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Response of amphipod assemblages to desalination brine discharge: Impact and recovery

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ABSTRACT

Desalination has become an important industry whose dense, high-salinity effluent has an impact on marine communities. Without adequate dilution, brine remains on the bottom increasing bottom salinity and affecting benthic communities. Amphipods showed high sensitivity to increased salinity produced by desalination brine discharge. A decrease in abundance and diversity of amphipods was detected at the station closest to the outfall, where salinity values reached 53. This salinity was later reduced by including a diffuser at the end of the pipeline. Six months after diffuser installation, amphipod abundance increased. During the first stage of this recovery, species such as *Photis longipes* recovered their abundance, others such as *Microdeutopus versiculatus* displayed opportunistic patterns, while others needed more time for recovery, e.g. *Harpinia pectinata*. These differences may be dependent on the organism living habits.

1. Introduction

Industrial and urban development in coastal areas has led to an increase in human activities: harbours, wastewater discharge, fish-farming, dredging, oil-wells, shipping etc. These are clearly a potential source of pollution for the coastal marine environment. Such impact induces changes in marine communities due to new physicochemical conditions: decreased hydrodynamic conditions, organic enrichment, presence of pollutants, hypoxia etc. (Borja et al., 2010). Moreover, new kinds of human activities have been established in recent years in these coastal areas including desalination which has become an important growing industry due to concern over local water scarcity and challenges in meeting future water demand (NRC, 2008). Its main impact on marine communities is caused by the discharge of an effluent with very high salinity. The production of water for public use from seawater leaves behind a concentrated salt solution, 'brine', that can have up to twice the salt content compared to the ambient seawater (Younos, 2005). Without proper dilution, a plume of high salinity discharge may spread out for a considerable distance beyond the mixing zone and harm the ecosystem (Einav et al., 2002). This effluent remains on the sea bottom because of its high density, affecting benthic communities (Lattemann and Höpner, 2003). It can cause osmotic pressure changes in cells, leading to mortalities in organisms that are not adapted to these high salinities (Sanchez-Lizaso et al., 2008). The impact may be reduced through dilution of the effluent, either using diffusers or by flushing with normal seawater added to the flow (Fernandez-Torquemada et al., 2009). Such measures facilitate the mixture of the effluent with the surrounding water (Loya-Fernandez et al., 2012), reducing the increase in salinity and its impact on the benthic community (Del-Pilar-Ruso et al., 2015).

Among groups that form part of benthic communities, the order Amphipoda is more sensitive to pollution than other organisms (Gomez Gesteira and Dauvin, 2000; Dauvin and Ruellet, 2007). Several studies have reported the response of amphipod assemblages to the impact of oil spills, harbours, wastewater outfalls or fish cages (Dauvin, 1987, 1998; Nipper et al., 1989; Swartz et al., 1994; Ingole et al., 2009; de-la-Ossa-Carretero et al., 2012; Fernandez-Gonzalez et al., 2013). These impacts are detectable as severe changes in the assemblages due to their high sensitivity, with a general decrease in amphipod abundance and diversity when pollution increases (Bellan-Santini, 1980; Conlan, 1994; de-la-Ossa-Carretero et al., 2012, 2015). However, amphipods are

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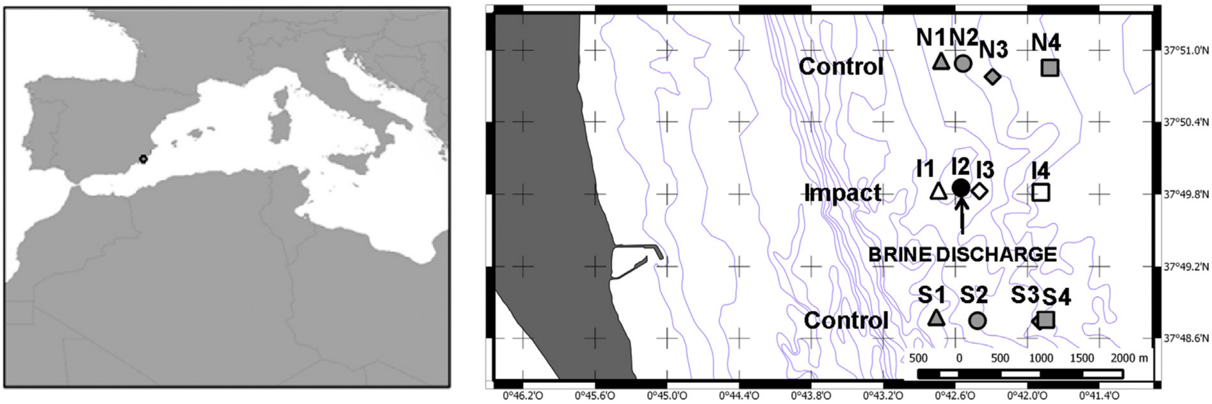

