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Prickly business: abundance of sea urchins on breakwaters and coral reefs in Dubai

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ABSTRACT

Echinometra mathaei is a common echinoid on tropical reefs and where abundant plays an important role in the control of algal communities. Despite high prevalence of *E. mathaei* on southern Persian/Arabian Gulf reefs, their abundance and distribution is poorly known. Spatial and temporal patterns in population abundance were examined at 12 sites between breakwater and natural reef habitats in Dubai (UAE) every 3 months from 2008 to 2010. Within the breakwater habitat, densities were greatest at shallow wave-exposed sites, and reduced with both decreasing wave-exposure and increasing depth. Interestingly, *E. mathaei* were significantly more abundant on exposed breakwaters than natural reef sites, presumably due to differences in habitat structure and benthic cover. Population abundances differed seasonally, with peak abundances during summer (July–September) and lower abundances in winter (December–February). Seasonal fluctuations are likely the result of peak annual recruitment pulses coupled with increased fish predation from summer to winter.

1. Introduction

Artificial structures (e.g. breakwaters, seawalls and jetties) are widely used to protect shorelines and coastal developments from erosion and wave action (Bacchiocchi and Airoldi, 2003; Airoldi et al., 2005). These man-made structures now dominate near-shore coastal environments in many regions (Airoldi et al., 2005; Sale et al., 2011; Wen et al., 2013). In addition to shoreline protection, coastal defense structures also provide substantial hard-bottom habitat and physical structure upon which marine communities develop (Svane and Peterson, 2001; Airoldi et al., 2005). Breakwaters and related structures may therefore represent large-scale engineered artificial reef habitats (Svane and Peterson, 2001; Bulleri and Chapman, 2010). Notably, many of these artificial reef habitats can have extensive marine communities develop, encompassing fish, coral and other taxa that have equal or greater abundances and diversities than nearby natural reefs (Burt et al., 2009; Wen et al., 2013). There is increasing recognition that artificial reef habitats may play an important ecological role in structuring coastal marine communities, and enhancing overall biodiversity in coastal marine ecosystems (Airoldi et al., 2005; Chapman and Underwood, 2009).

In the southern Persian/Arabian Gulf (hereafter termed “Gulf”), man-made structures have more than doubled the length of natural coastlines in many Gulf states (e.g. Burt et al., 2009, 2011; Sale et al., 2011). In particular, coastal development activities in Dubai (United Arab Emirates) have lengthened the shoreline from 50 to >1600 km, of which ~65 km are rocky breakwaters (Burt et al., 2009). Many of these breakwaters now support diverse and abundant fish and coral communities comparable to nearby coral reefs (Burt et al., 2009, 2011). Accordingly, the majority of research examining the structure and function of marine communities found within the breakwaters and reefs in Dubai have focused on coral and fish assemblages, predominantly examining patterns of community development and whether artificial reefs function similarly to nearby coral reefs (Burt et al., 2009, 2011, 2013). Despite this, our understanding of patterns and processes governing other important benthic invertebrate communities associated with these structures remain limited (Feary et al., 2011).

Sea urchins, although often viewed as a sign of reef degradation, can perform an important role as herbivores and bioeroders, on both natural coral reefs (e.g. Hughes, 1994; McClanahan et al., 1994) and reefs associated with artificial structures (e.g. Schuhmacher, 1974; Guidetti et al., 2005). Through these processes, sea urchins can heavily influence the structure and dynamics of reef benthic communities, by removing algae, reducing sediment accumulation, and increasing topographic complexity (McClanahan and Muthiga, 2013). However, variation in sea urchin population abundance can have a substantial effect on the extent and impact of these processes on benthic communities (e.g. Carreiro-Silva and McClanahan, 2001). For example, at high densities (i.e. in areas where natural predators have been extirpated) urchins can modify reefs through excessive grazing and may reduce the abundance of crustose coralline algae, negatively affecting hard coral recruitment and overall coral population abundance (O'Leary and McClanahan, 2010), or lead to the net erosion of the reef matrix (Eakin, 1996). In

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contrast, when densities of sea urchins are low (and other herbivores absent or rare) algal assemblages can be released from top-down control leading to a proliferation of algal biomass and a shift toward larger fleshy macroalgae (e.g. *Sargassum*; see McClanahan and Muthiga, 2013). Given the potential impact of sea urchin abundance on the structure and dynamics of benthic communities (Carreiro-Silva and McClanahan, 2001; O'Leary and McClanahan, 2010), it is vital to understand how urchin populations vary spatially and temporally (Dumas et al., 2007).

The burrowing urchin, *Echinometra mathaei*, is the world's most abundant tropical echinoid (Palumbi and Metz, 1991). *E. mathaei* is widely distributed throughout much of the Indo-Pacific (Clark and Rowe, 1971), including the southern Gulf, where they commonly inhabit patch reefs and rocky subtidal habitat (George, 2012). Large numbers of *E. mathaei* are also found along the seaward margins of breakwaters and wave-exposed platforms (John and George, 2003). Despite their prevalence on hard-bottom substrata in the Gulf there have been no systematic studies to establish the seasonality of *E. mathaei* abundance, or to explicitly examine spatial variation in local population abundance, both within and between natural and artificial reef structures. The objective of this study was to examine the spatio-temporal variability in abundance of *E. mathaei* on breakwaters and natural coral reefs in the southern Gulf.

