

# MORPHOMETRIC AND ENERGETIC DIFFERENCES BETWEEN NEMATODE FEEDING GROUPS OF MOENS, VINCX (1997) AND THEIR SUITABILITY FOR ENVIRONMENTAL BIOMONITORING

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## Abstract

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During September 2002, free-living nematodes were sampled from ten sites at Bizerte lagoon coasts associated with one reference marine site in order to study distribution, morphometry and energetics of the feeding groups. The availability of sedimentary chlorophyll *a* appears to be the main factor negatively affecting the abundance of epigrowth-feeders, deposit feeders and ciliate feeders which decrease when sediments are polluted by organic matter and metals. Nematode feeding groups have notably responded differently to the sediment quality across the energetic level according to their body size and feeding behaviour, and research results herein show that the mean individual respiration of deposit feeders is clearly higher than that of microvores and epigrowth feeders.

*Key words:* Bizerte lagoon, nematodes, feeding groups, pollution

## Introduction

It is commonly accepted that meiobenthic nematodes are efficient bioindicators of environmental conditions and are increasingly used as stress sentinels (Schratzberger, Warwick, 1998). However, despite a lot of data about these organisms, we are still far from understanding the mechanisms determining their morphometry and energetics and whether these topics are related to food. Few investigations have centred on these phenomena (Schwingamer,

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1981; Jensen, 1987; De Bovée, Labat, 1993; Ratsimbazafy et al., 1994; Soetaert et al., 1997; Heip et al., 2001).

In this paper, we attempted to detect morphometric and energetic differences between the nematode feeding groups described by Moens, Vincx (1997). Since then, this classification, contrary to that of Wieser (1953), was rarely used by nematologists as an effective method of detecting environmental stress. In this study, we tested the hypothesis that size and metabolism are food-related, and finally we give an ecological interpretation of nematode feeding structure according to the quality of the water and sediments collected from the Bizerte lagoon during September 2002. It is a fact that this region situated in the extreme north of Tunisia (9°48'–9°56' N – 37°08'–37°14' E), has shown a serious regression in its fisheries since 1950 because of its use for domestic and industrial wastewater discharge.

## Material and methods

### *Sampling and analysis of waters and sediments*

Sampling was carried out during the morning periods of 10 and 11 September 2002 in ten lagoonal sites (C, BC, F, T, MB, OBH, OGA, OG, MJ and MA) and one reference marine site R (Fig. 1). Salinity (Sal), water temperature (T) and dissolved oxygen (DO) were measured by using a multi-parameter WTW 340i. Additionally, we used the WTW pH 330/SET-1 pH meter and Murdmaa et al.'s (2000) methodology to determine the water pH and the suspended matter (SM) per litre of water. Sediments were dredged using a Van Veen grab sampler (0.1 m<sup>2</sup>) and then frozen until analysis of chlorophyll *a* (Danovaro et al., 2002) and total hydrocarbons by infrared spectrophotometry (Danovaro et al., 1995). Other sediment sub-samples were dried at 45 °C to a constant weight and wet-sieved on a 63 µm sieve to separate the silt/clay and coarse fractions (Buchanan, 1971). The cumulated curves of the coarse fraction were used to determine the mean grain size (Buchanan, 1971). Analysis of the sedimentary total organic matter and the Zn, Cu, Fe, Mn, Ni and Pb metals was achieved by measuring weight loss after ignition at 450 °C for 6 hours (Fabiano, Danovaro, 1994), and by atomic absorption spectrophotometry (Gil et al., 1999).

### *Nematode feeding groups*

The sediment samples were taken with three 10 cm<sup>2</sup> surface area plexiglass hand-cores from the surface to a 20 cm depth in each sampling site. After preservation in 4% neutralized formaldehyde, nematodes were stained with Rose-Bengal (0.2 g.l<sup>-1</sup>) and extracted by sieving sediments through 1 mm and 40 µm. The nematodes retained by 40 µm sieving were first counted and then at least one hundred nematodes per community were chosen and mounted on glycerine slides for observation under a Leitz Weltzlar HM lux 3 microscope. The list of genera was established on the basis of the pictorial keys of Platt, Warwick (1983, 1988) and Warwick et al. (1998). In this work, six feeding groups described by Moens, Vincx (1997) (M – microvores; DF – deposit-feeders; CF – ciliate-feeders; EF – epigrowth-feeders; FP – facultative predators; P – predators) were identified in order to calculate the Trophic Diversity Index  $TDI = \sum \theta^2$ , where  $\theta$  represents the percentage per community in each feeding group (Heip et al., 1985).

### *Morphometric and energetic variables of nematodes*

The equation  $V = 530 L.W^2$  proposed by Warwick, Price (1979) was used where V, L and W express the volume (in nl), the total length (in mm) and the maximum width (in mm) of nematodes measured by a microscope with

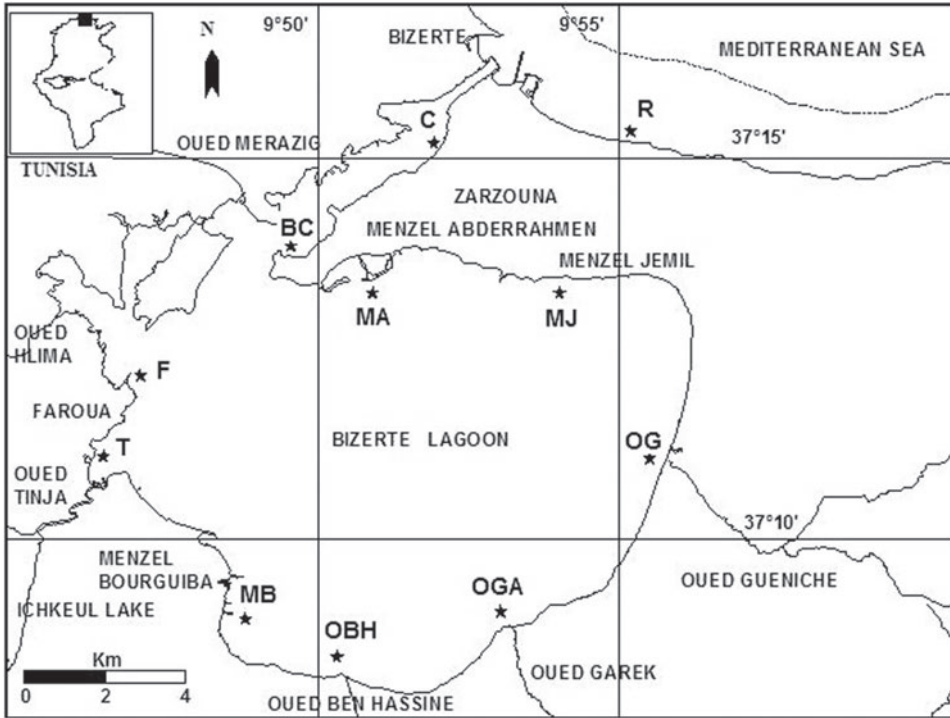


Fig. 1. Location of sampling sites in Bizerte lagoon at which free-living nematodes, waters and sediments were investigated during September 2002. Rimel (R), Canal (C), Baie des carrières (BC), Faroua (F), Oued Tinja (T), Menzel Bourguiba (MB), Oued Ben Hassine (OBH), Oued Garek (OGA), Oued Gueniche (OG), Menzel Jemil (MJ), Menzel Abderrahmen (MA).

