Spatial and temporal distribution of Nematoda in a subtropical estuary.

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ABSTRACT: Spatial and temporal distribution of Nematoda in a subtropical estuary. The spatial and temporal distribution of Nematoda communities was analysed in three environments: in the Tramandaí lagoon, where there is a constant input of fresh water, in the Armazém lagoon, where saline water enters more often, and in the Channel which links the lagoons to the Atlantic Ocean. A total of 27 genera of Nematoda were recorded. In the Armazém lagoon the Terschellingia, Pseudochromadora, Anoplostoma, Theristus and Metalinhomoeus were more representative. Daptonema and Viscosia were dominant in the Channel and Anonchus, Theristus and Oncholaimellus in the Tramandaí lagoon. Multivariate analysis showed that nematode community structure differs among environments. The density, diversity and number of genera were significantly higher in the Armazém lagoon. A simplified community structure of the Nematoda in the Channel and in the Tramandaí lagoon probably reflects the largest instability found in both environments. This distinction was also visualized in relation to the feeding groups, in the Armazém lagoon there was a dominance of epigrowth feeder and microvores, while the deposit feeders and facultative predators prevailed in the Channel and Tramandaí lagoon. A temporal variation was detected in the Nematoda genera and feeding groups. The highest densities of organisms occurred in the summer. In the Tramandaí-Armazém estuary, the interaction between the salinity, hydrodynamic, availablity of food and temperature conditions influence Nematoda community structure.
Key-words: nematoda, estuary, feeding group, spacial and temporal distribution.

RESUMO: Distribuição espacial e temporal de Nematoda num estuário subtropical. A distribuição espacial e temporal da associação de Nematoda foi analisada em três sub-ambientes do estuário Tramandaí-Armazém: na laguna Tramandaí, com aporte constante de água doce, laguna Armazém, com a entrada mais freqüente da cunha salina e o canal de ligação entre as lagunas e o Oceano Atlântico. Vinte e sete gêneros de Nematoda foram identificados. Na laguna Armazém os gêneros Terschellingia, Pseudochromadora, Anoplostoma, Theristus e Metalinhomoeus foram os mais representativos. No canal predominaram os gêneros Daptonema e Viscosia e na laguna Tramandaí Anonchus, Theristus e Oncholaimellus. A associação de Nematoda foi distinta entre os três ambientes coletados. Na laguna Armazém, a densidade, diversidade e riqueza de gêneros foram significativamente mais elevadas do que nos demais ambientes analisados. Uma estrutura mais simplificada de Nematoda no canal e na laguna Tramandaí provavelmente reflete uma maior instabilidade encontrada nestes ambientes. Esta distinção também foi visualizada em relação aos grupos tróficos, sendo que na laguna Armazém predominaram os nematódeos comedores de epistrato e de bactérias, enquanto que no canal e na laguna Tramandaí prevaleceram os comedores de depósito e predadores facultativos. Uma variação temporal foi detectada nos gêneros e grupos tróficos de Nematoda, sendo que as densidades mais elevadas ocorreram no verão. No estuário Tramandaí-Armazém, a interação entre a salinidade, hidrodinâmica, disponibilidade de alimento e temperatura condicionam a estrutura de Nematoda.
Palavras-chaves: nematoda, estuário, grupo trófico, distribuição espacial e temporal.

Introduction

Nematoda is the most representative meiofauna group in almost all aquatic environment, usually occurring in high densities and often exceeding other taxa (Coull, 1999). In addition to this, its great

taxonomic diversity and sensitivity to pollutants makes it an important tool in studies into environmental disturbance (Platt et al., 1984). Taxonomy of this group is particularly difficult, although using the picture keys developed by Platt & Warwick (1983, 1988) and Warwick et al. (1998), and the electronic picture key (Electronic Nematode Key v1.2), the identification of Nematoda genera is relatively simple (Austen, 2001).

In estuarine environments, salinity is an important factor determining the structure of Nematoda communities (Li & Vincx, 1993; Warwick & Gee, 1984; Soetaert et al., 1995). The invasion of Nematoda coming from the sea, with different degrees of tolerance to salinity variation can occur in high density, decreasing when approaching olighaline areas. The penetration of freshwater species occurs up to a maximum salinity of 10 (Heip et al., 1985). Some authors have attempted to group nematodes according to their tolerance to salinity. These groups differ, however, from place to place (Heip et al., 1985) due to the interaction of factors such as sediment type (Warwick & Gee,1984; Austen & Warwick, 1989) and availability of food (Moens et al., 1999).

Associated with the salinity, sedimentary characteristics also influence Nematoda community (Giere, 1993). Communities found on sandy bottoms are more resilient to natural physical disturbances, such as those created by currents and waves, than those found on muddy bottoms (Schratzberger & Warwick, 1998). When it comes to organic enrichment, muddy bottom communities tolerate its effects better than those found on sandy bottoms (Schratzberger & Warwick, 1999).

Epistrate feeder nematodes usually occur in greater numbers on sandy bottoms, while deposit feeders are more abundant on fine sediments (Wieser, 1953, 1959, apud Giere, 1993; Ansari & Parulekar, 1993).

