NUSANTARA BIOSCIENCE
Vol. 3, No. 2, pp. 73-81
July 2011

ISSN: 2087-3948
E-ISSN: 2087-3956
DOI: 10.13057/nusbiosci/n030204

Corals differential susceptibilities to bleaching along the Red Sea Coast, Egypt

MOHAMMED SHOKRY AHMED AMMAR[1,♥], AHMED HAMED OBUID-ALLAH[2], MONTASER ALY MAHMOUD AL-HAMMADY[3]

[1]National Institute of Oceanography and Fisheries (NIOF). P.O. Box 182, Suez, Egypt. Tel. +20 11 1072982, Fax. +20 623360016, [♥]email: shokry_1@yahoo.com.

[2]Department of Zoology, Faculty of Science, Assiut University, Assiut, Egypt

[3]National Institute of Oceanography and Fisheries (NIOF), Hurghada, Egypt

Manuscript received: 5 May 2011. Revision accepted: 16 July 2011.

Abstract. *Ammar MSA, Obuid-Allah AH, Al-Hammady MAM. 2011. Corals differential susceptibilities to bleaching along the Red Sea Coast, Egypt. Nusantara Bioscience 3: 73-81.* Coral bleaching was studied at four sites in four widely geographically separated areas. Three of these sites are subjected to different human activities and the fourth one is considered as a control site. Data were collected by using SCUBA diving, and the line transects method. A total of 3940 coral colonies, representing 62 species in 21genera and 10 families, were recorded on transects on the reefs of four studied sites.20.11% of all corals were affected by bleaching: 5.4% were moderately affected; 2.7% severely affected and 12.007% were dead. Overall, there were differences in the proportion of colonies affected by bleaching between the studied sites. Ras El-Behar, the site impacted by petroleum oil, has the maximum average proportion of moderately, severely bleached and dead colonies. While, the lowest average proportions of severely bleached colonies and dead colonies were found at Kalawy bay. Surprisingly, coral reef taxa at El-Hamraween harbor showed high resistance to bleaching probably because of having a new different clade of *Symbiodinium* which can withstand seawater temperature. Species with highest susceptibilities to bleaching in areas of oil pollution, increased sedimentation and heavy load of phosphate is *Stylophora pistillata*, *Acropora granulosa,* and *Montipora meandrina,* respectively while species with lowest susceptibilities are *Fungia fungites, Alveopora daedalea* and *Millepora dichotoma*, respectively.

Keywords: coral, bleaching, eutrophication, oil pollution, sedimentation, Red Sea.

Abstrak. *Ammar MSA, Obuid-Allah AH, Al-Hammady MAM. 2011. Kerentanan diferensial karang terhadap pemutihan di sepanjang Pantai Laut Merah, Mesir. Nusantara Bioscience 3: 73-81.* Pemutihan karang dipelajari di empat lokasi pada empat wilayah geografis yang terpisah secara luas. Tiga dari lokasi ini dipengaruhi aktivitas manusia yang berbeda dan lokasi yang keempat dianggap sebagai lokasi kontrol. Data dikumpulkan dengan menggunakan peralatan menyelam SCUBA dan metode garis transek. Sebanyak 3940 koloni karang, yang mewakili 62 spesies dari 21genera dan 10 famili, tercatat pada transek yang mewakili empat lokasi terumbu karang yang dipelajari. 20.11% dari semua karang mengalami pemutihan: 5,4% cukup terpengaruh; 2,7% terkena dampak parah, dan 12,007% mati. Secara keseluruhan, terdapat perbedaan proporsi koloni yang dipengaruhi oleh pemutihan antara masing-masing lokasi yang dipelajari. Ras El-Behar, lokasi yang dipengaruhi oleh minyak bumi, memiliki proporsi merata antara koloni yang cukup, parah dan mati. Sementara, proporsi rata-rata terendah dari koloni yang parah dan mati ditemukan di teluk Kalawy. Mengejutkannya, terumbu karang di pelabuhan El-Hamraween menunjukkan resistensi yang tinggi terhadap pemutihan kemungkinan karena memiliki kelompok baru *Symbiodinium* yang berbeda dan dapat menahan suhu air laut. Spesies dengan kerentanan tertinggi untuk pemutihan di lokasi yang mengalami pencemaran minyak, peningkatan sedimentasi dan fosfat secara berturut-turut adalah *Stylophora pistillata*, *Acropora granulosa* dan *Montipora meandrina*, sementara spesies dengan kerentanan terendah secara berturut-turut adalah *Fungia fungites, Alveopora daedalea* dan *Millepora dichotoma*.

Key words: karang, pemutihan, eutrofikasi, polusi minyak, sedimentasi, Laut Merah.

INTRODUCTION

Coral reefs are subject to extensive anthropogenic damage which is associated mainly with urbanization and coastal development (Wielgus et al. 2004; Hagedorn et al. 2010; Ammar 2011). Dramatic reversible decline in coral reef health has been reported from every part of the world. Between 50% and 70% of all coral reefs are under direct threat from human activities (Wilkinson 1999). In addition, coral reefs have experienced unprecedented levels of bleaching, disease, and mortality during the last three decades (Kramer 2003; Ammar 2009; Miller et al. 2011). Various stressors have led directly or interactively to coral reef decline, and may be linked to global changes in climate, land use or human activities in coastal areas (Yee et al. 2008; Miller et al. 2011). Carriquiry and Horta Puga (2010) and Ammar et al. (2007) reported that eutrophication, increased sedimentation flowing from disturbed terrestrial environment, mining and oil pollution are the main causes of reef destruction. Coral bleaching is yet another major contributing factor to decline of coral reefs (Obura 2005; Manzello et al. 2007; Baker et al. 2008). Coral bleaching results in the breakdown of a mutualistic symbiosis that is essential for the survival of corals, since the polyp receives a substantial part of its energy from the zooxanthellae (Douglas 2003), and any disruption of this relationship will affect photosynthetic potential, coral growth, and reproductive output; and might lead to eventually killing corals (Baker et al. 2008). Miller et al. (2011) found that bleaching and associated mortality is an extreme threat to the persistence of coral populations in the projected warming regime of the next few decades. Most coral reef biologists do agree that coral reefs are changing and will exist in the near future but they will not be the ‘‘coral reefs" we have come to know in many parts of the world (Knowlton 2001). It is essential for the coral reef community to work together for the common good of the ecosystem. Time is short, as finance, to conduct the integrative studies required to understand the range of acclimating capabilities that reef corals has in the face of continued environmental change, and to potentially predict which reefs will remain. This could be possible by monitoring different coral areas after a tough program of decreasing the global CO_2 transmission.

In this study, we examined the initial bleaching response of corals to test the predictions of coral taxa that vary in their susceptibility to bleaching. We also aimed to study the relative bleaching susceptibilities of taxa to different impacts, outlining the degree of harm of each impact, the possibility of recovery and putting the possible scientific solutions.

