Impact of discards of beam trawl fishing on the nematode community from the Tagus estuary (Portugal)

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ABSTRACT

The impact of dead discards, originating from beam trawl fishing on the nematode community from the Tagus estuary was investigated in terms of vertical distribution of the dominant nematode groups. Sediment cores were collected from a mud-flat from the Tagus estuary. Crangon crangon (Linnaeus, 1758) carcasses were added to the surface of the cores, simulating the settling of dead discards on the sediment. The vertical distribution of the dominant nematode groups was determined up to 4 cm deep at four different moments in time post deposition (0, 2, 4 and 6 h) and compared to control cores. The C. crangon addition to the sediment led to the formation of black spots and therefore oxygen depleted areas at the sediment surface. The Chromadora/Ptycholaimellus group, normally dominant at the surface layer, migrated downwards due to their high sensitivity to toxic conditions. Sabatieria presented the opposite trend and became the dominant group at the surface layer. Since Sabatieria is tolerant to oxygen stressed conditions and high sulphide concentrations, we suggest that it migrated opportunistically towards an unoccupied niche. Daptonema, Metachromadora and Terrichelliella did not show any vertical migration, reflecting their tolerance to anoxic and high sulphidic conditions. Our study showed that an accumulation of dead discards at the sediment surface might therefore alter the nematode community vertical distribution. This effect is apparently closely related to toxic conditions in the sediment, induced by the deposition of C. crangon at the sediment surface. These alterations might be temporal and reflect an adaptation of the nematode community to dynamic intertidal environments.

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1. Introduction

Fisheries are an important provider of food, employment and income. An increasing number of studies are focusing on the side effects of fishing activities on the marine ecosystem (Kaiser et al., 2000; Jennings et al., 2001). One of these side effects is the generation of “bycatch”, which are accidentally caught species of no commercial interest (Hall, 1996). This bycatch is often returned to the sea as discards (Jennings et al., 2001).

The Tagus estuary is the only Portuguese estuary, where beam trawl fishing is allowed and the beam trawl is the most used fishing gear in the upper part of the estuary. Information about beam trawl fishing in the Tagus estuary is scarce and no estimates on catches and fishing effort (Cabral et al., 2002) are available. Total amount of fishery discards in the upper part of the Tagus estuary is estimated to be approximately 1500 ton per year, representing ca. 90% of the captures. This corresponds to an input of particulate organic matter of more than 140 ton of carbon and 35 ton of nitrogen per year (Cabral et al., 2002). Beam trawl fishing in the Tagus estuary is mainly targeted towards the soles Solea solea (Linnaeus, 1758) and Solea senegalensis Kaup, 1858 and discards are dominated by C. crangon (Linnaeus 1758) (Cabral et al., 2002). After sorting on board, the bycatch is discarded. Mortality of C. crangon can be high and reach up to 96% (Gamito and Cabral, 2003). A large portion of the discard consists of carcasses which can attract different necrophagous species such as demersal fish and benthic invertebrates (Nickell and Moore, 1992; Kaiser and Spencer, 1996; Kaiser and Ramsay, 1997; Gamito and Cabral, 2003), pelagic fishes and dolphins (Hill and Wassenberg, 1990) or marine birds (Blaber et al., 1995; Garthe et al., 1996; Oro and Ruiz, 1997). An input of organic matter or general eutrophication can have a strong effect on the benthic community, altering diversity, density and community composition (e.g. Beukema, 1991; Palacin et al., 1992; Beukema and Cadée, 1997; Mazzola et al., 2000; Vanaverbeke et al., 2004).

Decomposition of C. crangon carcasses deposited on the sediment can create anoxic patches in the sediment (pers. observation), probably as a result of the oxygen consumption of the
microbes responsible for the decomposition of these organisms. It has previously been reported that fine grained sediments easily become anoxic after the settling of organic matter (OM) at the sediment surface (e.g. Olafsson, 1992; Van Duyl et al., 1992; Bickford, 1996; Kristensen, 2000; Steyaert, 2003). Since oxygen plays an important role in the vertical distribution of intertidal nematode communities (Steyaert et al., 2005), we investigated the effect of the addition of C. crangon carcasses on the surface of Tagus sediments. Nematodes are known to migrate both horizontally and vertically. Horizontal migration was observed in recolonisation experiments (Schratzberger et al., 2000, 2004), while vertical migrations were described as a response to tides (Steyaert et al., 2001) or changing oxygen concentrations (Steyaert et al., 2005). Here, we test the hypothesis that discards of C. crangon (through the triggering of anoxic patches in the sediment during the decomposition process) will not affect the vertical distribution of intertidal nematode communities.