In Brazil, studies on Nematoda identified at genera or species level, in estuarine environments, are scarce and very recent. There is the work carried out in the northeast of Brazil by Somerfield et al. (2003) in the Baía de Pina estuary (PE) and the studies conducted in the south of Brazil by Netto & Gallucci (2003) in the mangrove of the Ratones River estuary (SC), and Pinto & Bemvenuti (2004) in the Lagoa dos Patos estuarine region (RS).

The aims of this study are (1) to analyse the spatial and temporal distribution of the Nematoda community using its density, diversity, number of genera and feeding group and (2) to detect the abiotic factors measured which best correlate to of the Nematoda community structure.

Materials and methods

The Tramandaí-Armazém estuary is located on the north coast of Rio Grande do Sul (Fig. 1), between coordinates 29° 55' 49" S and 30° 00' 56" S and 50° 06' 21" W and 50° 11' 20" W (Tomazelli, 1990).

This estuary is linked to the Atlantic Ocean by way of a narrow and relatively short channel. The tidal effects, in this region are low, oscillating around 0.3m and meterological effects such as wind and precipitation are therefore dominant (Lira et al., 1976). In the Tramandaí lagoon, there is an input of water and fine sediments from the Tramandaí river (Tomazelli, 1990), while in the Armazém lagoon it is more common for saline water to enter.

In order to analyse the Nematoda, three areas in the Armazém lagoon (R, 1 and 2), three in the Tramandaí lagoon (4, 5 and 6) and one in the channel linking them to the Atlantic Ocean (3) were sampled in summer, autumn, winter and spring 2000 (Fig. 1). The sampling area "R" was located on a bank of Ruppia maritima spermatophyte.

Six sediment replicates were sampled in each area to a depth of 5cm with a corer which was 2.7cm in diameter. The material collected was fixed in the field with 10% formaldehyde, having previously been buffered with Borax and coloured with Bengal Rose. Three sediment samples were collected in order to analyse granulometry and organic content, with a corer with a diameter of 10cm, to a depth of 5cm.

The pH (WTW potentiometer, pH197 model), temperature ($^{\circ}$C thermometer), salinity (YSI-33) and dissolved oxygen (YSI-54 oxymeter) were measured in the bottom water. Depth of the water column (measuring tape) and water transparency (Secchi disk), were measured in the field.

In the laboratory, LUDOX TM, (1.15) (Somerfiel & Warwick, 1996) was used to extract the organisms from the sediment. The supernatant was passed through sieves with a 0.500 and 0.063mm mesh and only the organisms retained by the sieve with the smallest opening were considered. The biological material was analysed under a stereomicroscope and the Nematoda were separated and placed in an inclusion block with anhydrous glicerol, where they
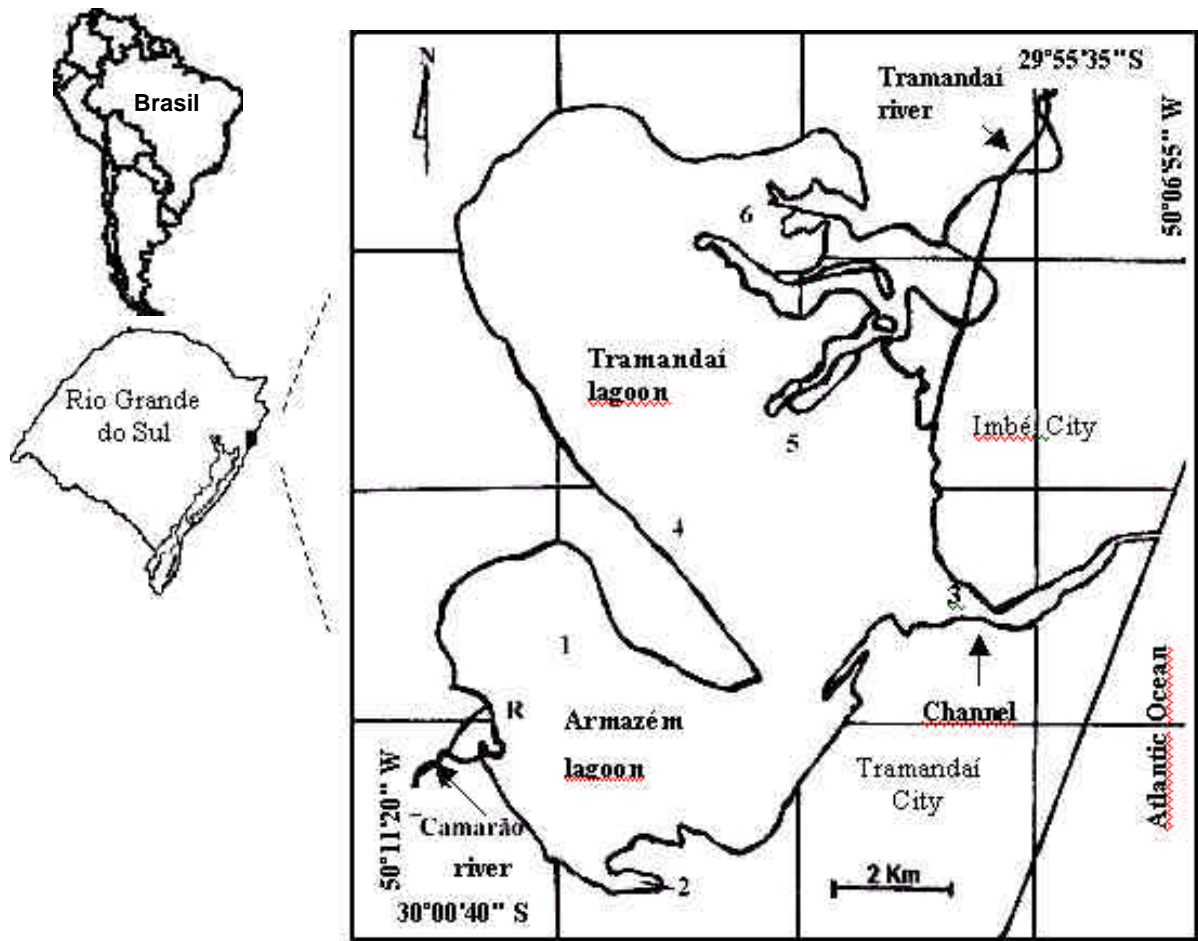
Figure 1: Map of the Tramandaí-Armazém estuary (S Brazil) showing the positions of the sampling areas (modified from Tabajara & Dillenburg, 1997).