MATERIALS AND METHODS

Study area

A preliminary visual survey of the Egyptian Red Sea coast, using snorkeling and SCUBA led to selection of four sites at four widely geographically separated areas along the western coast of the Red Sea (Figure 1). Which are Ras El-Behar (northern Hurghada), Middle reef (Hurghada), Kalawy bay (Safaga) and El-Hamraween harbor (El-Quseir). Three of these sites are subjected to different human activities and the fourth one is considered as a control site. Ras El-Behar (Site 1) lies at the northern part of the Red Sea, at a distance of about 60 km north to Hurghada city, between latitudes 27º 43’ 12” N and 27º

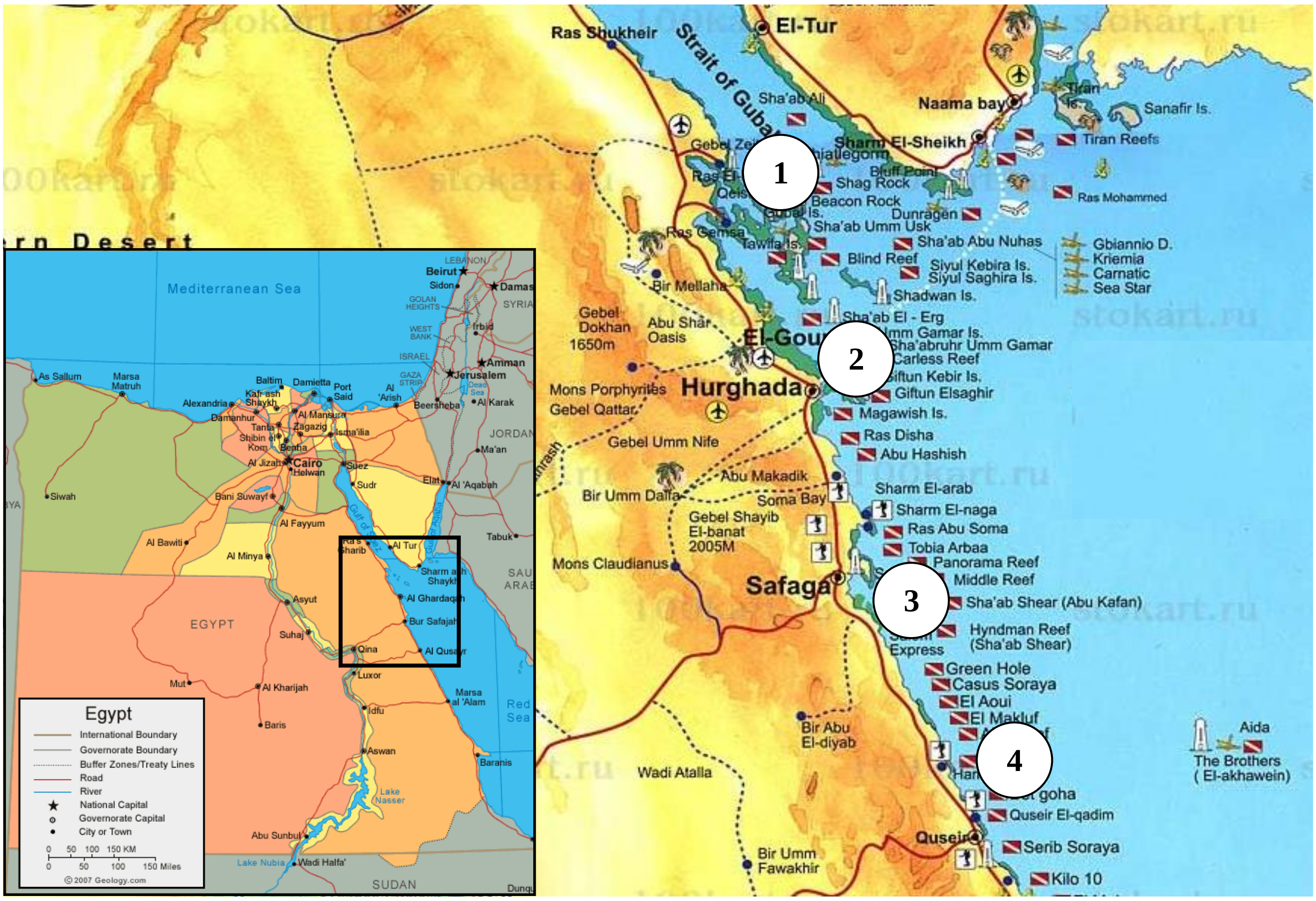

Figure 1. Location map of the studied site: 1. Ras El-Behar (northern Hurghada), 2. Middle Reef (Hurghada), 3.Kalawy bay (Safaga) and 4. El-Hamraween harbor (El-Quseir).

43’ 51” N and longitudes 33º 33’ 12” E and 33º 33’ 04” E. This site is impacted by petroleum oil pollution coming from the nearby petroleum fields and oil tankers. Furthermore, commercial fishing activities are impacting the same site.

Middle Reef (Site 2) is located 200 m offshore between the northern reef and crescent reef, directly in front of National Institute of Oceanography and Fisheries (NIOF). This location is about 5 km northern to Hurghada city, between longitudes 27º 17.13' N and 27 º 17.09' N and latitudes 33 º 46.43' E and 33 º 46.47' E.The middle reef is situated in the area that has been subjected to landfilling which is associated with high sedimentation rate

El-Hamraween harbor (Site 3) is located about 60 km south of Safaga, 20 km northern of El-Qusier City and about 120 from the Capital City of the Red Sea governorate (Hurghada). It is dominated between latitudes 26º 15' 02" N and 26º15’17” N and longitudes 34º 12' 07" E and 34º 12' 00" E. The site is impacted by heavy load of phosphate due to preparation and shipment operations of phosphate are in El-Hamraween harbor (Al-Hammady 2011).

Kalawy area (site 4) lies between latitudes 26º30’32” N and 26º 30’ 35” N and longitudes 34º 03’ 59” E and 34º 04’ 00” E. It lies about 30 km south Safaga City. This site is a pristine area having no source of pollution besides being difficult to be accessed by fishermen because of the heavy wave breaking in addition to the tough patrolling in the area, does not subject to any impact and thus it is considered as a control site in this study.

Bleaching monitoring

Coral bleaching has been detected at the studied sites using visual estimation, and Line Intercepted Transect (LIT) method (Wilkinson and Baker 1997). Bleaching was initially scored on a scale of 1 to 6 following the scheme of Gleason and Wellington (1993). However, we found that a four-point scale was more useful for comparing bleaching severity at our study sites, and was less prone to observer basis in allocating colonies to bleaching categories. The following categories were used: (i) unbleached = no visible loss of color; (ii) moderate = 1-50% of colony affected, or entire colony pale but not white; (iii) Severe= 51-100% of colony with strong pigment loss; (iv) dead = recently dead. Recently dead hard corals were recognized by an absence of living tissue and minimal algal overgrowth and were considered to be bleaching fatalities.

