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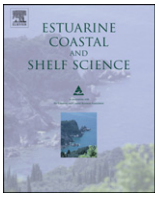

The effects of brine disposal on a subtidal meiofauna community

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ABSTRACT

Desalination plants generate notable (>1,000 s m^3) quantities of hypersaline brine which potentially affect the biological communities in the receiving area. We assessed whether proximity to a brine discharge point located off Gran Canaria (Canary Islands, eastern Atlantic) altered patterns in the abundance and assemblage structure of subtidal, soft-bottom, meiofauna. Samples were collected twice (May 2008 and January 2009) at 0, 15 and 30 m away from the brine discharge point, corresponding to a change in salinity from 45 to 36. Proximity to the brine discharge point affected overall meiofaunal abundances: lowest abundances were observed at 0 m (64.55 ± 39.86 ind 10 cm^{-2}, mean ± SD) than at 15 (210.49 ± 121.01 ind 10 cm^{-2}) and 30 m (361.88 ± 102.64 ind 10 cm^{-2}) away from the brine discharge point. This pattern was particularly notable for the most conspicuous meiofaunal groups: nematodes and copepods, and meiofaunal assemblage structure also differed with varying proximity to the brine discharge point. Although multivariate techniques identified changes in salinity as a relevant driver of patterns in meiofaunal assemblage structure with varying proximity to the brine outfall, a shift in particle size composition between May 2008 and January 2009 also contributed to explain differences in meiofaunal abundances and assemblage structure with varying proximity to the brine discharge point. Hence, meiofauna can be considered a suitable tool to monitor environmental impacts derived from the discharge of hypersaline effluents on subtidal, soft-bottom, assemblages if potential confounding drivers, i.e. here temporal changes in particle size composition, are accounted for to avoid possible confusing interpretations.

1. Introduction

In recent decades, water resources have been intensively used in numerous coastal, Mediterranean-like, climatic regions. This, together with low precipitation regimes typically associated with these regions, has resulted in freshwater scarcity. Desalination of seawater has then been proposed as an alternative, and so the number of constructed, as well as projected, desalination plants has increased considerably in recent years (Latteman and Höpner, 2008). Currently, there are more than 12,500 desalination plants worldwide across 120 countries, and the total world capacity is approaching 42 million m^3/day of potable water (GWI, 2006). For example, Spain has ca. 900 desalination plants and a production of 1.5 million m^3/day of potable water, with approximately 10 desalination plants with a production >60.000 m^3/day (Martínez de la Vallina, 2008). In the Canary Islands, there are currently 328 desalination plants, with a production of 215,000m^3/day (Ávila-Prats et al., 2011).

Desalination plants generate large quantities of hypersaline effluents, which are then discharged into the sea. The difference in density between the brine and the seawater induce the formation of a stratified system (Shiau et al., 2007), creating a bottom layer that can subsequently affect recipient benthic communities (Del Bene et al., 1994; Gacía and Ballesteros, 2001; Del Pilar-Ruso et al., 2008). Marine organisms live in an osmotic balance with their environment, and an increase in salt concentration may result in a dehydration of cells, a decrease in turgor pressure and, ultimately, death of larvae and young individuals (Einav et al., 2002). Brine discharges may contain chemicals used as antifouling materials (e.g. biocides, flocculants, etc), but their low concentrations and high dilution rates suggest that brine is the major stressor for recipient benthic communities (Morton et al., 1996; Younos, 2005). Available information regarding the effect of these hypersaline effluents over animal assemblages is, however, limited (e.g. Chesher, 1975; Castriota et al., 2001; Raventos et al., 2006; Del Pilar-Ruso et al., 2007, 2008). The majority of studies assessing the

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environmental effects of brine disposal have focused on seagrass physiology and morphology (Vries et al., 1997; Tomasko et al., 1999; Buceta et al., 2003; Fernández-Torquemada and Sánchez-Lizaso, 2005; Fernández-Torquemada et al., 2005a, b; Gacía et al., 2007; Koch et al., 2007; Ruiz et al., 2009), even in laboratory conditions (Pagés et al., 2010). Studies on the effects of brine disposal on subtidal, soft-bottom, infaunal and/or epifaunal communities are comparatively scarce (e.g. Castriota et al., 2001; Raventos et al., 2006; Del Pilar-Ruso et al., 2008). In particular, there is no study analyzing the potential impacts of brine disposal on subtidal meiobenthic assemblages (i.e. microscopic invertebrates, typically composed by metazoan animals than can pass through a 0.5 mm mesh, but retained by a 0.042–0.063 mm mesh, Giere, 1993).

Variations in the abundance and structure of meiobenthic assemblages have been previously observed along salinity gradients in estuaries, since different meiofaunal taxa have different capacities to withstand changes in osmotic cell pressure (Ingole and Parulekar, 1998; Nozais et al., 2005). In this study, we hypothesized that a change in salinity with varying proximity to a brine discharge point would alter the assemblage-level responses of soft-bottom meiofauna.