remained for 18 to 24 hours. Parafin moulds were then made on slides and permanent slides were prepared. Nematoda genera were identified with the aid of the identification keys drawn up by Platt & Warwick (1983, 1988) and Warwick et al. (1998).

After identification, the Nematoda genera were classified according to their feeding group according to available literature (Moens & Vincx, 1997; Tita et al., 1999, 2002).

Granulometric analysis was done according to Suguio (1973), while the organic matter content was determined by drying the sediment at $60^{o}C$ for 24 hours and measuring the loss of weight on ignition at $550^{o}C$ (Walkey & Black, 1934).

Data analyses

To assess the structure of the Nematoda, data were analysed using univariate and multivariate techniques. Univariate indexes such as diversity Index (Shannon-Wiener´s H´), equitativity (Pielou´s J´) and richness (number of genera) were calculated through DIVERSE analysis applied to Nematoda genera density data with the PRIMER[a] routine, version 5.2.4. Two-way analysis of variance (ANOVA) was applied to the indexes and the nematode genera mean density aiming to compare different sampled environments and seasons using Statistica® 5.0. In order to test the assumption of homogeneity of variances, Cochran's tests were applied and data were square root transformed. Tukey's multiple comparison tests were used when significant differences were detected ($p < 0.05$).

A multidimensional scaling ordination analysis (MDS) was applied to Nematode genera density data (ind/$10cm^2$) transformed through square root and the Bray-Curtis similarity index was used. The formal significance test for differences between samples, environment and season, was performed using the 2-Way ANOSIM permutation test.

In order to detect the abiotic variables which best correlate to the structure of the Nematoda, BIO-ENV analysis was carried out.

The abiotic data matrix was created using euclidian distances and the biological similarity matrix as described for the ordination analysis MDS.

All the above mentioned multivariate analyses were done using PRIMER v5.2.4

Results

The measured abiotic variables in the sampled areas can be seen in Tables I and II (mean values).

The shallowest depths were registered in the Armazém lagoon in all sampling situation and there was total transparency in almost all seasons. Higher salinity, oxygen and pH levels than in the Tramandaí lagoon were also found here. The mean percentage of fine sediments was relatively low in all the environments, although there was a tendency toward variability of fine sediments percentage in the Tramandaí lagoon and in the Channel throughout the whole year. The level of organic matter was generally higher in the Armazém lagoon due to the presence of submerged vegetation.

Table I: Values of temperature, salinity, dissolved oxygen and pH recorded for the bottom water, transparency and depth, sand, fine sediment and organic matter (OM) percentuals in the Armazém and Tramandaí lagoons and the Channel for summer, autumn, winter and spring 2000.

Season/ lagoon	Areas	Temp. (°C)	Transp. (cm)	Water depth (cm)	Salinity	O$_2$ (mg.L^{-1})	pH	sand (%)	silt+clay (%)	OM (%)
Summer										
Armazém	R	29	30	30	3	8.2	8.54	95.6	4.4	0.39
	1	29	50	50	3	8.8	8.57	98.8	1.2	0.20
	2	30	15	40	4	7.5	7.7	86.1	14.0	0.47
Channel	3	28	20	110	0	6.19	7.45	95.0	4.8	0.32
Tramandaí	4	27	40	40	0	7.8	7.7	99.2	0.8	0.42
	5	25	15	70	0	7.02	6.87	89.6	10.4	0.31
	6	25	40	60	0	7.0	6.7	92.4	7.6	0.54
Autumn										
Armazém	R	20	30	30	7	4.85	8.48	94.5	5.6	0.34
	1	20	35	35	6.5	5.88	8.04	100.0	0.0	0.07
	2	21	5	40	7	7.35	8.37	100.0	0.0	2.88
Channel	3	20	105	105	11.5	5.51	7.2	99.8	0.0	0.35
Tramandaí	4	20	10	45	4	4.98	7.22	99.1	0.9	0.15
	5	19	110	110	10	4.62	6.34	62.0	38.0	0.85
	6	19	25	125	1	4.57	5.2	91.2	8.8	0.42
Winter										
Armazém	R	15	30	30	1	7.44	7.93	97.0	3.0	0.19
	1	16	35	35	1	7.7	7.7	98.4	1.6	0.19
	2	18	20	20	10	8.83	8.08	84.1	16.0	2.87
Channel	3	17	40	80	8	7.3	7.86	86.8	12.6	0.37
Tramandaí	4	20	15	37	3.5	8.57	8.28	98.3	1.7	0.31
	5	18	70	80	6	6.54	7.41	94.8	5.2	0.29
	6	18	0	75	0	6.43	7.42	96.7	3.3	1.37
Spring										
Armazém	R	23	40	40	0	12.16	7.6	92.1	7.9	0.60
	1	23	45	45	0	10.7	7.5	97.5	2.5	0.26
	2	24	30	30	0.5	3.72	7.62	84.2	15.8	5.90
Channel	3	24	35	90	0.5	7.56	7.4	86.5	12.8	0.37
Tramandaí	4	23	50	50	1	10.2	7.8	100.0	0.0	0.17
	5	23	25	90	0	10.07	7.16	91.0	9.0	0.41
	6	23	35	65	0	4.87	7.2	97.4	2.6	0.45