2. Materials and methods

2.1. Study site

Sampling was conducted in an intertidal mudflat of the Tagus estuary (38°44′N, 9°08′W) near Alcochete (Fig. 1) in March 2005 during ebb tide. The sediment temperature was 16°C and the salinity of the interstitial water was 28%. The surface of the sediment was sampled for pigment analysis, grain size, Total Organic Matter (TOM) and water content. For each analysis triplicates of 5 ml of sediment were collected. These samples were stored in the cold in the field and frozen (−80°C) in the laboratory until further processing.

Chlorophyll a was analyzed by HPLC (Gilson) following Wright and Jeffrey (1997). Water content was estimated comparing sediment wet weight and dry weight measured after 24 h at 60°C. TOM content was determined by comparing dry weight and ash free dry weight after burning in a muffle furnace (2 h at 450°C).

Grain size analysis was performed using a Mastersizer 2000 Hydro G particle size analyser. From previous local beam trawl fishing campaigns sufficient amounts of the shrimp C. crangon were kept frozen (−20°C) until both experiments.

2.2. Bacterial community experiment

To determine the effect of the discards on the bacterial community 10 shrimps were fixed to the sediment surface using a wire. The sediment underneath (0–1 cm deep) was sampled after 0, 2, 4, 6 and 24 h (after two tidal cycles) using a 1.7 cm i.d. core, replicated twice. The same procedure was repeated in sediment with no shrimp as control.

For the bacterial density determination, 1 cm³ of sediment was added to 10 ml of sterilized physiologic serum and homogenised by shaking in a vortex for 15–30 s, creating the original resuspension. A series of dilutions (1:10) from the original resuspension was made by serial transferring 1 ml to another tube to which was added 9 ml of sterilized physiologic serum.

An initial inoculation of the solutions was done to determine the adequate dilutions to use in order to have an acceptable number of colonies (approximately 100–300) in each inoculated plate, only then the correct dilutions were inoculated and three replicates of each were made. The inoculation procedures were as follow: the solution to be inoculated was homogenised by shaking in a vortex for 15–30 s; with a sterilised pipette 0.2 ml were transferred to a plate; for each inoculation a new sterilised pipette was used; glass pearls were then added and the plate shook horizontally in order to homogeneously distribute the bacteria present in the inoculum; the glass pearls were redrew and the plate were incubated in a 28°C oven for three days.

After incubation the colonies present in each plate were counted. The bacterial density was then calculated and a mean of the replicates of each sample was calculated.

2.3. Nematode community experiment

Twenty seven C. crangon individuals were divided into 9 C. crangon units, each one comprising three shrimps. The shrimp units were thawed and weighed previous to the experiment, with an average of 2.302 g (±0.048SE) per shrimp unit.

In the field 3 large perspex cores (i.d. 10–15 cm) were collected for shrimp incubation. The shrimp units were placed at the surface of the sediment and left there for 4 h until the experiment started (time 0 h) in order to initiate the decomposition of the carcasses (following results from the previous experiment).

In addition, 21 perspex cores (i.d. 3.6 cm) were used to collected sediment to a depth of 10 cm, closed, and transported to the laboratory together with the shrimp incubation cores. After 4 h of shrimp incubation, 3 “Reference Cores” (Time 0 h) were sliced in to the following layers: 0–0.5; 0.5–1; 1–1.5; 1.5–2; 2–3 and 3–4 cm and the samples were fixed in a 4% formaldehyde tap water solution. Nine of the remaining cores were then incubated with the decomposing shrimps (3 shrimps per core – Shrimp Cores) and 9 cores were left without shrimps (Control Cores). Since the surface of the cores was 10 cm², decomposing shrimp covered almost the complete surface of the shrimp cores. The experiment ran for 6 h in total, which is the average exposure time of an intertidal flat. After 2, 4 and 6 h, 3 shrimp cores and 3 control cores were treated as described above. Ambient room temperature was 23°C during the duration of the experiment and resembled the outside temperature.

