Mediterranean Marine Science

Vol 3, No 2 (2002)

Response of free-living Nematodes to the quality of water and sediment at Bou Chrara Lagoon (Tunisia) during winter 2000

E. MAHMOUDI, H. BEYREM, L. BACCAR, P. AISSA

doi: 10.12681/mms.252

Mediterranean Marine Science
Vol. 3/2, 2002, 133-146

Response of free-living Nematodes to the quality of water and sediment at Bou Chrara Lagoon (Tunisia) during winter 2000

E. MAHMOUDI, H. BEYREM, L. BACCAR and P. AISSA

Environmental Biomonitoring Laboratory,
Science University of Bizerta, Zarzouna 7021 Bizerta, Tunisia

e-mail: Hamouda.Beyrem@fsb.rnu.tn

Abstract

The Bou Ghrara lagoon, a stretch of water in southeastern Tunisia, has shown an alarming reduction of its fishery resources since 1993. In order to study the response of free-living nematodes to the water and sediment quality of this area, thirteen stations have been sampled. According to this study, the heavy metal, organic carbon and hydrocarbon content of sediments are key factors negatively influencing the density, biomass and diversity of the nematofauna.

Keywords: Lagoon, Free-living nematodes, Diversity, Hydrocarbon, Heavy metal.

Introduction

The Bou Ghrara lagoon with an area of 500 km² is the biggest of all Tunisian lagoons. This important ecosystem has experienced an alarming reduction of its fishery resources since 1993. Before presenting the results of this work, it seems necessary to stress the importance of the meiofauna, one of the first links in the food web (SOGARD, 1984; CASTEL, 1992; AMARA & BODIN, 1995).

The meiobenthos and notably the free-living nematodes, the most abundant taxa (e.g. TEAL & WIESER, 1966; ALKEMADE *et al.*, 1993; BEYREM & AISSA, 2000), have been used in the impact studies of many aquatic ecosystems and several authors have demonstrated that these animals are ideal for pollution monitoring because of their potential for rapid response to environmental changes (e.g. WARWICK, 1993; BEYREM & AISSA, 2000, BURTON *et al.*, 2001, MAHMOUDI *et al.*, 2002).

It is no longer necessary to demonstrate the relevance of meiofauna as indicators of environmental stress . Indeed, ANSARI *et al.* (1984) noted a significant spatial and temporal variation in mean meiofauna density in Goa (India), in response to organic discharge via sewage and prevailing environmental conditions. SCHRATZBERGER & WARWICK (1998) revealed in a microcosm experiment that total abundance, diversity and species richness of the nematofauna decreased significantly with increasing levels of organic enrichment. BEYREM & AISSA (2000) showed, in the

Bay of Bizerta (Tunisia), that free-living nematode biomass and diversity were altered by hydrocarbon pollution. At Ghar El Melh lagoon (Tunisia), MAHMOUDI *et al.* (2002) reported that the salinity and dissolved oxygen of waters and the ammonia content of sediments affected density, biomass and the diversity of the nematofauna.

The aims of this study were to investigate the response of free-living nematodes to the quality of waters and sediments at Bou Ghrara lagoon and to validate the use of meiofauna in impact studies of lagoons.

Materials and Methods

Sampling and nematofauna analyses

Sediments were collected from 13 sampling stations in Bou Ghrara lagoon in February 2000 (Fig. 1). The stations' depth ranged from 0.9-10 m. For meiofauna analysis, three replicate 10 cm^2 hand-cores were taken at each station and fixed immediately in 4% buffered formaldehyde. Sampling depth was limited to the first 18 cm of the substrate. Meiofaunal taxa, defined here as metazoans that pass through a 1 mm mesh sieve and are retained on a 0.040mm sieve (VITIELLO & DINET, 1979), were sieved following the resuspension-decantation methodology (WIESER, 1960) and stained with Rose-Bengal (0.2 g/l). Nematodes were counted under a microscope and 100 randomly picked individuals (KOTTA & BOUCHER, 2001) were identified to genus or species using the pictorial keys of PLATT & WARWICK (1983, 1988), WARWICK *et al.* (1997) and AISSA & HERMI (1997). These individuals were also used for evaluating individual and total biomass. Their lengths and widths were measured (VITIELLO & AISSA,

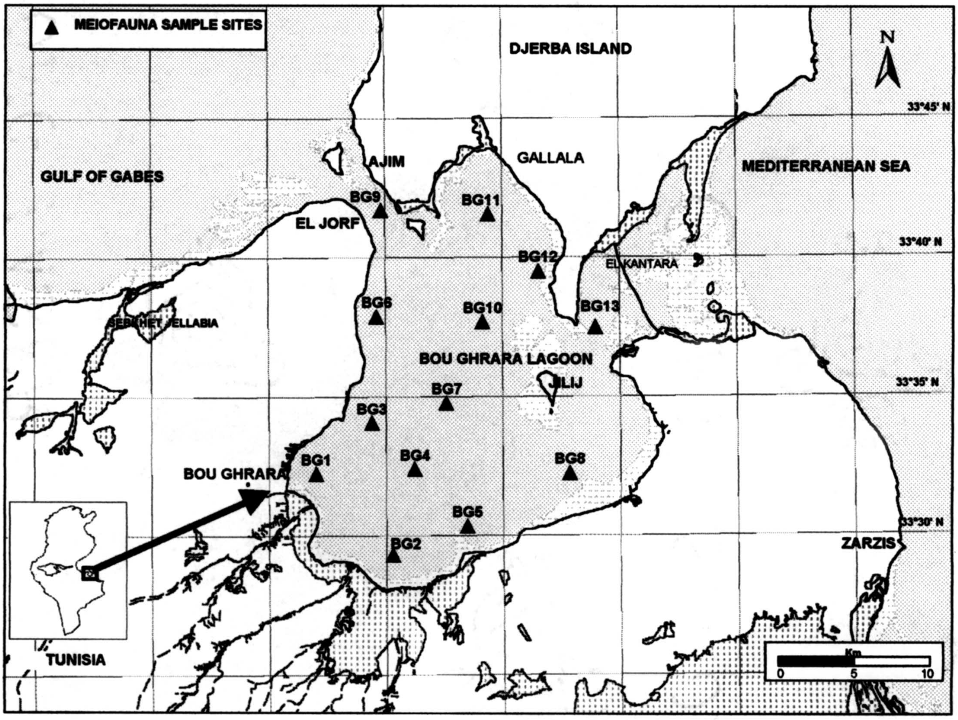

Fig. 1: Geographical location of the stations sampled in Bou Ghrara lagoon during winter 2000 (BG1 - BG13).

