Ocean and Coastal Management 165 (2018) 161–166

Contents lists available at ScienceDirect

Ocean and Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

Protecting threatened species from coastal infrastructure upgrades: The importance of evidence-based conservation

Lea T. Mamo[a], Brendan P. Kelaher[a,*], Melinda A. Coleman[a,b], Patrick G. Dwyer[c]

[a] National Marine Science Centre, School of Environment, Science and Engineering, Southern Cross University, Coffs Harbour, NSW, Australia
[b] New South Wales Fisheries, Department of Primary Industries, Coffs Harbour, NSW, Australia
[c] New South Wales Fisheries, Department of Primary Industries, Wollongbar, NSW, Australia

ARTICLE INFO

Keywords:
Coastal protection
Conservation
Ecological engineering
Macroalgae
Evidence-based management
Nereia
Threatened species

ABSTRACT

Increased coastal development and rising sea levels as a result of continuing climate-change put coastal regions at risk from flooding and inundation. A common mitigation response is the construction and upgrade of hard coastal protection structures, such as breakwaters, seawalls, and groynes. The alteration of the coast, together with the introduction of novel materials into coastal waters can negatively impact adjacent habitats and associated organisms. The implementation of management plans that involve scientists, as well as a variety of other stakeholders offer an opportunity to minimise adverse effects to biodiversity or even enhance it, while still protecting infrastructure and people. This study examines the management of an Australian breakwater upgrade and the progressive design finding process, including stakeholder engagement, determination of assessment criteria, and environmental impact assessment. In the course of the latter, scientific research led to the rediscovery of a presumed extinct algal species, *Nereia lophocladia*, which created an additional challenge and temporarily halted the upgrade. To accommodate this, the breakwater design solution was modified to avoid any impacts on the algal population and, in order to maximise the species' survival, novel ecological engineering approaches were proposed as mitigation strategies. Our case study underpins the value of evidence-based conservation and cooperation among stakeholders as important tools for minimising ecological impacts from coastal infrastructure upgrades.

1. Introduction

A large amount of the world's population is concentrated on the coast, making it an economically and socially important area (Harvey and Caton, 2010). As human populations increase, there is an intense pressure to protect infrastructure and coastal assets from environmental factors, such as coastal erosion (Bilkovic and Mitchell, 2013) and inundation (Jackson and McIlvenny, 2011). Installation and maintenance of coastal protection infrastructures, such as breakwaters, seawalls, and groynes are undertaken to safeguard coastal assets from storm tides and wave run-up (Arns et al., 2017).

As well as new coastal protection infrastructure, existing structures will likely need to be upgraded and regularly maintained to cope with rising sea levels related to climate-change (Gordon, 2014; Rahmstorf, 2007). The extent of future sea-level rise is somewhat unclear (Nicholls et al., 2011) and, in order to deal with uncertain future scenarios, coastal protection approaches need to be robust, safe, adaptive, and cost-effective (Spalding et al., 2014). Decision-making tools, such as cost-benefit analysis, which take into account investment and maintenance costs, as well as damage avoided by installing protection structures, can help to develop viable long-term management strategies and inform design criteria for upgrading coastal protection infrastructure (André et al., 2016). Nonetheless, social considerations, such as visual impact criteria or public access, as well as environmental impacts also need to be considered when developing coastal protection strategies (Bouma et al., 2009).

Coastal protection structures replace and fragment natural ecosystems (Cheong et al., 2013; Moreira et al., 2006), subsequently (positively or negatively) affecting the structure and function of coastal environments, both on local and regional levels (Aguilera, 2017, in press; Airoldi et al., 2005). Coastal ecosystems and the well-being of people are linked through the provisioning of ecosystem services (Menzel and Teng, 2010). Benefits to human well-being derived from ecosystem services are, however, often less tangible and comprehensible than immediate economic interests (Kansky and Knight, 2014). These often conflicting interests highlight the importance of a

* Corresponding author.
E-mail address: brendan.kelaher@scu.edu.au (B.P. Kelaher).

https://doi.org/10.1016/j.ocecoaman.2018.08.028
Received 13 April 2018; Received in revised form 22 August 2018; Accepted 24 August 2018

constructive multidisciplinary approach to environmental decision making, which is characterised by horizontal linkages among user groups at the same level of organisation, as well as vertical linkages across levels of organisation, such as stakeholders and Government. Such co-ordinated joint actions, associated with adherence to legal environmental protection statutes which help build a consensus among stakeholders, can lead to a path of problem-solving alternatives (Berkes, 2009) that are environmentally friendly, yet still satisfy engineering performance requirements (Naylor et al., 2017). However, problem-solving requires an accurate identification of the environmental issue in the first place. Problem identification amplifies the importance of evidence generated by scientific research because it minimises uncertainties that can bias decision-making.

In the present paper, we use an example of a coastal breakwater upgrade from Australia to demonstrate how the joint action and co-operation of multiple stakeholders and implementation of evidence-based conservation can help solve complex socio-ecological disparities involved in coastal protection infrastructure upgrades in response to sea-level rise. Given future predictions for continued rising sea levels and increasing frequency and magnitude of storms (DCC, 2009), this case study may have direct relevance to current and future coastal developments in many parts of the world.