Meiobenthos (animals passing a 1 mm sieve and retained on a 38 μm sieve) was extracted from the sediment by centrifugation with a LUDOX HS-40 solution (Heip et al., 1985) and kept in a 4%
formaldehyde solution, stained with rose Bengal. For counting and identification the meiobenthos samples were rinsed into a 100 ml graduated measuring cylinder which was topped with water until 100 ml. The samples were stirred on a stir plate which resuspended the organisms in the water. During stirring 10 times 1 ml of the solution (a total of 10 ml corresponding to 10% of the sample) was removed with a pipette at different water heights into a counting dish. The nematodes were then counted and identified and sorted into groups under binocular and high power microscope. On average 71 nematodes (±3SE) were identified per sample. The nematodes were sorted into the following groups: (1) Chromadora/Ptycholaimellus group; (2) Daptonema group; (3) Sabateria group; (4) Metachromadora group; (5) Terschellingia group and (6) an “other nematodes” group.

2.4. Data analysis

The effect of the shrimp deposition on the bacterial community was tested using a two-way ANOVA design (treatment, time and treatment × time). Homogeneity of variances was tested using Bartlett χ². Data was transformed when necessary. Whenever significant differences were found post hoc Tukey HSD tests were performed.

In order to investigate if mortality occurred during the experiment a one-way ANOVA was used to test for statistical differences in total densities (sum of all layers) between the reference, control and shrimp cores. The effect of treatment (control and shrimp cores), time (2 h, 4 h and 6 h) and treatment × time on nematode densities in each layer was tested using a two-way ANOVA.

A two-way ANOVA was used to test the effect of treatment, time and treatment × time on the relative abundance of each nematode group in the whole core (integrating all layers) and per sediment layer. Homogeneity of variances was tested using Bartlett χ². Data was transformed when needed, with relative data being Arcsine transformed. Whenever homogeneity of variances was not achieved, Kruskal-Wallis tests were conducted for the effect of treatment and time. The STATISTICA 6 software was used and a significance level of 0.05 was considered in all test procedures.

3. Results

3.1. Sediment characteristics and visual observations

The sediment had a medium grain size of 4.79 µm (SE = 0.02) with a water content of 63.4% (SE = 0.09) and a TOM content of 9.23% (SE = 0.12). The chlorophyll a concentration at the sediment surface was 29.2 µg g⁻¹ (SE = 1.33).

In the bacterial experiment, after two tidal cycles, we could only observe the shrimps’ exoskeletons attached to the wires indicating that probably during that period the shrimps’ carcasses were eaten by other scavenger organisms leaving only the exoskeletons behind.

In the nematode experiment the shrimps covered almost the whole surface of the treatment cores. When the shrimps were removed from the sediment surface, black sediment spots were observed underneath the shrimp covered area. Shrimps were decomposing and slowly sinking in the sediment.

3.2. Bacterial community

The bacterial community was highly affect by the deposition of shrimp at the sediment surface (treatment × time: F = 8.33; df = 4; p < 0.001). There was an increase in the bacterial densities within 2 h (Fig. 2). Post Hoc tests revealed that the shrimp samples from 2, 4 and 6 h were significantly different from all the other samples and shrimp 2 and 4 did not differ from each other. After two tidal cycles (24 h) the effect of the shrimp deposition on the bacterial community was no longer significant.

3.3. Total nematode communities

Total nematode densities in the upper 4 cm, ranged between 1774 ind 10 cm⁻² and 8103 ind 10 cm⁻², averaging 4338 ind 10 cm⁻² (SE = 302) considering all the cores (Fig. 3). No significant differences were found between the reference, control and shrimp cores in total abundance (one-way ANOVA, F = 1.09; df = 2; p > 0.05).