To estimate the percentage cover of bleached coral and other categories at each site, a 20 m long graded tap transect were surveyed on each reef flat and every other depth zone. A total of 12 transects were surveyed. Transects were laid down along the depth contour, parallel to the shore. The length of bleached coral colonies and other categories underlying the transect were measured (the intercepted length) and the number of coral colonies was also counted. Percent cover of each category was calculated as follow: percent cover = (intercepted length/transect length) × 100. All colonies were identified to species or genus level, according to Wallace (1999) and Veron (2000) by using digital underwater photos.

RESULTS AND DISCUSSION

Results

Of the 3940 studied coral colonies, 20.11% of all corals were affected by bleaching: 5.4% were moderately affected; 2.7% severely affected and 12.007% were dead (Table 1). Overall, there were differences in the proportion of colonies affected by bleaching between the studied sites. The maximum average proportion of moderately bleached colonies was 12.62% and recorded at Ras El-Behar (the site was impacted by oil pollution and fishing activities), while the minimum proportion was 2.01% and recorded at Kalawy bay (pristine site). Moreover, the highest average proportions of severely bleached colonies (5.74%) and dead colonies (25.33%) were also found at site 1, while, the lowest average proportions of severely bleached colonies (1.101%) and dead colonies (3.59%) were found at site 4. The weighted average proportion of unbleached colonies recorded are 56.28%, 79.73%, 90.19% and 93.28% in site 1, site 2, site 3 and site 4 respectively.

Table 1. Weighing average proportions of unbleached, moderately bleached, severely bleached and dead colonies at the studied sites.

Location	Unbleached (%)	Moderate (%)	Severe (%)	Dead (%)
Site 1	56.28	12.62	5.74	25.33
Site 2	79.73	4.92	3.35	12.009
Site 3	90.19	2.06	0.64	7.102
Site 4	93.28	2.01	1.101	3.59
Total average	79.87	5.4025	2.70525	12.00775

Many of the abundant taxa varied in their bleaching response according to their site. The five branching common acroporids varied between sites; *Acropora clathrata* (Brook 1891) was more susceptible to bleaching at Ras El-Behar (71% unbleached) than at Kalawy bay (99% unbleached), *Acropora granulose* (Milne Edwards and Haime 1860) was more susceptible to bleaching at Middle reef-NIOF (54% unbleached) than at Kalawy bay (72% unbleached), *Acropora humilis* (Dana 1846) was more susceptible to bleaching at Ras El-Behar (64% unbleached) than at El-Hamraween harbor and Middle reef-NIOF (92 and 91% unbleached respectively),*Acropora hyacinthus* (Dana 1846) was more moderately affected at Ras El-Behar (23% moderately bleached) than at El-Hamraween harbor and Middle reef-NIOF (5% and 7% moderately bleached respectively), and *Acropora pharaonis* (Edwards and Haime 1860) was consistently more severely affected at Middle reef-NIOF (26% bleached) than at Kalawy bay (1% bleached). *Stylophora pistillata* (Esper 1797) was another common branching coral varied in bleaching response between sites, *Stylophora pistillata* was 33% dead at Ras El-Behar, 17% dead at El-Hamraween harbor and 10% at Middle reef-NIOF. There were different effects of different sites on bleaching responses of some massive coral form. *Galaxea fascicularis* (Linnaeus 1758) and *Porites solida* (Forskal 1775) were more susceptible to bleaching at Middle reef-NIOF (79% and 77% unbleached respectively) than at Kalawy bay (100% unbleached). *Favia pallida* (Dana 1846) was another massive coral recorded 50% dead in Ras El-Behar and 1% dead in Middle reef-NIOF.

Table 2. Species susceptibilities to bleaching in Red Sea coastal area of Egypt; Site: 1. Ras El-Behar (northern Hurghada), 2. Middle Reef (Hurghada), 3.Kalawy bay (Safaga) and 4. (El-Quseir). Data were the percent of colonies in each of four bleaching categories (Unbleached: no visible loss of color, moderate: 1-50% of colony bleached or entire colony pale, severe: > 50% of colony bleached and dead: absence of living tissue and algal overgrowth) for all taxa which recorded on survey transects.

Category	Species name	Ras El-Behar (site 1)					Middle reef of Hurghada (site 2)					Kalawy bay (site 3)					El-Hamraween harbor (site 4)				
			Un	Bleached				Un	Bleached				Un	Bleached				Un	Bleached		
		n	Un blea-ched (%)	Mode-rate (%)	Seve-re (%)	Dead (%)	n	Un blea-ched (%)	Mode-rate (%)	Severe (%)	Dead (%)	n	Un blea-ched (%)	Mode-rate (%)	Seve-re (%)	Dead (%)	n	Un blea-ched (%)	Mode-rate (%)	Severe (%)	Dead (%)
Branching hard corals	*Acropora brueggmanni*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	5	98	0	0	2
	Acropora clathrata	29	71	22	5	2	*	*	*	*	*	*	*	*	*	*	16	99	0	0	1
	Acropora corymbosa	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	8	100	0	0	0
	Acropora cytheraea	*	*	*	*	*	*	*	*	*	*	34	94	2	0	4	*	*	*	*	*
	Acropora digitefera	13	82	3	4	11	*	*	*	*	*	18	96	1	0	3	*	*	*	*	*
	Acropora eurystoma	*	*	*	*	*	*	*	*	*	*	9	90	1	2	7	5	100	0	0	0
	Acropora formosa	*	*	*	*	*	27	93	1	1	5	9	93	1	1	5	*	*	*	*	*
	Acropora granulosa	24	50	16	23	11			17	8	21	*	*	*	*	*	19	72	13	4	11
	Acropora hemperchi	*	*	*	*	*	*	*	*	*	*	10	100	0	0	0	15	92	1	0	7
	Acropora humilis	31	64	21	7	8	21	91	0	0	9	129	92	0	0	8	*	*	*	*	*
	Acropora hyacinthus	42	51	23	5	21	43	78	7	3	12	7	88	5	2	5	36	81	6	3	10
	Acropora nasuta	9	67	4	2	27	*	*	*	*	*	*	*	*	*	*	8	100	0	0	0
	Acropora nobilis	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	27	97	0	0	3
	Acropora pharaonis	12	83	6	1	10	33	74	2	2	22	*	*	*	*	*	4	99	0	0	1
	Acropora squarrosa	17	81	7	3	9	12	79	2	3	16	21	90	0	0	10	*	*	*	*	*
	Acropora valenciennesi	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	11	100	0	0	0
	Lobophyllia corymbosa	*	*	*	*	*	67	79	0	0	21	2	79	0	0	21	*	*	*	*	*
	Lobophyllia hemperichi	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	21	84	0	0	16
	Pocillopora damicornis	*	*	*	*	*	*	*	*	*	*	76	95	3	1	1	23	99	0	0	1
	Pocillopora verrucosa	*	*	*	*	*	9	81	2	0	17	189	81	2	0	17	42	96	2	1	1
	Seriatopora hystrix	2	100	0	0	0	19	91	2	2	5	*	*	*	*	*	*	*	*	*	*
	Stylophora pistillata	823	49	13	5	33	54	59	16	15	10	7	65	11	7	17	44	73	9	7	11
	Weighing average		51.85	13.57	5.36	29.21		74.28	6.4	4.45	14.86		88.23	1.6	0.32	9.83		88.86	3.37	1.88	5.88
Massive hard corals	*Ctenactis ecchinata*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	6	100	0	0	0
	Echinopora lamellosa	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	10	100	0	0	0
	Favia amicorum	4	100	0	0	0	16	89	3	2	6	16	89	3	2	6	*	*	*	*	*
	Favia pallida	*	*	*	*	*	*	*	*	*	*	12	97	1	0	2	*	*	*	*	*
	Favia helianthoides	*	*	*	*	*	16	88	2	1	9	*	*	*	*	*	*	*	*	*	*
	Favia pallida	2	50	0	0	50	7	98	1	0	1	*	*	*	*	*	*	*	*	*	*
	Favites persi	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	6	100	0	0	0
	Favia speciosa	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	26	100	0	0	0

