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Management preferences and attitudes regarding environmental impacts from seawater desalination: Insights from a small coastal community

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ABSTRACT

The use of seawater desalination as a water supply option is increasing worldwide. Compared to other marine sectors, studies on marine users' perceptions and attitudes towards this new sector and its impacts on marine ecosystems are very limited. This study assessed differences in coastal stakeholder groups' preferences for managing marine impacts of a seawater desalination plant in a small coastal community. The majority of respondents placed high importance on the marine ecosystem, including ecosystem features that are less visible and charismatic, and were highly concerned about potential impacts on marine ecosystems and marine activities from the new desalination facility. Coastal residents further rated multiple management measures to reduce and off-set marine impacts as highly important, but indicated a lack of trust in institutions involved in regulating and managing environmental impacts. Logistic regression revealed that lack of institutional trust and concerns about marine impacts were significant predictors of opposition to the desalination facility and appeared to play a critical role in shaping local attitudes towards desalination. Findings further revealed that local opinions were primarily shaped by how respondents used the nearby marine system, and by gender. Age, education, and race did not seem to shape local opinions. At the same time, there were differences between consumptive and non-consumptive marine user groups' opinions indicating the potential for conflict regarding the most important management strategies.

1. Introduction

As water demand in many regions worldwide has surpassed availability of potable freshwater, seawater desalination is increasingly being integrated into freshwater supply (Dolnicar and Schäfer, 2009). According to the International Desalination Association (IDA), more than 18,000 seawater desalination plants were in operation in 2015, with a global capacity of more than 86 million cubic meters per day (International Desalination Association, 2015).

In the US, seawater desalination is an emerging ocean resource sector that is likely to grow in the future. Water supply from surface and groundwater sources has become increasingly unreliable in many coastal areas due to increased demand, saltwater intrusion into aquifers, and changing weather patterns (Bourne, 2008; Mirchi et al., 2013; Sellers, 2008; Heberger et al., 2009). California, with about nine proposed seawater desalination projects, is currently the state with the highest number of proposed seawater desalination plants in the US (State Water Resources Control Board, 2014; Pacific Institute, 2012). Seawater desalination is particularly valued for its ability to provide a reliable source of water even during extended drought conditions (Gibson et al., 2015; Morgan, 2017). At the same time, seawater desalination remains controversial due to high economic costs and environmental impacts related to seawater intake and brine discharge (Liu et al., 2013, Cooley et al., 2013, Fuentes-Bargues, 2014, Haddad, 2013).

Indirect environmental impacts on marine ecosystems, such as ocean acidification and sea-level rise, may occur due to the high energy consumption of desalination plants and subsequent increase in greenhouse gas emissions (Cooley and Heberger, 2013; Miller et al., 2015). Seawater intake and brine discharge from desalination plants add stresses to marine environments that may already be affected by a variety of anthropogenic activities (Halpern et al., 2008; Lattemann and Höpner, 2008). Examples of direct environmental impacts include degradation of marine habitats (e.g., loss of sea grass beds) mortality of bottom-dwelling organisms, coastal eutrophication, changes in seawater quality due to brine discharge, changes in microbial communities and microbial productivity when exposed to brine discharge, and

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mortality of larvae and other organisms due to impingement and entrainment during seawater intake (Del-Pilar-Ruso et al., 2008; de-la-Ossa-Carretero et al., 2016; Belkin et al., 2015; Lattemann and Höpner, 2008).

Another consideration for seawater desalination plants are potential effects on marine protected areas that are increasingly being established around the world. One example in the US is the Marine Protected Area (MPA) network along the coast of California. This network is the first of its kind in the US and consists of 124 individual MPAs intended to safeguard the productivity and diversity of marine life and habitats for current and future generations (Natural Resources Defense Council, 2014). Seawater intake and brine discharge from desalination plants close to MPAs could have impacts on protected ecosystems within individual MPA sites and compromise the effectiveness of the broader MPA network (Natural Resources Defense Council, 2014). Furthermore, the technology could lead to impacts on recreational and commercial activities, but these impacts have not been systematically studied to date (Monterey Bay National Marine Sanctuary and National Marine Fisheries Service, 2010; Liu et al., 2013).

Measures that can reduce impacts from brine discharge include development and enforcement of national pollution standards specific to contaminants found in desalination brine (including salinity thresholds) and multi-port diffusers to promote mixing at the point of discharge. Another option is the dilution of brine with effluent from a wastewater treatment plant or cooling water from a power plant (State Water Resources Control Board, 2014), which could become a less vital option in California due to an increasing interest in wastewater recycling. Mitigation measures that can help offset environmental impacts can be either in-kind or out-of-kind measures. In-kind-mitigation replaces the same types of ecosystem features that were lost (e.g., by creating new estuarine habitats if estuarine species are killed during water intake) (Ambrose, 1994; State Water Resources Control Board, 2014). Out-of-kind mitigation replaces lost features with dissimilar ones, for example not replacing all species impacted by entrainment (Ambrose, 1994; Stratus Consulting, 2004; State Water Resources Control Board, 2014). Examples include restoring up-stream habitats, adding to existing marine protected areas, or paying mitigation fees to programs that enhance viability and sustainability of marine life (Foster et al., 2012; State Water Resources Control Board, 2014).