Total nematode densities were highest at the surface layer of the sediment in the control cores, while in the shrimp cores densities were highest at the 0.5–1.0 cm after 2 h, at 1.0–1.5 cm after 4 h and at 1.5–2.0 cm after 6 h (Fig. 4).

Significant differences in nematode densities between treatments were only detected for the 0.0–0.5 cm layer (F = 39.4; df = 1; p < 0.001). The effect of time was only significant at the 1.5–2.0 cm (F = 4.44; df = 2; p < 0.05) and 3–4 cm (F = 5.02; df = 2; p < 0.05) sediment layers. Tukey HSD tests revealed significant differences between 2 h and 6 h and between 4 h and 6 h respectively. No significant differences for the interaction term (treatment × time) were detected for any of the layers.

The nematode community was dominated by the Chromadora/Ptycholaimellus group, having an overall average relative abundance
of 28.8% (SE = 1.6). The second most abundant group was Sabatieria (24.5%; SE = 1.4) followed by Daptonema (14.9%; SE = 0.8) and the lowest relative abundances were of the groups Terschellingia (9.8%; SE = 1.4) and Metachromadora (7.3%; SE = 0.6) (Fig. 5). Other
nematodes not belonging to these groups averaged 15% (SE = 0.9) of the total nematode community.

A two-way ANOVA for each nematode group on the relative abundance per core (integrating all layers) revealed no significant differences between the treatments, times or the interaction treatment × time.

3.4. Vertical distribution

In the reference situation (0 h) and in the control cores the Chromadora/Ptycholaimellus group was highly dominant at the 0.0–0.5 cm layer throughout the experiment, with relative densities fluctuating around 60% and 70% (Fig. 6). Deeper down this
dominance was shared first with the Daptonema group, at 0.5–1.0 cm, with relative densities of about 40% each, and also with the Sabatieria and Metachromadora groups, at 1.0–1.5 cm, where each group represented about 20% of the community. At 1.5–2.0 cm deep Sabatieria became the dominant nematode group, with relative densities fluctuating between 30% and 40% of the nematode community. In the deeper layers Terschellingia also became dominant and at the bottom layer (3.0–4.0 cm) dominance was shared between Sabatieria and Terschellingia, with relative densities fluctuating between 25% and 45% each. The other nematode groups showed low relative abundances below 5%.

Adding decomposing shrimp to the surface of sediment cores clearly affected the nematode community. At the surface layer significant changes in dominance were mostly observed among Chromadora/Ptycholaimellus and Sabatieria nematode groups (Table 1). There was a decrease in relative densities of the Chromadora/Ptycholaimellus group from values around 70% (control cores T6 h) to values around 40% (shrimp cores T6 h). Sabatieria relative densities on the shrimp cores reached almost 30% of the nematode community at the end of the experiment, while in the control cores it was almost absent in this layer throughout the experiment.

The Chromadora/Ptycholaimellus group also showed significant differences between treatments for layers 0.5–0.1, 0.1–1.5 and 2.0–3.0 cm due to higher relative densities in the shrimp cores at these layers. Significant differences for Sabatieria at layers 1.0–1.5 and 2.0–3.0 cm were due to lower relative densities at the shrimp cores. Significant differences between treatments were

### Table 1

Results from the two-way ANOVAs performed on each layer on the relative dominance of each nematode group (Chr./Pt.: Chromadora and Ptycholaimellus, Dapton.: Daptonema, Metach.: Metachromadora, Sabat.: Sabatieria, Tersch.: Terschellingia)

