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An assessment of Qatar's coral communities in a regional context

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ABSTRACT

Qatar's once extensive coral communities have undergone considerable change in recent decades. We quantitatively surveyed three coral assemblages in Qatar to assess current status, and compared these against 14 sites in Bahrain and the United Arab Emirates to evaluate Qatar in a larger biogeographic context. Umm Al-Arshan had the highest species richness of 17 sites examined in the southern Arabian Gulf, as well as the highest coral cover and the only *Acropora* observed on sites in Qatar. Coral cover and richness were more modest at Fuwayrit and Al-Ashat, reflecting greater impacts from earlier stress events. Two distinct communities were identified across the southern Gulf, with Umm Al-Arshan clustering with high-cover, mixed merulinid/poritid assemblages that were less impacted by earlier bleaching and long-term stress, while Fuwayrit and Al-Ashat grouped with a lower-cover, stress-tolerant community characteristic of more extreme environments in the southern Gulf. We recommend implementation of a nation-wide baseline assessment of coral communities to guide development of an MPA network and long-term coral monitoring program for Qatar.

1. Introduction

Qatar is a 300 km long peninsular nation extending into the southern Arabian Gulf. Coral communities in Qatar were historically among the most widespread in the region, and drew the attention of some of the earliest regional reef science (Kinsman, 1964; Shinn, 1976). Surveys during the 1960s documented widespread fringing assemblages extending over more than 200 km of coastline in northern and northeastern Qatar (Neuman, 1979; Shinn, 1976). These coral communities were heavily dominated by *Acropora* table corals, and were described as "extensive" and "lush", with fringing assemblages "…consisting of many miles of *Acropora* thickets" (Shinn, 1973a, 1976). Aerial photos in the 1960s show expansive *Acropora* stands with *Porites* understories growing on the windward margins of shallow rocky platforms throughout the capital city's Doha Bay (Shinn, 1973b).

Degradation of Qatar's corals began in the 1960s and accelerated in later decades. The first major impact occurred in 1964 when an unusually cold winter storm resulted in mass coral bleaching throughout Qatar (SST 4 °C in Doha Bay, 14 °C at 17 m; Shinn, 1976). While massive corals were minimally impacted, *Acropora* suffered heavy mortality and formerly dense thickets were replaced with extensive stands of dead coral across northeastern Qatar (Shinn, 1976). Despite the extent of impacts, juvenile *Acropora* began recruiting within a year and a half, growing in abundance and size over subsequent years (Shinn, 1976). Unfortunately, this recovery coincided with the onset of large scale dredging and industrial expansion at the start of Qatar's oil boom in the early 1970s, and this resulted in substantial degradation of coral communities around the capital city (El-Baz, 1979; Emara et al., 1985). However, extensive *Acropora* stands with high coral cover continued to dominate coastal areas to the north and southeast of the country through the 1980s (Emara et al., 1985; Sheppard and Sheppard, 1991). Later the 1991 Gulf War oil spill extended as far as Qatar but had minimal impacts, with post-spill surveys showing a number of offshore assemblages containing abundant live coral (60–70% cover) and communities dominated by healthy *Acropora* thickets and a mixed understory of merulinids (faviids) and large *Porites* bommies (Fadlallah et al., 1993; Mohammed and Al-Ssadh, 1996). Thus, outside of the major urban and industrial areas Qatar's coral communities were in relatively good condition through the early 1990s.

The longest-lasting and largest-scale impacts to corals in Qatar were the result of recurrent bleaching events that occurred in 1996 and 1998, when sea surface temperatures (SSTs) reached 37.7 °C in the southern Gulf, >2 °C above normal summer maxima (Riegl, 2002; Sheppard and Loughland, 2002). These bleaching events resulted in the near total loss of all coral from shallow (<3 m) habitats in Qatar, with *Acropora* virtually eliminated from all near-shore coral communities and only remnant patches of *Porites* and *Cyphastrea* with <10% live coral cover remaining in most coastal areas (Rezai et al., 2004; Sheppard et al., 2010; Sheppard and Loughland, 2002). The impacts from bleaching were exacerbated by anthropogenic activity, with sedimentation from dredging and pollution from the growing industrial sector impairing recovery (Al-Kuwari and Kaiser, 2011; Richer, 2008). As a result, by the late-2000s near-shore coral communities across much of northeastern Qatar were considered functionally extinct (Maghsoudlou et al., 2008).

