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MORPHOLOGICAL VARIATION IN NEMATODE COMMUNITIES IN RELATION TO EUTROPHICATION PROCESSES IN A SHALLOW-WATER MEDITERRANEAN BAY

Cruz PALACÍN[1], Josep-Maria GILI[2] & Daniel MARTIN[3]

[1]Departament de Biologia Animal (Invertebrats), Fac. Biologia, Univ. Barcelona, Avd. Diagonal 645, 08028 BARCELONA,
[2]Institut de Ciencies del Mar (CSIC), Passeig Nacional s/n, 08039 BARCELONA,
[3]Centre d'Etudis Avançats de Blanes (CSIC), Cami de Santa Barbara s/n, 17300 BLANES, Spain.

ABSTRACT

(1) Continental runoff imported considerable amounts of silt and organic matter during a short time-period into Alfacs Bay (Ebro Delta) affecting mainly the northern-central parts of the Bay. This eutrophication process coincided with the differentiation of nematode communities in the Bay.

(2) The species of the affected zone were characterised by having smooth or only finely striated cuticles, short cephalic setae, few somatic setae, and most of them were epigrowth feeders.

(3) The species of the non-affected zone were characterised by their strongly striated cuticles, the cephalic setae that were longer than in the species of the affected zone and the presence of a large number of somatic setae. Moreover, a great number of the species in this zone were omnivores or predators even though the epigrowth feeders were well represented.

INTRODUCTION

The general patterns of meiofaunal distribution in estuarine systems are largely determined by time-space fluctuations of a wide range of environmental factors. Salinity gradients, linked to the dynamics of the estuary's hydrographic processes have traditionally been considered as the main cause of the variations in diversity and abundance of the estuarine meiofauna (Carriker, 1967).

Continental waters which penetrate the estuaries frequently flush out an important fraction of suspended organic matter and sediments. If the inflows exceed the water renewal of a given area, this can start perturbation processes (i.e. eutrophication) to such an extent that both the abundance and the specific composition of the meiofaunal populations are modified (Pearson & Rosenberg, 1978; Gray, 1992). These perturbation processes are directly related to the intensity and duration of the runoff.

Meiofaunal organisms. and nematodes in particular, respond in an almost immediate way to an increase in environmental perturbation (Heip *et al.*, 1985). This is partly due to the high turn-over of some species and partly because the persistance of other species is assured because of their capacity to develop physiological adaptation mechanisms (Vernberg & Coull, 1981). Furthermore, the new characteristics of the sediment, generated by the continental runoff, also seem to be related to the morphological characteristics of the species which persist (Warwick, 1971).

The purpose of the work described in this paper is to analyse the effect of runoff on the nematode populations of a shallow-water semi-enclosed bay (Alfacs Bay, NW Mediterranean). The species composition of the communities in the affected areas has already been demonstrated to be clearly different from those in the rest of the Bay (Palacín *et al.*, 1992). Our working hypothesis deals with the assumption that the processes of sediment transportation and deposition are not the only factors that determine the presence of different nematode species in the affected or non-affected areas, but that this selection process is based on their morphological characteristics as well. Those characteristics which are the most suitable to ensure their survival on the different estuarine soft-bottoms dominate in the resulting community.

STUDY AREA

Alfacs Bay is located in the delta of the River Ebro (Western Mediterranean, 40°33' - 40°38' N, 0°32' - 0°44' E). Fresh water flows into the bay seasonally through a complex network of drainage canals with a maximum in summer. During the rest of the year, the water remains trapped in the crop fields and in the coastal lagoons of the deltaic plain (Figure 1). although the inflow period is relatively short, the intensity of the runoff can be such that it triggers a eutrophication process (Mallo *et al.*, 1993), which has a direct effect on the meiofaunal populations, including nematodes (Palacín *et al.*, 1992).

The hydrographic characteristics and the peculiar structure of Alfacs Bay imply that the greatest runoff impact occurs in the areas nearest the mouths of the drainage canals which are situated exclusively on the northern shore (Figure 1). In these areas, a very different community from that in the rest of the bay is generated, through the increase in spatial heterogeneity (Palacín *et al.*, 1991, 1992).