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Chr./Pt Tr Ti Tr×Ti</th>
<th>Dapton Tr Ti Tr×Ti</th>
<th>Metach Tr Ti Tr×Ti</th>
<th>Sabat Tr Ti Tr×Ti</th>
<th>Tersch Tr Ti Tr×Ti</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0–0.5</td>
<td>* ns ns</td>
<td>ns ps ns</td>
<td>ns ps ns</td>
<td>* ns ns ps ns</td>
<td>ns ns ns ns</td>
</tr>
<tr>
<td>0.5–1.0</td>
<td>* ns ns</td>
<td>ns * ns</td>
<td>ns ps ns</td>
<td>* ns ns ns ps</td>
<td>ns ns ns ns</td>
</tr>
<tr>
<td>1.0–1.5</td>
<td>* ns ns</td>
<td>ns * ns</td>
<td>* ns ns ps</td>
<td>* ns ns ns ps</td>
<td>ns ns ns ns</td>
</tr>
<tr>
<td>1.5–2.0</td>
<td>* ns ns</td>
<td>ns * ns</td>
<td>* ns ns ps</td>
<td>* ns ns ns ps</td>
<td>ns ns ns ns</td>
</tr>
<tr>
<td>2.0–3.0</td>
<td>* ns ns</td>
<td>ns * ns</td>
<td>ns * ns ps</td>
<td>* ns ns ns ps</td>
<td>ns ns ns ns</td>
</tr>
<tr>
<td>3.0–4.0</td>
<td>* ns ns</td>
<td>ns * ns</td>
<td>ns * ns ps</td>
<td>* ns ns ns ps</td>
<td>ns ns ns ns</td>
</tr>
</tbody>
</table>

Tr: treatment (control and shrimp cores); Ti: Time (2 h, 4 h and 6 h); Tr × Ti: Treatment × Time interaction. *Significant differences (p < 0.05); ns: non significant. Results in Bold Italics refer to Kruskal–Wallis tests.
found for the Metachromadora and Terschellingia groups at the 0.5–
1.0 cm layer as well.

The effect of time was only noticed at the 0.5–1.0 cm layer for the Daptonema and Metachromadora nematode groups, with signif-
icant differences between 4 and 6 h for both nematode groups. No significant differences for the interaction effect treatment × time were observed.

4. Discussion

4.1. Visual observations and bacterial densities

When removing the shrimps from the sediment surface, black sediment spots were observed at the sediment surface, indicating reduced sediment. In a microcosm experiment with decaying macrofauna, Ölafsson (1999) also observed black spots when removing the dead macrofauna from the sediment surface. The colour of the sediment gives an indication of the redox state in the sediment, with the darker colours reflecting a more negative redox potential (Rosenberg et al., 2001; Diaz and Trefry, 2006). Under decaying organisms oxygen is consumed due to bacterial activity, creating anoxic sediment patches. In both experiments we had similar re-
sults indicating that this was the case: black sediment spots under the shrimps and the increase on bacterial densities. Natural oxygen concentrations in muddy sediments of the Tagus estuary salt marshes reach already extremely low values in the first millimetre, and become undetectable at 14 mm deep (Cartaxana and Lloyd, 1999). Since the shrimps occupied almost all the core’s sediment surface, and these can induce a strong increase in the bacterial densities, oxygen stress at the surface layer was probably very high.

4.2. Nematode community

There were no significant differences in total nematode densi-
ties and relative densities between the reference, control and shrimp cores. This indicates that the experimental handling and the treatments had no significant effect on the nematode total den-
sities within the studied sediment depths (0–4 cm) and that the relative densities of each nematode group remained the same. This implies that the differences observed in this study were due to ver-
tical migration of the nematodes.

Heip et al. (1990) characterized muddy sediments as being dominated generally by a few dominant genera, including Sabatie-
tia, Terschellingia and Daptonema. Chromadorids become more important with increasing mean grain size. In the Oosterschelde estuary (The Netherlands) a very similar community was found, dominated by the genera Chromadora, Daptonema, Metachromadora, Sabatieria and Terschellingia (Steyaert et al., 2007). The nematode communities in the Tagus estuary are thus typical intertidal estu-
arine communities.

The nematodes were grouped according to genera except for the genera Chromadora and Ptycholaimellus, which were lumped. The nematodes in our samples belonging to the genera Chromadora and Ptycholaimellus were morphologically similar in terms of size and body shape. Their similar buccal cavities, together with previ-
ous feeding observations place them in the same feeding type, epi-
growth feeders sensu Moens and Vincx (1997).

