 1013 (F1 in September) ind/10 cm$^2$ at flood tide, from 38 (H2 in July) to 452 (H2 in May) ind/10 cm$^2$ at high tide and from 41 (E2 in July) to 654 (E1 September) ind/10 cm$^2$ at ebb tide. Post-hoc pairwise comparisons showed that nematode assemblages were different only between flood and ebb tide, and flood and high tide (Table 3). However when tides from the same month were compared, other significant differences were also found which were not always related to the flood tide (Table 4).

Table 3. Results of the paired tests for the structure of nematode assemblages between months and tides at Tamandaré beach, Brazil. Asterisks represent significant differences (p<0.05).

| Factor                | T     | P(perm) |
|-----------------------|-------|---------|
| May x July            | 4.1038| 0.0001* |
| May x September       | 4.5083| 0.0001* |
| May x November        | 6.6653| 0.0001* |
| July x September      | 2.7109| 0.0002* |
| July x November       | 4.613 | 0.0001* |
| September x November  | 3.6815| 0.0001* |
| Ebb x Low             | 1.1234| 0.2746  |
| Ebb x Flood           | 1.507 | 0.0329* |
| Ebb x High            | 0.539 | 0.9336  |
| Low x Flood           | 0.847 | 0.6465  |
| Low x High            | 1.3024| 0.1223  |
| Flood x High          | 1.7884| 0.0074* |

Table 4. Results of the paired tests for the structure of nematode assemblages between tides in each month at Tamandaré beach, Brazil. Asterisks represent significant differences (p<0.05).

| Factor    | T     | P(perm) |
|-----------|-------|---------|
| May       |       |         |
| Ebb x Low | 0.701 | 0.775   |
| Ebb x Flood| 1.298 | 0.159   |
| Ebb x High | 1.313 | 0.174   |
| Low x Flood | 1.746 | 0.012*  |
| Low x High  | 2.146 | 0.004*  |
| Flood x High | 1.459 | 0.132   |
| July      |       |         |
| Ebb x Low | 1.471 | 0.099   |
| Ebb x Flood| 1.821 | 0.021*  |
| Ebb x High | 0.798 | 0.758   |
| Low x Flood | 0.735 | 0.727   |
| Low x High  | 1.652 | 0.048*  |
| Flood x High | 2.037 | 0.006*  |
| September  |       |         |
| Ebb x Low | 1.473 | 0.056   |
| Ebb x Flood| 1.057 | 0.372   |
| Ebb x High | 1.011 | 0.461   |
| Low x Flood | 1.264 | 0.114   |
| Low x High  | 1.237 | 0.152   |
| Flood x High | 0.522 | 0.978   |
| November   |       |         |
| Ebb x Low | 1.007 | 0.443   |
| Ebb x Flood| 2.044 | 0.006*  |
| Ebb x High | 0.498 | 0.909   |
| Low x Flood | 1.547 | 0.043   |
| Low x High  | 0.721 | 0.841   |
| Flood x High | 1.937 | 0.003*  |
In May *Metachromadora* (with 4 species) was the most abundant genus for all tides, varying from 49 to 89%. The presence of the *Calomicrolaimus* and *Mesacanthion* genera, represented by the single species *C. formosus* and *M. hirsutum*, contributed with 14 and 10% during the first and second ebb tide, respectively. Other genera represented less than 10% of the nematode assemblage (Fig. 4). In July *Metachromadora* remained the most abundant genus, but was less expressive than in May (27 to 40%). The genera/species *Perepsilonema* (2 species), *Axonolaimus* sp., *Marylynnia* sp., *Microlaimus* sp., *Pseudosteineria scopae* and *Theristus* (2 species) occasionally comprised more than 10% of the assemblage. In September, *Metachromadora* represented more than 10% of total abundance only at second ebb tide. In that month the genus *Perepsilonema* was most abundant (from 39 to 85%) in all stages of the two consecutive tide cycles, with the exception of the second ebb when *Microlaimus* sp. was the dominant taxon, with 22%. In November *Perepsilonema* comprised more than 10% of total abundance during the first flood only. In that month *Microlaimus* sp. (L1, H2 and E2), *Axonolaimus* sp. (F1 and F2) and *Pseudosteineria scopae* (H1, E1 and L2) were dominant. Other species such as *Mesacanthion hirsutum*, *Bathylaimus capacosus* and *Bernardius lineatus* occasionally represented more than 10% of the total (Fig. 4).