Table II: Mean values and standard deviation of temperature, salinity, dissolved oxygen and pH recorded for the bottom water, transparency and depth, sand, fine sediment and organic matter (OM) percentuals in the Armazém and Tramandaí lagoons and the Channel for summer, autumn, winter and spring 2000.

	Temp. (°C)	Transp. (cm)	Water depth (cm)	Salinity	O₂ (mg.L⁻¹)	pH	sand (%)	silt+clay (%)	OM (%)
summer									
Armazém	29.2 ±0.8	32.0 ± 17.6	40.0 ± 10.0	3.3 ± 0.6	8.2 ±0.7	8.3 ± 0.5	93.5 ± 6.6	6.5 ± 6.6	0.3 ± 0.1
Channel	27.5	20	110	0.0	6.2	7.5	95.0	4.8	0.3
Tramandaí	25.7 ± 1.0	32.0 ± 14.4	57.0 ± 15.3	0.0 ± 0.0	7.3 ± 0.5	7.1 ± 0.5	93.7 ± 4.9	6.3 ± 4.9	0.4 ± 0.1
autumn									
Armazém	20.4 ± 0.7	23.3 ± 16.1	35.0 ± 5.0	6.8 ± 0.3	6 ± 1.3	8.3 ± 0.2	98.1 ± 3.2	1.9 ± 3.2	1.1 ± 1.5
Channel	20.0	50.0	105.0	11.5	5.5	7.2	99.8	0.0	0.3
Tramandaí	19.1 ± 0.3	48.3 ± 53.9	93.3 ± 42.5	5 ± 4.6	4.7 ± 0.2	6.3 ± 1.0	84.1 ± 19.5	15.9 ± 19.5	0.5 ± 0.4
winter									
Armazém	16.2 ± 1.4	28.3 ± 7.6	28.3 ± 7.6	4.0 ± 5.2	8.0 ± 0.7	7.9 ± 0.2	93.1 ± 7.9	6.9 ± 7.9	1.1 ± 1.5
Channel	17.0	40.0	80.0	8.0	7.3	7.9	86.8	12.6	0.4
Tramandaí	18.6 ± 1.2	28.3 ± 36.9	64 ± 23.5	3.2 ± 3.0	7.2 ± 1.2	7.7 ± 0.5	96.6 ± 1.8	3.4 ± 1.8	0.7 ± 0.6
spring									
Armazém	23.4 ± 0.3	38.3 ± 7.6	38.3 ± 7.6	0.2 ± 0.3	8.9 ± 4.5	7.6 ± 0.1	91.3 ± 6.7	8.7 ± 6.7	2.3 ± 3.2
Channel	24.3	35.0	90.0	0.5	7.6	7.4	86.5	12.8	0.4
Tramandaí	22.6 ± 0.1	36.7 ± 12.6	68.3 ± 20.2	0.3 ± 0.6	8.4 ± 3.0	7.4 ± 0.4	96.1 ± 4.6	3.9 ± 4.6	0.3 ± 0.1

From the analysis of the biological matrix and that with the abiotic data using BIO-ENV analysis, it could be seen that the transparency and depth variables had the highest Spearman correlation coefficient (0.553), with the biological data matrix.

Nematodes

A total of 27 genera of Nematoda were recorded in the Tramandaí-Armazém estuary. Terschellingia, Pseudochromadora, Anoplostoma, Theristus and Metalinhomoeus were the dominant genera, representing 55.9% of the organisms, and were found in high densities, in the Armazém lagoon (Tab.III). Daptonema and Viscosia were dominant (52.8%) in the channel, with relatively low density. Anonchus, Theristus and Oncholaimellus genera represented 53.3% of the organisms in the Tramandaí lagoon.

The results of the analysis of variance (Tab. IV) showed that the density, diversity and richness of nematodes genera were significantly higher in the Armazém lagoon (Fig. 2). Equitativity (J′) did not differ among the environments. The test showed that both the number of genera and densitiy of nematodes were significantly higher in summer.

The MDS ordination of nematodes data (Fig. 3) showed a clustering of samples from different environments studied. The spatial difference in the sampled environments can also be seen when the seasons are analysed separately. The Nematoda community found in the Channel and the Tramandaí lagoon was similar in summer and spring (Tab. V).

