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Bringing harbours alive: Assessing the importance of eco-engineered coastal infrastructure for different stakeholders and cities

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A B S T R A C T

Urbanisation and population growth continue to impact already pressured harbour environments, resulting in a proliferation of artificial structures in the marine environment. In response, there is a growing interest in ecological engineering these structures for the benefit of both nature and humankind. Since the decision to build or adapt coastal infrastructure is a socio-economic one, the views and perceptions of different users are likely to influence support for ecological engineering projects. A survey was developed and run in four harbours (Sydney, Hobart, Auckland and Tauranga) to quantify the perceptions of different stakeholder groups towards ecological engineering of artificial structures. This study tested whether respondents with a greater connection, concern for environment, with a higher socio-economic status or who lived in a more modified harbour environment are more likely to be supportive of ecological engineering than other respondents. The study also assessed whether respondents with prior knowledge about the dominant artificial structure in their harbour (seawalls) agreed with the positive effects, disagreed with negative effects, and were more willing to contribute to costs of ecological engineering than those without prior knowledge. Results showed that most people are supportive of ecological engineering (92.55%). However, stakeholders whose work is directly linked to the harbour are more supportive of ecological engineering in Sydney and Auckland, than in Tauranga or Hobart. Environmental concern, education, income and level of harbour modification all have a positive influence on support for ecological engineering. Prior knowledge also influenced willingness to pay for ecological engineering. These results are promising for councils and managers seeking to implement ecological engineering initiatives, and looking to understand stakeholder groups' attitudes and perceptions towards ecological engineering initiatives. Greater consideration of both ecology and public users' values are required for more holistic management strategies of artificial structures in urban marine harbours.

1. Introduction

Globally, coastal systems are being impacted through multiple stressors occurring over different timescales [1]. Over longer timescales, almost all coastal systems will be affected by climate change through increases in temperature, reductions in ocean pH, increased storminess and sea-level rise [2–4]. More immediately, the proliferation of man-made structures, often referred to as ocean sprawl presents challenges to coastal habitats [5]. Given that more than half of the world's population now lives in cities [6] and over two thirds live within 60 km of the coast [7], these coastal cities will need to increase infrastructure and investment in their protection, therefore the extent of ocean sprawl will only increase [5,8].

Artificial structures introduce novel substrata along shorelines whilst replacing existing habitats, causing numerous ecological impacts [9–12]. Shoreline armouring is the replacement or shielding of natural shoreline with resistant materials, such as seawalls [13], to both protect infrastructure and minimise erosion. It is a global phenomenon [14]

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and in some urban harbours, seawalls have replaced more than 50% of the natural foreshore [13–15]. Armouring of nearshore ecosystems will increase owing to rising sea levels from climate change [16]. Ecological engineering [17] is now gaining traction as an approach to mitigate contemporary and future impacts of coastal infrastructure.

Ecological engineering is the design and rehabilitation of sustainable ecosystems for the benefit of both humans and nature [11]. This approach combines ecological understanding and principles of engineering, structure and safety to enhance the ecological value of built infrastructure [17]. Ecological engineering projects have been delivered in rocky and soft-sediment systems, above and below the tidal zone. Soft shoreline engineering methods are implemented to partially restore degraded habitats [18] (such as dunes, mangroves, saltmarshes seagrass, shellfish and coral reef) and reduce the impact on biodiversity. Attempts to enhance habitat value for hard-substrata engineering projects are more extensive, and have been recently reviewed [19,20]. Where shoreline armouring cannot be avoided, the use of complex surfaces [21], flowerpots to function as rock pools [22], pits, crevices and cracks to add complexity to surfaces [21,23] and light penetrating panels to reduce shading effects [24–27] have been used to increase the biodiversity of seawalls and other infrastructure. Research into ecological engineering has demonstrated that targeted investment into ecological enhancements can improve biological outcomes [11,20,28]. It is important to note that whilst the ecological successes of the interventions are considerable, the positive effects on biodiversity were not the primary reason for the insertion of the built infrastructure. Adding coast and harbour infrastructure is fundamentally a socio-economic decision based on financial drivers and political considerations [22]. Whilst research on the ecological value of marine ecological engineering continues to grow, the importance of societal considerations and values in the management of urban shorelines is gaining recognition, [16,22,29,30], but continues to be an area lacking in structured research.