1985). The body volume of nematodes was estimated using the andrassy formula $V= LW^2 / 16x\,10^5$ (ANDRASSY, 1956), where V is the volume in nanolitres, L the length and W the maximum width (L and W expressed in micrometres). The wet weight of each nematode was obtained from multiplying volume by specific gravity (assumed to be 1.13) (FELLER & WARWICK, 1988). Dry weight was assumed to be 25% of the wet weight (JUARIO, 1975).

Hydrological parameters

Water temperature, dissolved oxygen and salinity were measured *in situ* by using a field thermometer-oxymeter (CG867) and a field salinometer (WTW LF 196).

Sediment parameters

For sediment parameter analysis, one replicate 10 cm² hand-core was used. Grain size distribution for each station was measured by the wet sieve method of COULL (1970) and mean grain size (*MZ*) and sorting coefficient (*‰ΔI*) (TRASK, 1932) were calculated. Hydrocarbon content in sediment was quantified spectrophotometrically (KANTIN, 1977) following the protocol described by BEYREM & AISSA (1998). Total organic carbon (*TOC*) was determined coulometrically using a Coulomat 702. Heavy metal analysis was performed by atomic absorption spectrometer.

Data processing

Nematode abundance, mean individual weight, mean total biomass, diversity (Shannon-Weaver index H') (SHANNON & WEAVER, 1963) and evenness (Pielou's J) (PIELOU, 1969) were calculated for each station.

Species abundance data were presented in k-dominance plots, in which species are ranked in decreasing order of dominance. The percentage cumulative abundance (k-dominance) is then plotted against the species rank k (LAMBSHEAD *et al.*, 1983, PLATT *et al.*, 1984; SCHRATZBERGER & WARWICK, 1998).

Data were tested for homogeneity of variance and for normal distribution. The following statistical treatment of the results consisted of pairwise comparisons (Student t-test) which allowed evaluating the influence of sampling stations on nematode distribution. Pearson correlations (r) (SCHWARTZ, 1983) were used to test for relationships between environmental variables and nematode density, biomass and diversity. Faunal affinity between stations was measured by regrouping the stations on the basis of Euclidean distance (LEGENDRE & LEGENDRE, 1998). The raw data were transformed to $\log_{10}(x+1)$ in order to stabilise the variance and all tests were performed using the SYSTAT 8.0 software package (WILKINSON *et al.*, 1992) and STATBOX™ 2.5 for Windows (GRIMMER *Logiciels*).

Results

Hydrological parameters

Water temperature and salinity did not show any appreciable change at the thirteen sampling sites. However, water dissolved oxygen content ranged from 7.68 mg l^{-1} at station (BG9) to 11.60 mg l^{-1} at site (BG6) (Fig. 2).

Sediment parameters

Table 1 gives data on the physical and chemical environmental factors of the sediment. Granulometric analysis showed that the sediment was mainly composed of larger to fine sands which were well sorted at all stations. Sediment hydrocarbon concentration fluctuated between 0.05 – 4.80 mg g^{-1} dry weight (*dw*) and the lowest values were recorded at stations near the marine inputs (BG6, BG 9 and BG13). Sediment total organic carbon content (*TOC*) ranged from 0.07 to 7.56 % (*dw*) and the lowest values are also observed at sites BG6, BG9 and BG13. Heavy metal (Zn, Cr, Pb) concentrations in sediment were lower than international norms for polluted marine sediments (RAPPORT DGPA, 2000).

Nematofauna

Nematofaunal abundance ranged from 154 ± 7.81 individuals 10 cm-^{2} at station BG2 to 5641 ± 28.05 individuals 10 cm-^{2} (mean ± SE) at site BG13 (Fig. 3). Highest densities were recorded at stations near the marine inputs (BG6, BG9 et BG13) and the lowest densities were found at the most isolated sites BG1 and BG2. Student t-test between stations supported the existence of a nematode density gradient from BG1 and BG2 to BG6, BG9 et BG13 and indicated that Bou Ghrara lagoon is an heterogeneous area (Table 2).

Table 1

Positions (latitude and longitude), depth and data on sediment parameters of the 13 stations investigated in Bou Ghrara lagoon during winter 2000. Hs: Sediment hydrocarbon content in mg g^{-1} dry weight, *TOC*: Sediment total organic carbon content in % dry weight, Pb: Sediment Pb content in ppm , Zn: Sediment Zn content in ppm, Cr: Sediment Cr content in ppm, FF: Sediment fine fraction content in %, *MZ:* mean grain size in µm , *ΔI*: sorting coefficient.

Stations	Latitude (South)	Longitude (East)	Depth (m)	Hs (mg g^{-1})	*TOC* (%)	Pb (ppm)	Zn (ppm)	Cr (ppm)	FF (%)	MZ (µm)	‰*ΔI*
BG1	33° 32' 23	10° 42' 03	10	3.42	4.8	63	324	30	0.80	140	1.44
BG2	33° 30' 56	10° 43' 87	9.5	1.99	3.31	72	475	42	67.60	980	1.32
BG3	33° 30' 56	10° 43' 87	1.2	2.94	4.65	22	15	15	47.80	320	2.14
BG4	33° 32' 39	10° 46' 25	3.8	1.57	1.21	50	13	7	4.00	250	2.15
BG5	37° 30' 34	10° 48' 47	2.5	6.4	5	30	14	14	33.00	400	0.40
BG6	33° 37' 88	10° 44' 64	1.4	0.05	0.07	21	19	13	7.20	130	1.41
BG7	33° 35' 88	10° 46'80	15.9	2.87	7.04	29	649	38	44.80	170	1.60
BG8	33° 32' 17	10° 50' 87	4.2	1.67	1.66	24	15	11	16.20	140	1.44
BG9	33° 41' 70	10° 44' 85	10.9	0.07	0.02	11	12	9	97.60	650	0.32
BG10	37° 08' 47	10° 11' 33	10.2	4.8	7.56	41	32	28	97.40	210	0.34
BG11	33° 41' 55	10° 49' 42	4.1	1.84	2.16	24	13	6	14.20	160	1.25
BG12	33° 39' 50	10° 51' 56	3.2	0.63	0.5	12	10	8	0.60	190	1.37
BG13	37° 37' 77	10° 53' 54	0.9	0.7	0.83	12	12	6	77.80	90	0.25