Understanding local opinions on this technology and its impacts is important in order to account for local preferences in the development of these plants. It further offers insights into social acceptability and support (Innes and Booher, 2004; Intergovernmental Panel on Climate Change, 2001; Gopnik et al., 2012; Thomassin et al., 2010). Scientific understanding of societal values and attitudes towards marine ecosystems and the use of marine resources is, however, still in its infancy, especially with regard to citizens who are not part of organized stakeholder groups, even though the public can have substantial influences on coastal development and management decisions (Potts et al., 2016; Marre et al., 2016).

Literature on attitudes towards seawater desalination is still limited. Previous studies explored mostly the acceptance to use of desalinated water (e.g., Dolnicar et al., 2011; Dolnicar et al., 2010; Dolnicar and Schäfer, 2009; Theodori et al., 2009). These studies have been informed by theoretical approaches in social psychology and psychological risk perception literature (e.g., Ajzen and Fishbein, 1988; Pidgeon and Beattie, 1998) and found that perceived environmental impacts, costs, quality of desalinated water and associated health concerns are the main concerns with the use of desalinated water, in addition to socio-economic variables (Dolnicar and Schäfer, 2009; Dolnicar et al., 2011).

Studies on attitudes towards desalination plants detected wide concerns about environmental issues from desalination (Domènech et al., 2013) and assessed the influence of attitudinal and socio-demographic factors on public voting behavior for or against additional desalination plants in Perth in 2007 and 2012 (Gibson et al., 2015). More detailed analysis of perceptions of specific environmental impacts and how these perceptions influence attitudes towards desalination have not been carried out. In addition, an understanding of how differences in perceptions and management priorities of marine users are connected to specific marine impacts of desalination plants is lacking.

This study addresses this gap by investigating coastal residents' perceptions and preferences for managing marine impacts of a seawater desalination facility in a small coastal community in Southern California. In particular, the study investigates the importance of the local marine ecosystem to coastal residents, identifies concerns about impacts from the desalination facility, and assesses preferred management options to reduce these impacts. In addition, the study explores how far these variables shape attitudes towards the local plant. Perceptions of threats to water supply and health in the context of using desalinated water have been found to influence attitudes towards the technology (Dolnicar et al., 2011; Mankad and Tapsuwan, 2011) and hence are not addressed here. Our study explores if perceived threats to the local marine environment and marine activities influenced the degree of support for the desalination facility. The study also identifies the influence of socio economic variables and marine user patterns on perceptions and attitudes and investigates if there are any differences in perceptions and attitudes among consumptive and non-consumptive marine user groups.

2. Methods

2.1. Case study location

Carlsbad, a seaside community with 112,299 residents (2016) in Southern California (Fig. 1), receives fresh water from the San Diego County Water Authority (SDCWA), which receives approximately 64% of its drinking water from the Colorado River, 20% from the State Water Project in northern California, and only 16% from local sources (Anderson, 2015). To diversify its water portfolio, SDCWA entered into a 30-year water purchase agreement with a private investor, Poseidon Resources, starting in December 2015 (San Diego County Water Authority, 2014).

The newly constructed desalination plant is located in an industrial area along the coast on the southern end of a 162 ha man-made, shallow coastal lagoon, the Agua Hedionda Lagoon, part of which is used for mussel and oyster aquaculture. The lagoon contains four main habitat types - marshlands, upland plant communities, intertidal mudflats, and subtidal habitats and supports a rich and diverse ecosystem. Both the lagoon and offshore areas are popular for fishing, paddle boarding, kayaking, beach walking, wildlife viewing (including nearby whale watching), recreational boating, and surfing. The offshore marine area adjacent to the plant site is part of the geographic zone known as the Southern California Bight (SCB), which encompasses about 56,979 km^2 from Point Conception in the north to Cabo Colnett in Baja California in the south. The coast adjacent to the plant consists of 50–70 m wide beaches backed in places by marine terrace bluffs. Important habitats in the area include intertidal sand habitats, subtidal soft bottom habitats, and subtidal hard bottom habitats. Abundant organisms in these habitats include clams, snails, polychaeta worms, arthropods (crabs and shrimp), fish and plankton and kelp beds are abundant offshore.

At full capacity, the seawater desalination plant pumps about 300 million gallons per day (mgd) of seawater indirectly via an open ocean intake technology (Poseidon Water, 2008; California Water Boards, 2014). The intake and outfall facilities are shared with the adjacent Encina power plant, while the power plant is still in operation. Specifically, water for the desalination plant is taken from the return flow of the powerplant cooling water, meaning no new intake was required for the new desalination facility. The desalination process uses 100 mgd of seawater to produce 50 mgd of high quality drinking water via seawater reverse osmosis, and 50 mgd of salty brine with a concentration of about 67,000 ppm (about twice the concentration of incoming seawater). This brine is combined with the rest of the powerplant thermal