Nematodes from the same functional group or same genera can behave differently (e.g. Moens et al., 1999b; De Mesel et al., 2003). However the vertical distribution of the Chromadora/Ptycholaimel-
lus group generally presented a unimodal distribution. They did not show several peaks of abundance as a result of different migra-
tion directions of closely related species. This was also true for the other groups. Therefore, grouping of nematode species in genus groups allowed a straightforward analysis of the response of the nematode community to the shrimp addition.

The first and most obvious response was the general decrease in nematode densities at the surface layer of the shrimp cores (Fig. 4). In a microcosm experiment with decaying microfauna, Ölafsson (1992) also observed lower numbers of nematodes in the patches with dead animals, although these differences were not statisti-
cally significant. In the referred experiment the microcosm con-
tained a ca. 7 cm thick mud layer. There was no vertical slicing of the sediment so if the effect of decaying macrofauna was mostly felt at the surface, it would be partly diluted when sampling to-
gether with deeper sediment. In fact we only found statistical dif-
fences in total densities at the surface layer.

The nematode communities normally concentrated at the sur-
face layer (control cores) tried to escape probably sulphidic and, therefore, toxic conditions by migrating downwards. This is not an unknown behaviour, since nematodes are able to migrate ac-
tively over a wide depth range for instance to pursue oxidised sed-
iment layers, irrespective of sediment depth (Steyaert et al., 2005). In fact the nematode density peak kept on changing with time, being at the 0.5–1.0 cm layer after 2 h, at the 1.0–1.5 cm layer after 4 h and at the 1.5–2.0 cm layer after 6 h (Fig. 4). The diffusion of toxic compounds from the surface deeper into the sediment ob-
ligated nematodes more sensitive to these toxins to keep on migrat-
ing downwards.

The lower densities at the sediment surface and higher densities deeper down in the sediment at the shrimp cores were mostly due to a downward migration of Chromadora/Ptycholaimellus. Indeed dominance of this group at the 0.0–0.5 cm layer decreased, while at deeper layers their relative densities became higher (Fig. 6, Table 1).

Both Chromadora and Ptycholaimellus mostly occur naturally at the surface of muddy sediments (e.g. Steyaert et al., 2003, 2005; this study) where the highest oxygen concentrations are found. Steyaert et al. (2007) observed a total absence of Chromadora mac-
rolaima after being subjected to two weeks of suboxic and anoxic conditions, coinciding with a high mortality of Ptycholaimellus pon-
ticus. According to their buccal cavity and feeding type, these nem-
atoles feed mostly on diatoms and other microalgae (Moens and Vincx, 1997), therefore they would not benefit from adding decay-
ing shrimp to the sediment surface. Their migration deeper into the sediment, therefore, reflects their sensitivity to toxic conditions, of-
ten associated with anoxia. Nematode migration is a known behav-
ior as a reaction to oxygen deficiency and sulphide stress (e.g. Ott et al., 1991, 2004; Hendelberg and Jensen, 1993; Steyaert et al., 2007).

The opposite behaviour could be observed in the Sabatieria group. Sabatieria relative abundance at the surface layer was signif-
icantly higher in the shrimp cores (Fig. 6, Table 1). The average density (times 2 h, 4 h and 6 h) of Sabatieria at the surface layer in the control cores was 5.8 ind cm−3 (±1.7SE) while in the shrimp cores was 18.1 ind cm−3 (±4.45E). Although the peak abundances were still located deeper down in the sediment, Sabatieria densities at the surface layer were comparatively higher in the shrimp cores. This shows that there was active migration of Sabatieria to the sur-
face and the increase in dominance was not only due to the ab-
sence of Chromadora and Ptycholaimellus. Although Sabatieria is sensitive to anoxia in the long term, it can tolerate periods of oxy-
gen depletion (Hendelberg and Jensen, 1993; Steyaert et al., 2007).