a drawing tube. The wet weight (in  $\mu\text{g}$ ) was obtained by multiplying the volume by the specific gravity of nematodes equal to  $1.13 \mu\text{g. nl}^{-1}$  (Wieser, 1960) and then converted to carbon weight by using the carbon/wet weight ratio of 0.125 (Vanaverbeke et al., 1997). The respiration (R) at  $20^\circ\text{C}$  expressed in  $\mu\text{gC. ind}^{-1}. \text{d}^{-1}$  was calculated by using the equation  $R = 0.0449 W^{-0.8544} \exp^{[\ln(Q_{10})/10](T-20)}$  (De Bovée, Labat, 1993; Soetaert et al., 1997; Heip et al., 2001) where W is the carbon weight in  $\mu\text{gC}$ ,  $Q_{10}$  the respiration variation for a  $10^\circ\text{C}$  increase and T the temperature in  $^\circ\text{C}$ . The conversion to the *in situ* temperatures was obtained by considering  $Q_{10} = 2$  (Soetaert et al., 1997; Heip et al., 2001). As Crisp (1971) stated, we consider that 0.4 gC metabolized is equivalent to 1 litre consumed  $\text{O}_2$ . The metabolic ratio (MR) was obtained by dividing individual respiration by individual carbon weight. Finally, the individual production (P) in  $\text{kJ. ind}^{-1}. \text{d}^{-1}$  was calculated by the log-transformed equation  $\log R = 0.367 + 0.993 \log P$  as proposed by Schwinghamer et al. (1986). 1 gC was considered equivalent to 45.7 kJ (Salonen et al., 1976).

### Statistical analysis

One-way ANOVA, made by SPSS 10.0 software for windows based on data previously log (x+1) transformed, was used to test the mean differences. The Tukey-HSD test was used in pairwise comparisons when significant differences were detected ( $P < 0.05$ ). The significance of differences between slopes is equally accomplished by

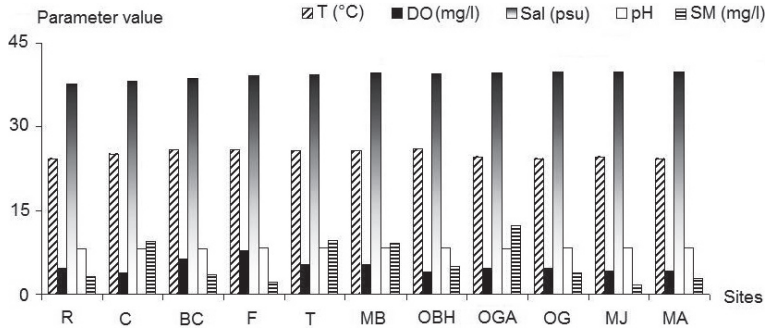


Fig. 2. Parameters measured at the sampled waters (Bizerte lagoon, September 2002). Temperature (T), dissolved oxygen (DO), salinity (Sal), suspended matter (SM). Rimel (R), Canal (C), Baie des carrières (BC), Faroua (F), Oued Tinja (T), Menzel Bourguiba (MB), Oued Ben Hassine (OBH), Oued Garek (OGA), Oued Gueniche (OG), Menzel Jemil (MJ), Menzel Abderrahmen (MA).

analysis of variance, so when significant differences were detected, a multiple comparison test was used to examine the significance of differences in slopes between each combination of pairs of regression lines. This was achieved by using the option “Compare regression” in StatistiXL 1.6 software. Relationships between the data of feeding groups and environmental variables along sampling sites were investigated by the Pearson coefficient ( $r$ ) using Statistica 5.0 software.

## Results

### *Environmental parameters (Fig. 2, Table 1)*

No clear spatial variability was noted for most hydrological parameters. Additionally, relatively low concentrations of dissolved oxygen (3.9–7.8 mg/l) associated with high value temperatures (24.3–26 °C) and salinity (37.6–40.1 psu) characterized the collected waters. The pH of water samples varied only marginally, ranging from 8.2 to 8.38. Important loads of suspended matter were recorded only in four sampling sites; OGA, T, C and MB.

The highest percentages of silt/clay fraction of up to 80% were noted at the South-Western sites of F, T and MB. The remaining lagoonal sediments were principally composed of fine and coarse sands. Muddy sediments (F, T and MB) were characterized by the overloads of organic and hydrocarbon contents, however, minimum concentrations of these variables were noted at reference site R with 0.85% and 0.006 mg/g respectively. The general distribution of the measured metals was “iron-like” and maxima were constantly observed in sediments collected at the MB site which is situated in front of the “El Fouledh” metallurgic factory. The maximum loads of chlorophyll *a* were observed in sediments sampled at the sites of OG (8.01 µg/g) and R (7.48 µg/g), and the minimum concentration was recorded at site MB (1.78 µg/g).

Table 1. Parameters measured in the collected sediments from Bizerte lagoon (September 2002). Silt/clay (S/C), mean grain size ( $Q_{50}$ ), total organic matter (TOM), total hydrocarbons (Hs), chlorophyll *a* (Chl *a*), nickel (Ni), zinc (Zn), copper (Cu), iron (Fe), lead (Pb), manganese (Mn). Maximum and minimum were respectively indicated with bold and underlined values.

Sites Parameters	R	C	BC	F	T	MB	OBH	OGA	OG	MJ	MA
Depth (m)	3.00	3.20	<b>3.90</b>	3.10	2.00	3.10	2.60	3.20	3.20	3.10	2.60
S/C (%)	0.10	15.71	39.95	<b>86.95</b>	80.14	85.29	56.10	38.24	19.24	30.09	23.97
$Q_{50}$ (mm)	0.95	0.20	0.20	0.90	<b>1.22</b>	0.20	0.14	0.09	0.16	0.75	0.20
TOM (%)	0.85	3.05	8.75	<b>22.14</b>	17.07	19.38	6.33	10.13	2.44	8.23	4.05
Hs ( $mg \cdot g^{-1}$ )	0.006	0.118	0.122	0.142	0.133	<b>0.580</b>	0.125	0.060	0.064	0.078	0.090
Chl <i>a</i> ( $\mu g \cdot g^{-1}$ )	7.483	2.701	2.988	2.644	2.816	1.783	7.355	5.667	<b>8.013</b>	5.043	5.267
Zn (ppm)	5.00	33.02	21.04	192.64	185.08	<b>520.52</b>	103.18	30.20	33.55	53.38	49.64
Cu (ppm)	1.67	6.21	3.63	<b>25.24</b>	22.65	24.67	11.07	2.64	2.81	8.29	11.98
Fe (ppm)	954.42	2633.10	2710.18	24900	27600	<b>40800</b>	12900	5395.94	4156.94	6473.18	6288.70
Mn (ppm)	26.53	43.04	41.50	156.61	216.21	<b>766.40</b>	165.05	131.53	125.92	101.36	114.36
Ni (ppm)	5.46	9.99	11.34	33.80	<b>37.63</b>	28.92	19.73	9.92	10.28	17.81	15.49
Pb (ppm)	10.00	26.99	19.90	80.69	79.21	<b>106.73</b>	26.19	14.13	17.88	32.92	25.85

Notes: R – Rimel; C – Canal; BC – Baie des carriers; F – Faroua; T – Oued Tinja; MB – Menzel Bourguiba; OBH – Oued Ben Hassine; OGA – Oued Garek; OG – Oued Gueniche; MJ – Menzel Jemil; MA – Menzel Abderrahmen.