When classifying the nematodes, in the Tramandaí-Armazém estuary, into feeding groups (Tab. III), it can be seen that all feeding groups were recorded except the predators. The classification showed that in Armazém lagoon there was a dominance of epigrowth feeders and microvores, while the deposit feeders and facultative predators prevailed in the Channel and Tramandaí lagoon (Fig. 4).

The densitiy of microvores, ciliate feeders, epigrowth feeders and facultative predators was significantly higher in the Armazém lagoon than in the Channel and Tramandaí lagoon (Tab. VI). The density of deposit feeders was similar in the Armazém lagoon and the Channel. Excepting microvores, the density of feeding groups was significantly higher in the summer.

A seasonal alteration in the dominant feeding group was verified in all environments. In the Armazém lagoon in the summer, the feeding group with the highest density was the epistrate feeder, while in the other seasons the microvores

Table III: Mean density of organisms (ind/10cm²), standard deviation and relative abundance (%) of the Nematoda genera collected from the Armazém lagoon (A), Channel (C) and Tramandaí lagoon (T). Classification of the genera by feeding group: bacteria feeders (MC), ciliate feeders (CF), deposit feeders (DF), epistrate feeders (EF) and facultative predators (FP).

| Armazém	density	%	Channel	density	%	Tramandaí	density	%
Terschellingia (MC)	141±45	19	Daptonema (DF)	58±111	40	Anonchus (FP)	34±20	22
Pseudochromadora (EF)	117±156	16	Viscosia (FP)	18±22	13	Theristus (DF)	27±32	18
Anoplostoma (CF)	54±31	7.3	Anoplostoma (CF)	15±25	11	Oncholaimellus (FP)	21±5	14
Theristus (DF)	53±33	7.2	Sabatieria (DF)	14±8	9.7	Pseudochromadora EF)	15±12	9.9
Metalinhomoeus (MC)	46±29	6.2	Theristus (DF)	14±18	9.6	Daptonema (DF)	15±24	9.5
Parodontophora (FP)	45±34	6.1	Cobbia (DF)	7±13	5.1	Cobbia (DF)	15±20	9.4
Dichromadora (EF)	44±43	6	Oncholaimellus FP)	7±12	4.9	Oxystomina (MC)	6±2	3.6
Chromadorina (EF)	39±107	5.3	Anonchus (FP)	6±6	4.1	Anoplostoma (CF)	5±10	3.5
Anonchus (FP)	36±31	4.9	Dichromadora (EF)	2±3	1.5	Parodontophora (FP)	4±6	2.5
Leptolaimus (MC)	28±25	3.8	Other	3±0.7	1.7	Terschellingia (MC)	3±2	2.0
Viscosia (FP)	27±13	3.6				Viscosia(FP)	2±3	1.5
Sabatieria (DF)	22±16	3				terrestrial invasor	2±4	1.4
Oncholaimellus (FP)	19±12	2.6				Sabatieria (DF)	2±2	1.2
Oxystomina (MC)	16±3	2.1				Other	3±0.7	2.2
Daptonema (DF)	16±16	2.1						
Ascolaimus DF)	14±15	1.8						
Cobbia (DF)	9±8	1.2						
Other	7±1	1.5						
Mean density	733±51		Mean density	144±25		Mean density	154±13	
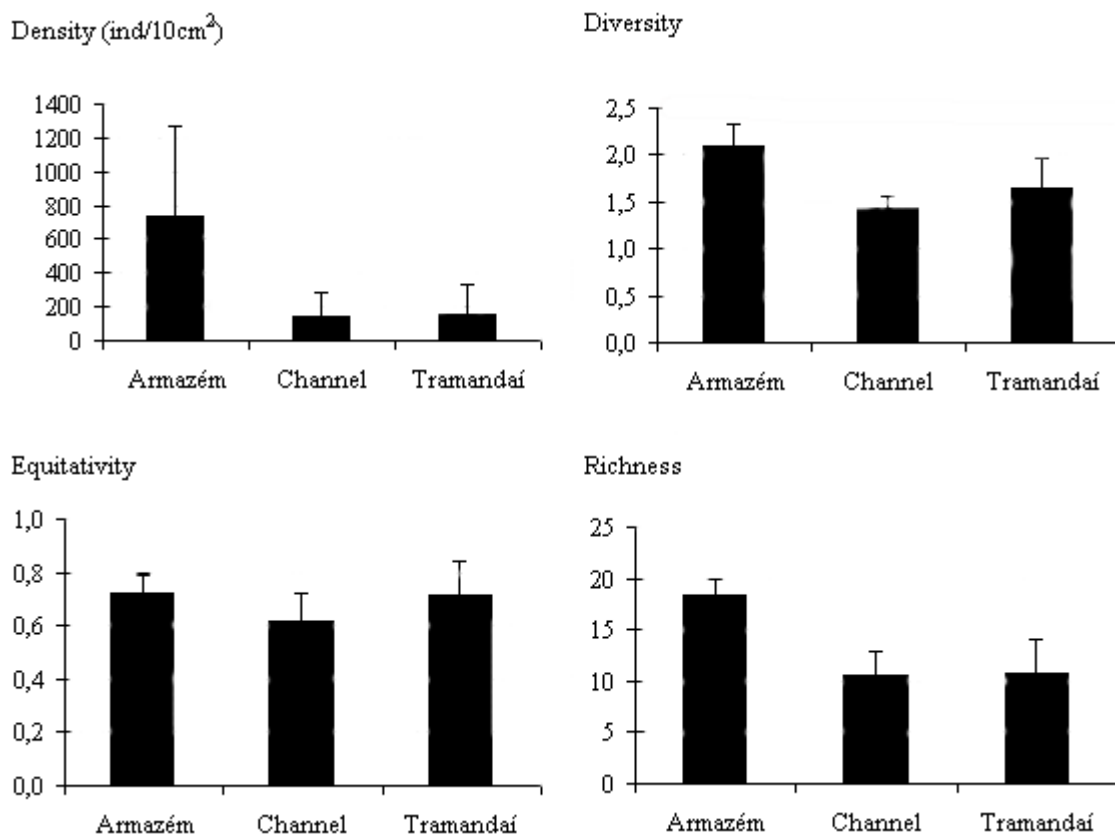
Figure 2: Mean and standard deviation of density (ind/10cm²), diversity (Shannon-Wiener), equitativity (Pielou) and richness (number of genera), by environment, in the Tramandaí-Armazém estuary.

