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Assessment of Survival, Mortality and Recovery of Coral Reefs of East Kish Island, Persian Gulf

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Abstract: Coral reefs are specialized communities that develop clear, well-lit tropical and subtropical water; they provide shelter and canopy for great variety of organisms, living in mean temperature of 20°C. Coral Bleaching and mortality have been associated with elevated seawater temperature. The aim of the study was to investigate coral bleaching and evaluate health condition of the corals. Distribution of coral reefs around Kish Island was determined by the Timed Swim (TS) technique. This survey carried out in 2 times (May and October, 2009) in 2 depths of 3-5 m and 6-10 m. Two Divers swam in constant speed for a set amount of time in three dive sites. The timed swim survey around the Kish Island showed that the most healthy live hard coral assemblages were found in the site called Persian Gulf seaport, whereas the greatest percentage of bleached corals were located in Jurassic Park station, located at the southeast of the Island. Branching corals (*Acropora* sp.) were bleached among all 3 stations and no sign of recovery could be detected. In Big coral site suitable substrate for accumulation of living organisms including *Echinometra mathaie* (sea urchin) existed due to presence of great amount of algae on dead corals and rocks. Based on the observation, it seems that the cause of reef destruction in Kish Island fall in to two categories, natural and human impacts.

Key words: Coral reef, Kish island, Coral reefs, Persian gulf, bleaching

INTRODUCTION

Persian gulf is a semi-enclosed marginal sea surrounded by landmasses. It is located in the subtropical northwest of the Indian Ocean. Corals live in a harsh condition because of high salinity, fluctuations and long temperature extremes as well as low tide exposures. Persian Gulf is a shallow sea with an average depth of about 35 m (Fatemi and Shokri, 2001). The thermal regime of this shallow Gulf is influenced to a great degree by solar radiation and wind. Sea temperature normally ranges between 14 to 34°C (Coles and Fadlallah, 1991).

Kish Island is the first Iranian duty free zone. It occupies 91 km^2 and is situated 18 km from the southern most tip of Iran's mainland in the Persian Gulf. Kish Island lies between 26°30'N and the 26°35'N and 53°54'E and 54°03'E.

Coral reefs are specialized assemblages that develop in clear, well-lit tropical and subtropical waters, characterized by great number of organisms (Wood, 1999). They grow on flat substrates (Riegl, 1999), in a mean sea temperature of 20°C (Coles and Fadlallah, 1991) with a salinity range normally between 32 to 42 ppt (Maghsoudlou, 2008). These ecosystems are sensitive to climate induced changes in their physical environment (Baker *et al*., 2008).

Corals bleach under broad range of external stimuli, when these exceed normal level and become stressful. Stimuli that elicit bleaching include high and low temperatures, high and low light level, low salinity, sedimentation and general stress. Under stressful conditions, mechanisms of bleaching include reduction in the pigment content of zooxantellae and in the density of zooxantellae in coral tissues (Obura, 2008). Coral bleaching and mortality have been associated with elevated seawater temperature (Glynn, 1993).

In Persian gulf, coral reefs experience long periods of extreme sea temperature (above 30°C) in summer and low (below 16°C) temperature in winter (Shokri *et al*., 2000). However, for the southern parts of Persian Gulf the cause of coral reef mortality has been reported to be low water temperature (below 13°C) lasting for a period of days or weeks (Coles and Fadlallah, 1991). While from our experience and observation, it is clear that the mortality of corals occurred in northern part of the Persian gulf is due to long summer with too warm waters observed in Kish Island in 1998 and 2007.