	Favia stelligera	21	79	7	5	9	28	90	1	1	8	*	*	*	*	*	11	100	0	0	0
	Galaxea fascicularis	*	*	*	*	*	683	79	5	3	13	*	*	*	*	*	5	100	0	0	0
	Goniastraea palauensis	*	*	*	*	*	*	*	*	*	*	18	99	0	0	1	*	*	*	*	*
	Goniastrea retiformis	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	7	100	0	0	0
	Goniopora somaliensis	*	*	*	*	*	*	*	*	*	*	15	90	3	1	6	*	*	*	*	*
	Leptoria phrygia	6	90	2	0	8	29	92	1	1	6	*	*	*	*	*	*	*	*	*	*
	Montipora circumvallata	14	79	5	4	12	14	70	2	0	28	*	*	*	*	*	*	*	*	*	*
	Montipora edwardsi	*	*	*	*	*	4	98	0	0	2	*	*	*	*	*	*	*	*	*	*
	Montipora gracilis	*	*	*	*	*	5	77	6	5	12	*	*	*	*	*	*	*	*	*	*
	Montipora meandrina	47	66	11	16	7	32	72	13	9	6	16	75	12	7	6	*	*	*	*	*
	Montipora monasteriata	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	13	99	0	0	1
	Montipora spongiosa	29	67	12	12	9	11	92	0	1	7	*	*	*	*	*	*	*	*	*	*
	Montipora stilosa	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	7	99	0	0	1
	Montipora verrucosa	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	19	100	0	0	0
	Pavona cactus	*	*	*	*	*	18	79	8	2	11	*	*	*	*	*	*	*	*	*	*
	Pavona yabei	*	*	*	*	*	6	91	2	0	7	*	*	*	*	*	*	*	*	*	*
	Platygyra daedalea	23	64	8	9	19	63	91	1	0	8	*	*	*	*	*	5	98	1	0	1
	Platygyra sinensis	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	6	100	0	0	0
	Porites compressa	*	*	*	*	*	*	*	*	*	*	19	100	0	0	0	*	*	*	*	*
	Porites lobata	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	16	96	1	0	3
	Porites lutea	*	*	*	*	*	*	*	*	*	*	30	97	2	1	0	*	*	*	*	*
	Porites rus	*	*	*	*	*	*	*	*	*	*	22	99	0	0	1	*	*	*	*	*
	Porites solida	*	*	*	*	*	8	77	4	3	16	61	91	5	2	2	9	100	0	0	0
	Porites undulata	*	*	*	*	*	*	*	*	*	*	43	96	1	0	3	*	*	*	*	*
	Weighing average		70.69	8.75	10.05	10.49		80.9	4.55	2.7	11.83		93.59	2.79	1.23	2.36		99.35	0.14	0	0.5
Encrusting	*Alveopora daedalea*	2	100	0	0	0	4	100	0	0	0	6	100	0	0	0	*	*	*	*	*
	Echinopora gemmacea	54	84	11	2	3	6	94	0	0	6	*	*	*	*	*	*	*	*	*	*
	Echinopora lamellosa	13	77	4	7	12	23	93	2	1	4	9	95	2	1	2	*	*	*	*	*
	Hydnophora microconos	8	90	0	4	6	12	90	1	1	8	1	94	1	3	2	*	*	*	*	*
	Weighing average		83.85	8.38	3	4.75		92.95	1.28	0.78	4.98		96.81	1.18	0.75	1.25	*	*	*	*	*
Solitary	*Fungia fungites*	4	100	0	0	0	25	89	4	0	7	*	*	*	*	*	*	*	*	*	*
	Fungia klunzingeri	*	*	*	*	*	18	90	6	1	4	*	*	*	*	*	*	*	*	*	*
	Fungia fungites	*	*	*	*	*	*	*	*	*	*	4	100	0	0	0	*	*	*	*	*
	Fungia repanda	1	100	0	0	0	25	64	7	23	6	21	78	8	2	12	*	*	*	*	*
	Fungia scutaria	*	*	*	*	*	11	88	2	2	8	*	*	*	*	*	*	*	*	*	*
	Weighing average		100	0	0	0		81.17	5.12	7.78	6.13		81.25	6.72	1.68	10.08	*	*	*	*	*
Hydrocorals	*Millepora dichotoma*	*	*	*	*	*	*	*	*	*	*	15	100	0	0	0	49	100	0	0	0
	Millepora platyphylla	*	*	*	*	*	*	*	*	*	*	11	100	0	0	0	6	100	0	0	0
	Weighing average												100	0	0	0		100	0	0	0
	Total		56.28	12.62	5.74	25.33		79.73	4.93	3.35	12.009		90.19	2.06	0.64	7.102		93.28	2.01	1.101	3.59

Note: n= number of colonies; * = n.a.