Table IV: Results of the two-way ANOVA considering density, diversity, equitativity and richness of Nematoda genera, among environment (Armazém lagoon -A, Channel -C and Tramandaí lagoon -T), and among seasons (S - summer, A - autumn, W – winter, P – spring). NS: non significant difference. Significant difference recorded by the Tukey analysis.

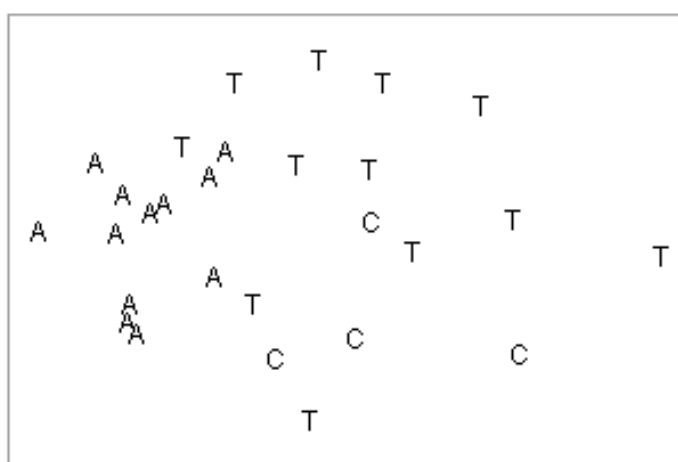|	among environment	among season
Density	A>T, C	S>A,W,S
(ind/10cm²)	(p=0.0000)	(p=0.0000)
Richness	A>T, C	S>A,W,S
(number of genera)	(p=0.0000)	(p=0.0047)
Equitativity	T>A,C	NS
(Pielou)	(p=0.0100)	(p=0.0590)
Diversity	A>T, C	NS
(Shannon)	(p=0.0000)	(p=0.1945)

Figure 3: Multi-dimensional scaling (MDS) ordination for square root nematode densities from the Armazém lagoon (A), Channel (C) and Tramandaí lagoon (T).

Table V: ANOSIM results, between the Tramandaí and Armazém lagoon and the Channel, considering the density of the Nematoda genera collected in the summer, autumn, winter and spring.

	Armazém – Channel		Armazém - Tramandaí		Channel - Tramandaí	
	R	p	R	p	R	p
Summer	0.860	0.001	0.404	0.001	0.108	0.198
Autumn	0.988	0.001	0.316	0.001	0.242	0.009
Winter	0.759	0.001	0.374	0.001	0.478	0.003
Spring	0.879	0.003	0.570	0.001	0.323	0.085

Table VI: Results of the two-way ANOVA analysis considering density of Nematoda feeding groups, among environments (Armazém lagoon -A, Channel -C and Tramandaí lagoon -T), and among season (S - summer, A - autumn, W – winter, P – spring). NS: non significant difference. Significant difference recorded by the Tukey analysis.

	among environment	among season
Microvores	A>T, C (p<0.001)	NS (p=0,520)
Ciliate feeders	A>T, C (p<0.001)	S>A,S (p<0.001)
Epistrate feeders	A>T, C (p<0.001)	S>A,W,S (p<0.001)
Deposit feeders	A,C>T (p<0.001)	S>A,W,S (p<0.001)
Facultative predators	A>T> C (p<0.001)	S>A,W (p<0.001)

prevailed (Fig. 4). In the Channel, it can be seen that the feeding groups alternated between the seasons as greater abundances of deposit feeders occurred in the summer and autumn, whereas in the winter the dominant was the ciliate feeders and in the spring the facultative predators.