Fig. 1. Studied area showing the sampling stations around the brine discharge. Three perpendicular transects to the coast were established: Transect N, I and S. Four distances were sampled at each transect (1, 2, 3 and 4). Control stations corresponded to transects N (N1, N2, N3 and N4) and S (S1, S2, S3 and S4) while impact stations corresponded to transect I (I1, I2, I3 and I4).

capable of inhabiting sediments with different physico–chemical characteristics (Reish, 1993; Thomas, 1993; Gomez Gesteira and Dauvin, 2000) and they show various feeding modes and life strategies (Bellan-Santini et al., 1998). These attributes result in differences in sensitivity, habitat requirements or dispersion capabilities among amphipod species (Thomas, 1993; King et al., 2006). Although most Amphipoda are sensitive to different kinds of pollution (Gomez Gesteira and Dauvin, 2000; Dauvin and Ruellet, 2007), several studies have concluded that some species are more tolerant than others, resulting in changes in amphipod assemblage composition according to the degree of pollution (Bellan-Santini, 1980; de-la-Ossa-Carretero et al., 2012).

The effect of brine on seagrass and its meadows (Fernández-Torquemada and Sánchez-Lizaso, 2005; Gacia et al., 2007), other benthic communities (Del-Pilar-Ruso et al., 2007; Raventos et al., 2006; Riera et al., 2012) and polychaete assemblages (Del-Pilar-Ruso et al., 2008, 2009, 2015) has previously been analysed. However, the impact on amphipod assemblages was only recently reported (de-la-Ossa-Carretero et al., 2015). The main objective of the present research was to determine their response to a brine discharge and assess their recovery succession after application of mitigation measures. Although amphipod sensitivity to this impact is expected, differences among species are hypothesised because of differences in their living habits (biological traits), such as feeding strategies and burrowing behaviour.

2. Materials and methods

2.1. Study site and sampling stations

The San Pedro desalination plants (SE Spain) discharge their effluent by means of a 5 km pipeline at approx. 33 m depth. These desalination plants began operations in 2006 and produce an effluent flow at full capacity of around 150,000 m^3/day characterized by its high salinity (around 70). This discharge caused a salinity increase from 2006 to 2010, reaching bottom salinities of 53 close to outfall. However, in May 2010, the construction of a diffuser at the end of the pipeline to facilitate the mixture of the effluent mitigated this increase to values close to natural salinities (Del-Pilar-Ruso et al., 2015).

The present study is based on the results of the environmental monitoring programme at San Pedro desalination plants, carried out from 2005 to 2014. A benthos survey was performed by establishing three transects perpendicular to the coast: one within

Table 1
Results of PERMANOVA based on Euclidean distance resemblance of abundance and Shannon–Wiener diversity data for the factors distance (Di), treatment (Treat), transect (Trans), period (Per) and time (Ti), df: degrees of freedom, MS: mean squares, Ps-F: Pseudo-F of each factor. P (perm): permutation P value. Values in bold indicate significant differences.

	df	Abundance			Shannon–Wiener diversity		
		MS	Pseudo-F	P (perm)	MS	Pseudo-F	P(perm)
Di	3	149.77	1.105	0.4369	1.1881	5.0635	**0.0035**
Treat	1	787.43	3.6318	0.0638	1.1738	2.0556	0.1943
Trans(Treat)	1	132.9	1.1523	0.2923	0.37,948	2.2945	0.1549
Per	2	3712.1	4.5594	**0.0154**	11.563	7.6123	**0.0015**
Ti(Per)	15	551.35	4.7804	**0.0058**	1.2317	7.4471	**0.0009**
DixTreat	3	54.094	0.61,322	0.7991	0.50,429	2.2745	0.0729
DixPer	6	243.45	2.447	**0.0169**	0.27,993	1.3304	0.256
TreatxPer	2	1219.5	3.3059	**0.0424**	1.9499	3.6402	**0.0277**
DixTrans(Treat)	3	119.18	1.4728	0.2328	0.0845	0.35,671	0.7458
DixTi(Per)	45	89.588	1.1072	0.3778	0.19,689	0.83,042	0.7267
TreatxTi(Per)	15	115.68	1.003	0.5061	0.27,201	1.6447	0.1595
Trans(Treat)xPer	2	288.11	2.498	0.121	0.30,907	1.8688	0.1941
DixTreat xPer	6	295.86	2.6173	**0.0114**	0.73,842	2.2522	**0.0291**
Trans(Treat)xTi(Per)	15	115.33	3.7619	**0.0001**	0.16,539	1.2037	0.2728
DixTreatxTi(Per)	45	100.99	1.2481	0.2329	0.24,139	1.0181	0.4779
DixTran(Treat)xPer	6	42.965	0.53,099	0.7576	0.19,175	0.80,875	0.5373
DixTran(Treat)xTi(Per)	45	80.916	2.6393	**0.0001**	0.23,709	1.7255	**0.0043**
Res	432	30.659			0.1374		
Total	647						