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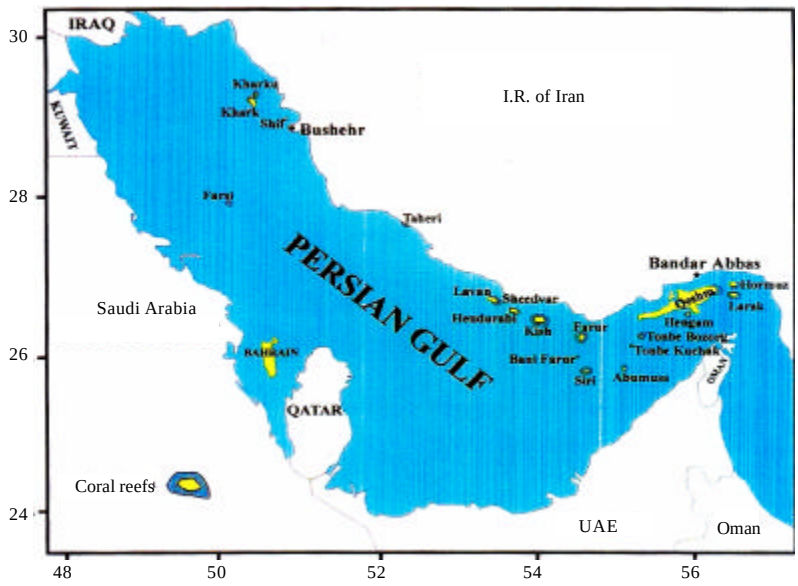

Fig. 1: Distribution of coral reef in Iran (Shokri *et al*., 2000)

In August 2007, coral bleaching occurred in the Northern Persian gulf, while there were no reports from the south. The extent of bleaching along the Iranian coastline is unknown, but it affected the Islands of Kish, Farur and Hendorabi, when mean SSts reached 36.2 and 34.2°C at 10 m depth and remained like this for about one month (Maghsoudlou *et al*., 2008).

Figure 1 shows the distribution of the coral reef in Persian Gulf. They are mostly developed as fringing reefs around Islands (Shokri *et al*., 2000) and along a few coastal districts. The healthiest reefs on the Iranian side are found around Khark and Kharku Islands in the far north and around the southern Islands, from Lavan to Hormuz (Shokri *et al*., 2000).

During two years of effort (Diving and photography), Rezaei (1996) studied the corals around different Islands of Persian gulf and identified 35 species of hard corals. In this study 12 selected sites were studied and the presence of soft coral (*Sacrophyton*), crown-of-thorns star fish (COTs) in the northern part of Persian Gulf (Tunb-e-Kuchak Island) and of hard coral (*Seriatopora*) around Larak Island were all reported for the first time (Rezaei, 1996). Surveys by Sadeghi (1997) on the hard corals of Kish Island, identified 19 species. Shokri investigated coral reefs around Kish Island and reported that approximately 15% of hard corals were bleached (Shokri *et al*., 2000). Fatemi and Shokri (2001) studied the coral reefs around Kish and Farur Islands and Nay Band Bay. They reported 27 species of hard corals, for Kish Island 21 species of hard corals.

Yellow Band Disease (YBD) in coral reefs around Kish Island is also investigated (Rezai *et al*., 2004). Maghsoudlou *et al*. (2008) studied bleaching in Larak and Kish Islands and Nay Band Bay. They reported 15% to 35% coral cover (hard and soft) in these areas.

The family Acroporidea was the most popular, while Favidae and Poritidae occurred most frequently and Agareciidae and Dendrophyllidae occurred most rarely (Shokri *et al*., 2000).

The present study aimed at investigating coral bleaching and evaluating the health condition of the corals.

MATERIALS AND METHODS

This survey carried out in 2 times of the year (May and October 2009) in 2 depths of 3-5 m and 6-10 m. Two Divers swam in constant speed for a set amount of time in three dive sites, called Persian Gulf seaport station(26°32' 3.6"E, 54°01' 78.6" N) in northeast part of island whereas usage for diving and boating, Big Coral station (26°30' 3.6" E, 54°02' 64.8" N) east of island and Jurassic Park station (26°30' 1.3"E, 54°02' 50.5 N) in front of dolphin park, in southeast of Kish Island whereas to estimate impact of bleaching in coral reef. Each site distance was 200-250 m from the shore. For each of the two depths in each site, divers equipped with SCUBA diving equipment moved slowly every 25 m^2 (a total of 200 m^2 for each site), equivalent to a slow walk, for 2 min. After each timed swim the percentage cover of live and dead coral,