### Distribution of nematode feeding groups

In terms of relative abundance, epigrowth feeders were the most dominant feeding group in all researched assemblages with maximal dominances in communities F, T, OG, MB and MA (Fig. 3, Table 2). The exceptions were nematodes inhabiting sites MJ and C where

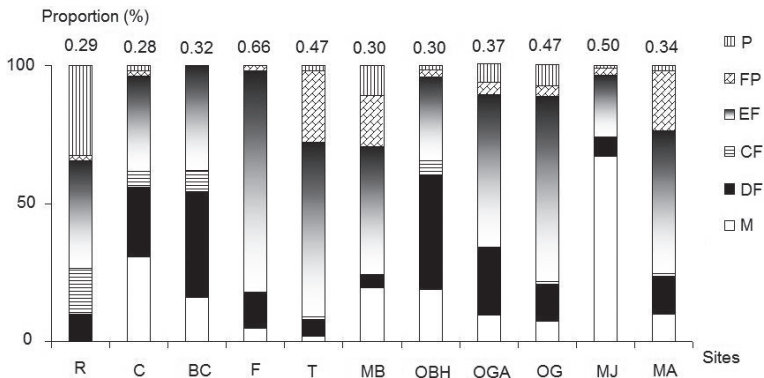


Fig. 3. Proportions of the six feeding groups (Moens, Vincx, 1997) and values of the Trophic Diversity Index (TDI) of the nematode assemblages from Bizerte lagoon (September 2002). Microvores (M); deposit-feeders (DF); ciliate-feeders (CF); epigrowth-feeders (EF); facultative predators (FP); predators (P).

Table 2. List and dominances of nematode genera encountered in sediments from the coastal zone of Bizerte lagoon during September 2002. Feeding groups (FG) according to Moens, Vincx (1997). Bold values indicate the most abundant genera.

Sites Genera	FG	R	C	BC	F	T	MB	OBH	OGA	OG	MJ	MA
<i>Acanthanchus</i>	EF	-	-	-	-	-	-	-	3.53	-	-	-
<i>Anoplostoma</i>	CF	2.97	-	-	-	-	-	-	-	-	-	-
<i>Anticoma</i>	M	-	-	1.45	-	1.00	19.60	-	-	1.88	-	0.99
<i>Axonolaimus</i>	CF	0.99	-	4.37	-	-	-	1.72	-	-	-	-
<i>Calomicrolaimus</i>	EF	<b>16.84</b>	-	3.64	0.99	1.00	-	-	-	-	-	-
<i>Chaetonema</i>	CF	9.90	-	-	-	-	-	-	-	-	-	-
<i>Chromaspirina</i>	EF	3.96	-	-	-	-	-	-	-	0.94	-	0.99
<i>Comesoma</i>	DF	-	-	1.45	0.99	-	-	<b>23.27</b>	-	-	-	-
<i>Cyatholaimus</i>	EF	-	-	-	-	-	-	3.44	5.30	-	-	0.99
<i>Daptonema</i>	DF	0.99	9.60	2.89	-	1.00	1.96	3.44	-	3.77	5.34	-
<i>Desmodora</i>	EF	-	-	-	-	4.00	-	-	-	3.77	-	-
<i>Desmolaimus</i>	DF	-	-	-	0.99	-	-	0.86	1.76	-	-	0.99
<i>Diodontolaimus</i>	DF	0.99	-	-	-	-	-	-	-	1.88	-	1.98
<i>Dorylaimopsis</i>	EF	-	6.73	-	2.97	1.00	0.98	-	6.19	3.77	5.35	3.96
<i>Eleutherolaimus</i>	DF	-	-	0.72	-	-	-	0.86	-	-	-	-
<i>Enoploides</i>	P	1.98	-	-	-	-	-	-	-	-	-	-
<i>Enoplolaimus</i>	P	7.92	-	-	-	-	-	-	-	-	-	-
<i>Ethmolaimus</i>	EF	1.98	-	-	-	-	-	-	-	-	-	-
<i>Filoncholaimus</i>	FP	-	-	-	-	-	-	-	0.88	-	-	-
<i>Halichoanolaimus</i>	P	-	-	-	-	2.00	9.80	0.86	7.07	4.71	0.89	1.98
<i>Latronema</i>	EF	0.99	-	-	-	-	-	-	-	-	-	-
<i>Leptolaimus</i>	M	-	-	-	-	-	-	0.86	-	-	-	-
<i>Linhomoeus</i>	M	-	-	-	-	-	-	-	4.42	2.83	-	-
<i>Longicyatholaimus</i>	EF	-	1.92	-	-	-	-	-	6.19	4.71	-	-
<i>Marylynnia</i>	EF	-	0.96	3.64	-	2.00	-	-	<b>18.77</b>	3.77	-	0.99
<i>Megadesmolaimus</i>	DF	-	-	-	-	-	-	-	-	2.83	-	-
<i>Mesacanthion</i>	P	18.81	1.92	-	-	-	-	0.86	-	0.94	-	-
<i>Metachromadora</i>	EF	-	-	-	0.99	5.00	2.94	0.86	-	-	-	0.99
<i>Metacomesoma</i>	DF	-	-	-	-	-	1.96	-	-	-	-	-
<i>Metacyatholaimus</i>	EF	-	-	-	-	-	-	-	0.88	-	-	-
<i>Metalinhomoeus</i>	M	-	-	-	-	1.00	-	-	2.65	0.94	-	2.97
<i>Monoposthia</i>	EF	6.93	-	-	-	-	-	-	-	-	-	-
<i>Neochromadora</i>	EF	0.99	-	-	0.99	-	-	-	-	-	0.89	-
<i>Neotonchus</i>	EF	-	16.38	10.94	-	-	2.94	0.86	5.30	-	8.03	-
<i>Odontophora</i>	CF	2.97	-	-	-	-	-	-	-	0.94	-	0.99
<i>Oncholaimellus</i>	FP	0.99	0.96	-	-	-	1.96	0.86	-	-	-	-
<i>Oncholaimus</i>	FP	-	-	-	-	-	-	-	1.76	1.88	-	0.99
<i>Paracomesoma</i>	EF	0.99	0.96	19.88	<b>73.27</b>	<b>45.00</b>	<b>39.24</b>	18.19	7.07	<b>33.24</b>	1.78	<b>35.71</b>
<i>Paralinhomoeus</i>	M	-	-	-	-	-	-	-	1.76	-	-	4.95

Table 2. (Continued)

Sites Genera	FG	R	C	BC	F	T	MB	OBH	OGA	OG	MJ	MA
<i>Paramonohystera</i>	DF	3.96	10.57	4.37	-	-	-	2.58	7.07	-	-	1.98
<i>Pareurystomina</i>	FP	-	-	-	-	-	0.98	-	-	0.94	-	-
<i>Parodontophora</i>	CF	-	5.76	2.91	-	1.00	-	3.44	-	-	-	-
<i>Prochromadorella</i>	EF	-	2.88	-	-	-	-	5.17	1.76	12.15	5.35	3.96
<i>Prooncholaimus</i>	FP	-	-	-	-	-	2.94	-	-	-	-	-
<i>Praecanthonchus</i>	DF	0.99	-	-	-	-	-	-	-	-	-	-
<i>Ptycholaimellus</i>	EF	2.97	3.84	-	0.99	5.00	-	1.72	-	4.71	0.89	2.97
<i>Rhinema</i>	EF	2.97	-	-	-	-	-	-	-	-	-	-
<i>Richtersia</i>	DF	0.99	-	-	-	-	-	-	-	-	-	-
<i>Sabatieria</i>	DF	-	3.84	<b>21.14</b>	10.89	2.00	-	9.47	3.52	1.88	0.89	0.99
<i>Setosabatieria</i>	DF	-	-	-	-	-	-	0.86	5.30	-	-	-
<i>Sigmophoranema</i>	P	3.96	-	-	-	-	-	-	-	-	-	-
<i>Siphonolaimus</i>	DF	-	-	-	-	3.00	-	-	-	1.88	-	0.99
<i>Spirinia</i>	M	-	-	-	-	-	-	-	0.88	-	-	-
<i>Steineria</i>	DF	-	-	-	-	-	-	-	1.76	0.94	-	-
<i>Stylotheristus</i>	DF	-	0.96	5.83	-	-	0.98	-	-	-	0.89	1.98
<i>Terschellingia</i>	M	-	<b>30.80</b>	14.59	4.95	-	-	18.10	-	1.88	<b>67.03</b>	0.99
<i>Thalassironus</i>	EF	-	-	-	-	-	-	-	-	-	-	0.99
<i>Theristus</i>	DF	-	-	2.18	-	-	-	-	5.30	-	-	4.95
<i>Trichotheristus</i>	DF	1.98	-	-	-	-	-	-	-	-	-	-
<i>Vasostoma</i>	EF	-	0.96	-	-	-	-	-	-	-	-	-
<i>Viscosia</i>	FP	0.99	0.96	-	1.98	26.00	13.72	1.72	1.88	2.82	2.67	20.73

