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Coastal residents' literacy about seawater desalination and its impacts on marine ecosystems in California

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ABSTRACT

This article examines coastal residents' awareness and knowledge about impacts of seawater desalination on marine ecosystems Carlsbad, California. The paper explores to what extent sociodemographics, motivational factors, and information use shape public awareness and self-assessed and factual knowledge. Data was collected using a mail survey (n=330) from a random sample of residents in Carlsbad. Both self-assessed and factual knowledge about the desalination plant and its impacts on marine ecosystem were low, with only two of 11 factual questions answered correctly by more than 50% of respondents. Gender, frequency of ocean use, and use of distinct information sources correlated positively with greater factual knowledge. Education, age, time of residency in local community, membership in an NGO, and place attachment to marine areas did not increase factual knowledge. Findings also demonstrate that knowledge shaped attitudes towards the seawater desalination plant as greater knowledge about marine impacts reduced support.

1. Introduction

Public knowledge about ocean issues and management is typically low, despite the high percentage of the human population that lives in coastal areas e.g., [1–3]. Because direct experiences of marine environments often require specialized training (e.g., scuba diving, boating, fishing etc.) [4], people engage with marine areas in very different ways compared to terrestrial ecosystems, and this may factor into public knowledge about marine areas and resources [5]. Compared to terrestrial areas, impacts on marine areas are also less visible and might be less known and understood by the public [6–9]. To address these deficiencies, there have been calls for increasing public understanding of coastal and marine ecosystems and how these systems are affected by human uses [10–13].

1.1. Public knowledge about the ocean and its resources

Public knowledge about the ocean and its resources is critical for multiple reasons. Many people are either directly or indirectly involved in activities and behaviors that have negative impacts on the ocean and coastal areas [14,15]. Public literacy about the ocean and its resources is vital as it may shape individual activities and behaviors that add to or reduce pressure on marine areas [1,16]. Ocean literacy is also important for policy decisions on the use and protection of ocean resources and ecosystems [17,18]. Coastal citizens can have significant influences in decision- making processes and they need to be literate about ocean issues if they are to engage in policy discussions in an informed way [1,8]. The recent National Ocean Policy emphasized this point and called for an increase in ocean and coastal literacy to empower coastal communities to become better stewards of ocean resources [13]. Assessing public literacy and identifying factors that increase policy-relevant knowledge is critical for identifying misconceptions and knowledge gaps, and for tailoring communication and outreach programs.

Two theories have been proposed to explain differences in public knowledge. One theory focuses on 'trans-situational' socio-economic variables that apply in multiple settings (e.g., level of formal education, income, education, age, or gender) [8,19]. A second theory suggests that knowledge acquisition is shaped by situation-specific variables that can increase knowledge irrespective of citizens' socio-economic status [20,21]. Situational factors are more motivational in character and might increase knowledge-seeking

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behavior by having a stake in a policy outcome, or having strong views on specific policies [22,23]. For example, people who live on the coast, visit the ocean for recreation or commercial purposes, or have a strong attachment to ocean areas might be very interested in the management of marine resources, seek more information on ocean management issues, and subsequently may be highly knowledgeable in these areas [1,23,24].

To understand public literacy about the ocean, it is also important to identify where people acquire information about marine issues. Television and the Internet, for example, are popular used sources for information on environmental topics, but many citizens and scientists question the reliability of information provided in these media [25–27]. The Internet, for example, offers excellent resources for learning about ocean and coastal issues and impacts of specific human activities (e.g., Sea Grant and NOAA websites) e.g., [28–30]. At the same time, information on the Internet can be inaccurate and/or reflect subjective opinions [1]. Understanding where people learn about the ocean is critical for tailoring communication strategies and ensuring that credible information reaches the public and subsequently increases ocean literacy.

To date, research on public knowledge about the ocean and its resources is very limited. Previous studies investigated ocean literacy among high school students [31] and the influence of attitudes towards science and ocean stewardship on ocean literacy among teenagers [32]. Studies on general public knowledge have investigated awareness of coastal and marine environmental issues [9], and the influences of proximity of residence to the ocean, use of information sources, environmental values, and socio-demographic variables on knowledge about the ocean [1,7]. A study by Perry et al. [33] investigated knowledge about marine protected areas. The authors assessed the influence of coastal vs. inland residency and place attachment on public knowledge about marine protected areas in Oregon. Our study builds on the existing literature and investigates the level of public literacy about the impacts of seawater desalination on marine ecosystems in a coastal community in Southern California.