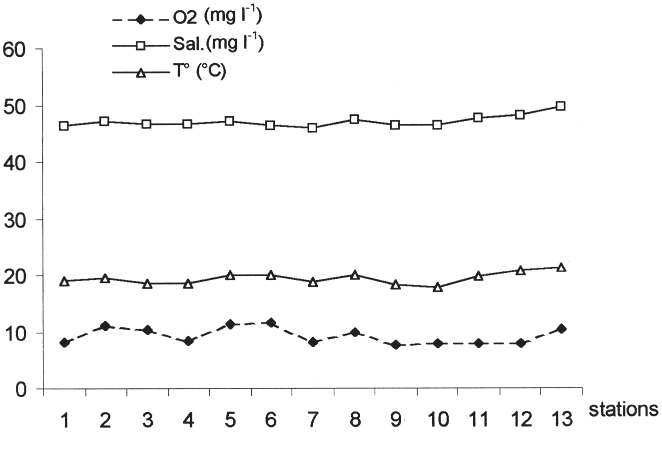

Fig. 2: Spatial variation of some hydrological parameters values in Bou Ghrara during winter 2000. O2: water dissolved oxygen content (mg l^{-1}), Sal. : Salinity (g l^{-1}), T°: Water temperature (°C). The stations 1-13 correspond to BG1 - BG13 in Fig.1.

Nematode mean individual weight fluctuated between 0.19 µg (*dw*) at station BG1 to 0.81 µg (*dw*) at station BG13 (Fig. 4). Following the same trend as observed for abundance, the highest and lowest mean individual weight values were found at stations near the marine inputs (BG6, BG9 et BG13) and at the most isolated sites (BG1 and BG2), respectively.

Nematofaunal mean total biomass ranged from 33.82 µg 10 cm-^{2} (*dw*) at station BG1 to 4569.21 µg 10 cm-^{2} (*dw*) at site BG13. The nematode biomass showed three peaks corresponding to marine influenced stations (Fig. 4).

A total of 47 free-living nematode species were identified. A list of these species arranged in decreasing mean general dominance (MGD) is presented in Table 3. Of the 47 species identified *Terschellingia longicaudata* was the most abundant form. This species was followed by *Paracomesoma dubium,*

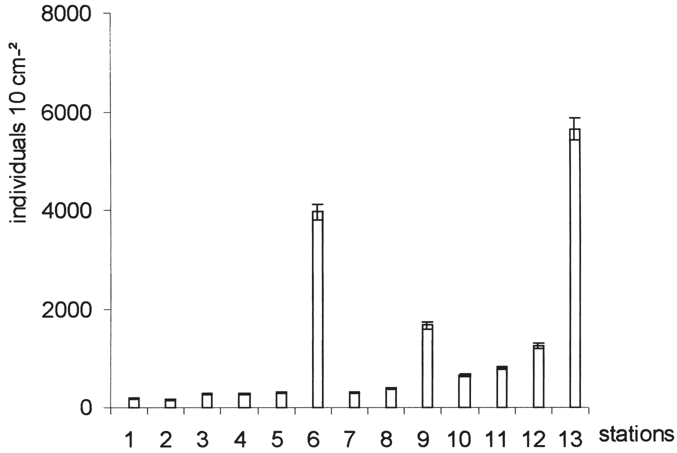

Fig. 3: Spatial variation of nematode mean densities (in individuals 10 cm-^{2}) in Bou Ghrara lagoon during winter 2000. The stations 1-13 correspond to BG1- BG13 in Fig.1.

Table 2
Significance of differences between nematofaunal abundances as a function of sampling stations.

Stations	BG1	BG2	BG3	BG4	BG5	BG6	BG7	BG8	BG9	BG10	BG11	BG12	BG13
BG1		1,67	17,54	16,35	13,38	216,90	20,42	17,45	17,80	64,49	76,95	49,85	323,88
BG2	NS		22,76	20,89	22,55	218,99	24,94	19,65	73,13	69,12	81,25	51,08	326,46
BG3	***	***		0,87	1,91	216,99	1,13	9,90	68,44	61,05	74,65	46,18	327,19
BG4	***	***	NS		1,70	214,06	1,06	9,26	67,64	55,21	69,03	45,61	322,58
BG5	***	***	NS	NS		210,43	0,98	7,14	66,04	48,043	62,44	44,24	317,46
BG6	***	***	***	***	***		211,72	179,88	87,94	187,66	176,33	101,80	71,76
BG7	***	***	NS	NS	NS	***		6,74	66,11	49,92	64,13	44,19	319,75
BG8	***	***	**	**	**	***	***		56,16	21,95	32,86	36,75	271,03
BG9	***	***	***	***	***	***	***	***		48,68	41,16	14,48	154,16
BG10	***	***	***	***	***	***	***	***	***		17,25	27,68	292,06
BG11	***	***	***	***	***	***	***	***	***	***		20,66	278,34
BG12	***	***	***	***	***	***	***	***	***	***	***		166,80
BG13	***	***	***	***	***	***	***	***	***	***	***	***	

NS: no significant difference at $p < 0.05$,
**: significant difference at $p < 0.01$,
***: very significant difference at $p < 0.001$.

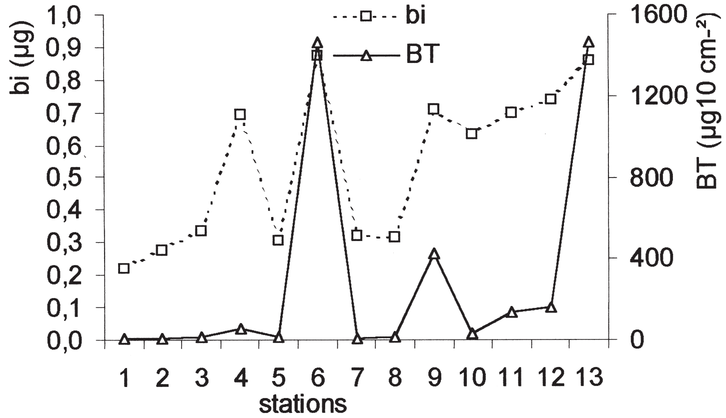

Fig. 4: Spatial variation of total biomasses (BT in dry weight, µg 10 cm^{-2}) and mean individual weight (bi in dry weight, µg) of nematodes in Bou Ghrara lagoon during winter 2000. The stations 1-13 correspond to BG1- BG13 in Figure1.

