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Coral Reefs and Communities of Qeshm Island, the Persian Gulf

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Javid Kavousi, Jafar Seyfabadi, Hamid Rezai, and Douglas Fenner (2011) Coral reefs and communities of Qeshm Island, the Persian Gulf. *Zoological Studies* **50**(3): 276-283. Density and destruction of hard-coral communities of Qeshm I., on the Iranian side of the Persian Gulf, were investigated using the line-intercept transect method in 2009. The study covered 2 main coral areas of the island designated as site SHD in the south with 2 stations and site SOEA in the southeast with 3 stations. The SOEA site had fringing reefs along with patches of coral colonies, whereas the SHD site's corals were distributed as separate colonies in the area. The live coral coverage recorded at Qeshm I. was 10.27% ± 6.4%, and significantly differed ($p < 0.05$) between sites SHD at 14.03% ± 4.8% and SOEA at 8.24% ± 6.4%; differences among stations within the 2 sites were not significant ($p > 0.05$). Overall, 10 coral genera were recorded from the island: 8 at each of the 2 sites. *Porites* was the dominant genus recorded at Qeshm, and the SOEA site and its stations. In contrast, the dominant genera at SHD were *Favia* and *Platygyra*. No difference in dominant genera among the stations at SOEA was observed, but the dominant genera between SHD stations differed. Among several factors contributing to the destruction of corals of Qeshm I., overgrowth of algae, red tides, human activities, coral diseases, and fish biting were most important. http://zoolstud.sinica.edu.tw/Journals/50.3/276.pdf

Key words: Coral community, Density, Destruction, Qeshm I., Persian Gulf.

No marine ecosystem is recognized as being more diverse than coral reefs, yet they have been seriously damaged by anthropogenic and natural factors in recent decades (Adjeroud et al. 2009, Selkoe et al. 2009, Shearer et al. 2009). This destruction is, unfortunately, rapidly increasing so that at least 58% (Bryant et al. 1998) to 66% (Wilkinson 2002) of coral reefs worldwide are threatened by human-associated activities.

Coral destruction and mortality are more severe in some areas such as the Persian Gulf (Riegl 2001, Sheppard and Loughland 2002), where the semi-closed water body with extreme conditions restricts coral diversity and abundances compared to Indo-Pacific areas (Sheppard and Sheppard 1991, Fadlallah et al. 1995, Coles 2003). Only about 10% of the species that occur in the Indo-Pacific are found in the Persian Gulf, and community species compositions substantially differ from assemblages that normally dominate Indo-Pacific reefs (Coles 2003).

The restrictive factors are temperature fluctuations, high salinities, extremely low tides, winter macroalgal blooms, pollution (Shinn 1976, Coles 1988, Coles and Fadlallah 1991, Sheppard et al. 1992, Burt et al. 2008), and other factors which are globally prevalent. The maximum summer temperature of the Persian Gulf may reach 38°C (Baker et al. 2004), whereas the minimum winter temperature may be as low as 12°C (Coles and Fadlallah 1991, Sheppard et al. 1992). Maximum temperatures and salinities (35-40 psu) are higher and minimum temperatures are lower than normal ranges recorded for tropical and subtropical corals (Coles 2003). Furthermore, bleaching events in the Persian Gulf require higher

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temperatures than elsewhere (Wellington et al. 2001, Aronson et al. 2002, Sheppard 2003).

A thin coral reef framework fringes the Saudi Arabian, Bahraini, and Iranian coastlines in the central sectors of the gulf; further south in the territorial waters of Qatar and United Arab Emirates, and in Kuwaiti waters to the north, there are fringing reefs around offshore islands, and patches have formed in waters deeper than 10 m (Maghsoudlou et al. 2008). This distribution pattern appears to be primarily controlled by high rates of sedimentation near the shore and the availability of hard substrate (Hodgson and Carpenter 1995). There are some differences in the coral communities between the southern and Iranian regions of the Persian Gulf. For example, it was reported that the lower coral diversity recorded in the Iranian area is due to more-marginal conditions regarding coral growth (Fatemi and Shokri 2001). However, the lower number of species could be also due to the fewer number of studies done on Iranian coral reefs.

Unlike the southern Persian Gulf, coral reef studies in the northern part (Iran) are limited to a few qualitative studies of the existence of coral genera and species (Rosen 1971, Harrington 1976, Harger 1984). However, more-detailed studies were recently undertaken, including the identification of zooxanthellae of some reef corals at Kish and Larak Is. (Ghavam Mostafavi et al. 2007), and the coral reef status at Farurgan, Hengam, Larak, and Kish Is. (Rezai et al. 2007 2009). In addition, Samimi-Namin and Ofwgen (2009) reported 31 soft-coral species from some Iranian islands.