Fig. 2: Map of Kish Island and position of sites from Google earth 2009

Table 1: Categories for estimation of dead coral

Visual assessment	Description	Percent	Index
No dead coral	Live coral	<1	0
Dead coral colonies seen occasionally	Low dead coral	1-10	1
Dead coral colonies seen conspicuous	Medium dead	10-25	2
Dead coral colonies frequent but less than half or all colonies	Moderate dead	25-50	3
Most of coral dead	High dead coral	50-90	4
Dead coral dominates landscape, live coral not common	Extremely dead	>90	5

In the present paper the distribution of coral reefs around Kish Island was determined by the Timed Swim (TS) technique described in Hill and Wilkinson (2004)

substrate and rock were estimated. To determine the existence of dead hard corals in different depths, after 8 dive carried out in each site, dead hard corals were estimated according to indices of categories shown in Table 1.

The air and seawater temperatures were recorded by a mercury thermometer. Figure 2 shows the position of research stations. Statistical analysis was carried out using a one way analysis of variance (One way ANOVA) with SPSS statistical software (Vers.16).

RESULTS

The timed swim survey around the Kish Island showed that most live hard corals were found on the northeast, the site called Persian Gulf seaport (Fig. 3 and Table 3, 4). Table 2 shows the description of related figures. The greatest percentage of dead corals was found on Jurassic Park station (Fig. 4 and Table 5, 6). Dead corals in Big Coral site was between Persian Gulf seaport station and Jurassic Park station (Fig. 5 and Table 7, 8).

Table 2: Show description of Fig. 6-11

No. of figure	Description
6	Show percent of dead coral (May 2009) in Big coral site
7	Show percent of dead coral (May 2009) in Jurassic park site
8	Show percent of dead coral (May 2009) in Persian Gulf seaport site
9	Show percent of dead coral (October 2009) in Persian Gulf seaport site
10	Show percent of dead coral (October 2009) in Jurassic park site
11	Show percent of dead coral (October 2009) in Big coral site.

Table 3: Estimate of Persian Gulf seaport, October

No. of dive	Index	Description
1	1	Low dead coral
2	1	Low dead coral
3	0	Live coral
4	1	Low dead coral
5	2	Medium dead
6	2	Medium dead
7	1	Low dead coral
8	1	Low dead coral

Table 4: Estimate of Persian Gulf seaport, May

No. of dive	Index	Description
1	2	Medium dead
2	2	Medium dead
3	1	Low dead coral
4	3	Moderate dead
5	1	Low dead coral
6	2	Medium dead
7	2	Medium dead
8	1	Low dead coral

Table 5: Estimate of Jurassic park site, May

No. of dive	Index	Description
1	3	Moderate dead
2	3	Moderate dead
3	3	Moderate dead
4	2	Medium dead
5	4	High dead coral
6	3	Moderate dead
7	2	Medium dead
8	2	Medium dead

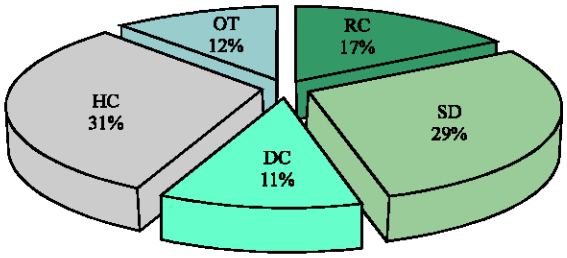

Fig. 3: Percent cover of different substrates in Persian Gulf seaport site (HC: Hard coral, DC: Dead hard coral, OT: Other, RC: Rock and SD: Sand)

Timed swims on the eastern side of the island showed that normally coral grow at 4 m deep and more, areas less than 4 m depth were covered by sand. Timed swim survey at two depth contours 3-5 m and 6-10 at the reef slope at the Persian Gulf seaport station in May and October,

Table 6: Estimate of Jurassic park, October

No. of dive	Index	Description
1	2	Medium dead
2	2	Medium dead
3	3	Moderate dead
4	3	Moderate dead
5	3	Moderate dead
6	2	Medium dead
7	2	Medium dead
8	3	Moderate dead

Table 7: Estimate of Big coral site, May

No. of dive	Index	Description
1	3	Moderate dead
2	2	Medium dead
3	2	Medium dead
4	3	Moderate dead
5	2	Medium dead
6	3	Moderate dead
7	3	Moderate dead
8	3	Moderate dead