Table 3
List of free-living nematode species from Bou Ghrara lagoon (February 2000). The list includes only species whose dominance (D%) is higher than 1 % at least in one of the samples. The dominance of the two most abundant species from each station is indicated in bold.

Stations	BG1	BG2	BG3	BG4	BG5	BG6	BG7	BG8	BG9	BG10	BG11	BG12	BG13	
Nematode species	D %	D %	D %	D %	D %	D %	D %	D %	D %	D %	D %	D %	D %	DGM %
Terschellingia longicaudata De Man. 1907	**22.00**	**10.00**	**5.00**	7.84	2.73	**24.29**	-	2.91	-	-	**60.20**	**68.32**	**22.53**	**23.35**
Paracomesoma dubium (Filipjev. 1918)	1.00	2.00	3.00	1.96	1.82	**14.56**	**79.83**	**29.13**	0.83	3.64	-	0.99	11.28	9.81
Daptonema fallax Lorenzen. 1971	-	-	-	**62.76**	1.82	9.71	**3.85**	1.94	-	-	-	1.98	0.75	7.76
Daptonema normandicum De Man. 1890	**64.00**	**70.00**	**75.00**	5.88	2.73	-	-	**38.84**	-	**61.80**	**13.27**	5.94	0.75	7.76
Metalinhomoeus numidicus Aïssa et Vitiello. 1977	-	-	1.00	0.98	2.73	4.85	0.96	0.97	**13.33**	-	13.27	0.99	7.52	6.21
Prochromadorella neapolitana (De Man. 1876)	-	1.00	-	-	-	-	-	1.94	**32.54**	-	-	-	3.76	4.84
Desmolaimus demani Schulz. 1932	-	-	-	-	-	-	1.92	-	3.33	-	-	-	11.24	4.44
Sabatieria granifer Wieser. 1954	-	-	-	-	8.18	-	-	-	-	-	2.04	1.98	10.53	4.19
Sabatieria longicaudata Filipjev .1922	-	-	-	-	-	8.74	1.92	-	-	-	-	-	2.26	3.05

Table 3 (Continued)

Terschellingia communis De Man. 1888	8.00	-	3.00	-	1.82	4.85	1.92	-	-	3.64	-	1.98	2.26	2.56
Metoncholaimus pristiurus Filipjev .1918	-	-	1.00	-	**72.71**	-	-	20.39	-	4.55	-	-	-	2.08
Terschellingia sp.	-	9.00	-	3.92	-	-	-	-	5.83	-	-	-	3.01	1.85
Microlaimus cyatholaimoïdes De Man. 1922	-	-	-	-	-	-	-	-	-	12.73	-	7.92	1.5	1.69
Viscosia glabra Bastian. 1865	-	-	-	-	-	-	-	-	5.83	4.55	-	-	2.26	1.61
Sabatieria pulchra Riemann. 1970	5.00	4.00	-	**10.78**	-	4.85	-	-	-	-	-	-	-	1.51
Halichoanolaimus dolichurus Ssweljev. 1912	-	-	-	-	-	5.83	-	-	-	-	-	-	-	1.47
Marilynia stekhoveni Wieser. 1954	-	-	-	-	-	-	0.96	-	-	-	-	-	3.01	1.10
Paralinhomoeus tenuicaudatus (Bütschli. 1874)	-	-	-	-	-	3.88	1.92	-	-	-	-	-	-	1.02
Prochromadorella longicaudata Lorenzen. 1972	-	-	1.00	-	-	3.88	-	-	-	-	-	-	-	1.00
Prooncholaimus megastoma (Eberth. 1863)	-	-	-	-	-	3.88	-	-	-	-	-	-	-	0.98
Chromadorita tenuis (Schneider.1906)	-	-	2.00	1.96	-	-	0.96	-	5.00	3.64	-	1.98	-	0.92
Sphaerolaimus gracilis De Man. 1876	-	-	-	-	-	-	-	-	0.83	-	-	-	2.26	0.90
Sabatieria punctata Stekhoven. 1935	-	-	-	-	0.91	-	-	-	-	-	-	-	2.26	0.83
Anticoma acuminata (Eberth.1863)	-	-	-	-	-	-	-	-	-	-	-	-	2.26	0.81
Desmodora ovigera Ott. 1979	-	-	-	-	-	-	-	-	-	-	-	-	2.26	0.81
Viscosia viscosa (Bastian. 1865)	-	-	-	-	-	-	-	-	-	-	-	-	2.26	0.81
Desmodora minuta Wieser. 1954	-	-	-	-	-	-	-	-	7.50	-	-	-	-	0.79
Dorylaimopsis mediterraneus De Zio.1968	-	-	-	2.94	-	2.91	-	-	-	-	-	-	-	0.79
Chromaspirina pontica Filipjev .1918	-	-	-	0.98	-	-	-	-	5.83	-	-	-	-	0.63
Camacolaimus tardus De Man. 1989	-	-	-	-	-	-	-	-	5.00	-	-	-	-	0.62

Table 3 (Continued)