1.2. Seawater desalination and its impacts on marine ecosystems

Seawater desalination is an emerging sector in the USA that is likely to grow in the future. Coastal areas that rely on imported water or groundwater resources are increasingly experiencing water shortages due to changes in weather patterns, recurring droughts, and increased water demand for municipal and industrial purposes [34–36]. In addition, saltwater intrusion, due to over pumping and depletion of groundwater, is likely to be aggravated by rising sea level in coastal areas [37]. In response to these concerns and statewide funding initiatives, about 15 seawater desalination projects have been proposed along the southern and central coast of California [36,38,39]. California is currently the state with the highest number of proposed seawater desalination plants in the United States [40–43]. A number of proposed plants will have capacities of up to 50 million gallons per day (mgd) compared to capacities of 0.02–0.6 million gallons per day (mgd) of most existing plants [38,44].

Even though seawater desalination is highly valued because of its independence of climate, the technology remains controversial due to high costs and potential environmental impacts in particular [45–47]. Environmental concerns about direct impacts on coastal ecosystems include mortality of marine life due to impingement and entrainment during water intake. An additional concern is the discharge of brine. Brine is generated as a by-product of desalination and may be twice the salinity of ocean water, if not diluted prior to discharge into the ocean [38]. Potential impacts of brine discharge include mortality of marine life (particularly larvae), changes in seawater quality, impacts on fish resources, degradation of marine habitats due to toxic concentrations of brine, anoxic or hypoxic conditions, and stress from turbulent mixing at the point of discharge [38,40,46,48–50].

These concerns about impacts on marine areas have contributed to the slow development of desalination plants in California. To date, only one high capacity plant has been constructed and it began operation in December 2015. As part of the planning process, coastal residents and interest groups have the opportunity to comment on environmental impact reports and local decisions about the development of new plants. Subsequently, these groups need to be literate about desalination to engage in informed discussions. Yet, public literacy about this new sector and its impacts on marine ecosystems is unknown. Our paper addresses this point by investigating the level of public awareness of desalination and the variables that increase public knowledge. The specific objectives of this paper are: (1) to determine the level of policy-relevant awareness and knowledge about brine discharge and its impacts on the ocean; (2) to identify socio-demographic factors, situation-specific factors, and information sources associated with higher levels of knowledge; and (3) to assess the relationship between knowledge and attitude towards seawater desalination.

2. Methods

2.1. Study area

Our case study is the newly constructed desalination plant in Carlsbad, a seaside town of 109,318 residents in Southern California that is part of the San Diego County Water authority district (Fig. 1). 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 (22,000 square miles) from Point Conception in the north to Cabo Colnett in Baja California in the South [51]. The coast adjacent to the plant consists of 50-70 m wide beaches backed in places by 12–24 m marine terrace bluffs. Important habitats in the area include intertidal sand habitats, subtidal soft bottom habitats, and subtidal hard bottom habitats. Abundant benthic organisms in soft bottoms include clams, snails, polychaete worms, arthropods (crabs and shrimps), fishes and offshore kelp beds, while the nearshore water column contains pelagic fishes, phytoplankton and zooplankton.

Freshwater supply in the area depends heavily on imported water. The San Diego water district receives about 64% of its drinking water from the Colorado River, approximately 20% from the state water project in Northern California, and only 16% from local sources [52]. The supply from imported resources has become increasingly unreliable due to changing weather patterns, including reduced snowpack in the Sierra Nevada, less precipitation, and continued drought conditions [35]. To diversify its water portfolio, the San Diego Water Authority entered a 30-year agreement with a private investor, Poseidon Resources, to purchase 56,000 acre-feet of desalinated water per year from the Carlsbad desalination plant [53]. This desalinated water will increase local supply to about 26%. The desalination plant is a 1 billion dollar project that will increase water price for homeowners by about $5 per month [54]. Development of the plant began in 1998 and, after multiple delays in the permitting process, the plant started operation in December 2015.

At full capacity, the desalination plant will use about 300 million gallons (mgd) of seawater every day via open ocean intake technology [55,56]. The reverse osmosis desalination process will use 100 mgd to produce 50 mgd of high quality drinking water and 50 mgd of salty brine (with a concentration of about