Notes: M – microvores; DF – deposit-feeders; CF – ciliate-feeders; EF – epigrowth-feeders; FP – facultative predators; P – predators.

microvores were dominant and these feeders also provided important percentages in communities BC, MB and OBH. A similar pattern to epigrowth feeders was noted in deposit feeders, although the relative abundances were lower (Fig. 3, Table 2). Facultative predators unidentified in nematodes collected from the BC site were generally rare in the study area and were relatively frequent only in the T, MB and MA. Predators represented 32.67% abundance in community R, they were poorly represented in MB, OGA, OG, MA, OBH, T and MJ sites and totally absent in BC and F communities. Ciliate feeders constituted the least frequent feeding group and they were absent or rarely present in seven of the eleven investigated communities. In the remaining collected sediments, the proportion of this feeding group ranged from 5.16 to 16.83%. The highest values of the Trophic Diversity Index were recorded at four recorded assemblages, F, T, OG and MJ at more than 0.47. This was clearly due to the 63–80.2% predominance of epigrowth-feeders in the first three communities and the 67.03% of microvores in the MJ site. Concurrently, the minimum values of the Trophic Diversity Index were observed in the R and C marine input area communities at less than 0.29.

The abundances of ciliate feeders, epigrowth feeders and predators were negatively significantly correlated with the following constituents : silt/clay (r equal to -0.73, -0.77 and -0.84 respectively), organic matter (r equal to -0.79, -0.93 and -0.81), Ni (r equal to -0.60, -0.82 and -0.72), Zn (r equal to -0.65, -0.82 and -0.60), Fe (r equal to -0.73, -0.83 and -0.60) and Pb (r equal to -0.67, -0.68 and -0.71). Additionally, the abundance of facultative predators showed a notable negative correlation with dissolved oxygen in the water (r = -0.73). The abundance of deposit feeders, epigrowth feeders and predators was significantly positively correlated with chlorophyll *a* in sediments (r equal to 0.61, 0.74 and 0.63 respectively). However, negative correlations were recorded between deposit feeder abundance and the following components: sediment load of organic matter (r = -0.75), hydrocarbons (r = -0.64), Ni (r = -0.76), Zn (r = -0.76), Cu (r = -0.71), Fe (r = -0.78) and Mn (r = -0.74). Finally, the Trophic Diversity Index increased, but only insignificantly, with sediment loads of Ni (r = 0.51) and organic matter (r = 0.46).

### *Morphometry and energetics of nematode feeding groups*

Maximum values of the morphometric variables of total length and maximum width were recorded in the case of predators and facultative predators (Tables 3, 4).

In contrast to the maximum width, significant differences in total length were identified when pair-wise Tukey-HSD comparisons were applied (Table 5). Two categories of feeding groups were then separated; the first was composed of microvores, ciliate feeders and facultative predators and was characterized by the lowest carbon weight at 0.14–0.38  $\mu\text{gC}$ , while the second composed of epigrowth feeders, deposit feeders and predators exhibited maximum carbon weights at 0.57–0.85  $\mu\text{gC}$ . A comparable classification was observed in the Tukey-HSD test for individual production with microvores and ciliate feeders recording  $\leq 0.41 \cdot 10^{-3} \text{ J} \cdot \text{d}^{-1}$  and deposit feeders, epigrowth feeders, facultative predators and predators recording  $\geq 0.38 \cdot 10^{-3} \text{ J} \cdot \text{d}^{-1}$ . The highest rates of individual respiration were observed for ciliate feeders and the lowest were for predators (Table 4). This was statistically verified, and significant differences were noted between the metabolic ratio of ciliate feeders and those of the remaining feeding groups (Table 5).

The linear regressions of body dimensions of total length and maximum width of the feeding groups of Moens, Vincx (1997) with all sampling on average for juveniles (A) and adults (B) are shown separately in Fig. 4. The probability of 0.000 for the ANOVA slope comparison strongly indicates that there are significant differences in slopes between the feeding groups. The multiple comparison Tukey-HSD test showed that the slope of predator juveniles differs from the other feeding groups except for juvenile ciliate-feeders (Table 6). Indeed, predators have the lowest slope value of 0.0017. This corroborates the differences observed between regressions in adult predators and facultative-predators and the remaining groups, excepting only when facultative-predator adults are compared with ciliate-feeders. The facultative-predator slope value for adults, at 0.0043, was generally significantly lower than those of the other feeding groups while the slope of predators was the highest at 0.0332. It is very important to acknowledge that significant differences



Table 3. Morphometric and energetic variables of the nematode feeding groups (Moens, Vincx, 1997) in the nematode assemblages from Bizerte lagoon (September 2002). Mean individual length MIL ( $\mu\text{m}$ ), mean individual width MIWd ( $\mu\text{m}$ ), mean body volume MBV ( $\text{nl}$ ), mean individual weight MIW ( $\mu\text{gC}$ ,  $\text{ind}^{-1}$ ), mean individual respiration MIR ( $\text{nl O}_2 \cdot \text{h}^{-1} \cdot \text{ind}^{-1}$ ), mean individual production MIP ( $10^3 \text{ J} \cdot \text{d}^{-1} \cdot \text{ind}^{-1}$ ), mean individual production MIP ( $10^3 \text{ J} \cdot \text{d}^{-1} \cdot \text{ind}^{-1}$ ), metabolic ratio MR ( $\text{nl O}_2 \cdot \text{h}^{-1} \cdot \mu\text{gC}^{-1}$ ), feeding group absent (-). Maximum and minimum were respectively indicated with bold and underlined values.