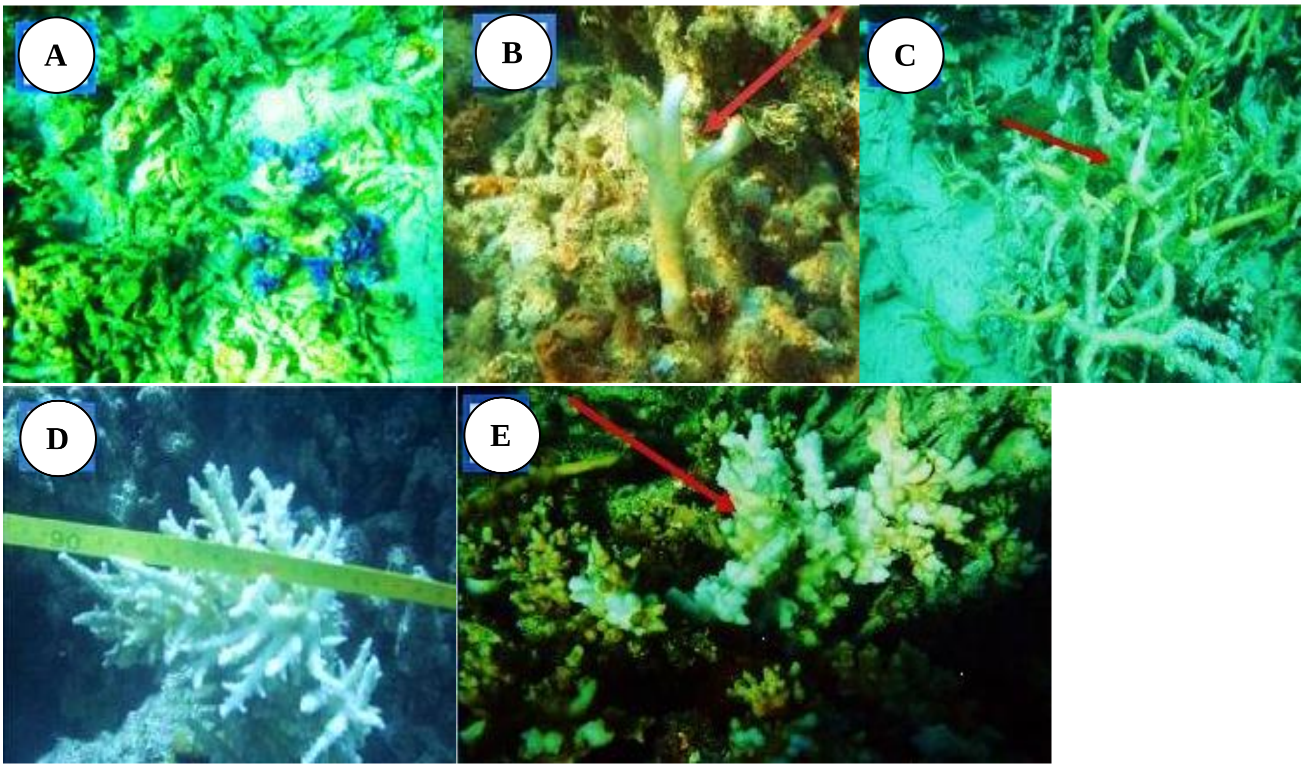

Figure 2. Patterns of bleaching at site 1 (Ras El-Behar). A. Dead colonies of *Stylophora pistillata;* B. Severe bleached colonies of *Stylophora pistillata*; C. Moderately bleached colonies of *Stylophora pistillata;* D. Severe bleached colony of *Acropora* spp. intercepted under the Line Intercepted Transect; E. Moderately bleached colony of *Montipora* spp.

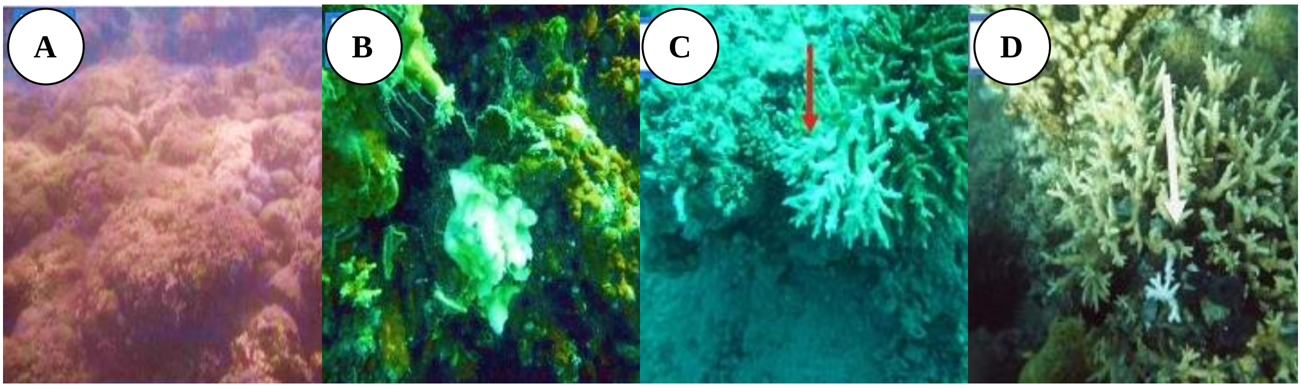

Figure 3. Patterns of bleaching at site 2 (Middle Reef-NIOF). A. *Galaxea fascicularis;* B.Moderately bleached colony of *Montipora* spp.*;* C. and D. Moderately bleached colony of *Acropora* spp.

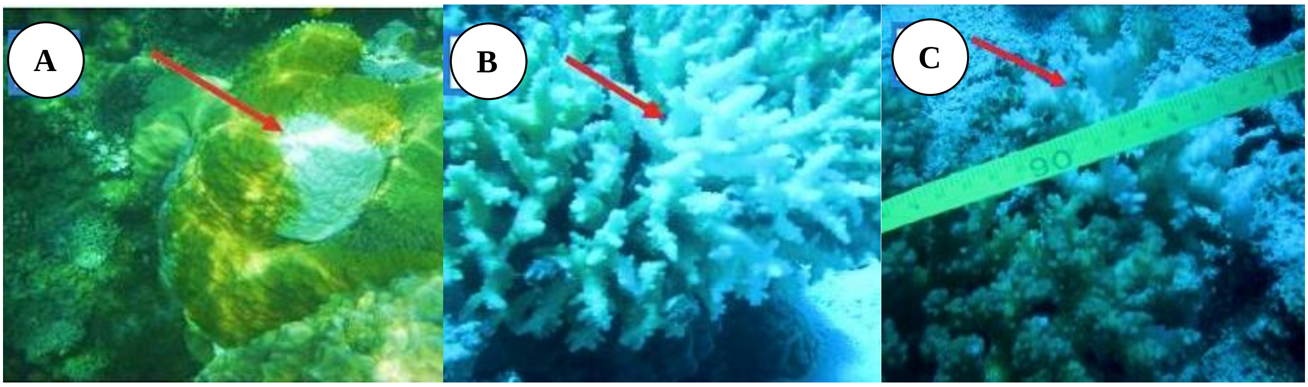

Figure 4. Patterns of bleaching at site 3 (Al Hamraween harbor). A. Moderately bleached colony of *Porites* spp.*;* B. Moderately bleached colony of *Acropora* spp.; C. Moderately bleached colony of *Pocillopora damicornis*.