Steineria pilosa Cobb. 1914	-	-	-	-	0.91	-	0.96	-	-	-	3.06	1.98	0.75	0.62
Metalinhomoeus torosus Jensen et Gerlach. 1976	-	-	-	-	-	-	-	-	-	-	6.12	2.97	-	0.54
Monhystera parva (Bastian. 1865)	-	-	-	-	-	-	-	-	-	-	-	-	1.5	0.54
Stylotheristus mutilus Lorenzen.1973	-	-	-	-	-	7.77	0.96	-	-	-	-	-	1.5	0.54
Vasostoma sp.	-	-	-	-	-	-	-	-	-	-	-	-	1.5	0.54
Longicyatholaimus longicaudatus (Marion. 1870)	-	-	-	-	-	-	-	-	5.00	-	-	-	-	0.53
Oncholaimus campylocercoïdes (De Coninck et Stekhoven. 1933)	-	-	2.00	-	0.91	-	-	1.94	-	-	-	-	0.75	0.37
Filoncholaimus ditlevseni (Kreis. 1932)	-	-	-	-	-	-	-	-	3.33	-	-	-	-	0.36
Mesacanthion hirsutum Gerlach. 1953	-	-	-	-	-	-	-	-	2.50	-	-	-	-	0.26
Aponema torosa (Lorenzen. 1973)	-	-	-	-	-	-	-	-	-	5.45	-	-	-	0.22
Chromadorina metulata Aïssa et Vitiello. 1977	-	-	-	-	-	-	-	-	-	-	-	1.98	-	0.16
Cyatholaimus prinzi (Marion. 1870)	-	-	-	-	-	-	-	1.94	-	-	2.04	-	-	0.15
Synonchiella edax Aïssa et Vitiello. 1977	-	-	3.00	-	2.73	-	0.96	-	-	-	-	-	-	0.12
Neochromadora poecilosomoides (Filipjev. 1918)	-	-	-	-	-	-	-	-	-	-	-	0.99	-	0.08
Euchromadora striata Eberth. 1863	-	-	3.00	-	-	-	-	-	-	-	-	-	-	0.05
Daptonema proprium (Lorenzen. 1971)	-	-	-	-	-	-	1.92	-	-	-	-	-	-	0.04
Odontophora villoti Luc et de Coninck. 1959	-	3.00	-	-	-	-	-	-	-	-	-	-	-	0.03
Theristus flevensis Stekhoven. 1935	-	-	1.00	-	-	-	-	-	-	-	-	-	-	0.02
Calomicrolaimus honestus (Jayasree et Warwick, 1970)	-	1.00	-	-	-	-	-	-	-	-	-	-	-	0.01

Daptonema fallax, Daptonema normandicum, Metalinhomoeus numidicus, Prochromadorella neapolitana, Desmolaimus demani, Sabatieria granifer, Sabatieria longicaudata, Terschellingia communis and *Metoncholaimus pristiurus*. These 11 species comprise more than 75% of the total number of nematodes collected.

As shown in Fig. 5, diversity (H') and evenness (J) were greatest at stations near the marine inputs (BG6, BG9 et BG13). The most isolated sites (BG1 and BG2), dominated by *Daptonema normandicum*, had the lowest nematode diversity and evenness. This species was absent from stations BG6, BG9 and BG13 (Table 3).

The overlapping of the k-dominance curves of the stations makes it difficult to compare their nematode community diversity. However, k-dominance curves of the sites near the marine inputs (BG6, BG9 et BG13) show a clear picture of decreasing dominance and increasing diversity (Fig. 6).

The regrouping of the sampling sites on the basis of Euclidean distance according to

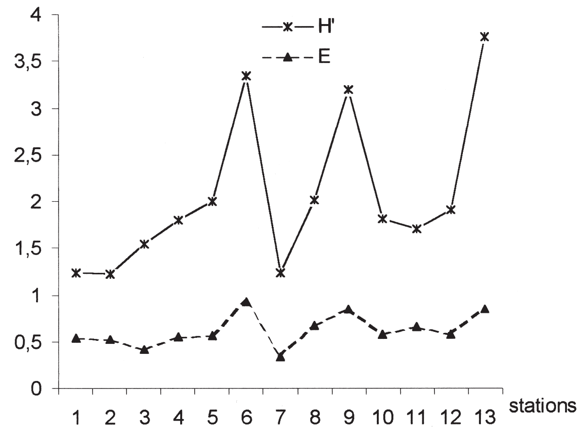

Fig. 5: Spatial variation of diversity indices (H' in bits and E) in Bou Ghrara lagoon during winter 2000. The stations 1-13 correspond to BG1- BG13 in Figure1.

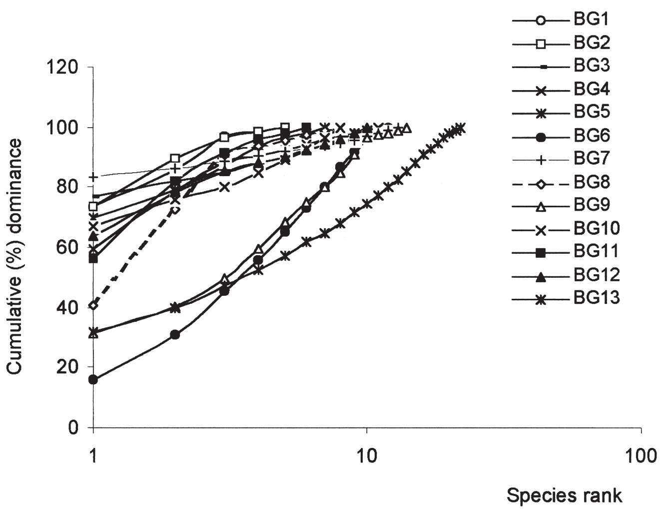

Fig. 6: Spatial variation of k-dominance curves in Bou Ghrara lagoon during winter 2000.

the Shannon diversity index values (H' in bits) showed a nematode diversity gradient from BG2 to BG6, BG9 and BG13 (Fig.7).

Discussion

Sediment hydrocarbon content recorded in Bou Ghrara lagoon, an ecosystem that has important fisheries, were comparable to those found in polluted marine sediment (Table 4).

The *TOC* concentrations we measured in Bou Ghrara lagoon were comparable to those observed in polluted sediments of the south lagoon (0.75 – 5.36 % *dw*) (HERMI, 2001) and higher than those measured in sediments from the Aegean Sea (0.22 – 0.78 % *dw*) (HATZIANESTIS *et al.*, 1998).

The total nematode abundance, mean individual weight, mean total biomass and diversity that we recorded were comparable to those reported in polluted marine sediments (Table 5).

