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Expanding coastal urban and industrial seascape in the Great Barrier Reef World Heritage Area: Critical need for coordinated planning and policy

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ABSTRACT

Coastal freshwater and tidal wetland habitats are being transformed as a result of increasing demand for commercial, residential and tourism activities. The consequence is a habitat seascape complex, comprising a mosaic of natural and engineered coastal features. This study used the freely available mapping tool (Google Earth) to define the extent of coastal engineering structures in the Great Barrier Reef World Heritage Area (GBR; Australia), a marine ecosystem of global biodiversity and cultural significance. Continuing threats to the heritage estate concomitant with expanding urban and industrial developments has raised concerns directed at the future conservation and resilience of the reef ecosystems, along with maintaining expected human lifestyles and livelihoods it provides. The data here shows that break walls and pontoons/jetties dominate development, contributing to approximately 10% (equivalent) of the coastline linear length. Most (60%) development occurs along the coastline or within the first few kilometres upstream along estuaries. While conservation and protection of natural coastal habitats is still preferred for the objective of fisheries production and biodiversity, managers must consider seascape implication/benefits more broadly when approving new marine infrastructure rather than a case-by-case approach which further contributes to an ad hoc mosaic seascape of natural and engineered habitats. Not only within the GBR heritage estate, but more broadly, coastal managers need to regard wider seascape connectivity processes during the assessment of any new development. There is an urgent need for policy and planning instrument reform that is inclusive of accumulative impacts of urban and industrial development in this heritage estate. Opportunities to include eco-friendly (green engineering) solutions, in the repair and revitalisation of existing artificial structures, is necessary in any new proposed urban and industrial development and expansion.

1. Introduction

In many of the world's estuaries, continuing human population growth and corresponding expansion of cities and industrial areas has resulted in a modern day multiuse coastal seascape consisting of natural and marine engineered infrastructure features [1–4]. Along with ecological services for fish nursery function and production [5], as well as carbon sequestration [6], the coastal seascape is also expected to provide services essential for humans, such as residential living, recreation, commercial, navigation/shipping, wastewater disposal and tourism [7]. More recently, the construction of coastal engineering infrastructure has been for the protection of expensive shoreline assets (e.g. bridges, residential property and port development; Fig. 1) under sea level rise and climate change [8,9]. These natural and man-made services are competing, and managers are continually challenged with balancing conservation and protection while also approving further coastal development [10]. While ecological research has centred on examining how well individual engineered habitats mimic natural habitats [11], data quantifying how much engineering exists in coastal seascape areas, what has been lost following this expansion, and determination of opportunities to repair and restore estuaries following post development, is not available [12,13].

Plans to expand development (mining, agricultural, farming) across northern Australia to meet increasing demands for food and energy supplies in Australia and Asia means that the risk of collateral damage from anthropogenic stresses is imminent [14]. Part of this development region includes the Great Barrier Reef (GBR) in northern Queensland;

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Fig. 1. Example of the engineering features in the Great Barrier Reef heritage estate. (a) rock wall for foreshore stability and protection in Townsville; (b) coastal port facility in Gladstone; (c) swimming netting area near Bowen; and (d) pontoons and boat ramp, with a recreational angler using this feature near Cairns. See Fig. 2 for township locations.

extending approximately 2300 km along the coast line, it is one of the natural wonders of the world and a marine ecosystem of globally significant biodiversity, with extensive environmental, cultural, social and economic values [15]. Recognised as a World Heritage Area and National Marine Park, the GBR has a series of inscribed international agreements, and national and state legislation/policies in place for its protection and management [15]. The GBR lagoon has important tangible linkages with adjacent coasts and estuaries, which are connected as part of a larger nursery and feeding complex that supports the life histories of marine and freshwater species [16]. Many economically important fisheries (up to 62% of the commercial and 76% of recreational catch [17]) have a critical estuary lifecycle phase [18], and rely directly on connectivity between the reef and the shallow tidal and freshwater wetland features often lost to development [19]. However, many functional characteristics of this habitat complex are under threat owing to on-going agricultural runoff contributing to poor water quality, loss of natural freshwater wetlands as nursery habitat, expansion of city centres for increasing population, port expansions following increasing mining activities [20]. Additionally, impacts come from illegal fishing which also places these biodiversity and conservation values under further threat [15].

The declining health and resilience of GBR ecosystems in response to continuing landscape and climate change, has attracted local and global media attention [20,21]. These concerns that the GBR was "*in danger*" led to a request by UNESCO (June 2011) for Australian government agencies to conduct a strategic assessment of the Great Barrier Reef World Heritage Area (GBRWHA). Central to this assessment was addressing exactly how future coastal development could continue while still satisfying conservation and protection obligations/responsibilities under the world heritage agreement. The assessments highlighted weaknesses in knowledge and uncertainty in the design and implementation of coastal infrastructure projects that have led to repeated problems with the implementation and operation of coastal development and reductions to the extent of productive wetland habitats [22]. These problems reflect adversely on developers and operators of coastal assets, even when complying with their legislative obligations; often there is no failure of governance or compliance, rather problems stem from incomplete knowledge and understanding of key values that prejudices effective decision making [20].

This paper provides policymakers and resource managers with critical baseline data on the extent of coastal urban and industrial development in the heritage estate—a recommendation in the strategic assessment [15]. This study used the freely available mapping tool (to allow for reproducibility in other coastal locations) to quantify the extent of marine engineered infrastructure in the heritage estate. These data raise awareness concerning future threat of coastal development, and highlight that planning decisions must simultaneously maximize human and biodiversity outcomes at the broader, seascape, scale and not focus solely on the encroachment of the development footprint under assessment. Opportunities to include innovative green eco-friendly engineering technology is also discussed for new proposed marine infrastructure, as well as its application for an objective of ecosystem repair.

2. Methods

2.1. Spatial mapping

Because of the large geographical extent of the GBRWHA (Fig. 2), Google Earth (GE) imagery was used as a basis for: (1) identifying the location of each engineering structure (measured as the individual unit in the imagery; there was no minimum size limit applied to structures; earth boat ramps were included where they could be distinguished in the imagery from disturbed land); (2) measuring the footprint dimensions of infrastructure [length, width and surface area (length *x* width)], and the distance upstream that structures were positioned along estuaries, using the scale ruler function in GE; (3) measuring the surface area of each estuary to Supplement data sourced from Geoscience Australia (Australian Government; http://www.ozcoasts.gov.au/search_data/index.jsp); and (4) examining the