Table 8: Estimate of Big coral site, October

No. of dive	Index	Description
1	3	Moderate dead
2	2	Medium dead
3	3	Moderate dead
4	2	Medium dead
5	3	Moderate dead
6	4	High dead coral
7	1	Low dead coral
8	2	Medium dead

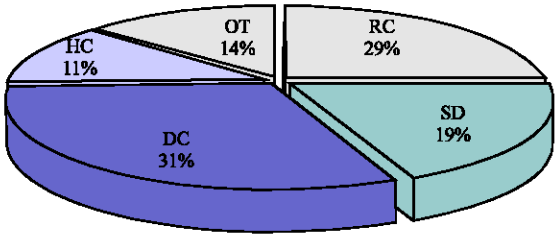

Fig. 4: Percent cover of Different substrates in Jurassic park site.Dead coral percent was major in this site

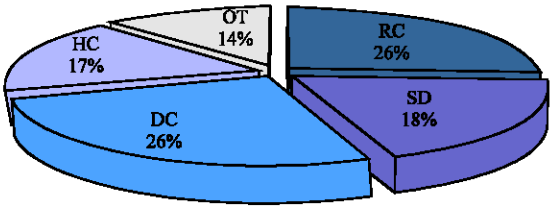

Fig. 5: Percent cover of Different substrates in Big coral site

showed alive colonies of *Porites* sp., species *P. lutea*, *P. compressa* and *Cyphastrea microphthalma* had normal growth and were abundant. Jurassic Park station, showed

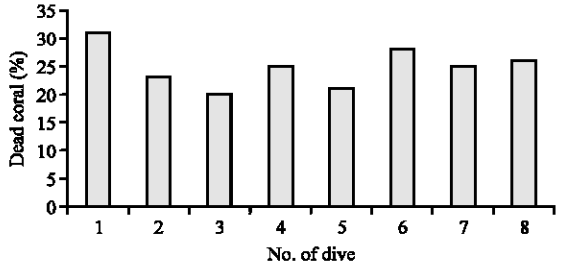

Fig. 6: Percent of dead coral in may in big coral site

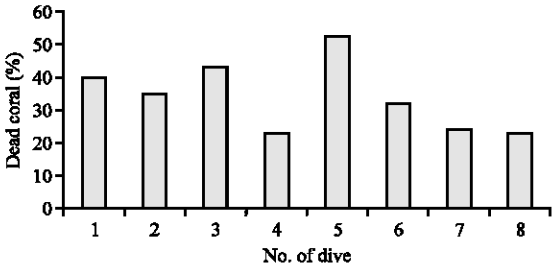

Fig. 7: Percent of Dead coral in May in Jurassic park site

abundant dead corals of *Acropora* sp., live corals in reef slope were species like *Plathygyra daedalea*, *Favia* sp. and *Porites lutea*, *Pavona decussate*. In Big Coral station great amount of dead coral cover was observed, but it was less than that of the JurassicPark station. Species seen were *Plathygyra daedalea* and *Favia* sp., *Porites lutea*, *Goniastrea australiensis*, *Psammocora contigua*, *Acanthastrea maxima* and *P. compressa*. The most diverse coral assemblages were found in Big Coral station, but healthiest corals were found in Persian Gulf seaport station.

Branching corals (*Acropora* sp.) were found dead among 3 stations and no sign of recovery was noticed. Alive *Acropora* sp. was not found in eastern Kish Island. In 2007 bleaching, most *Acropora* sp. species bleached and since then no live or juvenile *Acropora* sp. colonies were found around Kish Island. Dead branching coral skeletons were covered by seaweed and filamentous algae, this state observed on Jurassic Park and Big Coral stations too. In October 2009 serious bleaching was not observed and typically coral colonies were healthy.

Red tide of *Cochlodinium polykrikoides* had occurred in Persian Gulf during the study and it was existed in both studied months with a distant of 1 km from the Coast of Kish Island but was not observed in shallow waters of investigated zones. Despite the presence of red tide, no effect on the corals could be detected, however the consequence of this long lasting red tide and its effected on corals is yet to be investigated.