Human occupation has led to harbours being the focus of diverse and sometimes intense activities, from a wide variety of user groups [31]. Potential conflicts amongst different user groups and their use of nearshore ecosystems are however, still poorly understood and there have been few studies to date on the way people view and feel about coastal infrastructure (except see Morris, et al. [22], Evans, et al. [32], Gray, et al. [33]). It is important to quantify the social value of these environments so their development and impact on society might be better understood, as well as the connection of these groups of people to the harbour. Quantifying societal connections to the harbour and perceptions towards marine infrastructure can allow for integrated management techniques to be successfully implemented because key stakeholder groups will need to become invested and champion ecological engineering projects for them to be an ongoing success [32]. Studies into community concerns for climate change induced environmental hazards are covered in the literature [34,35] as are peoples connection to the beach [36,37]. Further study is required to assess how stakeholder groups perceive ecological engineering of artificial marine structures and what factors influence their support for environmental initiatives.

Community groups and key stakeholders can greatly impact an initiative or project so their support can be essential to the success of a development project [38,39]. Some research has shown that public support for ecological engineering can be independent of cost considerations [22]. Morris, et al. [22] found public support for ecological engineering in treatment groups regardless of whether costs of flowerpots were known, and residents in Sydney demonstrated a willingness to pay more towards initiatives where there was a demonstrable environmental benefit [22]. This finding [22] should be tempered by the fact that the study designers took a coarse-grained view of the stakeholder constituency, although they found that the public were supportive of marine initiatives [22]. Differences in values and perceptions exist among stakeholder groups [32] but it is not known why they exist or whether differences in context and location influence stakeholder values. Each of the key studies into stakeholder perceptions of harbour infrastructure [22,32] have highlighted the need for a more structured approach to the research of stakeholder groups' attitudes and perceptions of ecological engineering and marine infrastructure. Researching the differences in stakeholder attitudes towards ecological engineering of artificial structures could reveal stakeholder groups that are more likely to support ecological engineering, and those who are more likely to oppose such initiatives. It is possible that one of the key influences on how people may value ecological aspects of the harbour is the information they hold about the harbour. This in turn could be directly linked to educational success. Socio-economic and other factors that may influence people to support ecological engineering - income, education level, level of concern or prior knowledge on the topic- must be explored further.

Prior knowledge of a topic has been correlated with a higher level of concern across any issue, [35], indicating that a member of the public more informed on a topic will show greater concern for the health, treatment or well-being of the natural environment under scrutiny. People's concerns for the exploitation of the natural environment have been studied, such as for fisheries, aquaculture [40] and offshore wind farms [41], but specific community groups were often the main focal point [35,36,42], and the general public was often neglected in these community studies. Other socio-economic factors including generational differences through age, education, income, ancestry and location [43] can play a role in support for or against environmental initiatives: For example, people born on Reunion Island had less favourable views of marine protected areas compared to immigrants [44] on the island, showing that natal origin of residents can give rise to differences in perception. Studies on the public's willingness to pay for urban green spaces [45,46] shows urban green spaces are recognised as a common asset for the good of society [45] however socio-economic factors, prior knowledge on the topic and stakeholder group identified should also be recognised as factors that may influence the public's willingness to pay. Single discipline approaches cannot address the full scope of what threatens the coastal environment and those that use it [47] and more research is needed incorporating cross-institutional study. Both ecological and social research is necessary to improve the outcomes of ecological engineering approaches. In this study, harbours of greater and lesser modification by artificial marine structures were used to test the differing attitudes and perceptions of stakeholder groups and better understand why people may or may not be supportive of ecological engineering.

The aim of this study was to assess the attitudes and perceptions of people towards ecological engineering in four urban harbours, in which seawalls are the dominant artificial coastal structure [12,15,48,49]. It was hypothesised that people with a greater connection to the harbour, greater concern for the environment, and a higher socio-economic background would lead to more support for ecological engineering. It was also predicted that support for ecological engineering would be affected by the extent of artificial modification of the harbour. Finally, it was predicted that prior knowledge of the predominant harbour structure (seawalls) would influence a positive evaluation of ecological engineering, a nuanced view of negative consequences of ecological engineering and lead to greater propensity to pay for ecological engineering.

2. Methods

2.1. Study sites

The survey was done in two locations in Australia (Sydney and Hobart) and two in New Zealand (Auckland and Tauranga). These locations were chosen to compare the perceptions of respondents in harbours that are highly modified with extensive coverage of seawalls (> 50% in Sydney [12] and Auckland, [15]) against harbours that are