Sabatieria is commonly classified as a deposit feeder (sensu Moens and Vincx, 1997) which has bacteria and microphytoben-
thos as main food sources. Nematodes migrate towards an “opti-
mal” food source (Jensen, 1995; Santos et al., 1995; Moens et al., 1999a) and studies with stable isotopes and labelled food sources revealed opportunistic vertical migration of Sabatieria towards food sources (Franco et al., 2008, in press). Sabatieria species are
adapted to survive under low concentrations of oxygen and high sulphide concentrations which are often reflected in its vertical distribution (Hendelberg and Jensen, 1993; Steyaert et al., 1999, 2003; Franco et al., 2008, in press; this study). The intolerance of other nematodes to such conditions and also the ability to respond fast enabled Sabatieria to occupy and explore this niche. To what extent Sabatieria migration behaviour is a direct response to higher food availability or, instead, the consequence of the absence of competitors at the sediment surface or presence of competitors at the sediment horizon generally dominated by Sabatieria or even the combination of both factors, is difficult to determine. Nematodes tend to be selective feeders, showing different feeding preferences, between even congeneric species, allowing them to partition the available food sources (Moens et al., 1999b; De Mesel et al., 2004). Species interactions and different feeding strategies can be responsible by nematode vertical segregation (Steyaert et al., 2003).

Daptonema, Metachromadora and Terschellingia were not highly affected by the experiment. In the study by Steyaert et al. (2007) Daptonema species demonstrated high sensitivity to oxygen stress conditions; however, that experiment lasted for two weeks. The shorter observation time of our study might be responsible for the observed differences. Moreover, identification to species level might help clarifying this case, since more than one species of Daptonema was present in our samples (pers. obs.).

Metachromadora vivipara has been reported previously as highly adapted to low oxygen and highly sulphidic conditions (Van Geever et al., 2006; Steyaert et al., 2007). Therefore the fact that this genus was not affected was not surprising. The same is true for Terschellingia species, reported as tolerant to suboxic and anoxic conditions (Steyaert et al., 2007). However, the whole depth distribution of Terschellingia may not have been totally sampled in our experiment, since its vertical distribution can reach 10 cm deep, becoming more dominant in deeper sediment layers (Steyaert et al., pers. comm.). Even though some of these nematodes have been reported as tolerant to low oxygen and high sulphide concentrations conditions, they did not show an opportunistic behaviour as Sabatieria did.

Although significant differences between both treatments were noted at the 0.5–1.0 cm layer for the nematode groups Metachromadora and Terschellingia, these were probably influenced by the migration of the Chromadora/Pyzcholaimellus group. In the Metachromadora case, higher densities of the Chromadora/Pyzcholaimellus group at the 0.5–1.0 cm layer lowered their relative abundance in the shrimp cores (whose absolute densities were similar to the control cores). Terschellingia densities at the 0.5–1.0 cm layer were indeed higher in the control cores (after 4 and 6 h), however, as mentioned before, at this depth we were probably sampling the very upper distribution limit of Terschellingia and, except for one case, all subsamples contained 0 or 1 Terschellingia individuals. Due to calculations of densities and relative densities (also influenced by other nematode groups’ densities), these differences became significant, without really indicating active migration of these nematodes or a treatment effect.

In muddy sediments excessive organic enrichment leads to characteristically altered nematode community (Schatzberger and Warwick, 1998). Nematode species are differently adapted to living in low oxygen conditions and once subjected to hypoxia and/or anoxia some species might even disappear after a short period of time (Steyaert et al., 2005). An accumulation of dead discards at the sediment surface might therefore alter the nematode community or even have a permanent damage if remaining in the sediment for some time, favouring species well adapted to low oxygen conditions and high sulphide concentrations. However, the most probable situation is that the rising tide will bring it all back to normal conditions, as they would be if deposition of dead discards had not occurred. Estuaries are by nature very dynamic systems and the organism living there must be well adapted to such conditions. Moreover, beam trawl fishing has been happening in Tagus estuary for a long time with the bycatch being discarded to the system. The bycatch composition has been changing with changes on the target species. This constant disturbance might have been influencing the community composition already for sometime now, favouring species well adapted to this kind of disturbance. This experiment revealed two surviving strategies to such changing environment. On one hand nematodes that cannot withstand certain conditions, like oxygen stress and high sulphide concentrations, can actively migrate away from the stressed areas and on the other hand, also through migration within the sediment, more tolerant and opportunistic nematodes can, therefore, exploit niches left empty by others.

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