There are several environmental variables that determine the distribution of interstitial fauna (SWEDMARK, 1964; McINTYRE, 1971). In Bou Ghrara lagoon, the organic carbon, hydrocarbon and heavy metal content

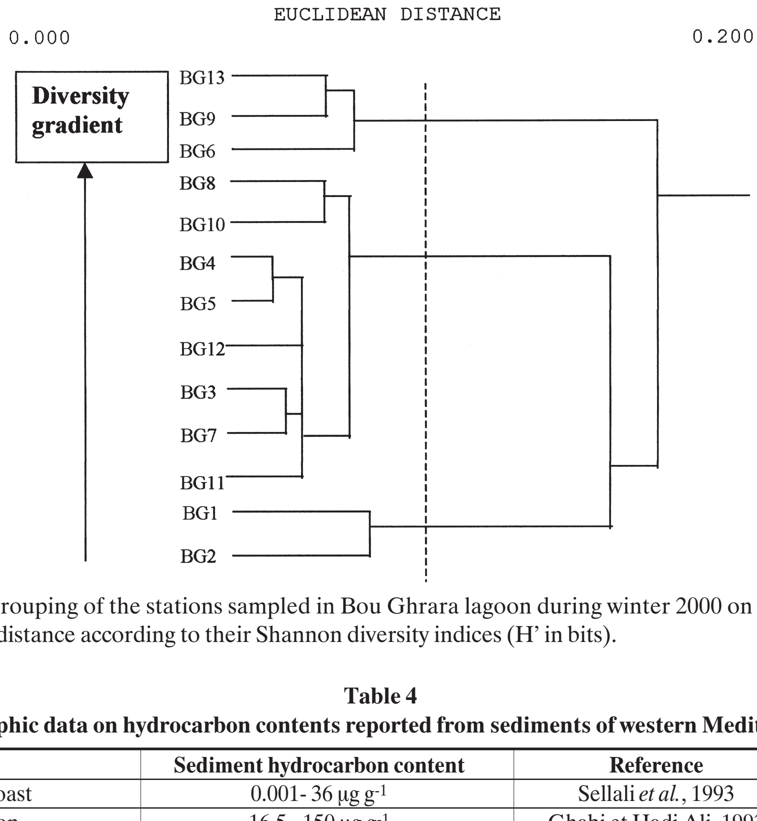

Fig. 7: Regrouping of the stations sampled in Bou Ghrara lagoon during winter 2000 on the basis of Euclidean distance according to their Shannon diversity indices (H' in bits).

Table 4
Bibliographic data on hydrocarbon contents reported from sediments of western Mediterranean.

Biotope	Sediment hydrocarbon content	Reference
Algerian coast	0.001- 36 $\mu g\ g^{-1}$	Sellali *et al.*, 1993
Tunis lagoon	16.5 - 150 $\mu g\ g^{-1}$	Ghabi et Hadj Ali, 1993
Gulf of Tunis	1.8 - 122.5 $\mu g\ g^{-1}$	Ghabi et Hadj Ali, 1993
Bizerta lagoon	2 - 20 $\mu g\ g^{-1}$	Ghabi et Hadj Ali, 1993
Gulf of Fos/mer	0.04 - 47.58 $g\ kg^{-1}$	Le Dréau *et al.*, 1997
Bay of Bizerta (1992)	0.07 - 7.61 $mg\ g^{-1}$	Beyrem et Aïssa, 1998
Bay of Bizerta (1996)	2.37 - 3.39 $mg\ g^{-1}$	Beyrem et Aïssa, 2000
Bou Ghrara lagoon	0.05 - 6.4 $mg\ g^{-1}$	*This work*

Table 5
Bibliographic data on free-living nematode abundance (Individuals 10 cm^{-2} (Ind. 10 cm^{-2})), individual weights (µg dry weight (dw)), total biomasse (µg 10 cm^{-2} dw) and diversity (H' in bits) in some disturbed areas. * Value given by the Author (s) in wet weight.

Sites	Abundance Ind. 10 cm^{-2}	Individual weight (µg dw)	Total biomass (µg 10 cm^{-2} dw)	H'	Reference
Marseilles' sewage outfall	2 - 4218	0.07* - 0.24*	0.28* - 844.5*	0.7 -7.34	Keller, 1984
North lagoon of Tunis	2 -1285	0.25* - 0.67*	0.50* - 785.50*	0.31 - 2.73	Vitiello & Aïssa, 1985
Bizerta Bay	14 - 837	0.27 - 1.08	15.25 - 729.25	0.72 - 5.06	Beyrem & Aïssa 2000
South lagoon of Tunis	1 - 2242	0.24* - 0.85*	8.25* - 1046.50*	0.24 - 2.23	Hermi, 2001
Ghar El Melh lagoon	10 - 210	0.06 - 0.88	1.15 - 183.75	0.56 -3.30	Mahmoudi *et al.*, 2002
Bou Ghrara lagoon	154 - 5641	0.19 - 0.81	33.82 - 4569.21	1.22 - 3.76	*This work*

of sediments were the most important factors influencing the abundance, biomass and diversity of the nematofauna.

Although a fraction of the organic matter deposited in sediments was labile and hence of potentially high nutritional value for benthic consumers (NEIRA *et al.*, 2001), nematode abundance, mean individual weight, mean total biomass and diversity were negatively and highly correlated with sediment total organic carbon (*TOC*) amount ($p<0.01$). Even though the effects of the organic matter generally, and the *TOC* in particular. on nematofauna have not been totally clarified, recent studies have indicated that total abundance, diversity and species richness decrease significantly with increasing level of organic enrichment (SCHRATZBERGER & WARWICK, 1998). After the organic loading has eliminated the deeper-living nematodes, the second stage in the faunal succession following the increasing level of the organic load is characterized by the numerical dominance of opportunistic species (PEARSON & ROSENBERG, 1978). These nematode species, better adapted to pronounced unbalanced situations, proliferate and total nematode density can then increase even under polluted conditions.

It is worth mentioning here the much delated Nematode/Copepode ratio of RAFFAELI-MASON (1981) which was based on this high resistance potentioal of this meiofaunal group.

Similary, negative and highly significant correlations have been noted between abundance, mean individual weight, mean total biomass and Shannon diversity indices (H') of free-living nematode communities and hydrocarbon sediment content ($p<0.01$). By increasing the mortality of the more sensitive species (BEYREM & AISSA, 2000; CARMAN *et al.*, 2000), hydrocarbon contamination is responsible for the decrease in nematode densities, total biomass and diversity. This is supported by the fact that the stations richest in hydrocarbons (BG1, BG2, BG3, BG5, BG7 and BG10) are those where we have recorded the lowest values of nematode densities, weights and diversity indices (H'). Besides their direct effect on nematode assemblages, hydrocarbons seem to indirectly influence the nematofauna. So, the accumulation of these pollutants in water entails a reduction its chlorophyll content chlorophyll (BOUCHER *et al.*, 1984), a decrease photosynthetic activity (LACAZE, 1993) and consequently a depletion of dissolved oxygen, a determining factor for quantitative and qualitative data of the nematofauna (JENSEN, 1987; HEIP, 1995; BEYREM & AISSA, 2000).