![Fig. 4. Relative abundance of nematode genera during two consecutive tidal cycles (1 and 2) in four different months (L = low tide; F = flood tide; H = high tide; E = Ebb tide) at Tamandaré beach, Brazil.](image)


**DISCUSSION**

The number of genera occurring in Tamandaré (48 genera) is similar to other Brazilian sandy beaches: 39 genera in Istmno de Olinda – Pernambuco (T. N. C. BEZERRA, pers. comm.)* 39 genera in Bananal Beach – Rio de Janeiro (MARIA et al., 2008) and 46 genera in Coqueiros Beach – Rio de Janeiro (MARIA et al., 2008). All 48 genera had already been recorded on the Brazilian coast (VENEKEY et al., 2010) with the exception of *Bernardiuss* which was recently described by FONSECA-GENEVOIS et al. (2009) as a new genus with specimens collected in Tamandaré during the present study. Apart from the new species *Bernardiuss lineatus*, of the nine species identified by name, *Bathylocalmus capacosus*, *Cynura cerambus* and *Mesacanthion hirsutum* were found for the first time in Brazil. The lack of records of these species in previous Brazilian studies does not mean that they are not present in other areas. This result is a consequence of the fact that few studies have been undertaken in Brazil with nematode identification at species level.

The highest nematode density at Tamandaré beach was 1,013 ind/10 cm². This value is in accordance with those found in similar habitats worldwide, whether in temperate (GHESKIERE et al., 2005 in Italy: 130 – 2001 ind/10 cm²) or tropical regions (BEZERRA et al., 1996 in Brazil: 380 - 4681 ind/10 cm²). Variation was observed in densities, as well as in taxonomic composition. As the tide amplitude was similar between months, it can be deduced that the differences found are due to other environmental factors. Many studies of meiofauna and nematodes associate changes in density with seasonal variations (HEIP et al., 1985). In temperate regions, where seasons are well-defined, low densities are usually recorded in winter and associated mainly with reductions in microphytobenthic biomass (RUDNIK et al., 1985; SANTOS et al., 1996). In tropical regions, the few studies that exist associate changes in nematode density with rain cycles (PATTNAIK; RAO, 1990; INGOLE; PARULEKAR, 1998; VENEKEY et al., 2014).

In terms of minimum and maximum densities during the study (38 and 1,013 ind/10 cm²), in May, densities fluctuated from low to medium and a clear dominance of *Metachromadora* was observed. In July densities and genera abundances were more or less constant. In September fluctuations were high, and again a clear dominance of one genus was observed, in this case *Perepsilonema*. In November density fluctuations varied from low to medium and the composition, dominance and abundance of genera were the most uniform during the study. Variations therefore appear to be connected to monthly seasonal variations. In the year studied, 536.3, 355.5, 59.2 and 61.2mm of precipitation were registered at Recife’s Meteorological Station for May, July, September and November, respectively (INMET, 2013). May and July may, therefore, be considered as rainy and September and November as dry. Both PERMANOVA and MDS presented a clear monthly distinction, the difference between them being evident. The change in genera dominance in sandy beaches occurred mainly during months that are transitional either from dry to rainy periods (May) or from rainy to dry periods (September), as had previously been observed in Ecuador by CALLES et al. (2005). In terms of monthly differences, densities were distinctly lower in July, with values that were consistently less than 150 ind/10 cm², results similar to those found by BEZERRA et al. (1996) who also found lower nematode densities in July when studying a tropical sandy beach, Istmno de Olinda (also in Pernambuco state, Brazil), during a one-year period, with monthly samplings.