2. Materials and methods

2.1. Study sites

This study was conducted in Dubai (United Arab Emirates) in the southern basin of the Gulf. The vast majority of sea floor in this region is shallow (<10 m) and dominated by sand and silt substrata, making it unsuitable for most reef development and associated fauna (Riegl, 1999). Within this region breakwaters associated with coastal development provide a substantial amount of additional substratum (>65 km) on which diverse marine communities develop including fish, corals and other benthic fauna (Burt et al., 2009, 2011). In comparison, natural reefs in Dubai are a series of discontinuous reef patches associated with areas of early diagenetic limestone or 'caprock' (Riegl, 1999). This series of patch reefs extends ~12 km along the western coast of Dubai.

To examine the abundance and distribution of *E. mathaei* populations between natural and artificial reefs, 12 sites at three locations (2 breakwaters, 1 natural reef) were selected across ~40 km of coastline in Dubai (Fig. 1). *Echinometra mathaei* populations were sampled at 4 sites on breakwaters surrounding each Palm Jumeirah (PJ) and Palm Jebel Ali (PJA) developments, and at 4 natural reef sites in the Jebel Ali Reserve (JAR). Sites at breakwaters (PJ and PJA) were equally divided by their exposure to wave action into 'windward' or 'leeward', whereas all natural reef sites were 'windward'. Each breakwater site was sampled at two depths (3 and 6 m), whereas JAR natural reefs were only sampled at a single depth (3 m).

2.2. Patterns of Echinometra mathaei abundance

The abundance of *E. mathaei* was quantified at each site every 3 months for 4 seasonally defined periods: January–March (winter), April–June (spring), July–September (summer), and October–December (autumn). This sampling procedure was repeated over a 2-year study period (January 2008 to January 2010). At each site a 30 m transect was randomly positioned at each survey depth, and all *E. mathaei* were counted within 9 or 10 replicate 0.50-m^2 quadrats, which were deployed haphazardly along the transect length.

2.3. Benthic assemblages

Following initial *E. mathaei* surveys (i.e. January–March 2008), the composition of sessile benthic assemblages was visually quantified at shallow sites in April and May 2008. Sampling was standardized at 3–4 m depth, the same depth as natural reefs; therefore the deep breakwater sites (6 m) were not sampled. At each site, 6 replicate 30-m long transects were photographed at 3 m intervals using a 0.25 m^2 quadrat; a total of 66 quadrats per site (equivalent of 16.5 m^2 area). Images were analyzed using CPCe version 5 (Kohler and Gill, 2006) using 50 randomly distributed points. Benthic groups surveyed were categorized into 8 major benthic groups: (1) hard coral, (2) fleshy macroalgae, (3) algal

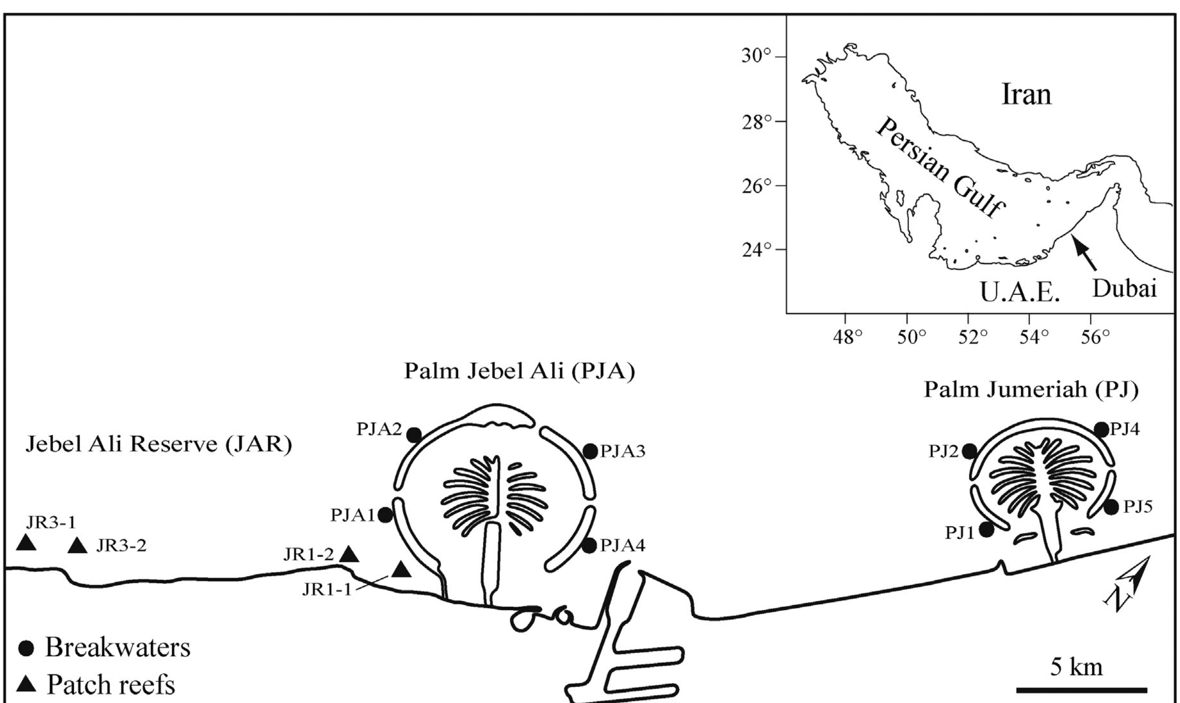

Fig. 1. Map of Dubai (United Arab Emirates) showing 12 study sites. Sites from west to east: Jebel Ali Reserve (JR3-1, JR3-2, JR1-2, JR1-1), Palm Jebel Ali (PJA1, PJA2, PJA3, PJA4), and Palm Jumeirah (PJ1, PJ2, PJ4, PJ5).

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