Figure 3 show average of percent covers of different substrates in Persian Gulf seaport site. Hard coral percent was in high quantity (between 3 stations).

Figure 5 show average of percent covers of different substrates in Big coral site. Rock percent was in high between 3 stations.

Figure 6 show dead coral percent in each dive, dead coral percent was between 20 and 31%.

Figure 7 show dead coral percent in each dive, dead coral percent was between 23 and 52%.

Figure 8 show dead coral percent in each dive, dead coral percent was between 8 and 20%.

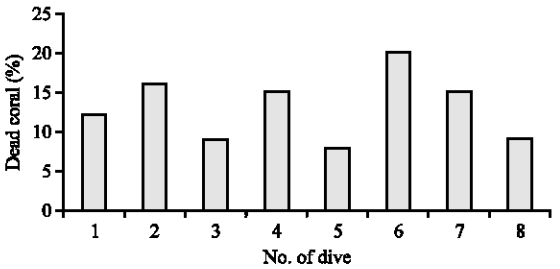

Fig. 8: Percent of dead coral in may in persian gulf seaport site

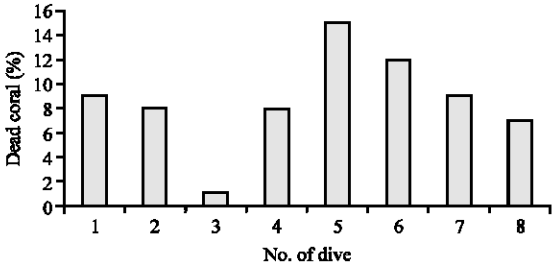

Fig. 9: Percent of dead coral, in October in persian gulf seaport site

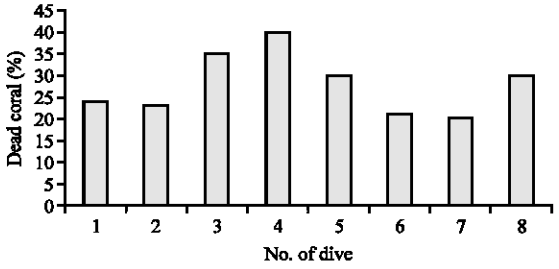

Fig. 10: Percent of dead coral, in October in jurassic park site

Figure 9 show dead coral percent in each dive, dead coral percent was under 15%.

Figure 10 show dead coral percent in each dive, dead coral percent was between 20 and 40%.

Figure 11 show dead coral percent in each dive, dead coral percent was between 10 and 52%.

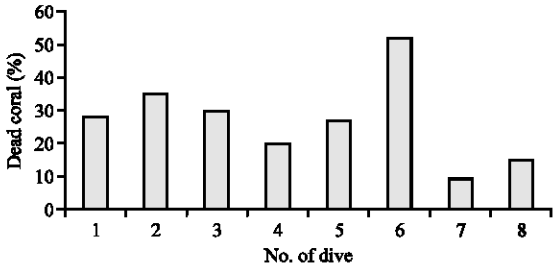

Fig. 11: Percent of dead coral, in October in big coral site

DISCUSSION

In the present study, we looked at survival condition of corals of Kish Island in east part of the island. According to observations and obtained results, the diversity of species in Big coral region was more than twice of the other regions. This is due to high extent of concerned coral zone which provides the corals with the possibility of a high diversity. There was a high diversity and low percentage of live corals in Big coral region. According to the observation was found great colonies of Acropora sp. In this area, after bleaching 2007 and coral mortality branching type of corals constituted high percent of dead corals. On the other hand because this station has suitable substrate, accumulation of organisms including *Echinometra mathaie* (sea urchin) due to presence of great amount of algae on dead corals and rocks was observed. This species separates a part of live tissue of coral and causes destruction of corals by grazing abundant algae on the dead coral (Goldberg and Wilkinson, 2004; Fadlallah *et al*., 1995) where the live coral is also present because this bed is more suitable for the aforesaid species in Big coral station and there is more abundance and destruction is in the greatest level, but there are reverse conditions in Persian Gulf seaport station. The percentage of live corals in Jurassic park station was very low (destruction the sea substrate) and sea bed in this station constituted of gravel and rubble. This part of the Island is the place where diving boats pass and anchor, therefore they cause breakage and crushing of corals (specially branching type of corals). Moreover, the influence of human on Jurassic park station including anchoring and coastal development and pollution not only impose high stress on corals, but also has changed organism of the ecosystem.