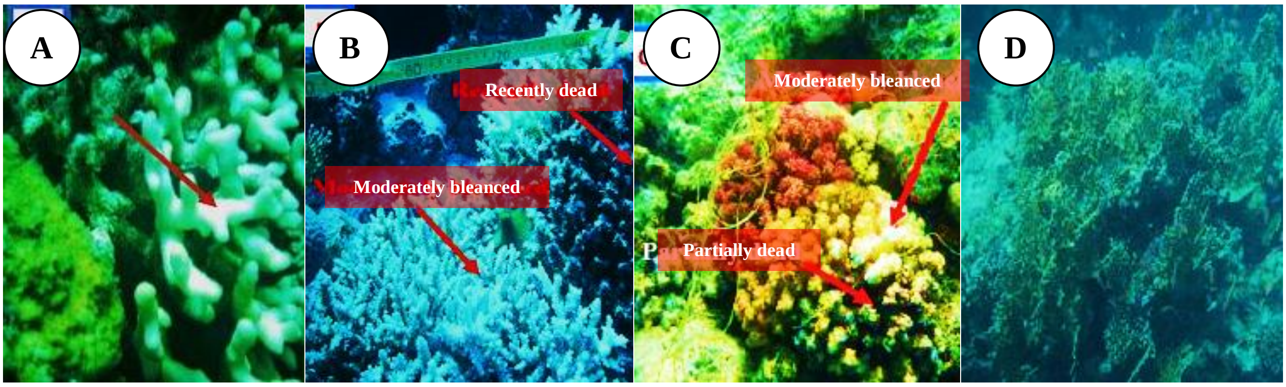

Figure 5. Patterns of bleaching at site 4 (Kalawy bay). A. Severely bleached colony of *Stylophora pistillata*; B. Moderately bleached and dead colony of *Acropora* spp.; C. Colony of *Pocillopora verrucosa* having unbleached, moderately bleached and dead branches; D. unbleached colony of *Millepora dichotoma*.

Stylophora pistillata, the only abundant species, with unusual big and thick branches, was the most susceptible to bleaching at site 1 (Figure 2), of which 33% of colonies dead, 5% severely bleached and 13% moderately bleached. However, over 49% of colonies remained unbleached at the time of the survey. Acroporids were also highly susceptible to bleaching; *Acropora granulosa* was the most affected, with 11% of colonies dead, 23% of colonies severely bleached and 16% moderately bleached. A number of taxa appeared resistant to bleaching, 100% of colonies of *Seriatopora hystrix* (Dana 1846), *Favia amicorum* (Edwards and Haime 1850), *Alveopora daedalea* (Dana 1846), *Fungia fungites* (Linnaeus 1758) and *Fungia repanda* (Dana 1846) were unbleached, although these corals were the least abundant species at site 1. *Leptoria phyrigia* (Milne Edwards and Haime 1860) and *Hydnophor amicroconos* (Lamark 1816) were less susceptible to bleaching, more than 90% of colonies of these species apparently unaffected by bleaching (Table 2).

The massive coral *Galaxea fascicularis*, the most abundant species at site 2 (Figure 3), was the Least resistance to bleaching, of which 13% of colonies were dead, 3% severely bleached and 5% moderately bleached. However, over 79% of coral colonies remained unbleached at the time of the survey. Acroporids were also low resistance to bleaching (Figure 3). *Acropora granulose* was the worst affected, with 21% of colonies have been dead, 8% severely bleached and 17% moderately bleached. However, over 54% of coral colonies remained unbleached. Only one species could be considered as being unaffected by bleaching; *Alveopora daedalea* (100% unbleached). A number of taxa appeared particularly resistant to bleaching. Less than 20% of colonies of *Pocillopora verrucosa* (Ellis and Solander 1786), *Favia amicorum* (Edwards and Haime 1850), *Favia helianthoides* (Edwards and Haime 1850), *Fungia scutaria* (Lamark 1801) and *Fungia fungites* (Linnaeus 1758) showed signs of bleaching with very few colonies severely bleached or dead (Table 3).

Two taxa relatively being affected by bleaching at site 3, which were *Stylophora pistillata* and *Montipora meandrina* (Ehrenberg 1834). *Stylophora pistillata*, the none expectedly expressing rare distribution as it is well known in literature as an opportunistic species, was the most susceptible to bleaching, of which 17% of colonies have dead, 7% severely bleached and 11% moderately bleached. However, over 65% of colonies remained unbleached at the time of the survey. *Montipora meandrina* was also highly susceptible to bleaching with over 12% of colonies moderately bleached and 75% unbleached. The branching coral *Pocillopora verrucosa*, the most abundant species at site 3 (Figure 4), was the worst affected of which 17% of colonies were dead, on the other hand, 81% was unaffected (Table 4).

Relatively, two species also being affected by bleaching at site 4; *Acropora granulosa* and *Stylophora pistillata*. On the other hand, 18 species could be considered as being unaffected by bleaching (100% unbleached) (Table 5).

In general, the scleractinian corals with branching growth form morphologies suffer higher rates of bleaching than species with massive, encrusting and solitary morphologies at the four study sites.

Discussion

Our results show that there were differences in the proportion of colonies affected by bleaching between the studied sites. Spatial variation in the severity of bleaching may be driven by variation between sites in environmental conditions that trigger the bleaching event (Manzello et al. 2007). The maximum average proportion of moderately and severely bleached and dead colonies at Ras El-Behar (site 1) is probably attributed to oil pollution, the prominent stressor in that site. This agrees with the laboratory finding of Frisch et al. (2007) who assessed the effects of clove oil solution on colonies of *Pocillopora damicornis*, finding that, corals treated with high concentrations (50 ppt) of clove oil solution died immediately. Carriquiry and Horta Puga (2010) reported that oil pollution is the main causes of reef destruction. Ammar et al. (2007) found that Ras El-Behar is characterized by the paucity of coral species and relatively high abundance of algae and sea urchin *Diadema setosum*.

Fishing activities is another important factor that may play an important role in increasing bleaching susceptibilities at site 1. Reef damage due to dynamite fishing, recent and old, is frequently encountered on Egyptian Red Sea reefs (Ammar 1998; Ammar and

Madkour 2011). Mac Manus et al. (1997), suggested that approximately 1.4%/year of the hermatypic coral cover may have been lost due to blasting fishing, 0.4%/year to cyanide fishing, and 0.03%/year to coral-grabbing anchors. Moreover, Ammar and Mohammed (2006) observed that moderate diving and low fishing are the main reasons for decreasing the percentage cover of coral community at Tobia Kebir-Safaga-Red Sea.