Sites	R	C	BC	F	T	MB	OBH	OGA	OG	MJ	MA
Microvores											
MIL	-	1142.17 ± 237.27	968.50 ± 315.50	1180.08 ± 408.10	2019.15 ± 271.95	1622.61 ± 212.03	1062.02 ± 443.82	2294.6 ± 729.30	2347.66 ± 1104.85	937.50 ± 141.45	<b>2490.00 ± 857.83</b>
MIWd	-	45.83 ± 12.43	32.75 ± 10.31	45.43 ± 9.18	41.66 ± 25.25	49.00 ± 11.24	33.66 ± 14.65	<b>56.05 ± 21.08</b>	55.95 ± 24.68	35.82 ± 6.52	53.93 ± 34.24
MIW	-	0.23 ± 0.17	0.10 ± 0.11	0.21 ± 0.13	0.36 ± 0.39	0.34 ± 0.16	0.17 ± 0.41	0.74 ± 0.73	0.90 ± 1.04	0.10 ± 0.04	<b>0.99 ± 1.49</b>
MIR	-	2.29 ± 0.23	<b>2.96 ± 0.36</b>	2.59 ± 0.27	2.43 ± 0.50	2.32 ± 0.20	2.96 ± 0.32	1.79 ± 0.24	1.67 ± 0.32	2.21 ± 0.14	1.70 ± 0.33
MIP	-	0.40 ± 0.04	<b>0.45 ± 0.05</b>	0.40 ± 0.04	0.38 ± 0.08	0.37 ± 0.03	<b>0.45 ± 0.05</b>	0.34 ± 0.04	0.35 ± 0.06	0.44 ± 0.02	0.36 ± 0.07
MR	-	16.69 ± 12.01	<b>59.84 ± 58.95</b>	18.33 ± 14.95	17.92 ± 20.81	9.86 ± 7.88	46.25 ± 28.08	5.94 ± 7.67	7.92 ± 9.33	26.41 ± 13.40	9.19 ± 9.12
Deposit-feeders											
MIL	885.06 ± 301.22	1134.69 ± 301.71	1569.65 ± 586.33	2092.87 ± 606.48	<b>2804.37 ± 1696.62</b>	1802.90 ± 1221.02	2443.81 ± 1139.31	1333.80 ± 355.12	1976.43 ± 952.48	1085.83 ± 371.04	1936.73 ± 1246.30
MIWd	29.20 ± 8.23	49.42 ± 10.39	47.55 ± 18.38	59.90 ± 13.28	61.31 ± 22.02	45.43 ± 12.14	<b>74.75 ± 28.94</b>	42.52 ± 15.76	47.87 ± 19.59	32.45 ± 16.27	46.93 ± 22.58
MIW	0.07 ± 0.05	0.25 ± 0.16	0.40 ± 0.52	0.70 ± 0.49	1.15 ± 0.98	0.40 ± 0.42	<b>1.58 ± 1.31</b>	0.25 ± 0.22	0.55 ± 1.07	0.12 ± 0.18	0.68 ± 1.32
MIR	2.26 ± 0.30	2.23 ± 0.19	<b>2.52 ± 0.43</b>	2.20 ± 0.24	2.14 ± 0.57	2.43 ± 0.41	2.16 ± 0.48	2.10 ± 0.31	1.76 ± 0.20	2.32 ± 0.32	1.81 ± 0.30
MIP	<b>0.48 ± 0.06</b>	0.39 ± 0.03	0.38 ± 0.06	0.33 ± 0.03	0.34 ± 0.09	0.38 ± 0.06	0.32 ± 0.07	0.40 ± 0.06	0.37 ± 0.04	0.46 ± 0.06	0.38 ± 0.06
MR	<b>71.90 ± 95.19</b>	12.99 ± 7.74	28.64 ± 66.32	5.77 ± 6.99	20.42 ± 44.85	17.74 ± 14.66	11.15 ± 25.67	26.22 ± 55.10	7.90 ± 4.49	49.83 ± 42.87	13.21 ± 13.37
Ciliate-feeders											
MIL	1060.52 ± 410.23	983.40 ± 103.65	901.45 ± 139.28	-	<b>3413.32</b>	-	1041.62 ± 176.42	-	1826.85	-	2211.45
MIWd	30.54 ± 10.20	46.51 ± 11.91	30.50 ± 4.38	-	<b>59.52</b>	-	36.90 ± 5.58	-	30.95	-	47.62
MIW	0.10 ± 0.08	0.19 ± 0.11	0.06 ± 0.01	-	<b>0.99</b>	-	0.12 ± 0.05	-	0.14	-	0.41
MIR	2.20 ± 0.36	2.31 ± 0.19	<b>2.98 ± 0.12</b>	-	1.94	-	2.81 ± 0.15	-	1.94	-	1.67
MIP	<b>0.46 ± 0.07</b>	0.40 ± 0.03	0.46 ± 0.02	-	0.31	-	0.42 ± 0.02	-	0.41	-	0.35
MR	<b>72.50 ± 111.36</b>	16.49 ± 9.54	46.95 ± 17.67	-	1.95	-	26.76 ± 10.41	-	13.50	-	4.04

Table 3. (Continued)

Sites	R	C	BC	F	T	MB	OBH	OGA	OG	MJ	MA
Epigrowth-feeders											
MIL	1386.84 ± 751.88	946.97 ± 325.71	1499.83 ± 660.62	2126.65 ± 536.74	2299.96 ± 657.54	1541.35 ± 494.84	1849.28 ± 871.01	1297.98 ± 584.05	1741.23 ± 510.68	1068.62 ± 520.71	<b>2305.50 ± 1217.09</b>
MIWd	46.26 ± 24.15	41.28 ± 11.52	50.32 ± 17.58	64.01 ± 17.34	<b>66.57 ± 22.69</b>	53.85 ± 14.50	58.81 ± 26.73	47.10 ± 19.73	42.00 ± 15.94	38.94 ± 21.19	62.42 ± 18.57
MIW	0.42 ± 0.71	0.15 ± 0.15	0.43 ± 0.40	0.84 ± 0.59	<b>1.01 ± 0.80</b>	0.43 ± 0.34	0.85 ± 1.17	0.35 ± 0.37	0.33 ± 0.32	0.25 ± 0.49	0.89 ± 0.77
MIR	1.96 ± 0.44	2.44 ± 0.25	<b>2.50 ± 0.43</b>	2.16 ± 0.28	2.07 ± 0.31	2.30 ± 0.25	2.39 ± 0.47	2.10 ± 0.40	1.86 ± 0.27	2.23 ± 0.36	1.59 ± 0.24
MIP	0.41 ± 0.09	0.42 ± 0.04	0.38 ± 0.06	0.33 ± 0.04	0.33 ± 0.05	0.36 ± 0.04	0.36 ± 0.07	0.40 ± 0.07	0.39 ± 0.05	<b>0.44 ± 0.07</b>	0.33 ± 0.05
MR	<b>46.68 ± 88.56</b>	28.28 ± 23.05	21.84 ± 26.55	6.09 ± 9.08	6.29 ± 11.50	10.11 ± 9.80	17.88 ± 30.34	31.26 ± 43.90	16.20 ± 17.29	43.68 ± 50.39	5.73 ± 10.27
Facultative predators											
MIL	<b>2950.20 ± 463.57</b>	1475.10 ± 231.78	-	2130.70 ± 231.78	2298.35 ± 275.67	1578.61 ± 350.72	1538.40 ± 486.21	2349.23 ± 1649.89	2523.93 ± 1145.25	1693.63 ± 662.39	2463.84 ± 911.93
MIWd	<b>71.39 ± 45.89</b>	51.92 ± 18.35	-	55.16 ± 4.58	39.79 ± 8.82	40.98 ± 12.62	41.22 ± 17.20	51.92 ± 23.40	54.36 ± 5.91	38.94 ± 6.49	41.07 ± 9.43
MIW	<b>1.62 ± 1.82</b>	0.33 ± 0.17	-	0.54 ± 0.14	0.31 ± 0.16	0.25 ± 0.22	0.31 ± 0.44	0.82 ± 1.06	0.63 ± 0.34	0.21 ± 0.09	0.37 ± 0.34
MIR	1.49 ± 0.33	2.11 ± 0.17	-	2.21 ± 0.08	2.34 ± 0.13	2.48 ± 0.26	<b>2.64 ± 0.33</b>	1.88 ± 0.45	1.59 ± 0.11	1.99 ± 0.14	1.74 ± 0.12
MIP	0.31 ± 0.07	0.37 ± 0.03	-	0.34 ± 0.01	0.37 ± 0.02	0.39 ± 0.04	<b>0.40 ± 0.05</b>	0.36 ± 0.08	0.33 ± 0.02	0.39 ± 0.02	0.36 ± 0.02
MR	2.85 ± 3.42	7.65 ± 4.63	-	4.26 ± 1.32	8.88 ± 3.30	17.13 ± 12.70	<b>19.95 ± 13.30</b>	13.00 ± 17.60	3.16 ± 1.67	11.26 ± 6.79	6.35 ± 3.12
Predators											
MIL	1380.73 ± 857.57	1147.31 ± 0.01	-	-	<b>5144.02 ± 2923.49</b>	2190.30 ± 877.35	2475.86 ± 441.92	1085.83 ± 446.17	2740.27 ± 1842.97	655.6	1730.70 ± 1087.81
MIWd	42.67 ± 28.88	51.92 ± 9.17	-	-	86.90 ± 72.39	85.55 ± 27.81	<b>94.04 ± 8.41</b>	46.24 ± 28.27	63.49 ± 24.31	38.94	83.33 ± 60.61
MIW	0.52 ± 1.08	0.25 ± 0.09	-	-	<b>2.79 ± 2.88</b>	1.65 ± 1.49	1.78 ± 0.00	0.36 ± 0.53	0.96 ± 1.00	<b>0.08</b>	1.70 ± 2.22
MIR	2.03 ± 0.43	2.17 ± 0.11	-	-	1.78 ± 0.33	1.93 ± 0.25	1.88 ± 0.00	2.18 ± 0.40	1.55 ± 0.18	<b>2.26</b>	1.60 ± 0.52
MIP	0.43 ± 0.09	0.38 ± 0.01	-	-	0.28 ± 0.05	0.30 ± 0.04	0.28 ± 0.00	0.42 ± 0.00	0.32 ± 0.03	<b>0.44</b>	0.34 ± 0.11
MR	<b>48.43 ± 87.14</b>	9.02 ± 3.57	-	-	1.49 ± 1.66	2.68 ± 2.46	1.05 ± 0.00	29.97 ± 22.00	2.98 ± 2.14	27.61	7.80 ± 10.50