Considering Fig. 3, the percentage of dead corals in Persian Gulf seaport station was much less than that of other stations and the higher cover of live hard corals on the Persian Gulf seaport station is likely due to the existence of massive (*Favia* sp.) and sub massive (*Porites* sp.) in this area, which are more tolerant to the destructive effects of storms and human activities(Shokri *et al*. 2000). Distraction of corals, especially of branching type, due to the bleaching in 2007 was followed by alternate weakeing of corals as a result of human-induced and natural pressures on these ecosystems. Other damages such as bleaching may be the result of either natural or human induced impacts. Iranian scientists monitored Kish island reef before and after the bleaching of mid-August 2007 which affected reefs on the eastern side and probably other parts and finally killed all of the branching type of corals (Maghsoudlou *etal*., 2008). Especially where the sea bed has a shallow slope which made branching corals vulnerable to high water temperature during low tides. Other corals such as *Favia* sp., *Plathygyra* sp. and *favia* sp. appear to be more resistant to temperature stress (Maghsoudlou *et al*., 2008). In Persian Gulf seaport station massive and sub massive corals recovery was noticed and had normally grown but there were no live colony of branching corals (*Acropora* sp.) around Kish Island.

Based on the observation, it seems that the causes of reef destruction in Kish Island fall into two categories, natural impacts and human impacts. The most severe natural factors threatening the reef corals in this Island are seemingly storms, bleaching events and extreme environmental conditions, especially the sudden rise in sea surface temperatures during the mid summer probably due to global climate change. Human-induced damage includes that resulting from construction activities along the coast of the island, which is presently under heavy development. Increasing anchoring, destructive fishing activities i.e. trap fishing, industrial pollution (Price, 1993), land based pollution from municipal sewage and probably dolphinarium are other factors threatening the coral reefs. Corals are in competition with seaweeds for space (Shokri *et al*., 2000), the dead corals such as great colonies of *Acropora* sp. in Big coral and Jurassic Park stations were completely covered by seaweed. A light growth of filamentous brown algae covered the dead portion of the corals (Fadlallah *et al*., 1995) and their growth could be enhanced by the increasing input of nutrients in to the sea. Persian Gulf seaport station showed this state but in low intensity. At Jurassic Park station water input of dolphin pools increase this state and all of dead branching corals were covered by seaweed. In Big coral station, nutrients enter into seawater due to runoff.

The relative importance of factors causing damage to reefs on this Island needs to be studied in more detail and an immediately reduction on diver and boat anchor damage is highly recommended. Mooring bouys should be installed at major reef sites to prevent further anchor damage to coral.

On the other hand, after bleaching in 1996 recovery through coral growth had already started in Kish island mainly for Acropora species which were damaged and

Table 9: Analyze one way ANPVA for 3 stations in May (X<0.05)

Analyze one way for 3 stations in May	Sum of squares	df	Mean square	F	Sig.
Between groups	10.083	2	5.042	9.736	0.001
Within groups	10.875	21	0.518		
Total	20.958	23			

Table 10: Analyze one way ANOVA for 3 stations in October (X<0.05)

Analyze one way for 3 stations in October	Sum of squares	df	Mean Square	F	Sig.
Between groups	4.750	2	2.375	5.620	0.011
Within groups	8.875	21	.423		
Total	13.625	23			

destroyed during bleaching. These corals fast growth (at least 10 cm per year) were observed in 2001 by Fatemi and Shokri. They suggested that Acropora population would be established in a few years. But after bleaching in 2007 Acropora species couldn't recover. The reason for the Acropora disaster of Kish Island is to be investigated in detail. There is still hope that if certain conservation measure deployed recovery of the highly valued branching Acropora would occur.

Statically analyze one way (ANOVA) between each station for two different months (May, October) showed significant difference (x<0.05) (Table 9, 10).

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