2. Coffs Harbour breakwater upgrade as a case study

More than 80% of Australia's population lives within 50 kilometres of the coast (Trewin, 2004). This zone, which includes low-lying coastal land and adjacent marine ecosystems (McInnes et al., 2016), is socially, economically, and environmentally significant (Bennett et al., 2016). The Coffs Harbour region on the east coast of Australia annually attracts over 1.5 M visitors (Wray et al., 2016). The foreshore is dominated by two large breakwaters, which create a marina and sheltered embayment for a jetty (Fig. 1a). The Coffs Harbour northern breakwater, originally built in 1924, provides the only land access to Muttonbird Island, a Nature Reserve and an area of cultural significance to indigenous traditional owners, with commanding views of the coastline, town, and mountains. Consequently, the breakwater is heavily used by pedestrians. The breakwater is also the main protective feature for a large marina that hosts a commercial fishing fleet, commercial tour operators that access the nearby Solitary Islands, and many recreational yachts and boats (GHD, 2015). The breakwater has been subject to regular wave overtopping during storms (Fig. 1b), which are predicted to increase in severity with climate change (Arns et al., 2017). Overtopping can be life-threatening and damaging to infrastructure and vessels (Jayewardene et al., 2010).

To improve public safety and infrastructure protection, the responsible Government authority (New South Wales Department of Industry - Lands [DI-Lands]) planned to upgrade the existing breakwater.

2.1. Stakeholder consultation

The planning of the breakwater upgrade initially involved consultation with key stakeholders and the community through workshops, meetings, and interviews, which led to a set of priority issues that encompassed a range of functional, economic, social and environmental considerations important for the development (Main et al., 2016). The stakeholder consultation and priority issues informed the development of four basic design solutions: a submerged toe berm; an increased crest height; a deflection barrier; and a submerged artificial reef. However, it was agreed that additional upgrade solutions that combined different aspects of the four basic options would create an opportunity to focus on the most wave-exposed zones of the breakwater, while improving cost-effectiveness in the lower risk zones. As a result, four hybrid solutions incorporating a submerged toe berm were developed and each option was assessed using prioritised assessment criteria (Table 1) with cost being the prime objective, followed by overtopping performance (Main et al., 2016).

The summation of scores from each criterion resulted in a preferred option: a composite armoured berm upgrade. It consisted of a newly constructed rock berm at the breakwater toe below mean sea level (MSL) to break the force of waves and concrete Hanbar armouring (consisting of three legged single units, see Blacka et al. (2005) for more details) above MSL to absorb wave energy. To test the practical application of this preferred design, a physical model was created and evaluated under 10 year and 100 year ARI (average recurrence interval) wave conditions (Main et al., 2016). The results were used to refine the preferred design solution, especially the size and positioning of concrete Hanbars to secure pedestrian views from the breakwater.

2.2. Environmental impact assessment

Land and coastal development in New South Wales are governed by a planning system with legislated threshold triggers for the scope of environmental assessment. Infrastructure development proposals may cross thresholds based on their purpose, location, size or impact on a

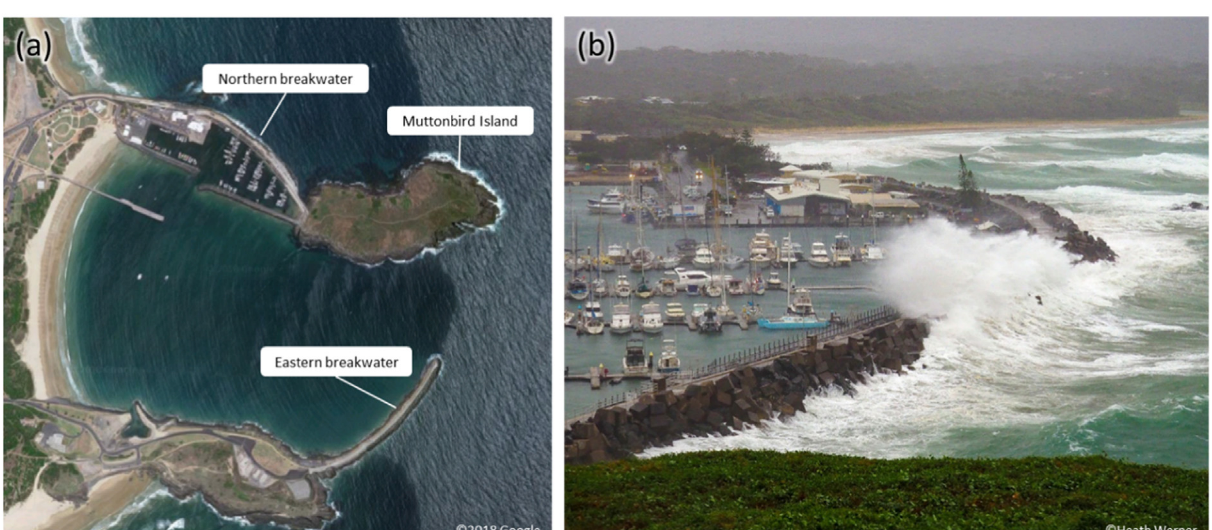

Fig. 1. Coffs Harbour marina area highlighting the breakwaters and Muttonbird Island (a), and waves overtopping the northern breakwater during a storm in 2016 (b).