Although heavy metal concentrations in the sediment of Bou Ghrara lagoon are lower than the international norms (RAPPORT DGPA, 2000), significant negative correlations have been recorded between these metals (Cu, Pb and Zn) and all indices of nematode communities ($p<0.05$). The harmful effect of heavy metals on nematofauna has been demonstrated by many authors and significant negative correlations between the sediment content in these contaminants and nematode densities have been revealed (FICHET & MIRAMAND , 1996 ; ESSID , 1999). According to BURTON *et al.* (2001), heavy metal contamination significantly alters the composition of meiofauna assemblages. In Bou Ghrara lagoon, we speculate that the response of nematodes to low heavy metal concentrations is, probably attributed to the fact that these animals have particular abilities to accumulate the Cd, Cu, Pb and Zn present in their biotopes (FICHET *et al.*, 1999).

Among the 11 most dominant species identified, *Terschellingia longicaudata* and *Terschellingia communis* have been found dominant in organically enriched sediments (SCHRATZBERGER & WARWICK, 1998) and both were characterised by low oxygen consumption rates (WARWICK & PRICE, 1998). *Paracomesoma dubium* was recorded abundant in the polluted sediments of the south lagoon (Tunisia) (HERMI, 2001) and *Prochromadorella neapolitana* was found dominant at the polluted sector of the orth lagoon (Tunisia) (VITIELLO & AISSA, 1985).

The free-living nematodes of Bou Ghrara lagoon have showed a decrease in density biomass and diversity in response to pollution stress. These changes in nematofauna community structure highlight the importance of including meiofauna in impact studies of lagoons.

The response of the nematofauna described for the Bou Chrara lagoon corresponds to the first stage reaction to an incoming pollution stress and maybe refers only to the deep-living nematodes.

References

AISSA, P. & HERMI, M., 1997. Clé de détermination des familles de nématodes libres marins. *Bulletin de l'Institut National des Sciences et Technologies de la Mer,* 24: 110-128.

ALKEMADE, R., WIELMAKER, A. & HEMMINGA, M.A., 1993. Correlation between nematode abundance and decomposition rate of *Spartina anglica* leaves. *Marine Ecology Progress Series*, 99: 293-300.

AMARA, R. & BODIN, P., 1995. L'environnement trophique méiobenthique en dehors des nourriceries côtières est il favorable à l'installation des jeunes soles ? *Oceanologica Acta*, 18: 583-590.

ANDRASSY, I., 1956. Die Rauminshals-und Gewichtbestmmung der Fadenwürmer (Nematoden). *Acta zoologica hungaria*, 2 (1/3): 1 - 15.

ANSARI, Z. A., ANIL, C. & PARULEKAR, A. H., 1984. Effect of domestic sewage on sand beach meiofauna at Goa, India. *Hydrobiologia*, 3: 229-233.

BEYREM, H. & AISSA, P., 1998. Impact de la pollution pétrolière sur les densités de la méiofaune du littoral de Bizerte (Tunisie). *Vie et Milieu*, 48: 183-190.

BEYREM, H. & AISSA, P., 2000. Les nématodes libres , organismes-sentinelles de l'évolution des concentrations d'hydrocarbures dans la baie de Bizerte (Tunisie). *Cahiers de Biologie Marine*, 41: 329-342.

BOUCHER, G., CHAMROUX, S. & RIAUX, C., 1984. Modification des caractéristiques physico-chimiques et biologiques d'un sable sublittoral pollué par les hydrocarbures. *Marine Environmental Research*, 12: 1-23.

BURTON, S. M., RUNDLE, S. D. & JONES M. B., 2001.The relationship between trace metal contamination and stream meiofauna. *Environmental Pollution*, 111: 159-167.

CARMAN, K. R., FLEEGER, J. W. & POMARICO, S. M., 2000. Does historical exposure to hydrocarbon contamination alter the response of benthic communities to diesel contamination?. *Marine Environmental Research,* 49: 255-278.

CASTEL, J., 1992. The meiofauna of coastal lagoon ecosystems and their importance in the food web. *Vie et Milieu,* 42: 125-135.

COULL, B. C., 1970. Shallow water meiobenthos of the Bermuda platform. *Oecologia,* 4: 325-357.

ESSID, N., 1999. Contribution à l'étude de la pollution organo-minérale de la lagune de Bizerte: caractérisation géochimique, sédimentologique et impact sur les nématodes libres marins. Diplôme d'Etudes Approfondies, Faculté des Sciences de Bizerte, 189 p.

FELLER, R., J. & WARWICK, R. M., 1988. Energetics. In: Higgins, R.P., Thiel, H. (Eds.), Introduction to the study of meiofauna. Smithsonian Institution Press, Washington, D.C., 181-196.

FICHET, D. & MIRAMAND, P., 1996. Métaux lourds et méiofaune benthique : indicateurs de pollution des sédiments portuaires (premiers résultats). Actes du 11ème Colloque de l'Union des Océanographes de France. *Journal de Recherche Océanographique*, 21: 82.

FICHET, D., BOUCHER, G., RADENAC, G. & MIRAMAND, P., 1999. Concentration and mobilisation of Cd, Cu, Pb and Zn by meiofauna populations living in harbour sediment : their role in heavy metal flux from sediment to food web. *The Science of the Total Environment*, 243 / 244: 263-272.

GHABI, H. & HADJ ALI, M., 1993. Petroleum hydrocarbons in water and marine sediment: Bizerte lake, Tunis gulf and lake. Workshop sur la circulation des eaux et la pollution des côtes Méditerranéennes du Maghreb, Rabat (MAROC). Publié par INOC, IZMIR- Turquie, 131-133.

HATZIANESTIS, J., SKILAVAGOU, E. & FRILIGOS, N., 1998. Hydrocarbons in surface sediments from the Northern Sea. *Rapport de la Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée*, 35: 264-265.

HEIP, C., 1995. Eutrophication and zoobenthos dynamics. Ophelia, 41: 113-136.

HERMI, M., 2001. Impact de la pollution sévissant dans le « lac » Sud de Tunis sur la méiofaune. Thèse de doctorat, Faculté des Sciences de Bizerte, 300 p.

JENSEN, P. 1987. Difference in microhabitat, abundance, biomass and body size between oxybiotic and thiobiotic free-living marine nematodes. *Oecologia,* 71: 564-567.