In the Tramandaí lagoon, with the exception of the summer when the most representative feeding group was the deposit feeders, there was a higher density of facultative predators than any other feeding group in the other seasons.
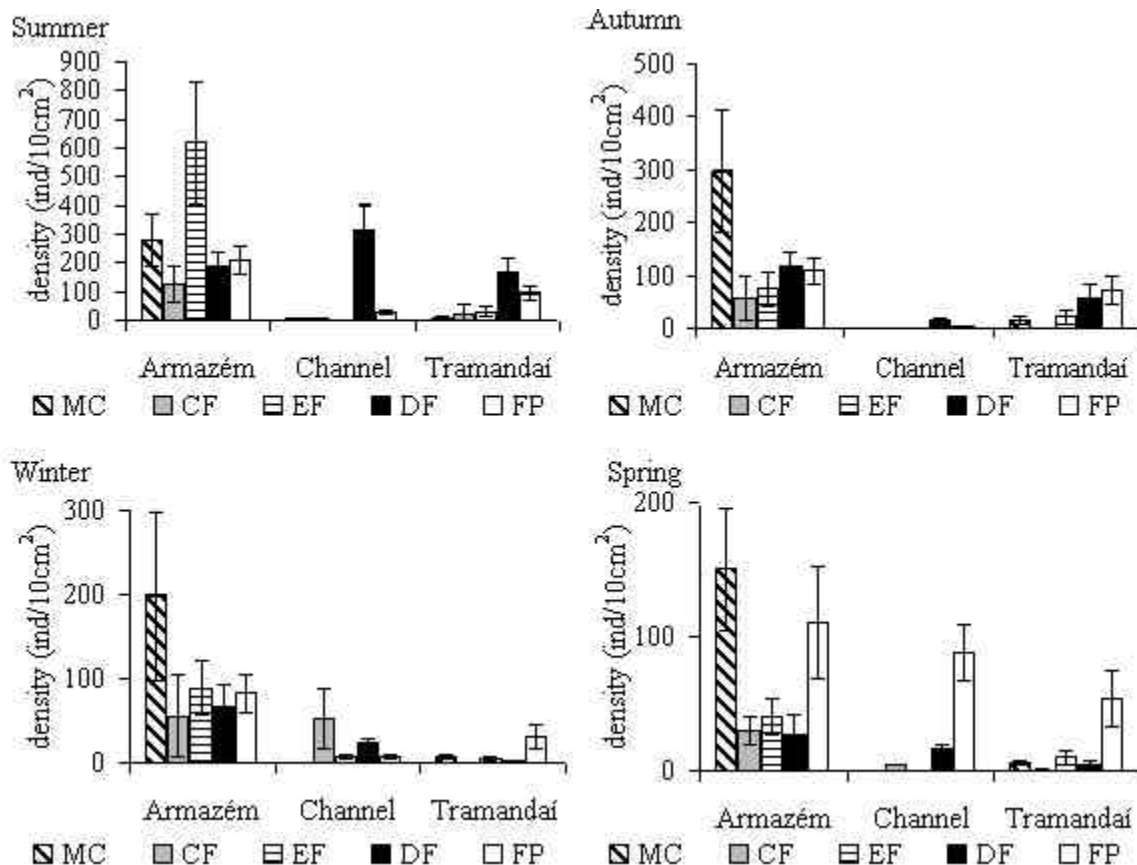

Figure 4: Mean and standard deviation of density organisms (ind/10cm²) of the feeding groups of Nematoda, by sampled environment in the Tramandaí-Armazém estuary in the summer, autum, winter and spring 2000. Microvores (MC), ciliate feeders (CF), deposit feeders (DF), epistrate feeders (EF) and facultative predators (FP).

Discussion

The association of Nematoda in the Tramandaí-Armazém estuary, which is composed of twenty-seven genera, has a similar number to those ones in other estuaries (Li & Vincx, 1993; Moens et al., 1999; Somerfield et al., 2003; Pinto & Bemvenuti, 2004), but inferior than what was found in an estuary (68 genus), in South Brazil by Fonseca (2003).

Salinity is one of the factors of greatest relevance in estuaries, being associated with the sediment and hydrodynamics and, of recognised importance determining the Nematoda community structure (Li & Vincx, 1993; Warwick & Gee, 1984; Soetaert et al., 1995). According to Austen & Warwick (1989),

the multivariate aspects of the nematodes communities are mainly correlated with salinity, while the univariate ones are more influenced by sediment disturbance and food availability, or a combination of these factors.

Variations in salinity require physiological adaptations by the organisms, with consequences for the composition and density of the species (Moens & Vincx, 2000a; 2000b), and a decrease in diversity has previously been linked to an increase in environmental fluctuations (Ott, 1972 apud Heip et al., 1985).

Multivariate analysis, in this study, showed that nematode community structure differs among environments. The density, diversity and number of genera were

significantly higher in the Armazém lagoon and a simplified structure of Nematoda was found in the Channel and in the Tramandaí lagoon.

The input of fresh water and the unpredictable entry of salt water into the Tramandaí lagoon lead to wide variations in salinity throughout the day, regardless of the time of year (Chomenko & Schäfer, 1984). In the Channel, extremely unstable conditions and wide fluctuations in the environmental conditions were recorded (Chomenko & Schäfer, 1984). In this environment there was a dominance of deposit feeders and facultative predators. Similarly, Austen & Warwick (1989) found in the upper area of the Tamar estuary (south coast of England) an increase in the number of deposit feeders and facultative predators and an accompanying decrease in the number of epistrate feeders.

Besides the salinity variations, in the Tramandaí lagoon and the Channel occurs great physical instability. The lower densities, richness and genera diversity found in these environments probably reflect this instability.