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Off-shore coral assemblages were also impacted by the 1996/98 bleaching events, but to a lesser extent. Four coral communities >50 km offshore from Doha that were surveyed immediately before the 1998 bleaching event had 30–60% coral cover, with *Acropora* dominant at all sites (Al-Ansi and Al-Khayat, 1999), suggesting that the earlier 1996 event had relatively limited impacts at these deeper off-shore sites. However, the 1998 event was hotter and longer lasting (Riegl, 2002), resulting in widespread mortality even at these offshore sites (Rezai et al., 2004; Riegl and Purkis, 2009). Surveys in 2004 showed that *Acropora* had begun recolonizing the off-shore sites of Umm Al-Arshan and Halul island (Abdel-Moati, 2006), but most were juveniles (80% <6.3 cm diameter) and overall coral cover remained depressed (<10%) (Foster et al., 2013). Extensive nation-wide surveys in 2007/8 found *Acropora* only at Halul, and several species that had been reported in earlier surveys were no longer observed in Qatar (Sheppard et al., 2010, 2012).

The close of the 2000s saw further degradation of the already fragile coral ecosystems in Qatar. Coastal dredging, reclamation, and channelization expanded rapidly, and the cumulative impacts of these projects would have represented a large-scale and long-term stressor for near-shore coral communities (Richer, 2008; Sheppard et al., 2012; van Lavieren et al., 2011). The decade was capped with yet another bleaching event in 2010, pushing many of the already stressed coastal ecosystems over the edge. SSTs reached 37.8 °C in Qatar and bleaching lasted for over six weeks (Al-Ansi, 2010; Riegl et al., 2012), resulting in dramatic declines of even robust massive coral genera that remained in these areas (e.g. two-thirds of Platygyra lost; Riegl et al., 2011, 2012).

Although there is a broad awareness that corals have undergone substantial change in recent decades, Qatar's coral communities are the least studied in the region (<3% of Gulf reef research; Burt, 2013) and there have been no recent assessments of the status of coral communities in the nation. This study provides a detailed quantitative assessment of three coral habitats in Qatar, including both near-shore and off-shore sites, in order to assess the current status of these communities. This will provide important baseline information against which future studies can assess trends in the condition of coral communities. Second, the structure of coral communities in Qatar is compared against that of coral assemblages in neighboring Bahrain and the UAE, providing an objective assessment of the status of Qatar's corals relative to the larger context of coral assemblages across the southern Arabian Gulf as a whole.

2. Methods

Sampling occurred at three locations in Qatar: Umm Al-Arshan is a seamount (14 m depth) located 42 km offshore from northern Qatar (N 26° 30' 49.8", E 51° 17' 58.4"), Fuwayrit is a shallow (<3 m) near-shore fringing community (<600 m from shore) located 80 km from Doha in northeastern Qatar (N 26° 01' 42.3", E 51° 23' 09.5"), and Al-Ashat is an off-shore island (<6 m depth) located 11 km from the south-eastern coast, 60 km south of Doha (N 24° 44' 45.7", E 51° 36' 02.8"). Halul island was not included in this study as sampling permits could not be obtained for this high-security area.

Coral communities were surveyed using the methods of Burt et al. (2011, 2013) to allow direct comparison of data among sites in the southern Gulf. In brief, coral communities were sampled using 0.25 m^2 quadrats photographed at 3 m intervals along six replicate 30 m transects spaced ~5 m apart across the coral community, for a total of 66 quadrat images per site. Images were analyzed using CPCe v6 (Kohler and Gill, 2006), with the benthos underlying 50 random points identified to the lowest taxonomic level possible (to species for coral) in each quadrat.