Despite previous studies on the corals of the Persian Gulf in recent years, information in this regard is still limited, particularly for Iranian corals, where many sites still remain unknown and some of them will probably perish unnoticed before such studies are conducted. Qeshm I. is the largest island in the Persian Gulf. What little information is available on its corals indicates that the majority of them are dead (Samimi-Namin et al. 2010).

The purpose of this work was to collect basic information on coral reefs of Qeshm I., such as the density and health of the reefs.

MATERIALS AND METHODS

Study area

Located near the Strait of Hormuz, in the northeastern Persian Gulf, Qeshm I. (26°45'N, 55°49'E) is the largest island of the Persian Gulf with few coral reefs. Due to its wide sandy and muddy shores, areas with corals are mainly restricted to 2 areas along the southern (SHD) and southeastern (SOEA) shorelines (Fig. 1), each < 2 km long.

Being located near the Strait of Hormuz, the location of one of the world's busiest shipping lanes, Qeshm I. is highly vulnerable to pollution and climatic fluctuations under the influence of the Indian Ocean and Sea of Oman. This work was, therefore, restricted to these 2 sites within shallow water (a maximum of 6 m deep).

The distance from the SOEA site to the coast is < 50 m in some places to about 150 m, which

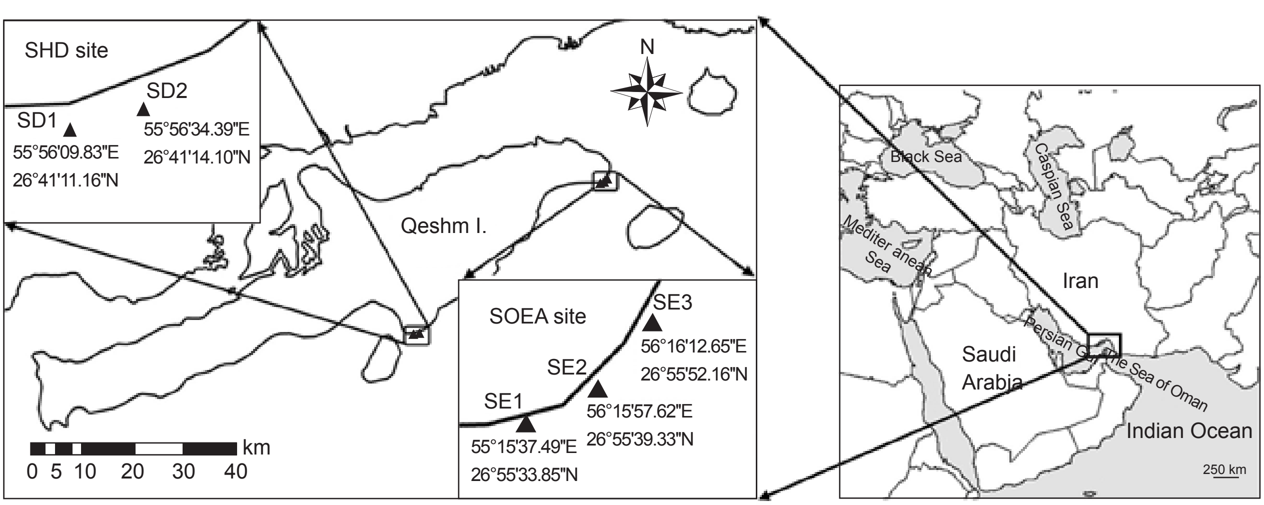

Fig. 1. Map of the study area: sites (SOEA and SHD) and stations (SD1, SD2, SE1, SE2, and SE3).

exposes it to high temperatures, light, and pollution during extremely low tides. It is possible for some reefs near shore to be exposed to air at low tide as well. In addition, the SOEA site is exposed to various human activities, such as construction, diving, and other activities. In contrast, the distance from the shore to site SHD is 100 to > 300 m. Site SHD is frequented by fishing boats and leisure sailing craft. Moreover, a 4-km gully between Qeshm and Hengam Is. exposes the corals of this site to intensive tidal currents.

Field and laboratory surveys

The study was performed during 2009, with 3 stations at the SOEA site (SE1, SE2, and SE3) and 2 stations at the SHD site (SD1 and SD2) (Fig. 1). Station locations were marked by a hand-held global positioning system device (Fig. 1). A 50-m line was used in this study for line-intercept transects, and anything observed under the transects was recorded, such as live coral coverage (LCC; down to genus level), dead coral, rubble, algae, sand, and others which included other fauna or flora. The length of each item was recorded. Four transects were established at each station except at stations SE2 and SE3 where 6 transects were established at each station.

Salinity and sea surface temperature were measured. Total suspended solids (TSS), sediments of < 125 μm, and the average reef height (ARH) were measured only once in the period of the study on 28-29 Sept.