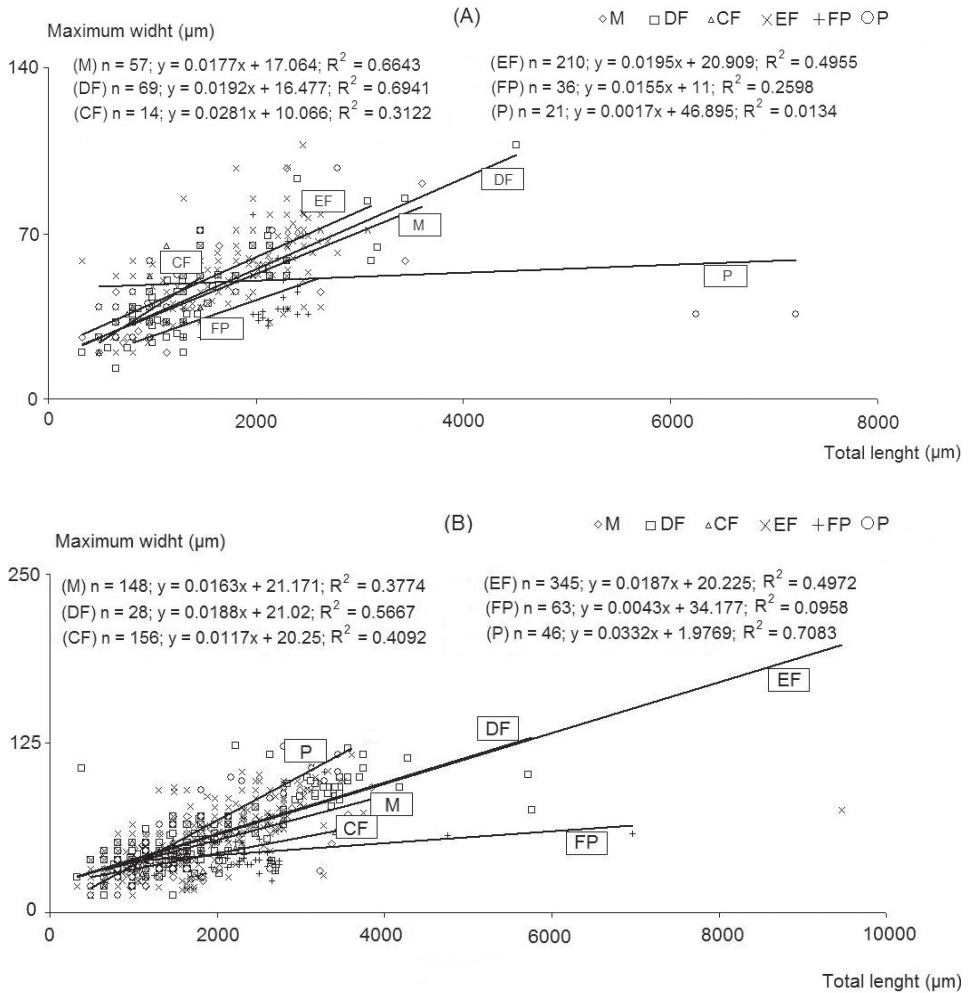


Fig. 4. Linear regressions between body dimensions (total length and maximum width) of feeding groups of Moens, Vincx (1997) (all sampling on average) juveniles (A) and adults (B) separately. Microvores (M); deposit-feeders (DF); ciliate-feeders (CF); epigrowth-feeders (EF); facultative predators (FP); predators (P).

were noted between the slopes of predators and facultative-predators in both juveniles and adults. Moreover, the slopes for both juveniles and adults differed significantly for both predators (juveniles < adults) and facultative-predators (juveniles > adults). According to each trophic group, the individual morphometric and energetic parameters can be essentially associated with five key factors; (i) depth, (ii) water temperature, (iii) the mean grain size, (iv) chlorophyll *a* in the sediments and (v) the sediment load of silt/clay,

Table 4. Morphometric and energetic variables of the nematode feeding groups (all sampling on average) from Bizerte lagoon (September 2002). Number of studied individuals (n), mean individual length MIL ( $\mu\text{m}$ ), mean individual width MIWd ( $\mu\text{m}$ ), mean body volume MBV (nl), mean individual weight MIW ( $\mu\text{gC} \cdot \text{ind}^{-1}$ ), mean individual respiration MIR ( $\text{nl O}_2 \cdot \text{h}^{-1} \cdot \text{ind}^{-1}$ ), mean individual production MIP ( $10^{-3} \text{ J} \cdot \text{d}^{-1} \cdot \text{ind}^{-1}$ ), metabolic ratio MR ( $\text{nl O}_2 \cdot \text{h}^{-1} \cdot \mu\text{gC}^{-1}$ ). Maximum and minimum were respectively indicated with bold and underlined values.

	M	DF	CF	EF	FP	P
n	207	225	42	555	99	67
MIL	1259.29 $\pm$ 617.91	1741.23 $\pm$ 951.54	1110.60 $\pm$ 511.08	1717.30 $\pm$ 790.51	<b>2135.65 <math>\pm</math> 767.35</b>	1737.86 $\pm$ 1240.63
MIWd	40.95 $\pm$ 15.41	52.58 $\pm$ 23.58	34.82 $\pm$ 10.86	53.09 $\pm$ 21.12	42.91 $\pm$ 13.05	<b>56.29 <math>\pm</math> 33.76</b>
MIW	0.26 $\pm$ 0.49	0.65 $\pm$ 0.95	0.14 $\pm$ 0.16	0.57 $\pm$ 0.65	0.38 $\pm$ 0.41	<b>0.85 <math>\pm</math> 1.26</b>
MIR	2.34 $\pm$ 0.44	2.21 $\pm$ 0.43	<b>2.46 <math>\pm</math> 0.45</b>	2.12 $\pm$ 0.41	2.12 $\pm$ 0.40	1.97 $\pm$ 0.39
MIP	0.41 $\pm$ 0.05	0.38 $\pm$ 0.07	<b>0.44 <math>\pm</math> 0.06</b>	0.37 $\pm$ 0.07	0.37 $\pm$ 0.03	0.38 $\pm$ 0.09
MR	26.24 $\pm$ 28.30	21.43 $\pm$ 47.21	<b>47.17 <math>\pm</math> 74.30</b>	18.69 $\pm$ 35.49	10.25 $\pm$ 9.08	29.13 $\pm$ 64.61