There was a difference in the susceptibility to bleaching stress among the corals at the studied species. Bhagooli and Hidaka 2004) confirmed this result. They found that *Montipora* spp. were highly susceptible to coral bleaching, inconsistent, bleaching of coral species on the same reef suggests that there is a range of tolerance within species (Celliers and Schleyer 2002). Statt et al. (2006) recorded significant variation in intra-specific bleaching and ascribed this phenomenon to difference in symbiont clade composition. While, bleached corals lose most of their symbiotic dinoflagellates and appear white after relatively short high-temperature exposures, adjacent colonies of the same, or another, species may display normal coloration for weeks or even months living in the same conditions on the same reef (Baghooli and Hidaka 2004).

In fact, several factors can apparently determine whether a coral colony being more susceptible to bleaching than the others. One such characteristic is tissue thickness (Ainsworth et al. 2008). Corals from genera such as *Porites* that have thicker tissues and appear more robust to thermal stress than corals from genera such as *Acropora* which has thinner tissues (Loya et al. 2001). Although the previous result seems to depend more on the host rather than on the *Symbiodinium*, no actual study related the tissue thickness with the clade of *Symbiodinium*. Thermal stress and tissue thickness also interact as shown by Manzello et al. (2007) and Fitt et al. (2000), who documented steady decreases in tissue biomass and symbiont density during summer months and interpreted it as an increase in metabolic demand and subsequent use of stored energy reserves. Fitt et al. (2009) concluded that *P. cylindrica* contains a heat resistant C^{15}Symbiodinium and critical host proteins are present at higher concentrations than observed for *S. pistillata*, the combination of which provides greater protection from bleaching conditions of high temperature in the light.

Size can also play a role in determining patterns of mortality on bleached reefs as discussed by Baker et al. (2008), Small juvenile colonies of some species can survive better than large, mature colonies (Loya et al. 2001; Riegl 2002; van Woesik et al. 2004). This could explain the high rate of mortality among *Stylophora pistillata* having unusual thick and big branches at site 1.

Millepora spp. among species that reported the least susceptibility to bleach (100% unbleached) among the 104 taxa included in our surveys, the least susceptibility of this hydrocoral genus has been reported by Gleason and Wellington (1993). He found that *Millepora* did not show any evidence of bleaching other than mild paling during the 1991 bleaching event in Moorea, French Polynesia. However, *Millepora* with most susceptibility to bleaching has been reported from bleaching episodes elsewhere (Glynn and de Weerdt 1991). Species of *Millepora* suffered particularly rapid mortality in the eastern Pacific during the 1982-1983 bleaching episode (Manzello et al. 2007). On the other hand, Ammar and Emara (2004) reported that *Millepora dichotoma* prefers clear water and cannot tolerate excessive sediments. Ammar (2004) also reported that *Millepora* sp. prefers highly illuminated sites and has a strong skeletal density to tolerate strong waves.

The least susceptibilities among coral taxa at El-Hamraween harbor can be explained by phosphorus enrichment at this site. This result is consistent with the result of Ammar et al. (2007). Who recorded that, the presence of sulfur beside phosphorus at El-Hamraween harbor (Site 3) may have beneficial synergetic effect that may lead to flourishing corals. Faxneld et al. (2010) found no physiological effects from nitrate enrichment alone, which is in accordance with Ferrier-Pagès et al. (2001), who found no effects on zooxanthellae density or photosynthesis with nitrate enrichment (2 µM).

The present surveys demonstrated that the scleractinian corals with branching growth form morphologies generally suffer from higher rates of bleaching than species with massive, encrusting and solitary morphologies at the four study sites. Surveys conducted over a broad range of habitats, biogeographic regions, and different sea warming events have confirmed our finding that scleractinian corals with branching colony morphologies generally suffer higher rates of bleaching than species with massive and encrusting morphologies (Loya et al. 2001; McClanahan and Maina 2003).

Field observations supporting differential mortality of branching and massive species have been supported experimentally for five species in the eastern Pacific (Hueerkamp et al. 2001). Massive species of *Porites* and *Diploastrea* are frequently among the survivors (McClanahan and Maina 2003; Schuhmacher et al. 2005). *Favia* spp. often survives, as do non-branching species in the family Agariciidae (Loya et al. 2001).

CONCLUSION AND RECOMMENDATIONS

Local anthropogenic stressors (e.g. fishing activity and oil pollution) expressed a higher bleaching event than areas subjected to eutrophication stressors. Bleaching susceptibility has extraordinarily decreased with increased phosphate level in contrast to most experimental literature. Therefore, review of various techniques dealing with the effect of phosphates on corals is necessary. *Stylophora pistillata*, the only abundant species at site 1 (with oil pollution), was the most susceptible to bleaching in that site. The massive coral *Galaxea fascicularis,* the most abundant species at site 2, was the most susceptible to bleaching. Some other species like *Acropora granulosa*, *Stylophora pistillata*, *Montipora meandrina*, *Fungia repanda* and other species have higher bleaching.

Tough control, public awareness and continuous shore patrolling to the activities of oil pollution and fishing activities at the vicinity of site 1 are urgent. Review of various techniques, dealing with the effect of phosphate on corals, and taking care of their precision is necessary because indications of the field work are different from many of the reviewed experimental literature. Site 4 is already virgin, and needs more guarding to keep that site always pristine. However, it could be also protected from any possible cause of rising sea temperature like installing desalination plants or any other industrial installation, urbanization and coastal development.

ACKNOWLEDGEMENTS

This work is a part of the Ph.D. of the student Montaser Aly Mahmoud Al-Hammady.

REFERENCES

Ainsworth TD, Hoegh-Guldberg O, Heron SF, Skirving WJ, Leggat W. 2008. Early cellular changes are indicators of pre-bleaching thermal stress in the coral host. J Exp Mar Biol Ecol 364 (2): 63-71.

Al-Hammady MAM. 2011. Patterns of bleaching and fertility in the two Red Sea corals *Stylophora pistillata* and *Acropora humilis* as biomonitors of environmental impacts. [Ph.D. Dissertation]. Zoology Department, Assiut University, Assiut, Egypt.

Ammar MSA, Madkour HA. 2011. Quantification of coral reef communities along the Gulf of Aqaba and Ras Mohammed, Red Sea, Egypt Curr Trop Ecol *In Print*.

Ammar MSA, Emara AM. 2004. Population studies on corals and other macrobenthic invertebrates in two flooded sites and a sheltered site around Ras Baghdad, Red Sea, Egypt. J Egypt Ger Soc Zool 45 (D): 217-232.

Ammar MSA, Ghobachi AA, Omran MA, Shabban AM. 2007. Status of coral reef affected by different impacts in some sites of the Red Sea. Egypt J Aqua Res 33: 224-237.

Ammar MSA, Mohammed MA. 2006. Effect of physic-chemical factors and human impacts on coral distribution at TobiaKebir and Sharm El-Loly Red Sea-Egypt. Egypt J Aqua Res 32 (1): 184-197.

Ammar MSA. 1998. Human impact on coral reef communities. Egypt J Zool 30: 191-208.