For TSS, at each station, 6 water samples (500 ml each) were collected from slightly below the sea surface, and another 6 samples were taken from near the seabed. Samples were taken to the laboratory and passed through a vacuum pump equipped with pre-weighed 0.45-μm filters. Then, the filters containing the suspended material were dried in a 100°C oven for 1 h and reweighed. The difference in the 2 weights was recorded as the amount of TSS.

To measure sediments of < 125 μm, samples were collected from the seabed surface at each site. Samples were dried at 70°C for 24 h to a constant weight. A 25-g subsample was removed and soaked in 250 ml of fresh water and 10 ml of a sodium hexametaphosphate solution (6.2 g/L) to disaggregate the particles, then washed on a 0.63-μm sieve to remove the silt. The remaining samples were held at 70°C for 8 h to redry them, and then they were consecutively sieved through 4-, 2-, 1-, 0.5-, 0.25-, 0.125-, and 0.063-μm filters (Buchanan and Kain 1971). Sediments on each sieve were weighed, and the proportion of each fraction was determined. Here only data on the percentage of particles of < 125 μm in size are presented.

The ARH was recorded from the vertical distance between the lowest and highest points in the reef or colony structure (Wilson et al. 2007), which was measured with a randomly placed metallic meter stick, at each station. There were 66, 74, 32, 46, and 30 placements of the meter stick at stations SD1, SD2, SE1, SE2, and SE3, respectively.

The most important destructive factors at the island were also recorded based on direct observations during the year. Observations included destruction resulting from biological, physical, and other processes.

Statistical analysis

A Kruskal-Wallis one-way analysis of variance (ANOVA) was used to compare live coral coverage between sites and among stations. A one-way ANOVA was used to test for differences in other factors such as the ARH, TSS, and sediments of < 125 μm.

RESULTS

Unlike the SOEA site, no reef buildup exists at SHD, but rather there is a community of separate colonies spread throughout the area.

The mean LCC of Qeshm was 10.27% ± 6.4% of all substrata (Fig. 2). The mean LCC extents at the SHD and SOEA sites were 14.03% ± 4.8% and 8.39% ± 6.4%, respectively (Fig. 3). The SHD and SOEA sites significantly differed ($p < 0.05$, Kruskal-Wallis), whereas no significant difference was observed among stations within sites ($p > 0.05$, ANOVA). Maximum and minimum LCC extents were observed at stations SD1 (13.39% ± 7.0%) and SE2 (5.49% ± 3.3%), respectively (Fig. 4).

Water temperatures ranged from 25°C in May and Apr. to 33°C in Aug. and Sept. but salinity was nearly constant (36-37 psu) throughout the study period. Surface and near-bottom TSSs, sediments of < 125 μm (the majority of which were terrestrial not white carbonates), and the ARH were measured at all stations (Table 1), among which, only the ARH showed significant differences between the 2 sites and among stations ($p < 0.05$).

The most important destructive factors

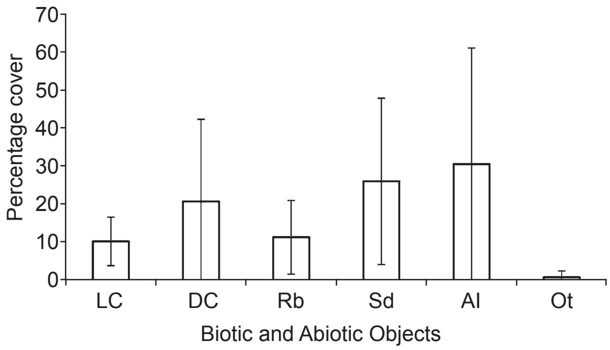

Fig. 2. Percentages of biotic and abiotic objects at Qeshm I. (LC, live coral; DC, dead coral; Rb, rubble; Sd, sand; Al, algae; Ot, others).

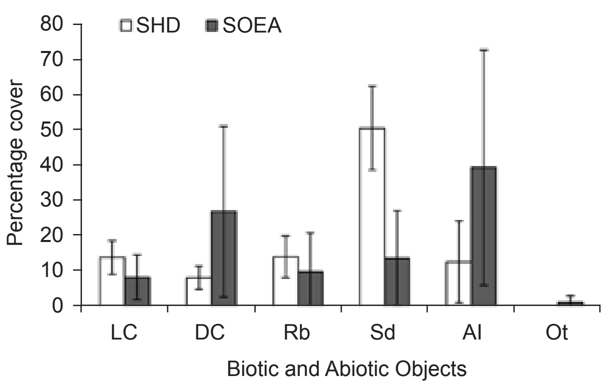

Fig. 3. Percentages of biotic and abiotic objects at the SHD and SOEA sites (LC, live coral; DC, dead coral; Rb, rubble; Sd, sand; Al, algae; Ot, others).