MATERIAL & METHODS

During July 1987 a total of 23 stations throughout the Bay were sampled (Figure 1). Samples were gathered using 12,5 cm diameter cores, with a maximum depth of 8 cm. the meiofaunal organisms were separated by density using an elutriator (Boisseau, 1957), collected on a 55 µm mesh and sorted under a stereomicroscope. The nematodes were dehydrated and mounted in glycerine for identification under a light microscope.

Additionally, measurenents were taken of different environmental parameters such as salinity, temperature, percentage of organic matter, granulometry of the sediment and the bacterial biomass (Palacín *et al.*, 1992).

The stations were classified by means of multivariate clustering analysis, using Czekanovski metrics for distance and the UPGMA aggragation algorithm. The analysis was carried out with the aid of a statistical package developed by D. J. Lleonart of the Instituto de Ciencias del Mar in Barcelona.

RESULTS

Using the classification analysis based on environmental parameters, two groups of stations can be identified (Figure 2). The first group basically includes those stations located around the northern shore of the Bay, the shore most directly affected by the continental runoff. The second group covers the rest of the Bay, where the perturbation process can hardly be detected (Table I).

The classification of stations using nematode species results in groups quite similar to the abovementioned ones, with two separate clusters, although they are rather more defined (Figure 3).

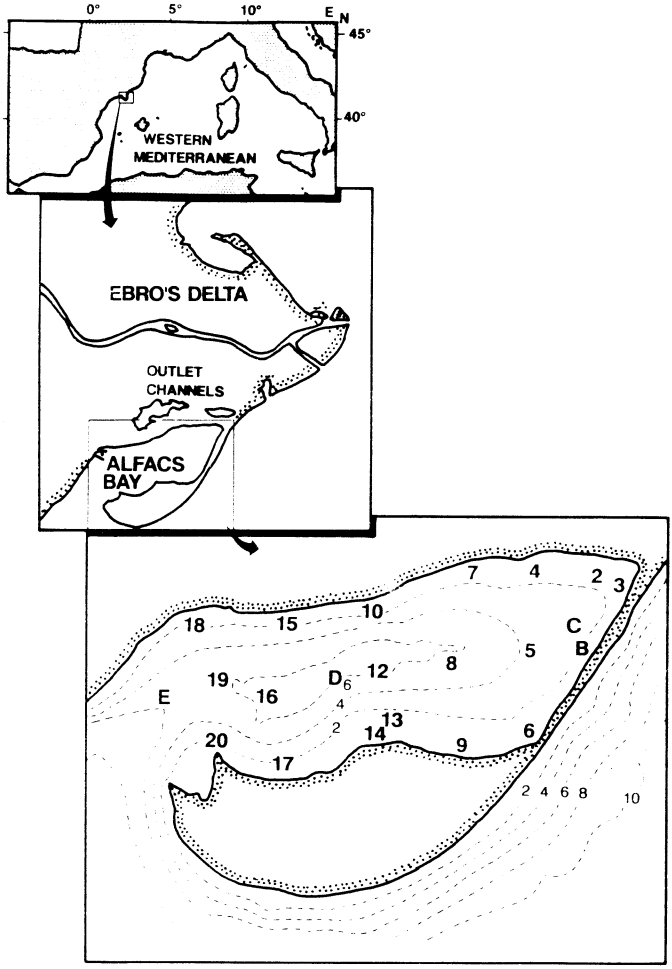

Figure 1. Location of Alfacs Bay and sampling station grid.

The first group covers the southern area whilst the second group is, in turn, divided into two, the northern area and the central basin. The two subgroups of the second group have muddy or sandy-muddy bottoms which are affected in a different way by the perturbation caused by the continental runoff. The northern subgroup receives the inflows directly, whilst the central area is affected by the sedimentation and subsequent accumulation processes. The group in the southern area, on the other hand, has an extremely clean sandy bottom with almost marine characteristics.

The differences between the morphological characteristics of the most abundant species in each of the two main groups (muddy bottoms and sandy bottoms, respectively) are shown in Table II. In general, it seems that species from the sandy bottoms tend to show a more balanced sex ratio, a more marked cuticular striation, a moderate number and size of somatic and cephalic setae and they are slightly smaller than the species from muddy bottoms. At the same time, the epigrowth feeders tend to dominate over the deposit feeders.

