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Holocene benthic foraminiferal assemblages indicate long-term marginality of reef habitats from Moreton Bay, Australia

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ABSTRACT

Since European settlement (ca. 1824 CE), the subtropical inshore reefs of Moreton Bay have undergone rapid deterioration in water quality from changes in land-use practices, resource exploitation and rapid population growth, spurring marine managers to assess the drivers of ecological shifts. However, the short temporal-scale of most studies is an inadequate baseline for understanding the severity and magnitude of biological response. We present millennial-scale records employing palaeoecological and quantitative multivariate techniques within a concise chronological framework to analyse benthic foraminiferal community structure of reefs in Moreton Bay, Queensland. Well-constrained, U/Th-dated, millennial-scale records from sediment cores were used to document the long-term response of foraminifers to natural environmental variability. The temporal and spatial distribution patterns of foraminifers reveal long-term marginality throughout the ~7400 years of Holocene history, prior to European settlement. While specific faunal response to the effects of relative ENSO-climate and sea level fall are difficult to disentangle, the earlier phases of reef development are already represented by marginal taxa indicating possibly an earlier response to a decline in conditions. Overall, long-term consistency in conditions favoured two types of low diversity reef assemblages: 1) high density of small, heterotrophic and opportunistic species and 2) low density of photosymbiotic foraminiferal assemblages. Comparison of foraminiferal community composition between the Holocene and the present day indicates overlap in species composition supporting long-term marginality, particularly in the Western Bay. Such combined palaeoecological and recent studies can benefit long-term initiatives for monitoring present and future water quality conditions in the Bay's reef habitats.

1. Introduction

Water quality in coral reefs is rapidly deteriorating from anthropogenic activities including land-use change, urban and agricultural runoff and eutrophication (Fabricius, 2005). Furthermore, the ability of ecosystems to cope with declining water quality may be undermined by predicted, unavoidable and unprecedented human-induced climate change (Beger et al., 2011; Fabricius, 2005; Gergis and Fowler, 2009; Gooday et al., 2009; Guinotte et al., 2003; Hughes et al., 2003; Pandolfi et al., 2003; Pandolfi et al., 2011). Several countries have enacted legislation including the Clean Water Act and the EU Water Framework Directive (WFD) and Australia's Great Barrier Reef Marine Park Authority (GBRMPA). These agencies promote strategies to: assess ecological status and implement continuous monitoring approaches to achieve 'good' water quality targets within set timeframes; make recommendations for best land-marine management practices, designate marine protected areas (MPAs) and return ecosystems to a pre-impact status (De'ath and Fabricius, 2008; EU-Water-Framework-Directive, 2009; Great-Barrier-Reef-Marine-Park-Authority, 2009). However, the combined effects of natural and anthropogenic stressors have far removed reef ecosystems from their historical baselines (Lotze et al., 2006). A long-term perspective is needed to better understand the ecological processes, which underpin ecological resistance and resilience in subtropical reefs (Beger et al., 2011) Contemporary global studies addressing ecological status are therefore enhanced when they go beyond short temporal scales to consider the age of the reef, its long-term ecological dynamics and the historical range in natural variability prior to significant anthropogenic impacts (Greenstein and Pandolfi, 2008; Lotze et al., 2006; Lybolt et al., 2011; Pandolfi et al., 2003; Roche et al., 2011; Roff et al., 2013; Tager et al., 2010).

Our detailed investigations of the palaeoecological changes in the reef sediments are based on analysis of benthic foraminifers. Their abundance and widespread preservation in marine sediments, short life cycles, high taxonomic diversity, easy collection methods and their sensitivity to environmental conditions, have allowed foraminifers to be commonly applied in palaeoecological and historical reconstructions (Cushman, 1928; Murray, 1991; Natland, 1933; Scott et al., 2005). Increasingly, foraminifers are gaining worldwide recognition as a promising tool: for establishing baseline conditions (Alve et al., 2009); in

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standard water quality monitoring (Bouchet et al., 2012; Reymond et al., 2012; Sabean et al., 2009; Schönfeld et al., 2012); and in establishing ecological quality status (EcoQs) (Bouchet et al., 2012). Large benthic foraminifers (LBFs), prominent calcium carbonate sediment producers in tropical/subtropical reefs, live in symbiosis with algae (Hallock, 1981, 1999, 2000). They make excellent bio-indicators of coral reef health (Hallock, 2000) and have been used with the FORAM Index as a simple, cost-effective measure of changes in water quality in reefs (Hallock, 2000; Hallock et al., 2003; Narayan and Pandolfi, 2010; Reymond et al., 2012; Schueth and Frank, 2008; Uthicke and Nobes, 2008).

