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Sensitivity of amphipods to sewage pollution

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ABSTRACT

Amphipods are considered a sensitive group to pollution but here different levels of sensitivity were detected among species, by analysing the impact of five sewage outfalls, with different flow and treatment levels, on amphipod assemblages from the Castellon coast (NE Spain). Sewage pollution produced a decrease in the abundance and richness of amphipods close to the outfalls. Most of the species showed high sensitivity, particularly species such as *Bathyporeia borgi*, *Perioculodes longimanus* and *Autonoe spiniventris*, whereas other species appeared to be more tolerant to the sewage input, such as *Ampelisca brevicornis*. These different responses could be related to burrowing behaviour, with fossorial species being more sensitive and domicolous species being less affected. Benthic amphipods, which live in direct contact with sediment, are widely used for bioassay and numerous species are usually employed in ecotoxicology tests for diverse contaminants. In order to consider amphipods for monitoring and biodiversity programmes, it is important to establish the degree of sensitivity of each species to different sources of pollution.

1. Introduction

The Order Amphipoda is an abundant and ecologically important component of soft-bottom marine benthic communities (Thomas, 1993). This high abundance and wide distribution suggest that amphipods could often play major roles in the ecology of these habitats (Conlan, 1994). Benthic amphipods meet several criteria that render them highly recommendable for inclusion in marine monitoring programmes and in sediment ecotoxicology tests. They are ecologically and trophically important, numerically dominant, exhibit a high degree of niche specificity, are tolerant to varying physico-chemical characteristics in sediment and water, have relatively low dispersion and mobility capabilities, live in direct contact with the sediment, have a documented sensitivity to pollutants and toxicants compared to other benthic organisms and indeed they have been considered capable of accumulating toxic substances (Reish, 1993; Thomas, 1993; Gómez Gesteira and Dauvin, 2000; Dauvin and Ruellet, 2009).

Despite it being established that most amphipods are sensitive to different kinds of pollutions (Dauvin, 1987, 1998; Gómez Gesteira and Dauvin, 2000; Dauvin and Ruellet, 2007), sensitivity to pollution for the same taxonomic group may differ from one species to another (Afli et al., 2008). In this way, Reish and Barnard (1979) observed that some amphipod species are more tolerant than others to organic pollution, and Bellan-Santini (1980) observed changes in compositions of amphipods inhabiting rocky environments related to the degree of pollution. There are >6300 species of Gammaridean amphipods (Gruner, 1993) and little is known about the ecology of most species. Conlan (1994) reviewed the role of amphipods in environment disturbance and compiled only biological information for less than 3% of all the described species. The wide distribution in both marine and fresh waters, together with the high abundance in both benthic and pelagic environments, means that there is a need for knowledge regarding the specific sensitivity of different species or at least of more abundant species. The application and use of amphipods as a biological indicator is limited by a comprehensive taxonomic and natural history knowledge (Thomas, 1993) that explains the degree of sensitivity of each species.

Moreover, ecological factors must also be considered when evaluating the potential information value of various amphipod groups. The sensitivity of a benthic species is dependent on the organism's living habits, such as burrowing behaviour and feeding strategy (Simpson and King, 2005; King et al., 2006). Tube builder amphipods may exhibit different habitat requirements and dispersion capabilities than burrowers (Thomas, 1993) and different

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trophic groups may be influenced by different routes of exposure to contaminants. These attributes must be taken into account when considering amphipods for monitoring and biodiversity programmes.

Shallow soft-bottom non-vegetated areas of the western Mediterranean Sea are commonly inhabited by the medium-to-fine sand community of *Spisula subtruncata* (Cardell et al., 1999). This community colonises exposed or semi-exposed sublittoral habitats, from the beach environment to depth of 30 m (Sardá et al., 1996). Although this community generally contains low numbers of individuals and low biomass values, a high abundance and diversity of amphipods has been reported (Bakalem et al., 2009). This widely distributed community is common off the Castellon coast (NE Spain), where several municipal treatment plants discharge wastewater. In this study, we examined the impact of five sewage outfall sites, with different flows and wastewater treatment processes, on amphipod populations.

The main objective of this paper is to test the effect of these outfalls on amphipod populations in order to characterise the sensitivity of different species and the relation with burrowing and feeding behaviour.

2. Materials and methods

In the study area off the Castellon coast (NE Spain), five locations affected by sewage outfalls along 40 km of coast were analysed (Fig. 1). These outfalls correspond to the villages of Vinaroz (location I), Benicarló (location II), Peñíscola (location III), Alcossebre (location IV) and Torreblanca (location V). Wastewater was discharged through submarine pipelines at a depth of approximately 15 m. The mean sewage flow was 222,597 m^3/month; the highest flow was registered at location II (502,612 m^3/month) whereas the lowest was registered at location V (43,256 m^3/month). Wastewater treatment plants from locations I, II, III and IV utilise a pre-treatment process, which includes an automated mechanically raked screen, a sand-catcher and a grease trap. Secondary treatment was only implemented at location V, consisting of the biological treatment of activated sludge with biological aerated filters, producing better values for water quality parameters in this location. Sediment characteristics (granulometry, percentage of organic matter and redox potential) and data related to the flow and water quality of sewage disposals have previously been presented by de-la-Ossa-Carretero et al. (2009, 2011). The study area has a constant water depth, homogeneous bottom sediment and uniform benthic communities. This homogeneous area with an established pollution gradient represents an ideal site for investigating links between macrofaunal assemblages and the effect of contaminants (de-la-Ossa-Carretero et al., 2008, 2009, 2010a,b; Del-Pilar-Ruso et al., 2010).