Notes: M – microvores; DF – deposit-feeders; CF – ciliate-feeders; EF – epigrowth-feeders; FP – facultative predators; P – predators.

organic matter and metals. For ciliate feeders and predators, the mean individual length was principally negatively affected by depth ( $r = -0.75$  and  $r = -0.70$ , respectively). For deposit feeders, this morphometric variable showed positive correlations with sediment loads of Ni ( $r = 0.74$ ), Fe ( $r = 0.74$ ), silt/clay ( $r = 0.72$ ), Zn ( $r = 0.68$ ), Cu ( $r = 0.65$ ), and Mn ( $r = 0.62$ ). Two other morphometric parameters, the mean individual width and the mean individual weight, appeared to be related to metals in sediments. The mean individual width was usually positively correlated with metals in the following four feeding groups: deposit feeders (Ni, Fe and Pb;  $r = 0.60$ ), ciliate feeders (Cu;  $r = 0.87$ ), epigrowth feeders (Ni, Cu and Fe;  $0.63 \leq r \leq 0.68$ ) and predators (Ni and Mn;  $r$  equal to 0.68 and 0.65 respectively). However, in facultative predators it was negatively correlated with all measured metals at  $0.64 \leq r \leq 0.67$ . Similarly, for deposit feeders, Ni showed a positive correlation with the mean individual carbon weight ( $r = 0.60$ ) which is proportional to Ni and Cu for ciliate feeders ( $r = 0.79$ ) and epigrowth feeders ( $r = 0.61$  and  $0.60$  respectively). Additionally, the mean individual weight of predators was correlated with three metals: Fe ( $r = 0.67$ ), Ni ( $r = 0.67$ ) and Cu ( $r = 0.66$ ). For facultative predators, microvores and epigrowth feeders, the mean individual respiration was positively correlated with the water temperature ( $r = 0.93$ ,  $0.91$  and  $0.71$ , respectively). However, positive correlations were found between this energetic variable and organic matter ( $r = 0.72$ ) and all measured metals ( $0.63 \leq r \leq 0.81$ ) only for facultative predators. A contrary situation was recorded for predators which had disproportional respiration rates in sediments to Ni ( $r = -0.68$ ), Zn ( $r = -0.71$ ), Cu ( $r = -0.66$ ) and Fe ( $r = -0.71$ ).

For deposit feeders, ciliate feeders and epigrowth feeders, the production rate was related disproportionately to silt/clay and metals. In absolute values, the production rate of the first feeding group was negatively correlated to silt/clay ( $r = -0.74$ ), Ni ( $r = -0.64$ ), Zn ( $r = -0.63$ ), Fe ( $r = -0.65$ ) and Pb ( $r = -0.62$ ), while the second and the third groups were negatively

Table 5. Pair-wise Tukey-HSD comparisons of morphometric and energetic variables of feeding groups of Moens, Vincx (1997) (all sampling on average). Bold values indicate significant differences at  $P < 0.05$ . Mean individual length (MIL), mean individual width (MIWd), mean individual weight (MIW), mean individual respiration (MIR), mean individual production (MIP), metabolic ratio (MR).

One-way ANOVA: F = 6.613 P = 0.000	MIL	M	DF	CF	EF	FP	P
	M		P = 1.000	P = 0.725	<b>P = 0.002</b>	P = 0.094	P = 0.621
	DF			P = 0.727	<b>P = 0.001</b>	P = 0.081	P = 0.598
	CF				<b>P = 0.008</b>	<b>P = 0.030</b>	P = 0.183
	EF					P = 1.000	P = 0.982
	FP						P = 0.989
	P						
One-way ANOVA (MIWd): F = 2.185; P = 0.054							
One-way ANOVA: F = 15.620 P = 0.000	MIW	M	DF	CF	EF	FP	P
	M		<b>P = 0.000</b>	P = 0.921	<b>P = 0.000</b>	P = 0.453	<b>P = 0.000</b>
	DF			<b>P = 0.000</b>	P = 0.998	<b>P = 0.034</b>	P = 0.717
	CF				<b>P = 0.000</b>	P = 0.277	<b>P = 0.000</b>
	EF					<b>P = 0.035</b>	P = 0.470
	FP						<b>P = 0.006</b>
	P						
One-way ANOVA: F = 3.616 P = 0.003	MIR	M	DF	CF	EF	FP	P
	M		<b>P = 0.010</b>	<b>P = 0.014</b>	P = 0.061	P = 0.608	P = 0.990
	DF			P = 0.756	P = 0.822	P = 0.890	P = 0.525
	CF				P = 0.327	P = 0.377	P = 0.169
	EF					P = 1.000	P = 0.886
	FP						P = 0.984
	P						
One-way ANOVA: F = 12.903 P = 0.000	MIP	M	DF	CF	EF	FP	P
	M		<b>P = 0.000</b>	P = 0.540	<b>P = 0.000</b>	<b>P = 0.000</b>	<b>P = 0.002</b>
	DF			<b>P = 0.000</b>	P = 0.765	P = 0.918	P = 0.967
	CF				<b>P = 0.000</b>	<b>P = 0.000</b>	<b>P = 0.000</b>
	EF					P = 1.000	P = 1.000
	FP						P = 1.000
	P						
One-way ANOVA: F = 7.670 P = 0.000	MR	M	DF	CF	EF	FP	P
	M		P = 0.228	<b>P = 0.019</b>	<b>P = 0.006</b>	<b>P = 0.034</b>	P = 0.961
	DF			<b>P = 0.000</b>	P = 0.942	P = 0.810	P = 0.982
	CF				<b>P = 0.000</b>	<b>P = 0.000</b>	<b>P = 0.011</b>
	EF					P = 0.979	P = 0.779
	FP						P = 0.619
	P						

Notes: M – microvores; DF – deposit-feeders; CF – ciliate-feeders; EF – epigrowth-feeders; FP – facultative predators; P – predators.

Table 6. Multiple Comparison tests for slope relating the body proportions of feeding groups of Moens, Vincx (1997) (all sampling on average) juveniles (A) and adults (B) separately and one-way ANOVA slope comparisons between juveniles and adults belonging to the same feeding group (C). Bold values indicate significant differences at probability (P) < 0.05.