In temperate regions it has previously been found that most animals use sediment layers immediately below the surface, migrating to lower depths (HARRIS, 1972) during the winter. On Tamandaré, and also on Istmno de Olinda, only the first 10 cm of the sediment was sampled without stratification, and it was therefore impossible to ascertain whether density variations occurred within the sediment column. However, certainly nematodes disperse/migrate through the sediment or water column.

Among the genera the dominance of *Metachromadora* (family Desmodoridae) in May and of *Perepsilonema* (family Epsilonematidae) in July was remarkable. On sandy beaches with medium sands, such as Tamandaré, families like Desmodoridae, Draconematidae and Epsilonematidae can become dominant (HEIP et al., 1985). Their presence in this kind of environment can be attributed to their morphological characteristics which include numerous ambulatory setae that are often used to attach to sediment grains (RAES et al., 2007). This later behavior can specially favor these taxa’s dominance in intertidal regions. The presence of *Metachromadora* is very common in Brazilian sandy beaches (VENEKEY et al., 2010), and it can even be one of the dominant genera in this type of environment (GHESKIERE et al., 2005). The genus *Perepsilonema* has also already been recorded in high abundance in other tropical sandy beaches (GOURBAULT; DE Craemer, 1993), including some on the Pernambuco coast (BEZERRA et al., 1996; VENEKEY et al., 2014). Other taxa such as *Axonolaimus* (family Axonolaimidae), *Theristus*

(*) BEZERRA, T. N.C., 2001. Dra. University of Gent, Belgium).
(family Xyalidae) and Pseudosteineria (family Xyalidae) appeared occasionally with more than 10% of total nematode abundance. These genera are non-selective deposit feeders according to WIESER'S (1953) classification and, due to their more generalist feeding habit, can become abundant. Particularly Xyalidae is a very common family in all types of marine environments and is frequently recorded with high abundances in fine to medium sands (HOURSTON et al., 2005; MORENO et al., 2006; MUNDO-OCAMPO et al., 2007). Furthermore, the differences in genera richness and diversity between months and tides were mainly caused by the presence or absence of rare genera (Acantholaimus, Chromaspirinia, Dichromadora, Halalaimus, Paracomesoma, Stephanolaimus and Tarvaia).

The interstitial habitat of sandy beaches has the ability to adapt in accordance with local energy fluctuations as it presents the dynamic characteristics which maintain sand grains, water and air in constant movement (BROWN; McLACHLAN, 1990). The adaptation to sediment erosion and deposition is dependent on beach energy (FLEMMING; FRICKE, 1983), and although these processes are influenced by many factors, tides are the most important (HULINGS; GRAY, 1976). On Tamandaré, nematodes reacted to tide changes and, in terms of the tidal cycle, flood and ebb tides seemed to have the greatest influence. However, the patterns were not very clear possibly because tides interact with waves and wind to determine energy variation and thus sand and water movements.

According to HULINGS and GRAY (1976) tides are determining factors for zonation and abundance of meiofauna. It is evident that sandy beaches are sensitive to changes in environmental factors, especially to waves and tides conditions, responding rapidly to different levels of energy (FLEMMING; FRICKE, 1983). The influence of tidal cycles in the vertical distribution of organisms is demonstrated by cyclical changes in the interstitial habitat associated with processes of movement in the sediment, hydrodynamic changes caused by currents, and differences in wave energy that act on the sediment column (BOADEN, 1968). Generally animals have ascendant movements during flood tide, when the sediment is saturated by water, resulting in high densities, and move in the opposite direction during ebb tide, when the first sediment layers become dry, resulting in low densities (McLACHLAN et al., 1977). In Tamandaré this pattern was only observed in the two consecutive tidal cycles in July and in the second tidal cycle in May. (SILVA, A. P. C. 2014, pers. comm.*) who studied only flood and ebb tides in Maracaípe, a sandy beach also in the south of the Pernambuco littoral, did not find any significant variations in nematodes densities, suggesting that they are resistant to the hydrodynamic changes that occur during tides. This observation is valid not only at phylum level but also for genera composition and abundance, according to (PEREIRA, L. L., 2008, pers. comm.*) according to who studied the same samples as (SILVA, A. P. C., 2006, pers. comm.*). Alternatively, many authors suggest that nematodes are influenced by tides (BOADEN; PLATT, 1971; PALMER; GUST, 1985; FEGLEY, 1987; PALMER 1988). The results in Tamandaré partly agree with this last group of authors, although it seems that either biotic/abiotic factors other than tides should be considered, or the studies should be undertaken at species level to better understand the variation in nematode assemblages during tidal cycles. VENEKEY et al. (2011), for instance, when studying the influence of tides on one isolated species, Mesacanthium hirsutum, unexpectedly found higher densities during high or ebb tides, but not in flood tides. Concerning Metachromadora and Perepsilonema, the most abundant genera recorded on Tamandaré, both have annulated cuticles that can offer strong protection in stressful habitats such as intertidal regions. BOADEN and PLATT (1971) had already noticed that nematodes with strong cuticles can be dominant in upper layers of the sediment in environments with tidal influence.