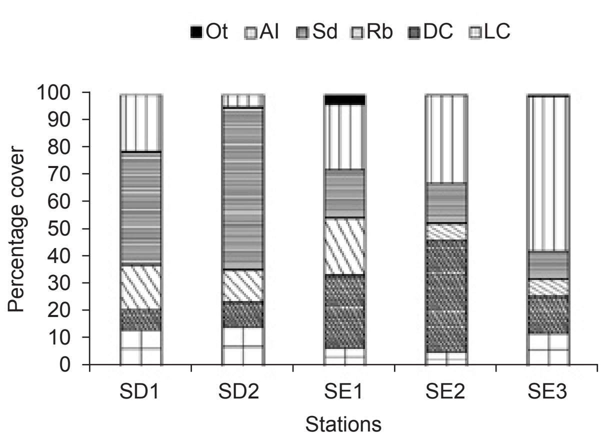

Fig. 4. Percentages of biotic and abiotic objects at the stations (LC, live coral; DC, dead coral; Rb, rubble; Sd, sand; Al, algae; Ot, others).

observed during the study or mentioned by local people are shown in table 2. The quality and quantity of these factors were not considered because no long-term monitoring data were available; some of them were clearly damaging the corals, e.g., the red tides which occurred periodically from Aug. 2008 to early 2010 in the study area.

In total, 10 hard coral genera were recorded at Qeshm I. (Fig. 5), 6 of which were commonly found at both sites, while 2 genera were only recorded at SHD and 2 others only at SOEA (Fig. 6). The dominant genus at Qeshm I. as a whole was *Porites* (51.42% ± 12.1% of all corals), and at site SOEA was also *Porites* (89% ± 12.2%), while at SHD, the dominant genera were *Favia* (31.88% ± 6.6%) and *Platygyra* (27.40% ± 5.9%). Detailed information is shown in figures. 5 and 6. Data on coral species for all stations are also given in table 3.

Table 1. Quantities of physical elements, measured during the study period. (TSS, total suspended solids; ARH, average reef height; *n*, no. of replicates)

Study area	Surface TSS (mg/L)	Near-bottom TSS (mg/L)	Sediments < 125 μm (%)
Station SD1	0.15	0.16	4.55 ± 1.79
Station SD2	0.13	0.16	8.18 ± 0.86
Station SE1	0.10	0.16	4.35 ± 1.38
Station SE2	0.10	0.13	10.12 ± 6.70
Station SE3	0.13	0.15	5.27 ± 1.94
Site SHD	0.14	0.16	6.62 ± 1.10
Site SOEA	0.11	0.15	6.32 ± 2.01
Qeshm I.	0.012	0.015	6.42 ± 1.37

Study area	*n*	ARH (cm)	*n*
Station SD1	3	19.15 ± 1.79	66
Station SD2	4	26.58 ± 2.56	74
Station SE1	5	74.72 ± 7.72	32
Station SE2	4	62.54 ± 5.48	46
Station SE3	5	40.43 ± 6.65	30
Site SHD	7	23.08 ± 1.62	140
Site SOEA	14	60.01 ± 3.93	108
Qeshm I.	21	39.16 ± 2.26	248

DISCUSSION

Low coral abundances and diversity in the Persian Gulf, reported for many years, are likely due to the harsh conditions such as the vast range of temperature changes, high salinities, sedimentation, and oil pollution (Coles 2003). Because of these severe conditions, along with human activities and limited hard substrate for coral settlement, the coral areas on Qeshm I. occupy only 2 very small parts of the coastline of this large island.

The hard corals of Qeshm I. are generally located on the southern (SHD site) and southeastern (SOEA site) sides of the island. SOEA corals have formed fringing reefs along with some separate colonies, but there are only separate colonies at the SHD site. This is probably due to the limited availability of hard substrate for larval settlement. At the SHD site, about 51% of the substrate is comprised of unstable substrate, i.e., sand.

Table 2. Destructive factors at Qeshm I. and their presence (+)/absence (-) at the sites

Destructive factor	Site SHD	Site SOEA
Diving and snorkeling	+	+
Boats	+	+
Fishing lines	-	+
-Stampping -on coral	+	+
Trap fishing	-	+
Fishing nets	+	+
Military maneuvers	+	-
Sedimentation due to construction	-	+
Spear fishing	-	+
Dumping of old fishing gear	+	+
Coral diseases	+	+
Red tide	+	+
Sea urchins (*Echinometra mathaei*, *Diadema setosum*, and *Diadema savignyi*)	-	+
Coral reef fishes	+	+
Extremely low tide	+	+
High human population pressure	-	+
Algal overgrowth	+	+
Littering	+	+
Oil pollution	+	+
Warm weather	+	+
Other factors	+	+