For each location, three distances from the discharge (0, 200 and 1000 m) were sampled, establishing two stations for each distance, keeping a constant depth of approximately 15 m (Fig. 1). Samples were collected during July, coinciding with the highest rate of sewage disposal, for a period of five years from 2004 to 2008. Three Van Veen grab samples (400 cm^2) were obtained at each station. Samples were sieved through a 0.5 mm screen, and preserved in 10% formalin. Amphipods were sorted and preserved in 70% ethanol for subsequent identification. These were identified using the Mediterranean amphipod fauna inventory established by Bellan-Santini et al. (1982, 1989, 1993, 1998), except for the genus *Bathyporeia*, which was identified according to d'Udekem d'Acoz and Vader (2005).

An analysis of variance (ANOVA), with location and distance as fixed factors and year as a random factor, was used in order to test differences in abundance, the Shannon–Wiener diversity index and the abundance of key species. Prior to ANOVA, the homogeneity of variance was tested using Cochran's test. Data were ln $(X+1)$ transformed when variances were significantly different. The SNK test (Student–Newman–Keuls) was used to determine which samples were responsible for the differences.

Non-parametric multivariate techniques were used to compare the composition of species and to determine key species that are mainly affected by sewage presence. All multivariate analyses were performed using the PRIMER version 6 statistical package (Clarke and Warwick, 1994). Triangular similarity matrices were calculated through the Bray–Curtis similarity coefficient using mean annual abundance values, in order to cluster stations according to

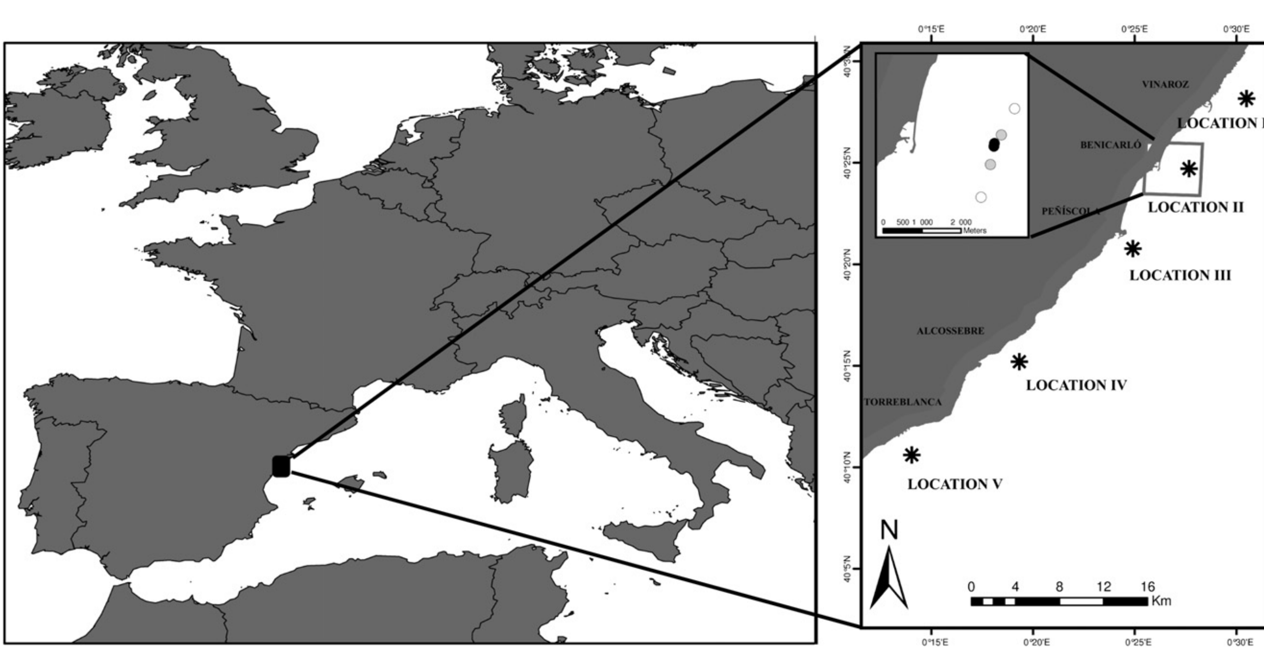

Fig. 1. Study area. Location of the five pipelines. Sampling stations of location II (colour of circle is related to distance to outfall (black: 0 m, grey: 200 m and white: 1000 m to outfall)).