This tendency towards a morphological differentiation is even more evident when one takes an overall view of the most typical species of the populations established in each of the two areas (Table III). Thus, the most dominant species in each area shows different examples of some of the distinctive morphologies towards which the respective populations could evolve (Figure 4).

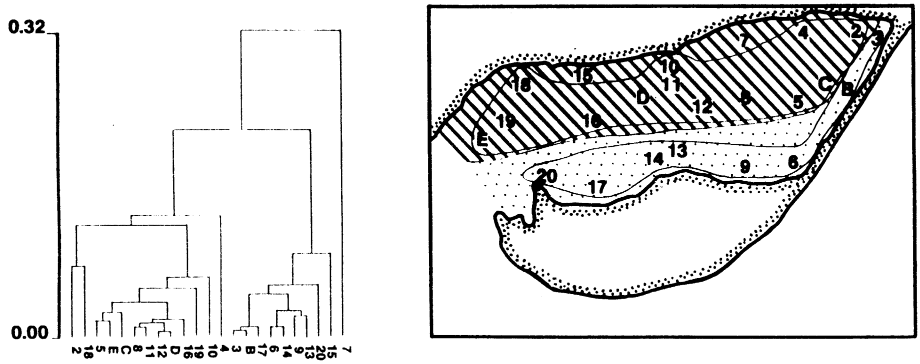

Figure 2 Cluster analysis based on environmental variables and location of the resulting assemblages in the bay (shaded zone corresponds to the muddy bottoms affected by runoff).

Table I

Minimum and maximun values for environmental factors (between samples) in the affected, and the zone non-affected zone by continental runoff in the bay.

	Affected (North)	Non-affected (South)
% silt and clay	4 / 94.23	0.01 / 2.5
% organic matter	0.73 / 7.37	0.57 / 0.89
Redox potential (mV)	-73.4 / -290.5	16.5 / -200
Temperature (°C)	23 / 29.3	23 / 29.5
Salinity (%)	20 / 36	29 / 37

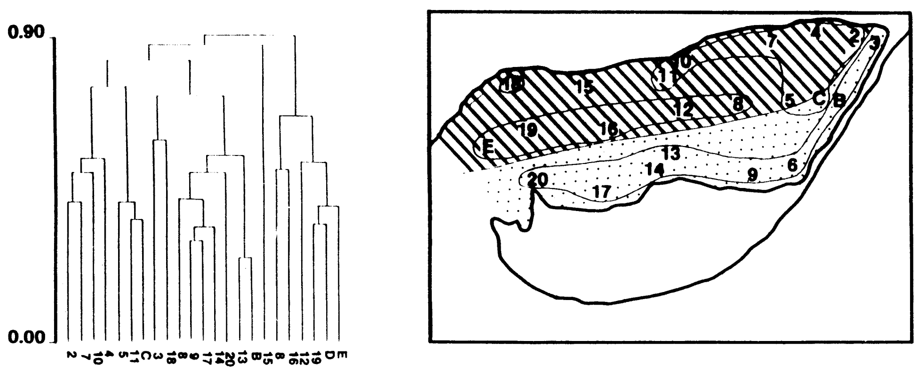

Figure 3. Cluster analysis based on nematode species and location of the resulting assemblages in the bay (shaded zone corresponds to the muddy bottoms affected by runoff)

Table II

Morphological features of the most abundant species of nematodes in Alfacs Bay; Sex ratio (♂ / ♀ %), Feeding group (1A, selective deposit feeders, 2A, epigrowthfeeders, 1B, no selective deposit feeders, 2B, omnivore predators), Cuticule striation (0 little to 5 much), Size of cephalic setae (considering absolute lengt) (1, small to 5, large), Number of somatic setae (0, little to 5, much), Size of somatic setae (1, small to 5, large), Size (mm), Abundance (mean number of individuals 10 cm $^{-2}$).