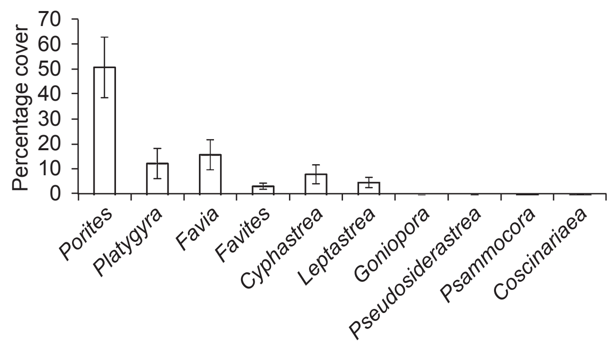

Fig. 5. Coral genera coverage at Qeshm I.

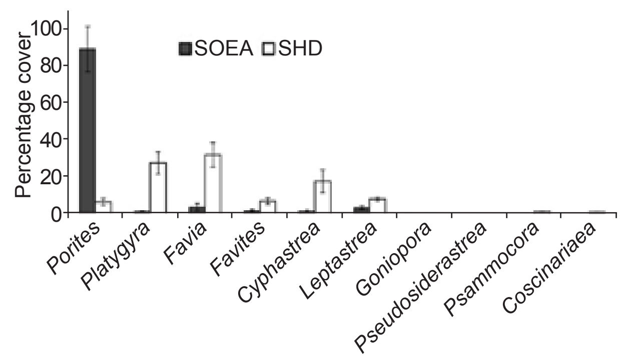

Fig. 6. Coral genera coverage at the SOEA and SHD sites.

Table 3. Coral genus coverage (%) at stations SD1, SD2, SE1, SE2, and SE3

Genus	SD1	SD2	SE1	SE2	SE3
Porites	6.0 ± 1.7	6.9 ± 1.7	81.3 ± 19.5	86.8 ± 9.7	93.2 ± 10.2
Platygyra	45.8 ± 5.4	10.7 ± 0.6	-	-	1.9 ± 0.4
Favia	10.6 ± 2.2	51.2 ± 3.9	10.7 ± 3.5	3.4 ± 0.8	1.2 ± 0.3
Favites	5.9 ± 1.8	7.9 ± 0.9	2.9 ± 1.1	0.7 ± 0.7	0.7 ± 0.3
Cyphastrea	25.2 ± 8.1	10.8 ± 1.0	2.5 ± 1.3	0.7 ± 0.3	0.9 ± 0.4
Leptastrea	5.8 ± 0.5	9.8 ± 0.8	1.9 ± 1.0	7.6 ± 1.7	2.0 ± 0.5
Goniopora	-	-	0.6 ± 0.3	-	-
Pseudosiderastrea	-	-	-	0.7 ± 0.3	-
Psammocora	0.7 ± 0.4	1.4 ± 0.5	-	-	-
Coscinariaea	-	1.4 ± 0.4	-	-	-

LCC is a critical component of a coral reef. The percentage of LCC is used as a health indicator of reefs (Brown 1988). The LCC of Qeshm I. is relatively poor. This could mainly be due to the shallowness of the coral beds (2-6 m), especially at the SOEA site which experiences higher temperatures during the extreme low tides in some areas. Rezai et al. (2007) compared the LCC of 2 Iranian islands, Hengam with 48.48% LCC and Farurgan with 25.91% LCC, and related the higher LCC percentage to a greater depth of the coral at Hengam I. The lower LCC at site SOEA (8.24% ± 2.1%) than at site SHD (14.03% ± 0.6%) may be due to the overgrowth of macroalgae, along with cyanobacteria, the harmful effects of which in the Persian Gulf were previously mentioned (Coles 2003). Macroalgae coverage extents recorded were 39.55% ± 33.4% at the SOEA site and 12.78% ± 11.6% at SHD site. Macroalgae in competition with corals for space can reduce the corals' energy, and cause defects in growth and fecundity processes (Tanner 1995, Jompa and McCook 2002 2003), and they can preempt the substrates onto which coral larvae need to settle (Mumby et al. 2005) and eventually kill the coral (Lirman 2001). The overgrowth of algae itself can be a result of coral death due to bleaching events (Kramer et al. 2003).

The Persian Gulf recently experienced at least 3 bleaching events in 1996, 1998, and 2002 (Rezai et al. 2004); the 2nd event was reported to have extirpated all *Acropora* corals and 6 other species in different genera from the southern Persian Gulf (Riegl 1999 2002, Sheppard 2006). It is possible that those events also killed the *Acropora* corals at Qeshm I., as no *Acropora* corals exist there now. According to the local people, *Acropora* was probably the dominant genus at the SHD site for most of the last decade, and even used to be exposed during low tides. The prior existence of *Acropora* on a large scale at SOEA was also confirmed by some researchers and experienced divers. So, live *Acropora* colonies were observed until at least several years after the bleaching events at these sites. Therefore, the bleaching events are likely not the only cause of *Acropora* extinction at the island. In other words, some other destructive factors must have affected the coral reef systems at Qeshm I.