2. Material and methods

2.1. Study area and sampling strategy

This study was conducted around 'Las Burras' desalination plant, located on the south coast off Gran Canaria (27°763′48 N, 15°550′86 W, Canary Islands, Fig. 1). The plant has a brine outfall of approximately 300 m running offshore. The diameter of the outfall is ~ 60 cm and discharges at 7 m depth on a sandy bottom without vegetation. The volume of seawater collected for desalination is approximately 42,000 m^3 day^{-1}, with an estimated production of potable freshwater around ca. 25,000 m^3 day^{-1}. The volume of discharged brine is ca. 17,000 m^3 day^{-1}. Salinity at the brine discharge point typically ranges between 47-50 (Table 1). At 30 m away from the brine disposal point, salinity ranges at 'natural' values, i.e. between 36.6 and 36.8 (Table 1). Indeed, a dilution from 75 to 38 within 20 m of a brine outlet has been registered in a zone adjacent to the study area (Sadhwani et al., 2005).

Collection of samples took place at 0, 15 and 30 m away from the brine discharge point through 3 radial transects. Collections at 0 m were as close to the brine discharge point as possible; a slight underestimation of the real distance was then assumed, although in terms of sampling design we refer this level as '0 m'. Sediment cores (3.6 cm of inner diameter, 10 cm^2) were pushed into the sediment, using a hammer, to a depth of 30 cm. Five replicates were collected randomly for faunal determination at each distance per transect, while one extra core at each distance (per transect) was collected for the analysis of abiotic variables. The level of replication was based on a previous study (Riera et al., 2011). Sampling was conducted in May 2008 and January 2009.

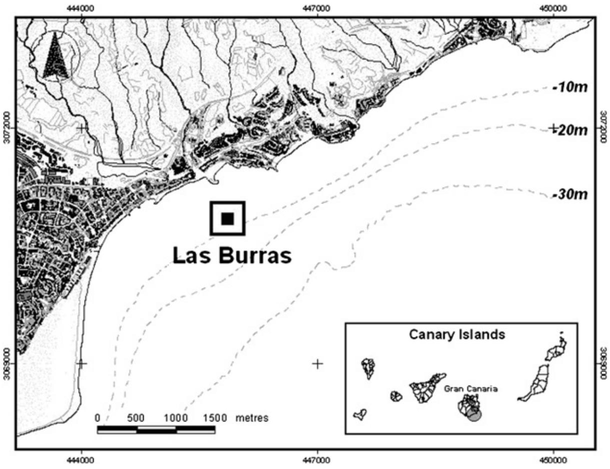

Fig. 1. Map of the study area, indicating the location of the brine discharge point.

2.2. Analysis of environmental factors

Since sediment features (e.g. particle size and organic matter content) can notably influence soft-bottom meiofaunal assemblages (Pearson and Rosenberg, 1978; Gray, 1981), we quantified these two attributes to estimate their potential confounding effects on the patterns of abundance and assemblage structure of meiofauna. To assess the particle size composition of the sediment, ca. 100 g of sediment from each sample was oven dried at 105 °C, passed through a graded series (2 mm, 1 mm, 0.5 mm, 0.25 mm, 0.125 mm and 0.063 mm) of sieves, and then dry-weighed (Buchanan, 1984). The method of Walkley and Black (1934) was used to determine the organic matter content of the sediment. Additionally, total nitrogen was determined following the Kjeldahl method (Bradstreet, 1965) and total phosphorus concentration calculated using a spectro-photometric method (Murphy and Riley, 1962).

2.3. Analysis of meiofauna

Samples were preserved in 10% seawater formaldehyde solution. A 0.5 mm sieve was used and the residue collected from a 0.063 mm sieve. The residue was then separated into different taxonomical groups under a binocular microscope, and preserved in 70% ethanol. Meiofaunal specimens were determined to a 'broad taxonomic group' level by means of a binocular microscope, or in a LEICA DMLB microscope equipped with Nomarski interference contrast (Higgins and Thiel, 1988; Somerfield and Warwick, 1996).

2.4. Statistical analysis

Differences in meiofaunal assemblage structure with varying proximity to the brine discharge point (i.e. distance: 0, 15 and 30 m) through the two surveys (May 2008 vs. January 2009) were tested by means of a permutational multivariate ANOVA (PERMANOVA) that included the factors: 'Distance' (fixed factor) and 'Time' (random factor, orthogonal to 'Distance'). The same model, but in a univariate context via permutation-based ANOVAs, tested for differences in overall meiofaunal abundance and the abundance of the two dominant meiofaunal groups (nematodes and copepods). Data from each distance were pooled among the 3 transects; this increased the power to detect differences among distances away from the brine discharge point from survey to survey. Despite variances remained heterogeneous, in all cases, despite transformations, we reduced an increase in a type I error by reducing the α value to a 0.01 level (Underwood, 1991). ANOVA is robust to such departures for balanced studies, and so ANOVA was carried out on untransformed data. Permutation-based pairwise tests were used to resolve differences in meiofaunal abundances among distances separately for each year.

To visualize affinities in meiofaunal assemblage structure, a nm-MDS (non-metric multidimensional scaling) ordination was carried out on square-rooted transformed abundance data via the Bray–Curtis similarity index. A distance-based redundancy analysis (db-RDA, Legendre and Anderson, 1999) tested whether variation in any of the measured abiotic variables significantly contributed to