The dynamic subtropical reefs of Moreton Bay, Queensland, Australia (Fig. 1) currently exist under high stress conditions that have brought about substantial ecological degradation (Pandolfi et al., 2003). Since European settlement (ca. 1824 CE), the Bay's catchments have undergone large-scale land use changes, intense logging and severe decline of estuarine vegetation leading to increased erosion of catchment sediments, while within the Bay overexploitation of marine resources has been extensive (e.g., corals for lime production and dugongs for oil), (Capelin et al., 1998; Duke et al., 2003; Neil, 1998). Today, the catchments support the fastest growing urban centre (Brisbane) in Australia. With rapid coastal development and increased

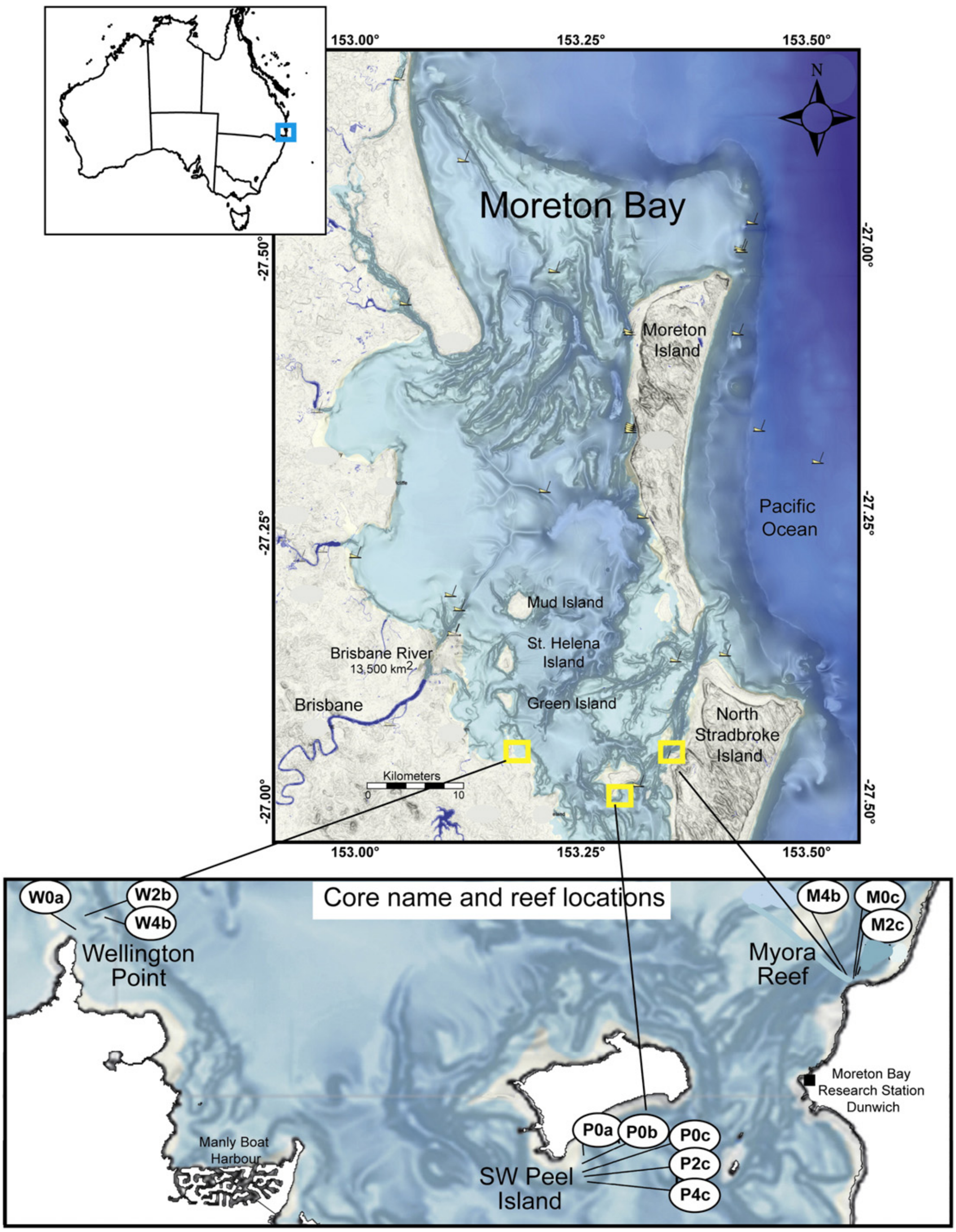

Fig. 1. Location of Moreton Bay in South-East Queensland, Australia. The city and port of Brisbane is located near the mouth of the Brisbane River. The location of the three study reefs (Wellington Point, SW Peel Island and Myora reefs) are shown with the location of replicate cores collected from each site depicted in the enlarged panel below. Sediment core names (i.e., W0a) are indicated by reef site i.e., (W = Wellington Point, P = SW Peel Island and M = Myora), depth (0, 2, 4 m) and core replicate (a, b, c). Seafloor map of Moreton Bay 1:250,000, GDA 94, Zone 56 modified from Australian Government, Maritime Safety Queensland (data sources EPA, NRW DPI&F, HWP, MSQ).