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Valuing coastal water quality: Adelaide, South Australia metropolitan area

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ABSTRACT

Coastal environments are increasingly under threat from multiple stressors and pressure from human activities across the land-sea interface. Managing these pressures from people requires, more than ever, understanding what is at stake in terms of the benefits and values associated with coastal waters. This article presents the results of a choice experiment which was designed to elicit society's willingness to pay in the context of economic and environmental trade-offs people to improve coastal water quality. The study site is a coastal Australian city, Adelaide, South Australia. The city discharges a large proportion of its stormwater and treated wastewater to the coastal waters of Gulf St Vincent. Willingness to pay for a package of improvements to urban water management is considerable. A mix of projects that restores 25 days per year of water clarity, seagrass area from 60% to 70% of the original area and five reef areas is worth $AUS67.1 M to households in the Adelaide metropolitan area. The results can inform public policy discussions including the cost-benefit analysis of different water management strategies including investments in urban infrastructure.

1. Introduction

Across the highly populated coastal zones of the world, coastal waters provide a range of ecosystem services including cultural services such as tourism and recreation, provisioning services through the production of food from fishing and areas such as reefs and seagrass meadows which serve an important function in the provision of habitat (The Economics of Ecosystems and Biodiversity [41,30]). These services are under threat from multiple stressors and pressure from human activities [50]. In particular, coastal water quality is impacted by urban and agricultural land use and urban land use [19], exacerbated by climate change and direct human activities such as fishing and the disposal of storm and wastewater in receiving waters [38,12]. Evaluating the complex trade-offs associated with the land use of coastal areas, human economic activities and the resulting coastal water quality requires detailed information on the potential costs and benefits to people.

The cooler temperate waters of the southern Australian coastline are a global hotspot for marine biodiversity that is vulnerable to human activities [47]. These waters support 30–40% of the world's species of macroalgae [34] whose diversity is disproportionately sensitive to nutrients pollution [12]. Urban expansion along this coast over the last three decades has substantially increased loss of marine habitats through storm and wastewater discharge [19,11]. Improvement to reducing nutrient loads not only reduces the impact of coastal pollution, but also brings disproportionately large conservation benefits under future climate [18].

The challenge for governments evaluating potential infrastructure investments is the incomplete set of information available. For instance, infrastructure costs can be estimated through tendering processes or market transactions, but often the benefits of action, for example, habitat improvements for non-commercial species, are not directly valued in markets. However people may hold existence values for the diversity of life in coastal waters.

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Estimates of the values for habitat services of temperate reefs and seagrass meadows remain limited [4]. To address this deficit of information on values specific improvements in water management are analysed which can ultimately feed into policy evaluation and standard economic tools such as cost-benefit analysis. The approach and results of this study are potentially transferable to other coastal urban locations where investments in infrastructure to divert stormwater from cities, land-use changes to address agricultural runoff or upgrades of sewage treatment are being considered. Our study adds to the small but growing body of work that presents estimates of the values associated with the existence and diversity of fish and mammals in coastal areas [5, 17], water clarity [14] and complement work on deep water ecosystems [3,24,25,45].

In this study, results of a choice experiment are reported. The experiment is used to elicit the preferences of people living in Adelaide South Australia for a set of coastal water quality improvements. Background context is provided followed by a summary of the survey underpinning a choice experiment. The survey was designed to capture the non-market values associated with water clarity, seagrass habitat and the health of rocky outcrop reefs. The article concludes with a discussion of how the results might be incorporated in policy analysis and limitations.

2. Background and case study context

This study focuses on coastal water quality off the Adelaide coastline in Gulf St Vincent (Fig. 1). It has been estimated that almost one-third of the original seagrass area (almost 5000 ha) has been lost off this coastline over the last 80 years (see Fig. 1). It is further noted that the health of the reef systems is declining and sediment instability is increasing [16]. Adelaide coastal waters are quite sheltered by the location of Kangaroo Island. These waters are naturally low in nutrients and relatively low turbidity with endemic species having evolved to these conditions. The addition of nutrients can, and may continue to, have disproportionate effects on the marine habitats [9,37]. Due to the north-south tidal regime, suspended solids and nutrients that are discharged to receiving waters will move along the coast for some time before being dispersed further offshore [28]. The Adelaide Coastal Waters Study (Fox at al 2007) presented evidence that nutrient and sediment from stormwater discharge, wastewater treatment plants and Penrice Soda products were the main contributors to declining health of the coastal water ecosystems.