The results of the present study showed the clear effect of rainfall and tides on nematodes, showing that the ecology of nematode assemblage structure can be better understood using studies that identify to lower taxonomic levels. The identification of nematodes at genera level, and when possible at species level, is recommended for future studies. Furthermore, the sampling design of future studies should take into consideration that nematode genera/species do not all possess the same movement or migration patterns.

ACKNOWLEDGEMENTS

Virág Venékey is grateful for a CAPES postgraduate research scholarship (Brazil) and PJPS is grateful for a CNPq research fellowship. The authors are grateful to James Young for the English revision.

(*) SILVA, A. P. C. 2006. M.Sc. Universidade Federal de Pernambuco.
(**) SILVA, A. P. C. 2006. M.Sc. Universidade Federal de Pernambuco.
REFERENCES

ANDERSON, M. J.; GORLEY, R. N.; CLARKE, K. R. PERMANOVA+ for PRIMER: guide to software and statistical methods. Plymouth: PRIMER-E, 2008.

BEZERRA, T. N. C.; FONSECA-GENEVOIS, V. G.; GENEVOIS, B. Distribuição horizontal e vertical da meiofauna em uma região tropical intermareal (Istmo de Olinda – Pernambuco – Brasil). Trab. OceanoG. Univ. Fed. PE. v. 24, p. 249-264, 1996.

BEZERRA, T. N. C.; GENEVOIS, B.; FONSECA-GENEVOIS, V. G. Influência da granulometria na distribuição e adaptação da meiofauna na praia arenosa do Istmo de Olinda-PE. Oecol. Bras., v. 5, p. 107-116, 1997.

BOADEN, P. J. S. Water movement – a dominant factor in interstitial ecology. Sarsia, v. 34, n. 1, p. 125-136, 1968.

BOADEN, P. J. S.; PLATT, H. M. Daily migration patterns in an intertidal meiobenthic community. Thalassia Jugosl., v. 7, p. 1-12, 1971. [Proceedings of the sixth European Symposium on Marine Biology, Rovinj, Croatia, Yugoslavia, September 27-October 2, 1971].

BROWN, A. C.; McLACHLAN, A. Ecology of sandy shores. Amsterdam: Elsevier Science Publishers, 1990. 328 p.

CALLES, A.; VINCX, M.; COMEJO, P.; CALDERÓN, J. Patterns of meiofauna (especially nematodes) in physical disturbed Ecuadorian sandy beaches. Meiofauna Mar., v. 14, p. 121-129, 2005.

COBB, N. A. Notes on Nemas. In: Contributos a science of nematologology. Baltimore: Waverly Press, 1917. v. 5, p. 117-128.

DE GRISSE, A. T. Redescription ou modification de quelques techniques utilisés dans l’ étude des nématodes phytoparasitaires. Meded. Rijksfac. Landbouwwet., Gent, v. 34, p. 351-369, 1969.

DYE, A. H. An ecophysiological study of the meiofauna of the Swartkops estuary. I. The sampling sites: Physical and chemical features. Zool. Afr., v. 13, p. 1-18, 1978.