Sedimentation has severely damaged coral reefs throughout the Persian Gulf (Riegl 1999, Rezai et al. 2004). Although no sediment traps were established due to human and natural intervention, sediment depths (measured by a metal ruler on dead corals) at SOEA varied 1-7 mm in different areas. The amount of sediments on the corals at SHD was too low to measure, mm probably due to the absence of coral reef formation, as clearly increases the sediment load. Another factor which greatly increased the accumulation of sediments on dead corals at SOEA was the expanse of filamentous algae that helps trap sediments. The existence of more-intensive tidal currents at SHD is another probable reason for the lower sediment load there; the SHD site is located between Qeshm and Hengam Is., which creates a gully of about 4 km long, causing more-intensive tidal currents than at the SOEA site. These currents which made work on this study very difficult, continually suspend the sediments and transfer other harmful factors like oil pollution and red tides. An unusual red tide composed of *Cochlodinium polykrikoides* which occurred in the Persian Gulf in Aug. 2008 and was also observed in early 2010 at the study sites may have been one of the most destructive factors. Although its impacts on SHD corals were relatively minor, probably due to the prevailing intense tidal currents, it impacted the coral ecosystems at the SOEA site both directly and indirectly by increasing the population of serpulid worms (Samimi-Namin et al. 2010) as the most evident abnormality in the island's reefs; a serpulid infestation was not observed at the SHD site. Some other abnormalities such as growth anomalies and bleaching were also observed, particularly at the SOEA site. Fish biting, especially by *Scarus persicus*, was documented on more than 80% of *Porites* colonies at the SOEA site in Sept. 2009. During Nov. no signs of fish biting were observed, and colonies had completely recovered. The most important destructive factors that may have contributed to low LCC in the island are listed in table 2.

Furthermore, we predict that the circumstances at the island will worsen due to anthropogenic activities such as establishing wharfs and breakwaters, which are increasing in number. Similarly, the destructive effects of breakwaters around coral areas of Larak I. were reported (Rezai et al. 2009).

In total, 10 hard coral genera were recorded at Qeshm I., which include more than 20 species. This number is comparable to that of Kish I. (21 species), and higher than the 16 species at Farur I. and 5 species at Nay-Band Bay (Fatemi and Shokri 2001). Only 1 or 2 colonies of some genera such as *Coscinariaea*, *Goniopora*, and

Pseudosiderastrea were observed, probably due to the harsh conditions. Currently, 25 genera of hard corals (21 of which are zooxanthellate) are reported from the waters of Kuwait (Carpenter et al. 1997), 16 from the UAE (Sheppard 1988), 8 genera from Qatar (Emara et al. 1985), and 16, 11, and 4 genera from Kish I., Farur I. and Nay-Band Bay, respectively (Fatemi and Shokri 2001). However, there are certainly more coral genera and species in the Gulf, particularly in Iranian waters where the reef sites in several spots have received little or no study.

It seems that conditions for different coral genera at the sites differ; for instance, while the circumstances at SOEA are probably not quite suitable for the growth of any genera except *Porites*, the abundance of this genus at the SHD site is limited (Fig. 6). The dominant genera at stations SD1 and SD2 differed not only from stations SE1, SE2, and SE3, but also from each other, despite being only about 1 km apart. *Platygyra* (45.8% ± 5.4%) and *Favia* (51.2% ± 3.9%) were the dominant genera at the SD1 and SD2 sites, respectively.

In conclusion, the conditions for corals at Qeshm are very harsh. The current absence of branching corals, particularly *Acropora* as one of the most vulnerable coral genera, from the island, along with the low numbers of genera and species compared to most of the Indo-Pacific, and the fact that only 1 or 2 small colonies of genera such as *Coscinariaea*, *Pseudosiderastrea*, and *Goniopora* were observed can all be considered indications of the harsh conditions for corals.

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REFERENCES

Adjeroud M, F Michonneau, PJ Edmunds, Y Chancerelle, T Lison de Loma, L Penin et al. 2009. Recurrent disturbances, recovery trajectories, and resilience of coral assemblages on a South Central Pacific reef. Coral Reefs **28:** 775-780.

Aronson R, WF Precht, MA Toscano, KH Koltes. 2002. The 1998 bleaching event and its aftermath on a coral reef in Belize. Mar. Biol. **141:** 435-447.

Baker AC, CJ Starger, TR McClanahan, PW Glynn. 2004. Corals' adaptive response to climate change. Nature **430:** 741.