SANDY ZONE

Species	Abundance	Sex ratio	Feeding group	Cuticle striation	Cephalic setae	Somatic setae n	Somatic setae size	Body size ♂	Body size ♀
Richtersia vincxae	56.4	23/77	1B	5	1	3	1	0.6	0.5
Chromaspirina chabaudi	29.4	33/67	2A	4	3	1	1	2.2	2.2
Paracanthonchus mediterraneus	45.5	36/64	2A	4	3	3	2	2.6	2.5
Chromaspirina papillicaudata	22.1	42/58	2A	4	3	2	1	2.4	1.8
Nannolaimoides decoratus	23.0	29/71	2A	5	3	1	1	1.9	1.9
Pomponema complexa	20.6	72/2	2B	5	3	1	3	2.9	2.6
Desmodora ovigera	16.7	14/86	2A	5	2	5	3	1.6	1.5
Spirina parasitifera	14.8	29/71	2A	3	1	1	1	2.7	2.7

MUDDY ZONE

Species	Abundance	Sex ratio	Feeding group	Cuticle striation	Cephalic setae	Somatic setae n	Somatic setae size	Body size ♂	Body size ♀
Paracomesoma dubium	59.1	20/80	2A	3	2	1	1	2.8	2.8
Sabatieria pulchra	70.1	20/80	1B	3	1	0	0	1.5	1.5
Spirina parasitifera	42.7	28/72	2A	3	1	1	1	2.7	2.7
Terschellingia longicaudata	25.6	45/55	1A	0	2	1	2	1.3	1.3
Stylotheristus mutilus	22.6	22/78	1B	1	3	2	2	1.5	1.5
Paracomesoma longispiculum	15.1	35/65	2A	3	4	1	1	2.3	2.7
Dorylaimopsis mediterranea	14.8	21/79	2A	3	1	1	1	2.9	2.5
Metoncholaimus albidus	17.1	32/68	2B	0	1	2	2	7.1	7.1

Table III

Percentage of species in muddy (N. 64) and sandy (N. 50) bottoms having each morphological features considered (see caption of Table I).

	MUDDY	SANDY
Feeding group		
1A	15	10
2A	47	34
1B	24	32
2B	14	24
Size of cephalic setae		
0	1	2
1	21	23
2	28	30
3	34	27
4	14	16
5	2	2
Size of somatic setae		
0	22	20
1	20	40
2	21	18
3	6	16
4	1	6
5	0	2

	MUDDY	SANDY
Cuticle striation		
0	30	24
1	16	12
2	18	14
3	18	16
4	10	16
5	8	18
Number of somatic setae		
0	25	20
1	39	30
2	15	24
3	11	16
4	5	6
5	5	4

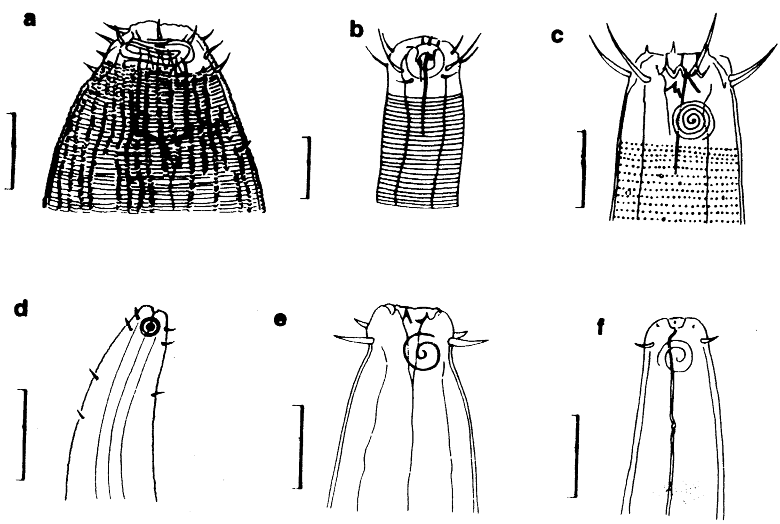

Figure 4. Graphic representation of the three most characteristic species in sandy bottoms (**a**, *Richtersia vincxae*, **b**, *Chromaspirina chabaudi*, **c**, *Paracanthonchs mediterraneus*) and muddy bottoms (**d**, *Spirinia parasitifera*, **e**, *Paracomesoma dubium*, **f**, *Sabatieria pulchra*). Scale a, b, c, e, f equals 20 μm; Scale d equals 40 μm.