ELMGREN, R. Methods of sampling sublittoral soft bottom meiofauna. Oikos, v. 15, suppl., p. 112-120, 1973.

FEGLEY, S. R. Experimental variation of near-bottom current speeds its effects on depth distribution of sand-living meiofauna. Mar Biol., v. 95, n. 2, p. 183-191, 1987.

FENCHEL, T. M. The ecology of micro- and meiobenthos. Annu. Rev. Ecol. Syst., v. 9, p. 99-121, 1978.

FLEMMING, B. W.; FRICKE, A. H. Beach and nearshore habitats as a function of internal geometry; primary sedimentary structures and grain size. In: McLACHLAN A.; ERASMUS, T. (Eds.). Sandy beaches as ecosystems. Hague: Dr. W. Junk Publishers, 1983. p. 115-132. [First International Symposium on Sandy Beaches, held in Port Elizabeth, South Africa, 17-21 Jan, 1983].

FONSECA-GENEVOIS, V.; SMOL, N.; DECREAEMER, W.; VENEKEY, V. Bernardius lineatus gen. n., sp.n. (Enoplida: Enchelediidae), a remarkable nematode with ornamented cuticle from a Brazilian tropical sandy beach. Nematology, v. 11, n. 2, p. 275-287, 2009.

GHESKIERE, T.; HOSTE, E.; VANAVERBEKE, J.; VINCX, M.; DEGRAER, S. Horizontal zonation patterns and feeding structure of marine nematode assemblages on an macrotidal, ultra-dissipative sandy beach (De Panne, Belgium). J. Sea Res., v. 52, n. 3, p. 211-226, 2004.

GHESKIERE, T.; VINCX, M.; URBAN-MALINGA, B.; ROSSANO, C.; SCAPINI, F.; DEGRAER, S. Nematodes from wave-dominated sandy beaches: diversity, zonation patterns and testing of the isocommunities concept. Estuarine, Coastal Shelf Sci., v. 62, p. 365-375, 2005.

GIERE, O. Meiobenthology: the microscopic motile fauna in aquatic sediments. 2.ed. Berlin: Springer-Verlag, 2009. 527 p.

GOURBAULT, N.; DECREAEMER, F. New species of Glochinema and Metaglochinema (Nematoda, Epsilonematidae) from New Caledonia. Zool. Scr., v. 22. n. 3, p. 223-227, 1993.

GOURBAULT, N. E.; WARWICK, R. M.; HELLEOUT, M. N. A survey of intertidal meiobenthos (Especially Nematoda) in coral sandy beaches of Moorea (French Polynesia). Bull. Mar. Sci., v. 57, n. 2, p. 476-488, 1995.

HARRIS, R. P. Seasonal changes in the meiofauna population of an intertidal sand beach. J. Mar. Biol. Assoc. U. K., v. 52, p. 389-403, 1972.

HEIP, C.; VINCX, M.; SMOL, N.; VRANKEN, G. The systematics and ecology of free-living marine Nematodes. Helminthol. Abstr. Ser. B, Plant Nematol., v. 51, n. 1, p. 1-31, 1982.

HEIP, C. H. R.; VINCX, M.; VRANKEN, G. The ecology of marine nematodes. Oceanogr. Mar. Biol., v. 23, p. 399-489, 1985.

HOURSTON, M.; WARWICK, R. M.; VALESIINI, F. J.; POTTER, I. C. To what extent are the characteristics of nematode assemblages in nearshore sediments on the west Australian coast related to habitat type, season and zone? Estuarine, Coastal Shelf Sci., v. 64, n. 4, p. 601-612, 2005.

HULINGS, N. C.; GRAY, J. S. Physical factors controlling abundance of meiofauna on tidal and atidal beaches. Mar. Biol., v. 34, n. 1, p. 77-83, 1976.

INMET. Instituto de Meteorologia. Dados de pluviometria. 2013. Available in: www.inmet.gov.br. Accessed on: Sept. 12, 2013

INOLVE, B. S.; PARULEKAR, A. H. Role of salinity in structuring the intertidal meiofauna of a tropical estuarine beach: field evidence. Indian J. Mar. Sci., v. 27, p. 356-361, 1998.