In the Tramandaí lagoon, the bidirectional currents continually resuspend the substrate (Machado, personal communication). However, a greater floculation of fine sediments transported by the Tramandaí Rivermand is seen in the lagoon when saline water enters (Tabajara & Dillenburg, 1997). In the present study, the high variability found in fine sediments percentage among seasons are an evidence of the extreme instability of this area. The genera Anonchus and Oncholaimellus, facultative predators which occur in great abundance in this lagoon, may be benefiting from the silt and clay variability. Some species of Theristus, a deposit feeder also abundant there, are considered as good indicators of stressful conditions (Gyedu-Ababio et al., 1999).

In the Channel also occur bidirectional currents with a constant ressuspension of the substrate (Tabajara & Dillenburg, 1997). In this area a lower number of nematode genera was found, with Daptonema, a deposit feeder, and Viscosia, a facultative predator, dominating.

A more complex Nematoda community was found in the Armazém lagoon, where occurs a tendency toward the input of salt water (Würdig, 1987, 1988; Schwarzbold & Schäfer, 1984), probably because the residence time of this water in the lagoon is larger than in Tramandaí lagoon and in the channel. Besides, in the Armazém lagoon the presence of the macrophyte Ruppia maritime was observed. Studies on beds of submerged macrophytes have shown that there is a decrease in current speed in these areas, causing fine particles to be deposited (Madsen et al., 2001), thus reducing turbidity and increasing water transparency. Another important function of the seagrass beds, according to aforementioned authors, is the decrease in the meiofauna potential to be suspended (see review by Madsen et al., 2001). Terschellingia, one of the most representative genera in this lagoon, although found in finer sediments with no vegetation (Warwick & Gee, 1984; Hodda & Nicholas, 1986; Vincx et al., 1990; Soetaert et al. 1995), also occurs in high densities in seagrass bottoms (Ndaro & Ólafsson, 1999; Fisher, 2003), as in the case of this study. It is probable that a greater availability of detritus, which is this genera's main food item, favours bacterial activity (Moens & Vincx, 1997). Metalinhomoeus, also representative in this lagoon, presents similar environmental requirements to the Terschellingia ones. The genera Pseudochromadora (epistrate feeders), Anoplostoma (ciliate feeders) and Parodontophora (facultative predator) may be benefiting from the availability and diversity of food resources.

The dominant feeding groups in the Armazém lagoon were the microvores and epistrate feeders. In general, epistrate feeders have been recorded as the most abundant group in estuaries (Bowman et al., 1984; Ndaro & Ólafsson, 1999), confirming their tendency to occur in greater numbers in sandy-textured sediment, with deposit feeders more abundant in finer sediments (Wieser, 1953, 1959, apud Giere, 1993; Ansari & Parulekar, 1993).

The environmental conditions found in the Armazém lagoon – with lower hydrodynamics, a predominance of fine sand, a higher level of organic matter, higher mean levels of oxygen and pH, and total transparency, associated with shallow water, probably favour the establishment of a greater diversity of nematodes than was found in the Tramandaí lagoon and the Channel. From the BIO-ENV analysis, it could be seen that the depth and transparency variables had the highest

correlation with the similarity matrix constructed with the biological data. These two variables probably reflect the indirect effect of the environmental conditions already commented.

The densities of organisms were significantly higher in summer in all the assessed areas. According to Heip et al. (1985), temperature and food supply are the most important factors in explaining temporal changes in density. The temporal variation in the dominant feeding groups found in this study is probably linked to food availability, as the feeding types composition of a Nematoda reflects the quantity and quality of the food source (Moens & Vincx, 1997; Danovaro & Gambi, 2002).

A greater abundance of epistrate feeder Nematoda has previously been cited for spring and summer, coinciding with an increase in benthic microalgae (Heip et al., 1985). A similar result was found in the Tramandaí-Armazém estuary, although the nematodes with this feeding habit were significantly higher in the summer, reflecting mainly this feeding group's high density in the Armazém lagoon. The development of this food source there was probably favoured by the shallow water, total transparency and the presence of the R. maritima seagrass. A greater abundance of epistrate feeders in areas vegetated by seagrasses has been documented in other studies (Ndaro & Ólafsson, 1999; Danovaro & Gambi, 2002).

Along with microalgae, bacteria are cited as the most important food sources for meiofauna (Heip et al., 1985 ; Moens & Vincx, 1997). Bacteria feeders were dominant in the Armazém lagoon in all seasons except summer. No significant variations were found in this feeding group in the different seasons, however, suggesting that there is a constant supply of this food resource. The availablity of organic substrate for decomposition, which contributes significantly to the increase in bacteria, comes from a saltmarsh located on the southeast shore and the decline of the R. maritima bed at the end of the summer.

An alternating of dominant feeding groups between seasons was seen in the Channel, with deposit feeders dominant in the summer and autumn, ciliate feeders in the winter and facultative predators in the spring. These temporal variations in the feeding structure of the Nematoda are largely controlled by the availability of food sources and the temporal change in food composition (Danovaro & Gambi, 2002) and they demonstrate the instability to which this area is submitted.

From analysis of the genera and feeding groups, it could be seen that the Nematoda community in the Armazém lagoon is more complex. In the Tramandaí lagoon and the Channel, the occurrence of a more simplified community reflects the largest instability found in these environment. The predominance of different feeding groups demonstrates that the food availability is also differentiated among the environments, and together with the salinity, hydrodynamic and temperature influences the marked spatial differences in the Nematoda communities observed in the estuary.

Acknowledgements

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