Ammar MSA. 2004. Zonation of coral communities and environmental sensitivity offshore a resort site at Marsa Alam, Red Sea, Egypt. Egy. J Zool 42: 67-18.

Ammar MSA. 2009. Assessment of present status and future needs of four coral reef sites along the Gulf of Aqaba, Egypt. Open Environ Pollut Toxic J 1: 34-42.

Ammar MSA. 2011. Coral diversity indices along the Gulf of Aqaba and Ras Mohammed, Red Sea, Egypt. Biodiversitas 12 (2): 92-98.

Baker AC, Glynn PW, Riegl B. 2008. Climate change and coral reef bleaching: An ecological assessment of long-term impacts, recovery trends and future outlook. Estuar Coast Shelf Sci 80: 435-471.

Bhagooli R, Hidaka M. 2004. Photoinhibition, bleaching susceptibility and mortality in two scleractinian corals, *Platygyra ryukyuensis* and *Stylophora pistillata*, in response to thermal and light stresses. Comp Biochem Physiol, Part A: Mol Integ Physiol 137 (3): 547-555.

Carriquiry JD, Horta Purga G. 2010. The Ba/Ca record of corals from the Southern Gulf of Mexico: Contributions from land-use changes, fluvial discharge and oil drilling muds. Mar Pollut Bull 60 (9): 1625-1630

Celliers L, Schleyer MH. 2002. Coral bleaching on high-latitude marginal reef at Soswana Bay, South Africa. Mar Pollut Bull 44: 1380-1387.

Douglas AE. 2003. Coral bleaching-how and why? Department of Biology (Area 2), University of York, York, UK.

Faxneld S, Jörgensen TL, Tedengren M. 2010. Effects of elevated water temperature, reduced salinity and nutrient enrichment on the metabolism of the coral *Turbinaria mesenterina*. Estuar Coast Shelf Sci 88: 482-487.

Ferrier-Pagès C, Schoelzke V, Jaubert J, Muscatine L, Hoegh-Guldberg O. 2001. Response of a scleractinian coral, *Stylophora pistillata*, to iron and nitrate enrichment. Exp Mar Biol Ecol J 259: 249-261.

Fitt WK, Gates RD, Hoegh-Guldberg O, Bythell JC, Jatkar A, Grottoli G, Gomez M, Fisher P, Lajuenesse TC, Pantos O, Iglesias-Prieto R, Franklin DJ, Rodrigues LJ, Torregiani JM, van Woesik R, Lesser MP. 2009. Response of two species of Indo-Pacific corals, *Porites cylindrica* and *Stylophora pistillata*, to short-term thermal stress: The host does matter in determining the tolerance of corals to bleaching. J Exp Mar Biol Ecol 373: 102-110.

Fitt WK, McFarland FK, Warner ME. 2000. Seasonal patterns of tissue biomass and densities of symbiotic dinoflagellates in reef corals and relation to coral bleaching. Limnol Oceanogr 45 (3): 677-685.

Frisch AJ, Ulstrup KE, Hobbs JA. 2007. The effects of clove oil on coral: An experimental evaluation using *Pocillopora damicornis* (Linnaeus). J Exp Mar Biol Ecol 345 (2): 101-109.

Gleason DF, Wellington GM. 1993. Ultraviolet radiation and coral bleaching. Nature 365: 836-838.

Glynn PW, de Weerdt WH. 1991. Elimination of two reef-building hydrocorals following the 1982-83 El Nino warming event. Science 253: 69-71

Hagedorn M, Carter VL, Leong JC, Kleinhans FW. 2010. Physiology and cryosensitivity of coral endosymbiotic algae (*Symbiodinium*). Cryobiol 60: 147-158.

Hueerkamp C, Glynn PW, D’Croz L, Maté JL, Colley SB. 2001. Bleaching and recovery of five eastern Pacific corals in an El Niño-related temperature experiment. Bull Mar Sci. 69:215– 236.

Knowlton N. 2001. The future of coral reefs. Proc Natl Acad Sci USA 98: 5419-5425.

Kramer PA. 2003. Synthesis of coral reef health indicators for the Western Atlantic: results of the AGRRA program (1997-2000). Atoll Res Bull 496: 1-57.

Loya Y, Sakai K, Yamazato K, Nakano H, Sambali H, van Woesik R. 2001. Coral bleaching: the winners and the losers. Ecol Lett 4: 122-131.

Manzello DP, Berkelmans R, Hendee JC. 2007. Coral bleaching indices and thresholds for the Florida Reef Tract, Bahams, and St. Croix, Us Virgin Islands. Mar Pollut Bull 54 (12): 1923-1931

Mc Manus J, Rodolfo B, Reyes JR. 1997. Effects of Some destructive fishing methods on coral cover and potential rates of recovery. Environ Manag 21 (1): 69-78

McClanahan TR, Maina J. 2003. Response of coral assemblages to the interaction between natural temperature variation and rare warm-water events. Ecosystems 6: 551-563.

Miller MW, Piniak GA, Williams DE. 2011. Coral mass bleaching and reef temperatures at Navassa Island, 2006. Estuar Coast Shelf Sci 91: 42-50

Obura DO. 2005. Resilience and climate change: lessons from coral reefs and bleaching in the Western Indian Ocean. Est Coast Shelf Sci 63 (3): 353-372

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.

Schuhmacher H, Loch K, Loch W, See WR. 2005. The aftermath of coral bleaching on a Maldivian reef a quantitative study. Facies 51: 80-92.

Statt M, Carter D, Hoegh-Guldberg O. 2006. The evolutionary history of *Symbiodinium* and scleractinian hosts. Symbiosis, diversity, and effect of climate change. Persp. Pl Ecol Evol Sys 8 (1): 23-43

Van Woesik R, Irikawa A, Loya Y. 2004. Coral bleaching: signs of change in southern Japan. In: Rosenberg E, Loya Y (eds) Coral health and disease. Springer, Berlin.

Veron JEN. 2000. Corals of the world. Vol. 3. Australian Institute of Marine Science, Townsville, Australia.

Wallace CC. 1999. Staghorn Corals of The World: A Revision of The Coral Genus *Acropora*. CSIRO Publishing, Canberra, Australia.

Wielgus J, Chadwick-Furman NE, Dubinsky Z. 2004. Coral cover and partial mortality on anthropogenically impacted coral reefs at Eilat, northern Red Sea. Mar Poll Bull 48: 249-253.

Wilkinson C, Baker V. 1997. Survey manual for tropical marine resources. 2nd ed. Australian Institute of Marine Science, Townsville.

Wilkinson CR. 1999. Global and local threats to coral reef functioning and existence: review and prediction. Mar Fresh W Res 50: 867-878.

Yee SH, Santavy DL, Barron MG. 2008. Comparing environmental influences on coral bleaching across and within species using clustered binomial regression. Ecol Mod 218 (1-2): 162-174.