Brown BE. 1988. Assessing environmental impact on coral reefs. Proc. 6th Int. Coral Reef Symp. (Townsville, Australia) **1:** 1-7.

Bryant D, L Burke, J McManus, M Spalding. 1998. Reefs at risk: a map-based indicator of threats to the world's coral reefs. Washington DC: World Resources Institute, 56 pp.

Buchanan JB, JM Kain. 1971. Measurement of the physical and chemical environment. *In* NA Holme, AD McIntyre, eds. Methods for the study of marine benthos. IBP Handbook no 16. Oxford, UK: Blackwell Scientific Publications, pp. 30-58.

Burt J, A Bartholomew, P Usseglio. 2008. Recovery of corals a decade after a bleaching event in Dubai, United Arab Emirates. Mar. Biol. **154:** 27-36.

Carpenter KE, PL Harrison, G Hodgson, AH Alsafar, SH Althazeem. 1997. The corals and coral reef fishes of Kuwait. Kuwait: Kuwait Institute for Scientific Research, 166 pp.

Coles S. 2003. Coral species diversity and environmental factors in the Arabian Gulf and the Gulf of Oman: a comparison to the Indo-Pacific region. Atoll Res. Bull. **507:** 1-19.

Coles SL. 1988. Limitations of reef coral development in the Arabian Gulf: temperature or algal competition? Proc. 6th Int. Coral Reef Symp. (Townsville, Australia) **3:** 211-216.

Coles SL, YH Fadlallah. 1991. Reef coral survival and mortality at low temperatures in the Arabian Gulf: new species-specific lower temperature limits. Coral Reefs **9:** 231-237.

Downing N. 1985. Coral reef communities in an extreme environment: the northwest Arabian Gulf. Proc. 5th Int. Coral Reef Congr. **6:** 343-348.

Emara HI, MI El-Samra, KZ El-Beed, IF Ahmed. 1985. A preliminary study of the chemical characteristics of coral reef areas in the Qatari waters (Gulf area). Proc. 5th Int. Coral Reef Congr. **6:** 343-348.

Fadlallah YH, KW Allen, RA Estudillo. 1995. Damage to shallow reef corals in the Gulf caused by periodic exposures to air during extreme low tides and low water temperatures (Tarut Bay, eastern Saudi Arabia). *In* RN Ginsburg, ed. Proceedings of the Colloquial Global Aspects of Coral Reefs, Health, Hazards, and History. RSMAS Univ. of Miami, **1993:** 371-377.

Fatemi SMR, MR. Shokri 2001. Iranian coral reefs status with particular reference to Kish Island, Persian Gulf. *In* Proceedings of the International Coral Reef Initiative (ICRI) Regional Workshop for the Indian Ocean, Maputo, Mozambique.

Ghavam Mostafavi P, SMR Fatemi, MH Shahhosseiny, O Hoegh-Guldberg, WK Weng Loh. 2007. Predominance of clade D *Symbiodinium* in shallow-water reef-building corals of Kish and Larak Islands (Persian Gulf, Iran). Mar. Biol. **153:** 25-34.

Harger JRE. 1984. Rapid survey techniques to determine distribution and structure of coral communities. *In* Comparing coral reef survey methods, UNEP-UNESCO workshop: Thailand, pp. 88-91.

Harrington FA. 1976. Iran: survey of the southern Iranian coastline with recommendations for additional marine reserves. In promotion of the establishment of marine parks and reserves in the northern Indian Ocean including the Red Sea and the Persian Gulf. IUNC Publ. New Ser. **35:** 50-75.

Hodgson G, K Carpenter. 1995. Scleractinian corals of Kuwait. Pac. Sci. **49:** 227-246.

Jompa J, LJ McCook. 2002. Effects of competition and herbivory on interactions between a hard coral and a brown alga. J. Exp. Mar. Biol. Ecol. **271:** 25-39.

Jompa J, LJ McCook. 2003. Coral-algal competition: macroalgae with different properties have different effects on corals. Mar. Ecol. Progr. Ser. **258:** 87-95.

Kramer PA, PR Kramer, RN Ginsburg. 2003. Assessment of the Andros Island reef system, Bahamas (Part 1: Stony corals and algae). Atoll Res. Bull. **496:** 77-100.

Lirman D. 2001. Competition between macroalgae and corals: effects of herbivore exclusion and increased algal biomass on coral survivorship and growth. Coral Reefs **19:** 392-399.

Maghsoudlou A, P Eghtesadi Araghi, S Wilson, O Taylor, D Medio et al. 2008. Status of coral reefs in the ROPME sea area (the Persian Gulf, Gulf of Oman and Arabian Sea). *In* C. Wilkinson, ed. Status of coral reefs of the world. Townsville, Australia: Global Coral Reef Monitoring Network Reef and Rainforest Research Centre, 304 pp.