DISCUSSION

The continental runoff reaching the northern-central zone of Afacs Bay gave rise to a depositing process of fine sediments and organic matter which substantially modified the physical and chemical conditions of the sediments in the area during the period of this study in such a way that the original sediments, which were sandy to start with, became more compact and even covered by a clayey, muddy layer. This layer favours the increase of bacterial biomass (Mallo *et al.*, 1993), whilst the phytobenthic biomass tends to decrease (Delgado, 1989). At the same time, the benthic macrofauna is also affected, showing a drastic reduction in density (Palacín *et al.*, 1991).

Given the massive response to the perturbaton process detected in the area's different benthic compartments, it is hardly surprising that the species of nematodes which were found there also present morphological and physiological characteristics adapted to ensure their survival on the newly originated bottoms (Table II).

Most of the silty bottom species tend to have an opportunistic way of life and to occupy only the first few centimetres of the sediment column (Pearson & Rosenberg, 1978). The nematode species which do not have to penetrate the substratum do not need to develop very striated cuticles and long somatic and cephalic setae. Thus, the abundance of organic bacteria and detritus favours deposit feeders (the principal component of whose diet is bacteria) as opposed to epigrowth feeders (Montagna, 1984). The sex ratio, which leans towards the female, could be related to the need to possess a greater reproductive capacity in answer to the inherent instability of the habitat. Changes in the growth rates and in the duration of the life cycles of marine invertebrates are, perhaps, one of the most evident phenomena which occur as a phenotypical answer to variations in environmental conditions (Appledoorn, 1989).

The development of more striated cuticles and a greater number of setae in species from sandy bottoms is directly linked to the nature and structure of the substratum (more oxygenated, less compact and with a larger volume of available interstitial space). Indirectly, this is also due to the greater number of interspecific relationships which can be established in a habitat where there is a high level of environmental stability and specific diversity, leading to very high possibilitites of contact and competition between species (Warwick & Gee, 1984). Furthermore, the organic matter, although sufficient, does not constitute an additional influx of perturbation and the available food resources are more varied, favouring the presence of other trophic-functional groups, especially of the epigrowth feeders. On the other hand, the reduction in population losses has been linked to a decrease in reproduction rates in the stable-habitat meiofaunal species (Vernberg & Coull, 1981).

A guideline of spatial distribution of nematode populations, and one that is equivalent to the populations observed in Alfacs Bay, has been described in a more defined way, and on a larger scale, in the Exe estuary (Warwick, 1971). Species with characteristics typical of muddy bottoms subject to environmental perturbations are found in the innermost part of the estuary, whilst those species typical of sandy, more stable bottoms, similar to the marine type, are located around the mouth of the estuary. In this way, it is clear that the morphology of meiofaunal species established in the different benthic habitats of an estuary is an excellent indicator of the environmental factors (biotic or abiotic) which have deliminated the specific composition of each community.

Changes in the specific composition and abundance of nematode communities as a response to a process of organic contamination have been previously reported (Platt *et al.*, 1984; Moore & Bett, 1989; Newell *et al.*, 1991). The fact that these changes lead to variations in the morphology and functionality of the species has received comparatively little attention (Heip *et al.*, 1985; Palacín, 1991). For example, the nematodes react to the environmental changes replacing species with long setae by those with short ones or vice versa. The nematodes' capacity for rapid adaptation in front of changes in environmental conditions is higher than that of other meiofaunal organisms and also higher than that of the majority of the macrofaunal organisms (McIntyre, 1977; Warwick *et al.*, 1990). Nematodes are thus a group particularly suitable to study those processes which are related to punctual inflows of organic contamination.

In conclusion, changes produced in the structure and composition of sediments, due to processes of environmental perturbation (i.e. eutrophication), have been found to be associated with a community differentiation process. This process can be detected not only through the variation in the specific composition of the nematode populations but also, and in a more evident manner, in the species morphology. The morphological characteristics of the most abundant species are adequate for survival in each generated environment, including the organically polluted area.

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