	Juveniles	M	DF	CF	EF	FP	P
(A) One-way ANOVA: F = 17.307 P = 0.000	M		P = 0.997	P = 0.984	P = 0.989	P = 0.998	<b>P = 0.000</b>
	DF			P = 0.992	P = 1.000	P = 0.974	<b>P = 0.000</b>
	CF				P = 0.993	P = 0.967	P = 0.505
	EF					P = 0.958	<b>P = 0.000</b>
	FP						<b>P = 0.047</b>
	P						
(B) One-way ANOVA: F = 15.942 P = 0.000	Adults	M	DF	CF	EF	FP	P
	M		P = 0.916	P = 0.963	P = 0.917	<b>P = 0.002</b>	<b>P = 0.000</b>
	DF			P = 0.751	P = 1.000	<b>P = 0.000</b>	<b>P = 0.000</b>
	CF				P = 0.756	P = 0.767	<b>P = 0.002</b>
	EF					<b>P = 0.000</b>	<b>P = 0.000</b>
	FP						<b>P = 0.000</b>
(C)	Juveniles /Adults	M	DF	CF	EF	FP	P
	M	F = 0.283 P = 0.595					
	DF		F = 0.019 P = 0.890				
	CF			F = 2.170 P = 0.149			
	EF				F = 0.169 P = 0.681		
	FP					F = 5.648 <b>P = 0.019</b>	
	P						F = 49.863 <b>P = 0.000</b>

Notes: M – microvores; DF – deposit-feeders; CF – ciliate-feeders; EF – epigrowth-feeders; FP – facultative predators; P – predators.

related to Ni (r equal to -0.79 and -0.67 respectively), Zn (r equal to -0.76 and -0.60), Cu (r equal to -0.85 and -0.68) and Fe (r equal to -0.77 and -0.65). Positive relationships were observed between silt/clay (r = 0.65) and Pb (r = 0.72) and the individual production of facultative predators. Finally, the metabolic ratios of ciliate feeders, epigrowth feeders and predators were negatively associated with Ni (r equal to -0.76, -0.74 and -0.69 respectively), Zn (r equal to -0.76, -0.69 and -0.73), Cu (r equal to -0.80, -0.76 and -0.66) and Fe (r equal to

-0.75, -0.71 and -0.71). However, one positive correlation was noted between the metabolic ratio of facultative predators and Pb where  $r$  equalled 0.65.

## Discussion

A spatial homogeneity was observed in water variables except for suspended matter. Naturally low water oxygenation associated with high temperature values was recorded for the dry season, as expected. The distribution of sedimentary hydrocarbons, organic matter and metals was mainly influenced by two factors; (i) silt/clay content and (ii) sewage from the “El Fouledh” metallurgic factory. Apart from those recorded in sediments collected from the MB site in front of this metallurgic factory, concentrations of Cu, Pb and Zn measured at the Bizerte lagoon coastal domain were on average similar to those observed in sediments from Marannes Oléron bay (France) (Rzeznik-Orignac et al., 2003). Additionally, they were not heavily contaminated compared with those from the Fal Estuary in Cornwall (Somerfield et al., 1994). The concentration of chlorophyll *a* in sediments was negatively associated with Ni and Zn ( $r$  equal to -0.60 and -0.63, respectively). Since Joux-Arab et al. (2000) have demonstrated that copper can inhibit planktonic diatom's development, this finding may also hold true for benthic diatoms.

The Tukey-HSD comparisons in Table 5 prove that the feeding classification of Moens, Vincx (1997) may be valid. In fact, the classification of Wieser (1953) presents the same groups with deposit feeders and ciliate feeders contrasted to facultative predators and predators. Despite the absence of significant difference in slope relationships for body proportions in our study, deposit feeders and ciliate feeders can be separated into two groups because of their significant statistical differences in individual mean carbon weights and their individual production and metabolic ratios. The classification of facultative predators and predators in two separate groups as described by Moens, Vincx (1997) may also be valid. The ANOVA slope comparisons shown in Table 6 certainly necessitate important observations concerning each of these feeding groups. In both cases, the growth of juveniles and adults differed significantly. Additionally, the volume growth of facultative predators and predators appears clearly different. In contrast to facultative-predators, the volume increase in predator juveniles results more from length than from width. An opposite situation was noted for the adults in these feeding groups, where the body growth of facultative-predator adults mainly involved length increase when compared with predators. However, a significant difference was noted when comparing the individual mean carbon weights alone.

As noted in Wieser (1953), sediment characteristics efficiently control the trophic structure of nematode communities. Indeed, it is known that an enrichment of clayey sediment with potentially toxic elements (PTEs) may cause a dearth of chlorophyll *a* which is derived mainly from benthic diatoms (De Jonge, 1992). As a result, the low feeding availability for diatom-cracking or epigrowth-feeders, diatom-ingesting or deposit feeders and ciliate feeders may explain the decrease in their abundance when sediments are contaminated. The proportionally related abundances of epigrowth feeders and ciliate feeders with predators ( $r = 0.70$  and  $r = 0.54$ , respectively) can be partly explained when it is considered that

members of the first feeding groups may be consumed by those of the second group. The relationship between facultative predator abundance and water oxygenation may be due to their high body size and oxygen consumption in comparison with the other feeding groups (Heip et al., 1982).

Curiously, the T, F and MB communities inhabiting the most organically contaminated sediments were dominated by the epigrowth-feeder species of *Paracomesoma dubium*, and not by microvorous species which dominated in the C and MJ communities. This may have been due to the quality of organic matter, where *Paracomesoma dubium* dominates nematode assemblages when benthic diatoms constitute the major part of the organic matter. However when the organic matter was derived from domestic sewage and easily decomposed by micro-organisms, the microvore *Terschellingia longicaudata* represented almost the entire community. This may partly explain the high trophic diversity index values recorded at the F and T communities (0.66 and 0.47, respectively) and also at the MJ community (0.50).

Our results show that oxygen consumption was higher in deposit feeders than in microvores and epigrowth feeders, confirming those of Wieser, Kanwisher (1961). The morphometric and energetic variables were clearly adopted by the feeding groups. Indeed, ciliate feeders and facultative predators were visibly and respectively separated from deposit feeders and predators. This finding appears to support the trophic classification of Moens, Vincx (1997).

According to Teal and Wieser (1966), the respiration rate is associated with feeding behaviour and buccal cavity structure. This gives a partial explanation for differences observed between trophic groups across factors controlling the variability of individual energetic parameters. The respiration rate of microvores, epigrowth feeders and facultative predators is clearly influenced by water temperature. Indeed, it is accepted that an increase in temperature is generally associated with an increase in individual respiration (Schiemer, 1982a, b). At the same time, low sediment quality appears to reduce oxygen consumption in predators.

For deposit feeders, ciliate feeders and epigrowth feeders, the mean individual production appears to be a good bioindicator of environmental conditions. Indeed, this variable was highly negatively correlated to metals in the sediments. A different situation was recorded for facultative predators which registered positive correlations between their respiration and production rates and metals. This relationship may be due to their irregular feeding behaviour (Epstein, Shiaris, 1992) which increases their tolerance to stressful conditions. On the other hand, ciliate feeders were mainly represented at higher depths by shorter organisms with higher metabolic ratios. This may be due to the poverty of the generally chlorophyll-associated bacteria and algae in the deeper sediments (Pfannkuche et al., 1999), and these are the principal food for ciliates. The same morphometric picture was noted in predators, characterized by their small body size in deeper sites. In fact, Soetaert, Heip (1989) observed that an increase in depth is generally associated with dwarf species. For deposit feeders, the proportionally related length with silt/clay, and eventually with organic matter, may be explained when we consider that eutrophication causes nematode corpulence on one hand (Jensen, 1987) and the feeding behaviour of this trophic group on the other hand.



## Conclusion

Our results validate the nematode feeding classification of Moens, Vincx proposed in 1997 for meiobenthic nematodes, although few nematologists have utilized it since that date. Our morphometric and energetic data and the ecology trophic observations of Moens, Vincx (1997) concerning each of their six proposed feeding group (microvores, ciliate-feeders, deposit-feeders, epigrowth-feeders, facultative predators and predators) demonstrates that there are significant statistical differences between ciliate feeders and deposit feeders on one hand and between facultative predators and predators on the other. In fact, according to Wieser (1953), the first two groups belong to the same group of non-selective deposit feeders (1B) and the last two groups are part of the one single group of real predators and scavengers (2B). Additionally, our study clearly showed the relationships between the morphometry and energetics of the feeding groups of Moens, Vincx (1997) and the four environmental key factors of depth, water temperature, silt/clay and chlorophyll *a* in sediments. These results should certainly support their use as an efficient tool in environmental biomonitoring.

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