Mumby PJ, NL Foster, EA Glynn Fahy. 2005. Patch dynamics of coral reef macroalgae under chronic and acute disturbance. Coral Reefs **24:** 681-692.

Rezai H, K Samimi-Namin, K Kabiri, M Jalili, P Ghavam Mostafavi, M Mokhtari. 2007. Distribution and abundance of corals around Hengam and Farurgan Islands, Persian Gulf. Tehran, Iran: Iranian National Centre for Oceanography, Department of Living Sciences. Report no. 385-1-08. (in Persian with English abstract)

Rezai H, K Samimi-Namin, K Kabiri, E Kamrani, M Ghavassi. 2009. Coral degradation, distribution and abundance around Larak and Kish Islands, Persian Gulf. Tehran, Iran: Iranian National Centre for Oceanography, Department of Living Sciences. Report no. 386-1-09. (in Persian with English abstract)

Rezai H, S Wilson, M Claereboudt, B Riegl. 2004. Coral reef status in the ROPME Sea area, Arabian/Persian Gulf, Gulf of Oman and Arabian Sea. *In* C. Wilkinson, ed. Status of coral reefs of the world. Vol. 1. Australian Institute of Marine Science, Townsville, Queensland, Australia, pp. 155-170.

Riegl B. 1999. Corals in a non-reef setting in the southern Arabian Gulf (Dubai, UAE): fauna and community structure in response to recurrent mass mortality. Coral Reefs **18:** 63-73.

Riegl B. 2001. Inhibition of reef framework by frequent disturbance: examples from the Arabian Gulf, South Africa, and the Cayman Islands. Palaeogeography, Palaeoclimatology, Palaeoecology **175:** 79-101.

Riegl B. 2002. Effects of the 1996 and 1998 positive sea surface temperature anomalies on corals, coral diseases and fish in the Arabian Gulf (Dubai, UAE). Mar. Biol. **140:** 29-40.

Rosen BR. 1971. The distribution of reef coral genera in the Indian Ocean. Symp. Zool. Soc. Lond. **28:** 263-299.

Samimi-Namin K, MJ Risk, BW Hoeksema, Z Zohari, H Rezai. 2010. Coral mortality and serpulid infestations associated with red tide, in the Persian Gulf. Coral Reefs **29:** 509.

Samimi-Namin K, LP Van Ofwegen. 2009. Some shallow water octocorals (Coelenterata: Anthozoa) of the Persian Gulf. Zootaxa **2058:** 1-52.

Selkoe KA, BS Halpern, CM Ebert, EC Franklin, ER Selig, KS Casey et al. 2009. A map of human impacts to a “pristine” coral reef ecosystem, the Papahanaumokuakea Marine National Monument. Coral Reef. **28:** 635-650.

Shearer TL, I Porto, AL Zubillaga. 2009. Restoration of coral populations in light of genetic diversity estimates. Coral Reefs, **28:** 727-733.

Sheppard C, R Loughland. 2002. Coral mortality and recovery in response to increasing temperature in the southern Arabian Gulf. Aquat. Ecosyst. Health Manage. **5:** 395-402.

Sheppard CRC. 1988. Similar trends, different causes: responses of corals to stressed environments in Arabian seas. Proc. 6th Int. Coral Reef Symp. (Townsville, Australia) **3:** 297-302.

Sheppard CRC. 2003. Predicted recurrences of mass coral mortality in the Indian Ocean. Nature **425:** 294-297.

Sheppard CRC. 2006. Longer term impacts of climate change. *In* I Cote, J Reynolds. eds.: Coral Reef Conservation, Cambridge Univ. Press, pp. 264-290.

Sheppard CRC, P Price, C Roberts. 1992. Marine ecology of the Arabian Region. London: Academic Press, 347 pp.

Sheppard CRC, ALS Sheppard. 1991. Corals and coral communities of Arabia. Fauna Saudi Arab. **12:** 3-170.

Shinn EA. 1976. Coral reef recovery in Florida and the Persian Gulf. Environ. Geol. **1:** 241-254.

Tanner JE. 1995. Competition between scleractinian corals and macroalgae: an experimental investigation of coral growth, survival and reproduction. J. Exp. Mar. Biol. Ecol. **190:** 151-168.

Wellington GM, PW Glynn, AE Strong, SA Nauarrete, E Wieters, D Hubbard. 2001. Crisis on coral reefs linked to climate change. EOS **82:** 1-7.

Wilkinson C. 2002. Status of coral reefs of the world. Townsville, Australia: Australian Institute of Marine Sciences.

Wilson SK, NAJ Graham, NVC Polunin. 2007. Appraisal of visual assessments of habitat complexity and benthic composition on coral reefs. Mar. Biol. **151:** 1069-1076.