Local natural resource management organisations have designed a number of sediment basins to remove a portion of the sediment coming from the catchment (MacDowell and Pfennig 2013). The water utility, SA Water through optimising operations and investing in a number of wastewater treatment upgrades has reduced discharge by 48% since the 1975-85 timeframe when much of the degradation occurred (ACWQIP p.70). However, further reductions in sediments and nutrients will require large public investments that the South Australia community may or may not be prepared to make.

The State of South Australia faces a series of challenges with respect to water security. Adelaide is located at the bottom of the Murray-Darling Basin, a system which is subject substantial agricultural extraction of water and to periodic drought. Historically, the water supply for Adelaide has come from the immediate Mt Lofty Ranges which surround the Adelaide metropolitan area and the River Murray. Due in part to the critically low levels of water in storages during a recent severe drought, a number of wastewater and stormwater projects were funded by the Commonwealth government to facilitate the reuse of these water sources on outdoor areas. Demand management options including water efficiency measures and outdoor watering restrictions were used to reduce daily household demand. A new source of water from a recently constructed desalination plant has been brought online and augments the traditional sources of water. All these potential sources of water have different financial costs, social acceptability [15] and environmental implications [21]. Comparisons of different water management strategies have been impeded by the lack of research on the costs and benefits of not disposing of stormwater and wastewater into receiving waters [27]. Further, the dearth of research on the value of coastal water quality and marine ecosystems has limited the assessment of policies such as marine conservation areas.

3. The choice experiment approach

Improvements in coastal water quality, as outlined in the Adelaide Coastal Water Quality Improvement Plan, will require additional investments in stormwater diversion and wastewater treatment. The ultimate impact on critical marine attributes such as water clarity, seagrass and healthy reefs will depend on the ultimate mix of investments in stormwater diversion and wastewater treatment across the Adelaide metropolitan area. Choice experiments are means of eliciting society's preferences for these potential trade-offs. If choice tasks employ a status baseline and improvements over a baseline in other options, the results are suitable for use in cost-benefit analysis.

Choice experiments are built on the early work of Thurstone [42] and random utility theory [8,29]. In this framework, utility of participant i for alternative j in choice situation t is represented as U_{ijt} comprised an observed component V_{ijt} and an unobserved component ε_{ijt} such that

$$U_{ijt} = V_{ijt} + \varepsilon_{ijt} \tag{1}$$

Utility is assumed to be linear in attributes

$$U_{ijt} = \sum_{k=1}^{K} \beta_{ik} x_{ijtk} + \varepsilon_{ijt} \tag{2}$$

where β_{ik} being the marginal utility associated with each attribute, k, and the error terms ε_{ijt} are assumed to be independently and identically distributed with an extreme value Type 1 distribution. Marginal utilities for each attribute for each individual are typically specified for in the multinomial logit model by allowing one or more parameters to be distributed as

$$\beta_{ik} = \widehat{\beta_k} + \theta_k z_{ik} \tag{3}$$

where $\widehat{\beta_k}$ represents the mean of the distribution of marginal utilities, θ_k is the deviation from the mean and z_{ik} are individual-specific draws from an assumed distribution (e.g., $z_{ik} \sim N(0, 1)$). This is commonly referred to as a random-parameter or mixed-logit model. A variant, the error-component (EC) model, is used to analyse the data here and can be written as

$$\begin{aligned} U_{ijt} &= \left(\widehat{\beta_k} + \theta z_{ij}\right) x_{ijt} + \varepsilon_{ijt} \\ &= \widehat{\beta} x_{ijt} + \theta z_{ij} x_{ijt} + \varepsilon_{ijt}. \end{aligned} \tag{4}$$

The EC model utilizes dummy variables to place subsets of alternatives into different ‘grouping' or ‘branches' as follows

$$U_{ijt} = \widehat{\beta} x_{ijt} + \theta z_i g_h + \varepsilon_{ijt} \tag{5}$$

where $g_h = \begin{cases} 1 & \text{if } j \text{ belongs to grouping } h \\ 0 & \text{otherwise} \end{cases}$

such that the error component applies only to alternatives where $g_h = 1$.

In specifying eq. (5), one variable is used for each attribute listed in Table 1. The variables are coded according to their