JUARIO, J. V., 1975. Nematode species composition and seasonal fluctuation of a sublittoral meiofauna community in the German Bight. *Veröffentlichungen der Instituts für Meeresforschung in Bremerhaven*, 15: 283-337.

KANTIN, R., 1977. Application de la spectrophotométrie infra-rouge au dosage des hydrocarbures et des composés phénoliques dans l'eau de mer. *Thétys,* 4: 413-418.

KELLER, M., 1984. Influence du rejet en mer de l'égout de Marseille sur les peuplements du méiobenthos. Thèse 3ème cycle, Université Aix-Marseille II, 131 p.

KOTTA, J. & BOUCHER, G., 2001. Interregional variation of free-living nematode assemblages in tropical coral sands. *Cah. Biol. Mar.,* 42 : 315-326.

LACAZE, J. C., 1993. La dégradation de l'environnement côtier – Conséquences écologiques. Masson : Paris, Milan, Barcelone, Bonn, 149 p.

LAMBSHEAD, P. J. D., PLATT, H. M. & SHAW K.M., 1983. The detection of difference among assemblages of marine benthic species based on assessment of dominance and diversity. *Journal of natural History,* 17: 859-874.

LE DREAU, Y., JACQUOT, F., GUILIANO, M., BERTRAND, J. C. & MILLE, G., 1997. Hydrocarbon balance of a site which had been highly and chronically contaminated by petroleum wastes of a refinery (from 1956 to 1992). *Marine Pollution Bulletin,* 34: 456-458.

LEGENDRE, L. & LEGENDRE, P., 1998. Numerical Ecology, Developments in Environmental modelling. Elsevier, Amsterdam, 853 p.

MAHMOUDI, E., BEYREM, H. & A_SSA P., 2002. Réponse des nématodes libres à la qualité des eaux et des sédiments de la lagune de Ghar El Melh (Tunisie) en été 1999. *Cahiers de Biologie Marine,* 43: 83-93.

McINTYRE, A. D., 1971. Control factors on meiofauna population. *Thalassia jugoslavica,* 7: 209-215.

NEIRA, C., SELLANES, J., SOTO, A., GUTIERREZ, D. & GALLARDO, V.A., 2001. Meiofauna and sedimentary organic matter off central Chile : response to change caused by the 1997-1998 *El Ni_o. Oceanologica Acta,* 24: 313-328.

PIELOU, E. C., 1969. An introduction to mathematical ecology. Wiley-Intersciences, New-York, 286 p.

PEARSON, T. H. & ROSENBERG, R., 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. *Oceanography and Marine Biology, Annual Review,* 16: 229-311.

PLATT, H. M., SHAW, K.M. & LAMBSHEAD, P. J. D., 1984. Nématodes species abundance patterns and their use in the detection of environmental perturbations. *Hydrobiologica,* 118 : 59-66.

PLATT, H. M. & WARWICK, R. M., 1983. Free-living marine nematodes. Part I. British enoploids. Synopses of the British Fauna. Cambridge University Press, Cambridge, 314 p.

PLATT, H. M. & WARWICK, R. M., 1988. Free-living marine nematodes. Part II. British chromadorids. Synopses of the British Fauna. Cambridge University Press, Cambridge, 510 p.

RAFFAELI, DC.&MASON, C.F., 1981.Pollution monitoring with Meiofauna : Using the ratio Nematods-Copepods. *Marine Pollution Bulletin,* 12(5) : 158-163.

RAPPORT DGPA (Direction Générale de la pêche et de l'Aquaculture), 2000. Etude de l'amélioration de la qualité des eaux de la lagune de Bou Ghrara, phase I – partie II : diagnostic de la situation actuelle, 349 p.

SCHRATZBERGER, M., & WARWICK, R. M., 1998. Effects of intensity and frequency of organic enrichment on two estuarine nematodes communities. *Marine Ecology Progress Series*, 164: 83-94.

SCHWARTZ, D., 1983. Méthodes statistiques à l'usage des médecins et des biologistes. Flammarion Médecine Science, Paris, 318 p.

SELLALI, B., CHOUIKHI, A., HOCINI, N., YAHI, D. & BOUDJELLAL, B., 1993. Contamination des sédiments de la côte algérienne par les hydrocarbures polyaromatiques. *Workshop sur la circulation des eaux et la pollution des côtes Méditerranéennes du Maghreb, Rabat (MAROC).* Publié par INOC, IZMIR- Turquie, 131-133.

SHANNON, C. E. & WEAVER W., 1963. The mathematical theory of communication. Illinois University Press, Urbana. 117 p.

SOGARD, S. M., 1984. Utilisation of meiofauna as a food source by a grassbed fish, the spotted dragonet *Callionymus pauciradiatus. Marine Ecology Progress Series*, 17: 183-181.

SWEDMARK, B.,1964. The interstitial meiofauna of marine sand. *Biological Reviews,* 39: 1-42.

TEAL, J. M., WIESER, W., 1966. The distribution and ecology of nematodes in a Georgia salt marsh. *Limnology and Oceanography,* 11: 217-222.

TRASK, P. D., 1932. *Origin and environment of source sediments of petroleum.* Gulf Publication House, Houston, 323 p.

VITIELLO, P. & AISSA, P., 1985. Structure des peuplements de nématodes en milieu lagunaire pollué. 110ème *Congrès National des Sociétés Savantes, Montpellier. Sciences*, 2: 115-126.

VITIELLO, P. & DINET, A., 1979. Définition et échantillonnage du méiobenthos. *Rapport de la Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée*, 25 / 26 (4) : 279 - 283.

WARWICK, R. M., 1993. Environmental impact studies on marine communities: pragmatical considerations. *Australian Journal of Ecology,* 18: 63-80.

WARWICK, R. M., PLATT, H. M. & SOMERFIELD, P. J., 1997. Free-living marine nematodes. Part III. British monhysterids. Field Studies Council, Shrewsbury.

WARWICK, R. M. & PRICE, R. 1979. Ecological and metabolic studies on Free-living marine nematodes from an estuarine mud-flat. *Estuarine and Coastal Marine Science*, 9: 257 - 271.

WIESER, W., 1960. Benthic studies in Buzzards Bay. II. The meiofauna. *Limnology and Oceanography,* 5 : 121 - 137.

WILKINSON, L., HILL, M., WELNA, J. P., BIRKENBEUEL, G. K., 1992. Systat for Windows: Statistics, Version 5. Systat, Inc., Evanston, IL.