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Courage under fire: Seagrass persistence adjacent to a highly urbanised city–state

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ABSTRACT

Due to increasing development Southeast Asia's coastlines are undergoing massive changes, but the associated impacts on marine habitats are poorly known. Singapore, a densely populated island city–state, is a quintessential example of coastal modification that has resulted in the (hitherto undocumented) loss of seagrass. We reconstructed the historic extent and diversity of local seagrass meadows through herbarium records and backwards extrapolation from contemporary seagrass locations. We also determined the current status of seagrass meadows using long-term monitoring data and identified the main threats to their presence in Singapore. Results show that, even though ~45% of seagrass has been lost during the last five decades, species diversity remains stable. The main cause of seagrass loss was, and continues to be, land reclamation. We conclude that strict controls on terrestrial runoff and pollution have made it possible for seagrass to persist adjacent to this highly urbanised city–state.

1. Introduction

Coastlines worldwide are undergoing rapid urbanization and development. In East Asia alone, there are 12 coastal cities with a population of more than 15 million (Gill and Kharas, 2007) that are still expanding, placing an unprecedented strain on natural nearshore resources and habitats (Yeung, 2001). The impacts of development, such as increased pollution, eutrophication and sedimentation caused by construction, reclamation and dredging, are major threats to coastal marine ecosystems such as coral reefs and seagrass meadows (Hughes et al., 2003; Waycott et al., 2009; Grech et al., 2012). Seagrasses are habitat forming marine angiosperms that are common in shallow coastal waters. They provide a range of valuable ecosystem services (Costanza et al., 1997) but are being degraded at an alarming rate with associated reductions in their diversity, resilience and ecosystem functions (Orth et al., 2006; Grech et al., 2012). Without appropriate management, the reported widespread loss of seagrass habitats is predicted to continue (Waycott et al., 2009).

Singapore is a highly urbanized island city state located at the southern tip of the Malay Peninsula and comprises of one main island and more than 60 smaller islands. Despite her small size and limited natural resources, Singapore is an economic powerhouse in the region with a per capita GDP that rivals most of the developed world (Department of Statistics Singapore, 2013). With a total land area of 714.3 km^2 and a population of 5.3 million, Singapore is representative of the types of changes and challenges that are currently facing many other coastal cities experiencing rapid expansion and industrialization. Due to Singapore's equatorial setting and its vicinity to the Coral Triangle, it supports a wide variety of nearshore habitats including mangroves, coral reefs and seagrass meadows, all of which sustain high biodiversity (Huang et al. 2006,2009; Chou, 2008; Lee et al., 2012).

During the late 1960s to 1970s, Singapore initiated a number of large-scale land reclamation projects to ease the burden of land scarcity coupled with rapid population growth. This systematically obliterated a large proportion of coastal habitats (Todd and Chou, 2005), mostly through seaward expansion from the southeast of the main island and also the amalgamation of a group of 11 islands just off the southwestern coast. In total, land reclamation has resulted in the loss of an estimated 60% of coral reef area and 95% of mangroves (Chou, 2008) but, to date, the loss of seagrass meadows has not been documented. Mangroves are represented as forest on Singapore's maps and corals reefs are clearly delineated due to their potential as a shipping hazard. Seagrass meadows have traditionally not been treated as a navigational hazard; hence,

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