For comparison between sites in Qatar, one-way ANOVAs with post-hoc Tukey's tests were used to test for differences in percent cover of benthos (arcsine squareroot transformed) and species richness ($\log_{10}(n+1)$ transformed). In order to put the Qatar coral communities in the larger context of the southern Arabian Gulf, coral community structure at these sites was compared against those reported earlier for the neighboring nations of Bahrain (Burt et al., 2013) and the UAE (Burt et al., 2011), which were surveyed using identical techniques. Transect data were pooled for each site and compared among 2 sites in Bahrain, 12 sites in the UAE, and the 3 Qatar sites surveyed here. Statistical approaches for the large-scale comparison followed those described above for coral cover and richness. In addition, multivariate community structure was examined. A hierarchical agglomerative cluster analysis was performed on the Bray Curtis distance matrices, and a Similarity Profile (SIMPROF) routine used to test for structure in the data (based on 999 permutations) to identify significantly different groupings. Significant coral community groups identified by SIMPROF were then overlaid on a two-dimensional NMS ordination of the same distance matrix to allow visualization of community structure. Coral species characteristic to the distinct community groups and the species driving differences among groups were identified using a Similarity Percentage (SIMPER) routine. All multivariate analyses were performed in Primer-E v7 software, with rare species (occurring in <5% of samples) excluded to avoid the influence of outliers.

3. Results and discussion

Coral communities throughout the southern Arabian Gulf have undergone substantial decline in recent decades as a result of recurrent bleaching events and widespread coastal development (Burt, 2014; Burt et al., 2011, 2013). This study provides a current assessment of coral communities at three sites in Qatar, providing baseline data against which future trends can be assessed, and compares these communities against those in neighboring nations to assess them in the larger regional context. The results show that there has been considerable change in coral abundance and composition relative to historic records, and highlight the need for immediate management intervention to conserve these fragile ecosystems.

3.1. Qatar's coral communities

Qatar's coral communities have been understudied relative to all other Gulf countries (Burt, 2013), and limited quantitative information is available on historic coral assemblages at the sites examined here. Umm Al-Arshan has historically been considered an important coral site in Qatar. This offshore seamount is located >40 km from northern Qatar and is surrounded by deep (>25 m) water, and this location likely buffers the coral community against many of the stressors affecting corals elsewhere in Qatar. Although the 1996/98 bleaching event decimated corals elsewhere in the nation, effects on Umm Al-Arshan were less extreme and it was considered among the least impacted communities in the country (Abdel-Moati, 2008). By the mid-2000s recovery of *Acropora* was well underway (Abdel-Moati, 2006; Riegl and Purkis, 2009, 2012), and this site was considered among the most diverse in Qatar (Abdel-Moati, 2006). However, widespread bleaching was observed here in 2010 (Al-Ansi, 2010), and there have been no further records of the coral community at this site in subsequent years.

Our results show that Umm Al-Arshan continues to be an important coral habitat in Qatar, but that the coral community remains impaired compared with earlier observations. The benthic community here was dominated by live coral and algae, which together covered over three-quarters of the substrate at this site, and dead coral was also relatively common (6% cover) (Fig. 1a). In terms of coral cover, Umm Al-Arshan had the highest coral cover of all sites (22.9%; Fig. 1b), with significantly more coral than Al-Ashat island (ANOVA $F_{(2,15)} = 6.1$, $p < 0.05$; Tukey's $p < 0.05$). This was also the most species rich site, containing 24 of the 26 coral species observed in this study (Supplementary Table 1), and had mean richness that was significantly higher than at all other sites (Fig. 1b; ANOVA $F_{(2)} = 289.7$, $p < 0.001$, Tukey's $p < 0.001$ each). These data are particularly important for adding to the historical