KOTWICKI, L.; DE TROCH, M.; URBAN-MALINGA, B.; GHESKIERE, T.; WESLAWSKI, J. M. Horizontal and vertical distribution of meiofauna on sandy beaches of the North Sea (The Netherlands, Belgium, France). Helgoland Mar. Res., v. 59, n. 4, p. 255-264, 2005.

MAIDA, M.; FERREIRA, B. P. Coral reefs of Brazil: an overview. In: INTERNATIONAL CORAL REEF SYMPOSIUM, 8., 1997, Balboa. Proceedings. Balboa, 1997. n. 1, p. 263-274.

MARIA, T. F.; ESTEVES, A. M.; SMOL, N.; VANREUSEL, A.; DECREAEMER, W. Nematodes from sandy beaches of Guanabara Bay, Rio de Janeiro, Brazil. Biociências, v. 16, n. 2, p. 92-103, 2008.
MARIA, T. F.; VANEVERBEKE, J.; ESTEVES, A. M.; DE TROCH, M.; VANREUSEL, A. The importance of biological interactions for the vertical distribution of nematodes in a temperate ultra-dissipative sandy beach. *Estuarine, Coastal Shelf Sci.*, v. 97, p. 114-126, 2012.

MARIA, T. F.; PAIVA, P. C.; VANREUSEL, A.; ESTEVES, A. M. The relationship between sandy beach nematodes and environmental characteristics in two Brazilian sandy beaches (Guanabara Bay, Rio de Janeiro). *An. Acad. Bras. Cienc.*, v. 85, n. 1, p. 257-270, 2013.

McLACHLAN, A.; WINTER, P. E. D.; BOTHA, L. Vertical and horizontal distribution of sub-littoral meiofauna in Algoa Bay, South Africa. *Mar. Biol.*, v. 40, n. 4, p. 355-364, 1977.

McLACHLAN, A. The definition of sandy beaches in relation to exposure: a simple rating system. *S. Afr. J. Sci.*, v. 76, p. 137-138, 1980.

McLACHLAN, A. Sandy beach ecology: a review. In: McLACHLAN A.; ERASMUS, T. (Eds.). *Sandy beaches and ecosystems*. Hague: Dr. W. Junk Publishers, 1983. p. 321-381. [First International Symposium on Sandy Beaches, held in Port Elizabeth, South Africa, 17-21 Jan, 1983].

McLACHLAN, A.; TURNER, I. The interstitial environment of sandy beaches. *Mar. Ecol.*, v. 15, n. 3/4, p. 177-211, 1994.

MELO, T. P. G.; ROSA-FILHO, J. S.; VENEKEY, V. Marine nematoda from Ajuruteua beach, Amazon coast, Brazil. *Atlântica*. 2013, [In press].

MORENO, M.; FERRERO, T. J.; GRANELLI, V.; MARIN, V.; ALBERTELLI, G.; FABIANO, M. Across shore variability and trophodynamic features of meiofauna in a microtidal beach of the NW Mediterranean. *Estuarine, Coastal Shelf Sci.*, v. 66, n. 3/4, p. 357-367, 2006.

MUNDO-OCAMPO, M.; LAMBSHEAD, P. J. D.; DEBENHAM, N.; KING, I. W.; DE LEY, P.; BALDWIN, J. G.; DE LEY, I. T.; ROCHA-OLIVARES, A.; WAUMANN, D.; THOMAS, W. K.; PACKER, M.; BOUCHER, G. Biodiversity of littoral nematodes from two sites in the Gulf of California. *Hydrobiologia*. v. 586, n. 1, p. 179-189, 2007.

NETTO, S. A.; PAGLIOSA, P. R.; FONSECA, A. L. O.; GALLUCCI, F.; FONSECA, G. F. C.; SOUZA, R. S. Interações entre microfitobentos, meiofauna e macrofauna (Praia Comprida, Santa Catarina). *Braz. J. Ecol.*, v. 11, n. 1. 78-82, 2007.

NICHOLAS, W. L. Seasonal variations in nematode assemblages on an Australian temperate ocean beach; the effect of heavy seas and unusually high tides. *Hydrobiologia*. v. 464, n. 1/3, p. 17-26, 2001.

NICHOLAS, W. L.; HODDA, M. The free-living nematodes of a temperate, high energy, sandy beach, faunal composition and variation over space and time. *Hydrobiologia*. v. 394, p. 113-127, 1999.

PALMER, M. A. Dispersal of marine meiofauna: a review and a conceptual model explaining passive transport and active emergence with implications for recruitment. *Mar. Ecol.: Prog. Ser.*, v. 48, n. 1, p. 81-91, 1988.

PALMER, M. A.; BRANDT, R. R. Tidal variation in sediment densities of marine Benthic Copepods. *Mar. Ecol.: Prog. Ser.*, v. 4, p. 207-212, 1981.

PALMER, M. A.; GUST, G. Dispersal of meiofauna in a turbulent tidal creek. *J. Mar. Res.*, v. 43, n. 1, p. 179-210, 1985.

PATTNAIK, A.; RAO, M. V. L. Composition and distribution of interstitial meiofauna of the sandy beach at Golpapur South Orissa Coast. *Indian J. Mar. Sci.*, v. 19, p. 165-170, 1990.

RAES, M.; DE TROCH, M.; NDARO, S. G. M.; MUTHUMBI, A.; VULISI, K.; VANREUSEL, A. The structuring role of microhabitat type in coral degradation zones: a case study with marine nematodes from Kenya and Zanzibar. *Coral Reefs.*, v. 26, n. 1, p. 113-126, 2007.

RUDNIK, D. T.; ELMGREN, R.; FRITHSEN, J. B. Meiofaunal prominence and benthic seasonality in a coastal marine ecosystem. *Ecologia*, v. 67, n. 2, p. 157-170, 1985.

SANTOS, P. J. P.; CASTEL, J.; SOUZA-SANTOS, L. P. Seasonal variability of meiofaunal abundance in the oligo-mesohaline area of the Gironde Estuary, France. *Estuarine, Coastal Shelf Sci.*, v. 43, n. 5, p. 549-563, 1996.

SANTOS, L. P.; RIBEIRO, V. S. S.; SANTOS, P. J. P.; FONSECA-GENEVOIS, V. Seasonality of intertidal meiofauna on a tropical sandy beach in Tamandaré Bay (Northeast Brazil). *J. Coast. Res.*, v. 35, p. 369-377, 2003.

SHARMA, J.; WEBSTER, J. M. The abundance and distribution of free-living nematodes from two Canadian Pacific beaches. *Estuarine, Coastal Shelf Sci.*, v. 16, n. 2, p. 217-227, 1983.

VENEKEY, V.; FONSECA-GENEVOIS, V. G.; SANTOS, P. J. P. Biodiversity of free-living marine nematodes on the coast of Brazil: a review. *Zootaxa*. v. 2568, p. 39-66, 2010.

VENEKEY, V.; FONSECA-GENEVOIS, V. G.; SANTOS, P. J. P. Influence of the tidal and rainfall cycles on the population structure and density of Mesacanthion hirsutum Gerlach (Nematoda, Thoracostomopsidae) on a tropical sandy beach (Tamandaré Bay, Pernambuco, Brazil). *Braz. J. Oceanogr.*, v. 59, n. 3, p. 253-258, 2011.

VENEKEY, V.; FONSECA-GENEVOIS, V. G.; SANTOS, P. J. P. Influence of environmental factors on intertidal Nematoda in a tropical sandy beach (Tamandare Bay, Pernambuco, Brazil). *J. Coastal Res.*, v. 30, n. 4, p. 785-794, 2014.

WIESER, W. Die beziehung zwischen mundhoehlengstalt, ernahrungsweise und vorkommen bei frei lebenden marinen nematoden. Eine oekologisch – morphologische studie. *Arkiv Zool.*, v. 2, n. 4, p. 439-484, 1953.